A COMPARISON OF THE DESIGN APPROACH RECOMMENDED IN THE SOUTH AFRICAN NATIONAL STANDARD FOR A REINFORCED SOIL WALL WITH A FINITE ELEMENT DESIGN TO IDENTIFY AN OPPORTUNITY TO OPTIMISE THE DESIGN

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EXAMINER'S COPY

As the candidate's Supervisor I agree to the submission of this thesis.

27/11/2019

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ABSTRACT

Reinforced soil structures are used extensively for retaining wall applications in South Africa, with the design methodology recommended within the civil engineering fraternity as specified in the design code SANS 8006-1:2018, which was previously published as the SANS 207:2011.

Given the improvement in the geosynthetic market, the design methods recommended within the design codes may be over-conservative. Although there have been revisions to the codes over the years, there has been limited improvements to the recommended design methods in the code. The design methods were developed at a time when there were limitations in computing capabilities and much of the designs were undertaken by simplified analytical 'hand' calculation.

Numerical tools available today together with improved reinforcement quality provides an opportunity to optimize reinforced soil wall designs. Using an existing reinforced soil wall constructed at the N2 – Umgeni Road Interchange as a case study; the design code was used to design the reinforced soil wall. This design was verified using a finite element analysis using Rocscience's Phase 2 software.

The finite element analysis confirmed the adequacy of the reinforced soil wall developed using the design code. The displacements determined in the analysis concludes that the acceptability of the wall would be dictated by serviceability limit states rather than ultimate limit state. It is however concluded that the design code may indeed be over-conservative in light of the stresses, vertical displacement and factor of safety achieved in the FEA. This conservatism is attributed to the several partial and reduction factors applied in the determination of the reinforcement stresses and design strength.

A parametric study was undertaken to assess the effects of altering the reinforcement configuration to identify opportunities to optimise the analytical design of the case study wall. The results confirm that various combinations of increasing the vertical spacing, or reducing the length, coverage ratio and tensile strength of the reinforcement could be acceptable, however is dependent on the deformation and strain tolerances of the structure, hence resulting in possible cost and construction time savings while still maintaining the integrity of the reinforced soil wall.

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1. INTRODUCTION

1.1 Background

Economic growth and job creation are critical to reduce poverty, reduce unemployment and improve living standards and conditions of the country's population and also promote sustainability. Reducing poverty and improving living standards are achieved by the provision of housing and basic infrastructure services, healthcare and education.

Economic growth and sustainability cannot be achieved unless we have the infrastructure required to achieve this growth. Infrastructure growth in power, transportation and broadband are all necessary to attract foreign investment to the country which leads to economic growth, sustainable development and job creation.

Since our first democratically elected government, there has been a steady improvement in the living standards of the less fortunate in South Africa by the provision of housing, domestic services (electricity, sanitation, sewer and water services) access to healthcare, education and the provision of transportation infrastructure. Additionally, there has been growth, in the industrial, commercial and transportation sectors.

The desire to improve the quality of life within rural communities has led to the rural citizens seeking employment and subsequent flocking to large towns and cities in seek of a better future. Construction and development within towns and cities are therefore under pressure in order to accommodate more people due to the boom in urbanization and growth in business, industry and transportation infrastructure.

This has resulted in development of areas that were previously considered to be unsuitable, possibly as a result of poor subsoil conditions or difficult terrain. Aside from the need to optimize and develop the space available, some instances require the construction of certain structures such as roads and railways in areas that cannot be avoided. Space constraints due to undulating topography and steep slopes have necessitated the need for embankment construction and extensive cut and fill operations to optimize the space available for development.

The construction of various structures within unsuitable subsoil conditions have been resolved by removing the poor-quality soils and replacing with better quality soils, by by-passing the weak soils (for e.g. deep foundation), or by improving the subgrade (by deep compaction, chemical stabilization and preloading techniques). Over the last 30 years the advancements in technology and materials engineering has provided viable solutions for construction within weak soils, by implementing ground improvement methods which are proving to be more cost effective than the conventional solutions indicated above.

Geosynthetics have gained favor within the civil engineering industry due to its versatility and affordability as a ground improvement solution and has widely been accepted for use in a number of geotechnical and engineering applications. These products have produced viable technical solutions which are environmentally friendly and in some instance's energy efficient to civil engineering problems where conventional solutions using construction materials are more expensive, restricted due to space constraints or unsuitable for use in certain environments (Shukla 2012, p.IX). Given its sustainability these high-quality engineering solutions has made geosynthetics a game-changer within the construction industry as a result of innovative materials engineering and construction technologies (McGown 2000 p.1).

Geosynthetic products have numerous material and performance properties. The material properties are generally related to the quality control of the manufacturing processes, while the performance properties are related to the usage of these products which need to satisfy certain criteria to perform a specific function (Zornberg 1994). The industries manufacturing geosynthetics are continuously trying to improve the performance of their products by reducing the rate of material deterioration, improving durability over the life of the product, improving load distribution and reducing creep strain as well as enhancing chemical resistance of the geosynthetic material while maintaining the affordability of these products (Koerner 2005, p.5).

"Geosynthetics have been used to improve the performance or used in the construction of retaining walls, bridge abutments, steep slopes, embankments, foundations, railroads, airfields and road construction, and subsequently has been recommended for use in various design codes and design standards" (McGown 2000, p.1).

Error! Reference source not found. illustrates the use of geosynthetic in hazardous waste landfill sites as a lining to prevent seepage of contaminant into the ground, whereas **Error! Reference source not found.** is a photograph of the use of geosynthetics over sinkhole prone areas along the Gautrain in South Africa to provide additional reinforcement in the event of a sinkhole developing.

Geosynthetics applications in civil engineering are varied due to the following characteristics and properties that these products possess (Shukla 2012, p.34):

- Geosynthetic products are generally flexible, strong, non-corrosive and depending on its correct application can withstand biological and chemical degradation.
- The performance of some structures has been improved due to the use of geosynthetics where traditional techniques were not possible.
- Geosynthetics are manufactured using strict quality control hence guaranteeing the product properties as compared to traditional soil and rock construction solutions.
- The minimal thickness of geosynthetics compared to solutions using natural soils is an advantage given its light weight on subgrade layers and less airspace used.
- Under strict supervision the installation of geosynthetics may be carried out by unskilled labour as it is easier to lay than soil horizons (sands, gravels) which require large earthmoving equipment.
- Geosynthetic designs generally use energy efficient and environmentally friendly materials and hence are considered to be sustainable solutions which are more economical compared to traditional geotechnical designs.

Figure 1-1: Hazardous Waste Landfill Site Lined with Geosynthetic Lining in Newcastle for Chrome International South Africa (EngNet, 2010)

Figure 1-2: Use of Geotextiles in Reinforced Platform over Sinkhole Prone Areas along the Gautrain Route in Gauteng, South Africa (Gewanlal 2009)

1.2 Problem Statement

1.2.1 Introduction

In South Africa the design methodology recommended for reinforced soil walls is the SANS 8006-1:2018 Code of Practice which supersedes the SANS 207:2011. The SANS 207:2011 , first published in 2006, was the relevant code at the time of the commencement of this study which was based on the old BS8006 first published in 1995. During the course of this study the SANS207:2011 was revised to the SANS 8006-1:2018, however the design approach for reinforced soil walls in the newly revised code is the same as in SANS 207:2011.

The code recommends an external stability analysis to confirm resistance against overturning, sliding and bearing pressure failure and hence the stability of the structure as a single mass. The recommended internal stability analysis includes either the Coherent Gravity method or the Tie-back Wedge method depending on whether inextensible or extensible reinforcements are used to determine the tensile stresses on the reinforcement and the reinforcement adherence capacity.

Given the improvement in the properties of geosynthetic, the analytical techniques for the design of reinforced soil walls may need to be modified in light of the improvements in the properties of reinforcement. Although there have been revisions to the code over the years, there has been limited changes or improvements to the recommended design methods specified in the code. These analytical methods were developed at a time when there were limitations in computing 'power and speed' and much of the designs were undertaken by 'hand' calculation. Hence simplified analytical methods were developed which could be done without the use of a computer.

Improvements in technology since the 1990's have provided us with computers that are exceptionally powerful and fast thus enabling design computations to be carried out more efficiently using a personal computer. As such finite element and finite difference solutions that were considered laborious in the 1990's can be easily undertaken today using a computer. These calculations can be conducted using various finite element/difference software that is readily available and have quick processing times compared to the time it would have taken in the 1990's to undertake the same analysis.

In addition to the design processing speeds available today, the numerical software packages have the advantage of calculating strength and strains that are likely to develop in reinforced soil structures. Furthermore, numerical analyses factor the strength and stiffness of the reinforcement material in the analysis. The disadvantage, in fact, of the method proposed in the code are that only the stresses that develop in the reinforced soil structure are calculated.

In parallel to the introduction of numerical approaches in design, there have also been new products and significant improvements in the quality and applicability of the already existing reinforcements. The design methods in the code was developed when the reinforcements in the market were not of the same quality as the reinforcements available today. Hence the possibility of overdesign exists given the various partial factors applied.

1.2.2 Research Question

The computation capabilities available today together with the improvements in the quality of reinforcements available provides an opportunity to further optimize the design of reinforced soil walls. It is thus proposed that the Finite Element Method (FEM) be used to verify the adequacy of a design of an existing structure developed using the South African SANS8006-1:2018 Code of Practice for Strengthened/Reinforced Soils and Other Fills, which at the time of the commencement of this study was the SANS 207:2011.

As indicated, the design methods in the code were developed in the 1970's when the reinforcements available were of a poorer quality than the reinforcements available today. Hence the design criteria recommended were developed for poorer quality reinforcements. Use of these design criteria with the improved quality reinforcements may be too conservative and could possibly be considered as overdesign. Therefore, the possibility of further optimising a reinforced soil wall design may exist, which can have a huge cost saving potential for a project. It is therefore proposed to assess a design based on the South African design code to verify the premise that the code is over conservative.

In addition, a parametric study to determine the effects of altering the reinforcement configuration and reinforcement strength parameters on the safety of the design is assessed to identify the possibility of developing a more optimal and economical design.

The key questions of this project are as follows:

- Using an existing reinforced soil wall, what is the difference in the design of the wall using the Finite Element Method and the South Africa Design Code SANS 8006-1:2018 method?
- Which of the internal design parameters (length, vertical spacing, coverage and strength) of the reinforcement has the most significant influence on the stability of the reinforced soil wall?
- Can the internal reinforcement configuration and strength parameters be adjusted to optimise the design while still maintaining the integrity of the structure?

1.3 Aims and Objectives of the Research

An iterative approach is generally used when determining the reinforcement configurations of the case study wall. To minimise the number of iterations, a 'baseline' criterion of the reinforcement configuration is selected as prescribed in the code.

The baseline criteria which is the original design of the wall is assessed to confirm stability. An internal and external stability analysis is undertaken to determine the stability of the structure as a whole and to confirm the reinforcement adherence capacity and reinforcement strength required to maintain internal stability of the structure.

This original design based on the code is verified using the finite element method and a comparison of the two methods provided.

In addition, a parametric study is proposed using the finite element method to determine the influence of the reinforcement configuration and reinforcement strength on the reinforced wall design.

In summary the aim and objectives of this study is as follows:

- To assess the results of a finite element analysis of a reinforced soil wall designed in accordance with the South African code for the design of reinforced soil walls, to verify if the code is conservative and is considered to be overdesign.
- To identify alternative reinforcement configurations (based on the sensitivity of each of the reinforcement parameters) to further optimise the design of the wall so as to minimise construction costs.

1.4 Significance of the Research

Significant costs and time are associated with the design and construction of various civil infrastructure such as reinforced soil walls. It is the requirement of all infrastructure designs to ensure functionality and safety of the structure while optimizing the design to minimize construction time and costs. The significance of this research is to ascertain if the industry accepted design code for the design of reinforced soil walls that are used in South Africa (RSA) can be improved. The design codes are based on design approaches that have not changed over the decades despite material quality improvements and quality control improvements in the manufacturing of geosynthetic materials that are widely used in the construction industry today. The opportunity to optimize design solutions as a result of these improvements may include more economical geosynthetic reinforced soil wall configurations. Additionally given the accessibility of analysis and design tools that are currently available, the use of numerical methods should be prescribed when designing reinforced soil walls, which are capable of providing far more detailed analyses such as the quantification of strains and displacements within the reinforced soil wall which is not the case when using the analytical design methods recommended in the design codes.

The findings of the proposed comparative study for the design of a reinforced soil wall in accordance with the design code and the design analysed using a finite element numerical solution, together with the results of the parametric analysis is likely to illustrate the potential for further optimising of the design configuration while still maintaining the integrity of the structure.

1.5 Limitations of the Study

One of the major limitations of this study is that a single reinforced soil wall scenario is being assessed as part of this research. Depending on the wall requirements reinforced soil wall structures may have varying wall configurations and dimensions; additionally, the walls may be constructed using various geosynthetic reinforcement types (such as strips or geogrids) that are available in the market today. Therefore, there is an opportunity to extend this assessment to include several wall designs (including designs that use various geosynthetic reinforcements) to assess definitively if there is an opportunity to improve the design approach recommended in the RSA design code.

1.6 Structure of the Report

The first chapter of this dissertation provides a brief background and information for this study including the motivation for the research undertaken. A literature review is presented in Chapter Two which includes an overview of geosynthetics, introduction to reinforced soil walls and the design thereof. A brief comparison of conventional retaining structures and reinforced soil walls are also included within Chapter Two together with an introduction into Finite Element Methods (FEM). Chapter Three elaborates on the approach and methodology adopted for the design with the results of the design using the design approach specified in SANS 207:2011 included in Chapter Four, while the results of the analysis using the FEM is presented in Chapter Five. Chapter Six discusses the inputs and results of the parametric study. Chapter Seven provides a detailed discussion of the findings of the results obtained with the overall conclusions and recommendations provided in Chapter Eight.

2. LITERATURE REVIEW

2.1 Overview Of Geosynthetics

"Geosynthetics is defined as a planar product manufactured from polymeric materials often used in conjunction with soil, rock or other geotechnical engineering materials as an integral component of man-made structures or system" (Shukla 2012, p.1). Geosynthetics which are manufactured from either natural or artificial materials are generally used in geotechnical applications to strengthen the soil structure, however are used to perform other functions as well.

Prior to the 1970's geosynthetic uses included woven reed mats and woven cotton fabrics to strengthen the soils in road construction over soft soils; as pond liners to prevent desiccation of clay liners; and woven materials to prevent soil migration around coastal structures (Shukla 2012).

However, it was only in the 1970s that geosynthetics were being widely manufactured and promoted for use in earth dams, as basal reinforcement below embankments, and for a few other soil reinforcement applications. In the 1980s geotextile nets for erosion control and road bases, and geocell mattresses as foundation layers below embankments, roads and buildings over soft soils emerged and were being promoted (Shukla 2012).

Between 1970 and 1985 geosynthetic polyester (PET) strips, geotextiles and polypropylene and polyester geogrids were being developed for soil reinforcements in France, USA and the UK.

In modern day, various natural products have been used in the manufacturing of geosynthetics, such as coir, jute or hemp, with artificial geosynthetics being manufactured from polymeric or metallic materials.

Since the development and promotion of geosynthetics, these products have been extensively used in various geotechnical, hydraulic, environmental and transportation applications. The choice of geosynthetic is usually dependent on the application, function, costs, durability and availability (Shukla 2012).

The most commonly used geosynthetics in the twenty first century includes the following:

- **Geotextiles** are generally produced from woven or non-woven, knitted or stitched synthetic fibres to produce a flexible and porous fabric. Their primary function includes separation, reinforcement, filtration and drainage (Koerner 2005). Secondary functions of geotextiles include protection, cushioning and absorption (Shukla 2012).
- **Geogrids** have a grid geometry and is predominantly used as reinforcement due to their high tensile strength, high tensile modulus and low creep strain which have apertures between longitudinal and transverse ribs that are bonded together. The apertures allow for interlocking with the soil particles thus forming a strong reinforced soil (Koerner 2005). In addition to reinforcing geogrids can also provide a separation function as well.

- **Geonets** are similar to geogrids with the exception that the apertures have acute angles between the ribs. Their main function is drainage to convey liquids and occasionally as cushioning and protection (Koerner 2005). These geosynthetics are often used on either side of geotextiles or geomembranes to prevent the migration of soil particles during drainage (Shukla 2012).
- **Geomembranes** are thin, impervious sheets of polymeric materials used for liquid/solid containment, as liners or fluid barriers, in landfills, reservoirs, and canals (Koerner 2005).
- **Geosynthetic Clay Liners** comprise a bentonite clay layer between geotextiles or is bonded to a geomembrane. Given their impermeability these liners are used predominantly for containment applications (as fluid barrier or liners) either with a geomembrane or by itself (Koerner 2005).
- **Geocomposites** comprise a combination of geotextile, geogrid, geonets and or geomembranes which are combined with other synthetic material or soil. These composites may be used in various applications, some of which include drainage by geomembrane-geonet composite, and separation-filtration-drainage function by a geotextile-geonet composite (Koerner 2005). Geocomposites may also include the use of other materials besides geosynthetics, for example, geomembranes used with clay to perform as a liner to reduce leakage and increase breakthrough time (Shukla 2012).
- **Geofoam** is another type of geosynthetic which is predominantly used as a separator however may perform as a fill, thermal insulator and as a drainage channel when used in geotechnical applications (Shukla 2012).
- **Geocells** are thick cellular reinforcements that filled with soil forms a stiff mattress which is used to spread loads. These have been used for earth retaining structures, and for road and rail load support (Rajagopal 2013).

Figure 2-1***: Types of Geosynthetics (Shukla 2010, Koerner 2005 and Rajagopal 2013)***

represents the most common types of geosynthetics available in the industry today.

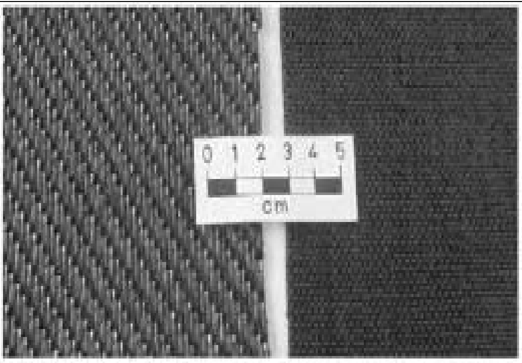
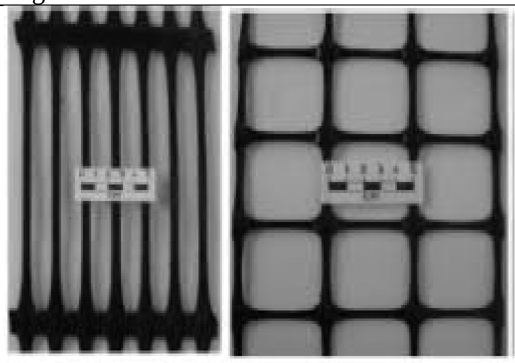
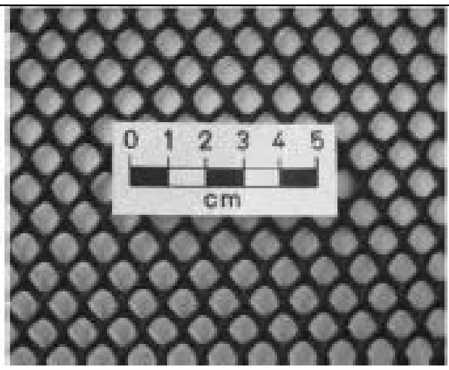
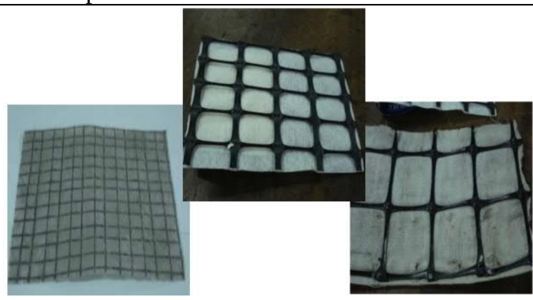
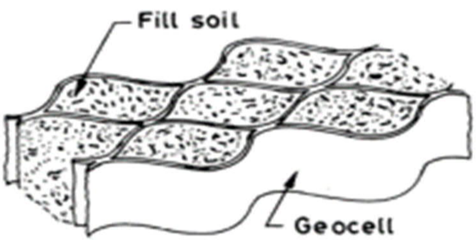
Geotextile	Geogrid
	
Geonet	**Geomembrane**
	 Rough surface texture; Smooth – double sided membrane
Geosynthetic Clay Liner	**Geocomposite**
	
Geocell	
	

Figure 2-1: Types of Geosynthetics (Shukla 2010, Koerner 2005 and Rajagopal 2013)

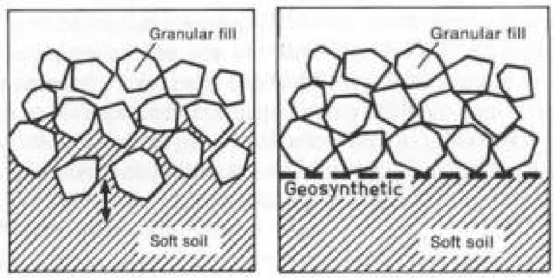
2.1.1 Geosynthetic Function

As highlighted, there are a several functions that are performed by different geosynthetics, with some having more than one function when utilized with natural materials. The predominant functions of geosynthetics include the following:

- **Separation**

Separation is often used to prevent the mixing of two different material layers such as the separation of poorer quality material from granular soils, thus maintaining the integrity of the granular fills as illustrated in Figure 2-2***: Illustration Indicating Separation Function of Geosynthetics (Shukla 2012, p.10)***

(Shukla 2012).



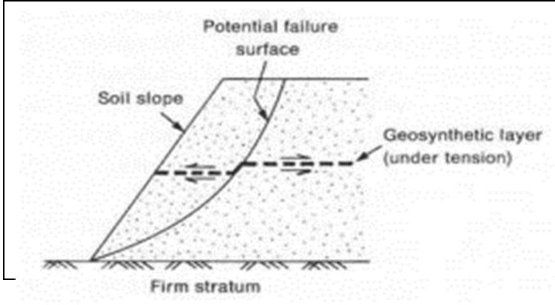
Separation Function

Figure 2-2: Illustration Indicating Separation Function of Geosynthetics (Shukla 2012, p.10)

- **Reinforcement**

Geosynthetics are used extensively to reinforce soil masses thereby leading to the improvement of the strength of the soil structure, hence maintaining stability and integrity of the soil mass. In reinforced soil walls geosynthetics are laid between soil layers to improve the tensile strength of the soil mass (Shukla 2012). The three most common reinforced soil systems as defined below.

- Stabilization and reinforcement of embankments over soft soils by improving the bearing capacity of the weaker soil, which is referred to as reinforced embankments over soft foundations (RESF) (Mirafi 2017, p.4).
- Construction of steep reinforced embankments and slopes which reduced the need for large slope footprints is referred to as reinforced soil slopes (RSS) (Mirafi 2017, p.5);
- Reinforced soil walls for various retaining wall applications is commonly referred to as mechanically stabilized earth wall (MSEW) (Mirafi 2017, p.6).

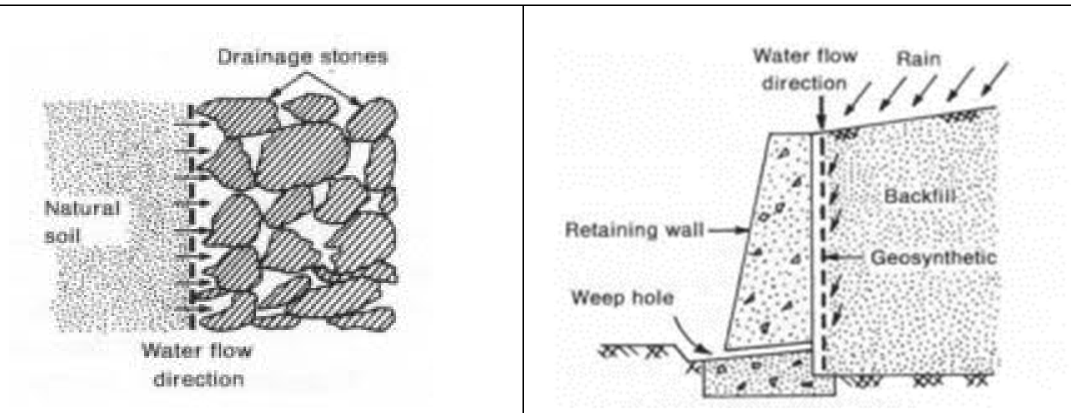


Reinforcing Function

Figure 2-3: Illustration Indicating Reinforcement Function of Geosynthetics (Shukla 2012, p.10)

- **Filtration and Drainage**

Geosynthetics may perform as a filter by allowing the flow of fluid across the geosynthetic plane while preventing the migration of soil particles together with the fluid. Another function of geosynthetics includes drainage by promoting the removal of water from the immediate surrounding which flows along the plane of the geosynthetic to a drainage system such as a weep hole (Shukla 2012).

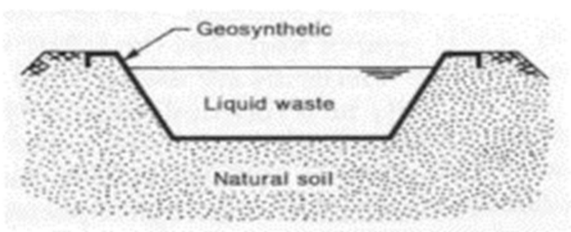


Filtration Function | **Drainage Function**

Figure 2-4: Illustration Indicating Filtration and Drainage Functions of Geosynthetics (Shukla 2002, p.10)

- **Fluid barrier**

Geosynthetics have been used as an impermeable membrane at the base of water bearing structures such as ponds and dams. These barriers have also been used extensively on landfill sites to prohibit the infiltration of potentially contaminated fluids into the ground (Shukla 2012).



Fluid Barrier Function

Figure 2-5: Illustration Indicating Fluid Barrier Function of Geosynthetics (Shukla 2012, p.10)

Secondary functions performed by geosynthetics include protection, cushioning, absorption, insulation and screening (Shukla, 2012).

In 1926 the South Carolina Highways Department undertook trials which included placing of woven cotton fabric onto a prepared subgrade, overlain by asphalt followed by a layer of sand on the asphalt. The results showed a reduction in cracking, ravelling and localized failures up to the point when the fabric began to deteriorate. This was hence the precursor for the separation and reinforcement function of geosynthetics (Koerner 2005, p.4).

The service life of a road and pavement are influenced by various factors such as environmental factors, subgrade conditions, traffic loads, and aging, however the predominant problem lies in the infiltration of surface water into the layers leading to softening and weakening of the pavement layers with subsequent degradation of the road (Carthage Mills, n.d). It is therefore paramount to prevent infiltration of water into the pavement layers by designing the pavement to either stabilize the subgrade against moisture increase and strengthening the base while maintaining drainage of the layer (Carthage Mills, n.d.). Geosynthetics function as subgrade separation, stabilization and basal reinforcement and has transformed the transportation industry by providing an alternative to conventional solutions for the strengthening and stabilization of roads. Installation of reinforcement within / or on the subgrade layer of a pavement can significantly improve the road structure, while geosynthetics placed between the pavement layers provides reinforcement leading to a higher stiffness and strengthening of the road pavement layers. Placement of geosynthetics at the interface of different material layers performs a separation function thus maintaining the integrity of different materials within the pavement (Carthage Mills, n.d.). All of these treatments and design modifications have significantly improved the performance of road pavements by reducing deterioration and rutting and hence resulting in reduced maintenance and extending the service life of a road (Carthage Mills, n.d., p.11).

During maintenance of roads it is common practice to use geosynthetics over distressed pavements to prevent further propagation of the underlying cracks into the overlay. The geosynthetic provides tensile strength, and hence retards the development of cracks by absorbing the stresses that arise in the damaged pavements (Maccaferri, 2016). **Error! Reference source not found.** illustrates the use of a geosynthetic reinforcement within the subbase layer of a road constructed in Nylstroom, South Africa.

Figure 2-6: Subbase Reinforcement on a T55/1 Road in Nylstroom, Limpopo Province, South Africa (Maccaferri, 2016)

The stability of subgrade soils is influenced by the water content of the soils which are generally weaker when the moisture content is high. Additionally, changes in moisture content of expansive soils will result in heaving and shrinkage hence it is critical to manage the moisture content to improve the strength of the subgrade (Carthage Mills, n.d., p.23). The construction of sand and gravel (with fine sands as a filter to prevent particle migration) subsoil drains adjacent to the subgrade layers will promote drainage of low permeability soils. As an alternative geosynthetic products promote drainage and filtration within a soil while preventing the migration of fine soils, additionally geotextiles have excellent filtration and separation functionality and may be used together with aggregates to promote filtration. The use of geosynthetics for drainage and filtration are possible at a far lower cost compared with the use of traditional drainage materials when considering the associated transportation and earthworks costs to implement the traditional options (Koerner 2005, p.4).

Implementing of geosynthetic drainage can control hydrostatic pressures and seepage forces within soils adjacent to concrete foundations and retaining walls. These hydrostatic pressures may lead to uplift of foundations or overturning of retaining structures. As shown in Figure 2-7, geosynthetic drainage layers have the advantage of being placed horizontally, vertically and at an inclined angle which is not always possible with conventional drainage solutions (Carthage Mills, n.d., p.28).

Figure 2-7: Use of Geodrains for Drainage Behind and Within a Reinforced Soil Wall (Escobar and Madriz 2010)

Space constraints within challenging terrain often dictates the need for constructing of very steep slopes or vertical soil walls for transportation infrastructure such as bridge abutments. Reinforced soils are soils which comprise high tensile strength elements (such as geosynthetics) to strengthen the soil wall and improve its mechanical properties. “Reinforced soil structures are being used extensively in highway construction to reduce the width of new right of ways and facilitate construction within narrow right of ways” (Fraser et al. 2012).

Slope angles of greater than ±30 degrees that would generally not be possible within unreinforced slopes are possible with geosynthetic reinforced slopes, with angles of up to 70 degrees being achievable (Carthage Mills, n.d., p.44). Steeper slopes create space either at the crest of the slope or at the toe given that the horizontal extent of the slope is reduced.

Conventional retaining walls act to retain soils and to prevent collapse of the retained soil. Geosynthetic reinforced soil walls (or Mechanically Stabilized Earth Wall) are also retaining structures which can be constructed at slopes that are greater than 70 degrees and is constructed to retain existing soil masses or backfill soils (Koerner, 2005). The inclusion of reinforcements provides additional tensile strength to the reinforced soil mass.

“Past studies by the European Association for Geosynthetic Product Manufacturers (EAGM) has shown that the non-renewable cumulative energy demand of the construction and disposal of a 1m long reinforced concrete retaining wall with a height of 3m is 12700MJ-eq as compared to 3100MJ-eq for a reinforced soil wall of the same dimension” (Fraser et al. 2012, p.3). Furthermore, the cumulative green-house gas emissions amount to 1.3t CO_2-eq from a reinforced concrete structure while for a reinforced soil structure this value is 0.2t CO_2-eq (Fraser et al. 2012, p.3). Based on these numbers, reinforced soil structures are considered far more sustainable than conventional reinforced concrete structures.

The low shear strength of soft soils and excessive consolidation settlement make construction over cohesive soils difficult and requires special designs and construction practices. Conventional solutions include the removal and replacement of soft soils, the installation of drains to try and facilitate consolidation, the preloading of the site to induce the settlement of the structure and improve the strength, or soil modifications which include stabilizing with cement, sand or lime. The use of geosynthetics such as geotextiles or geogrids between soil layers have increased in popularity given the improvement in the bearing capacity and subsequent stiffness of weaker subgrade horizons thus enabling construction over weaker soils, as illustrated in Figure 2-8. Geosynthetic basal reinforcement confines the soils within the base layer, hence preventing lateral spreading which in turn improves the stiffness of the subgrade thereby increasing the stress distribution and reduces shear stress within the subgrade layer (Koerner 2005).

The use of geosynthetics (specifically geogrids and geotextiles) over areas prone to sinkholes or subsidence provides a solution for development in areas that were previously considered ‘no-go’ areas. The installation of geogrid layers within the subgrade layer below a structure such as foundations or roads can prevent failure due to loss of subgrade support caused by the development of subsurface voids. The geosynthetic acts in tension and spans the void which helps to minimise the effect of subgrade failure (Mirafi 2017, p.8). This system provides the users with a ‘warning’ sufficiently early so that appropriate safety measures can be implemented. This solution provides a situation of “non-catastrophic failure”, therefore should subsidence occur the measures in place would allow persons to evacuate the area safely and timeously before a ‘catastrophe’ occurs.

Figure 2-8: Basal Reinforcement over Soft Soils to Increase the Bearing Capacity of the Subsoils for the Construction of Warehouses at the Valley Terminal in Richards Bay (Maccaferri 2010)

Snake Valley between Centurion and Pretoria in Gauteng is underlain by dolomite which is prone to the development of sinkholes (Gewanlal 2009). The Gautrain Rapid Rail Link crosses over Snake Valley and hence measures to minimise the impacts due to formation of sinkholes below the rail tracks were essential. The solution adopted included the tracks being laid on post tensioned reinforced concrete beams on grade with movement joints. The concrete beams were founded on a fill embankment. The construction process included the dynamic compaction of the subsoils to collapse any possible cavities close to the surface and to stiffen the subgrade. The fill embankment was constructed with geosynthetic reinforced fabric (geotextiles) over the compacted subgrade. The geotextiles provided stiffness needed within the fill embankment to prevent the propagation of the potential sinkholes and to span over potential sinkholes. The geosynthetic provided the reinforcing and drainage requirements necessary to aid stability of the embankment structure at an acceptable cost, with the construction being undertaken within reasonable timeframes (Gewanlal 2009).

Conventional solutions for seepage control have included low permeability silt and clay liners or bitumen and cement product which have been used since the 1900's to reduce liquid migration. The development of rubber butyl liners in the 1930's was the first geosynthetic solution to act as a liner and was the precursor that led to the development of geosynthetics combined with bentonite to act as a barrier which is used extensively for containment purposes (Koerner 2005, p.4).

Geosynthetic clay liners (GCL) and geomembranes are also used to prevent seepage and act as a fluid barrier for containment in ponds, tanks and reservoirs. These geosynthetic fluid barriers have prevented environmental contamination from leakage of landfills and other waste deposits, prevented seepage of untreated liquids in waste water treatment structures and enabled the collection of biodegradation gasses such as methane (Carthage Mills, n.d., p.50).

Some of the challenges of conventional silt and clay barriers is the difficulty of vertical placement against vertical structures, and the influence of variation in texture, moisture control, compaction, temperature exposure and exposure to chemicals on the performance of the silt and clay barriers (Carthage Mills, n.d., p.50). Geosynthetic liners generally perform according to its specification and are generally easy to install in both the horizontal and vertical direction (Carthage Mills, n.d., p.50). They are useful for waterproofing of tunnels, foundations, basement walls and bridge abutments. Geomembranes have also been used in earth dams which require an impervious core and hence replaces the use of silt and clay which is sometimes difficult to source.

2.1.2 Polymeric Components of a Geosynthetic

Most geosynthetics used in the construction industry are manufactured using synthetic polymers together with various other additives for various purposes. The most common polymers used for geosynthetics as highlighted by Shukla (2012) and Koerner (2005) include the following:

- High density polyethylene (HDPE)
- Medium density polyethylene (MDPE)

- Linear low-density polyethylene (LLDPE)
- Very low-density polyethylene (VLDPE)
- Polypropylene (PP)
- Polyvinyl chlorides (PVC)
- Expanded Polystyrene (EPS)
- Extruded polystyrene (XPS)
- Chlorosulphonated polyethylene (CSPE)
- Chlorinated polyethylene (CPE)
- Polyester (PET)
- Polyamids (PA)
- Thermoset polymers such as ethylene propylene diene terpolymer (EPDM).

Polymers comprise a series of small molecular compounds called monomers that are combined to form a polymer. Polymers generally comprise a number of repeated molecular units that link to form chains. The molecular weight of polymers is the number of repeated molecule units multiplied by the molecular weight of the repeated molecule. Geosynthetics are made up of polymer resin together with anti-oxidants, screening agents, fillers and various other additives. "These additives vary in quantity and are used for Ultra violet (UV) light absorbers, antioxidants, thermal stabilizers, plasticizers, biocides, flame retardants, lubricants, colorants, foaming agents or antistatic agents, all of which are included to improve the durability of the geosynthetic (Kay, Blond, and Mlynarek 2004)".

Polymers used to make geosynthetics are required to have durability requirements of at least 50 years (up to 100 years), as most structures in which these may be used are expected to function for these timelines (Kay, Blond, and Mlynarek 2004, p.1). As such the polymers need to be manufactured taking into consideration the functional use of the geosynthetic, the environment it will be used in and the installation process. Additionally, the manufacturing process needs to account for degradation mechanisms and the durability required of the product for its use as a geosynthetic over the lifetime of the geosynthetic structure.

Each small group of molecules within a polymer has its own stability characteristics. The chemical components of the small molecules dictate the physical and chemical degradation mechanism of the polymer. "The durability of the polymer is dictated by the polymers chain structure, molecular weight distribution, the morphology (chain orientation or crystallinity), the polymer irregularity such as impurities or structural irregularities and the additives in the polymers such as antioxidants and UV stabilizers (Kay, Blond, and Mlynarek 2004)".

The thermal and shear stresses induced during the manufacture of these polymer materials also has an influence on the degradation of the materials. Different polymers have different sensitivities that can be influenced by the environmental conditions in which it is used and by the installation method of the geosynthetic.

2.1.3 Geosynthetic Properties

2.1.3.1 Physical Properties

The physical properties that influence performance of a geosynthetic material include specific gravity, mass per unit area, reinforcement thickness and stiffness. Additionally, for geonets and geogrids the structure of the apertures, rib dimensions, angles between intersecting ribs also influence performance (Shukla 2012).

2.1.3.2 Mechanical Properties

According to Shukla (2012), some of the most fundamental mechanical properties that influence geosynthetic performance include the following, however are not necessarily applicable to all geosynthetic applications:

- the compressibility of the geosynthetic under applied load;
- the tensile strength is required for design purposes and includes the tensile modulus (which is the slope of the stress strain curve). This modulus defines the deformation required to develop stress in the geosynthetic material for reinforcement applications;
- the Poisson's ratio which is the ratio of the lateral normal strain to the longitudinal normal strain under loading and is important in reinforcing applications;
- the seam strength is the ability of the geosynthetic to transfer load from one geosynthetic to another when two ends of a geosynthetic are joined;
- the structure as a result of fatigue, burst, tear, impact and puncture influences the survivability and separation function of a geosynthetic; and
- the soil-geosynthetic interaction is essential for the effectiveness of reinforcements used in reinforced soil structures (Shukla 2012).

2.1.3.3 Hydraulic Properties

The hydraulic properties dictate the effective performance of geosynthetics that are used for drainage applications. These properties include the following;

- the porosity of the geosynthetic which is the measure of the ability for liquid to flow through it and is the ratio of the void volume to the total volume;
- the permeability (volume flow rate) of the geosynthetic to water flow is generally expressed by Darcy's coefficient, or by the cross-plane permeability;
- the transmissivity of the geosynthetic is the product of the in-plane water flow and the geosynthetic thickness.

Additionally, the fibre type, size and orientation, void ratio, confining stresses, repeated loading, contamination and aging influences the performance of a geosynthetic for drainage purposes (Shukla 2012).

2.1.4 Degradation of Geosynthetics

Degradation of the polymers used in geosynthetics differs from one to the other. The environment in which a geosynthetic is used dictates the choice of geosynthetic material. “The following factors that need to be considered when selecting the type of geosynthetic, include the application, temperature, moisture conditions, ultraviolet (UV) radiation, thermal stress, chemical environment, mechanical stress, microbiological activity and atmospheric pollution (Kay, Blond, and Mlynarek 2004)." These factors hence influence the polymer structure which in turn affects the functionality and degradation of the geosynthetic (Kay, Blond, and Mlynarek 2004).

2.1.4.1 Aging Mechanism

2.1.4.1.1 Physical Aging

Physical aging of polymers is one of the degradation mechanisms that can be expected in polymer geosynthetics. This refers to the extraction of additives within the polymer by the environment in which the geosynthetic is installed or the change in the morphology of the material. This mechanism does not include the modifications to the molecular structure (Kay, Blond, and Mlynarek 2004).

- **Additive Extraction**

Additives are added to polymers to improve the performance properties of the polymer. However, exposure to unsuitable environments and conditions (such as UV radiation or moist environments) may lead to the extraction of these additives by processes such as leaching or evaporation.

- **Solvent Action**

Exposure of the geosynthetic to solvents may also result in the physical aging of the geosynthetic. Weak molecular chains making up the polymer may be altered by solvent interaction. The solvent molecules (which are stronger) penetrate and breakdown the polymer molecular chains with subsequent reduction in the cohesion between the polymer molecules and thus reducing the stiffness of the polymer.

Polymers comprise amorphous and semi-crystalline phases in the solid state (Kay, Blond, and Mlynarek 2004). "In an amorphous polymer the molecules are oriented randomly and are intertwined while in semi-crystalline polymers, the molecules are packed together in ordered regions called crystallites (Kay, Blond, and Mlynarek 2004)." Cracks develop due to absorption of solvents hence stressing the interface of the amorphous and crystalline phase of the polymer leading to chain rupture and modification to the chemical structure of the polymer (Kay, Blond, and Mlynarek 2004).

- **Internal Chain Reorganisation**

Shear stresses that develop during the manufacturing of polymers may be sustained within the polymers resulting in chain deformation. Cooling processes lead to the polymer chains freezing in their deformed unstable state which when exposed to increase in temperatures reorganises the internal chain structure as a result of the internal stresses which may influence the geosynthetic properties (Kay, Blond, and Mlynarek 2004). "Furthermore, prolonged stresses may lead to reversible elastic deformation or irreversible slow viscous deformation in polymers, with the latter being linked to the slipping of chain segments to release stresses (Kay, Blond, and Mlynarek 2004)". This movement is referred to as creep which is defined as deformation as a result of prolonged constant stress.

- **Environmental Stress Cracking**

Exposure of the polymer to certain chemicals (sensitizing agents) may lead to the brittle failure of the polymer which is referred to as environmental stress cracking, which influences the density and crystallinity of the polymer. Some polymers (such as polyethylene) have molecular chains in both the amorphous and the crystalline phase which hold together crystallites. Applied stresses are transferred to the tie molecules and other entangled molecules that extend out of the crystallites. Exposure to sensitizing chemicals lubricates the tie molecules which disentangles and slips into the amorphous phase leading to fracturing between the crystalline regions. Environmental stress cracking is dependent on the applied stress, temperature and the properties of the chemicals (Kay, Blond, and Mlynarek 2004).

- **Thermal Stress**

Temperature changes within a polymer may result in dilation (due to increased temperatures) or contraction (due to decreased temperatures) of the polymer which is referred to as thermal stresses. When the deformations in the material are restricted or restrained, thermal stresses may develop within the polymer. In some geosynthetics the contractions and dilations may lead to the change in the dimensions of the geosynthetic. For thick geosynthetics the thermal stresses affect aging of the materials. Additionally, the stresses may lead to the loss of cohesion at the soil-reinforcement interface in composite geosynthetics (Kay, Blond, and Mlynarek 2004).

2.1.4.2 Chemical Degradation

Chemical degradation alters the molecular chain structure within a polymer. The modifications that may occur include the following:

- Chain scissions (cuts) or separation resulting in a reduction in the molecular weight which affects the mechanical resistance of the material making it more brittle.
- Cross linking which is the creation of molecular bonds between molecular chains. This reduces mobility and changes the mechanical properties by increasing the stiffness of the polymer.
- Substitution of chain molecular structure or the elimination of molecules. These substitutions usually only affect the appearance of the polymer, however may promote other modes of degradation.

Chemical degradation mechanisms include chemical resistance, oxidation and hydrolysis (Kay, Blond, and Mlynarek 2004).

- **Chemical Resistance**

As highlighted previously solvent chemicals have the potential to alter the polymer molecular chain structure. Diffusion of chemicals into the polymer is influenced by the increase in temperatures (by 10 degrees) which acts as a catalyst to increase (double) the rate of reaction. These chemicals may be neutralized by additives that are added to the polymer (Kay, Blond, and Mlynarek 2004).

- **Oxidation**

Polymer materials may degrade due to the chemical reactions that occur in the environment. Polyolefins, polymers and blends of these degrade due to oxidation between the polymer and oxygen molecules. The oxidation process is influenced by the temperature and the rate of surface reaction. The tie molecules in the amorphous state are broken leading to a reduction in the strength or in some polymers (PE) higher molecular mass and less flexibility (Greenwood, Schroeder and Voskamp 2012, p.112).

This process is usually inhibited by the addition of long-term antioxidants during the manufacture of the polymer which retards the process over its service life and service temperature (Greenwood, Schroeder and Voskamp 2012, p.118).

- **Hydrolysis**

The chemical reaction between absorbed water molecules with molecular bonds along the molecular chains is referred to as hydrolysis. This process is common in polyester fibres, and polyester plasticizers (in flexible PVC). The process is catalysed by alkaline or acidic environments. Acidic environments cause chain scission hence leading to reduction in molecular weight. Alkaline environments lead to a reduction in the polymer fibre diameter and a reduction in the polymer weight. These reactions are generally dependant on the temperature, where increases in temperature speeds up the reaction. The crystallinity of the polymer has an influence on the reaction as well where a high percentage of crystallinity in an acidic environment reduces the diffusion of the water while in alkaline environments the high percentage of crystallinity may reduce the rate of surface erosion (Kay, Blond, and Mlynarek 2004). Reduction in the molecular weight alters the mechanical properties of the polymer making it more brittle.

2.1.4.3 Thermal Degradation

Molecules within a polymer are connected to other molecules via bonds with bond energy. Stability of the bonds are dictated by the magnitude of the bond energy strength. Heat energy imparts a vibration within the molecular structure. When this vibration energy increases and reaches or exceeds the bond energy there is a high probability of bond dissociation (disconnecting), which may result in chain scissions and molecule elimination. This however is only a problem when the geosynthetic is exposed to the sun or when there is an increase in the temperature (Kay, Blond, and Mlynarek 2004).

The greatest exposure to high temperatures and shear stresses occurs during the manufacturing of the geosynthetics. The exposure of the polymeric materials to high temperatures and stresses to ensure the durability of the geosynthetic in the long term and prevent any structural irregularities is generally controlled by the inclusion of thermal stabilizers in the polymer resin. (Kay, Blond, and Mlynarek 2004).

Thermal degradation may lead to thermal oxidation of the polymer chains which lowers the temperature required to initiate degradation, which may be retarded by the inclusion of antioxidants within the resin (Kay, Blond, and Mlynarek 2004).

2.1.4.4 Photo-Oxidation Degradation

This process of degradation is similar to thermal degradation, except that the energy source is a result of radiation rather than heat. The radiation energy may lead to the breaking of molecular bonds when the energy reaches the molecular bond energy. Ultra-violet (UV) stabilizers are added to the geosynthetic to reduce the sensitivity of the polymer to photo-oxidation thereby retarding the process. The various antioxidants added to the polymer leads to a thicker material which reduces the time taken for the oxygen to penetrate the polymer thereby improving its resistance to photo degradation (Kay, Blond, and Mlynarek 2004).

2.1.4.5 Microbiological Degradation

Metabolization or assimilation in polymers is the mechanism of degradation by microorganisms. This process usually involves hydrolysis or enzymatic oxidation which leads to a loss in weight and polymer chain scissions making the polymer more brittle. The microbiological activity is generally influenced by temperature, moisture, UV radiation and visible light and is generally uncommon in resin based geosynthetics, however should be taken into consideration when working within organic soils, water and within tropical environments (Kay, Blond, and Mlynarek 2004).

2.1.5 Durability

The durability of geosynthetics is its ability to maintain its essential properties against various influences over the design life of the geosynthetic and is generally governed by the composition of the polymer used to manufacture the geosynthetic and is a measure of the geosynthetics construction survivability and longevity or durability (Shukla 2012).

2.1.5.1 Creep

Creep is the elongation of a geosynthetic that has sustained a continuous applied stress over long periods of time. According to Koerner, Koerner and Hsuan (2014, p.1) creep deformation has three stages, namely;

- “primary creep which is work hardening as the materials adjust to the applied stress and is related to visco-elastic strain”
- “secondary or steady-state creep” and
- “tertiary creep which increases exponentially with stress and leads to creep failure or creep rupture” (Koerner, Koerner &Hsuan 2014).

Error! Reference source not found. illustrates the three stages of creep under sustained loads at constant temperature.

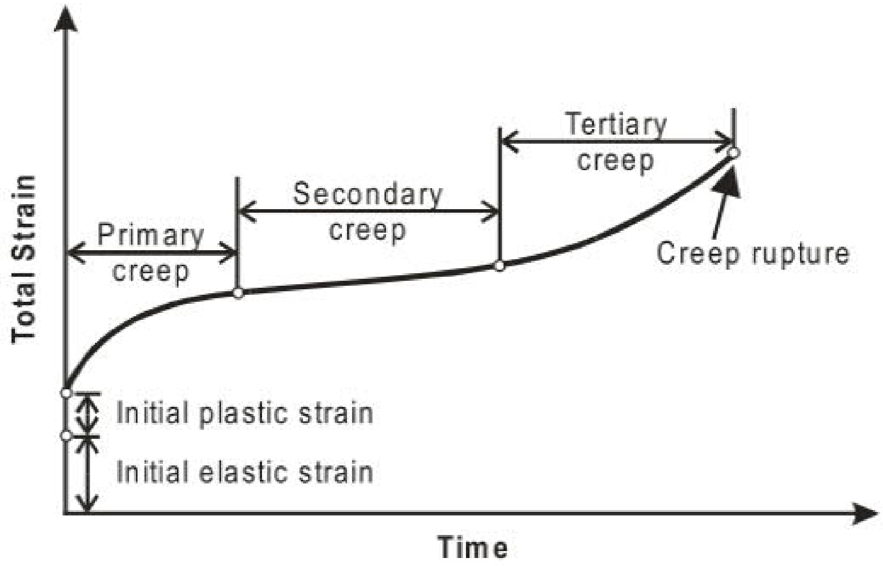


Figure 2-9: The Three Stages of Creep (McGown 2000)

As geosynthetics are susceptible to creep, strains within the reinforced soil may lead to deformation of the structure. The degree of creep strain depends on loading, type of polymer and its manufacturing process (Vashi, Desai and Solanki 2011).

Error! Reference source not found. indicates the secondary and tertiary creep experienced in various polymers at low (20%) and high (60%) stresses of the ultimate strength of a polymer with time (Shukla 2012). The graphs highlight the difference in the total strain and the rate of strain for the different polymers.

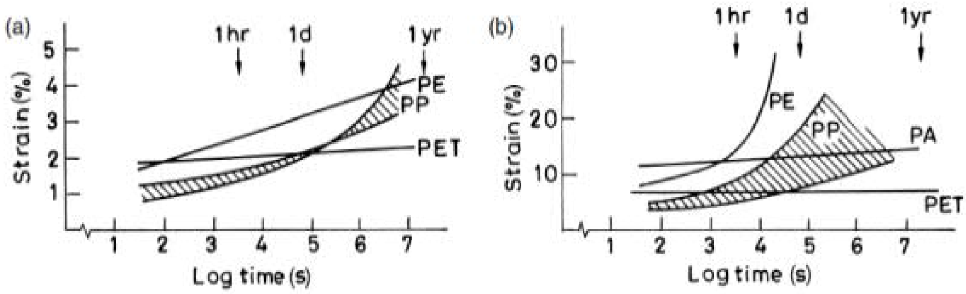


Figure 2-10: Creep Results for various Polymers (a) creep at 20% load, (b) creep at 60% load (Shukla 2012)

During geosynthetic design the ultimate tensile strength of a geosynthetic is downrated, by the application of reduction factors, to an allowable design value to accommodate degradation factors such as creep (Vashi, Desai and Solanki 2011).

Laboratory testing determines creep of various geosynthetics used in reinforced walls, slopes and foundations. Reduction factors are determined from the evaluation of creep strain of the geosynthetic which are applied to limit the strain of the soil structure and are used in the design calculations to account for creep strain. The three types of tests that are carried out to determine the creep strain and reduction factors are as follows. Typical reduction factors, which are determined from creep tests, used for geosynthetic reinforcement are indicated in **Error! Reference source not found.**.

- **Conventional Creep Testing**

This test subjects a geosynthetic specimen with a fixed end to a constant load, while measuring the strain continuously over time or at time intervals. The ambient temperature and humidity are maintained constant during the test. The test duration is equivalent to 10,000 hrs or to failure depending on which occurs first. The creep rate is the slope of the creep-time curve and hence is calculated by plotting the strain percentage versus the log of time (Vashi, Desai and Solanki 2011).

As indicated testing is generally conducted over a 10,000-hour period which is equivalent to 1.14 yrs. The prediction required to assess the creep over a 100-year life will need to be extrapolated to 100,000 hours and to 1,000,000 hours (Koerner, Koerner and Hsuan 2014).

- **Time Temperature Superposition (TTS) Testing**

Given the extensive duration of the conventional test method, the load strain behaviour can be determined using the accelerated time-temperature superposition principals. This test imposes higher temperatures which accelerates the performance of geosynthetics. The elevated temperatures beyond standard test temperatures of 20 degrees will result in all degradation mechanisms increasing proportionally, hence increasing the temperature will reduce testing times (Koerner, Koerner and Hsuan 2014).

- **Stepped Isothermal Method (SIM)**

This test method is similar to the TTS method using elevated temperatures; however, is conducted in steps within a single testing chamber on a single test specimen within much shorter timeframes (Koerner, Koerner and Hsuan 2014).

Table 2-1: Typical reduction factors for reinforcing geosynthetics that are used in design calculations to accommodate creep strain of the geosynthetic material (Koerner, Koerner and Hsuan 2014)

Type of Reinforcing Geosynthetic	Reduction Factors
Integral HDPE Types	2.60-2.70
Woven or knit PET Types	1.40-1.58
Rod or strap PET Types	1.40-1.45

The prolonged loads over extensive periods that geosynthetics experience in structures that have a design life of 50 to 100 years warrants the consideration of load-strain with time behaviour (creep) during design. This form of degradation is based on the type of polymer used to manufacture the geosynthetic and the ambient temperature within the environment that the geosynthetic is used may be critical at stresses equivalent to 20% of the ultimate strength (Shukla 2012, p.28). The loading applied and the design load of a geosynthetic is hence governed by the creep strains of the geosynthetic (Shukla 2012).

Stress relaxation occurs when the soil strength increases due to consolidation of the soil which usually occurs after construction. This leads to increased soil strength and decreased tensile stresses in the reinforcement. However, in reinforced soil walls and slopes the loading on the geosynthetic is usually sustained hence leading to high creep strain, which should be accounted for during design (Shukla, 2012).

2.1.5.2 Installation Damage

The installation and construction process may lead to damages in the geosynthetic and changes in the properties leading to compromised performance of the reinforcement (Paula, Pinho-Lopes, and Lopes 2008). The placement in terms of fill lift thickness, the composition of the fill (which includes the gradation, particle size, angularity of the grains), compaction (including compaction equipment used and compaction energy (number of pass of the compactor)) of the fill and the type and weight of the geosynthetics may lead to geosynthetic installation damages (Hufenus et al. 2005). As a result, design considerations or reduction factors need to be allowed for to downrate the strength of the reinforcement to account for potential damages.

Damages from installation includes severing, cuts, bruises and abrasion of the geosynthetics leads to reduced peak strength, changes to the modulus of the stress strain curve (tensile modulus) and strain at failure (Allen and Bathurst 1994). Experimental tests have in some cases shown that the Young's modulus (Tensile Modulus) is unchanged irrespective of the reduction in maximum tensile strength and strain at failure (Hufenus et al. 2005).

Minor damage in the geosynthetics may lead to defects in the reinforcement. These damages result in elevated stresses that may result in premature failure in the geosynthetic at reduced stains (Allen and Bathurst 1994). Severe damage to geosynthetic fibres / yarns / ribs would lead to the load that would have been carried by damaged fibres being transferred to adjacent fibres, hence resulting in increased strain and decreased overall modulus of the geosynthetic as the applied load remains constant. The loss of modulus is dependent on the fibre thickness and macrostructure. Greater thickness allows the geosynthetic to sustain greater damages and stress (loss) before severing occurs (Allen and Bathurst 1994, p.195).

Similar to the reduction factors for creep, design approaches account for installation damage by the application of reduction factors to the geosynthetics tensile strength.

A study performed in 1998 has shown that by using a granular fill layer with a lift thickness of 250mm over the geosynthetic with the maximum gravel sizes of 25% of the lift thickness will minimize the degree of installation damage (Hufenus et al. 2005).

2.1.5.3 Weathering and Temperature

The photon energy of UV radiation leads to a loss of strength in polymers. This loss of strength is due to the exposure to UV radiation which results in photo oxidation and bond breakage of the main chains of the polymer.

The wavelength of the UV radiation and the effect of temperature influence the rate of degradation. A temperature increases of 1 degree Celsius can increase the rate of change of a property by 8% (Greenwood Schroeder and Voskamp 2012, p.166). Increased temperatures may decrease strength, increase creep and reduce the durability of the geosynthetic. To mitigate the influence of increased temperatures it is recommended that geosynthetics be manufactured using polypropylene which have a higher resistance to temperature (Shukla, 2012).

Additives such as carbon black are added to the polymer to inhibit the influence of UV radiation during the storage and installation when the geosynthetic is exposed. Carbon black absorbs the UV radiation and reduces the access to the polymer hence providing a degree of resistance to weathering (Greenwood Schroeder and Voskamp 2012). Testing methods are available to estimate the maximum amount of time a material can be exposed to radiation during installation.

2.1.5.4 Importance of Design Life

Design life of a geosynthetic is the duration that a geosynthetic is required to maintain its required properties. The geosynthetic is generally required to have an equivalent or greater lifetime than the structure in which it is used. The methods to predict the service / design life of a geosynthetic include direct measurement on recovered (exhumed) geosynthetics together with data extrapolation. Alternative methods include index testing which provides assurance for 25years, with accelerated testing predicting the lifetime for greater than 25years.

It is essential to note that the design life of a geosynthetic is dependent on the correct design, selection of geosynthetic and installation process. Damage to geosynthetics may occur even before installation such as during production, transportation (at high temperatures), mechanical damage (during transportation), and excessive exposure to UV radiation due to long storage periods.

2.1.6 MARV

MARV or Minimum Average Roll Value is the published values of various geosynthetic test properties such as mass, unit weight, and tensile strength amongst other properties. Given the manufacturing process, testing equipment and methods, the properties of a particular geosynthetic may vary from one to the next. The property values of a particular product will often produce a statistical variation. Geosynthetic properties are therefore specified as average or mean values minus two standard deviations. This is referred to as MARV and equates to a 97.5% confidence that all measured values (of a particular property) will be greater than the MARV value (Koerner and Koerner 2011).

MARV is also used as a quality control tool by manufacturers to confirm the reported strength properties of a specific geosynthetic.

2.2 Reinforced Soil Walls

"Reinforced soils describe a soil mass which has had its shear strength improved by combining it with resisting elements such as bars, strips, grids and sheets" (Pedley 1990, p.2.1). The reinforcements in the soil mass complement the soils tensile and compressive strength. Reinforced soils can support higher tensile loads (than an unreinforced soil) while also limiting the amount of deformation. In addition to improved shear strength of the soil structure, poorer quality soils may be used in conjunction with reinforcements in soil structures (Mirafi 2017).

As previously stated geosynthetic reinforced soil walls are commonly referred to as mechanically stabilized earth walls (MSEW) and generally use sheets, grids or strip reinforcements to reinforce the soil (Pedley 1990). Reinforced soil walls act as a retaining structure with the purpose of stabilizing the in-situ soil mass by means of resisting lateral soil loads and pressures using the dead weight of the wall. The soil and reinforcement interact and creates a stable monolithic body used for earth retention and as a load supporting structure.

The improvement in stability and strength of the soil mass has led to the increased use of reinforced soil walls in the construction industry. These structures have been implemented since the 1980's and has proven to be a successful retaining solution. **Error! Reference source not found.** is a graphical representation of geosynthetic reinforced soil walls.

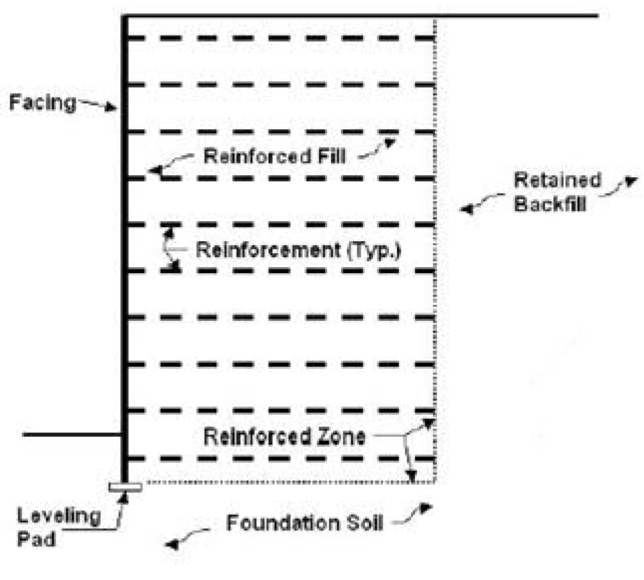


Figure 2-11: Graphical Representation of a Geosynthetic Reinforced Soil Walls (National Highway Institute Federal Highway Administration 2009)

The various reinforcements are usually categorized into inextensible or extensible, both of which have different behavioural characteristics. "When internal and external loads (design load) applied to a reinforced soil wall is sustained at axial tensile strains of less than or equal to 1%, then the reinforcement is classified as inextensible, whereas extensible reinforcements are those where design loads are sustained at a total axial tensile strain exceeding 1% (South African Bureau of Standards 2011, p.24)".

2.2.1 History of Soil Reinforcements

Reinforced soil is not a new concept and has been demonstrated in nature by birds and animals. To protect themselves from predators, Beavers (semi-aquatic rodent) built beaver dams and nests using soil (mud and stone) and timber (reeds and twigs, etc.). The twigs and reeds are used as reinforcing to strengthen the beaver dams and nests and is evidence of the principle of soil reinforcement being used in nature.

The concept of utilizing other materials together with soil to strengthen the soil structure dates back to ancient times. These soil strengthening techniques include mixing straw with clay to strengthen the quality of material, construction of roads over tree trunks and branches placed over soft soils and the use of tree branches to strengthen soil retaining structures (National Highway Institute Federal Highway Administration 2001). Trees, branches, grass, reeds, straws, roots, bamboo and tree trunks have all been used with soil to construct high structures.

The success of soil reinforcing is evident in various landmarks around the world including the following structures which have been constructed using reinforced soil concepts:

- In 7000BC Adobe bricks were being made by the Arabs which comprised of straw embedded in blocks of mud, that were dried to provide bricks with increased tensile strength. The bricks resisted tearing and squeezing and hence provided an excellent building material which was used extensively in rural North Africa. These bricks were used in the construction of the Arg-e-Bam citadel in Iran which was constructed around 579-323BC. This structure stood until it unfortunately was damaged in 2003 by a major earthquake that destroyed 70% of the buildings. There is also evidence that similar bricks were used by the Incas and Aztecs in America and in Morocco (Rajagopal 2013).
- Three thousand years ago the Agar–Quf Ziggurat (also referred to as Ziggurat of Mesopotamia) near Baghdad was constructed of 130-400mm clay bricks with layers of woven reed mats laid horizontally on a layer of sandy gravel. The reeds were placed with a vertical spacing varying between 0.5 and 2.0m. The original height of the stepped pyramid temple was approximately 80m high; however, the structure was burned but still stands at a height of 57m (Rajagopal 2013).
- The western part of the Great Wall of China which was constructed to keep the Mongolians and other invaders out of China, was constructed between 7th Century BC and 17th century AD, with clay or pounded earth reinforced with tamarisk tree branches and hence is evidence of soil reinforcing concepts used in the construction of the longest man-made structure in the world.
- In ancient Egypt, dwellings were constructed using a straw mixed with clay to improve the quality of the materials (Osman 1990).
- The early French settlers in Canada used mud and sticks to construct low dykes to protect farm lands (Osman 1990).

- In 1904 F.H. Reed patented a system to reinforce downstream slopes of an earth and rockfill dam in the United States (US). The slope was reinforced with horizontal metal railway lines which were connected to diamond shaped grids comprising rails which formed the facing of the slope (Osman 1990). This approach was implemented in Mexico, South Africa, Australia and New Guinea (Osman 1990).
- In the 1920's corduroy mats where used on forest access roads constructed over soft soils in South Carolina in the United States ((Koerner, 2005).
- In the 1960's Henry Vidal, while playing on the beach with his children discovered that by placing some reeds and roots in between the sand, he was able to build higher sand structures using the beach sand ((Rajagopal 2013, p.22). Vidal pursued his theory on reinforced earth which led to the idea of using more permanent materials for the construction of very high soil structures. He conducted models in a laboratory using steel strips or reinforced products, with metallic sheets used to restrict the soil at the front. Vidal introduced reinforced earth walls, which comprised regularly spaced flat horizontal metal strips that were laid from the face of the soil wall and extended backwards into the soil between sand layers. The reinforcement strips anchor the facing panels at the edge of the soil structure and reinforces the soil structure. This strengthening of the soil structure is attributed to the frictional stresses that develop between the strips and the fill soil. This led the way forward for the development of various strap and mesh reinforcement materials for use in reinforced soil walls (Koerner 2005). In the late 1960's Vidal introduced precast concrete facing units to be used with the reinforced soil structures. Vidal has built various structures using the reinforced earth concepts since 1964; however, the first major retaining wall using the concept of reinforced earth was constructed in the South of France (Nice-Menton Highway) in 1968. Vidal's concept was first implemented in 1972 in the United States for the rehabilitation of a landslide in California. In the UK, the first reinforced earth structure was constructed on the Leith Granton Road near Edinburgh in 1972 and comprises a 106m long and 7m high wall (Osman 1990).
- The Sikkim Airport project is evidence of the success of using geosynthetic solutions for civil engineering problems. The Sikkim airport in India was constructed in 2011 within a hilly terrain due to the shortage of land supply in Sikkim. The local authorities did not allow the importing and exporting of fill, hence the proposed footprint of the airport required a balance of cut and fill to the tightest possible footprint. Additionally, the valley side's downslope of the airport footprint was densely populated which prohibited the creation of shallower slopes and the environmental impacts prohibited construction activities beyond the project boundary. As such the most viable solution was to build a very high reinforced soil retaining structure. The solution adopted for retaining on the fill side of the embankment (up to 74m high fill embankments) included composite soil reinforcement system (using Maccaferri's ParaMesh System) while the cut slope (up to 111m high cut slopes) which was excavated to its angle of repose was protected from erosion by an erosion control blanket and a gabion toe wall. The composite soil reinforcement system comprised primary and secondary reinforcement (Veettil 2012). Primary reinforcement provided reinforcement and stability of the reinforced soil structure while the secondary

reinforcement provides stability and prevention of sloughing on the face side of the retaining wall or slope. In September 2011 a 6.9 magnitude earthquake occurred in Sikkim. The seismic event was more than the design magnitude allowed for in the Paramesh system, yet there were no damages as a result of the seismic event hence proving the resilience of the reinforced soil retaining structure. In 2012 Maccaferri won the Ground Engineering Geotechnical Award for International Project of the year for the Sikkim Reinforced Soil Structure (Veettil 2012).

Henry Vidal defined reinforced earth as a composite material comprising two materials specifically earth and reinforcement (Osman 1990, p.13). The reinforcement elements have a higher lateral and tensile strength. This improves the tensile strength, which the soil lacks, within the composite structure and is due to the friction and adhesion mobilized at the reinforcement soil interface. Vidal has patented the term Reinforced Earth and as such reinforced soil structures are commonly described as mechanically stabilized earth walls.

2.2.2 Components of a Reinforced Soil Wall

Reinforced soil comprises three main elements namely, the soil, the reinforcement and the facing which is illustrated in **Error! Reference source not found.**.

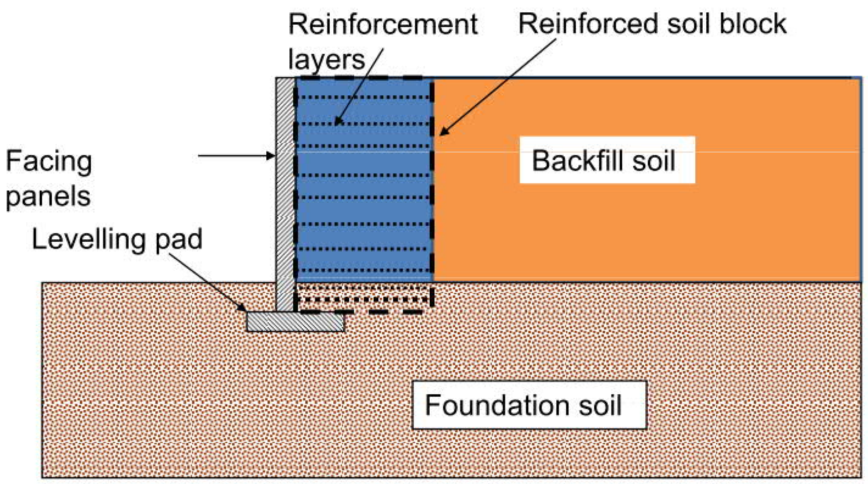


Figure 2-12: Graphical Representation of a Reinforced Soil Wall (Rajagopal 2013)

2.2.2.1 Soil

The three soil types that constitute a reinforced soil wall include the following.

- The **retained soil** is the backfilled or in-situ soil adjacent to the reinforced soil. Earth pressures that acts on the reinforced soil are exerted from the retained soil, and hence needs to be resisted by the reinforced soil mass (National Highway Institute Office of Bridge Technology 2001).

- The **foundation soil** refers to the soil on which the reinforced soil mass and retain soils are founded. The facing foundation (referred to as levelling pad in **Error! Reference source not found.**) is constructed within the foundation soil.
- The **reinforced soil** is placed adjacent to the facing in layers with the reinforcements placed between the soil layers. Granular soils are recommended for used as reinforced fill material, which usually has a high angle of friction and minimal fines.

2.2.2.2 Reinforcement

Several layers of reinforcement elements are placed within the soil within a reinforced soil wall, where it compensates for the soils lack of tensile resistance (National Highway Institute Office of Bridge Technology 2001). The reinforcement is generally attached to the facing unit and extends back into the reinforced soil. The reinforcement elements for reinforced soil structures include sheets, grids and straps (South African Bureau of Standards 2011).

Joining of reinforcements within the structure include the overlapping of reinforcements when small tensile stresses develop, stapling of geotextile reinforcements have been used as a temporary joining method or sewn connections may also be used. However, depending on the load carrying efficiency and any displacement limitations each join type needs to be assessed for each case. Bodkin joints are also commonly used to join polymeric grid reinforcements however consideration of deformations, stress concentrations and pre-tensioning is necessary when selecting bodkin joints (South African Bureau of Standards 2011).

2.2.2.3 Facing

Once constructed the reinforced soil wall (or MSEW) generally has an exposed face, which may lead to the deterioration of the exposed reinforcement and slumping and downward movement of the soil at the open end. Hence a facing unit provides leverage to the reinforced structure to prevent the downward movement (in terms of slumping, sloughing or spilling) of the backfill soil which constitutes the reinforced soil structure. Additionally, the facing element acts as an outer membrane to protect the reinforcement.

The material selected to fasten the reinforcement, or the facing connections referred to as fasteners should be selected based on the design life of the structure and the ultimate strength required for the connections.

2.2.3 Behaviour of Reinforced Soil

Soils are generally characterised as having a relatively high compressive strength compared to its low tensile and shear strength. Similar to reinforced concrete where the reinforcement improves the strength capabilities of the concrete, the placement of reinforcement along the direction of maximum stresses within the soil improves the tensile strength of the reinforced soil structure (South African Bureau of Standards 2011, p.25).

Compressive loads on soil result in excessive deformation of the soil and subsequent development of tensile and shear stresses. This is best illustrated when considering a cylindrical soil sample in a triaxial test as indicated in **Error! Reference source not found.**. When applying compression in the vertical direction (σ_1) there is a tensile strain in the horizontal direction (excessive lateral strain) as soil is weak in tension thus resulting in failure.

When reinforcements are placed at intervals (based on the design) within the cylindrical soil sample and a compressive load is applied, the reinforcement reduces the amount of lateral strain and strengthens the structure, as graphically represented in **Error! Reference source not found.**. The spacing of reinforcement layers is based on the reinforcement properties and backfill material used, the dimensions of the proposed structure and the loading on the soil mass. These parameters are used to confirm the spacing intervals and length of reinforcement to counteract any stresses and loads acting on the soil mass in order to prevent failure of the structure.

The loads applied by compressive stresses are distributed within the reinforcement. The reinforcement adds tensile stiffness within the structure that is greater than that of the soil, hence withstanding the shear stresses imposed on the soil.

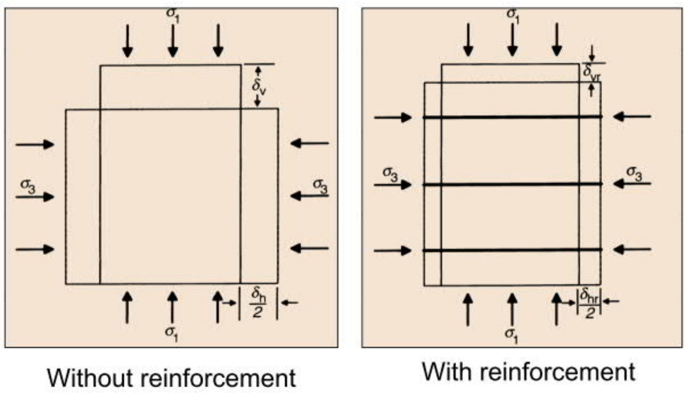


Figure 2-13: Effect of Reinforcement on Soil Structures (Rajagopal 2013)

2.2.4 Specification of the Components of a Reinforced Soil Wall

2.2.4.1 Soil

The South African National Standard Code of Practice for Strengthened/ Reinforced Soils and Other Fills, SANS80006-1:2018 (previously SANS 207:2011 Ed1.1) specifies that soils that are frictional or cohesive and frictional may be used as fill material in reinforced soil walls or abutments. Furthermore, the grading criteria requires that less than 15% of the soil should be less than 0.075mm and the maximum particle size should not exceed 37.5mm or 2/3^{rds} of the layer thickness.

The US Federal Highway Association (FHWA) specification recommends that selected granular fill material (with an approximate angle of friction of 34 degrees) is recommended as the fill for the reinforced soil layers. The materials considered suitable should be free of organic content, deleterious materials, soft soils and poor durability soils. The specification states that less than 15% of the soil should be less than 0.075mm with a plasticity index of less than 6. Poorer quality materials may be considered for use; however, the properties of this soil need to be evaluated with respect to the internal and external stability of the reinforced structure as well as consideration of the drainage characteristics of the material (National Highway Institute Office of Bridge Technology 2001).

Shukla (2012) recommends the use of granular soils for the reinforced soils, the strength and stiffness of which is considered to be dependent on the density of the soil. The behaviour of granular soils is also influenced by confinement stress, grain shape and size distribution. The grain shape and size distribution influence the density of the soil. Grain size has a significant influence on the soil-reinforcement interaction especially when used with geogrid reinforcement. The soil properties do not change when used with reinforcements, however the soil structure strength is improved due to the presence of the reinforcement provided it is aligned in the direction of maximum tensile strain (Shukla 2012).

As opposed to the general recommendation of granular materials for the reinforced soil walls, Koerner (2005) recommends the use of sand for the reinforced material in the reinforced soil structure. Koerner (2005) argues that the cost of granular materials is generally higher, and the large stones or sharp angular gravels have the potential to damage the reinforcement during installation. Hence sand is considered more suitable for use and generally has sufficient permeability to allow drainage.

Soil particle size also influences the soil geosynthetic interaction specifically when using geogrid reinforcements. For cohesionless soils the bond resistance between the soil and reinforcement is frictional, depending on the reinforcement surface roughness or passive resistance. Whereas for cohesive soils (which may be used however is not recommended) the bond between the soil and the reinforcement is adhesion. It is however highlighted that particle size does not have a significant influence when using strip reinforcements (South African Bureau of Standard 2011). In addition to the shear strength parameters, grain size, soil particle shape, density, water content and pore water pressure, soil stiffness also influences the development of soil reinforcement interaction.

Shallow ground water behind a soil wall or slope imposes pore water pressures (hydrostatic pressures) on the soil structure, hence it is essential to install suitable drainage measures to alleviate the pore water pressures exerted on the reinforced soil wall (Shukla 2012). The type of soil used as fill in the reinforced soil mass must be considered when selecting a drainage solution as granular materials are generally free draining however cohesive soils generally have poor permeability leading to poor drainage and moisture retention.

The chemical degradation of geosynthetic reinforcements should be considered when selecting soils for the reinforced soil wall, as potential chemical reactions may occur due to the reinforced soil composition (such as in the case of argillaceous material) which may lead to oxidation which impedes the reinforcement function. As such the use of argillaceous materials is not recommended with polymeric geosynthetics (Shukla 2012).

2.2.4.2 Reinforcement

The bond resistance between the soils and reinforcement is frictional and / or passive resistance depending on the mechanical properties, shape and geometry of the reinforcement and the surface roughness (National Highway Institute Office of Bridge Technology 2001, p. 53). The normal effective stress; the grid aperture dimensions (for geogrid reinforcements), the thickness and elongation characteristics of the reinforcement influences the redistribution of stress and loads within the reinforced soil (National Highway Institute Office of Bridge Technology 2001).

The soil structure has improved tensile properties as a result of the interaction between the soil and the reinforcement. The reinforcement materials need to resist degradation while still sustaining tensile loads and the effects of deformation during the design life of the structure (South African Bureau of Standards 2011). Furthermore, the durability of the reinforcement is dependent on the environment in which it is used, where chemical, electrochemical and thermal interaction within the soil may degrade the reinforcement which in turn influences its mechanical properties (Shukla 2012). Durability of the reinforcement over a specified design life influences the choice of reinforcement used for an application. Creep strain which is both loading and time dependent may result at 20% of the ultimate tensile strength and hence has a significant influence on the reinforcement selection.

Laboratory testing is undertaken to determine the geosynthetic’s characteristic short-term tensile strength. The long-term creep rupture tensile strength is usually a percentage of the short-term tensile strength as it accounts for creep. This percentage is generally determined using long term creep rupture test data which is extrapolated for the design life of the structure. Based on this percentage it is possible to determine the creep reduction factor for a specific type of geosynthetic (British Board of Agrément 2012).

The design strength for strap type reinforcements such as the Geostrap or Paraweb are calculated for the limit states. For the ultimate limit state, the long-term tensile creep rupture strength for a specified design life and design temperature is divided by the product of a partial factor and material safety factor. The partial factor accounts for the ramifications of failure while the material safety factor accounts for strength reduction due to installation damage, weathering, chemical and environmental effects and a factor of safety due to the extrapolation of time and creep related data.

For the serviceability limit state, the strap reinforcements may not exceed post construction strains, these limiting strain values have a corresponding maximum allowable tensile load. The strain limits are indicated on **Error! Reference source not found.** for bridge abutments and retaining walls.

The maximum allowable tensile strength is divided by the various partial and materials safety factors and creep reduction factors to determine the design strength of the reinforcement. (British Board of Agrément 2012).

Table 2-2: Serviceability Limits on Post Construction Internal Strains reproduced here from the British Board of Agrément Approval Inspection Testing Certification, HAPAS Certificate 12/H191 (2012, p.9)

Structure	Strain (%)	Design period for the purposes of determining limiting strain
Bridge abutments and retaining walls with permanent structural loading	0.5	2 months – 120 years
Retaining walls, with no applied structural loading i.e. transient live loadings only	1.0	1 month – 120 years

The design strength of Paragrids and Paralink geosynthetics which are planar structures with a perpendicular array of geosynthetic straps, are determined by dividing the long-term characteristic strength by the product of the partial safety factors. Similar to the strap reinforcements, the long-term tensile strength is a percentage of the short-term tensile strength of the reinforcement which factors the creep, design temperature and design life of the structure. Partial safety factors are applied to determine the allowable tensile strength to ensure that no failure of the geosynthetic results over its design life. The partial safety factors account for variation in the manufacturing process, slight differences in dimensions of the geosynthetic, and any ‘error’ related to the extrapolation of the data to determine the long-term tensile strengths. Partial factors for installation damage and environmental effects (such as pH levels, design life and design temperature) are also allowed for when deriving the design strength (British Board of Agrément 2010).

2.2.4.3 Facing

Typical facings include gunite sprayed onto the face, gabion baskets or precast concrete panels (Research Designs and Standards Organisation 2005).

The facing unit such as concrete panels, should meet the relevant material standards and the design requirements to function adequately. Fillers for facing units are required to be durable, flexible and resistant. The pioneer material to be used at the base of the facing will depend on the structural requirements of the facing in accordance with the design of the wall. Additionally, the sealing of the joints should include polyethylene foam or polyurethane foam strips (South African Bureau of Standards, 2011).

High stresses are imposed on the facing connections, which tie the reinforcement to the facing panel, particularly if settlement of the foundation soils occurs with subsequent deformation of the reinforcements. The magnitude of stress according to Koerner (2005, p.372) depends on the reinforced soil material, density, moisture content, compactive effort and foundation condition and hence assumes the strength of the reinforcement as the required connection strength (Koerner, 2005, p.372). Joint systems are required between the facing and the reinforcements which are usually prefabricated or made during the execution of the work. Common examples of joints include galvanised steel loops or connectors which are cast inside the concrete facing units. The joints between the facing and the reinforcement should be durable and meet the required strength for the connection based on the design (South African Bureau of Standards 2011).

2.3 Design Of Reinforced Soil Walls

Reinforced soil walls can fail internally and externally. Internal failures occur when insufficient bond exists between the reinforcement and the soil which may lead to sliding out of the reinforcement or where the reinforcement strength is insufficient to withstand the load/stress leading to rupture of the reinforcement (South African Bureau of Standards 2011). External failure is the failure of the reinforced soil structure as a monolithic body by bearing or tilt failure, sliding along the base, settlement or external slip (South African Bureau of Standards 2011) . Internal and external stability analysis is therefore required as part of the design method of a reinforced soil wall to assess the possible failure modes of the reinforced soil structure (South African Bureau of Standards 2011).

Internal stability analysis determines the spacing, length, coverage and strength requirements of the reinforcement required. The external stability analysis assesses the stability of the entire reinforced soil wall with respect to overturning, sliding, bearing capacity and settlement of the structure (South African Bureau of Standards 2011, p.79).

2.3.1 Internal Mechanisms of a Reinforced Soil Structure

As previously highlighted compressive loads applied to a soil mass develop lateral tensile strains in the soil with subsequent lateral expansion. The inclusion of reinforcements in the soil promotes soil reinforcement interaction which develops a confining stress (Δs_3) within the soil mass which reduces the deformation of the structure (South African Bureau of Standards 2011, p.25). Movement between the soil and reinforcement develops bonds which in turn allows the transfer of loads between the two elements. It is essential for the reinforcement to be axially stiff in the tensile direction confining to allow for movement of the soil at the interface. Shear stress develops due to the soil movement along the reinforcement interface and is influenced by the roughness of the reinforcement.

The tensile stresses generated due to shear stresses are redistributed as internal stress (Δs_3), which is in addition to any other external confining stresses (South African Bureau of Standards 2011, p.25). The mobilized tensile strength in the reinforcement and frictional forces at the soil reinforcement interface exhibits increased structure strength reducing lateral deformations and strains within the soil structure (Research Designs and Standards Organisation 2005).

In an unreinforced soil (which has a constant confining stress) failure may result due to the increased loads inducing increased shear stresses [$0.5(s_1-s_3)$] which approach the shear strength of the soil. In a reinforced soil structure increased loads (s_1) induce confining stresses (Δs_3) which result in small increases to the shear stress [$0.5(s_1-(s_3+\Delta s_3)$]. As such larger compressive loads are required to induce failure (South

African Bureau of Standards 2011). Tensile rupture of the reinforcement and bond failure will hence dictate the strength improvement of the reinforced soil mass.

Stress distribution in the reinforcement is variable along the reinforcement with higher tensile stresses along the shear failure plane. As the failure plane propagates from the toe of the wall to a distance behind the facing at the crest of the wall, higher connection strengths are required lower down the wall than further up the wall due to the higher stresses along the failure plane. The soil wall comprises an active and a resistant zone, with the dividing line between the two zones identified as the locus of maximum shear and possible shear failure plane. In an unreinforced wall, the unstable active zone (wedge of soil) moves outwards and downwards relative to the resistant zone which remains in place (Research Designs and Standards Organisation 2005). **Error! Reference source not found.** is a graphical illustration indicating the active and resistant zone within a reinforced soil wall.

The placement of reinforcements across both zones (and across the shear plane) in the soil wall stabilizes the active zone. The embedment length which is the reinforcement embedded in the resistant zone mobilizes bond strength due to interaction at the soil reinforcement interface which resists the disturbing forces in the active zone (South African Bureau of Standards 2011, p.26). Forces from the active zone are transferred to the resistant zone where there is sufficient embedment length of the reinforcement to prevent pull out of the reinforcement (Shukla 2012).
Provided there is adequate bond strength and sufficient reinforcement tensile strength, the tensile strains are absorbed from the active zone and dissipated in the stable resistant zone (South African Bureau of Standards 2011, p.26). Tensile rupture occurs when the loads imposed over the design life of the structure is greater than the tensile strength of the reinforcement. “Pull out resistance is the product of the reinforcement coverage along the bond length, the angle of the bond stress (tand) and the vertical effective stress along the bond length”(South African Bureau of Standards 2011, p.26).

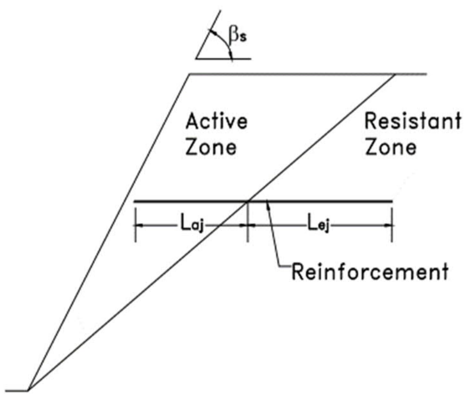


Figure 2-14: Active and Resistant Zone in a Reinforced Soil Wall (South African Bureau of Standards 2011, p.36)

Ultimate limit state failure of the reinforced structure occurs when there is rupture of the reinforcement or a weak bond between the soil and reinforcement, whereas serviceability limit state failure is classed as deformations or strains that exceed the prescribed limits (South African Bureau of Standards 2011).

Internal stability is dictated by tension absorbed in the active zone and transferred to the resistant zone in the case of planar reinforcements, whereas in the case of geogrid reinforcements internal stability is dictated by the interlocking between the soil particles at the apertures of the grids which contributes to bond resistance (South African Bureau of Standards 2011, p.28).

Shear strength is mobilized by skin friction in strap reinforced structures. Soil dilation and the reinforcement surface roughness generate shear strength of the reinforced structure. The sliding of the soil on one side of the reinforcement and the pull out of the reinforcement relative to the surrounding soil mobilize shear strength within the structure. For strap reinforced structures the number of straps used, and the vertical and horizontal spacing dictates the stabilizing forces that are developed. The length of the strap also influences the external stability of the structure by moving the failure plane further away (back) from the open face of the soil mass (South African Bureau of Standards 2011). Longer strap lengths distribute the load of the structure and imposed loads over a larger foundation area hence reduced bearing pressures are required.

2.3.2 In-situ Verification of the Soil Reinforcement Interaction

The direct shear and the pull-out tests are undertaken to quantify the soil reinforcement interface strength. These tests define the shear stress – shear displacement interaction of the reinforcement placed within the soil (Perkins and Cuelho 1999, p.322). The direct shear test determines the direct shear movement where the soil slides relative to a fixed geosynthetic layer while the pull-out test measures the pull-out movement of the geosynthetic from a reinforced soil structure (Perkins and Cuelho 1999, p.322). **Error! Reference source not found.** and **Error! Reference source not found.** are graphical representations of the direct shear and pull out test apparatus respectively.

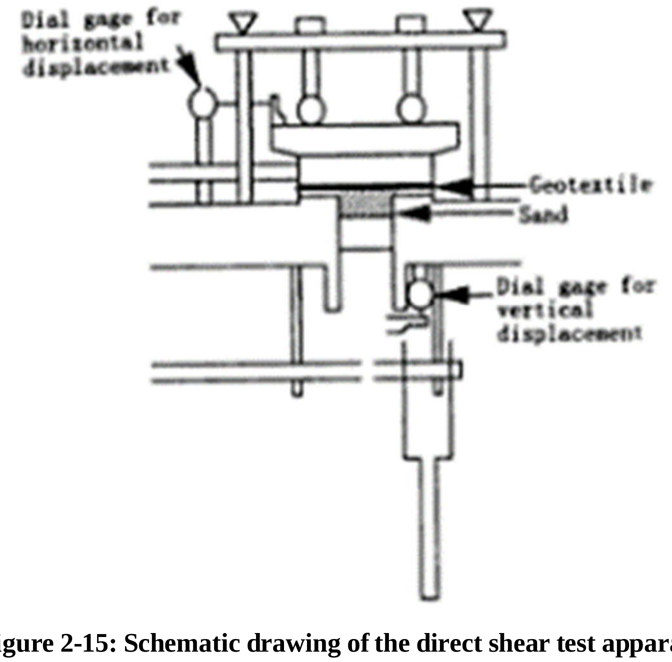


Figure 2-15: Schematic drawing of the direct shear test apparatus (Varma, Rao and Rao 1998, p.389)

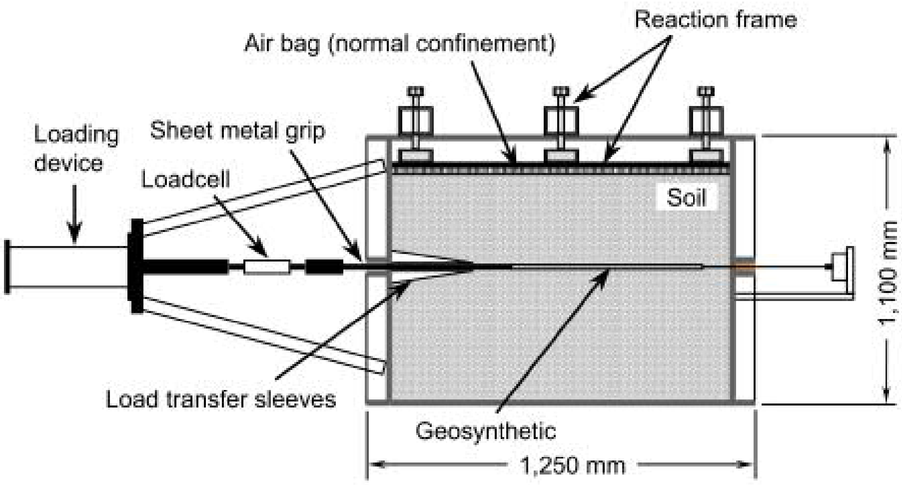


Figure 2-16: Schematic drawing of the pull-out apparatus (Perkins and Cuelho 1999, p.324)

The direct shear test models the interface shear or interaction that occurs at the soil reinforcement interface during sliding, specifically the skin friction or interface friction angle along the area of contact (Shukla 2012). It is highlighted by Perkins and Cuelho (1999) that the shear stress-shear displacement parameters need to take account of the influence of edge effects and non-uniform boundary conditions within the shear box apparatus.

The pull-out test is used to define the coefficient of bond. The pull-out apparatus is limited due to the non-uniform stress and strain conditions which can be accounted for as compared with the direct shear test (Perkins and Cuelho 1999, p.322). Displacements measured during the pull-out test have two components:

- "The movement between the reinforcement and the surrounding soil, which is the shear strain on the soil reinforcement interface, and
- the reinforcement elongation, which is usually significant at the front of the structure" (Shukla 2012).

Adequate controls and calibrations are required when undertaking the pull-out tests, as interpretation of these results are considered difficult due to the influence of boundary conditions, different test procedures and different types of testing equipment. It has been suggested by Shukla (2012) that for strap reinforcements the results obtained in the pull-out test are similar to results of the direct shear tests.

Shear stresses that develop during the pull-out tests, as a result of the reinforcement extensibility are usually accounted for by numerical solutions when interpreting the results of the pull-out test. There have been a number of numerical solutions proposed for the interpretation of the pull-out test to determine the load strain relationship of the reinforcement. These solutions are developed based on assumptions related to the movement of the soil surrounding the geosynthetic. Some of the numerical solutions that have been commonly used are as follows:

- In 1988, Juran and Chen proposed a linear relationship for the load strain curve. Movement of the geosynthetic is considered to be equal to the relative movement between the soil and the geosynthetic. This numerical solution assumes an elasto-plastic relationship for shear stress-shear displacement of the interface. Furthermore, the interface shear resistance is dependent on the extensibility of the reinforcement (Perkins and Cuelho 1999, p.322).
- Perkins and Cuelho proposed a solution that assumes a non-linear relationship for the shear stress-shear displacement interface. This solution assumes that the soil does not move relative to the geosynthetic (Perkins and Cuelho 1999). The study conducted illustrated that elastic-perfectly plastic and rigid-plastic interface behaviour describes the pull-out behaviour of reinforcement. A linear relationship for the geosynthetic load strain is applicable when complete pull-out is achieved and when small strains develop in the reinforcement. When significant strains occur the non-linear relationship, numerical solutions are better suited (Perkins and Cuelho 1999).

Based on the small-scale direct shear test, it has been shown that a vertical pressure applied to a loose sand in the shear box results in the densification of the sand leading to the over-estimation of the interface shear stress (between a geotextile and the sand). The tests concluded that the higher the applied vertical pressure the higher the geotextile interface strength in loose sands (Varma, Rao and Rao 1998, p.392). Results of pull-out and direct shear testing using a geotextile in dense sand have shown that the stiffness of the geotextiles are greater when confined in dense sand, by at least 2 to 3 times the stiffness of the geotextile alone, under plane strain conditions. The increased stiffness is considered to be a result of the increase in the tensile force in the geotextile (Varma, Rao and Rao 1998, p.394). The geotextile stiffness in the field is likely to be less than the laboratory results due to the sustained loads on the soil structure and the subsequent creep of the geotextile.

2.3.3 Stability Analysis

The South African Bureau of Standard Code of Practice for Strengthened/ Reinforced Soils and Other Fills., SANS8006-1:2018 (2018), which has subsequently replaced the SANS 207:2011 Ed.1.1 (2011), specifies that all reinforced soil walls are to be designed in accordance with ultimate and serviceability limit state principals. Ultimate limit state represents the ultimate collapse or failure of a reinforced soil structure, which occurs when the disturbing forces exceed the restoring forces for each failure type. The ultimate limit state of a reinforced structure occurs when either rupture of the reinforcement occurs or when a failure of the bond at the soil-reinforcement interface occurs.

Generally, deformation influences the performance of reinforced soils rather that the ultimate limit state. Therefore, if the strains or deformations are greater than the prescribed tolerances for the serviceability limit state, lower design strengths would need to be considered so that strains and deformations are within acceptable ranges (Koerner 2002). Serviceability limit states prescribed tolerable deformation limits that a structure may not exceed over its design life to ensure it serviceability. Excessive deformations of the reinforced soil wall that render the structure unserviceable dictate prescribed tensile strains that are not to be exceeded for the entire design life of the structure (South African Bureau of Standard 2011, p.33).

The purpose of the retaining structure is to contain and prevent the downward movement of the retained material. This is achieved by resisting lateral pressures of the retained soil, pore water pressures, surcharge loads, self-weight of the soil wall and external forces applied to the wall such as earthquake loads.

The at-rest, active and passive earth pressures are determined using the Rankine Earth Pressure Theory or the Coulomb Earth Pressure Theory. Rankine Theory is suitable for simple situations, where a smooth vertical wall is assumed and where the backfill has a horizontal surface and friction between the soil and the wall is not taken into consideration (Whitlow 1995). The Coulomb theory is based on the wedge planar slip surface sliding out the wall. This approach also accounts for sloping backfill surfaces and the angle of wall friction (related to the angle of friction of the soil and the roughness of the wall) (Whitlow 1995, p.292).

The Coulomb Theory may be used in the design of gravity, semi-gravity and cantilever walls while the Rankine formula is generally used to calculate the earth pressure coefficient for semi-gravity, cantilever walls and for reinforced soil walls.

Retaining walls are designed on the assumption that drainage measures are implemented within the soil structure. As such drainage forms an integral part of the construction of a retaining structure, in order to prevent the accumulation of water in the retained soil and reduce any hydrostatic pressures behind the wall. However, if the retained soil is not drained, hydrostatic pore water pressures need to be added to the lateral forces acting on the wall.

Surcharge loads imposed on the wall or behind the crest of the wall creates a horizontal thrust on the wall. These loads may be either permanent loads such as horizontal earth loads, surcharge loads or vertical pressure from dead load of earth fill. Additionally, transient loads may be exerted on a reinforced wall, these include vehicular collision force, earthquake loads, vehicle live loads and live load surcharge (National Highway Institute Office of Bridge Technology 2001, p.4-3). Earthquake loads are critical when designing structures such as bridge abutments, walls that support buildings and other structures that have a low tolerance to movement and could lead to detrimental failure.

2.3.3.1 Partial Factors

The limit state approach to design of reinforced soil structures applies partial factors (with values of unity or greater) to provide a margin of safety against the ultimate limit state (failure) and against serviceability limit state (South African Bureau of Standards 2011, p.22). These factors account for any uncertainty and variability in materials used and loading on a structure at various times during its service life.

The four primary partial factors used for design include factors for dead and live loads, material factors which are applied to the reinforcement, soil and soil/reinforcement interaction and a partial factor that considers the economic ramifications of failure of the structure which takes into considering the structure geometry and end use (South African Bureau of Standards 2011, p.60). The consequence of failure and the economic consequences of such failure at a certain time in the life of the structure are considered when applying the partial factor.

Both the ultimate and serviceability limit state should be assessed for internal and external stability of the design. The factored restoring forces need to exceed the factored disturbing force to prevent failure (South African Bureau of Standards 2011, p.22).

The internal stability analysis is dependent on the soil reinforcement interaction which is reliant on friction or adhesion as noted previously. The partial load factors increase the loading and the partial material factors reduce the shear strength parameters and reinforcement design strength in order to provide a factor of safety against reaching the limit state (South African Bureau of Standards 2011, p.22).

The design life of a reinforced wall may be a few months to 100 years. For long term walls, the tensile rupture strength of the reinforcement may decrease with time due to degradation, and hence the partial material factors applied to the reinforcement accounts for this degradation. As an example, the effect of creep in polymeric geosynthetics is accounted for by the application of a partial material factor.

Partial material factors for reinforcement have two principal factors (f_{m1} and f_{m2}) namely a factor related to the properties of the material itself with the second factor related to construction and environmental effects. The South African Bureau of Standard (2011, p.61) provides a table that illustrates the various components (including its intended purpose) to make up the primary partial material factor for reinforcement and is reproduced here in **Error! Reference source not found.**. The principal factors are the product of the component factors.

Table 2-3: Re-produced Reinforcement partial material factor from the South African Design Code (South African Bureau of Standards 2011, p.61)

Principal Factor	Component Factor	Intended Purpose
f_{m1}	f_{m11}	*Manufacture:* to cover the possible reductions in the capacity of the material as a whole compared with the characteristic value deduced from the control test specimens and possible inaccuracy in the assessment of the resistance of a structural element resulting from modelling errors.
	f_{m12}	*Extrapolation of test data:* to take account of the confidence of the long-term capacity assessment. This factor may vary with the required service life of the structure.
f_{m2}	f_{m21}	*Susceptibility to damage:* to take account of damage during construction. This factor may be derived from site damage tests

Principal Factor	Component Factor	Intended Purpose
	f_{m22}	*Environment:* to take account of different rates of degradation due to environmental conditions.

Partial material factors are also applied to account for uncertainty and variability in soil properties, with the design value being determined by dividing the characteristic soil parameter by a prescribed partial factor (South African Bureau of Standard 2011, p.63). Similarly, partial factors are also applied to soil reinforcement interaction mechanisms, to cater for any variability (South African Bureau of Standard 2011, p.64).

Partial load factors are applied to determine the design load which is the product of the unfactored disturbing load and the partial load factor. The partial load factor comprises three components, namely, partial load factors for soil self-weight, external dead load and external live loads. Different factors apply for the ultimate limit state, while values of unity apply for the serviceability limit state (South African Bureau of Standard 2011, p.64).

The South African Bureau of Standard (2011, p.75) provides several tables with explanations for the various partial factors and its intended application has been reproduced here as **Error! Reference source not found.**, **Error! Reference source not found.** and **Error! Reference source not found.**. The load factors, material factors, soil/reinforcement interaction factors, and external stability factors of safety which are applied during the internal and external stability analysis of a reinforced soil wall are tabulated.

Table 2-4: Re-produced Partial Factors from the South African Design Code (South African Bureau of Standards 2011, p.75)

Partial Factors		Ultimate Limit State	Serviceability Limit State
Load Factors	Soil unit mass, e.g. wall fill	The appropriate value of f_{fs} to be chosen according to Table 4.3 for the particular load combination	
	External dead loads, e.g. line or point loads	The appropriate value of f_f to be chosen according to Table 4.3 for the particular load combination	
	External live loads, e.g. traffic loading	The appropriate value of f_q to be chosen according to Table 4.3 for the particular load combination	
Soil Material Factors	to be applied to tan ϕ'_p	$f_{ms} = 1.0$	$f_{ms} = 1.0$
	to be applied to c'	$f_{ms} = 1.6$	$f_{ms} = 1.0$
	to be applied to c_u	$f_{ms} = 1.0$	$f_{ms} = 1.0$
Reinforced material factor	to be applied to the reinforcement base strength	The value of f_m should be consistent with the type of reinforcement to be used and the design life over which the reinforcement is required	

Partial Factors		Ultimate Limit State	Serviceability Limit State
Soil/reinforcement interaction Factors	Sliding across surface of reinforcement	$f_s = 1.3$	$f_s = 1.0$
	Pull out resistance of reinforcement	$f_p = 1.3$	$f_p = 1.0$
Partial factors of safety	Foundation bearing capacity: to be applied to q_{ult}	$f_{ms} = 1.35$	NA
	Sliding along base of structure or any horizontal surface where there is soil-to-soil contact	$f_s = 1.2$	NA

Table 2-5: Reproduced Partial Load Factors for Load Combinations for Walls from the South African Design Code (South African Bureau of Standards 2011, p.77)

Effects	Combination		
	A	B	C
Mass of the reinforced soil body	$f_{fs} = 1.5$	$f_{fs} = 1.0$	$f_{fs} = 1.0$
Mass of the backfill on top of the reinforced soil wall	$f_{fs} = 1.5$	$f_{fs} = 1.0$	$f_{fs} = 1.0$
Earth pressure behind the structure	$f_{fs} = 1.5$	$f_{fs} = 1.5$	$f_{fs} = 1.0$
Traffic load: on reinforced soil block: behind reinforced soil block	$f_q = 1.5$	$f_q = 0$	$f_q = 0$
Traffic load: behind reinforced soil block	$f_q = 1.5$	$f_q = 1.5$	$f_q = 0$

Note: The following descriptions of load cases identify the usual worst combination for the various criteria but are for guidance only. All load combinations should be checked for each layer of reinforcement within each structure to ensure the most critical condition has been found and considered.

Combination A

This combination considers the maximum values of all loads and therefore normally generates the maximum reinforcement tension and foundation bearing pressure. It may also determine the reinforcement requirement to satisfy pull-out resistance although pull-out resistance is usually governed by combination B.

Combination B

This combination considers the maximum overturning loads together with minimum self-mass of structure and superimposed traffic load. This combination normally dictates the reinforcement requirement for pull-out resistance and is normally the worst case for sliding along the base.

Combination C

This combination considers dead loads only without partial load factors. This combination is used to determine foundation settlements as well as generating reinforcement tensions for checking the serviceability limit state.

The partial factor to account for the ramifications of failure has a value dependent on the level of risk for a particular structure. This factor is applied to the reinforcement design strength. **Error! Reference source**

not found., which is repeated here from the South African Bureau of Standards (2011) illustrates typical structure categories and their corresponding partial factor that should be applied to account for the ramification of failure of the structure.

Table 2-6: Category of Structure Depending upon Ramifications of Failure Repeated from the South African Design Code (South African Bureau of Standards 2011, p.38)

Category	Partial factor f_n	Examples of Structures
1 (low)	Not applicable *	Retaining walls and slopes less than 1.5m in retaining height where failure would result in minimal damage and loss of access
2 (medium)	1	Embankments and structures where failure would result in moderate damage and loss of services
3 (high)	1,1	Abutments, structures directly supporting motorway, trunk and principal roads or railways or inhabited buildings, dams, sea walls and slopes, river training walls and slopes
* structures of category 1 should be restricted to simple structures designed by experience without analysis		

2.3.3.2 Internal Stability Analysis

The internal stability assessment of a reinforced soil wall is essential during design. Loading and pressures on the wall creates a tension in the reinforcement which develops across the failure plane leading to deformations. The internal stability analysis assesses the stability of the structure against wedge failure along the failure plane and possible failure of the geosynthetic by rupture or pull-out.

As noted previously the failure plane coincides with the line of maximum tensile force. **Error! Reference source not found.** illustrates a bi-linear failure plane for a reinforced soil wall constructed with inextensible reinforcements, while a linear failure plane is assumed in reinforced soil walls using extensible reinforcements (Reproduced here from the South African Bureau of Standards (2011, p.116 and p.122)). The failure plane in both these cases passes through the toe of the wall.

(a) **(b)**

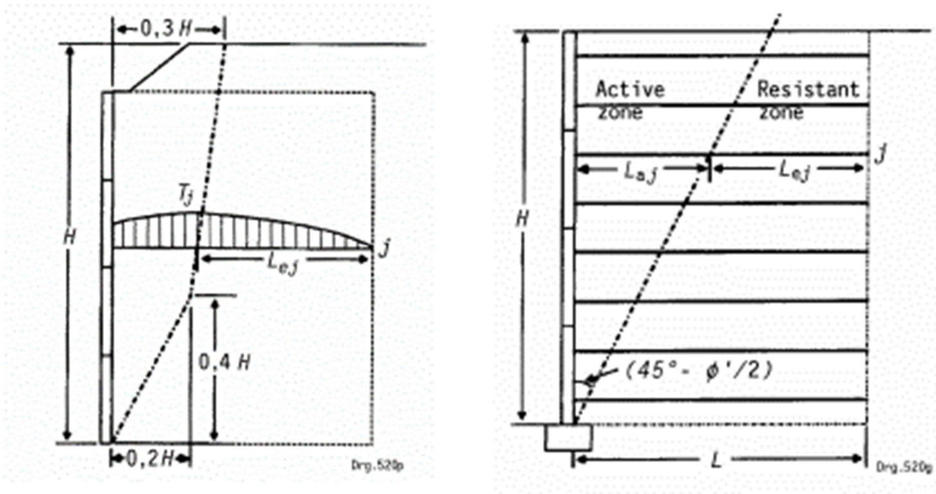


Figure 2-17: Potential Failure Surface for Internal Stability Design of a Reinforced Soil Wall (a) inextensible reinforcements (b) extensible reinforcements (South African Bureau of Standards 2011, p.116 and p.122)

The internal stability analysis gives rise to the number of reinforcement layers / vertical spacing, reinforcement length and the facing connection strength to ensure stability of the structure; as illustrated in **Error! Reference source not found.** (Koerner 2005, p.368).

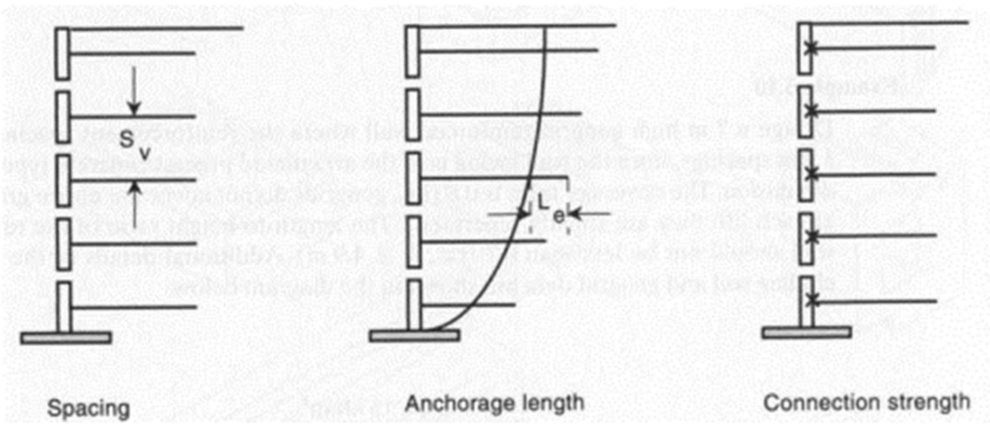


Figure 2-18: Elements of a Reinforced Soil Wall Based on the Internal Analysis (Koerner 2005, p.368)

As indicated partial factors for materials, loads, reinforcement material (for limit states and design life) and economic ramifications of collapse are applied during the internal stability analysis to provide a margin of safety against the ultimate limit state. The following assessments are undertaken to check for the ultimate limit state:

- the stability of each reinforcing layer in terms of the maximum tensile loads applied to each layer;
- the resistance of the reinforcement against rupture;
- adherence capacity of the reinforcement; and
- line of maximum tension (failure plane) (South African Bureau of Standards 2011, p.95).

A global internal stability analysis is usually necessary for structures with unusual configurations (such as tiered slopes) and structures with high concentrated loading.

For the serviceability limit state, a stable structure geometry is essential and to ensure that all construction and post construction related movements are to acceptable limits. The deformations over the service life of the structure are usually related to creep strain due to sustained load on the structure. The magnitude of bulges, overhangs and uneven alignment are some of the considerations when determining the acceptable deformation limits of the wall (South African Bureau of Standards 2011, p.85). The serviceability limits for post construction internal strains is 1% strain for retaining walls and 0.5% strain for bridge abutments (South African Bureau of Standards 2011, p.86).

There are various methods to assess the internal stability of a reinforced soil wall; however, the three most commonly used methods for internal stability include the Tie-back Wedge Method, the Coherent Gravity Method and the FHWA Structure Stiffness Method. The Tie-Back Wedge Method utilizes basic design principals to design a standard classic, anchored retaining wall and for reinforced soil walls constructed using extensible reinforcements, while the Coherent Gravity Method is used for inextensible reinforcements. All three of these methods use the limit equilibrium approach.

- **Coherent Gravity Method**

The coherent gravity method was first used to estimate reinforcement stresses for steel strip mechanically stabilized earth walls and was developed by Juran and Schlosser in 1978 (Mathew and Katti 2014).

The Meyerhof bearing pressure distribution beneath an eccentrically loaded (vertical and horizontal forces are applied) rigid footing is applied to the design of the reinforced soil structure (Allen et al. 2001, p.3). The approach assumes that the soil structure is a rigid body with lateral pressures acting on the wall. The lateral stress is the product of the vertical stress and the lateral earth pressure coefficient, which is based on the soil angle of friction. The method assumes that the reinforced soil structure needs to counteract vertical and overturning stresses.

The coherent gravity method assumes a bi-linear envelope of maximum reinforcement tension. The lateral earth pressure at the upper portion of the wall is assumed to be the at-rest pressure (K_o) which decreases to the active earth pressure (K_a) at a depth of 6m to where the failure surface intersects the soil vertical surface. These earth pressure coefficients are used to translate the vertical stress to lateral stress. The assumptions made are based on the behaviours recorded of full-scale reinforced soil walls.

In reinforced soil structures constructed using inextensible reinforcement; the reinforcement is usually under tension over the length of the reinforcement as such acting as a coherent gravity mass therefore the coherent gravity method is employed.

- **Tie-back Wedge Method**

The tie-back wedge method was developed by Bell in 1975 and the US Forest Services and is used for geosynthetic reinforced soil walls specifically using extensible reinforcements. This approach assumes that the reinforced soil structure is flexible and hence the lateral loads applied to the wall do not influence the vertical stresses within the reinforced wall. Furthermore, the method assumes that the vertical stress is based solely on the height of the soil structure and its unit weight (Allen et al. 2001, p.7).

The method assumes that the failure plane develops along the Rankine-rupture surface which is the straight line passing at an angle of $45+\phi/2$ to the crest of the wall to the toe. It is believed that sufficient deformations develop active earth pressures which exist from the top to the bottom of the wall. The reinforcement layers in this method are designed to resist these lateral stresses within its area of influence hence acting as a tieback when the failure plane develops and restrains the active wedge from failing.

The lateral stresses are calculated using the active earth pressure coefficient (K_a) and is also based on the type of reinforcement used. The tie-back wedge method only considers gravitational or vertical forces.

An extensible reinforcement within a reinforced soil structure is generally not under tension over the full length and therefore the tie-back wedge method is employed (Allen et al. 2001).

One of the limitations of this method is that it has been developed based on assumptions, and empirical adjustments which have been made for specific design conditions and situations. Some of the assumptions based on Allen et al.(2001) in the design method include:

- The soil reinforcement stress is based on lateral earth pressures alone;
- Limit equilibrium conditions are assumed;
- It is assumed that the reinforcement stress is directly related to the soil stress state;
- Granular soils are assumed for backfill; and
- Cohesion of the soil is not considered.

These assumptions may not apply to all situations, and therefore this design method is to be used with caution.

- **FHWA – Structure Stiffness Method**

The Structure Stiffness Method was developed by Christopher, Gill, Juran and Mitchell in 1990 (Anderson etal, 2012), as part of a research project conducted by the American Federal Highway Administration (FHWA) and the National Highway Institute (NHI) and is considered to be very similar to the Tie-back wedge method. The difference between the Tie-back wedge method and this method is that the FHWA Method assumes a bi-linear envelop of maximum reinforcement tension for inextensible reinforcements and the Rankine failure plane angled at $45+\phi/2$ from the horizontal is assumed for extensible reinforcements (Anderson etal, 2012).

The coefficient of lateral earth pressure (K_r) varies with depth and is dependent on the type of reinforcement used and the global wall stiffness, which is the product of the reinforcement area and the reinforcement modulus of elasticity. The lateral earth pressure is at its maximum at the top of the wall and decreases with depth. The failure surface determined is similar to the coherent gravity method for extensible reinforcements. As with the tie-back wedge method, the FHWA method assumes only gravitation forces (vertical forces) while not considering the overturning forces.

2.3.3.3 External Stability Analysis

The reinforced soil wall acts as a coherent structure compatible to a gravity wall for the external stability analysis. External stability analysis assesses the probability of failure of the entire soil wall behind and below the reinforced soil mass (National Highway Institute Office of Bridge Technology 2001) . Traditional retaining wall design methods to check for sliding, overturning, bearing capacity and deep-seated rotational instabilities is typically undertaken to design against these external failure modes (National Highway Institute Office of Bridge Technology 2001).

Global stability analysis can also be undertaken to assess the potential for deep seated instability beyond the extent of the reinforced structure. Rotation or wedge analysis may be used to identify and assess the potential failure planes that can develop behind or below the reinforcement soil structure.

In the event of the analysis indicating unstable conditions, it may be necessary to increase the length of the reinforcement or improving the foundation soils (National Highway Institute Office of Bridge Technology 2001).

Load and material partial factors are applied to the external disturbing and restoring forces with the disturbing forces not exceeding the restoring forces to ensure stability. The external stability analysis which considers the loads and forces acting on the reinforced wall provides input into the length and strength of the reinforcement layers required.

The following external failure modes are assessed as part of the external stability analysis which are illustrated in **Error! Reference source not found.**.

- **Lateral Sliding Failure**

  The lateral sliding failure analysis determines the mass required in the reinforced soil structure to provide adequate resistance at the base of the structure to counteract the sliding forces acting between the reinforced structure and the founding soil. The sliding forces are the horizontal thrust at the back of the wall (National Highway Institute Office of Bridge Technology 2001, p.94). Permanent loading on the reinforced soil wall should be taken into consideration as this provides a degree of resistance to sliding (National Highway Institute Office of Bridge Technology 2001, p.94). The resistance against movement is based on the weaker soil material between the subsoil and the reinforced fill material and sliding on the reinforcement layers at the interface is to be considered. Partial factors for load and soil material, and soil/reinforcement interaction factors or soil/soil sliding factors are applied to account for variability and any uncertainty (South African Bureau of Standards 2011, p.80).

- **Overturning Failure**

The overturning failure analysis or eccentricity check at the base of the wall determines the resistance of the reinforced structure, as a result of the self-weight, to counteract the overturning forces that act on the reinforced soil (Koerner 2002). The forces exerted by the wall facing are generally not considered. The eccentricity is the distance between the resultant foundation load and the centre of the reinforced soil and is calculated by the difference between the overturning moment and the resisting moment divided by the vertical load at the base centre of the wall (National Highway Institute Federal Highway Administration 2009, p.4-22). The eccentricity is acceptable if the location of the resultant vertical force is within the middle one half of the base width when founded in soil and within the middle three fourths of the base width when founded on rock (National Highway Institute Federal Highway Administration 2009, p.4-23).

- **Bearing Capacity Failure**

Two bearing capacity failure modes are possible, specifically general shear failure and local shear failure. To prevent general shear failure (squeezing of the foundation soils) on loose or soft soils the allowable bearing capacity of the foundation soil should be greater than the vertical stress at the base of the wall. Prevention of local shear (large horizontal movement of the structure on weak cohesive soils) may require improvement of the foundation soils (National Highway Institute Office of Bridge Technology 2001, p.96).

The design estimates the bearing pressure of the reinforced soil wall based on the Meyerhof distribution, which is compared to the ultimate bearing capacity of the founding soil. The partial load factor applied to the imposed bearing pressure and the partial material factor applied to the founding soils ultimate bearing capacity provides for any uncertainty or variability related to the loading and material properties. The imposed bearing pressure should be lower than the allowable bearing pressure of the founding soil (South African Bureau of Standards 2011, p.80).

- **Settlement Failure**

The settlement analysis assesses the total and differential settlement of the foundation soil under the load of the reinforced soil structure. Settlement determinations should include immediate / elastic settlement, primary consolidation settlement and secondary settlement where applicable (National Highway Institute Office of Bridge Technology 2001).

It is highlighted that the foundation settlement of a reinforced soil wall is generally less than conventional retaining structures due to the reinforced soil wall imposing a reduced and evenly distributed load.

The settlement of the reinforced soil wall is dependent on the fill material, compaction, loading within the fill, surcharge and the height of the wall. Differential settlement of the structure may negatively impact the facing and the connection to the facing. As such reasonable settlement limits so as not to impair the function of the reinforced soil structure and the facing and connections are necessary for the serviceability limit state. This may include measures to accommodate the amount of expected settlement such as the use of slip joints between precast panels to accommodate differential movements (National Highway Institute Office of Bridge Technology 2001, p.102).

Although not forming part of the exercise undertaken in this study, global failure mechanisms are assessed in terms of slip circle failure analysis especially for structures on soft foundation soils or where reinforced soil structures are constructed on high slopes. Other factors that may have an influence on the stability of the structure include changes in soil type used as fill in the reinforced soil wall, differences in reinforcement lengths, surcharge loads, and slopes at the toe or crest of the wall (National Highway Institute Office of Bridge Technology 2001, p.96).

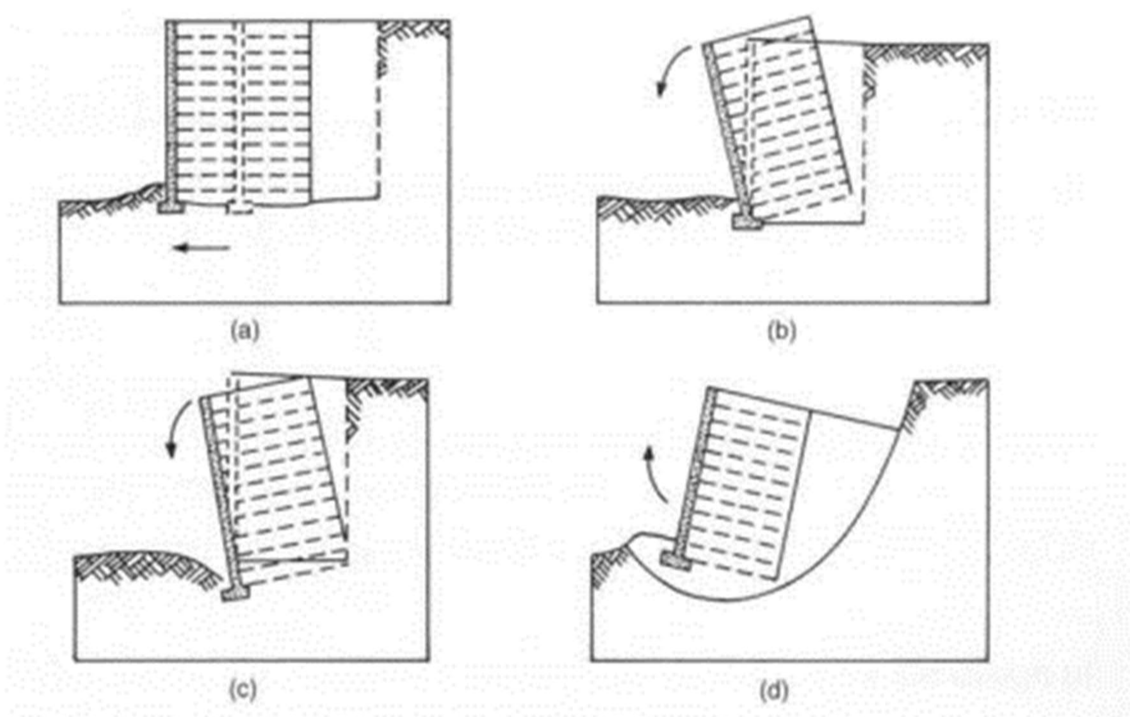


Figure 2-19: External Stability Analysis: (a) Lateral Sliding (b) Overturning (c) Bearing Capacity and Settlement (d) Global Failure Mechanisms (Shukla 2002)

2.3.4 Design Guidelines for Geosynthetic Reinforced Soil Walls

Various guidelines for the design of reinforced soil walls are available, two of the most commonly used standards include:

- **BS8006: Strengthened /Reinforced soils and other fills – British Code of Practice (1995 and 2006)**; the BS8006 code provides guidelines for reinforced walls, steep slopes and anchored earth walls. The code is based on the Limit State Design (LSD) Approach and employs load and resistance partial factors. This approach requires the serviceability and ultimate limit states to be analysed.
- **FHWA Mechanically Stabilized Earth Walls and Reinforced Soil Slopes: Design and Construction Guidelines – FHWA-NH1-0043 (2001)**; the FHWA is based on the Factor of Safety Approach and provides guidelines for Mechanically Stabilized Earth Walls and Reinforced Soil Slopes.

As highlighted previously the design method adopted for reinforced soil walls in South Africa is based on the limit state approach in accordance with the "SANS8006-1:2018 South African National Standard Code of Practice for Strengthen / Reinforced Soils and other Fills", which is based on the BS 8006 Code of Practice discussed above. At the commencement of this study the design code for reinforced structures was the "SANS 207:2011 South African National Standard for the Design and Construction of Reinforced Soils and Fills" which was also based on the BS8006 Code of Practice.

It is highlighted that this study was initially based on the design approach presented in the SANS 2007:2011 standard, however it is emphasised that the design approach in the new SANS 8006-01:2018 standard has not changed from the previous code, and hence the design approach assessed in this study is aligned with the new SANS 8006 Code of Practice design standard as well.

According to the previous and new codes reinforced soil walls should be designed to the ultimate limit state of the structure while still maintaining serviceability limits. As discussed previously partial material and load factors are applied to maintain a margin of safety against ultimate and serviceability limit state.

In addition to the abovementioned guidelines, the code also indicates the properties of the foundation soil, reinforced soil and backfill material which are required to ensure the strength of the materials and their interaction with each other. The following parameters are required for the design of a reinforced soil wall.

- Shear strength parameters of the reinforced and the backfill soil.
- Calculated lateral earth pressure and the overturning moment.
- Design loads of the reinforced soil structure due to soil self-weight, dead and live load, horizontal loads, vertical loads and seismic loads.
- Engineering properties of the founding, reinforced and backfill soils.

2.3.5 Design Parameters Specified in the Code of Practice

There are a number of soil and reinforcement parameters that should be considered when designing a reinforced soil wall. These soil and reinforcement design parameters are generally determined from laboratory tests or in-situ testing, however other design considerations cannot be determined by testing and as such are factored into the design calculation to account for any undesirable conditions that cannot be easily measured. The design code provides an overview of some of the considerations which are discussed in the following subsections.

2.3.5.1 Fill and In-Situ Soil

- **Soil Shear Strength**

Shear strength of soils are mobilized as a result of axial and lateral strains when subjected to compressive loads. For design purposes the peak shear strength parameters of the soils are used in the design. These peak values may be mobilized by small strains in frictional soils, whereas in elasto-plastic soils the peak shear strength may only be mobilized at strains in excess of that required to mobilize peak strength. In strain softening soils the peak strength may decrease with excess strains (South African Bureau of Standards 2011, p.53).

- **Fill Deformation and Strength**

The shear strength and the coefficient of earth pressure are mobilized based on strains within the reinforced soil structure. The earth pressures mobilized are further dictated by compactive stress within the soil, which may give rise to at rest earth pressures, and hence need to be considered during the design (South African Bureau of Standards 2011, p.54).

- **Fill material Strength**

The soils effective angle of friction and cohesion are based on the shear box or triaxial tests. Considerations that are essential during the testing to ensure the accurate shear strength values are used in the design include the following:

- The soil sample should be consolidated at each stress level that is applied before shearing of the sample is undertaken; and
- Drainage conditions of the sample tested should be representative of the conditions in the field (South African Bureau of Standards 2011, p 53).

- **Effect of Chemistry on Durability**

The chemistry of the soil and water in the soil affects the durability of the reinforcement which may affect its load carrying capacity. This is a defining characteristic when using steel reinforcement which may be susceptible to corrosion. For geosynthetic reinforcements the influence of chemicals depends on the polymer used and the additives added in the manufacture of the geosynthetics. It is essential to note that acidic or alkaline environments and the presence of inorganic chemicals can affect the performance of the polymer materials (South African Bureau of Standards 2011, p.54). As such specific requirements such as the thickness of the reinforcement should be selected to accommodate deterioration of the reinforcement.

- **Site Damage**

The fill material grading, particle shapes, hardness, and degree of compaction may affect the durability of both steel and polymeric reinforcements, as damages such as cuts, tears and perforations of the geosynthetic may result during construction. Quantification of the degree of damage during installation is not possible and hence reduction factors to downgrade the reinforcement tensile strength are necessary to account for any damages that may occur during installation (South African Bureau of Standards 2011).

2.3.5.2 Soil Reinforcement

- **Limit States**

As discussed, reinforced soils should be designed to maintain a margin of safety against reaching the ultimate limit state of collapse. Tensile strain dictates serviceability limits, beyond which the structure becomes unserviceable. These limits depend on the type of structure and the stages during the design life of the structure (South African Bureau of Standards 2011, p.54).

- **Bond Strength**

The peak bond strength determined by the direct shear test to assess pull-out or sliding resistance of reinforcement is used in design calculations (South African Bureau of Standards 2011, p.55). The pull-out test also determines the bond strength of rough linear reinforcements such as geosynthetic straps (South African Bureau of Standards 2011).

- **Design Strength**

The tensile stiffness of a reinforcement classifies the geosynthetic as either extensible or inextensible. The design strength of polymeric reinforcements is usually mobilized at axial strains of more than 1% hence are extensible, however there are some polymeric materials that mobilize the design strength at less than 1% and these are considered as inextensible reinforcements; the design method employed depends on whether the reinforcement is extensible or inextensible (South African Bureau of Standards 2011).

- **Durability and Performance with Time**

The durability of a geosynthetic refers to the ability of the reinforcement to maintain its properties over the design life of the structure (South African Bureau of Standards 2011, p.55). Critical properties need to be assessed and its deterioration quantified with respect to time including the rate at which the change occurs.

As discussed in previous chapters several factors influence the durability and performance of both metallic and polymeric reinforcements with time, which include the structure design life, loading, moisture content, UV, temperature and installation damage. The deterioration due to a combination of these factors may negatively affect the structure performance.

Variables that affect the durability and performance (e.g. creep rupture) of polymeric reinforcements or the additives used need to be assessed and quantified where possible. The influence of environmental hazards is generally site specific and therefore site-specific conditions need to be considered for each application.

- **Design Parameters**

The reinforcement strength at the end of the structure design life is to be determined to assess the potential tensile rupture. "The base strength of polymeric reinforcement is the lesser of the base strength due to tensile creep rupture or the base strength with respect to creep strain (South African Bureau of Standards 2011, p.57)".

- **Tests for Polymeric Reinforcements**

The results of the testing requirements specified in the design code for polymeric reinforcements are generally provided by the supplier in the form of a product data sheet or certificate which includes the various reinforcement properties including tensile strength, tensile modulus and reduction factors which are based on the testing described below:

- Index Testing – these tests determine the basic properties of the geosynthetic products (South African Bureau of Standards 2011,p.58).
- Quality Control Testing – Quality control testing are rapid testing to confirm that the quality of the reinforcement is maintained (South African Bureau of Standards 2011).
- Performance Testing – The polymer reinforcements are tested with soils in a laboratory to represent site conditions to assess the performance of the reinforcement (South African Bureau of Standards 2011, p.58).
- Tensile Strength and Creep Properties – The base strength at the structure design life is based on the reinforcement stress strain properties. Tensile tests determine the short-term tensile strength properties. Creep rupture testing is undertaken to determine the creep strain, which is used to determine tensile creep rupture performance with increased loading (South African Bureau of Standards 2011, p.58).
- Temperature influences the performance of reinforcements and therefore testing needs to be undertaken at the operational temperature to simulate field conditions accurately (South African Bureau of Standards 2011).
- Site Damage – Testing to assess the susceptibility of polymeric reinforcement to installation damage and to determine the partial material factors is generally done by site testing or full-scale models (South African Bureau of Standards p.58).

2.3.5.3 Facing

It is recommended that facing units are to be designed according to relevant national standards for and may be verified by testing to ensure compliance with the relevant standard (South African Bureau of Standards 2011, p.59).

2.3.6 Serviceability Tolerances

The post construction displacement tolerances are structure specific and depend on the tolerances of the facing panel, however the design code specifies construction tolerances for vertical deflection is 5mm per meter height of wall (South African Bureau of Standards 2018). The acceptable limits for foundation settlement are also dependent on the structure type and hence is case specific for each type of wall and therefore based on the structural requirements of the wall. It is however stipulated in the BS8006-1:2018 code that maximum differential settlement tolerances of 1:100 is considered "normal safe limits without the need for special measures" (South African Bureau of Standards 2018).

2.4 Conventional Retaining Vs Reinforced Soil Walls

Aside from the development of lateral earth pressures, retaining walls (including reinforced soil walls) are designed to accommodate a certain degree of movement given the variability of soil material. This tolerance to movement varies from one retaining structure to another. Gravity, semi gravity and cantilever walls are generally 'rigid' structures that have low tolerances to movement (California Department of Transportation 2004).

The predominant disadvantages of conventional lateral support structures are their intolerance to settlement or displacement movements and hence the sensitivity of these structures to seismicity. This is due to the high rigidity, low ductility and the development of high bending moments within the structures (National Highway Institute Office of Bridge Technology 2001).

Reinforced soil walls or mechanically stabilized earth walls are generally flexible and can accommodate some settlement without compromising the integrity of the structure.

Reinforced soil walls have a higher resistance to and perform adequately under seismic loads than traditional concrete retaining structures (Indiana Department of Transportation Design Manual 2013). This was evident at the Sikkim Airport in India where a reinforced soil wall was constructed up to 80m in height, at a far more reasonable cost than for other retaining systems (Veettil 2012). In September 2011 a 6.9 magnitude earthquake occurred in Sikkim, India. The seismic event was more than the design magnitude allowed for in the reinforced structure, yet there were no damages as a result of the seismic event hence proving the resilience of the reinforced soil retaining structure.

The high foundation stresses exerted by retaining walls often require good founding conditions to resist the forces of the wall and retained soil. In the case of conventional gravity walls (which gains its stability from the weight of the structure) and cantilever walls (which gains its stability from the embedded portion of the structure) soft founding soils may lead to settlement and possible bearing capacity failure. Deep foundations or ground improvement are therefore necessary for the founding of rigid concrete retaining structures which results in increased cost and construction time (National Highway Institute Office of Bridge Technology 2001). Reinforced soil walls on the other hand spread the foundation loads over a larger area due to its larger footprint and hence lower bearing pressures are required. Although foundation preparation is essential before the construction of the reinforced soil structure, it is often limited in comparison to foundation preparation required for conventional retaining walls. As such the use of reinforced soil structures are more cost effective as this solution eliminates the need for significant foundation improvements, however it should be borne in mind that preparation of the founding soils (such as subgrade compaction or installation of a pioneer layer) is necessary.

Conventional reinforced concrete structures are often limited to the height to which they can be constructed. This is largely due to the amount of reinforced steel required to stiffen the concrete structure to counteract the increasing bending moment as the structure height increases hence making these conventional systems very costly.

The cost of a reinforced soil wall is based on a number of factors which include the cut and fill, wall dimensions, availability of suitable backfill material and the facing type. Despite these variables and their respective costs, it has been found that for retaining walls greater than 3m in height, reinforced soil walls constructed within average founding conditions can see a 25% to 50% cost saving compared to reinforced concrete retaining walls. These savings could be even higher if the conventional retaining structures would need to be founded on deep foundations such as piles or require improvements to the founding soils (National Highway Institute Office of Bridge Technology 2001).

Additional cost savings are also realised in reinforced soil structures due to the ease of construction. A comparison of different retaining wall costs is presented in the National Highway Institute Office of Bridge Technology (2001) manual and in Koerner (2005) and has been included as **Error! Reference source not found.** below. These statistics are based on a survey by the US State and Federal Transportation Agency (National Highway Institute Office of Bridge Technology 2001, p.17). Although the costs today would be higher than illustrated in the figure from 2001, the graph illustrates a comparison of costs between the different retaining solutions, with the geosynthetic reinforced walls being the most cost effective for walls between 2m up to 11m.

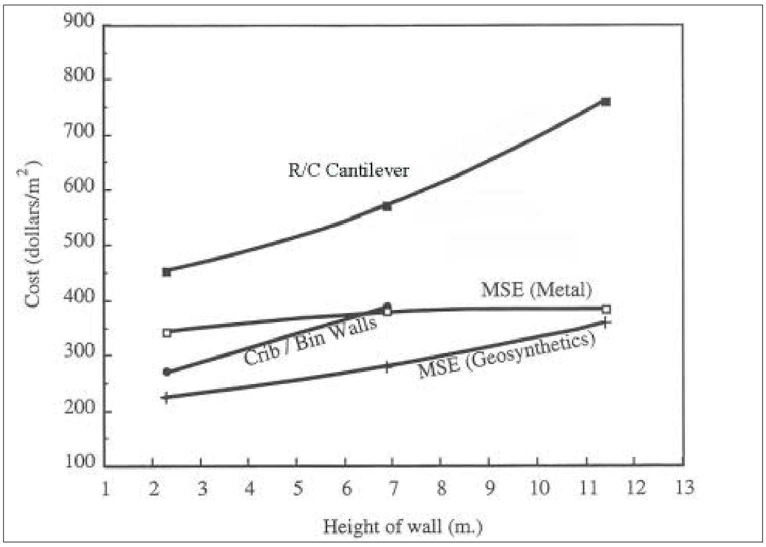


Figure 2-20: Cost Comparison of Different Retaining Wall Systems (National Highway Institute Office of Bridge Technology 2001, p.17)

The cost implication of importing suitable construction material may be excessive depending on the location of the structure; as such there is an increase in the use of poorer quality materials for reinforced soil walls. Where poorer quality material is used between the geosynthetic layers, the use of stronger geosynthetics may be required to improve the mechanical properties of the retaining wall.

Construction of reinforced soil walls depend on the geometry of the site that often dictates the choice of retaining solution, together with the cost effectiveness of the solution. Space limitations may also prohibit the construction of conventional retaining solutions. As such reinforced soil walls are considered to be an alternative to concrete retaining structures, as construction is possible in areas with space limitations.

2.5 Construction

Construction of reinforced soil structures are considered to be simple and fast in comparison to conventional retaining wall systems. Other advantages include the use of unskilled labour to undertake the rapid construction procedure. Additionally, construction does not require large heavy machinery and the site preparation for this solution is minimal. All of these factors have a significant influence on the cost savings associated with the construction of reinforced soil walls (Rajagopal, 2013).

The reinforced structure is usually constructed with local backfill materials (depending on availability and quality) and hence is considered to be a sustainable solution. However, in cases where the quality of the material on site is of very poor quality, then local sources should be considered for the supply of construction material (Koerner 2005). The materials are usually imported from the surrounding areas (where possible) to reduce the costs associated with transportation from greater distances. Where local suppliers are not an option, then design modifications are necessary to improve the quality of the existing materials (e.g. stabilization using cement or lime) or by redesigning the reinforced structure to accommodate the use of poorer quality material that is locally available.

2.5.1 Construction of Reinforced Soil Walls

Construction of reinforced walls is generally done in a sequential manner. This involves the preparation of the soil foundation which in some instances includes the removing of poor founding materials. Once unsuitable materials are removed the in-situ material is compacted. The removed material is replaced with better quality more suitable foundation soils compacted in layers up to the founding depth of the reinforced soil wall.

Once the ground has been prepared, the concrete foundation for the facing units are cast just below the foundation level. The first level of facing units should be erected with the adjacent units clamped together. The reinforcement is placed directly on the foundation soil or on a layer of compacted fill above the foundation soil, behind the facing unit, and usually aligned with the maximum stress direction and is attached to the facing panel. The soil fill is placed and compacted in the specified lift heights over the first reinforcement layer up to the next reinforcement layer. The reinforcement layer vertical spacing is based on the design specifications. The second layer of reinforcement is placed over the compacted backfill soil which is attached to the facing unit. Another compacted backfill layer is constructed over the reinforcement as per the design specifications. Once the top of the facing panel has been reached, the next level of panels is erected. These steps are undertaken for each panel added until the full height of the wall has been constructed (Koerner 2005).

Light compaction should be used within 1.5 to 2.0m of the wall facing to prevent high lateral pressure build-up and to prevent damage of facing panels. Due to the light compaction near the wall, good quality soils (that have high friction angles and good drainage characteristics) should be considered for use directly adjacent to the wall to provide strength and minimize settlement (National Highway Institute Office of Bridge Technology 2001).

Acceptable construction tolerances for soil retaining wall facing panels is ±5mm per meter height of wall from the vertical, with bulges and bows limited to 20mm per 4.5m, and horizontal alignments allowed to deviate by 15mm from the reference alignment (South African Bureau of Standards 2018).

2.5.2 Drainage

Polymeric reinforcements have limited drainage capacity and therefore it is recommended that surface water should be controlled to prevent seepage into the reinforced soil. If the reinforced soil structure becomes waterlogged, increased water pressures develop within the reinforced soils, which can induce additional tensile forces.

Drained conditions are generally assumed for reinforced soil wall design, as most references recommend the use of free draining fill materials such as granular fills or sand fills hence there should be no build-up of hydrostatic pressures. However, drainage control may need to be provided in the case of cohesive in-situ retained soils. Additionally, adequate drainage control is critical when using fine grained silts and clays for the backfill material (which is generally not recommended). Prevention of water entering into the backfill zone from the surface by either the use of a geomembrane or a geosynthetic clay liner is required (Koerner 2005).

2.6 Finite Element Method (FEM)

Numerical modelling has been widely used to validate the principals of soil reinforcement and to evaluate the behaviour of reinforced soil structures (Zornberg 1994). Numerical modelling divides the structure into elements for which the stresses and strains are calculated. “This method approximates the partial differential equations for the elements resulting in the algebraic equations to characterise the behaviour of each element” (Chiwaye 2010).

FEM is a numerical analysis method, which may be used for various applications in any field of study. This tool may be used to undertake complex designs of two- or three-dimensional structures when accuracy and speed of analysis is necessary. Finite element applications may be divided into three categories as discussed by Osman (1990, p.360):

- “Equilibrium or time-independent problems: Involves the determination of displacement, stresses, pressures, velocity and temperature distribution” (Osman 1990, p.360).

- "Eigen-value problems of solid and fluid mechanics: Steady state problems that require the determination of the natural frequency and vibration of solids and fluids" (Osman 1990, p.360).
- "Time-dependent or propagation problems of continuum mechanics: This approach adds the time dimension to either of the two categories above" (Osman 1990, p.360).

FEM has become common for assessing the overall displacements and stresses of reinforced soil walls and analysing the stability of the structure. The analyses assess the possibility of external failure of the wall while also confirming the adequacy of the reinforcement length. The model allows for the determination of strains, stresses and deformations of the soil and reinforcement during various stages of the structure construction and post construction depending on how the model is set-up.

The ratio of the actual shear strength to the minimum shear strength at failure is calculated as the factor of safety computed by the FEM and is referred to as the Shear Strength Reduction method (Chiwaye 2010, p.25). The method incrementally reduces the shear strength properties of all materials simultaneously until failure commences and hence giving the shear strength reduction factor or factor of safety (Chiwaye 2010, p.26).

FEM's are considered suitable for parametric studies of structures under working stress and loading conditions to identify the parameters that dominate the performance of the structure. This method is especially useful when assessing non-standard wall geometries or with complicated loading conditions.

2.7 Major Findings from Literature and their Implications

Geosynthetics provide a variety of solutions and functions for construction related problems. The most common function and example applications of geosynthetics used in the construction industry include the following:

- Separation between different material layers; as is required to separate a granular fill pioneer layer from an underlying soft soil.
- Reinforcement of soil masses where reinforcement layers are included between soil layers in embankments, slopes and as a retaining soil structure to provide stability and to improve the strength of the soil mass as a whole unit.
- Filtration and drainage layers were subsoil drains are required or behind a retaining wall to alleviate pore-water pressure build-up and provide drainage.
- As an impermeable barrier or lining such as required for use in landfill sites or tailings dams for containment.

There are various types of geosynthetics in the market that provide these various functions namely geogrids for reinforcement, geonets for drainage, geomembranes as fluid barriers and geosynthetic clay liners for containment with some products referred to as geocomposites having more than one function.

Manufacturers of geosynthetics are continuously improving the polymers from which geosynthetics are made. Polymers are characterised by various material properties and these all influence the materials durability. Improvements by the addition of various additives are used to ensure the longevity and survivability of these geosynthetics. The various additives are used to mitigate against degradation of the geosynthetics by the process of aging, chemical degradation, thermal degradation, photo oxidation and microbiological degradation (Kay, Blond, and Mlynarek 2004). A geosynthetic's durability is its ability to maintain its properties over its design life (Shukla 2012).

Reinforced soil walls which is the geosynthetic solution being assessed in this study, improves the tensile strength thereby maintaining stability and integrity of the soil mass which performs as a retaining structure. Several characteristics dictate reinforcement durability which includes the elongation of the geosynthetic under prolonged loads (referred to as creep strain), installation damage, weathering and temperature and design life.

The design strength of geosynthetic reinforced soil walls are generally calculated for the limit states with the ultimate strength downrated by using partial factors to account for creep strain, temperature variations, ramifications of failure, with material factors applied to account for strength reduction due to installation damage, weathering, chemical and environmental affects and the for the extrapolation of time and creep related data (British Board of Agrément 2010).

Extensive research and quality control measures are employed to improve the durability of geosynthetics, together with the accepted industry guidelines for determining the various partial factors that need to be applied when designing geosynthetic reinforced soil walls which are based on geosynthetic product data and engineering principals.

Detailed design approaches are undertaken to ensure the internal and external stability of reinforced soil walls. External stability analysis assesses the failure of the reinforced soil wall by bearing or overturning failure, sliding along the base or settlement and external slip failure, whereas internal stability analysis of the reinforced soil structure assesses the failure of the reinforcement against rupture and against pull-out from within the soil mass (South African Bureau of Standards 2011).

The analysis undertaken for the external stability is similar as for all retaining structures. There are several methods available for the internal stability analysis of a reinforced soil wall are presented in various design guidelines and codes. The South African Bureau of Standards (2011) which employs the British standards hence recommends either the Tie-Back Wedge Method for extensible reinforcement with the Coherent Gravity method employed when using inextensible reinforcement.

The design methods recommended in the code employ the limit equilibrium approach which applies partial factors to provide a margin of safety against the ultimate and serviceability limit state (South African

Bureau of Standards 2011, p22). The partial factors account for uncertainty and variability in materials and loading applied to the structure.

The soil and reinforcement parameters used in the design and analysis are generally determined from laboratory or in-situ testing of the materials to be used. However, there are other factors that need to be factored into the design to account for undesirable conditions or variability in conditions; these may include poor quality fill and in-situ material conditions, chemistry of the environment and its impact on the reinforcement's durability, site damage, bond strength between the soil and the reinforcement, the durability of the reinforcement and its performance with time (which is impacted by various field and environmental factors). As noted, these are usually addressed by the application of partial factors to the reinforcement strength which are determined by intense testing, quality control and property determination by the product manufacturers.

The benefits of using reinforced soil walls include the flexibility of the structure to tolerate settlement while still maintaining its functionality compared to conventional retaining systems (California Department of Transportation 2004). Since the reinforce soil wall spreads the foundation loads due to its large footprint, the imposed stress on the founding soils is typically lower than for traditional retaining structures hence reinforced soil structures may be used in areas where the founding conditions are less than desirable. As the height of a retaining structure increases, the cost of the structure tends to increase significantly due to the cost of reinforcement, this however is not the case with reinforced soil walls which may provide costs savings of up to 25-50% compared to conventional retaining wall (National Highway Institute Office of Bridge Technology 2001). In addition to the cost savings, the time taken for the construction of reinforced soil walls are a fraction of that required for construction conventional retaining walls and can also be undertaken by an unskilled labour force with limited equipment requirements (Rajagopal, 2013). Hence the flexibility, cost and time savings of reinforced soil walls make them an extremely viable retaining wall solution which has been gaining popularity within the civil industry.

Numerical modelling is being extensively used as a modelling and design tool to assess behaviour of reinforced soil structures. Although it is known that numerical methods can validate hand calculated empirical design methods, it has far more benefits such as the prediction of the behaviour of the wall at failure, including deformation of the facing, the location of maximum strains within the reinforced soil structure hence confirming the failure surface and most importantly quantify the structure deformation for each reinforced layer. These numerical simulations are also beneficial for parametric studies to assess the sensitivity of various design input parameters on the stability of a reinforced soil wall design, where the various input parameters are varied in several simulations to identify how each parameter influences the stability of the design.

Given the continuous improvements in geosynthetics properties (and hence improvement in durability) it is considered worthwhile to assess the suitability of the design approaches to configure a reinforced soil wall and to identify if there is room for improving on the design. Furthermore, the efficiency, speed and accessibility of numerical modelling software encourages the use of numerical simulations for design purposes. Given the various other outputs that can be determined from numerical analysis such as the deformations and strains that develop within the reinforced soil wall which is not determined from the empirical coherent gravity method for internal stability analysis, it is definitely worth considering the benefits of using numerical design methods for reinforced soil structures.

3. METHODOLOGY

This study uses the soil conditions of an existing reinforced soil wall constructed at Durban's National Route N2-Umgeni Road interchange as a case study. The 8m high reinforced soil wall has an applied strip load of 20kN at the crest. A design was undertaken for the case study wall (referred to as the original design) in accordance with the SANS 8006-1:2018 Code of Practice for Strengthened/Reinforced Soils and Other Fills, in this study. The design was analysed using the FEM to determine the stresses and displacements of the structure to identify if the code is conservative with respect to the design approach prescribed.

Additionally, a parametric study to determine the influence of the reinforcement length, vertical spacing, coverage, and strength on the stability of the structure was undertaken. These results identify if the case study design may be optimised and if so, determines the most favourable reinforcement configuration.

The following tasks were undertaken using the case study of the N2-Umgeni Road Interchange Reinforced soil wall;

- Design of the reinforced soil wall, using the design code comprising the following analysis:
  - Selection of wall geometry.
  - External stability.
  - Internal stability.
- FEM analysis of the original design developed using the code.
- Parametric study.
- Comparison of the results of the analysis with respect to the adequacy of the original design and discussion of parametric study results and proposed optimized design.

3.1 Design Based on Code of Practice

In accordance with the SANS 8006-1:2018 Code of Practice for Strengthened/Reinforced Soils and Other Fills, the following design approach was employed.

3.2 External Stability Analysis

The geometry of the wall is selected based on the guidelines provided in the code. SANS 8006-1:2018 prescribes the minimum length dimensions for the reinforced wall based on the type of structure (e.g. walls, abutments, trapezoidal walls). The minimum prescribed reinforcement length is the product of 0.7H where H is the height of the structure, or a minimum of 3m length. The minimum embedment depth of the toe of the wall and wall facing specified in the design code is H/20, which is based on the required structure slenderness ratio of greater than L/H=0.7, where L is the reinforcement length (South African Bureau of Standards 2011, p.79).

The SANS 8006-1:2018 design code recommends an external stability analysis of the wall geometry. The external stability analysis assesses the probability of failure of the monolithic reinforced soil structure. To ensure stability the disturbing forces should not exceed the restoring forces. The external stability analysis considers the loads and forces acting on the structure. The failure modes that were analysed include the following:

- **Lateral Sliding Failure**

  The lateral sliding failure analysis determines the mass required in the reinforced soil structure to provide adequate resistance at the base of the structure to counteract the sliding forces acting between the reinforced structure and the founding soil.

- **Overturning Failure**

  The overturning failure analysis or eccentricity check at the base of the wall determines the resistance as a result of the self-weight of the reinforced structure to counteract the overturning forces that act on the reinforced soil (Koerner 2005).

- **Bearing Capacity Failure**

  This analysis evaluates the bearing capacity of the foundation soil on which the reinforced soil structure is constructed to assess the adequacy of the founding soil to accommodate the bearing pressure imposed by the reinforced soil wall. Additionally, settlement determination is necessary to confirm that settlement of the founding horizon as a result of the imposed loads, are within tolerable limits.

Load and material partial factors apply to the external disturbing and restoring forces to account for any variability and uncertainty of loads and material properties. For external stability, the partial load factors were applied to the disturbing forces while partial material factors were applied to the restoring forces. The factored restoring forces need to exceed the factored disturbing force to prevent failure (South African Bureau of Standards 2011, p.22).

The load factors, material factors, soil/reinforcement interaction factors, and external stability partial factors of safety which have been applied (where relevant) during the external stability analysis (and for the internal stability analysis) of the reinforced soil wall according to the design code is tabulated in **Error! Reference source not found.**and **Error! Reference source not found.**, which is repeated here for ease of reference from the code and from previous chapters.

The partial factor to account for the ramifications of failure has a value dependent on the level of risk and is based on the type of structure that is being designed. This factor is applied to the design strength to account for the ramifications of failure. The partial factors for different structure types are listed in **Error! Reference source not found.** and is repeated here for ease of reference from the code and from previous chapters.

Table 3-1: Summary of Partial Factors (South African Bureau of Standards 2011, p75)

Partial Factors		**Ultimate Limit State**	**Serviceability Limit State**
Load Factors	Soil unit mass, e.g. wall fill	The appropriate value of f_{fs} to be chosen according to Table 9.2 for the particular load combination	
	External dead loads, e.g. line or point loads	The appropriate value of f_f to be chosen according to Table 9.2 for the particular load combination	
	External live loads, e.g. traffic loading	The appropriate value of f_q to be chosen according to Table 9.2 for the particular load combination	
Soil Material Factors	to be applied to tan ϕ'_p	f_{ms} = 1.0	f_{ms} = 1.0
	to be applied to c'	f_{ms} = 1.6	f_{ms} = 1.0
	to be applied to c_u	f_{ms} = 1.0	f_{ms} = 1.0
Reinforced material factor	to be applied to the reinforcement base strength	The value of f_m should be consistent with the type of reinforcement to be used and the design life over which the reinforcement is required	
Soil/reinforcement interaction Factors	Sliding across surface of reinforcement	f_s = 1.3	f_s = 1.0
	Pull out resistance of reinforcement	f_p = 1.3	f_p = 1.0
Partial factors of safety	Foundation bearing capacity: to be applied to q_{ult}	f_{ms} = 1.35	NA
	Sliding along base of structure or any horizontal surface where there is soil-to-soil contact	f_s = 1.2	NA

Table 3-2: Partial Load Factors for Load Combinations for Wall (South African Bureau of Standards 2011, p77)

Effects	**Combination**		
	A	**B**	**C**
Mass of the reinforced soil body	f_{fs} = 1.5	f_{fs} = 1.0	f_{fs} = 1.0
Mass of the backfill on top of the reinforced soil wall	f_{fs} = 1.5	f_{fs} = 1.0	f_{fs} = 1.0
Earth pressure behind the structure	f_{fs} = 1.5	f_{fs} = 1.5	f_{fs} = 1.0
Traffic load: on reinforced soil block: behind reinforced soil block	f_q = 1.5	f_q = 0	f_q = 0

Effects	Combination		
	A	**B**	**C**
Traffic load: behind reinforced soil block	$f_q = 1.5$	$f_q = 1.5$	$f_q = 0$
Note: The following descriptions of load cases identify the usual worst combination for the various criteria but are for guidance only. All load combinations should be checked for each layer of reinforcement within each structure to ensure the most critical condition has been found and considered. **Combination A** This combination considers the maximum values of all loads and therefore normally generates the maximum reinforcement tension and foundation bearing pressure. It may also determine the reinforcement requirement to satisfy pull-out resistance although pull-out resistance is usually governed by combination B.			
Combination B This combination considers the maximum overturning loads together with minimum self-mass of structure and superimposed traffic load. This combination normally dictates the reinforcement requirement for pull-out resistance and is normally the worst case for sliding along the base. **Combination C** This combination considers dead loads only without partial load factors. This combination is used to determine foundation settlements as well as generating reinforcement tensions for checking the serviceability limit state.			

Table 3-3: Partial Factor for Category of Structure Depending upon Ramifications of Failure (South African Bureau of Standards 2011, p38)

Category	Partial factor f_n	Examples of Structures
1 (low)	Not applicable *	Retaining walls and slopes less than 1.5m in retaining height where failure would result in minimal damage and loss of access
2 (medium)	1	Embankments and structures where failure would result in moderate damage and loss of services
3 (high)	1,1	Abutments, structures directly supporting motorway, trunk and principal roads or railways or inhabited buildings, dams, sea walls and slopes, river training walls and slopes
* structures of category 1 should be restricted to simple structures designed by experience without analysis		

The input parameters and the calculation methodology applied for the external stability analysis of the N2-Umgeni Road Interchange case study to verify the adequacy of the reinforced soil wall geometry are as described in the following sections.

3.2.1 External Stability Analysis Inputs

The material properties, wall geometry and loading information reflected on **Error! Reference source not found.** are used for the external stability analysis. These are the properties of the imposed load and the soil properties of the reinforced wall for the case study analysed. The sections that follow stipulates the calculation steps undertaken to assess the external stability of the wall.

Table 3-4: Input Parameters used in the External Stability Analysis Calculations

INPUT PARAMETERS	Symbol	Unit
Height of retaining wall	H	m
Cohesion of Foundation soil	c_f	kPa
Friction Angle of Backfill Soil	f_b	degrees
Friction Angle of Foundation Soil	f_f	degrees
Unit Weight of Backfill Soil	g_b	KN/m^3
Unit Weight of Reinforced Soil	g_r	KN/m^3
Unit Weight of Foundation Soil	g_f	KN/m^3
Length of Reinforced Block	L	m
width of the surcharge load on the reinforced wall	a'	m
Width of the strip load over the reinforced block only	a	m
Distance of strip load from the facing of the reinforced block	b	m
Surcharge	q	kPa

3.2.2 Rankine Active Pressure Coefficient

According to Das (2011) the active earth pressure coefficient is calculated in accordance with the following:

$k_a = \tan^2 (45- f_b/2)$ Equation 1

where

k_a - active earth pressure coefficient

f_b - angle of friction of the backfill soil.

3.2.3 Total Force Acting per Unit Length of Wall

Using the material properties and the calculated active earth pressure coefficient, the force acting on the wall is determined as per the following equations (Das, 2011). Load factors (f_{fs}) for the soil unit mass and for the earth pressure behind the backfill are applied to the calculation, as indicated below.

$P_a = 0.5*f_{fs}*g_b*H^2*f_{fs}*k_a$ Equation 2

where

P_a - force acting on the wall.

The location of this resultant force (P_a) acts at a distance from the bottom of the wall (z’), which is determined as follows (Das 2011).

$z' = H/3.$ Equation 3

3.2.4 Total force acting per unit length of wall due to the strip load only

Forces that develop as a result of the strip load, which is applied over the backfill and reinforced soil, is determined in accordance with the following equations (Das 2011).

$P = q/90 *[H(\sigma_2-\sigma_1)]\}$ Equation 4

where;

P	-	force as a result of the strip load
q	-	strip load
σ_1	-	$\tan^{-1}(b'/H)$
σ_2	-	$\tan^{-1}[(a'+b')/H]$

where;

a'	-	width of the strip load over the backfill soil only
b'	-	distance from the wall edge/ facing to the strip load.

The location (Z) of the resultant force P which acts from the bottom of the wall upwards, is determined in accordance with the following equations (Das 2011):

$R = (a'+ b')^2 (90-\sigma_2)$ Equation 5

$Q = b'^2 (90-\sigma_1)$ Equation 6

$Z = H – \{[H^2 * (\sigma_2-\sigma_1) + (R-Q) – (57.3a'*H)] / [2H*(\sigma_2-\sigma_1)]\}$ Equation 7.

3.2.5 Overturning

The analysis for overturning assesses whether the overturning moment (M_O) is less than the resisting moment (M_R) to ensure safety against overturning of the structure. The overturning and resisting moments are determined as per the following equations (Das 2011).

$M_O = (P_a*z') + (P*Z)$ Equation 8

For the resisting moment the reinforced soil weight and the strip load applied to the surface of the reinforced block are considered only.

$M_R = [W*(L/2)] + [q*a*(b+a/2)]$ Equation 9

where;

$W = LH\gamma_r$ Equation 10

and;

a	-	length of the strip load over the reinforced block only
b	-	distance of the strip load from the facing.

3.2.6 Sliding Analysis

The equations that follow assesses the long-term stability of the reinforced soil wall against sliding where there is soil to soil contact at the base of the wall as is the condition for the case study assessed.

The calculation steps are as follows and are in accordance with the code SANS8006-1:2018 (South African Bureau of Standards 2018, p.80):

$f_s{*}R_h \leq R_v (\tan f_p/f_{ms}) + (c'/f_{ms}) L$; Equation 11

where the right-hand side of the equation is calculated as follows;

$R_v (\tan f_p/f_{ms}) + (c'_r/f_{ms}) L = [(LHg_r) + (qa)] {*}(\tan f_p/f_{ms}) + (c'_f/f_{ms}) {*}L$ Equation 12

where;

- f_{ms} - partial soil material factors applied to $\tan f_p$ and to c'
- $\tan f_p$ - peak angle of shearing resistance under effective stress conditions (for the foundation soil)
- a - width of the strip load over the reinforced block.

The left-hand side of the equation is calculated as follows;

$f_s R_h = f_s (P_a + P)$ Equation 13

where;

P_a and P are calculated above.

- f_s - partial factor of safety for sliding along the base of the structure where there is soil to soil contact.

The following formula determines the short-term stability of the soil wall against sliding where there is soil to soil contact at the base of the wall (South African Bureau of Standards 2018, p.81).

$f_s R_h \leq (c_u/f_{ms}) L$ Equation 14

where;

- c_u - undrained shear strength of the soil.

As drained conditions apply to the case study used, the above equation is not applicable.

3.2.7 Bearing Capacity and Elastic Settlement

The bearing pressure imposed on the founding soil as a result of the reinforced soil wall is determined in accordance with the following equations (Das, 2011).

Calculate Overturning and Resisting Moment:

MO = (Pa*z') + (P*Z) Equation 15

where P_a, z', P and Z are from calculations indicated in preceding sections excluding the application of partial factors.

To calculate the resisting moment, the soil weight of the reinforced soil and the strip load applied at the surface of the reinforced block is considered only.

$M_R = [W{*}(L/2)] + [q{*}a{*}(b+a/2)]$ Equation 16

where;

$W = LH\gamma_r$

a - width of the strip load over the reinforced block only

b - distance of the strip load from the facing.

The eccentricity is determined as per the following equation;

$e = (L/2) – [(\Sigma M_R – \Sigma M_O)/\Sigma V]$ Equation 17

where R_v is the resultant of factored vertical load components;

$\Sigma V = R_v = (L*H*f_{fs}*\gamma_r) + \{q*a*[b+(a/2)]\}$ Equation 18

and;

f_{fs} - partial load factor for reinforced soil body.

The imposed bearing pressure on the foundation soil is calculated as follows:

$q_r = R_v/ L-2e$ Equation 19

The Ultimate Bearing Capacity of the foundation soil is determined as per the following equation (Das 2011):

$Q_{ult} = (c_f*N_c*F_{cd}*F_{ci}) + (q*N_q*F_{qd}*F_{qi}) + (0.5*\gamma_f*B'*N_\gamma* F_{\gamma d}*F_{\gamma i})$ Equation 20

where;

$q = \gamma_f *D_m$

γ_f - unit weight of the foundation soil

D_m - embedment depth

And,

$B' = L-2e$ (where L is the length of reinforcement)

$F_{qd} = 1 + (2\tan \phi_f) *(1-\sin \phi_f)^2*(D_m/B')$

$F_{cd} = F_{qd} – [(1- F_{qd}) / (N_c*\tan \phi_f)]$

$F_{\gamma d} = 1$

$\psi = \tan^{-1} [(P_a\cos\alpha)/(\Sigma V)]$ (where α is the slope of the backfill surface)

$F_{ci} = F_{qi} = [1- (\psi/90)^2$

$F_{\gamma i} = [1- (\psi/ \phi_f)^2$

N_c, N_q and N_γ are factors that can be found in various geotechnical literature, however was obtained from the Bearing Capacity factors presented in Das (2011, p.144).

The imposed bearing pressure is compared to the ultimate bearing capacity to assess the potential for failure as a result of the imposed pressure exceeding the ultimate bearing capacity of the foundation soil. Based on the design code SAN8006-1:2018, the following condition should suffice to confirm stability (South African Bureau of Standards 2018, p.80).

$$q_r \leq (q_{ult} / f_{ms}) + (g_f * D_m) \qquad \text{Equation 21}$$

where;

f_{ms} - partial factor of safety applied to q_{ult}.

The last step in the external stability analysis is to calculate the elastic settlement of the foundation soil based on the loading applied as a result of the reinforced soil structure. From a serviceability perspective, the foundation settlement should be within tolerable limits for a retaining structure with a discrete panel facing.

The elastic settlement (S_e) is calculated as follows (Das 2010, p.296):

$$S_e = Ds(aB')[(1-m_s^2)/E_s]\, I_s I_f \qquad \text{Equation 22}$$

where;

Ds - applied pressure on the foundation

m_s - Poisson's ratio of the soil

E_s - average modulus of elasticity of the founding soil

B' - width of the foundation, B/2 when calculating the settlement at the centre of the structure and B when calculating settlement at the corner of the structure

a - factor that depends on the location of the settlement to be determined (corner or centre of the foundation footprint)

I_s - shape factor

I_f - depth factor (based on the Poisson's Ratio and the B/L Ratio): $I_f = f\,(D_f/B, m_s,$ and $L/B)$, where, D_f is the embedment depth. This factor can be found in various geotechnical literature for elastic settlement calculations (Das 2011, p.252).

The shape factor is determined as follows (Das, 2011):

$$I_s = F_1 + [(1-2m_s)/(1-m_s)]F_2 \qquad \text{Equation 23}$$

Where;

$$F_1 = {}^{1}/_{\prod} (A_0 + A_1)$$

$$F_2 = {}^{n'}/_{2\prod} \tan^{-1} A_2$$

$$A_0 = m' \, \mathrm{In} \frac{\left(1 + \sqrt{m'^2 + 1}\right)\sqrt{m'^2 + n'^2}}{m'\left(1 + \sqrt{m'^2 + n'^2 + 1}\right)}$$

$$A_1 = \ln \frac{\left(m' + \sqrt{m'^2 + 1}\right)\sqrt{1 + n'^2}}{m' \left(1 + \sqrt{m'^2 + n'^2 + 1}\right)}$$

$$A_2 = m' / \left(n' \sqrt{m'^2 + n'^2 + 1}\right)$$

When calculating the settlement at the centre of the structure footprint (foundation) the following factors apply:

$a = 4$

$m' = L/B$

$n' = H/(B/2)$

where,

L	-	length of structure foundation / footprint
B	-	breadth of structure foundation / footprint
H	-	depth of founding soil horizon

To calculate the settlement at the corner of the structure footprint (foundation) the following parameters apply compared to when calculating the settlement at the structure centre:

$a = 1$

$m' = L/B$

$n' = H/B$.

This concludes the steps required (and were undertaken) to determine the settlement of the case study reinforced soil structure.

3.3 Internal Stability Analysis

The internal stability analysis determines the reinforcement length, spacing, strength and coverage necessary for the structural integrity of the reinforced soil wall. As such the internal stability analysis confirms the number of reinforcement layers and spacing, reinforcement strength, reinforcement length, coverage ratio and the facing connection strength to ensure stability.

In accordance with the design code, the ultimate limit state approach recommended for internal stability analysis assesses the stability of each reinforcing layer. The maximum tensile stress imposed on each reinforcement layer is calculated to determine the reinforcement strength required to prevent rupture, additionally the adherence capacity of the reinforcement and wedge stability (line of maximum tension) to confirm that pull-out of the reinforcement does not occur is also assessed (South African Bureau of Standards 2011, p.95).

A stable geometry to ensure that construction and post construction related movements are to acceptable limits are necessary for the serviceability limit state. The deformations over the service life of the structure are usually related to creep strain due to sustained load on the structure. The serviceability limits for post construction internal strains as specified in the code is 1% strain for retaining walls and 0.5% strain for bridge abutments (South African Bureau of Standards 2018).

3.3.1 Partial Factors

Partial factors (with values of unity or greater) to provide a margin of safety against the ultimate limit state (failure) and against serviceability limit state were applied to account for any uncertainty and variability in materials properties and loading at various times during the structures service life (South African Bureau of Standards 2011, p.22).

The primary partial factors used for design include factors for dead and live loads, material factors which are applied to the soil properties and reinforcement bas strength, soil/reinforcement interaction factors and factors of safety for bearing capacity and sliding along the base. Additionally, a factor to account for the economic ramifications of collapse are also applied when determining the reinforcement design strength.

The partial factors which are applied to the internal stability analysis are tabulated in **Error! Reference source not found.** to **Error! Reference source not found.**.

3.3.2 Internal Stability Analysis Overview

Geosynthetic reinforcements such as geogrids and Paraweb straps that have strains of less than 1% are considered to be inextensible reinforcements and hence the internal design approach recommended when using these reinforcements is the Coherent Gravity Design method. This approach has therefore been adopted for the internal stability analysis undertaken in this study with the applicable partial factors applied to the calculations for each reinforcement layer (j^{th} layer). The various material properties, wall geometry and loading information that are used in the calculations are listed in :.

Table 3-5: Input Parameters to be used in the various Internal Stability Calculations

INPUT PARAMETERS	Symbol	Unit
Height of retaining wall	H	m
Height of retaining wall - Embedment Depth	H_1	m
Cohesion of reinforced soil	c_r	kPa
Cohesion of Foundation soil	c_f	kPa
Cohesion of Backfill soil	c_b	kPa
Friction Angle of reinforced fill soil	f_r	degrees
Friction Angle of Backfill Soil	f_b	degrees
Friction Angle of Foundation Soil	f_f	degrees
Unit Weight of Backfill Soil	g_b	KN/m^3
Unit Weight of Reinforced Soil	g_r	KN/m^3
Unit Weight of Foundation Soil	g_f	KN/m^3
Length of Reinforced Block	L	m
Total width of the strip load on the entire wall		m

INPUT PARAMETERS	Symbol	Unit
Width of the strip load over the reinforced block only	a (or also - b)	m
Distance of strip load from the facing over the reinforced block / Distance from the wall to the end of the strip footing (b')	b (or also - d) (or b')	m
Distance from edge of wall to the strip load	b'	m
Width of the strip load on the backfill portion of the wall	a'	m
Distance from the facing to the centre of the strip load (portion of strip load over the reinforcement block only)	d	m
Surcharge (Strip Load)	q (S_L)	kPa
Slope of top surface of wall to the horizontal	α	degrees
Friction angle between soil and the wall	d'	degrees
Angle of the retaining wall back face to the vertical	θ	degrees
Width of Reinforcement	B	m

3.3.3 Lateral Earth Pressure Coefficient

The lateral earth pressure of the soil to be retained is required for input into the design of a reinforced soil retaining structure, with the active earth pressure calculated as follows (Das 2011):

$$k_a = \tan^2 (45- f_b/2)$$

whereas the lateral earth pressure at rest is determined as follows (Das 2011):

$$k_0 = 1 - \sin\ f_b$$

For both the ultimate and serviceability limit state, the coefficient of earth pressure is to be taken as k_0 at the top of the wall reducing linearly with depth to the value of k_a at depths of 6m below the top of the structure as follows (South African Bureau of Standards 2018):

$k = k_o (1-z/z_o) + (k_a*(z/z_o))$ for $z \leq z_0 = 6m$ Equation 24

or,

$k = k_a$ for $z > z_0$ Equation 25

3.3.4 Vertical loading due to the self-weight of the soil (T_{pj}):

The resultant factored vertical load (R_v) acting on a reinforced layer (j^{th} layer), excluding any external strip load is determined as per the following equations (Das 2011). The partial load factor for the reinforced soil mass f_{fs} is applied.

$R_{vj} = f_{fs} * g_r * L * H$ Equation 26

Once the vertical load is determined, this is followed by the determination of the overturning moment as per the equation that follows (Das 2011). Partial load factors for the reinforced soil mass are applied:

$M_o = 0.5 * f_{fs} * g_r * H^2 * k * (H/3)$ Equation 27

Using the vertical load and overturning moment, the eccentricity (E or e_j) is calculated as using the following (Das, 2011).

$E = M_o / R_v$ Equation 28

The next step is to calculate the vertical stress on the jth reinforcement layer using the following formulae (South African Bureau of Standards 2018).

$\sigma_{vj} = R_{vj} / (L_j - 2e_j)$ Equation 29

where;

σ_{vj}	-	vertical stress acting on the jth reinforcement layer
R_{vj}	-	resultant vertical loading acting on the jth reinforcement layer
L_j	-	length of the reinforcement at the jth reinforcement layer
e_j	-	eccentricity of the resultant vertical load at the jth reinforcement layer

The final step required to establish the vertical loading due to self-weight (T_{pj}) is the product of the lateral earth pressure coefficient, vertical stress and spacing. S_{vj} is half the distance from the reinforcement under consideration to the reinforcement above plus half the distance to the reinforcement below (vertical spacing of the reinforcement at the jth layer). However, when considering the uppermost reinforcement layer, it is the total distance of the soil above the uppermost reinforcement plus half the distance to the reinforcement below. The vertical force applied to the reinforcement due to self-weight of the reinforced soil is as per the following equation in accordance with the code SANS8006-1:2018 (South African Bureau of Standards 2018).

$T_{pj} = k\, \sigma_{vj}\, S_{vj}$ Equation 30

3.3.5 Strip Load Tensile Force (T_{sj})

Dispersal of the vertical strip load (S_L) from the contact area on top of the reinforced soil wall is taken at a slope of 2 vertical to 1 horizontal. The tensile force generated as a result of the strip load applied on top of the wall is calculated in accordance with the following formulae based on the code SANS8006-1:2018 (South African Bureau of Standards 2018).

$T_{sj} = k_a\, S_{vj}\, [f_f\, (S_L/D_j)]$ Equation 31

where;

$D_j = h_j+b$ [if $h_j \leq (2d-b)$]

$D_j = [(h_j+b)/2] + d$ [if $h_j > (2d-b)$]

and;

d - distance of the strip load from the facing

b - width of the contact area of the strip load

f_f - partial load factor for external concentrated dead load, however is only applicable to abutments

S_L - strip load (surcharge)

k - coefficient of earth pressure as per Equation 24 or 25.

3.3.6 Tensile Force (T_{fj}) as a Result of Applied Horizontal Shear (F_L)

As there in no horizontal shear applied in the case study analysed, the tensile force as a result of horizontal shear was not applicable. However, if there is a horizontal shear as a result of strip loading the following tensile force calculations would apply (South African Bureau of Standards 2018).

$T_{fj} = 2\ S_{vj}\ f_f\ F_L\ Q\ (1\text{-}h_jQ)$ Equation 32

where;

$Q = [\tan(45° - f'_p/2) / (d+b/2)]$

f_f - partial load factor for external concentrated dead loads

f'_p - peak angle of shearing resistance under effective stress conditions.

3.3.7 Ultimate Limit State Tensile Force (T_j)

The total ultimate limit state tensile force (T_j) applied to the j^{th} reinforcement layer is a sum of the various applicable forces; hence for frictional fill, T_j is as follows according to SANS8006-1:2018 (South African Bureau of Standards 2018).

$T_j = T_{pj} + T_{sj} + T_{fj}$ Equation 33

3.3.8 Location of Maximum Tension Line 2

The location of maximum Tension Line 2 is influenced by the strip load applied at the wall surface. According to the design code, “if the strip load is located beyond the location of tension line 2, the upper $1/6^{th}$ portion of line 2 coincides with the rear end of the load, however does not exceed the value of H_m” (South African Bureau of Standards 2018). **Error! Reference source not found.** indicates the location of line 2 re-presented here from the design code (South African Bureau of Standards 2018).

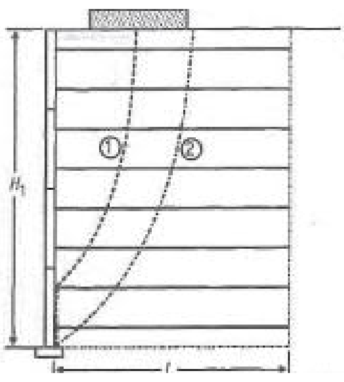


Figure 3-1: Location of Lines of Maximum Tension for Structures with Strip Loads according to the Coherent Gravity Method (South African Bureau of Standards 2018)

H_m is the greater of the following:

H or $[H_1 + Q_m / \gamma_1]$

Where,

H is the total height of the wall and Q_m is the average pressure over an area of $0.5H_1$ beyond the facing and is calculated using the Meyerhof Method with load factors of 1 (South African Bureau of Standards 2018).

A second tension line referred to as maximum Tension Line 1 also applies to the reinforced soil wall when there is a strip load acting on the wall, hence maximum tension along the reinforcement is encountered at the location of both tension line 1 and 2 as depicted in Figure 9-1.

Q_m is determined in accordance with the following steps, with the first step being the determination of the active earth pressure coefficient as previously shown.

The total force acting per unit length of wall is calculated as follows (Das, 2011).

$P_a = 0.5\gamma_r H_1^2 k$ Equation 34

The location of the resultant force from the bottom of the wall occurs at:

$z' = H_1/3$ Equation 35

The total force acting per unit length of wall due to strip load, only considers the strip load over the portion of the reinforced soil and over an area of $0.5H_1$ behind the facing; therefore $L=0.5H_1$.

Therefore, the width of the strip load is considered for only $0.5H_1$ behind the face (a') and is determined as follows (Das, 2011).

$a' = 0.5(H_1)-b'$ Equation 36

where;

b' - distance from wall edge to strip load

The total force per unit length due to strip load only is determined as follows (Das, 2011):

$P = q/\{20[H(\sigma_2-\sigma_1)]\}$ Equation 37

where;

q	-	strip load
σ_1	-	$\tan^{-1}(b'/H_1)$
σ_2	-	$\tan^{-1}[(a'+b')/H_1]$

The location Z' of the resultant force P is determined in accordance with equations that follow:

$R = (a'+b')^2 (90-\sigma_2)$ Equation 38

$Q = b'^2 (90-\sigma_1)$ Equation 39

$z = H - \{[H^2(\sigma_2-\sigma_1) +(R-Q)-57.3a'H] / [2H(\sigma_2-\sigma_1)]\}$ Equation 40

The next steps are to determine the Overturning Moment (M_O) and the Resisting Moment (M_R) as per the following equations (which are repeated here from previous sections - for east of reference) (Das, 2011):

$M_O = P_a z' + PZ$ Equation 41

$M_R = [W*(L/2)] + \{qa'*[b'+ (a'/2)]\}$ Equation 42

where,

$W = LH\gamma_r$ Equation 43

The eccentricity is calculated using the overturning and resisting moments, and is calculated as per the following equations (Das 2011):

$e = (L/2) – [(M_R-M_O) / (\Sigma V)]$ Equation 44

where, $\Sigma V = R_v$ and,

$R_v = LH\gamma_r + qa'$ Equation 45

The last step calculates the bearing pressure as per the following formulae within the design code SANS8006-1:2018 (South African Bureau of Standards, 2018):

$q_r = R_v / (L-2e)$ Equation 46

where Q_m is equal to q_r.

As stated previously the location of Tension line 2 does not exceed that defined by a structure of equivalent height H_m, where H_m is the greater of:

H or $H_1+ Q_m /\gamma_1$

where;

γ_1 – Unit weight of the structural fill.

As indicated previously, when there is a strip load located beyond the position of Tension line 2, then the upper portion ($1/6^{th}$) of line 2 coincides with the rear of the strip load, however, does not exceed H_m.

3.3.9 Tension in the Reinforcement

The tension in the reinforcement for frictional fill is determined at the facing, Tension line 1 and 2 along each reinforcement layer that makes up the reinforced soil wall. This is determined in accordance with the following equations from the design code SANS8006-1:2018 (South African Bureau of Standards 2018):

At the facing:

$T_j = \alpha_0 T_{pj} + T_{sj} + T_{fj}$ Equation 47

At maximum Tension Line 1:

$T_j = \alpha_1 T_{pj} + T_{sj} + T_{fj}$ Equation 48

At maximum Tension Line 2:

$T_j = T_{pj} + T_{sj} + T_{fj}$ Equation 49

Where (for an articulated face);

α_0	-	0.85	if $h_j \leq z_2$
α_0	-	$1 - 0.15 (H_1-h_j) / (H_1-z_2)$	if $h_j > z_2$
α_1	-	1	if $h_j \leq z_1$
α_1	-	$\alpha_0 + [(1-\alpha_0) *(z_0-h_j)] / (z_0-z_1)$	if $z_1 < h_j < z_0$
α_1	-	α_0	if $h_j \geq z_0$
z_0	-	minimum of (d+b/2) and H_1	
z_1	-	width b of the strip load	
d	-	distance from the facing to the centre of the strip load	
$z_2 = 1.5 [(H_1/2) - X]$			
X	-	width of the active zone at underside of the strip load.	

The results of the maximum tension in the reinforcement will be used to determine the tensile strength of the reinforcement required.

3.3.10 Adherence Capacity of the Reinforcement

The adherence capacity of the reinforcement should be greater than or equal to the tension in the reinforcement to prevent sliding or pull out, therefore the following function should be satisfied (SANS8006-1:2018):

$T_j \leq (2B\mu/f_pf_n)*(f_{fs}*\sigma_v)*[(L^2/2)-\{(L-L_{aj})^2\}/2]$ Equation 50

where;

L	-	length of reinforcing strip
B	-	width of reinforcing strip
μ	-	friction coefficient relating soil friction angle
f_p	-	partial factor for the reinforcement pull out resistance
f_n	-	partial factor for the economic ramifications of failure
f_s	-	partial load factor
L_{ej}	-	length of reinforcement strap beyond the maximum tension line within the resistant zone ($L_{ej} = L-L_{aj}$)
L_{aj}	-	if layer depth D <1/6H then L_{aj}=L, otherwise 1.05*(H-D), where D is layer depth.

3.3.11 Long Term Rupture Capacity

The final stage in the design of the reinforced soil wall is to estimate the long-term rupture capacity of the grade of geosynthetic reinforcement selected based on the design strength required which is determined from the maximum tension in the reinforcement. According to the British Board of Agrément Approval

Inspection Testing Certification 12/H191 (2012) for the Paraweb reinforcement used in the case study, the design strength of the reinforcement is determined as per the following equations:

For the ultimate limit state, the design strength is calculated as follows:

$T_D = T_{CR}/(f_n * f_m)$ Equation 51

Where;

$T_{CR} = T_{char} / RF_{CR}$ Equation 52

- T_{CR} - long term tensile creep rupture strength of the reinforcement at the specified design life and design temperature
- T_{char} - short term strength of the reinforcement multiplied by the number of Paraweb straps across the meter length of wall or across the facing width
- RF_{CR} - reduction factor for creep
- f_n - partial factor for the ramification of failure for the type of structure

And;

$f_m = RF_{ID} * RF_W * RF_{CH} * f_s$ Equation 53

where,

- f_m - material safety factor to allow for the effects of installation damage, weathering, chemical and environmental effects and for the extrapolation of data
- RF_{ID} - reduction factor for installation damage
- RF_W - reduction factor for weathering
- RF_{CH} - reduction factor for chemical / environmental effects
- f_s - factor of safety for the extrapolation of data.

For the serviceability limit state, the design strength may be determined as follows:

$T_D = T_{CS}/f_{m,}$ Equation 54

Where,

$T_{CS} = T_{char}/RF_{CR(SLS)}$

Equation 55

T_{char} and f_m are similar as for the ultimate limit state design strength above, however the values selected for the various reduction factors are for serviceability limit states, and;

- T_{CS} - maximum allowable tensile load to ensure that the prescribed post construction limiting strains specified for SLS is not exceeded
- $RF_{CR(SLS)}$ - creep reduction factor

All reduction factors and partial factors selected to determine the final design strength were for a structural design life of 120 years with a design temperature of 20° for both limit states.

The number of reinforcement straps used to determine the design strength of the reinforcement for both the limit states is used when determining the coverage ratio of the reinforcement (more specifically the horizontal spacing between the straps), as follows:

Coverage ratio = width of the straps / centre to centre horizontal spacing Equation 56

This ratio is multiplied with the design strength (T_D) of the reinforcement to give the final design strength, which is necessary where full coverage across the reinforced wall surface is not applicable, as in the case of the Paraweb strap, which is used for the case study investigated.

To ensure stability, the factored reinforcement design strength should be greater than the maximum tension in the reinforcement, hence the following condition is applicable according to the design code SANS8006-1:2018 (South African Bureau of Standards 2018):

$T_D \geq T_j$.

3.3.12 Facing Connection

The facing connection strength for an articulated face (e.g. discrete concrete panel facing) using the Coherent Gravity Method for both the ultimate and serviceability limit states is 85% of the maximum tension in the reinforcement (T_j) from the surface to a depth of 0.6H meters increasing to 100% of T_j between depths of 0.6H meters and the base of the wall (where H is the wall height) (South African Bureau of Standards 2018). Hence the connection strengths required for the case study wall investigated is calculated in accordance with the above prescribed percentages of the reinforcement tension calculated.

3.4 Finite Element Method (FEM)

The design established using the SANS8006-1:2018 code was verified and analysed numerically using the finite element program, Rocscience Phase 2. A model using the geometry and material properties of the design established from the design code was created in Phase 2, referred to as the original design, and was analysed using a finite element analysis (FEA).

Rocscience Phase 2 software is a 2D elasto-plastic finite element program which is used to calculate stresses and displacements for various geotechnical structures and applications (Chiwaye 2010, p.46).

Reinforced soil structures may exhibit large deformations and hence a non-linear soil model for the stress strain analysis was adopted with the Mohr-Coulomb failure criterion used to describe the behaviour of all materials which were indicated as plastic to allow for deformation. A single stage model was used with plane strain analysis assumed. The initial in-situ stress conditions selected for the model analysed was a gravitational field stress using the actual ground surface. The initial element loading was set to field stress and body force for the foundation soil, backfill soil and pioneer layer, whereas body force only was selected for the reinforced soil and the layerworks on the reinforced wall. The properties of the soils and the concrete facing were defined, namely unit weight, Young's modulus, Poisson's ratio, and the material shear strength parameters. In addition, the tensile strength of the concrete was included together with the tensile strength and tensile modulus of the geosynthetic reinforcement.

The reinforced soil wall model was created using coordinates to define the geometry of the structure, including external boundaries. The vertical boundaries that are parallel to the y-axis were restrained in the x direction (hence no displacement in this direction)while the horizontal boundary parallel to the x -axis at the base of the model was restrained in both the x and y direction (hence no displacement allowed) with the surface of the model not restrained.

The next step was to generate a finite element mesh which needs to be discretised, hence forming the framework of the finite element mesh. The program generates either triangular or quadrilateral mesh elements for which the stresses and strains are determined for each element. The mesh comprises nodes which could be 3 or 6 node triangular mesh or 8 node quadrilateral mesh; the more nodes in the mesh the more accurate the analysis results, albeit with increase in processing time for the analysis. Uniform 3 noded triangular mesh elements were used in the analysis.

Once all elements of the model were defined, and the structure mesh has been generated, the final step was to run the two-dimensional plane strain analysis. The results provided includes graphical representation of the stresses and displacements that are determined.

As an additional check, the stability of the reinforced wall was also verified by applying shear strength reduction in the finite element analysis, which calculates the factor of safety against failure of the structure.

A parametric study was carried out to assess the influence of various reinforcement geometry combinations to identify the possibility of optimizing the design. Analysis was undertaken on several models which varied the reinforcement length, spacing, strength and coverage, to assess the parameters or combination of parameters that would provide a more economical design while still maintaining stability of the reinforced soil wall.

All soil and facing properties remained constant in the parametric study with only changes to the reinforcement input parameters being varied to assess their influence on the wall stability.

4. SANS8006-1:2018 DESIGN METHOD

4.1 Reinforced Soil Wall Geometry and Design Input Parameters

Based on the recommendations and minimum guidelines provided within the SANS8006-1:2018 design code, the reinforced wall dimensions for the N2-Umgeni Road Interchange retaining wall was selected. The wall comprises a Paraweb strap reinforced soil wall with a total height of 8m, and an embedment depth of 1m. Reinforcement depth intervals were selected at 0.5m (with the exception of the first two layers where the reinforcement is at 0.4m and the next layer at 1.0m below the surface) with a reinforcement length of 7m selected for the wall. The soil used in the construction of the reinforced soil wall is in accordance with industry standards for fair quality soil for construction material with a unit weight of 19.5kN/m^3, cohesion of 0kPa, and an angle of friction of 27°. The retained backfill soil is similar to the reinforced soil with the exception of the cohesion of 5kPa, whereas the foundation soil properties include cohesion of 5kPa, and an angle of friction of 27°. A strip load located 2.8m behind the facing panel is imposed on the reinforced soil wall. The reinforced soil wall geometry, all relevant soil properties including loading information required as input parameters to undertake the internal and external stability analysis prescribed in the code SANS8006-1:2018 has been included in **Error! Reference source not found.**.

Table 4-1: Input Parameters used in the Stability Analysis Calculations using the SANS8006-1:2018 Design Method

INPUT PARAMETERS	**Symbol**	**Parameter Value**	**Unit**
Height of retaining wall	H	8,00	m
Cohesion of reinforced soil	c_r	0,00	kPa
Cohesion of foundation soil	c_f	5,00	kPa
Friction angle of reinforced fill soil	f_r	27,00	degrees
Friction angle of backfill soil	f_b	27,00	degrees
Friction angle of foundation soil	f_f	25,00	degrees
Unit weight of backfill soil	g_b	19,50	KN/m^3
Unit weight of reinforced soil	g_r	19,50	KN/m^3
Unit weight of foundation soil	g_f	18,50	KN/m^3
Length of reinforced block	L	7,00	m
Width of the surcharge strip load on the reinforced wall	a'	7,40	m
Width of the strip load over the reinforced block only	a	4,40	m
Distance of strip load from the facing of the reinforced block	b	2,80	m
Width of the strip load on the backfill portion of the wall	a'	3,00	m
Distance from the facing to the centre of the strip load (portion of strip load over the reinforcement block only)	d	5,00	m
Surcharge (Strip Load)	q	20,00	kPa
Slope of top surface of wall to the horizontal	α	0,00	degrees

INPUT PARAMETERS	Symbol	Parameter Value	Unit
Angle of the retaining wall back face to the vertical	θ	0,00	degrees
Width of Paraweb reinforcement	B	0,09	m

4.2 Results

4.2.1 External Stability Analysis

As described in the methodology partial factors for each relevant load case were applied to the load and material parameters. The Ultimate Limit State Load Case A was used to assess the Overturning of the wall, and to assess the Foundation Bearing Pressure. Load Case B was applied for Sliding along the Foundation Base. While Load Case C was applied in the assessment of Foundation Settlements and for the Serviceability Limit State assessment.

The results of the external stability analysis confirm that the design and geometry proposed for the reinforced soil wall is acceptable and will perform adequately as a reinforced soil wall.

The results verify that the resisting moment of 4262 kN-m/m is greater than the overturning moment of 1465kN-m/m, and hence mitigating against overturning of the reinforced soil wall. Additionally, the factored equations (by the application of partial factors) for sliding along the base confirm the long-term sliding stability where there is soil to soil contact at the base of the structure. Resisting forces of 572kN/m versus the driving forces of 443kN/m were calculated corroborating that no sliding failure will occur. Based on the materials used for the reinforced soil wall, long-term and short-term stability are anticipated to be the same given that drained shear strength properties apply.

The bearing pressure imposed on the founding soil by the reinforced soil wall was calculated as 445kPa while the factored ultimate allowable bearing capacity of the founding soil was calculated as 617kPa hence no bearing capacity failure is anticipated below the reinforced soil wall. Furthermore, settlement of the founding horizon, as a result of the bearing pressure of the reinforced soil wall, are considered to be within generally acceptable limits for typical structures. For foundations on sand Terzaghi and Peck suggested that differential settlements are not anticipated to exceed 75% of the total movement (Tomlinson 2001, p.63). As per the design code SANS 8006-1:2018 (2018) maximum differential settlement of 1 in 100 is considered as “Normal safe limits that do not require special measures for discrete concrete panel facings”. Hence the total settlement calculated is between 11mm at the edge of the wall and 27mm within the middle of the wall footprint hence a differential settlement of up to 20.25mm can be anticipated, which is considered as “normal safe limits” for reinforced soil retaining walls.

The analysis confirms that the proposed retaining wall geometry and design for the case study is considered adequate from an external stability perspective with no sliding, overturning or bearing capacity failure expected as presented by the analysis results included in **Error! Reference source not found.**.

Table 4-2: Results of the External Stability Analysis Calculated based on the SANS8006-1:2018 Method

External Stability	Symbol	Ultimate Limit State			Serviceability Limit State	Unit
		Load Case A	Load Case B	Load Case C	Load Case C	
		Foundation Bearing Pressure, Overturning	Sliding Along Base	Foundation Settlements	Foundation Settlements and SLS	
Rankine Active Pressure Coefficient						
Earth Pressure (K_a)	**K_a**	**0,38**	**0,38**	**0,38**	**0,38**	
Total Force acting per unit length of wall						
Force (P_a)	**P_a**	**527,24**	**351,49**	**234,33**	**234,33**	**kN/m**
Resultant Force P_a acts from bottom of wall at a height of z'						
Distance z' = H/3	**z'**	**2,67**	**2,67**	**2,67**	**2,67**	**m**
Total Force acting per unit length of wall due to strip load only						
Only consider the strip load applied over the portion of backfill soil alone						
Width of strip load over backfill only	a'	3,00	3,00	3,00	3,00	m
Distance from wall edge (reinforced block edge) to strip load over backfill only	b'	7,20	7,20	7,20	7,20	m
Factor σ_1	σ_1	41,99	41,99	41,99	41,99	°
Factor σ_2	σ_2	51,89	51,89	51,89	51,89	°
Force (P)	**P**	**17,61**	**17,61**	**17,61**	**17,61**	**kN/m**
The location of z of the resultant force P						
Factor R	R	3964,71	3964,71	3964,71	3964,71	
Factor Q	Q	2488,98	2488,98	2488,98	2488,98	
Distance z (from bottom of wall upwards)	**z**	**3,37**	**3,37**	**3,37**	**3,37**	**m**
Check for Overturning						
Overturning moment (M_o)	M_o	**1465,23**			**684,14**	**kN-m/m**
Resisting Moment (M_r)						
Strip load applied only to the surface of the reinforced block is considered; therefore:						
Length of strip load over reinforced block only	a	4,40			4,40	m
Distance of strip load from the facing of the reinforced block	b	2,80			2,80	m
Resisting Moment (M_r)	**M_r**	**4262,00**			**4262,00**	**kN-m/m**
M_o<M_r		**OK**			**OK**	

External Stability	Symbol	Ultimate Limit State			Serviceability Limit State	Unit
		Load Case A	**Load Case B**	**Load Case C**	**Load Case C**	
		Foundation Bearing Pressure, Overturning	**Sliding Along Base**	**Foundation Settlements**	**Foundation Settlements and SLS**	
Check for Sliding						
ULS - Long term stability for soil to soil contact at base						
Load (R_v)	R_v		1180,00		1180,00	
$\tan\phi_p/f_{ms}$			0,47		0,47	
$(c'/f_{ms})L$			21,88		35,00	
$R_v(\tan\phi_p/f_{ms})+(c'/f_{ms})L$			**572,12**		**585,24**	**kN/m**
f_sR_h			**442,92**		**251,94**	**kN/m**
$f_sR_h \leq R_v(\tan\phi_p/f_{ms})+(c'/f_{ms})L$			**OK**		**OK**	
Check for Bearing Capacity Failure						
Force (P_a)	P_a	234,33		234,33	234,33	kN/m
Force Location - Distance z' = H/3	z'	2,67		2,67	2,67	m
Force (P)	P	17,61		17,61	17,61	kN/m
Force Location - Distance z (from bottom of wall upwards)	z	3,37		3,37	3,37	m
Overturning moment (M_o)	M_o	684,14		684,14	684,14	kN-m/m
Resisting Moment	M_r	4262,00		4262,00	4262,00	kN-m/m
Eccentricity	e	1,16		1,16	1,16	m
Load (R_v)	R_v	2078,00		1532,00	1532,00	
Bearing Pressure acting on the base of the wall	**q_r**	**444,89**		**327,99**	**327,99**	**kPa**
Ultimate Bearing Capacity of the Foundation Soil						
$q_{ult} = C_fN_cF_{cd}F_{ci}+qN_qF_{qd}F_{qi}+0.5\gamma_fB'N_\gamma F_{\gamma d}F_{\gamma i}$						
Embedment Depth	D_m	1,00			1,00	m
Unit Weight of the Foundation soil	g_f	18,50			18,50	KN/m^3
$q = \gamma_fD_m$		18,50			18,50	kN/m^2
B' = L-2e		4,67			4,67	m
$F_{qd} = 1+2\tan\phi_f(1-\sin\phi_f)^2 * D/B$		1,07			1,07	
N_c (Das, 2011, p.144) for ϕ=25°	N_c	20,72			20,72	
$F_{cd} = F_{qd} - (1-F_{qd}) / (N_c \tan\phi_f)$		1,07			1,07	
$F_{\gamma d}$	$F_{\gamma d}$	1,00			1,00	
Inclination of load on foundation with respect to the vertical	α	90,00			90,00	
$\psi = \tan^{-1}((P_a\cos\alpha)/(\Sigma V))$	ψ	0,00			0,00	
$F_{ci} = F_{qi} = (1-\psi/90)^2$		1,00			1,00	
$F_{\gamma i} = (1-\psi/\phi_f)^2$		1,00			1,00	
N_γ (Das, 2011, p.144) for ϕ=25°	N_γ	10,88			10,88	
N_q (Das, 2011, p.144) for ϕ=25°	N_q	10,66			10,66	

External Stability	**Symbol**	**Ultimate Limit State**			**Serviceability Limit State**	**Unit**
		Load Case A	**Load Case B**	**Load Case C**	**Load Case C**	
		Foundation Bearing Pressure, Overturning	**Sliding Along Base**	**Foundation Settlements**	**Foundation Settlements and SLS**	
$q_{ult} = C_fN_cF_{cd}F_{ci} + qN_qF_{qd}F_{qi} + 0.5\gamma_fB'N_\gamma F_{\gamma d}F_{\gamma i}$		**808,67**			**808,67**	**kPa**
Bearing Pressure acting on the base of the wall	**q_r**	**444,89**			**327,99**	**kPa**
$q_{ult} / f_{ms} + \gamma D_m$		**617,52**			**827,17**	**kPa**
$q_r \leq q_{ult} / f_{ms} + \gamma D_m$		**OK**			**OK**	
Check Elastic Settlement						
$S_e = Ds(aB')*[(1-u_s^2)/E_s]*I_sI_f$						
Assumed Poisson's Ratio for a silty sand (foundation soil)	u_s			0,40	0,40	
Assumed Modulus of Elasticity	E_s			20000,00	20000,00	kN/m^2
Length	L			7,00	7,00	m
Breath	B			1,00	1,00	m
Approximated thickness of Foundation Soil	H			10,00	10,00	m
Calculating the Settlement at the centre of the Foundation						
a				4,00	4,00	
m' = L/B				7,00	7,00	
n' = H/(B/2)				20,00	20,00	
Factors F_1 and F_2 (Das 2010, p.398) based on variations in m' and n'						
F_1				0,95	0,95	
F_2				0,05	0,05	
$I_s = F_1 + [(1-2u_s)/(1-u_s) * F_2$				0,96	0,96	
I_f (when D_f is 0m then $I_f = 1$)				1,00	1,00	
$S_e = Ds(a(B'/2))*[(1-u_s^2)/E_s]*I_sI_f$				**26,52**	**26,52**	**mm**
Calculating the Settlement at the corner of the Foundation						
a				1,00	1,00	
m' = L/B				7,00	7,00	
n' = H/B				10,00	10,00	
Factors F_1 and F_2 (Das 2010, p.398) based on variations in m' and n'						
F_1				0,77	0,77	
F_2				0,09	0,09	
$I_s = F_1 + [(1-2u_s)/(1-u_s) * F_2$				0,80	0,80	
I_f (when D_f is 0m then $I_f = 1$)				1,00	1,00	
$S_e = Ds(aB')*[(1-u_s^2)/E_s]*I_sI_f$				**11,03**	**11,03**	**mm**
Settlement Tolerances for Serviceability Limit State				**OK**	**OK**	

4.2.2 Internal Stability Analysis

The internal stability analysis assesses each layer of reinforcement within the soil wall. The results of which confirmed the adequacy of the design, as it meets the stability requirements of the reinforced soil wall. The tables that follow indicates the calculated vertical loading as a result of the soil self-weight and as a result of the strip load exerted at the crest of the reinforced soil wall. The total tension along the wall and the adherence capacity of the reinforcement for each reinforcing layer has been determined.

The results of Load Case A which is used to determine the tension in the reinforcement and to assess pull-out resistance are represented in **Error! Reference source not found.** for each reinforcement layer. The tension along the wall for each layer, i.e. at the facing, at tension line 1 and at tension line 2 was determined to assess wedge stability. Additionally, the adherence capacity of the reinforcement beyond the tension line along each reinforcing layer has been calculated and is greater than the reinforcement tension along the wall and hence meets the requirements for pull-out resistance.

The magnitude of tension along the wall and within the reinforcement layers differs from one layer to the next, however for practical construction it is best to use a consistent reinforcement strength and geometry for the case study wall. Therefore, the reinforcement grade has been selected based on the maximum tensile strength requirements. The tension in the reinforcement was used to determine the design strength of the reinforcement, with the maximum tension in the reinforcement being 44.4kN/m, with the exception of the tension of 48.5kN/m at a depth of 7.5m, which is within the embedment depth of the wall and hence has been omitted. Factoring the various reduction factors for handling damage, environmental conditions, the extrapolation of data, creep strain and the economic ramification of failure, the grade of reinforcement for the reinforced soil wall was selected as a Grade 75 Paraweb Strap with an ultimate load of 75kN. The design strength of this grade of strap was calculated to be 187.8kN/m however after factoring in the 24% coverage ratio of the reinforcement the design strength of the Grade 75 Paraweb strap is 45.1kN/m.

The results of Load Case B are presented in **Error! Reference source not found.** which is the predominant load case to assess pull out resistance (hence the adherence capacity of the reinforcement). The adherence capacity calculated using the partial load factors applicable for Load Case B exceeds the tension imposed at tension lines 1 and 2 along each layer of reinforcement, hence confirming that the design meets the requirements for pull out resistance at each layer of reinforcement.

All partial factors are set to unity for Load Case C and hence only dead loads are considered. This load case determines the tension in the reinforcement for the serviceability limit state. The maximum tension is 29.74kN/m except for the 32.69kN/m calculated at a depth of 7.5m which is within the embedment depth of the wall. The Paraweb strap selected based on Load Case A, has a design strength of 45kN/m as noted above and hence meets the requirement to accommodate the tensions for the serviceability limit state.
Error! Reference source not found. represents the results for the serviceability limit state and includes the tension in the reinforcement along each layer, the adherence capacity of the reinforcement hence confirming adequate pull-out resistance and confirmation of the facing connection required.

As noted previously, the facing connection is estimated to be 85% of the tension in the reinforcements at depths of less than 0.6H and is 100% at depths greater than 0.6H (where H is the wall height), for the ultimate and serviceability limit states. Based on the Load Case A (which presents the maximum tension conditions), the maximum facing connection strength required is 48.53kN/m (based on the maximum tension calculated), which is recommended for all connections irrespective of the position in the wall (to omit the possibility of using the incorrect connection strength along any specific location along the height of the wall during construction) despite a connection strength of 41.25kN/m required in the upper portion of the wall.

The detailed calculation spreadsheets for the internal stability analysis is included in Appendix A.

Table 4-3: Internal Stability Analysis – Ultimate Limit State – Load Case A (Tension, and Pull Out Resistance (although governed by Case B))

INTERNAL STABILITY CALCULATIONS - ULTIMATE LIMIT STATE - LOAD CASE A													
Effective Depth	**Reinforcement Length**	**Active Earth Pressure**	**Vertical Load - T_{pj}**	**Strip Load - T_{sj}**	**Tension in the Reinforcement**			**Adherence Capacity of Reinforcement**	**Facing Connection**	**Design of the wall**			
H	L	$K=K_o(1-z/z_o)+(K_a*(z/z_o))$ Or $K=K_a$	Vertical Loading due to Self-weight	Strip Load Tensile Force	Tension at Facing (T_{fj} not applicable)	Tension at Line 1 (T_{fj} not applicable)	Tension at Line 2 (T_{fj} not applicable)	Adherence Capacity of Reinforcement	Facing Connection	Design Strength of Paraweb Strap	Para-web Cover-age Ratio	Design Strength (Accounting for Coverage)
$H = z=h_j$			$T_{pj} = K\sigma_{vj}S_{vj}$	$T_{sj}=KS_{vj}(f_fS_L/D_j)$	$T_j = \alpha_0T_{pj} + T_{sj}$	$T_j = \alpha_1T_{pj} + T_{sj}$	$T_j=T_{pj} + T_{sj}$	$(2Bm/f_pf_n)*(f_{fs}s_v)*(L^2/2 - (L-L_{aj})^2/2)$	85% at depths <0.6H and 100% at depths >0.6H	$T_D = T_{CR} / (f_n*f_m)$		
m	**m**		**kN/m**	**kN/m**	**kN/m**	**kN/m**	**kN/m**	**kN/m**	**kN/m**	**kN/m**	**%**	**kN/m**
0,4	7	0,53	4,38	1,56	5,60	5,94	5,94	32,49	5,05	187,79	0,24	45,07
1	7	0,52	8,36	1,05	8,81	9,41	9,41	81,47	8,00	187,79	0,24	45,07
1,5	7	0,50	11,13	0,88	11,27	12,00	12,00	122,64	10,20	187,79	0,24	45,07
2	7	0,49	14,50	0,82	14,45	15,32	15,32	162,91	13,02	187,79	0,24	45,07
2,5	7	0,47	17,72	0,76	17,53	18,48	18,48	200,80	15,71	187,79	0,24	45,07
3	7	0,46	20,80	0,71	20,52	21,51	21,51	234,96	18,29	187,79	0,24	45,07
3,5	7	0,45	23,74	0,66	23,41	24,40	24,40	263,95	20,74	187,79	0,24	45,07
4	7	0,43	26,54	0,62	26,21	27,16	27,16	286,25	23,09	187,79	0,24	45,07
4,5	7	0,42	29,20	0,58	28,91	29,74	29,78	300,19	29,78	187,79	0,24	45,07
5	7	0,40	31,72	0,54	31,50	32,08	32,26	304,01	32,26	187,79	0,24	45,07
5,5	7	0,39	34,08	0,50	33,97	34,33	34,59	295,82	34,59	187,79	0,24	45,07
6	7	0,38	36,29	0,47	36,33	36,49	36,76	273,58	36,76	187,79	0,24	45,07
6,5	7	0,38	40,02	0,46	40,23	40,28	40,47	236,25	40,47	187,79	0,24	45,07
7	7	0,38	43,95	0,44	44,39	44,39	44,39	180,26	44,39	187,79	0,24	45,07
7,5	7	0,38	48,10	0,43	48,82	48,82	48,53	102,66	48,53	187,79	0,24	45,07
8	7	0,38	26,26	0,21	26,78	26,78	26,47	0,00	26,47	187,79	0,24	45,07

Table 4-4: Internal Stability Analysis – Ultimate Limit State – Load Case B (Pull Out Resistance)

INTERNAL STABILITY CALCULATIONS - ULTIMATE LIMIT STATE - LOAD CASE B												
Effective Depth	**Reinfor -cement Length**	**Active Earth Pressure**	**Vertical Load - T_{pj}**	**Strip Load - T_{sj}**	**Tension in the Reinforcement**			**Adherence Capacity of Reinforcement**	**Facing Connection**	**Design of the wall (based on Load Case A)**		
H	L	$K=K_o(1-z/z_o)+(K_a*(z/z_o))$ Or $K=K_a$	Vertical Loading due to Self-weight	Strip Load Tensile Force	Tension at Facing (T_{fj} not applicable)	Tension at Line 1 (T_{fj} not applicable)	Tension at Line 2 (T_{fj} not applicable)	Adherence Capacity of Reinforcement	Facing Connection	Design Strength of Paraweb Strap	Para-web Cover-age Ratio	Design Strength (Accounting for Coverage)
$H = z=h_j$			$T_{pj} = K\sigma_{vj}S_{vj}$	$T_{sj}=KS_{vj}(f_fS_L/D_j)$	$T_j = \alpha_0 T_{pj} + T_{sj}$	$T_j = \alpha_1 T_{pj} + T_{sj}$	$T_j=T_{pj} + T_{sj}$	$(2Bm/f_pf_n)*(f_{fs}s_v) * (L^2/2 - (L-L_{aj})^2/2)$	85% at depths <0.6H and 100% at depths >0.6H	$T_D = T_{CR} / (f_n*f_m)$		
m	**m**		**kN/m**	**kN/m**	**kN/m**	**kN/m**	**kN/m**	**kN/m**	**kN/m**	**kN/m**	**%**	**kN/m**
0,4	7	0,53	2,92	1,56	4,25	4,48	4,48	14,44	3,81	187,79	0,24	45,07
1	7	0,52	5,57	1,05	6,23	6,63	6,63	36,21	5,63	187,79	0,24	45,07
1,5	7	0,50	7,42	0,88	7,81	8,29	8,29	54,51	7,05	187,79	0,24	45,07
2	7	0,49	9,67	0,82	9,91	10,48	10,48	72,41	8,91	187,79	0,24	45,07
2,5	7	0,47	11,82	0,76	11,94	12,58	12,58	89,24	10,69	187,79	0,24	45,07
3	7	0,46	13,87	0,71	13,91	14,58	14,58	104,43	12,39	187,79	0,24	45,07
3,5	7	0,45	15,83	0,66	15,83	16,49	16,49	117,31	14,02	187,79	0,24	45,07
4	7	0,43	17,69	0,62	17,68	18,31	18,31	127,22	15,57	187,79	0,24	45,07
4,5	7	0,42	19,47	0,58	19,46	20,02	20,04	133,42	20,04	187,79	0,24	45,07
5	7	0,40	21,14	0,54	21,18	21,57	21,68	135,12	21,68	187,79	0,24	45,07
5,5	7	0,39	22,72	0,50	22,82	23,05	23,22	131,47	23,22	187,79	0,24	45,07
6	7	0,38	24,19	0,47	24,37	24,48	24,66	121,59	24,66	187,79	0,24	45,07
6,5	7	0,38	26,68	0,46	26,97	27,00	27,13	105,00	27,13	187,79	0,24	45,07
7	7	0,38	29,30	0,44	29,74	29,74	29,74	80,12	29,74	187,79	0,24	45,07
7,5	7	0,38	32,07	0,43	32,69	32,69	32,50	45,63	32,50	187,79	0,24	45,07
8	7	0,38	17,51	0,21	17,93	17,93	17,72	0,00	17,72	187,79	0,24	45,07

Table 4-5: Internal Stability Analysis – Serviceability Limit State – Load Case C

INTERNAL STABILITY CALCULATIONS –SERVICEABILITY LIMIT STATE - LOAD CASE C												
Effective Depth	**Reinfor-cement Length**	**Active Earth Pressure**	**Vertical Load - T_{pj}**	**Strip Load - T_{sj}**	**Tension in the Reinforcement**			**Adherence Capacity of Reinforcement**	**Facing Connection**	**Design of the wall (based on Load Case A)**		
H	L	$K=K_o(1-z/z_o)+(K_a*(z/z_o))$ Or $K=K_a$	Vertical Loading due to Self-weight	Strip Load Tensile Force	Tension at Facing (T_{fj} not applicable)	Tension at Line 1 (T_{fj} not applicable)	Tension at Line 2 (T_{fj} not applicable)	Adherence Capacity of Reinforcement	Facing Connection	Design Strength of Paraweb Strap	Para-web Cover-age Ratio	Design Strength (Accounting for Coverage)
$H = h_j$			$T_{pj} = K\sigma_{vj}S_{vj}$	$T_{sj}=KS_{vj}(f_f S_L/D_j)$	$T_j = \alpha_0 T_{pj} + T_{sj}$	$T_j = \alpha_1 T_{pj} + T_{sj}$	$T_j = T_{pj} + T_{sj}$	$(2Bm/f_p f_n)*(f_{fs}s_v)*(L^2/2 - (L-L_{aj})^2/2)$	85% at depths <0.6H and 100% at depths >0.6H	$T_D = T_{CR} / (f_n*f_m)$		
m	**m**		**kN/m**	**kN/m**	**kN/m**	**kN/m**	**kN/m**	**kN/m**	**kN/m**	**kN/m**	**%**	**kN/m**
0,4	7	0,53	2,92	1,56	4,25	4,48	4,48	18,77	3,81	187,79	0,24	45,07
1	7	0,52	5,57	1,05	6,23	6,63	6,63	47,07	5,63	187,79	0,24	45,07
1,5	7	0,50	7,42	0,88	7,81	8,29	8,29	70,86	7,05	187,79	0,24	45,07
2	7	0,49	9,67	0,82	9,91	10,48	10,48	94,13	8,91	187,79	0,24	45,07
2,5	7	0,47	11,82	0,76	11,94	12,58	12,58	116,02	10,69	187,79	0,24	45,07
3	7	0,46	13,87	0,71	13,91	14,58	14,58	135,75	12,39	187,79	0,24	45,07
3,5	7	0,45	15,83	0,66	15,83	16,49	16,49	152,51	14,02	187,79	0,24	45,07
4	7	0,43	17,69	0,62	17,68	18,31	18,31	165,39	15,57	187,79	0,24	45,07
4,5	7	0,42	19,47	0,58	19,46	20,02	20,04	173,44	20,04	187,79	0,24	45,07
5	7	0,40	21,14	0,54	21,18	21,57	21,68	175,65	21,68	187,79	0,24	45,07
5,5	7	0,39	22,72	0,50	22,82	23,05	23,22	170,92	23,22	187,79	0,24	45,07
6	7	0,38	24,19	0,47	24,37	24,48	24,66	158,07	24,66	187,79	0,24	45,07
6,5	7	0,38	26,68	0,46	26,97	27,00	27,13	136,50	27,13	187,79	0,24	45,07
7	7	0,38	29,30	0,44	29,74	29,74	29,74	104,15	29,74	187,79	0,24	45,07
7,5	7	0,38	32,07	0,43	32,69	32,69	32,50	59,31	32,50	187,79	0,24	45,07
8	7	0,38	17,51	0,21	17,93	17,93	17,72	0,00	17,72	187,79	0,24	45,07

5. RESULTS OF THE FEM ANALYSIS

The design developed based on the code SANS8006-1:2018 was analysed using Rocscience's Phase 2 finite element analysis. The geometry, material and load properties and the reinforcement strength are as per the original design developed in accordance with the design code. In addition to the parameters in **Error! Reference source not found.** the properties stipulated in **Error! Reference source not found.** were also used to model the original design for the finite element analysis, with the soil shear strength properties the same as that used in the analytical analysis.

Table 5-1: Design Input Parameters to be used in the Finite Element Analysis

Material Properties	Foundation Soil	Pioneer Layer	Backfill	Reinforced Soil	Layerworks	Concrete Facing	Geosynthetic Joint	Geosynthetic Reinforce-ment Liner	Unit
Unit Weight	18.5	21	19.5	19.5	22	24			kN/ m^3
Youngs Modulus	20000	40000	30000	30000	50000	24173000			kPa
Poisson's Ratio	0.3	0.15	0.3	0.35	0.15	0.2			
Failure Criterion	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb (slip criterion)		
Peak Tensile Strength	0	0	0	0	0	450	0	200	KPa / kN/m
Residual Tensile Strength	0	0	0	0	0	0	0	0	kPa
Peak Friction Angle	25	36	27	27	36	35	25		degrees
Peak Cohesion	5	0	5	0	10.5	365	0		kPa
Material Types	Plastic	Plastic	Plastic	Plastic	Plastic	Plastic			
Residual Friction Angle	25	36	27	27	36	0	25		degrees
Residual Cohesion	5	0	5	0	10.5	0	0		kPa
Normal Stiffness							100000		kPa/m
Shear Stiffness							10000		kPa/m
Tensile Modulus								5000	kN/m

Across the 1.5m length of the facing (which is the typical length of the discrete facing panels that was used in the case study), a coverage of 4 strips were proposed for the wall geometry which equated to a coverage ratio of 24%. The Paraweb grade selected based on the design strength required was the 75kN strap. The 75kN is the ultimate tensile strength per strap, hence the ultimate tensile strength of the 4 straps across the length of the facing panel is the product of the number of straps and the ultimate tensile strength thus equating to 300kN across a 1.5m wide discrete facing panel. To determine the tensile strength per meter length the load is divided by the length of the facing panel, hence 200kN/m, which is the reinforcement tensile strength that is used in the Finite Element Analysis (FEA).

According to the Load-Extension Curve for the Paraweb strap provided in the British Board of Agrément Approval Inspection Testing Certification 12/H191 (2012), which has been included in **Error! Reference source not found.** for ease of reference, reinforcement extension of 8% can be expected for loads of 75kN. The tensile modulus is therefore calculated to be 5000kN based on the load and extension properties, which was used in the FEA.

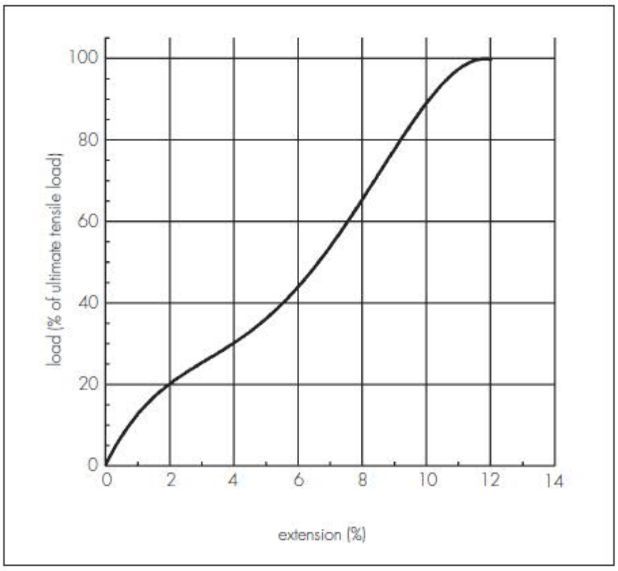


Figure 5-1: Load-Extension Curve for Paraweb Strap (British Board of Agrément, 2012)

Error! Reference source not found. is a representation of the original design that was analysed and has been labelled as Design 1 in the analysis. As highlighted the finite element mesh used to discretize the model comprises 3 noded triangular elements as shown.

The results of the analysis include the determination of the stresses, strains, displacements and an indication of yielding elements. As depicted in **Error! Reference source not found.** and **Error! Reference source not found.** the maximum stress in the z-direction occurs within the founding soil at the base of the structure where stresses of approximately 105 to 135kPa are exerted, with mean stresses in the same range.

The maximum strain contours indicate that the maximum strain occurs at the foundation below the levelling pad of the wall facing, with high strains also experienced along the facing panels and within the backfill soil immediately behind the reinforced soil wall as indicated in **Error! Reference source not found.**. Maximum strains of approximately 1.19% were encountered within the facing foundation soil and directly adjacent to the facing. The strains within the reinforced soil structure is less than 1%, while the maximum strain within the backfill behind the reinforced block is in the order of 1.12%. It is unfortunately not clear from the analysis as to whether the maximum strains are encountered within the soils or in reinforcement.

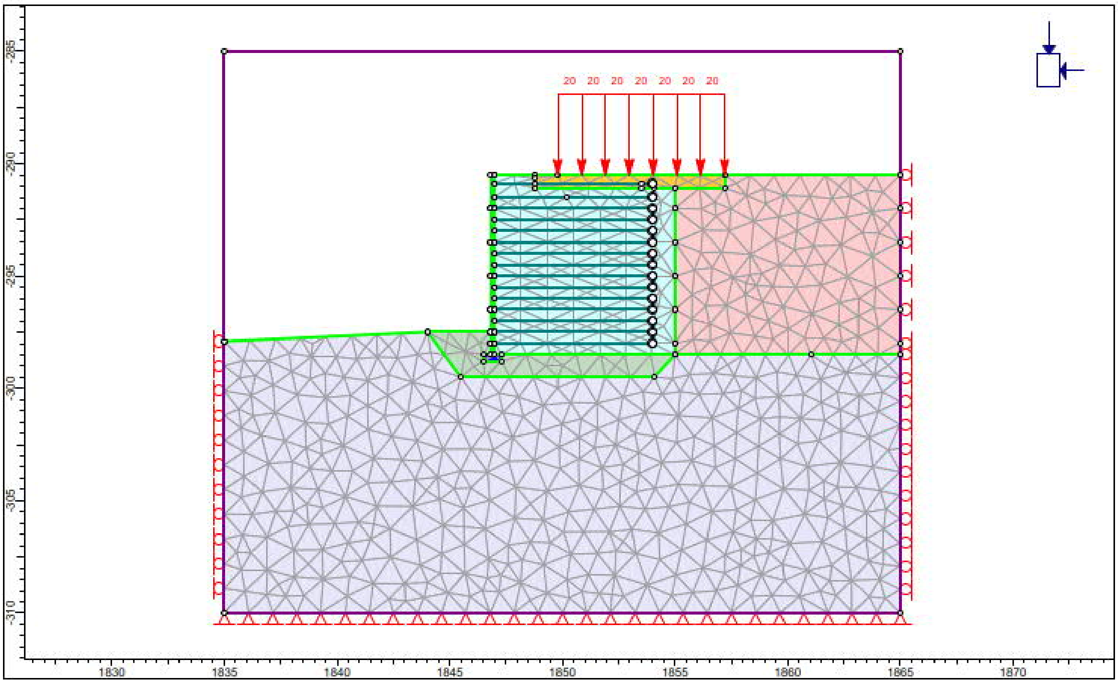


Figure 5-2: Phase 2 Finite Element Model of Design 1 Developed in Accordance with SANS8006-1:2018 Code (Phase 2: 8, 2011)

Based on the displacement contours indicated in **Error! Reference source not found.** to **Error! Reference source not found.**, the maximum horizontal and vertical displacements were approximately 68.9mm and 7.2mm respectively with maximum total displacement in the order of 90mm. Maximum horizontal displacements occur within the upper portion of the reinforced soil wall towards the facing while the maximum vertical and total displacements occur within the upper half of the reinforced soil wall below the strip loading.

Potential failure within the backfill is controlled and stabilized by the reinforced soil structure, where the shear strains are lower than within the backfill. The yielding of the elements is largely due to tension at the surface (crest) of the wall, and as a result of tension and shear at the wall facing. The contour plots illustrates the yielded finite elements which are indicated by the red shaded strips around the reinforcement in the upper layers of the wall along the facing, however the results affirms that there is no yielding of the reinforcement layers (which is referred to as liners in Phase 2) however yielding of the surrounding material elements have occurred, hence no rupture of the reinforcement layers.

The Factor of Safety (FoS) against failure for the proposed structure based on the Shear Strength Reduction method of analysis is 2 as indicated in **Error! Reference source not found.**. As the FoS is well over the value of unity, 1, the analysis confirms the adequacy of the design against failure, albeit with displacement and shear strains. The results however illustrate that the failure mechanism would be a deep-seated slip circle global failure beyond the extent of the reinforced structure rather than failure of the reinforced soil wall.

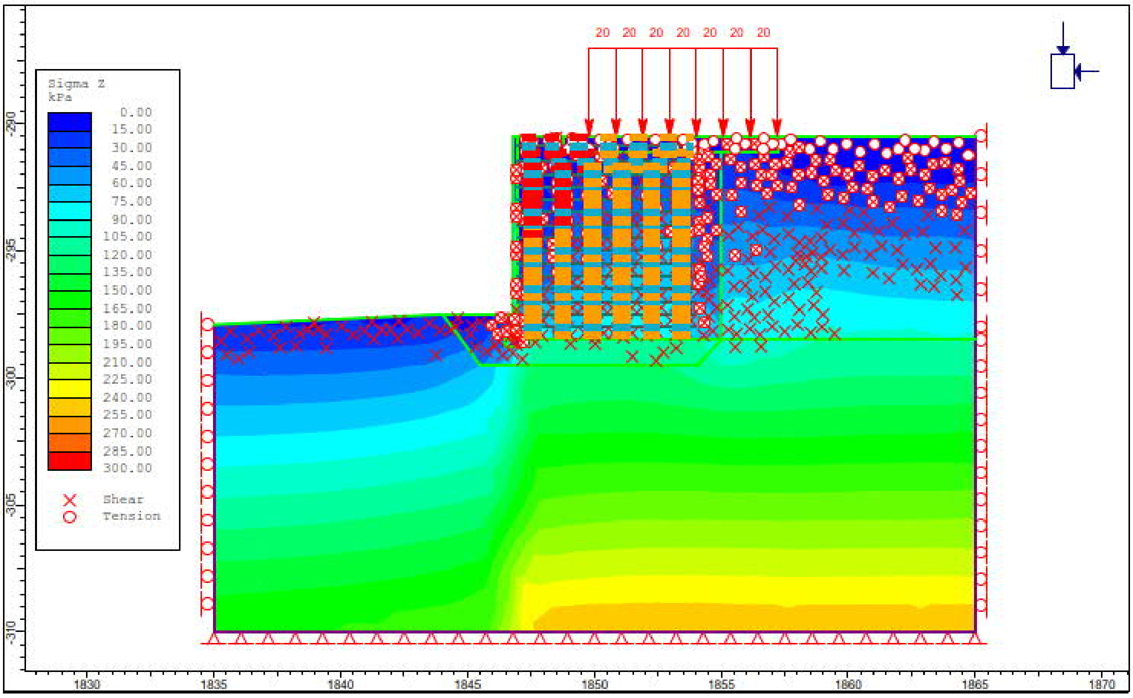


Figure 5-3: Maximum Stress in the Z Direction for the Reinforced Soil Wall Design (Phase 2: 8, 2011)

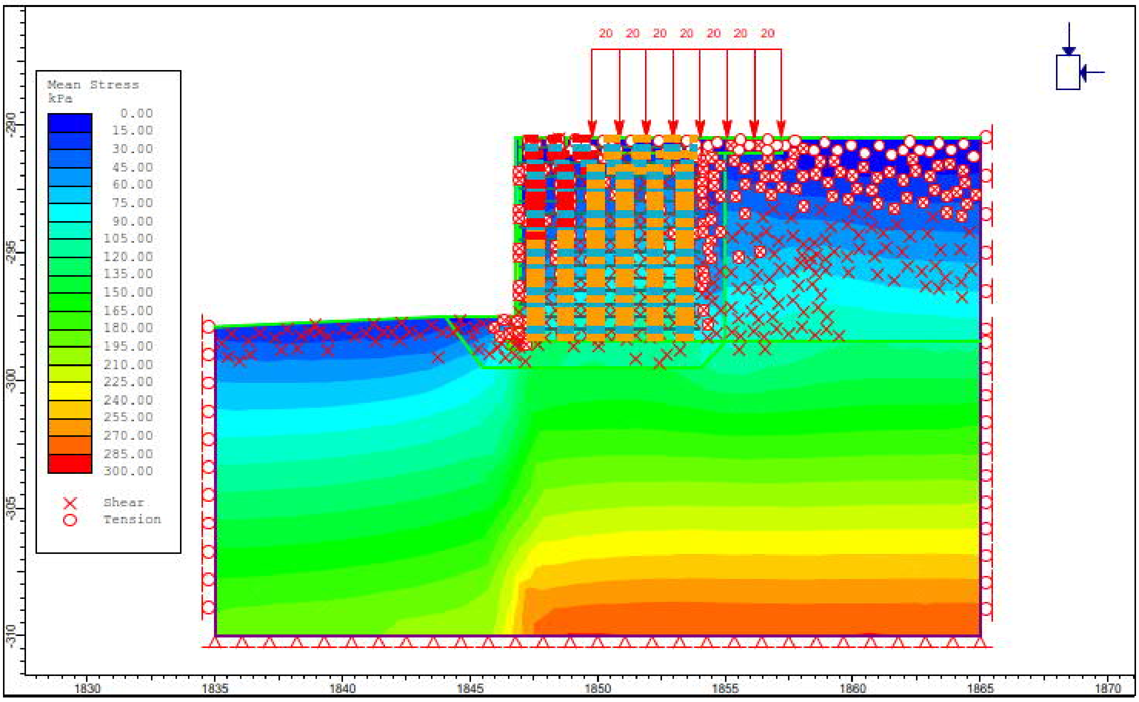


Figure 5-4: Mean Stress Contours for the Reinforced Soil Wall Design (Phase 2: 8, 2011)

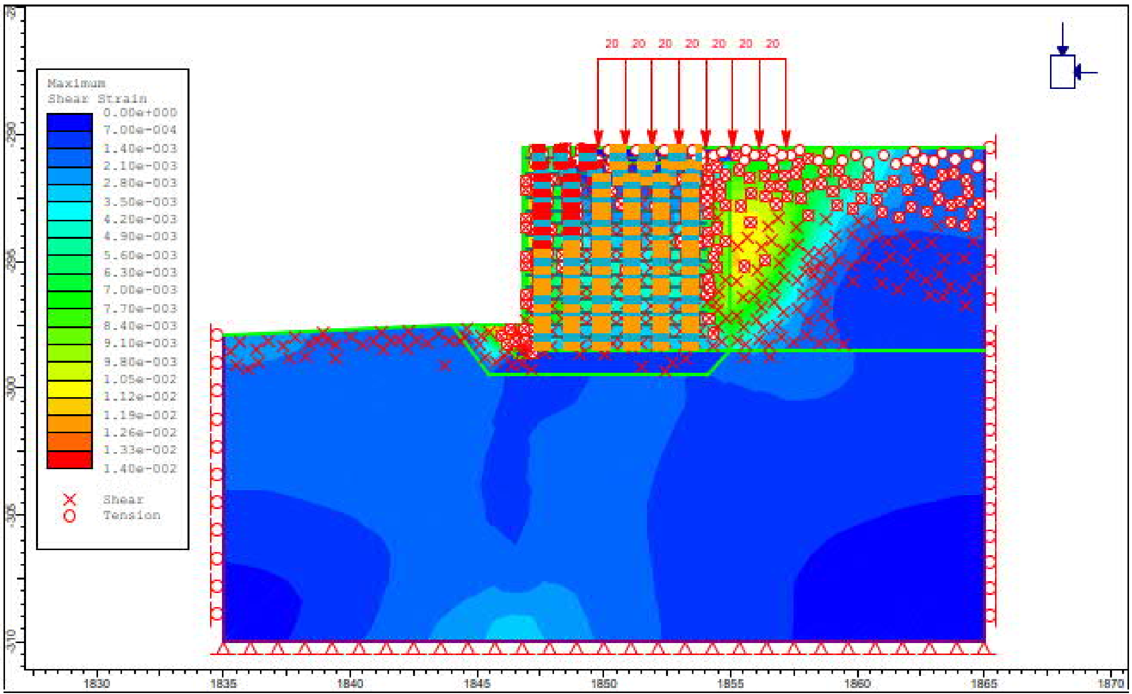


Figure 5-5: Maximum Shear Strain Contours for the Reinforced Soil Wall Design (Phase 2: 8, 2011)

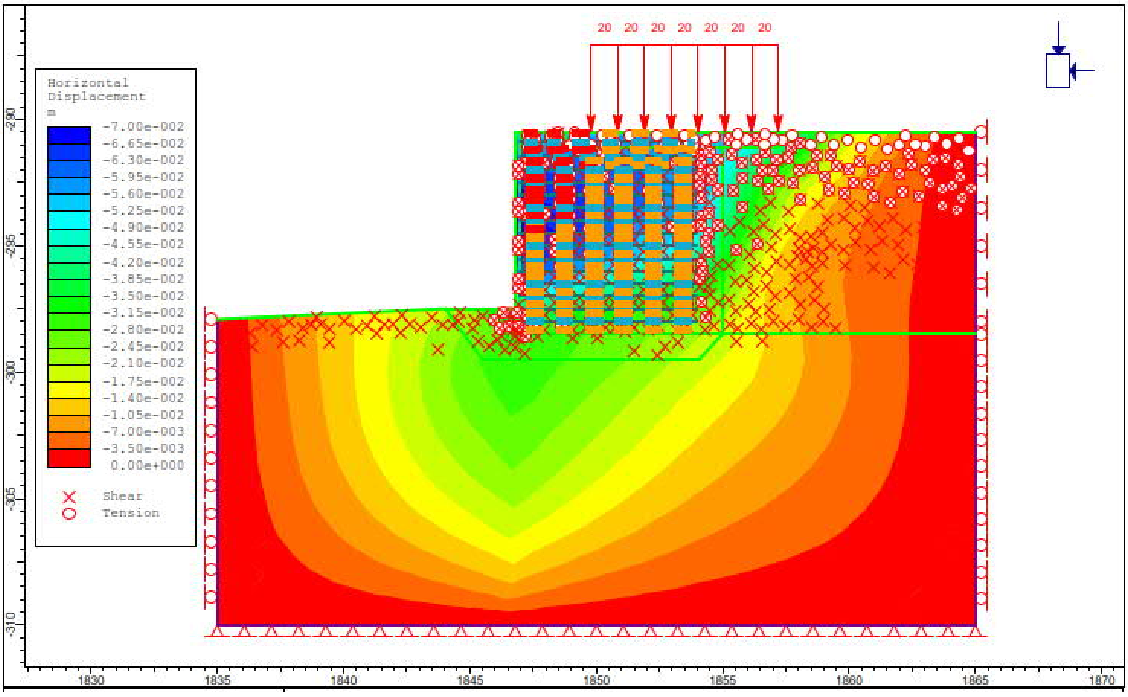


Figure 5-6: Horizontal Displacement Contours for the Reinforced Soil Wall Design (Phase 2: 8, 2011)

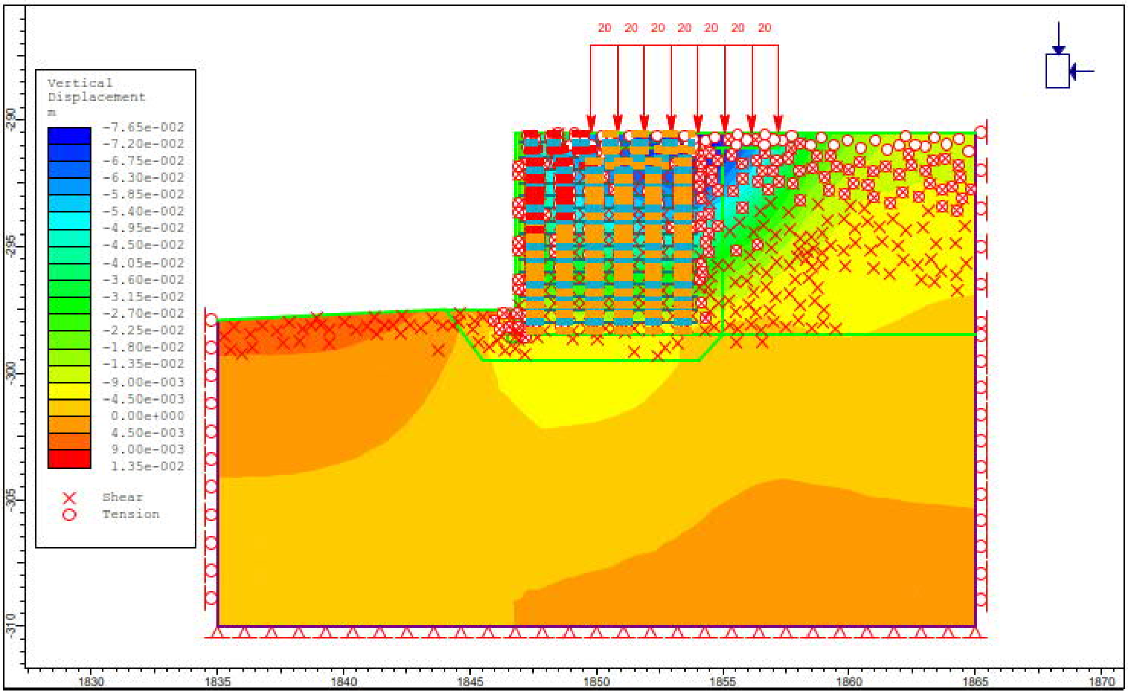


Figure 5-7: Vertical Displacement Contours for the Reinforced Soil Wall Design (Phase 2: 8, 2011)

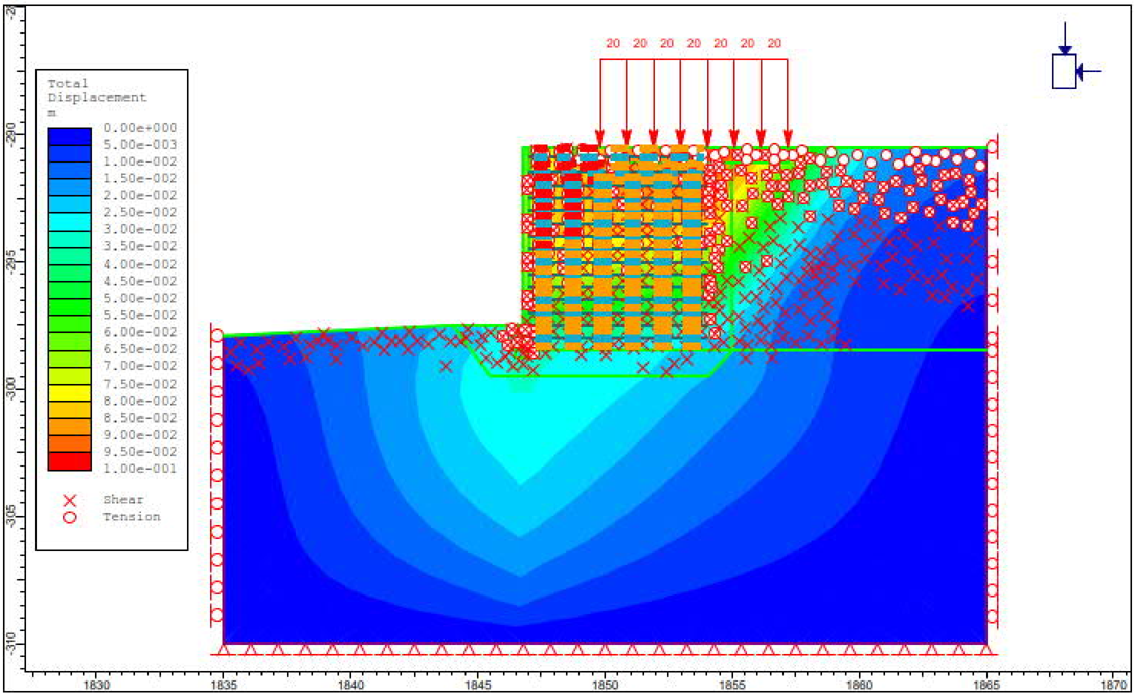


Figure 5-8: Total Displacement Contours for the Reinforced Soil Wall Design (Phase 2: 8, 2011)

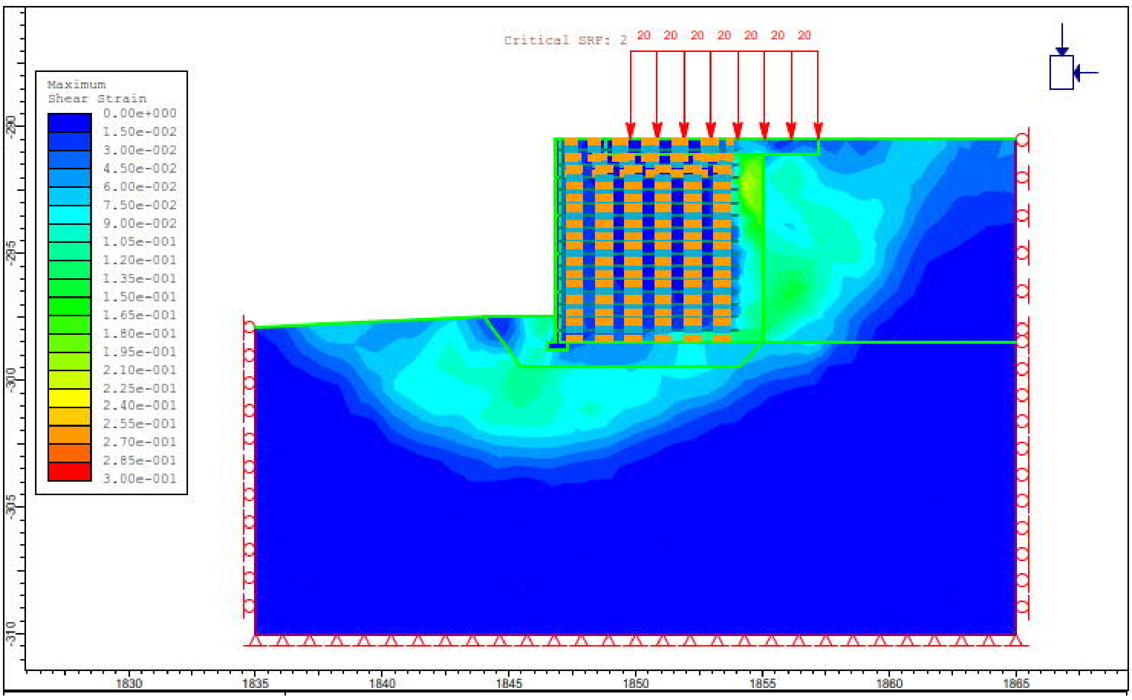


Figure 5-9: Shear Reduction Factor (Factor of Safety) using the Shear Strength Reduction Method of Analysis (Phase 2: 8, 2011)

6. PARAMETRIC STUDY

As discussed in the methodology a parametric study was carried out to assess the influence of various reinforcement configurations to identify the possibility of optimizing the design developed based on the SANS8006-1:2018 code. The original design was used as the baseline condition with the results of the parametric study referenced to the original design. Several finite element analyses were undertaken which varied the length of the reinforcement from the original design length of 7m to 6m, 5m and 4m; for each of the reinforcement lengths analysed the vertical spacing of the reinforcement layers were also varied from the original 0.5m to 0.75m and 1m. Additionally, for the reinforcement lengths and vertical spacings noted above, two grades of Paraweb were also considered, these being the Grade 75, which was used for the original design, with an ultimate tensile strength of 75kN and the Grade 50 which has an ultimate tensile strength of 50kN. The last variable combination that was included in the analysis was the reinforcement coverage ratio which was reduced from the original 24% (4 straps across a facing block) to 18% (3 straps across a facing block) and 12% (2 straps across a facing block). These configurations equated to 72 finite element models which varied in either geometry, strength and coverage ratio of the reinforcement are tabulated in **Error! Reference source not found.** with each model configuration labelled from Design 1(Original Design) up to Design 72.

The tensile modulus for each design option was determined based on the tensile strength of the strap and the percentage extension, which was defined by the Load-Extension curve provided in the British Board of Agrément Approval Inspection Testing Certification 12/H191 (2012) for the Paraweb straps. At loads of 75kN the extension is 8% whereas at loads of 50kN the extension is 7%.

Table 6-1: Reinforcement Configurations Analysed as part of the Parametric Study

Design ID	Design Parameters						Design ID	Design Parameters					
	Length (m)	Vertical Spacing (m)	Paraweb Grade (kN)	Tensile Strength (kN/m)	Tensile Modulus (kN/m)	Coverage Ratio (%)		Length (m)	Vertical Spacing (m)	Paraweb Grade (kN)	Tensile Strength (kN/m)	Tensile Modulus (kN/m)	Coverage Ratio (%)
1	7	0,5	75	200	5000	24,0%	37	7	0,5	50	66,67	1905	12,0%
2	6	0,5	75	200	5000	24,0%	38	6	0,5	50	66,67	1905	12,0%
3	5	0,5	75	200	5000	24,0%	39	5	0,5	50	66,67	1905	12,0%
4	7	0,75	75	200	5000	24,0%	40	4	0,5	50	66,67	1905	12,0%
5	6	0,75	75	200	5000	24,0%	41	7	0,75	50	66,67	1905	12,0%
6	5	0,75	75	200	5000	24,0%	42	6	0,75	50	66,67	1905	12,0%
7	7	1	75	200	5000	24,0%	43	5	0,75	50	66,67	1905	12,0%
8	6	1	75	200	5000	24,0%	44	4	0,75	50	66,67	1905	12,0%
9	5	1	75	200	5000	24,0%	45	7	1	50	66,67	1905	12,00%
10	7	0,5	50	133,33	3810	24,0%	46	6	1	50	66,67	1905	12,0%
11	6	0,5	50	133,33	3810	24,0%	47	5	1	50	66,67	1905	12,0%
12	5	0,5	50	133,33	3810	24,0%	48	4	1	50	66,67	1905	12,0%
13	7	0,75	50	133,33	3810	24,0%	49	7	0,5	75	150	3750	18,0%
14	6	0,75	50	133,33	3810	24,0%	50	6	0,5	75	150	3750	18,0%
15	5	0,75	50	133,33	3810	24,0%	51	5	0,5	75	150	3750	18,0%
16	7	1	50	133,33	3810	24,0%	52	4	0,5	75	150	3750	18,0%

Design ID	Design Parameters						Design ID	Design Parameters					
	Length (m)	Vertical Spacing (m)	Paraweb Grade (kN)	Tensile Strength (kN/m)	Tensile Modulus (kN/m)	Coverage Ratio (%)		Length (m)	Vertical Spacing (m)	Paraweb Grade (kN)	Tensile Strength (kN/m)	Tensile Modulus (kN/m)	Coverage Ratio (%)
17	6	1	50	133,33	3810	24,0%	53	7	0,75	75	150	3750	18,0%
18	5	1	50	133,33	3810	24,0%	54	6	0,75	75	150	3750	18,0%
19	4	0,5	75	200	5000	24,0%	55	5	0,75	75	150	3750	18,0%
20	4	0,75	75	200	5000	24,0%	56	4	0,75	75	150	3750	18,0%
21	4	1	75	200	5000	24,0%	57	7	1	75	150	3750	18,0%
22	4	0,5	50	133,33	3810	24,0%	58	6	1	75	150	3750	18,0%
23	4	0,75	50	133,33	3810	24,0%	59	5	1	75	150	3750	18,0%
24	4	1	50	133,33	3810	24,0%	60	4	1	75	150	3750	18,0%
25	7	0,5	75	100	2500	12,0%	61	7	0,5	50	100	2857	18,0%
26	6	0,5	75	100	2500	12,0%	62	6	0,5	50	100	2857	18,0%
27	5	0,5	75	100	2500	12,0%	63	5	0,5	50	100	2857	18,0%
28	4	0,5	75	100	2500	12,0%	64	4	0,5	50	100	2857	18,0%
29	7	0,75	75	100	2500	12,0%	65	7	0,75	50	100	2857	18,0%
30	6	0,75	75	100	2500	12,0%	66	6	0,75	50	100	2857	18,0%
31	5	0,75	75	100	2500	12,0%	67	5	0,75	50	100	2857	18,0%
32	4	0,75	75	100	2500	12,0%	68	4	0,75	50	100	2857	18,0%
33	7	1	75	100	2500	12,0%	69	7	1	50	100	2857	18,0%
34	6	1	75	100	2500	12,0%	70	6	1	50	100	2857	18,0%
35	5	1	75	100	2500	12,0%	71	5	1	50	100	2857	18,0%
36	4	1	75	100	2500	12,0%	72	4	1	50	100	2857	18,0%

The results of the Shear Strength Reduction Method of analysis indicate that the factor of safety (FoS) obtained for the various combinations of geometry, strength and coverage ratios for the reinforcement vary between 2.0 and 1.4 with the degree of displacement increasing as the FoS decreases from 2 to 1.4. The configurations that resulted in a FoS of 1.4 were for the design cases where there was a combination of 12% coverage ratio, 50kN Paraweb straps with lengths of either 4m or 5m and with vertical reinforcement spacings of either 0.75m or 1.0m.

Models that resulted in a FoS of 1.6 generally comprised all combinations of coverage ratio, vertical spacing and reinforcement strength provided that these were not all the minimum value in any single design, with the defining parameter being the reinforcement length, which was generally 4m. There were however occurrences were a FoS of 1.6 resulted where the reinforcement length was 5m and 6m however this occurred where these lengths were coupled with lower values for the reinforcement coverage, strength and increased vertical spacing.

Models which varied in reinforcement lengths of 5m, 6m and 7m coupled with varied coverage ratios, vertical spacing and reinforcement strength generally calculated a FoS of either 2 or 1.8.

Within the Phase 2 software used to undertake the finite element analysis, the coverage ratio is represented by the reinforcement tensile strength and tensile modulus, which is adjusted based on the percentage of coverage. Where the coverage ratio varies from the original design coverage ratio of 24% the inputted tensile strength and tensile modulus per meter length of wall is reduced to account for lower coverage. Hence the results from the models analysed where the reinforcement strength (based on the Paraweb grade selected) is similar to the strength for models where the strength parameters have been adjusted to account for variable coverage ratios, produces similar displacement and FoS results. This similarity in results were evident for the model configurations with a 50kN reinforcement and 24% coverage, compared with the models with a 75kN reinforcement and a coverage ratio of 18%. Similarly, this was apparent in models where the 50kN Paraweb with an 18% coverage ratio is compared to the models with 75kN Paraweb with a corresponding coverage ratio of 12%. The similarity in the Tensile Strength and Modulus parameters based on the particular combination of the reinforcement grade and coverage ratio is highlighted in bold text in **Error! Reference source not found.**.

Table 6-2: Tensile Strength and Modulus Dependant on the Coverage Ratio and Paraweb Grade Selected

Paraweb Grade	Tensile Strength	Tensile Modulus	Coverage Ratio
75kN	200kN/m	5000kN/m	24%
50kN	**133kN/m**	**3810kN/m**	**24%**
75kN	**150kN/m**	**3750kN/m**	**18%**
50kN	**100kN/m**	**2857kN/m**	**18%**
75kN	**100kN/m**	**2500kN/m**	**12%**
50kN	66.67kN/m	1905kN/m	12%

Maximum shear strains vary between approximately 1.19% for the original design condition up to 3.4% for the worst-case model, which has a 4m reinforcement length, 1m vertical spacing between reinforcement layers, 50kN reinforcement tensile strength and 12% reinforcement coverage ratio. As was evident in the original design, the higher strains were encountered at the toe of the facing within the foundation soil, in the reinforced soil directly adjacent to the facing of the wall and within the backfill soil adjacent to the reinforced soil wall.

The stresses developed as a result of the strip load and the reinforced soil structure are consistent for all models analysed in the parametric study, with stress in the z direction varying between 105kPa and 135kPa at the foundation level of the structure with mean stresses generally of similar values, which occasionally varies between 100 and 150kPa.

The horizontal, vertical and total displacement results of the parametric study is represented graphically in **Error! Reference source not found.** to **Error! Reference source not found.**. The displacement results vary considerably for the series of 72 analyses undertaken. As is evident in the figures there is a general trend of increasing displacement as the wall geometry decreases either in length, coverage ratio or reinforcement strength, and where the vertical spacing between reinforcement layers increase.

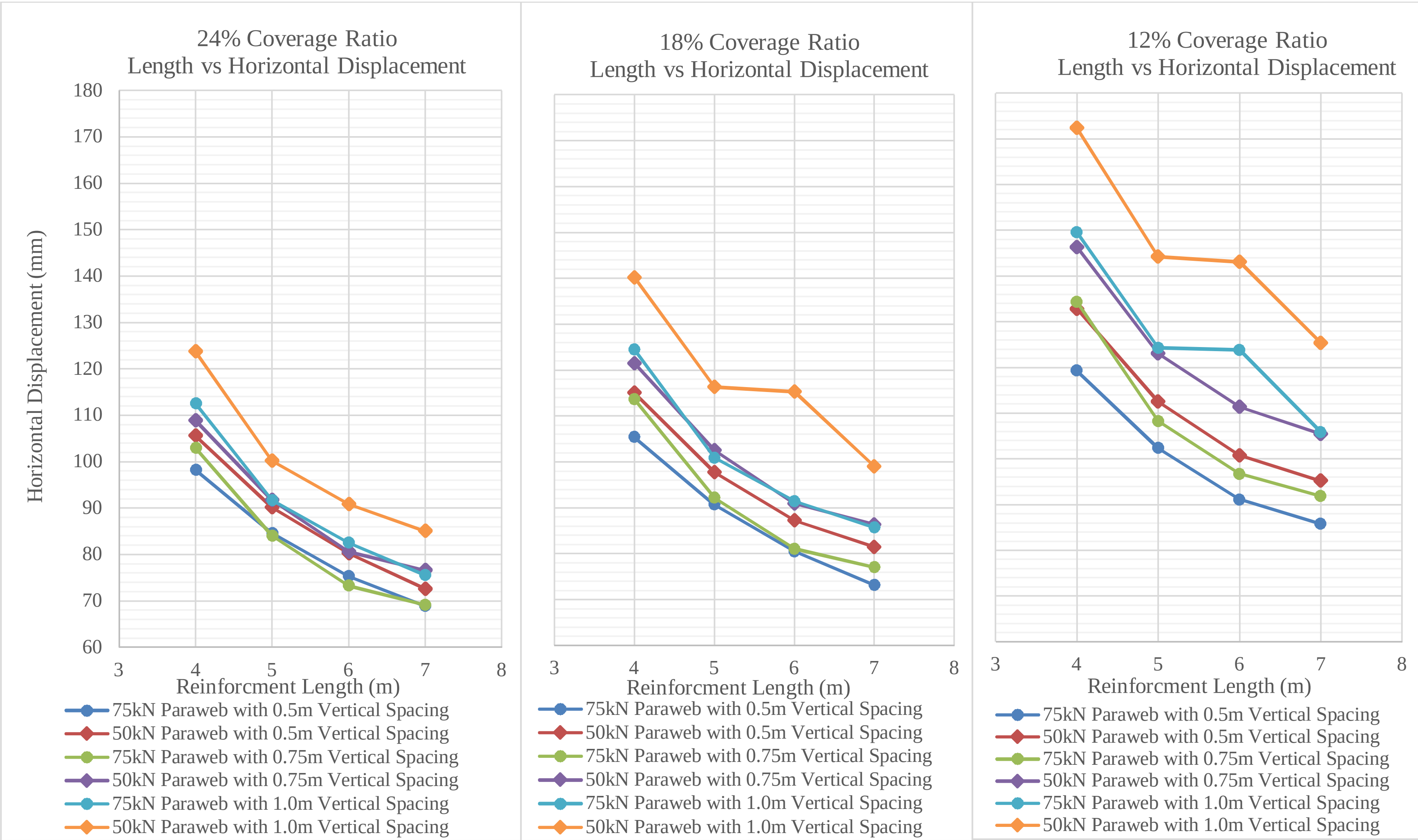


Figure 6-1: Horizontal Displacement Results vs Reinforcement Length for the Various Reinforced Soil Wall Configurations

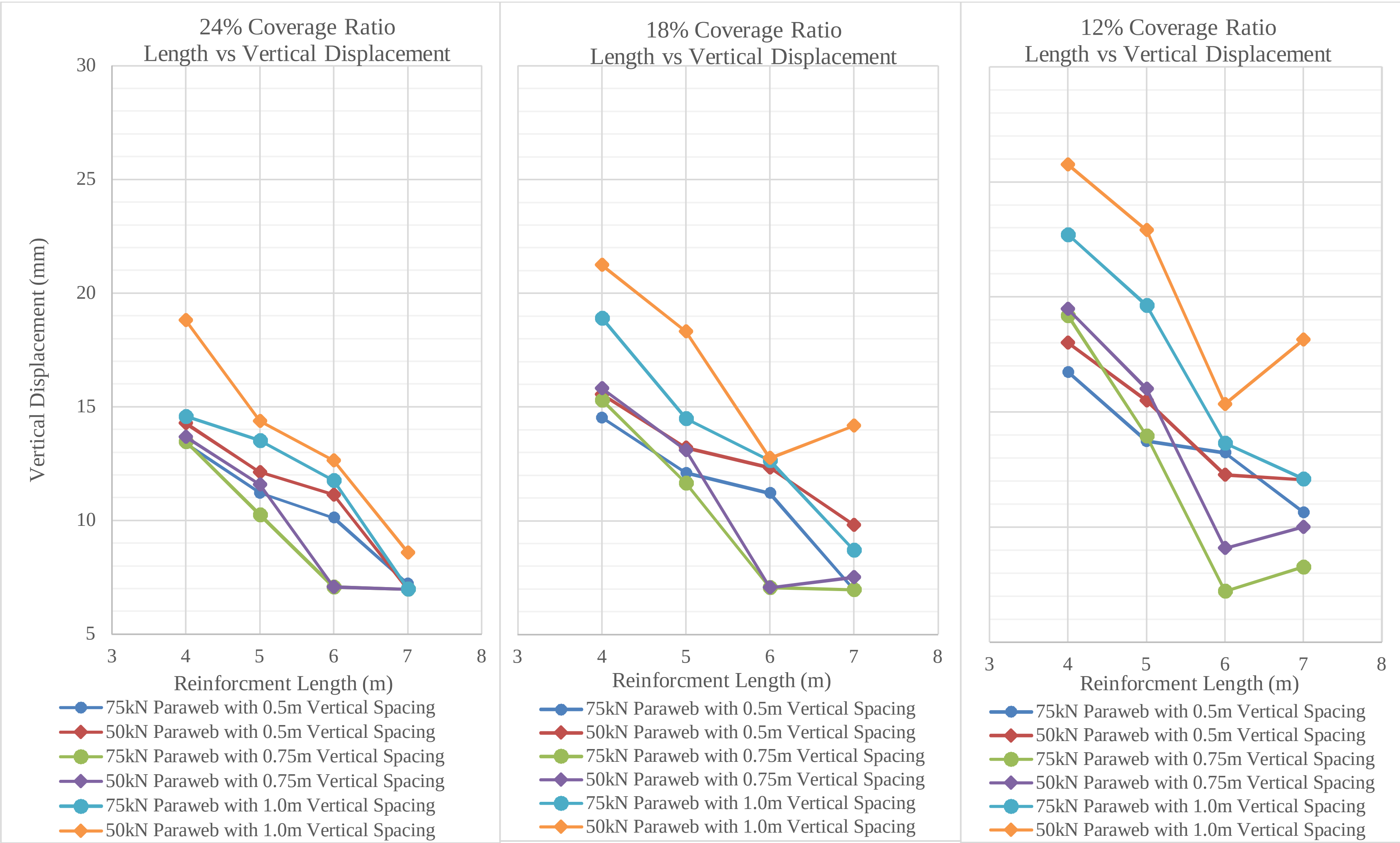


Figure 6-2: Vertical Displacement Results vs Reinforcement Length for the Various Reinforced Soil Wall Configurations

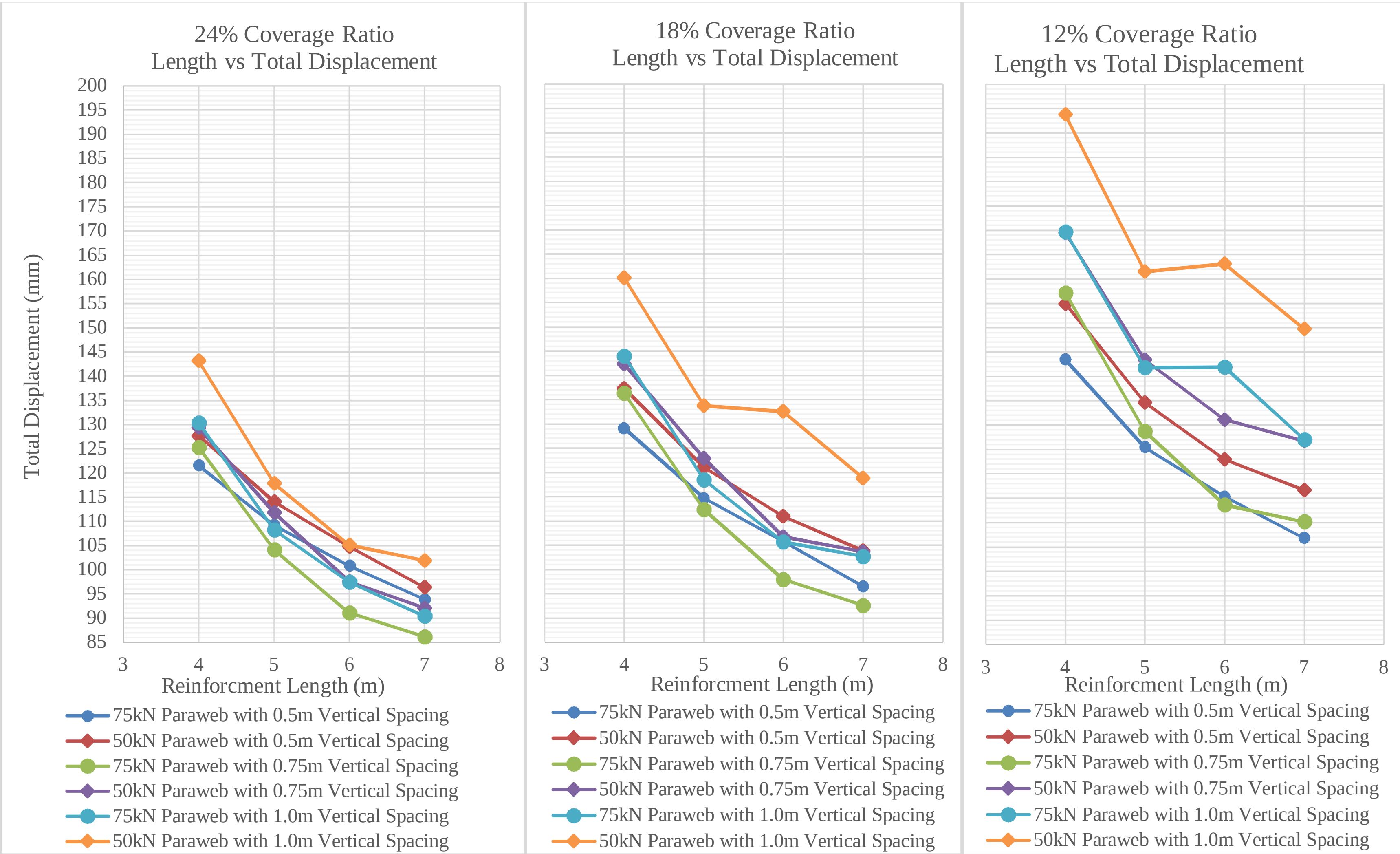


Figure 6-3: Total Displacement Results vs Reinforcement Length for the Various Reinforced Soil Wall Configurations

A few exceptions to the increasing trend are evident in the vertical displacement graph which has a knock-on effect on the total displacement graph which incorporates both the vertical and horizontal displacements into one. The vertical settlement encountered for several of the models in particular 6m length walls (where varying coverage, strength and vertical spacing of the reinforcement were applied) was lower than the original design (and often 7m length walls). There is no clear explanation as to why the results deviate from the trend of increasing vertical displacement however is likely related to an increase in the vertical spacing and reduction in coverage ratio of the reinforcement layers which were the common elements in each of the models where the vertical displacement was lower for a reinforcement length of 6m rather than 7m, despite the load spread over the larger footprint.

The horizontal displacements vary between 68.91mm (for the original design) and 172.31mm for the worst-case configuration; whereas the vertical displacement varies between 6.96mm (for the original design) and 25.72mm. Based on these values it is clear that the defining factor for serviceability is the horizontal displacement of the wall facing, as the vertical displacement is considered to fall within generally acceptable total settlements for structural elements, with the exception for settlement intolerant structures.

For comparative purposes, the displacements obtained for the various models analysed were converted to a percentage of the original design, to easily assess which model configurations produced the smallest deviation from the original design in terms of displacements. The displacements are represented in millimetres, and as a percentage of the Original Design displacement which are sorted based on the horizontal displacement and then by the vertical displacements as tabulated in **Error! Reference source not found.** and **Error! Reference source not found.** respectively.

Table 6-3: Results from the FEA on the various model configurations – Sorted Based on the Percentage Increase in Horizontal Displacement from the Original Design

Design ID	Design Parameters						Displacements						Factor of Safety	Maximum Strain (%)	Sigma z (kPa)	Mean Stress (kPa)
	Length (m)	Vertical Spacing (m)	Paraweb Grade (kN)	Tensile Strength (kN/m)	Tensile Modulus (kN/m)	Coverage Ratio (%)	Horizontal (mm)	Percentage increase in Horizontal Displacement from the Original Design	Vertical (mm)	Percentage increase in Vertical Displacement from the Original Design	Total (mm)	Percentage increase in Total Displacement from the Original Design				
1	7	0,5	75	200	5000	24%	68,91	0,00%	7,21	0,00%	93,84	0,00%	2	1,19	120-135	120-135
4	7	0,75	75	200	5000	24%	69,11	0,29%	6,97	-3,36%	86,13	-8,22%	2	1,26	105-135	105-135
10	7	0,5	50	133,33	3810	24%	72,58	5,33%	6,96	-3,51%	96,31	2,63%	2	1,28	105-135	105-135
49	7	0,5	75	150	3750	18%	73,20	6,22%	6,96	-3,53%	96,48	2,81%	2	1,28	105-135	105-135
5	6	0,75	75	200	5000	24%	73,24	6,28%	7,06	-2,15%	91,05	-2,97%	1,8	1,28	105-135	105-135
2	6	0,5	75	200	5000	24%	75,28	9,24%	10,11	40,18%	100,78	7,40%	2	1,52	105-135	105-135

Design ID	Design Parameters						Displacements						Factor of Safety	Maximum Strain (%)	Sigma z (kPa)	Mean Stress (kPa)
	Length (m)	Vertical Spacing (m)	Paraweb Grade (kN)	Tensile Strength (kN/m)	Tensile Modulus (kN/m)	Coverage Ratio (%)	Horizontal (mm)	Percentage increase in Horizontal Displacement from the Original Design	Vertical (mm)	Percentage increase in Vertical Displacement from the Original Design	Total (mm)	Percentage increase in Total Displacement from the Original Design				
7	7	1	75	200	5000	24%	75,52	9,59%	6,98	-3,20%	90,37	-3,70%	2	1,27	105-135	125-150
13	7	0,75	50	133,33	3810	24%	76,57	11,12%	6,97	-3,38%	92,02	-1,94%	2	1,28	105-135	105-135
53	7	0,75	75	150	3750	18%	77,06	11,83%	6,97	-3,38%	92,58	-1,34%	2	1,28	105-135	105-135
11	6	0,5	50	133,33	3810	24%	80,24	16,45%	11,13	54,20%	104,80	11,68%	1,8	1,62	105-135	105-135
50	6	0,5	75	150	3750	18%	80,51	16,84%	11,21	55,33%	105,70	12,64%	2	1,62	105-135	105-135
14	6	0,75	50	133,33	3810	24%	80,60	16,96%	7,06	-2,15%	97,51	3,90%	1,8	1,44	105-135	105-135
54	6	0,75	75	150	3750	18%	81,06	17,64%	7,06	-2,15%	97,91	4,34%	1,8	1,44	105-135	105-135
61	7	0,5	50	100	2857	18%	81,45	18,20%	9,81	35,97%	103,86	10,68%	1,8	1,53	105-135	105-135
8	6	1	75	200	5000	24%	82,48	19,69%	11,75	62,80%	97,43	3,82%	1,8	1,53	105-135	105-135
6	5	0,75	75	200	5000	24%	84,01	21,91%	10,24	41,93%	104,09	10,92%	1,8	1,53	105-135	105-135
3	5	0,5	75	200	5000	24%	84,59	22,76%	11,21	55,38%	109,19	16,35%	1,8	1,81	105-135	105-135
16	7	1	50	133,33	3810	24%	85,03	23,39%	8,59	19,01%	101,87	8,56%	1,8	1,53	105-135	100-150
57	7	1	75	150	3750	18%	85,67	24,32%	8,70	20,63%	102,67	9,40%	2	1,61	105-135	100-150
25	7	0,5	75	100	2500	12%	85,74	24,42%	10,64	47,43%	106,77	13,78%	1,8	1,53	105-135	105-135
65	7	0,75	50	100	2857	18%	86,36	25,33%	7,52	4,25%	103,63	10,43%	1,8	1,52	105-135	105-135
62	6	0,5	50	100	2857	18%	87,19	26,53%	12,34	71,04%	110,97	18,25%	1,8	1,81	105-135	105-135
12	5	0,5	50	133,33	3810	24%	90,12	30,79%	12,11	67,78%	114,03	21,51%	1,8	1,8	105-135	105-135
51	5	0,5	75	150	3750	18%	90,68	31,59%	12,10	67,75%	114,64	22,16%	1,8	1,8	105-135	105-135
17	6	1	50	133,33	3810	24%	90,85	31,84%	12,62	74,95%	105,11	12,00%	1,8	1,71	105-135	105-135
66	6	0,75	50	100	2857	18%	90,86	31,85%	7,06	-2,18%	106,69	13,69%	1,8	1,8	105-135	105-135
26	6	0,5	75	100	2500	12%	91,10	32,21%	13,23	83,41%	115,30	22,87%	1,8	1,8	105-135	105-135
58	6	1	75	150	3750	18%	91,45	32,72%	12,66	75,43%	105,65	12,58%	1,8	1,71	105-135	105-135
15	5	0,75	50	133,33	3810	24%	91,68	33,04%	11,56	60,24%	111,80	19,13%	1,8	1,8	105-135	105-135
9	5	1	75	200	5000	24%	91,71	33,09%	13,51	87,27%	108,17	15,27%	1,8	1,8	105-135	105-135
29	7	0,75	75	100	2500	12%	91,85	33,30%	8,27	14,61%	110,16	17,39%	1,8	1,6	105-135	105-135

Design ID	Design Parameters						Displacements						Factor of Safety	Maximum Strain (%)	Sigma z (kPa)	Mean Stress (kPa)
	Length (m)	Vertical Spacing (m)	Paraweb Grade (kN)	Tensile Strength (kN/m)	Tensile Modulus (kN/m)	Coverage Ratio (%)	Horizontal (mm)	Percentage increase in Horizontal Displacement from the Original Design	Vertical (mm)	Percentage increase in Vertical Displacement from the Original Design	Total (mm)	Percentage increase in Total Displacement from the Original Design				
55	5	0,75	75	150	3750	18%	92,15	33,73%	11,65	61,42%	112,28	19,65%	1,8	1,8	105-135	105-135
37	7	0,5	50	66,67	1905	12%	95,20	38,15%	12,06	67,17%	116,65	24,30%	1,8	1,8	105-135	105-135
30	6	0,75	75	100	2500	12%	96,71	40,34%	7,21	-0,02%	113,65	21,11%	1,8	1,95	105-135	105-135
63	5	0,5	50	100	2857	18%	97,76	41,87%	13,21	83,05%	120,98	28,92%	1,8	2,25	105-135	105-135
19	4	0,5	75	200	5000	24%	98,16	42,44%	13,38	85,38%	121,51	29,48%	1,6	1,95	105-135	105-135
69	7	1	50	100	2857	18%	99,03	43,71%	14,18	96,50%	118,76	26,55%	1,8	2,1	105-135	105-135
18	5	1	50	133,33	3810	24%	100,20	45,41%	14,37	99,15%	117,78	25,51%	1,8	2,1	105-135	105-135
38	6	0,5	50	66,67	1905	12%	100,71	46,15%	12,28	70,14%	122,93	31,00%	1,8	2,4	105-135	105-135
59	5	1	75	150	3750	18%	100,87	46,38%	14,48	100,73%	118,47	26,24%	1,8	2,25	105-135	105-135
27	5	0,5	75	100	2500	12%	102,35	48,53%	13,73	90,29%	125,44	33,67%	1,8	2,25	105-135	105-135
67	5	0,75	50	100	2857	18%	102,53	48,79%	13,10	81,57%	122,90	30,96%	1,8	2,1	105-135	105-135
20	4	0,75	75	200	5000	24%	102,94	49,39%	13,46	86,53%	125,29	33,51%	1,6	2,4	105-135	105-135
52	4	0,5	75	150	3750	18%	105,40	52,96%	14,53	101,43%	129,06	37,53%	1,6	2,25	105-135	105-135
41	7	0,75	50	66,67	1905	12%	105,45	53,03%	9,99	38,47%	126,78	35,10%	1,8	1,95	105-135	105-135
22	4	0,5	50	133,33	3810	24%	105,55	53,17%	14,26	97,70%	127,66	36,03%	1,6	2,55	105-135	105-135
33	7	1	75	100	2500	12%	105,86	53,62%	12,10	67,67%	127,05	35,39%	1,8	2,25	105-135	100-150
31	5	0,75	75	100	2500	12%	108,27	57,12%	13,96	93,46%	128,72	37,17%	1,8	2,25	105-135	105-135
23	4	0,75	50	133,33	3810	24%	108,86	57,98%	13,66	89,31%	129,34	37,83%	1,6	2,4	105-135	105-135
42	6	0,75	50	66,67	1905	12%	111,38	61,63%	9,08	25,82%	131,05	39,65%	1,6	2,4	105-135	105-135
39	5	0,5	50	66,67	1905	12%	112,46	63,20%	15,48	114,60%	134,61	43,44%	1,8	2,55	105-135	105-135
21	4	1	75	200	5000	24%	112,54	63,32%	14,58	102,03%	130,36	38,91%	1,6	2,7	105-135	100-140
56	4	0,75	75	150	3750	18%	113,64	64,91%	15,31	112,20%	136,27	45,21%	1,6	2,55	105-135	105-135
64	4	0,5	50	100	2857	18%	115,03	66,93%	15,56	115,63%	137,24	46,25%	1,6	2,55	105-135	105-135
70	6	1	50	100	2857	18%	115,30	67,32%	12,75	76,69%	132,57	41,27%	1,8	2,25	105-135	105-135
71	5	1	50	100	2857	18%	116,32	68,80%	18,33	153,99%	133,67	42,44%	1,8	2,4	105-135	105-135

Design ID	Design Parameters						Displacements						Factor of Safety	Maximum Strain (%)	Sigma z (kPa)	Mean Stress (kPa)
	Length (m)	Vertical Spacing (m)	Paraweb Grade (kN)	Tensile Strength (kN/m)	Tensile Modulus (kN/m)	Coverage Ratio (%)	Horizontal (mm)	Percentage increase in Horizontal Displacement from the Original Design	Vertical (mm)	Percentage increase in Vertical Displacement from the Original Design	Total (mm)	Percentage increase in Total Displacement from the Original Design				
28	4	0,5	75	100	2500	12%	119,26	73,07%	16,73	131,94%	143,41	52,82%	1,6	2,7	105-135	105-135
68	4	0,75	50	100	2857	18%	121,48	76,29%	15,82	119,30%	142,27	51,60%	1,6	2,4	105-135	105-135
43	5	0,75	50	66,67	1905	12%	122,99	78,48%	16,00	121,74%	143,44	52,85%	1,6	2,55	105-135	105-135
24	4	1	50	133,33	3810	24%	123,72	79,54%	18,80	160,56%	143,13	52,52%	1,6	2,7	105-135	100-120
34	6	1	75	100	2500	12%	123,79	79,64%	13,64	89,11%	141,91	51,22%	1,8	2,4	105-135	105-135
35	5	1	75	100	2500	12%	124,26	80,32%	19,64	172,19%	141,79	51,10%	1,6	2,55	105-135	105-135
60	4	1	75	150	3750	18%	124,50	80,67%	18,91	162,11%	143,95	53,39%	1,6	2,55	105-135	100-140
45	7	1	50	66,67	1905	12%	125,36	81,92%	18,15	151,52%	149,68	59,50%	1,8	2,7	105-135	105-135
40	4	0,5	50	66,67	1905	12%	132,77	92,67%	18,01	149,57%	154,89	65,06%	1,6	2,7	105-135	105-135
32	4	0,75	75	100	2500	12%	134,30	94,89%	19,19	165,94%	157,13	67,44%	1,6	3,2	105-135	105-135
72	4	1	50	100	2857	18%	140,19	103,44%	21,24	194,39%	160,08	70,59%	1,6	2,85	105-135	100-140
46	6	1	50	66,67	1905	12%	143,07	107,62%	15,34	112,63%	163,09	73,79%	1,6	2,7	105-135	100-140
47	5	1	50	66,67	1905	12%	144,16	109,20%	22,90	217,42%	161,52	72,12%	1,4	2,85	105-135	105-135
44	4	0,75	50	66,67	1905	12%	146,28	112,28%	19,47	169,81%	169,42	80,54%	1,4	2,7	105-135	100-140
36	4	1	75	100	2500	12%	149,50	116,95%	22,71	214,77%	169,63	80,76%	1,6	3	105-135	100-140
48	4	1	50	66,67	1905	12%	172,31	150,05%	25,75	256,85%	193,70	106,41%	1,4	3,4	105-135	100-140

Table 6-4: Results from the FEA on the various model configurations – Sorted Based on the Percentage Increase in Vertical Displacement from the Original Design

Design ID	Design Parameters						Displacements						Factor of Safety	Maximum Strain (%)	Sigma z (kPa)	Mean Stress (kPa)
	Length (m)	Vertical Spacing (m)	Paraweb Grade (kN)	Tensile Strength (kN/m)	Tensile Modulus (kN/m)	Coverage Ratio (%)	Horizontal (mm)	Percentage increase in Horizontal Displacement from the Original Design	Vertical (mm)	Percentage increase in Vertical Displacement from the Original Design	Total (mm)	Percentage increase in Total Displacement from the Original Design				
49	7	0,5	75	150	3750	18%	73,20	6,22%	6,96	-3,53%	96,48	2,81%	2	1,28	105-135	105-135
10	7	0,5	50	133,3	3810	24%	72,58	5,33%	6,96	-3,51%	96,31	2,63%	2	1,28	105-135	105-135

Design ID	Design Parameters						Displacements						Factor of Safety	Maximum Strain (%)	Sigma z (kPa)	Mean Stress (kPa)
	Length (m)	Vertical Spacing (m)	Paraweb Grade (kN)	Tensile Strength (kN/m)	Tensile Modulus (kN/m)	Coverage Ratio (%)	Horizontal (mm)	Percentage increase in Horizontal Displacement from the Original Design	Vertical (mm)	Percentage increase in Vertical Displacement from the Original Design	Total (mm)	Percentage increase in Total Displacement from the Original Design				
53	7	0,75	75	150	3750	18%	77,06	11,83%	6,97	-3,38%	92,58	-1,34%	2	1,28	105-135	105-135
13	7	0,75	50	133,3	3810	24%	76,57	11,12%	6,97	-3,38%	92,02	-1,94%	2	1,28	105-135	105-135
4	7	0,75	75	200	5000	24%	69,11	0,29%	6,97	-3,36%	86,13	-8,22%	2	1,26	105-135	105-135
7	7	1	75	200	5000	24%	75,52	9,59%	6,98	-3,20%	90,37	-3,70%	2	1,27	105-135	125-150
66	6	0,75	50	100	2857	18%	90,86	31,85%	7,06	-2,18%	106,69	13,69%	1,8	1,8	105-135	105-135
54	6	0,75	75	150	3750	18%	81,06	17,64%	7,06	-2,15%	97,91	4,34%	1,8	1,44	105-135	105-135
14	6	0,75	50	133,3	3810	24%	80,60	16,96%	7,06	-2,15%	97,51	3,90%	1,8	1,44	105-135	105-135
5	6	0,75	75	200	5000	24%	73,24	6,28%	7,06	-2,15%	91,05	-2,97%	1,8	1,28	105-135	105-135
30	6	0,75	75	100	2500	12%	96,71	40,34%	7,21	-0,02%	113,65	21,11%	1,8	1,95	105-135	105-135
1	7	0,5	75	200	5000	24%	68,91	0,00%	7,21	0,00%	93,84	0,00%	2	1,19	120-135	120-135
65	7	0,75	50	100	2857	18%	86,36	25,33%	7,52	4,25%	103,63	10,43%	1,8	1,52	105-135	105-135
29	7	0,75	75	100	2500	12%	91,85	33,30%	8,27	14,61%	110,16	17,39%	1,8	1,6	105-135	105-135
16	7	1	50	133,3	3810	24%	85,03	23,39%	8,59	19,01%	101,87	8,56%	1,8	1,53	105-135	100-150
57	7	1	75	150	3750	18%	85,67	24,32%	8,70	20,63%	102,67	9,40%	2	1,61	105-135	100-150
42	6	0,75	50	66,67	1905	12%	111,38	61,63%	9,08	25,82%	131,05	39,65%	1,6	2,4	105-135	105-135
61	7	0,5	50	100	2857	18%	81,45	18,20%	9,81	35,97%	103,86	10,68%	1,8	1,53	105-135	105-135
41	7	0,75	50	66,67	1905	12%	105,45	53,03%	9,99	38,47%	126,78	35,10%	1,8	1,95	105-135	105-135
2	6	0,5	75	200	5000	24%	75,28	9,24%	10,11	40,18%	100,78	7,40%	2	1,52	105-135	105-135
6	5	0,75	75	200	5000	24%	84,01	21,91%	10,24	41,93%	104,09	10,92%	1,8	1,53	105-135	105-135
25	7	0,5	75	100	2500	12%	85,74	24,42%	10,64	47,43%	106,77	13,78%	1,8	1,53	105-135	105-135
11	6	0,5	50	133,3	3810	24%	80,24	16,45%	11,13	54,20%	104,80	11,68%	1,8	1,62	105-135	105-135
50	6	0,5	75	150	3750	18%	80,51	16,84%	11,21	55,33%	105,70	12,64%	2	1,62	105-135	105-135
3	5	0,5	75	200	5000	24%	84,59	22,76%	11,21	55,38%	109,19	16,35%	1,8	1,81	105-135	105-135
15	5	0,75	50	133,3	3810	24%	91,68	33,04%	11,56	60,24%	111,80	19,13%	1,8	1,8	105-135	105-135
55	5	0,75	75	150	3750	18%	92,15	33,73%	11,65	61,42%	112,28	19,65%	1,8	1,8	105-135	105-135

Design ID	Design Parameters						Displacements						Factor of Safety	Maximum Strain (%)	Sigma z (kPa)	Mean Stress (kPa)
	Length (m)	Vertical Spacing (m)	Paraweb Grade (kN)	Tensile Strength (kN/m)	Tensile Modulus (kN/m)	Coverage Ratio (%)	Horizontal (mm)	Percentage increase in Horizontal Displacement from the Original Design	Vertical (mm)	Percentage increase in Vertical Displacement from the Original Design	Total (mm)	Percentage increase in Total Displacement from the Original Design				
8	6	1	75	200	5000	24%	82,48	19,69%	11,75	62,80%	97,43	3,82%	1,8	1,53	105-135	105-135
37	7	0,5	50	66,67	1905	12%	95,20	38,15%	12,06	67,17%	116,65	24,30%	1,8	1,8	105-135	105-135
33	7	1	75	100	2500	12%	105,86	53,62%	12,10	67,67%	127,05	35,39%	1,8	2,25	105-135	100-150
51	5	0,5	75	150	3750	18%	90,68	31,59%	12,10	67,75%	114,64	22,16%	1,8	1,8	105-135	105-135
12	5	0,5	50	133,3	3810	24%	90,12	30,79%	12,11	67,78%	114,03	21,51%	1,8	1,8	105-135	105-135
38	6	0,5	50	66,67	1905	12%	100,71	46,15%	12,28	70,14%	122,93	31,00%	1,8	2,4	105-135	105-135
62	6	0,5	50	100	2857	18%	87,19	26,53%	12,34	71,04%	110,97	18,25%	1,8	1,81	105-135	105-135
17	6	1	50	133,3	3810	24%	90,85	31,84%	12,62	74,95%	105,11	12,00%	1,8	1,71	105-135	105-135
58	6	1	75	150	3750	18%	91,45	32,72%	12,66	75,43%	105,65	12,58%	1,8	1,71	105-135	105-135
70	6	1	50	100	2857	18%	115,30	67,32%	12,75	76,69%	132,57	41,27%	1,8	2,25	105-135	105-135
67	5	0,75	50	100	2857	18%	102,53	48,79%	13,10	81,57%	122,90	30,96%	1,8	2,1	105-135	105-135
63	5	0,5	50	100	2857	18%	97,76	41,87%	13,21	83,05%	120,98	28,92%	1,8	2,25	105-135	105-135
26	6	0,5	75	100	2500	12%	91,10	32,21%	13,23	83,41%	115,30	22,87%	1,8	1,8	105-135	105-135
19	4	0,5	75	200	5000	24%	98,16	42,44%	13,38	85,38%	121,51	29,48%	1,6	1,95	105-135	105-135
20	4	0,75	75	200	5000	24%	102,94	49,39%	13,46	86,53%	125,29	33,51%	1,6	2,4	105-135	105-135
9	5	1	75	200	5000	24%	91,71	33,09%	13,51	87,27%	108,17	15,27%	1,8	1,8	105-135	105-135
34	6	1	75	100	2500	12%	123,79	79,64%	13,64	89,11%	141,91	51,22%	1,8	2,4	105-135	105-135
23	4	0,75	50	133,3	3810	24%	108,86	57,98%	13,66	89,31%	129,34	37,83%	1,6	2,4	105-135	105-135
27	5	0,5	75	100	2500	12%	102,35	48,53%	13,73	90,29%	125,44	33,67%	1,8	2,25	105-135	105-135
31	5	0,75	75	100	2500	12%	108,27	57,12%	13,96	93,46%	128,72	37,17%	1,8	2,25	105-135	105-135
69	7	1	50	100	2857	18%	99,03	43,71%	14,18	96,50%	118,76	26,55%	1,8	2,1	105-135	105-135
22	4	0,5	50	133,3	3810	24%	105,55	53,17%	14,26	97,70%	127,66	36,03%	1,6	2,55	105-135	105-135
18	5	1	50	133,3	3810	24%	100,20	45,41%	14,37	99,15%	117,78	25,51%	1,8	2,1	105-135	105-135
59	5	1	75	150	3750	18%	100,87	46,38%	14,48	100,73%	118,47	26,24%	1,8	2,25	105-135	105-135
52	4	0,5	75	150	3750	18%	105,40	52,96%	14,53	101,43%	129,06	37,53%	1,6	2,25	105-135	105-135

Design ID	Design Parameters						Displacements						Factor of Safety	Maximum Strain (%)	Sigma z (kPa)	Mean Stress (kPa)
	Length (m)	Vertical Spacing (m)	Paraweb Grade (kN)	Tensile Strength (kN/m)	Tensile Modulus (kN/m)	Coverage Ratio (%)	Horizontal (mm)	Percentage increase in Horizontal Displacement from the Original Design	Vertical (mm)	Percentage increase in Vertical Displacement from the Original Design	Total (mm)	Percentage increase in Total Displacement from the Original Design				
21	4	1	75	200	5000	24%	112,54	63,32%	14,58	102,03%	130,36	38,91%	1,6	2,7	105-135	100-140
56	4	0,75	75	150	3750	18%	113,64	64,91%	15,31	112,20%	136,27	45,21%	1,6	2,55	105-135	105-135
46	6	1	50	66,67	1905	12%	143,07	107,62%	15,34	112,63%	163,09	73,79%	1,6	2,7	105-135	100-140
39	5	0,5	50	66,67	1905	12%	112,46	63,20%	15,48	114,60%	134,61	43,44%	1,8	2,55	105-135	105-135
64	4	0,5	50	100	2857	18%	115,03	66,93%	15,56	115,63%	137,24	46,25%	1,6	2,55	105-135	105-135
68	4	0,75	50	100	2857	18%	121,48	76,29%	15,82	119,30%	142,27	51,60%	1,6	2,4	105-135	105-135
43	5	0,75	50	66,67	1905	12%	122,99	78,48%	16,00	121,74%	143,44	52,85%	1,6	2,55	105-135	105-135
28	4	0,5	75	100	2500	12%	119,26	73,07%	16,73	131,94%	143,41	52,82%	1,6	2,7	105-135	105-135
40	4	0,5	50	66,67	1905	12%	132,77	92,67%	18,01	149,57%	154,89	65,06%	1,6	2,7	105-135	105-135
45	7	1	50	66,67	1905	12%	125,36	81,92%	18,15	151,52%	149,68	59,50%	1,8	2,7	105-135	105-135
71	5	1	50	100	2857	18%	116,32	68,80%	18,33	153,99%	133,67	42,44%	1,8	2,4	105-135	105-135
24	4	1	50	133,3	3810	24%	123,72	79,54%	18,80	160,56%	143,13	52,52%	1,6	2,7	105-135	100-120
60	4	1	75	150	3750	18%	124,50	80,67%	18,91	162,11%	143,95	53,39%	1,6	2,55	105-135	100-140
32	4	0,75	75	100	2500	12%	134,30	94,89%	19,19	165,94%	157,13	67,44%	1,6	3,2	105-135	105-135
44	4	0,75	50	66,67	1905	12%	146,28	112,28%	19,47	169,81%	169,42	80,54%	1,4	2,7	105-135	100-140
35	5	1	75	100	2500	12%	124,26	80,32%	19,64	172,19%	141,79	51,10%	1,6	2,55	105-135	105-135
72	4	1	50	100	2857	18%	140,19	103,44%	21,24	194,39%	160,08	70,59%	1,6	2,85	105-135	100-140
36	4	1	75	100	2500	12%	149,50	116,95%	22,71	214,77%	169,63	80,76%	1,6	3	105-135	100-140
47	5	1	50	66,67	1905	12%	144,16	109,20%	22,90	217,42%	161,52	72,12%	1,4	2,85	105-135	105-135
48	4	1	50	66,67	1905	12%	172,31	150,05%	25,75	256,85%	193,70	106,41%	1,4	3,4	105-135	100-140

The FEA contour plots of the results for each model analysed is included in Appendix B, with the stress in the z direction, mean stress, shear strain, vertical displacement, horizontal displacement, total displacement and strength reduction factor (or factor of safety) presented for each design analysed.

7. DISCUSSION

The case study retaining wall was designed in accordance with the SANS8006-1:2018 code which recommends certain guidelines for the geometry of a reinforced soil wall. Once established the geometry was used to assess the external stability of the wall against overturning, sliding and bearing capacity failure. The driving forces for the above-mentioned failure mechanisms were lower than the resisting forces and hence the overall external stability of the whole reinforced soil wall was proven.

The wall geometry was thereafter used to assess the internal stability of the wall, which included the calculation of the reinforcement tensile stress along each reinforcement layer. Furthermore, the adherence capacity of the reinforcement along each layer was determined for the wall geometry selected, which verified that pull-out is not anticipated to present a problem for this case study. The calculated tensile strength defined the most suitable grade of reinforcement required to mitigate against tensile rupture as a result of the tensile stress on the reinforcement due to loading from soils self-weight and as a result of external strip loading on the wall. The ultimate tensile strength of the reinforcement was downrated to a tensile design strength to accommodate variability and uncertainty in material parameters due to installation damage, as well as chemical and environmental effects, weathering and UV, and for the extrapolation of reinforcement data. Reduction factors were also applied to account for reinforcement creep strain and for the ramifications of failure. Once downrated, it was confirmed that the reinforced soil wall should comprise Grade 75 Paraweb Straps installed at 7.0m reinforcement lengths with a 0.5m vertical spacings between layers, and a coverage ratio of 24% (4 straps across a facing panel).

Using the finite element program Rocscience Phase 2, the SANS8006-1:2018 design was analysed for comparative purposes. The analysis indicates foundation stresses of approximately 135kPa which is far lower than the bearing pressures of 445kPa calculated using the design code, although it is highlighted that the latter includes applied partial load factors to mitigate against failure.

According to the finite element analysis (FEA) maximum strains in the order of 1.19% should be expected within the soils at the footing of the facing, directly adjacent to the facing in the middle of the wall, and in the backfill, which cannot be determined using the design method proposed in the SANS8006-1:2018 code. It is not clear from the results if these strains have developed in the reinforcement however the contours suggest that the maximum strains are within the soil.

No yielding of the reinforcement occurred in the FEA however yielding of the material elements surrounding the reinforcement was evident in the upper wedge of the wall adjacent to the facing. It is however reiterated that stability of the structure is dictated by both the pull-out resistance and the strength of the reinforcement, hence should rupture of a reinforcement occur (which has not occurred according to the analysis) the remaining reinforcements compensates for this as the stresses are re-distributed to the remaining reinforcements and hence does not mean the ultimate collapse of the structure however is likely to lead to increased strains and displacements.

Furthermore, the FEA calculates horizontal displacements of 69mm which is not determined using the analytical method in the design code, however the code does include for settlement determination of the foundation soil which was estimated to be between 11mm and 26mm, and hence is greater than the maximum vertical displacements calculated by the FEA of 7.2mm. The vertical displacement falls within acceptable tolerances; however, the horizontal displacements of the structure may be considered intolerable however this is dependent on the serviceability limits of the structure and hence is project specific.

Construction tolerances of the facing panels are 5mm per meter height of wall from the vertical, which is well below the vertical displacements calculated in the analysis. The post construction displacement limits and serviceability limits stipulated in the code is thus 40mm for an 8m wall, which is far lower than the horizontal displacements calculated in the FEA. However, as this wall has been constructed and is presently in use, it is assumed that these displacements are within the tolerances accepted for the existing structure, hence project specific tolerances that may have higher limits for the particular case study may be applicable however was not available for confirmation.

Using the Shear Strength Reduction method of analysis, a FoS of 2 was achieved using the FEA. Failure of the structure would occur at a FoS of less than 1, hence it is evident that the design has a "safety contingency" for any variations/ uncertainty in material properties. The design code however accounts for this by the application of partial factors, which are not applied by the FEM.

Based on the above-mentioned results it is established that acceptance of the reinforced soil wall design is governed by the Serviceability Limit State rather than the Ultimate Limit State. Hence the reinforced soil wall is stable against ultimate failure, however is dictated by the serviceability limit state in terms of the allowable displacement and strain tolerances of the structure.

The first key question of this study was to identify the difference in the design of a reinforced soil wall using the SANS8006-1:2018 design code compared to using a finite element analysis. Using the N2-Umgeni Road Interchange retaining wall case study, it has been confirmed that the design developed based on the SANS8006-1:2018 is considered to be an adequate and acceptable solution for the reinforced soil wall. However, based on the comparison with the finite element analysis of the design, the SANS8006-1:2018 method is considered to be conservative to some extent when considering the lower founding stresses and vertical displacements and higher FoS achieved using the numerical analysis, without applying any partial factors to the properties used in the FEA.

As such it is concluded that depending on the type, dimensions and tiers of a reinforced soil wall, the approach recommended in the design code should be verified using an alternative method such as the use of a finite element analysis, as this may lead to a more economical design being developed (in terms of wall geometry, reinforcement strength and coverage ratio) which could have significant cost and time savings on a project.

The results of the parametric study conducted indicate that ultimate failure of the wall did not occur for the reinforcement configurations analysed where factors of safety of greater than 1.5 were generally achieved, with the exception of the models where the reinforcement length was 4m and 5m, with vertical spacing of 0.75m and 1.0m, and with a Grade 50 Paraweb installed with a 12% coverage ratio which yielded a factor of safety of 1.4.

The vertical and mean stresses were generally consistent at between 105kPa and 135kPa for all model configurations analysed.

Although all the reinforcement parameters influence the analysis results, the parameter that has a higher influence, albeit only minimally, on the factor of safety, maximum shear strain and horizontal and vertical displacement is the reinforcement length of the reinforced soil wall. This is followed closely by the tensile strength and coverage ratio (which has similar levels of influence as the coverage ratio in the program is accounted for by adjusting the tensile strength of the reinforcement) which is considered marginally more influential than the reinforcement vertical spacing, which has the lowest level of influence on the resulted outcome of the analysis.

Similarly, to the original design conclusion the high horizontal displacements achieved for the models of the parametric study are likely to dictate the serviceability of the structure. The serviceability may also be influence by the percentage of strain which were calculated to be great than 1% for all models analysed, however it has not been established confidently from the graphical representation of the shear strain contours (of the structure as a whole) if the strain values are within the reinforcement or the soil, however appears to be the latter. Based on the design code and the Paraweb certification sheet, reinforcement strains for retaining walls are to be limited to 1%.

The other measured factors, namely the stresses and vertical displacements are considered to be within generally acceptable ranges.

The configurations / models which resulted in the least (<10%) increase in horizontal displacement from the original design were identified as possible options for alternative design solutions provided these meet the horizontal displacement tolerances for the structure and have acceptable strains. **Error! Reference source not found.** includes the design configuration alternatives which vary in reinforcement parameters and may be more economical that the original design yet still within serviceability limits. The original design labelled Design 1 is also included in the first row of the table for comparative purposes. As documented the parameter that predominantly influences the design is the reinforcement length, hence the alternatives considered generally have an unchanged length from the original design with the exception of one alternative where the length is 6m.

The alternative design options with the least difference in terms of displacements and strains to the original design is Design 4, where the length, Paraweb grade and coverage ratio is unchanged from the original design with only an increase in the vertical spacing from 0.5m (in the original design) to 0.75m. The analysis confirms a 0.29% increase in the horizontal displacement with a 3% decrease in the vertical displacement compared to the original design. The factor of safety determined using the Shear Strength Reduction Method, remains unchanged however the maximum strain has increased from 1.19% to 1.26% (which is a 0.07% increase) at the facing. Given the small variation in the strains and horizontal displacement calculated from the original design, Design 4 is considered to be a more optimal design for the reinforced soil wall rather than the original design. This is in light of tolerance limits for the structure being unavailable for the case study wall. Although the only difference between the original Design 1 and Design 4 is the increase in the reinforcement vertical spacing from 0.5m to 0.75m, the alternative is considered as possibly having a modest savings in terms of costs and construction time for the reinforced soil wall.

Similarly, to Design 4, there are several other reinforcement configurations that yield a horizontal displacement of less than 10% of the original design and increased strains of a maximum of 1.28% directly adjacent to the facing (compared to the original design where the strains were 1.19%, hence an increase of 0.09%) and are also tabulated below with the associated horizontal and vertical displacement, maximum strain and FoS calculated. The vertical displacement tolerances for the case study wall are unknown, however provided that the displacements and strains are within acceptable limits for the structure, it is concluded, that several design configurations with increased vertical spacings, or lower strength and coverage ratio combinations (compared with the original design) could also be acceptable solution for the case study reinforced soil wall. The displacements and strains in the alternative solutions are marginally greater than the original design, and hence possibly within tolerable limits for the structure in which cases these could pass as more economical design solutions.

Table 7-1: Alternative Design Options

	Design Parameters						**Displacements**							
Design ID	**Length (m)**	**Vertical Spacing (m)**	**Paraweb Grade (kN)**	**Tensile Strength (kN/m)**	**Tensile Modulus (kN/m)**	**Coverage Ratio (%)**	**Horizontal (mm)**	**Percentage increase in Horizontal Displacement from the Original Design**	**Vertical (mm)**	**Percentage increase in Vertical Displacement from the Original Design**	**Total (mm)**	**Percentage increase in Total Displacement from the Original Design**	**Factor of Safety**	**Maximum Strain (%)**
1	**7**	**0,5**	**75**	**200**	**5000**	**24%**	**68,91**	**0,00%**	**7,21**	**0,00%**	**93,84**	**0,00%**	**2**	**1,19**
4	7	0,75	75	200	5000	24%	69,11	0,29%	6,97	-3,36%	86,13	-8,22%	2	1,26
10	7	0,5	50	133,33	3810	24%	72,58	5,33%	6,96	-3,51%	96,31	2,63%	2	1,28
49	7	0,5	75	150	3750	18%	73,20	6,22%	6,96	-3,53%	96,48	2,81%	2	1,28
5	6	0,75	75	200	5000	24%	73,24	6,28%	7,06	-2,15%	91,05	-2,97%	1,8	1,28
7	7	1	75	200	5000	24%	75,52	9,59%	6,98	-3,20%	90,37	-3,70%	2	1,27

To identify which reinforcement configuration is the most suitable design for any given reinforced soil wall will require an analysis approach that is more robust than that recommended in the SANS8006-1:2018 code, as several design options will need to be investigated to identify the most economical yet acceptable solution in terms of serviceability tolerances. Hence there is a need to consider alternative numerical design approaches such as the use of a FEA particularly when designing higher reinforced soil walls and walls with more complex geometries, were the cost savings for minor reductions in the reinforcement strength, length, coverage, or increase in vertical spacing could have significant cost and time savings for a project.

Furthermore, this study highlights that the SANS8006-1:2018 design method recommended applies several levels of contingencies against failure of the design in terms of the partial factors applied to determine the tension in the reinforcement and adherence capacity along the soil reinforcement interface, and in terms of the reduction factors and factors of safety applied to the ultimate tensile strength of the reinforcement to determine the design strength; hence is considered to be an over-conservative design approach. With only one case study having been undertaken, it is deemed necessary to further investigate the conservatism of the design code, and how the code could be updated to include for the use of numerical analysis tools to design reinforced soil walls, as these are readily available (and affordable) and generally uncomplicated and a quick analysis to carry out making modelling and designing of reinforced soil walls more efficient.

8. CONCLUSIONS AND RECOMMENDATIONS

8.1 Conclusions

Reinforced soil walls have been used extensively for geotechnical engineering applications in South Africa as an alternative to retaining structures given its cheaper cost compared to traditional retaining structures and the ability to construct such structures to great heights. The design methodology recommended within the civil engineering fraternity for the design of reinforced soil walls are provided in the design code SANS 8006-1:2018, which was previously published as the SANS 207:2011, both of which were based on the British BS8006 standard, first published in 1995.

An existing retaining structure constructed along the National Road N2 - Umgeni Interchange in Durban, KZN was selected as a case study to assess the recommended design approach in the SANS 8006-1:2018 Code of Practice for Strengthened/Reinforced Soils and Other Fill. In accordance with the design code specification a configuration for the case study reinforced soil wall was determined and the required tensile strength calculated, to ensure the stability of the wall. The design code approach includes the selection of a wall geometry based on prescribed guidelines for the embedment, length and spacing of the reinforcement. The wall geometry is analysed to assess the external stability of the wall namely the sliding, overturning and bearing capacity and settlement of the overall reinforced soil structure. An internal stability analysis of the reinforced soil structure is conducted to determine the reinforcement tensile strength to mitigate against tensile rupture, and the adherence capacity is determined to ensure mitigation against reinforcement pull-out. Partial factors are applied to the soil and load properties used in the external and internal analysis, to allow a “factor of safety” against uncertainty and variance in these parameters. Based on the tensile strength requirements calculated a reinforcement grade is selected. The ultimate tensile strength of the grade of reinforcement selected is downrated to a design strength. The downrating accounts for uncertainty and variability of the properties of the reinforcement as a result of handling / installation damage, environmental conditions, weathering, creep strain, and for the extrapolation of reinforcement data, as well as to account for the ramifications of failure.

Several numerical analysis tools are available that have the advantage of calculating strength and strains that are likely to develop in reinforced soil structures. These methods can also account for the strength and stiffness of the reinforcement material. The disadvantage of the design approach specified in the design code is that only the stresses that develop in the reinforced soil structure are calculated. The design code solution was compared to a finite element analysis of the solution to assess the difference in the approaches.

Using the case study design a finite element analysis (FEA) confirmed the adequacy of the solution based on the design code. The magnitude of the horizontal displacements from the analysis concludes that the acceptability of the reinforced soil wall would be dictated by serviceability limit states rather than ultimate limit state. It is however concluded that the design code approach may indeed be more conservative in light of the stresses, vertical displacement and factor of safety achieved in the FEA. This conservatism is attributed to the several partial factors that are applied to the material and load parameters during the determination of the reinforcement stresses and the reduction factors and safety factors applied to downrate the ultimate tensile strength of the reinforcement to a design strength.

As noted, FEA has the capability to provide a thorough evaluation of reinforced soil wall designs, and hence it is an extremely useful tool for use in the designing of complex reinforcement structures. FEA provides details of stresses, strains, vertical and horizontal displacements and identifies yielding elements (of any material modelled). Furthermore, the model may be set up in different stages to better define the stresses and strains that could be encountered at varying stages of the construction. With the availability of the various finite element packages on the market, it is possible to undertake a quick analysis on any design to confirm its performance. Given the speed of analysis including the ease of setting up a model makes the finite element method of analysis for design extremely viable when trying to identify alternative designs that may be more optimal for a reinforced soil wall.

Using the FEM, a parametric study included several analyses on various configurations of the reinforcement length, vertical spacing, strength and coverage ratio of the case study wall, to identify if there is any one parameter that has the greatest influence on the stability of the wall and to identify the possibility of optimizing the design by altering the reinforced soil wall configuration.

The study suggests that the defining element in a reinforced soil wall is the length of the wall, with the coverage ratio and tensile strength of the reinforcement having similar influences on the stability of the wall with the vertical spacing of the reinforcing layers having the least significance. It is however noted that the degree of influence between these parameters are marginal, as these configurations work in unity to maintain the stability of the structure. Hence it is concluded that it is more critical to define which combination of reinforcement geometry, strength and coverage ratio produces the most economical design while still maintaining the stability of the reinforced soil wall and restricting displacements and strains to within serviceability limit tolerances for the given wall. Furthermore, the parametric study on the various wall configurations indicated that there were a few models where the displacements and strains deviated only slightly from the results of the baseline model, hence concluding that the alternative wall configurations (in terms of reinforcement length, vertical spacing, strength and coverage ratio) may provide an equally suitable solution that could be more economical than that of the original design which was based on the SANS8006-1:2018 code.

Depending on the height, type and number of tiers of a reinforced soil wall to be design, even a slight optimizing of the design, as was the case from the parametric study undertaken for the N2-Umgeni Interchange reinforced soil wall investigated, is likely to lead to cost and time savings on a project. These savings on projects can be tremendous depending on the structure being designed, and hence warrants the use of an alternative design method to verify the design developed using the SANS8006-1:2018 code.

8.2 Recommendations

As only one case study has been examined in this study, it is recommended that further studies on this subject should be undertaken with additional case studies being assessed to confirm these findings for various types, height and tiers of walls. If it is possible, an analysis using several case studies illustrating approximate cost savings (in terms of the cost of material, time, construction works, etc.) should be undertaken to illustrate how minor reductions to either the reinforcement length, strength or coverage ratio and increases to the vertical spacing can impact on the project costs, provided that stability and serviceability limits of a reinforced soil wall are still maintained. Additionally, further investigation is deemed necessary to identify what modifications could be added into the currently used design codes to improve the approach and design method, in order to develop solutions that are not as over-conservative. It is further concluded that allowances or recommendations should be included in the design code for the use of numerical methods to verify the designs developed using the analytical methods proposed in the SANS8006-1:2018 code, particularly for higher walls and walls with imposed loads.

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A COMPARISON OF THE DESIGN APPROACH RECOMMENDED IN THE SOUTH AFRICAN NATIONAL STANDARD FOR A REINFORCED SOIL WALL WITH A FINITE ELEMENT DESIGN TO IDENTIFY AN OPPORTUNITY TO OPTIMISE THE DESIGN

APPENDICES

Rannel Sashnee Naidoo

APPENDIX A

INTERNAL STABILITY ANALYSIS CALCULATION SHEETS

INTERNAL STABILITY ANALYSIS INPUTS AND RESULTS

Input Parameters	**Symbol**	**Parameter Value**	**Unit**
Height of retaining wall	H	8,00	m
Height of retaining wall - Embedment Depth	H_1	7,00	m
Half the wall height	H/2	4,00	m
Cohesion of reinforced soil	c_r	0,00	kPa
Cohesion of Foundation soil	c_f	5,00	kPa
Cohesion of Backfill soil	c_b	0,00	kPa
Friction Angle of reinforced fill soil	f_r	27,00	degrees
Friction Angle of Backfill Soil	f_b	27,00	degrees
Friction Angle of Foundation Soil	f_f	25,00	degrees
Unit Weight of Backfill Soil	g_b	19,50	kN/m^3
Unit Weight of Reinforced Soil	g_r	19,50	kN/m^3
Unit Weight of Foundation Soil	g_f	18,50	kN/m^3
Length of Reinforced Block	L	7,00	m
Total width of the surcharge load on the entire wall		7,40	m
Width of the strip load over the reinforced block only	a (or also - b)	4,40	m
Distance of strip load from the facing over the reinforced block / Distance from the wall to the strip footing (b')	b (or also - d) (or b')	2,80	m
Distance from edge of wall to the surcharge load (assuming the wall edge is the end of the reinforce soil block)	b'	0,00	m
Width of the strip load on the backfill portion of the wall	a'	3,00	m
Distance from the facing to the centre of the strip load (portion of strip load over the reinforcement block only)	d	5,00	m
Surcharge	q	20,00	kPa
Slope of top surface of wall to the horizontal	α	0,00	degrees
Friction angle between soil and the wall (2/3 f_b)	d'	18,00	degrees
Angle of the retaining wall back face to the vertical	θ	0,00	degrees
Width of Reinforcement	B	0,09	m
tanδ (for Paraweb)	m	0,60	
Z_0 (for the calculation of Earth Pressure K)	Z_0	6	m

Partial Factors		**Ultimate Limit State**	**Serviceability Limit State**
Load Factors	Soil unit mass, e.g. wall fill	The appropriate value of f_{fs} to be chosen according to Table below	
	External dead loads, e.g. line or point loads	The appropriate value of f_f to be chosen according to Table below	
	External live loads, e.g. traffic loading	The appropriate value of f_q to be chosen according to Table below	
Soil Material Factors	to be applied to tan ϕ'_p (f_{ms})	1	1
	to be applied to c' (f_{ms})	1,6	1
	to be applied to c_u (f_{ms})	1	1
Reinforced material factor	to be applied to the reinforcement base strength (f_m)	The value of f_m should be consistent with the type of reinforcement to be used and the design life over which the reinforcement is required.	
Soil/reinforcement interaction Factors	Sliding across surface of reinforcement (f_s)	1,3	1
	Pull out resistance of reinforcement (f_p)	1,3	1
Partial factors of safety	Foundation bearing capacity: to be applied to q_{ult} (f_{ms})	1,35	NA
	Sliding along base of structure or any horizontal surface where there is soil-to-soil contact (f_s)	1,2	NA
Effects	**Load Case Combination**		
	A	**B**	**C**
Mass of the reinforced soil body (f_{fs})	1,5	1	1
Mass of the backfill on top of the reinforced soil wall (f_{fs})	1,5	1	1
Earth pressure behind the structure (f_{fs})	1,5	1,5	1
Traffic load: on reinforced soil block (f_q)	1,5	0	0
Traffic load: behind reinforced soil block (f_q)	1,5	1,5	0

Partial Factor for Ramifications of Failure (f_n)		
Category	**Partial factor**	**Example Structures**
1 (low)	NA	Retaining walls with a slope les than 1.5m in height (minimal damage and loss of access)
2 (medium)	1	Embankment and structure that would result in moderate damage and loss of services
3 (high)	1,1	Abutments structures supporting roadways, railways or buildings, dams, seawalls and slopes , river training walls and slopes

INTERNAL STABILITY CALCULATIONS - ULTIMATE LIMIT STATE - LOAD CASE A (Tension and Pull Out Resistance [although this is governed by Case B])

1					2						
Effective Depth	Length of Reinforcement	Earth Pressure		Earth Pressure Selected depending in Depth	Vertical Loading due to Self Weight - T_{pj}						
H	L	Ka	Ko	K	Vertical Loading - Rv	Overturning Moment - Mo	Eccentricity - e	Vertical Stress	Half distance from above + below reinforcement	Vertical Loading due to Self Weight
$H = z=h_j$		$K_a=\tan^2(45-\phi_b/2)$	$K_o=1-\sin\phi_b$	$K=K_o(1-z/z_o)+(K_a*(z/z_o))$ Or $K=K_a$	$R_{vj}=f_{fs}*\gamma_r*L*H$	$M_o=0.5*f_{fs}*\gamma_r*H^2*K*(H/3)$	$e_j=M_o/R_{vj}$	$\sigma_{vj} = R_{vj} / (L_j-2e_j)$	S_{vj}	$T_{pj} = K\sigma_{vj}S_{vj}$
m	m				kN/m	kN-m/m	m	kN/m^2	m	kN/m
0,4	7	0,38	0,55	0,53	81,90	0,17	0,0020	11,71	0,70	4,38
1	7	0,38	0,55	0,52	204,75	2,52	0,0123	29,35	0,55	8,36
1,5	7	0,38	0,55	0,50	307,13	8,28	0,0270	44,22	0,50	11,13
2	7	0,38	0,55	0,49	409,50	19,08	0,0466	59,29	0,50	14,50
2,5	7	0,38	0,55	0,47	511,88	36,18	0,0707	74,63	0,50	17,72
3	7	0,38	0,55	0,46	614,25	60,65	0,0987	90,30	0,50	20,80
3,5	7	0,38	0,55	0,45	716,63	93,34	0,1302	106,33	0,50	23,74
4	7	0,38	0,55	0,43	819,00	134,89	0,1647	122,78	0,50	26,54
4,5	7	0,38	0,55	0,42	921,38	185,75	0,2016	139,67	0,50	29,20
5	7	0,38	0,55	0,40	1023,75	246,15	0,2404	157,04	0,50	31,72
5,5	7	0,38	0,55	0,39	1126,13	316,10	0,2807	174,90	0,50	34,08
6	7	0,38	0,55	0,38	1228,50	395,43	0,3219	193,27	0,50	36,29
6,5	7	0,38	0,55	0,38	1330,88	502,75	0,3778	213,13	0,50	40,02
7	7	0,38	0,55	0,38	1433,25	627,92	0,4381	234,05	0,50	43,95
7,5	7	0,38	0,55	0,38	1535,63	772,32	0,5029	256,19	0,50	48,10
8	7	0,38	0,55	0,38	1638,00	937,31	0,5722	279,73	0,25	26,26

INTERNAL STABILITY CALCULATIONS - ULTIMATE LIMIT STATE - LOAD CASE A (Tension and Pull Out Resistance [although this is governed by Case B])

3										
Effective Depth	Length of Reinforcement	Earth Pressure		Earth Pressure Selected depending in Depth	Strip Load Tensile Force- T_{sj}					
H	L	Ka	Ko	K	2d-b	Option1 for Dj [if $h_j \leq (2d-b)$]	Option 2 for Dj [if $h_j > (2d-b)$]	D_j	Half distance from above + below reinforcement	Strip Load Tensile Force
$H = z=h_j$		$K_a=\tan^2(45-\phi_b/2)$	$K_o=1-\sin\phi_b$	$K=K_o(1-z/z_o)+(K_a*(z/z_o))$ Or $K=K_a$		$D_j=h_j+b$	$D_j=(h_j+b)/2 + d$		S_{vj}	$T_{sj}=KS_{vj}(f_fS_L/D_j)$
m	m				m	m	m	m	m	kN/m
0,4	7	0,38	0,55	0,53	1,20	4,80	5,20	4,80	0,70	1,56
1	7	0,38	0,55	0,52	1,20	5,40	5,50	5,40	0,55	1,05
1,5	7	0,38	0,55	0,50	1,20	5,90	5,75	5,75	0,50	0,88
2	7	0,38	0,55	0,49	1,20	6,40	6,00	6,00	0,50	0,82
2,5	7	0,38	0,55	0,47	1,20	6,90	6,25	6,25	0,50	0,76
3	7	0,38	0,55	0,46	1,20	7,40	6,50	6,50	0,50	0,71
3,5	7	0,38	0,55	0,45	1,20	7,90	6,75	6,75	0,50	0,66
4	7	0,38	0,55	0,43	1,20	8,40	7,00	7,00	0,50	0,62
4,5	7	0,38	0,55	0,42	1,20	8,90	7,25	7,25	0,50	0,58
5	7	0,38	0,55	0,40	1,20	9,40	7,50	7,50	0,50	0,54
5,5	7	0,38	0,55	0,39	1,20	9,90	7,75	7,75	0,50	0,50
6	7	0,38	0,55	0,38	1,20	10,40	8,00	8,00	0,50	0,47
6,5	7	0,38	0,55	0,38	1,20	10,90	8,25	8,25	0,50	0,46
7	7	0,38	0,55	0,38	1,20	11,40	8,50	8,50	0,50	0,44
7,5	7	0,38	0,55	0,38	1,20	11,90	8,75	8,75	0,50	0,43
8	7	0,38	0,55	0,38	1,20	12,40	9,00	9,00	0,25	0,21

INTERNAL STABILITY CALCULATIONS - ULTIMATE LIMIT STATE - LOAD CASE A (Tension and Pull Out Resistance [although this is governed by Case B])

4												
Effective Depth	Length of Reinforcement	Position of Maximum Tension Line 2 (All Load factors are set to 1)										
H	L	Earth Pressure	Total force acting per unit length of wall	Location of Resultant Force from the bottom of the wall	Only consider the strip load over the reinforced soil over an area of $0.5H_1$ behind the facing	Width of Strip Load (only consider 0.5H1 behind facing)	$\sigma_1=\tan^{-1}(b'/h_1)$	$\sigma_2=\tan^{-1}((a'+b')/H_1)$	Resultant Force	The location of the resultant force P		
$H = z=h_j$		$K=K_o(1-z/z_o)+(K_a*(z/z_o))$ Or $K=K_a$	$Pa=0.5\gamma_r H_1^2 K$	$z'=H_1/3$	$L=0.5H_1$	$a'=0.5H_1-b'$			$P=q/90[H(\sigma_1-\sigma_2)]$	$R=(a'+b')^2(90-\sigma_2)$	$Q=b'^2(90-\sigma_1)$	$z=H-[\{H^2(\sigma_2-\sigma_1)+(R-Q)-57.3a'H\}/2H(\sigma_2-\sigma_1)]$
m	m		kN/m	m	m	m	degrees	degrees	kN/m			m
0,4	7	0,53	255,43	2,33	3,50	0,70	21,80	26,57	7,41	777,08	534,68	4,08
1	7	0,52	247,28	2,33	3,50	0,70	21,80	26,57	7,41	777,08	534,68	4,08
1,5	7	0,50	240,49	2,33	3,50	0,70	21,80	26,57	7,41	777,08	534,68	4,08
2	7	0,49	233,71	2,33	3,50	0,70	21,80	26,57	7,41	777,08	534,68	4,08
2,5	7	0,47	226,92	2,33	3,50	0,70	21,80	26,57	7,41	777,08	534,68	4,08
3	7	0,46	220,13	2,33	3,50	0,70	21,80	26,57	7,41	777,08	534,68	4,08
3,5	7	0,45	213,34	2,33	3,50	0,70	21,80	26,57	7,41	777,08	534,68	4,08
4	7	0,43	206,56	2,33	3,50	0,70	21,80	26,57	7,41	777,08	534,68	4,08
4,5	7	0,42	199,77	2,33	3,50	0,70	21,80	26,57	7,41	777,08	534,68	4,08
5	7	0,40	192,98	2,33	3,50	0,70	21,80	26,57	7,41	777,08	534,68	4,08
5,5	7	0,39	186,19	2,33	3,50	0,70	21,80	26,57	7,41	777,08	534,68	4,08
6	7	0,38	179,41	2,33	3,50	0,70	21,80	26,57	7,41	777,08	534,68	4,08
6,5	7	0,38	179,41	2,33	3,50	0,70	21,80	26,57	7,41	777,08	534,68	4,08
7	7	0,38	179,41	2,33	3,50	0,70	21,80	26,57	7,41	777,08	534,68	4,08
7,5	7	0,38	179,41	2,33	3,50	0,70	21,80	26,57	7,41	777,08	534,68	4,08
8	7	0,38	179,41	2,33	3,50	0,70	21,80	26,57	7,41	777,08	534,68	4,08

INTERNAL STABILITY CALCULATIONS - ULTIMATE LIMIT STATE - LOAD CASE A (Tension and Pull Out Resistance [although this is governed by Case B])

4										
Effective Depth	Length of Reinforcement	Position of Maximum Tension Line 2 (All Load factors are set to 1)								
H	L	Overturning Moment	Resisting Moment	Eccentricity	Stress	Bearing Pressure=Q_m	Total Wall Height	H_1+Q_m/γ	Hm is the greater of H or H_1+Q_m/γ	Line 2 does not exceed this value, however located at the strip load distance within the upper 1/6H of the wall.
$H = z=h_j$		$M_o=P_az'+Pz$	$M_r=[LH\gamma_{r*}(L/2)] + [qa'*(b'+(a'/2))]$	$e=L/2-[(M_r-M_o)/\Sigma V]$	$R_v=LH\gamma_r+qa'$	$q_r=R_v/L-2e$	H		H_m	
m	m	kN-m/m	kN-m/m	m	kN/m	kN/m^2	m	m	m	m
0,4	7	626,19	880,16	1,23	491,75	476,08	8,00	31,41	31,41	31,41
1	7	607,19	880,16	1,19	491,75	442,93	8,00	29,71	29,71	29,71
1,5	7	591,35	880,16	1,16	491,75	418,64	8,00	28,47	28,47	28,47
2	7	575,51	880,16	1,13	491,75	396,88	8,00	27,35	27,35	27,35
2,5	7	559,68	880,16	1,10	491,75	377,27	8,00	26,35	26,35	26,35
3	7	543,84	880,16	1,07	491,75	359,50	8,00	25,44	25,44	25,44
3,5	7	528,00	880,16	1,03	491,75	343,33	8,00	24,61	24,61	24,61
4	7	512,16	880,16	1,00	491,75	328,56	8,00	23,85	23,85	23,85
4,5	7	496,33	880,16	0,97	491,75	315,00	8,00	23,15	23,15	23,15
5	7	480,49	880,16	0,94	491,75	302,52	8,00	22,51	22,51	22,51
5,5	7	464,65	880,16	0,91	491,75	290,99	8,00	21,92	21,92	21,92
6	7	448,81	880,16	0,87	491,75	280,31	8,00	21,37	21,37	21,37
6,5	7	448,81	880,16	0,87	491,75	280,31	8,00	21,37	21,37	21,37
7	7	448,81	880,16	0,87	491,75	280,31	8,00	21,37	21,37	21,37
7,5	7	448,81	880,16	0,87	491,75	280,31	8,00	21,37	21,37	21,37
8	7	448,81	880,16	0,87	491,75	280,31	8,00	21,37	21,37	21,37

INTERNAL STABILITY CALCULATIONS - ULTIMATE LIMIT STATE - LOAD CASE A (Tension and Pull Out Resistance [although this is governed by Case B])

5										
Effective Depth	Length of Reinforcement	Tension in the Reinforcement								
H $H = z = h_j$	L	d+b/2	H_1	Z_0 is the minimum of (d+b/2) and H_1	Z_1 is width b of the strip load	X = Width of the active zone at underside of strip footing.	$Z_2=1.5(H_1/2 - X)$	h_j	$\alpha_0 = 0.85$ (if $h_j \le Z_2$) OR $\alpha_0=1-0.15(H_1-h_j)/H_1-z_2)$ (if $h_j > z_2$)	$\alpha_1= 1$ (if $hj \le z1$) OR $\alpha_1=\alpha_0+(1-\alpha_0)(z_0-h_j)/(Z_0-Z_1)$ (if $z_1<h_j<z_0$) OR $\alpha_1=\alpha_0$ (if $h_j \ge z_0$)
m	m	m	m	m	m	m	m	m		
0,4	7	7,20	7,00	7,00	4,40	7,20	-5,55	0,40	0,92	1,00
1	7	7,20	7,00	7,00	4,40	7,20	-5,55	1,00	0,93	1,00
1,5	7	7,20	7,00	7,00	4,40	7,20	-5,55	1,50	0,93	1,00
2	7	7,20	7,00	7,00	4,40	7,20	-5,55	2,00	0,94	1,00
2,5	7	7,20	7,00	7,00	4,40	7,20	-5,55	2,50	0,95	1,00
3	7	7,20	7,00	7,00	4,40	7,20	-5,55	3,00	0,95	1,00
3,5	7	7,20	7,00	7,00	4,40	7,20	-5,55	3,50	0,96	1,00
4	7	7,20	7,00	7,00	4,40	7,20	-5,55	4,00	0,96	1,00
4,5	7	7,20	7,00	7,00	4,40	7,20	-5,55	4,50	0,97	1,00
5	7	7,20	7,00	7,00	4,40	7,20	-5,55	5,00	0,98	0,99
5,5	7	7,20	7,00	7,00	4,40	7,20	-5,55	5,50	0,98	0,99
6	7	7,20	7,00	7,00	4,40	7,20	-5,55	6,00	0,99	0,99
6,5	7	7,20	7,00	7,00	4,40	7,20	-5,55	6,50	0,99	1,00
7	7	7,20	7,00	7,00	4,40	7,20	-5,55	7,00	1,00	1,00
7,5	7	7,20	7,00	7,00	4,40	7,20	-5,55	7,50	1,01	1,01
8	7	7,20	7,00	7,00	4,40	7,20	-5,55	8,00	1,01	1,01

INTERNAL STABILITY CALCULATIONS - ULTIMATE LIMIT STATE - LOAD CASE A (Tension and Pull Out Resistance [although this is governed by Case B])

5				
Effective Depth	Length of Reinforcement	Tension in the Reinforcement		
H	L	Tension at Facing (T_{fj} not applicable)	Tension at Line 1 (T_{fj} not applicable)	Tension at Line 2 (T_{fj} not applicable)
$H = z = h_j$		$T_j = \alpha_0 T_{pj} + T_{sj}$	$T_j = \alpha_1 T_{pj} + T_{sj}$	$T_j = T_{pj} + T_{sj}$
m	m	kN/m	kN/m	kN/m
0,4	7	5,60	5,94	5,94
1	7	8,81	9,41	9,41
1,5	7	11,27	12,00	12,00
2	7	14,45	15,32	15,32
2,5	7	17,53	18,48	18,48
3	7	20,52	21,51	21,51
3,5	7	23,41	24,40	24,40
4	7	26,21	27,16	27,16
4,5	7	28,91	29,74	29,78
5	7	31,50	32,08	32,26
5,5	7	33,97	34,33	34,59
6	7	36,33	36,49	36,76
6,5	7	40,23	40,28	40,47
7	7	44,39	44,39	44,39
7,5	7	48,82	48,82	48,53
8	7	26,78	26,78	26,47

INTERNAL STABILITY CALCULATIONS - ULTIMATE LIMIT STATE - LOAD CASE A (Tension and Pull Out Resistance [although this is governed by Case B])

6										7
Effective Depth	Adherence Capacity of Reinforcement									Facing Connection
H	Wall Height *1/6	Total Length of Reinforcement	Length of Reinforcement in the Failure zone	Length of reinforcement beyond the line of maximum tension	Adherence Capacity of Reinforcement	$f_{fs}s_v$	$L^2/2 - (L-L_{aj})^2/2$	$(2B\mu/f_pf_n)*(f_{fs}s_v)*(L^2/2 - (L-L_{aj})^2/2)$	Tension at Line 2 (Worst case is at Tension line 2)	
$H = z=h_j$		L	L_{aj}	$L_{ej} = L-L_{aj}$	$2B\mu/f_pf_n$				T_j	85% at depths <0.6H and 100% at depths >0.6H
m	m	m	m	m				kN/m	kN/m	kN/m
0,4	1,33	7,00	7	0,00	0,08	17,56	24,50	32,49	5,94	5,05
1	1,33	7,00	7	0,00	0,08	44,03	24,50	81,47	9,41	8,00
1,5	1,33	7,00	6,825	0,18	0,08	66,32	24,48	122,64	12,00	10,20
2	1,33	7,00	6,3	0,70	0,08	88,93	24,26	162,91	15,32	13,02
2,5	1,33	7,00	5,775	1,23	0,08	111,95	23,75	200,80	18,48	15,71
3	1,33	7,00	5,25	1,75	0,08	135,45	22,97	234,96	21,51	18,29
3,5	1,33	7,00	4,725	2,28	0,08	159,50	21,91	263,95	24,40	20,74
4	1,33	7,00	4,2	2,80	0,08	184,17	20,58	286,25	27,16	23,09
4,5	1,33	7,00	3,675	3,33	0,08	209,51	18,97	300,19	29,78	29,78
5	1,33	7,00	3,15	3,85	0,08	235,56	17,09	304,01	32,26	32,26
5,5	1,33	7,00	2,625	4,38	0,08	262,35	14,93	295,82	34,59	34,59
6	1,33	7,00	2,1	4,90	0,08	289,91	12,50	273,58	36,76	36,76
6,5	1,33	7,00	1,575	5,43	0,08	319,69	9,78	236,25	40,47	40,47
7	1,33	7,00	1,05	5,95	0,08	351,07	6,80	180,26	44,39	44,39
7,5	1,33	7,00	0,525	6,48	0,08	384,28	3,54	102,66	48,53	48,53
8	1,33	7,00	0	7,00	0,08	419,60	0,00	0,00	26,47	26,47

INTERNAL STABILITY CALCULATIONS - ULTIMATE LIMIT STATE - LOAD CASE A (Tension and Pull Out Resistance [although this is governed by Case B])

8												
Effective Depth	Length of Reinforcement	Reinforcement Design Strength										
H	L	Paraweb Short-term Strength from BBA	Number of Straps across 1 Facing Panel	Total T_{char} across Facing Panel	Reduction Factor for Creep from BBA	Long-term Tensile Creep Rupture Strength of Paraweb	Partial Factor for Ramifications of Failure	Reduction Factor for Installation Damage	Reduction Factor for Weathering	Reduction Factor for Chemical / Environmental Effects	Safety factor for the Extrapolation of Data	Material Safety Factor
$H = z=h_j$		T_{char}	No. Straps	Total T_{char} = T_{char} * No. Straps	RF_{CR} (for a Design Temperature of 20°C)	$T_{cr} = T_{char} / RF_{CR}$	f_n (for Retaining Structures)	RF_{ID}	RF_W	RF_{CH}	f_s	$f_m = RF_{ID}*RF_W*RF_{CH}*f_s$
m	m	kN		kN		kN						
0,4	7	75	4	300	1,38	217,39	1	1,05	1	1,05	1,05	1,16
1	7	75	4	300	1,38	217,39	1	1,05	1	1,05	1,05	1,16
1,5	7	75	4	300	1,38	217,39	1	1,05	1	1,05	1,05	1,16
2	7	75	4	300	1,38	217,39	1	1,05	1	1,05	1,05	1,16
2,5	7	75	4	300	1,38	217,39	1	1,05	1	1,05	1,05	1,16
3	7	75	4	300	1,38	217,39	1	1,05	1	1,05	1,05	1,16
3,5	7	75	4	300	1,38	217,39	1	1,05	1	1,05	1,05	1,16
4	7	75	4	300	1,38	217,39	1	1,05	1	1,05	1,05	1,16
4,5	7	75	4	300	1,38	217,39	1	1,05	1	1,05	1,05	1,16
5	7	75	4	300	1,38	217,39	1	1,05	1	1,05	1,05	1,16
5,5	7	75	4	300	1,38	217,39	1	1,05	1	1,05	1,05	1,16
6	7	75	4	300	1,38	217,39	1	1,05	1	1,05	1,05	1,16
6,5	7	75	4	300	1,38	217,39	1	1,05	1	1,05	1,05	1,16
7	7	75	4	300	1,38	217,39	1	1,05	1	1,05	1,05	1,16
7,5	7	75	4	300	1,38	217,39	1	1,05	1	1,05	1,05	1,16
8	7	75	4	300	1,38	217,39	1	1,05	1	1,05	1,05	1,16

INTERNAL STABILITY CALCULATIONS - ULTIMATE LIMIT STATE - LOAD CASE A (Tension and Pull Out Resistance [although this is governed by Case B])

8						
Effective Depth	Length of Reinforcement	Reinforcement Design Strength				
H	L	Design Strength of Paraweb Strap	Width of Paraweb x 4 Straps (Across a facing panel)	Width of the Facing Panel	Paraweb Coverage Ratio	Design Strength (Factoring Coverage)
$H = z=h_j$		$T_D = T_{CR} / (f_n*f_m)$				
m	m	kN	m	m	%	kN/m
0,4	7	187,79	0,36	1,5	0,24	45,07
1	7	187,79	0,36	1,5	0,24	45,07
1,5	7	187,79	0,36	1,5	0,24	45,07
2	7	187,79	0,36	1,5	0,24	45,07
2,5	7	187,79	0,36	1,5	0,24	45,07
3	7	187,79	0,36	1,5	0,24	45,07
3,5	7	187,79	0,36	1,5	0,24	45,07
4	7	187,79	0,36	1,5	0,24	45,07
4,5	7	187,79	0,36	1,5	0,24	45,07
5	7	187,79	0,36	1,5	0,24	45,07
5,5	7	187,79	0,36	1,5	0,24	45,07
6	7	187,79	0,36	1,5	0,24	45,07
6,5	7	187,79	0,36	1,5	0,24	45,07
7	7	187,79	0,36	1,5	0,24	45,07
7,5	7	187,79	0,36	1,5	0,24	45,07
8	7	187,79	0,36	1,5	0,24	45,07

INTERNAL STABILITY CALCULATIONS - ULTIMATE LIMIT STATE - LOAD CASE B (Pull Out Resistance)

1					2					
Effective Depth	Length of Reinforcement	Earth Pressure		Earth Pressure Selected depending in Depth	Vertical Loading due to Self Weight - T_{pj}					
H	L	Ka	Ko	K	Vertical Loading - Rv	Overturning Moment - Mo	Eccentricity - e	Vertical Stress	Half distance from above + below reinforcement	Vertical Loading due to Self Weight
$H = z=h_j$		$K_a=\tan^2(45-\phi_b/2)$	$K_o=1-\sin\phi_b$	$K=K_o(1-z/z_o)+(K_a*(z/z_o))$ Or $K=K_a$	$R_{vj}=f_{fs}*\gamma_r*L*H$	$M_o=0.5*f_{fs}*\gamma_r*H^2*K*(H/3)$	$e_j=M_o/R_{vj}$	$\sigma_{vj} = R_{vj} / (L_j-2e_j)$	S_{vj}	$T_{pj} = K\sigma_{vj}S_{vj}$
m	m				kN/m	kN-m/m	m	kN/m^2	m	kN/m
0,4	7	0,38	0,55	0,53	54,60	0,11	0,0020	7,80	0,70	2,92
1	7	0,38	0,55	0,52	136,50	1,68	0,0123	19,57	0,55	5,57
1,5	7	0,38	0,55	0,50	204,75	5,52	0,0270	29,48	0,50	7,42
2	7	0,38	0,55	0,49	273,00	12,72	0,0466	39,53	0,50	9,67
2,5	7	0,38	0,55	0,47	341,25	24,12	0,0707	49,75	0,50	11,82
3	7	0,38	0,55	0,46	409,50	40,43	0,0987	60,20	0,50	13,87
3,5	7	0,38	0,55	0,45	477,75	62,23	0,1302	70,89	0,50	15,83
4	7	0,38	0,55	0,43	546,00	89,93	0,1647	81,85	0,50	17,69
4,5	7	0,38	0,55	0,42	614,25	123,84	0,2016	93,11	0,50	19,47
5	7	0,38	0,55	0,40	682,50	164,10	0,2404	104,69	0,50	21,14
5,5	7	0,38	0,55	0,39	750,75	210,74	0,2807	116,60	0,50	22,72
6	7	0,38	0,55	0,38	819,00	263,62	0,3219	128,85	0,50	24,19
6,5	7	0,38	0,55	0,38	887,25	335,17	0,3778	142,09	0,50	26,68
7	7	0,38	0,55	0,38	955,50	418,62	0,4381	156,03	0,50	29,30
7,5	7	0,38	0,55	0,38	1023,75	514,88	0,5029	170,79	0,50	32,07
8	7	0,38	0,55	0,38	1092,00	624,87	0,5722	186,49	0,25	17,51

INTERNAL STABILITY CALCULATIONS - ULTIMATE LIMIT STATE - LOAD CASE B (Pull Out Resistance)

3										
Effective Depth	Length of Reinforcement	Earth Pressure		Earth Pressure Selected depending in Depth	Strip Load Tensile Force- T_{sj}					
H	L	Ka	Ko	K	2d-b	Option1 for Dj [if $h_j \leq (2d\text{-}b)$]	Option 2 for Dj [if $h_j > (2d\text{-}b)$]	D_j	Half distance from above + below reinforcement	Strip Load Tensile Force
$H = z=h_j$		$K_a=\tan^2(45-\phi_b/2)$	$K_o=1-\sin\phi_b$	$K=K_o(1-z/z_o)+(K_a*(z/z_o))$ Or $K=K_a$		$D_j=h_j+b$	$D_j=(h_j+b)/2 + d$		S_{vj}	$T_{sj}=KS_{vj}(f_fS_L/D_j)$
m	m				m	m	m	m	m	kN/m
0,4	7	0,38	0,55	0,53	1,20	4,80	5,20	4,80	0,70	1,56
1	7	0,38	0,55	0,52	1,20	5,40	5,50	5,40	0,55	1,05
1,5	7	0,38	0,55	0,50	1,20	5,90	5,75	5,75	0,50	0,88
2	7	0,38	0,55	0,49	1,20	6,40	6,00	6,00	0,50	0,82
2,5	7	0,38	0,55	0,47	1,20	6,90	6,25	6,25	0,50	0,76
3	7	0,38	0,55	0,46	1,20	7,40	6,50	6,50	0,50	0,71
3,5	7	0,38	0,55	0,45	1,20	7,90	6,75	6,75	0,50	0,66
4	7	0,38	0,55	0,43	1,20	8,40	7,00	7,00	0,50	0,62
4,5	7	0,38	0,55	0,42	1,20	8,90	7,25	7,25	0,50	0,58
5	7	0,38	0,55	0,40	1,20	9,40	7,50	7,50	0,50	0,54
5,5	7	0,38	0,55	0,39	1,20	9,90	7,75	7,75	0,50	0,50
6	7	0,38	0,55	0,38	1,20	10,40	8,00	8,00	0,50	0,47
6,5	7	0,38	0,55	0,38	1,20	10,90	8,25	8,25	0,50	0,46
7	7	0,38	0,55	0,38	1,20	11,40	8,50	8,50	0,50	0,44
7,5	7	0,38	0,55	0,38	1,20	11,90	8,75	8,75	0,50	0,43
8	7	0,38	0,55	0,38	1,20	12,40	9,00	9,00	0,25	0,21

INTERNAL STABILITY CALCULATIONS - ULTIMATE LIMIT STATE - LOAD CASE B (Pull Out Resistance)

4													
Effective Depth	Length of Reinforcement	Position of Maximum Tension Line 2 (All Load factors are set to 1)											
H	L	Earth Pressure	Total force acting per unit length of wall	Location of Resultant Force from the bottom of the wall	Only consider the strip load over the reinforced soil over an area of $0.5H_1$ behind the facing	Width of Strip Load (only consider 0.5H1 behind facing)	$\sigma_1=\tan^{-1}(b'/h_1)$	$\sigma_2=\tan^{-1}((a'+b')/H_1)$	Resultant Force	The location of the resultant force P			
$H = z=h_j$		$K=K_o(1-z/z_o)+(K_a*(z/z_o))$ Or $K=K_a$	$Pa=0.5\gamma_r H_1^2K$	$z'=H_1/3$	$L=0.5H_1$	$a'=0.5H_1-b'$			$P=q/90[H(\sigma_1-\sigma_2)]$	$R=(a'+b')^2(90-\sigma_2)$	$Q=b'^2(90-\sigma_1)$	$z=H-[\{H^2(\sigma_2-\sigma_1)+(R-Q)-57.3a'H\}/2H(\sigma_2-\sigma_1)]$
m	m		kN/m	m	m	m	degrees	degrees	kN/m			m
0,4	7	0,53	255,43	2,33	3,50	0,70	21,80	26,57	7,41	777,08	534,68	4,08
1	7	0,52	247,28	2,33	3,50	0,70	21,80	26,57	7,41	777,08	534,68	4,08
1,5	7	0,50	240,49	2,33	3,50	0,70	21,80	26,57	7,41	777,08	534,68	4,08
2	7	0,49	233,71	2,33	3,50	0,70	21,80	26,57	7,41	777,08	534,68	4,08
2,5	7	0,47	226,92	2,33	3,50	0,70	21,80	26,57	7,41	777,08	534,68	4,08
3	7	0,46	220,13	2,33	3,50	0,70	21,80	26,57	7,41	777,08	534,68	4,08
3,5	7	0,45	213,34	2,33	3,50	0,70	21,80	26,57	7,41	777,08	534,68	4,08
4	7	0,43	206,56	2,33	3,50	0,70	21,80	26,57	7,41	777,08	534,68	4,08
4,5	7	0,42	199,77	2,33	3,50	0,70	21,80	26,57	7,41	777,08	534,68	4,08
5	7	0,40	192,98	2,33	3,50	0,70	21,80	26,57	7,41	777,08	534,68	4,08
5,5	7	0,39	186,19	2,33	3,50	0,70	21,80	26,57	7,41	777,08	534,68	4,08
6	7	0,38	179,41	2,33	3,50	0,70	21,80	26,57	7,41	777,08	534,68	4,08
6,5	7	0,38	179,41	2,33	3,50	0,70	21,80	26,57	7,41	777,08	534,68	4,08
7	7	0,38	179,41	2,33	3,50	0,70	21,80	26,57	7,41	777,08	534,68	4,08
7,5	7	0,38	179,41	2,33	3,50	0,70	21,80	26,57	7,41	777,08	534,68	4,08
8	7	0,38	179,41	2,33	3,50	0,70	21,80	26,57	7,41	777,08	534,68	4,08

INTERNAL STABILITY CALCULATIONS - ULTIMATE LIMIT STATE - LOAD CASE B (Pull Out Resistance)

4										
Effective Depth	Length of Reinforcement	Position of Maximum Tension Line 2 (All Load factors are set to 1)								
H		Overturning Moment	Resisting Moment	Eccentricity	Stress	Bearing Pressure=Q_m	Total Wall Height		Hm is the greater of H or H_1+Q_m/γ	Line 2 does not exceed this value, however located at the strip load distance within the upper 1/6H of the wall.
$H = z=h_j$	L	$M_o=P_a z'+Pz$	$M_r=[LH\gamma_{r^*}(L/2)] + [qa'^*(b'+(a'/2))]$	$e=L/2-[(M_r-M_o)/\Sigma V]$	$R_v=LH\gamma_r+qa'$	$q_r=R_v/L-2e$	H	H_1+Q_m/γ	H_m	
m	m	kN-m/m	kN-m/m	m	kN/m	kN/m^2	m	m	m	m
0,4	7	626,19	880,16	1,23	491,75	476,08	8,00	31,41	31,41	31,41
1	7	607,19	880,16	1,19	491,75	442,93	8,00	29,71	29,71	29,71
1,5	7	591,35	880,16	1,16	491,75	418,64	8,00	28,47	28,47	28,47
2	7	575,51	880,16	1,13	491,75	396,88	8,00	27,35	27,35	27,35
2,5	7	559,68	880,16	1,10	491,75	377,27	8,00	26,35	26,35	26,35
3	7	543,84	880,16	1,07	491,75	359,50	8,00	25,44	25,44	25,44
3,5	7	528,00	880,16	1,03	491,75	343,33	8,00	24,61	24,61	24,61
4	7	512,16	880,16	1,00	491,75	328,56	8,00	23,85	23,85	23,85
4,5	7	496,33	880,16	0,97	491,75	315,00	8,00	23,15	23,15	23,15
5	7	480,49	880,16	0,94	491,75	302,52	8,00	22,51	22,51	22,51
5,5	7	464,65	880,16	0,91	491,75	290,99	8,00	21,92	21,92	21,92
6	7	448,81	880,16	0,87	491,75	280,31	8,00	21,37	21,37	21,37
6,5	7	448,81	880,16	0,87	491,75	280,31	8,00	21,37	21,37	21,37
7	7	448,81	880,16	0,87	491,75	280,31	8,00	21,37	21,37	21,37
7,5	7	448,81	880,16	0,87	491,75	280,31	8,00	21,37	21,37	21,37
8	7	448,81	880,16	0,87	491,75	280,31	8,00	21,37	21,37	21,37

INTERNAL STABILITY CALCULATIONS - ULTIMATE LIMIT STATE - LOAD CASE B (Pull Out Resistance)

5										
Effective Depth	Length of Reinforcement	Tension in the Reinforcement								
H $H = z = h_j$	L	d+b/2	H_1	Z_0 is the minimum of (d+b/2) and H_1	Z_1 is width b of the strip load	X = Width of the active zone at underside of strip footing.	$Z_2=1.5(H_1/2 - X)$	h_j	$\alpha_0 = 0.85$ (if $h_j \leq Z_2$) OR $\alpha_0=1-0.15(H_1-h_j)/H_1-z_2)$ (if $h_j > z_2$)	$\alpha_1= 1$ (if $hj \leq z1$) OR $\alpha_1=\alpha_0+(1-\alpha_0)(z_0-h_j)/(Z_0-Z_1)$ (if $z_1<h_j<z_0$) OR $\alpha_1=\alpha_0$ (if $h_j \geq z_0$)
m	m	m	m	m	m	m	m	m		
0,4	7	7,20	7,00	7,00	4,40	7,20	-5,55	0,40	0,92	1,00
1	7	7,20	7,00	7,00	4,40	7,20	-5,55	1,00	0,93	1,00
1,5	7	7,20	7,00	7,00	4,40	7,20	-5,55	1,50	0,93	1,00
2	7	7,20	7,00	7,00	4,40	7,20	-5,55	2,00	0,94	1,00
2,5	7	7,20	7,00	7,00	4,40	7,20	-5,55	2,50	0,95	1,00
3	7	7,20	7,00	7,00	4,40	7,20	-5,55	3,00	0,95	1,00
3,5	7	7,20	7,00	7,00	4,40	7,20	-5,55	3,50	0,96	1,00
4	7	7,20	7,00	7,00	4,40	7,20	-5,55	4,00	0,96	1,00
4,5	7	7,20	7,00	7,00	4,40	7,20	-5,55	4,50	0,97	1,00
5	7	7,20	7,00	7,00	4,40	7,20	-5,55	5,00	0,98	0,99
5,5	7	7,20	7,00	7,00	4,40	7,20	-5,55	5,50	0,98	0,99
6	7	7,20	7,00	7,00	4,40	7,20	-5,55	6,00	0,99	0,99
6,5	7	7,20	7,00	7,00	4,40	7,20	-5,55	6,50	0,99	1,00
7	7	7,20	7,00	7,00	4,40	7,20	-5,55	7,00	1,00	1,00
7,5	7	7,20	7,00	7,00	4,40	7,20	-5,55	7,50	1,01	1,01
8	7	7,20	7,00	7,00	4,40	7,20	-5,55	8,00	1,01	1,01

INTERNAL STABILITY CALCULATIONS - ULTIMATE LIMIT STATE - LOAD CASE B (Pull Out Resistance)

5				
Effective Depth	Length of Reinforcement	Tension in the Reinforcement		
H	L	Tension at Facing (T_{fj} not applicable)	Tension at Line 1 (T_{fj} not applicable)	Tension at Line 2 (T_{fj} not applicable)
$H = z = h_j$		$T_j = \alpha_0 T_{pj} + T_{sj}$	$T_j = \alpha_1 T_{pj} + T_{sj}$	$T_j = T_{pj} + T_{sj}$
m	m	kN/m	kN/m	kN/m
0,4	7	4,25	4,48	4,48
1	7	6,23	6,63	6,63
1,5	7	7,81	8,29	8,29
2	7	9,91	10,48	10,48
2,5	7	11,94	12,58	12,58
3	7	13,91	14,58	14,58
3,5	7	15,83	16,49	16,49
4	7	17,68	18,31	18,31
4,5	7	19,46	20,02	20,04
5	7	21,18	21,57	21,68
5,5	7	22,82	23,05	23,22
6	7	24,37	24,48	24,66
6,5	7	26,97	27,00	27,13
7	7	29,74	29,74	29,74
7,5	7	32,69	32,69	32,50
8	7	17,93	17,93	17,72

INTERNAL STABILITY CALCULATIONS - ULTIMATE LIMIT STATE - LOAD CASE B (Pull Out Resistance)

6										7
Effective Depth	Adherence Capacity of Reinforcement									Facing Connection
H	Wall Height *1/6	Total Length of Reinforcement	Length of Reinforcement in the Failure zone	Length of reinforcement beyond the line of maximum tension	Adherence Capacity of Reinforcement	$f_{fs}s_v$	$L^2/2 - (L-L_{aj})^2/2$	$(2Bm / f_pf_n)*(f_{fs} s_v)*(L^2/2 - (L-L_{aj})^2/2)$	Tension at Line 2 (Worst case is at Tension line 2)	
$H = z=h_j$		L	L_{aj}	$L_{ej} = L-L_{aj}$	$2Bm/f_pf_n$				T_j	85% at depths <0.6H and 100% at depths >0.6H
m	m	m	m	m				kN/m	kN/m	kN/m
0,4	1,33	7,00	7	0,00	0,08	7,80	24,50	14,44	4,48	3,81
1	1,33	7,00	7	0,00	0,08	19,57	24,50	36,21	6,63	5,63
1,5	1,33	7,00	6,825	0,18	0,08	29,48	24,48	54,51	8,29	7,05
2	1,33	7,00	6,3	0,70	0,08	39,53	24,26	72,41	10,48	8,91
2,5	1,33	7,00	5,775	1,23	0,08	49,75	23,75	89,24	12,58	10,69
3	1,33	7,00	5,25	1,75	0,08	60,20	22,97	104,43	14,58	12,39
3,5	1,33	7,00	4,725	2,28	0,08	70,89	21,91	117,31	16,49	14,02
4	1,33	7,00	4,2	2,80	0,08	81,85	20,58	127,22	18,31	15,57
4,5	1,33	7,00	3,675	3,33	0,08	93,11	18,97	133,42	20,04	20,04
5	1,33	7,00	3,15	3,85	0,08	104,69	17,09	135,12	21,68	21,68
5,5	1,33	7,00	2,625	4,38	0,08	116,60	14,93	131,47	23,22	23,22
6	1,33	7,00	2,1	4,90	0,08	128,85	12,50	121,59	24,66	24,66
6,5	1,33	7,00	1,575	5,43	0,08	142,09	9,78	105,00	27,13	27,13
7	1,33	7,00	1,05	5,95	0,08	156,03	6,80	80,12	29,74	29,74
7,5	1,33	7,00	0,525	6,48	0,08	170,79	3,54	45,63	32,50	32,50
8	1,33	7,00	0	7,00	0,08	186,49	0,00	0,00	17,72	17,72

INTERNAL STABILITY CALCULATIONS - ULTIMATE LIMIT STATE - LOAD CASE B (Pull Out Resistance)

8												
Effective Depth	Length of Reinforcement	Reinforcement Design Strength										
H	L	Paraweb Short-term Strength from BBA	Number of Straps across 1 Facing Panel	Total T_{char} across Facing Panel	Reduction Factor for Creep from BBA	Long-term Tensile Creep Rupture Strength of Paraweb	Partial Factor for Ramifications of Failure	Reduction Factor for Installation Damage	Reduction Factor for Weathering	Reduction Factor for Chemical / Environmental Effects	Safety factor for the Extrapolation of Data	Material Safety Factor
$H = z = h_j$		T_{char}	No. Straps	Total T_{char} = T_{char} * No. Straps	RF_{CR} (for a Design Temperature of 20°C)	$T_{cr} = T_{char} / RF_{CR}$	f_n (for Retaining Structures)	RF_{ID}	RF_W	RF_{CH}	f_s	$f_m = RF_{ID}*RF_W*RF_{CH}*f_s$
m	m	kN		kN		kN						
0,4	7	75	4	300	1,38	217,39	1	1,05	1	1,05	1,05	1,16
1	7	75	4	300	1,38	217,39	1	1,05	1	1,05	1,05	1,16
1,5	7	75	4	300	1,38	217,39	1	1,05	1	1,05	1,05	1,16
2	7	75	4	300	1,38	217,39	1	1,05	1	1,05	1,05	1,16
2,5	7	75	4	300	1,38	217,39	1	1,05	1	1,05	1,05	1,16
3	7	75	4	300	1,38	217,39	1	1,05	1	1,05	1,05	1,16
3,5	7	75	4	300	1,38	217,39	1	1,05	1	1,05	1,05	1,16
4	7	75	4	300	1,38	217,39	1	1,05	1	1,05	1,05	1,16
4,5	7	75	4	300	1,38	217,39	1	1,05	1	1,05	1,05	1,16
5	7	75	4	300	1,38	217,39	1	1,05	1	1,05	1,05	1,16
5,5	7	75	4	300	1,38	217,39	1	1,05	1	1,05	1,05	1,16
6	7	75	4	300	1,38	217,39	1	1,05	1	1,05	1,05	1,16
6,5	7	75	4	300	1,38	217,39	1	1,05	1	1,05	1,05	1,16
7	7	75	4	300	1,38	217,39	1	1,05	1	1,05	1,05	1,16
7,5	7	75	4	300	1,38	217,39	1	1,05	1	1,05	1,05	1,16
8	7	75	4	300	1,38	217,39	1	1,05	1	1,05	1,05	1,16

INTERNAL STABILITY CALCULATIONS - ULTIMATE LIMIT STATE - LOAD CASE B (Pull Out Resistance)

8						
Effective Depth	Length of Reinforcement	Reinforcement Design Strength				
H	L	Design Strength of Paraweb Strap	Width of Paraweb x 4 Straps (Across a facing panel)	Width of the Facing Panel	Paraweb Coverage Ratio	Design Strength (Factoring Coverage)
$H = z{=}h_j$		$T_D = T_{CR} / (f_n{*}f_m)$				
m	m	kN	m	m	%	kN/m
0,4	7	187,79	0,36	1,5	0,24	45,07
1	7	187,79	0,36	1,5	0,24	45,07
1,5	7	187,79	0,36	1,5	0,24	45,07
2	7	187,79	0,36	1,5	0,24	45,07
2,5	7	187,79	0,36	1,5	0,24	45,07
3	7	187,79	0,36	1,5	0,24	45,07
3,5	7	187,79	0,36	1,5	0,24	45,07
4	7	187,79	0,36	1,5	0,24	45,07
4,5	7	187,79	0,36	1,5	0,24	45,07
5	7	187,79	0,36	1,5	0,24	45,07
5,5	7	187,79	0,36	1,5	0,24	45,07
6	7	187,79	0,36	1,5	0,24	45,07
6,5	7	187,79	0,36	1,5	0,24	45,07
7	7	187,79	0,36	1,5	0,24	45,07
7,5	7	187,79	0,36	1,5	0,24	45,07
8	7	187,79	0,36	1,5	0,24	45,07

INTERNAL STABILITY CALCULATIONS - SERVICEABILITY LIMIT STATE - LOAD CASE C

1					2					
Effective Depth	Length of Reinforcement	Earth Pressure		Earth Pressure Selected depending in Depth	Vertical Loading due to Self Weight - T_{pj}					
H	L	Ka	Ko	K	Vertical Loading - Rv	Overturning Moment - Mo	Eccentricity - e	Vertical Stress	Half distance from above + below reinforcement	Vertical Loading due to Self Weight
$H = z = h_j$		$K_a = \tan^2(45-\phi_b/2)$	$K_o = 1-\sin\phi_b$	$K = K_o(1-z/z_o)+(K_a*(z/z_o))$ Or $K = K_a$	$R_{vj} = f_{fs}*\gamma_r*L*H$	$M_o = 0.5*f_{fs}*\gamma_r*H^2*K*(H/3)$	$e_j = M_o/R_{vj}$	$\sigma_{vj} = R_{vj} / (L_j-2e_j)$	S_{vj}	$T_{pj} = K\sigma_{vj}S_{vj}$
m	m				kN/m	kN-m/m	m	kN/m^2	m	kN/m
0,4	7	0,38	0,55	0,53	54,60	0,11	0,0020	7,80	0,70	2,92
1	7	0,38	0,55	0,52	136,50	1,68	0,0123	19,57	0,55	5,57
1,5	7	0,38	0,55	0,50	204,75	5,52	0,0270	29,48	0,50	7,42
2	7	0,38	0,55	0,49	273,00	12,72	0,0466	39,53	0,50	9,67
2,5	7	0,38	0,55	0,47	341,25	24,12	0,0707	49,75	0,50	11,82
3	7	0,38	0,55	0,46	409,50	40,43	0,0987	60,20	0,50	13,87
3,5	7	0,38	0,55	0,45	477,75	62,23	0,1302	70,89	0,50	15,83
4	7	0,38	0,55	0,43	546,00	89,93	0,1647	81,85	0,50	17,69
4,5	7	0,38	0,55	0,42	614,25	123,84	0,2016	93,11	0,50	19,47
5	7	0,38	0,55	0,40	682,50	164,10	0,2404	104,69	0,50	21,14
5,5	7	0,38	0,55	0,39	750,75	210,74	0,2807	116,60	0,50	22,72
6	7	0,38	0,55	0,38	819,00	263,62	0,3219	128,85	0,50	24,19
6,5	7	0,38	0,55	0,38	887,25	335,17	0,3778	142,09	0,50	26,68
7	7	0,38	0,55	0,38	955,50	418,62	0,4381	156,03	0,50	29,30
7,5	7	0,38	0,55	0,38	1023,75	514,88	0,5029	170,79	0,50	32,07
8	7	0,38	0,55	0,38	1092,00	624,87	0,5722	186,49	0,25	17,51

INTERNAL STABILITY CALCULATIONS - SERVICEABILITY LIMIT STATE - LOAD CASE C

3											
Effective Depth	Length of Reinforcement	Earth Pressure		Earth Pressure Selected depending in Depth	Strip Load Tensile Force- T_{sj}						
H	L	Ka	Ko	K	2d-b	Option1 for Dj [if $h_j \le (2d-b)$]	Option 2 for Dj [if $h_j > (2d-b)$]	D_j	Half distance from above + below reinforcement	Strip Load Tensile Force
$H = z=h_j$		$K_a=\tan^2(45-\phi_b/2)$	$K_o=1-\sin\phi_b$	$K=K_o(1-z/z_o)+(K_a*(z/z_o))$ Or $K=K_a$		$D_j=h_j+b$	$D_j=(h_j+b)/2 + d$		S_{vj}	$T_{sj}=KS_{vj}(f_fS_L/D_j)$
m	m				m	m	m	m	m	kN/m
0,4	7	0,38	0,55	0,53	1,20	4,80	5,20	4,80	0,70	1,56
1	7	0,38	0,55	0,52	1,20	5,40	5,50	5,40	0,55	1,05
1,5	7	0,38	0,55	0,50	1,20	5,90	5,75	5,75	0,50	0,88
2	7	0,38	0,55	0,49	1,20	6,40	6,00	6,00	0,50	0,82
2,5	7	0,38	0,55	0,47	1,20	6,90	6,25	6,25	0,50	0,76
3	7	0,38	0,55	0,46	1,20	7,40	6,50	6,50	0,50	0,71
3,5	7	0,38	0,55	0,45	1,20	7,90	6,75	6,75	0,50	0,66
4	7	0,38	0,55	0,43	1,20	8,40	7,00	7,00	0,50	0,62
4,5	7	0,38	0,55	0,42	1,20	8,90	7,25	7,25	0,50	0,58
5	7	0,38	0,55	0,40	1,20	9,40	7,50	7,50	0,50	0,54
5,5	7	0,38	0,55	0,39	1,20	9,90	7,75	7,75	0,50	0,50
6	7	0,38	0,55	0,38	1,20	10,40	8,00	8,00	0,50	0,47
6,5	7	0,38	0,55	0,38	1,20	10,90	8,25	8,25	0,50	0,46
7	7	0,38	0,55	0,38	1,20	11,40	8,50	8,50	0,50	0,44
7,5	7	0,38	0,55	0,38	1,20	11,90	8,75	8,75	0,50	0,43
8	7	0,38	0,55	0,38	1,20	12,40	9,00	9,00	0,25	0,21

INTERNAL STABILITY CALCULATIONS - SERVICEABILITY LIMIT STATE - LOAD CASE C

4													
Effective Depth	Length of Reinforcement	Position of Maximum Tension Line 2 (All Load factors are set to 1)											
H	L	Earth Pressure	Total force acting per unit length of wall	Location of Resultant Force from the bottom of the wall	Only consider the strip load over the reinforced soil over an area of $0.5H_1$ behind the facing	Width of Strip Load (only consider 0.5H1 behind facing)	$\sigma_1=\tan^{-1}(b'/h_1)$	$\sigma_2=\tan^{-1}((a'+b')/H_1)$	Resultant Force	The location of the resultant force P			
$H = z=h_j$		$K=K_o(1-z/z_o)+(K_a*(z/z_o))$ Or $K=K_a$	$Pa=0.5\gamma_r H_1^2 K$	$z'=H_1/3$	$L=0.5H_1$	$a'=0.5H_1-b'$			$P=q/90[H(\sigma_1-\sigma_2)]$	$R=(a'+b')^2(90-\sigma_2)$	$Q=b'^2(90-\sigma_1)$	$z=H-[\{H^2(\sigma_2-\sigma_1)+(R-Q)-57.3a'H\}/2H(\sigma_2-\sigma_1)]$
m	m		kN/m	m	m	m	degrees	degrees	kN/m			m
0,4	7	0,53	255,43	2,33	3,50	0,70	21,80	26,57	7,41	777,08	534,68	4,08
1	7	0,52	247,28	2,33	3,50	0,70	21,80	26,57	7,41	777,08	534,68	4,08
1,5	7	0,50	240,49	2,33	3,50	0,70	21,80	26,57	7,41	777,08	534,68	4,08
2	7	0,49	233,71	2,33	3,50	0,70	21,80	26,57	7,41	777,08	534,68	4,08
2,5	7	0,47	226,92	2,33	3,50	0,70	21,80	26,57	7,41	777,08	534,68	4,08
3	7	0,46	220,13	2,33	3,50	0,70	21,80	26,57	7,41	777,08	534,68	4,08
3,5	7	0,45	213,34	2,33	3,50	0,70	21,80	26,57	7,41	777,08	534,68	4,08
4	7	0,43	206,56	2,33	3,50	0,70	21,80	26,57	7,41	777,08	534,68	4,08
4,5	7	0,42	199,77	2,33	3,50	0,70	21,80	26,57	7,41	777,08	534,68	4,08
5	7	0,40	192,98	2,33	3,50	0,70	21,80	26,57	7,41	777,08	534,68	4,08
5,5	7	0,39	186,19	2,33	3,50	0,70	21,80	26,57	7,41	777,08	534,68	4,08
6	7	0,38	179,41	2,33	3,50	0,70	21,80	26,57	7,41	777,08	534,68	4,08
6,5	7	0,38	179,41	2,33	3,50	0,70	21,80	26,57	7,41	777,08	534,68	4,08
7	7	0,38	179,41	2,33	3,50	0,70	21,80	26,57	7,41	777,08	534,68	4,08
7,5	7	0,38	179,41	2,33	3,50	0,70	21,80	26,57	7,41	777,08	534,68	4,08
8	7	0,38	179,41	2,33	3,50	0,70	21,80	26,57	7,41	777,08	534,68	4,08

INTERNAL STABILITY CALCULATIONS - SERVICEABILITY LIMIT STATE - LOAD CASE C

4										
Effective Depth	Length of Reinforcement	Position of Maximum Tension Line 2 (All Load factors are set to 1)								
H	L	Overturning Moment	Resisting Moment	Eccentricity	Stress	Bearing Pressure=Q_m	Total Wall Height	H_1+Q_m/γ	Hm is the greater of H or H_1+Q_m/γ	Line 2 does not exceed this value, however located at the strip load distance within the upper 1/6H of the wall.
$H = z=h_j$		$M_o=P_a z'+Pz$	$M_r=[LH\gamma_{r*}(L/2)] + [qa'*(b'+(a'/2))]$	$e=L/2-[(M_r-M_o)/\Sigma V]$	$R_v=LH\gamma_r+qa'$	$q_r=R_v/L-2e$	H		H_m	
m	m	kN-m/m	kN-m/m	m	kN/m	kN/m^2	m	m	m	m
0,4	7	626,19	880,16	1,23	491,75	476,08	8,00	31,41	31,41	31,41
1	7	607,19	880,16	1,19	491,75	442,93	8,00	29,71	29,71	29,71
1,5	7	591,35	880,16	1,16	491,75	418,64	8,00	28,47	28,47	28,47
2	7	575,51	880,16	1,13	491,75	396,88	8,00	27,35	27,35	27,35
2,5	7	559,68	880,16	1,10	491,75	377,27	8,00	26,35	26,35	26,35
3	7	543,84	880,16	1,07	491,75	359,50	8,00	25,44	25,44	25,44
3,5	7	528,00	880,16	1,03	491,75	343,33	8,00	24,61	24,61	24,61
4	7	512,16	880,16	1,00	491,75	328,56	8,00	23,85	23,85	23,85
4,5	7	496,33	880,16	0,97	491,75	315,00	8,00	23,15	23,15	23,15
5	7	480,49	880,16	0,94	491,75	302,52	8,00	22,51	22,51	22,51
5,5	7	464,65	880,16	0,91	491,75	290,99	8,00	21,92	21,92	21,92
6	7	448,81	880,16	0,87	491,75	280,31	8,00	21,37	21,37	21,37
6,5	7	448,81	880,16	0,87	491,75	280,31	8,00	21,37	21,37	21,37
7	7	448,81	880,16	0,87	491,75	280,31	8,00	21,37	21,37	21,37
7,5	7	448,81	880,16	0,87	491,75	280,31	8,00	21,37	21,37	21,37
8	7	448,81	880,16	0,87	491,75	280,31	8,00	21,37	21,37	21,37

INTERNAL STABILITY CALCULATIONS - SERVICEABILITY LIMIT STATE - LOAD CASE C

5										
Effective Depth	Length of Reinforcement	Tension in the Reinforcement								
H $H = z = h_j$	L	d+b/2	H_1	Z_0 is the minimum of (d+b/2) and H_1	Z_1 is width b of the strip load	X = Width of the active zone at underside of strip footing.	Z_2=1.5(H_1/2 - X)	h_j	α_0 = 0.85 (if $h_j \le Z_2$) OR α_0=1-0.15(H_1-h_j)/ H_1-z_2) (if $h_j > z_2$)	α_1= 1 (if hj ≤ z1) OR $\alpha_1 = \alpha_0+(1-\alpha_0)(z_0-h_j)/(Z_0-Z_1)$ (if $z_1<h_j<z_0$) OR $\alpha_1=\alpha_0$ (if $h_j \ge z_0$)
m	m	m	m	m	m	m	m	m		
0,4	7	7,20	7,00	7,00	4,40	7,20	-5,55	0,40	0,92	1,00
1	7	7,20	7,00	7,00	4,40	7,20	-5,55	1,00	0,93	1,00
1,5	7	7,20	7,00	7,00	4,40	7,20	-5,55	1,50	0,93	1,00
2	7	7,20	7,00	7,00	4,40	7,20	-5,55	2,00	0,94	1,00
2,5	7	7,20	7,00	7,00	4,40	7,20	-5,55	2,50	0,95	1,00
3	7	7,20	7,00	7,00	4,40	7,20	-5,55	3,00	0,95	1,00
3,5	7	7,20	7,00	7,00	4,40	7,20	-5,55	3,50	0,96	1,00
4	7	7,20	7,00	7,00	4,40	7,20	-5,55	4,00	0,96	1,00
4,5	7	7,20	7,00	7,00	4,40	7,20	-5,55	4,50	0,97	1,00
5	7	7,20	7,00	7,00	4,40	7,20	-5,55	5,00	0,98	0,99
5,5	7	7,20	7,00	7,00	4,40	7,20	-5,55	5,50	0,98	0,99
6	7	7,20	7,00	7,00	4,40	7,20	-5,55	6,00	0,99	0,99
6,5	7	7,20	7,00	7,00	4,40	7,20	-5,55	6,50	0,99	1,00
7	7	7,20	7,00	7,00	4,40	7,20	-5,55	7,00	1,00	1,00
7,5	7	7,20	7,00	7,00	4,40	7,20	-5,55	7,50	1,01	1,01
8	7	7,20	7,00	7,00	4,40	7,20	-5,55	8,00	1,01	1,01

INTERNAL STABILITY CALCULATIONS - SERVICEABILITY LIMIT STATE - LOAD CASE C

5				
Effective Depth	Length of Reinforcement	Tension in the Reinforcement		
H	L	Tension at Facing (T_{fj} not applicable)	Tension at Line 1 (T_{fj} not applicable)	Tension at Line 2 (T_{fj} not applicable)
$H = z = h_j$		$T_j = \alpha_0 T_{pj} + T_{sj}$	$T_j = \alpha_1 T_{pj} + T_{sj}$	$T_j = T_{pj} + T_{sj}$
m	m	kN/m	kN/m	kN/m
0,4	7	4,25	4,48	4,48
1	7	6,23	6,63	6,63
1,5	7	7,81	8,29	8,29
2	7	9,91	10,48	10,48
2,5	7	11,94	12,58	12,58
3	7	13,91	14,58	14,58
3,5	7	15,83	16,49	16,49
4	7	17,68	18,31	18,31
4,5	7	19,46	20,02	20,04
5	7	21,18	21,57	21,68
5,5	7	22,82	23,05	23,22
6	7	24,37	24,48	24,66
6,5	7	26,97	27,00	27,13
7	7	29,74	29,74	29,74
7,5	7	32,69	32,69	32,50
8	7	17,93	17,93	17,72

INTERNAL STABILITY CALCULATIONS - SERVICEABILITY LIMIT STATE - LOAD CASE C

6										7
Effective Depth	Adherence Capacity of Reinforcement									Facing Connection
H	Wall Height *1/6	Total Length of Reinforcement	Length of Reinforcement in the Failure zone	Length of reinforcement beyond the line of maximum tension	Adherence Capacity of Reinforcement	$f_{fs}s_v$	$L^2/2 - (L-L_{aj})^2/2$	$(2B\mu/f_pf_n)*(f_{fs}s_v)*(L^2/2 - (L-L_{aj})^2/2)$	Tension at Line 2 (Worst case is at Tension line 2)	
$H = z=h_j$		L	L_{aj}	$L_{ej} = L-L_{aj}$	$2B\mu/f_pf_n$				T_j	85% at depths <0.6H and 100% at depths >0.6H
m	m	m	m	m				kN/m	kN/m	kN/m
0,4	1,33	7,00	7	0,00	0,10	7,80	24,50	18,77	4,48	3,81
1	1,33	7,00	7	0,00	0,10	19,57	24,50	47,07	6,63	5,63
1,5	1,33	7,00	6,825	0,18	0,10	29,48	24,48	70,86	8,29	7,05
2	1,33	7,00	6,3	0,70	0,10	39,53	24,26	94,13	10,48	8,91
2,5	1,33	7,00	5,775	1,23	0,10	49,75	23,75	116,02	12,58	10,69
3	1,33	7,00	5,25	1,75	0,10	60,20	22,97	135,75	14,58	12,39
3,5	1,33	7,00	4,725	2,28	0,10	70,89	21,91	152,51	16,49	14,02
4	1,33	7,00	4,2	2,80	0,10	81,85	20,58	165,39	18,31	15,57
4,5	1,33	7,00	3,675	3,33	0,10	93,11	18,97	173,44	20,04	20,04
5	1,33	7,00	3,15	3,85	0,10	104,69	17,09	175,65	21,68	21,68
5,5	1,33	7,00	2,625	4,38	0,10	116,60	14,93	170,92	23,22	23,22
6	1,33	7,00	2,1	4,90	0,10	128,85	12,50	158,07	24,66	24,66
6,5	1,33	7,00	1,575	5,43	0,10	142,09	9,78	136,50	27,13	27,13
7	1,33	7,00	1,05	5,95	0,10	156,03	6,80	104,15	29,74	29,74
7,5	1,33	7,00	0,525	6,48	0,10	170,79	3,54	59,31	32,50	32,50
8	1,33	7,00	0	7,00	0,10	186,49	0,00	0,00	17,72	17,72

INTERNAL STABILITY CALCULATIONS - SERVICEABILITY LIMIT STATE - LOAD CASE C

8											
Effective Depth	Length of Reinforcement	Reinforcement Design Strength									
H	L	Paraweb Short-term Strength from BBA	Number of Straps across 1 Facing Panel	Total T_{char} across Facing Panel	Reduction Factor for Creep from BBA	Maximum Allowable Tensile Load of Paraweb	Reduction Factor for Installation Damage	Reduction Factor for Weathering	Reduction Factor for Chemical / Environmental Effects	Factor Safety for the Extrapolation of Data	Material Safety Factor
$H = z=h_j$		T_{char}	No. Straps	Total $T_{char} = T_{char}$ * No. Straps	$RF_{CR(SLS)}$ (for a Design Temperature of 20°C)	$T_{cs} = T_{char} / RF_{CR(SLS)}$	RF_{ID}	RF_W	RF_{CH}	f_s	$f_m = RF_{ID}*RF_W*RF_{CH}*f_s$
m	m	kN		kN		kN					
0,4	7	75	4	300	1,54	194,81	1	1	1	1,05	1,05
1	7	75	4	300	1,54	194,81	1	1	1	1,05	1,05
1,5	7	75	4	300	1,54	194,81	1	1	1	1,05	1,05
2	7	75	4	300	1,54	194,81	1	1	1	1,05	1,05
2,5	7	75	4	300	1,54	194,81	1	1	1	1,05	1,05
3	7	75	4	300	1,54	194,81	1	1	1	1,05	1,05
3,5	7	75	4	300	1,54	194,81	1	1	1	1,05	1,05
4	7	75	4	300	1,54	194,81	1	1	1	1,05	1,05
4,5	7	75	4	300	1,54	194,81	1	1	1	1,05	1,05
5	7	75	4	300	1,54	194,81	1	1	1	1,05	1,05
5,5	7	75	4	300	1,54	194,81	1	1	1	1,05	1,05
6	7	75	4	300	1,54	194,81	1	1	1	1,05	1,05
6,5	7	75	4	300	1,54	194,81	1	1	1	1,05	1,05
7	7	75	4	300	1,54	194,81	1	1	1	1,05	1,05
7,5	7	75	4	300	1,54	194,81	1	1	1	1,05	1,05
8	7	75	4	300	1,54	194,81	1	1	1	1,05	1,05

INTERNAL STABILITY CALCULATIONS - SERVICEABILITY LIMIT STATE - LOAD CASE C

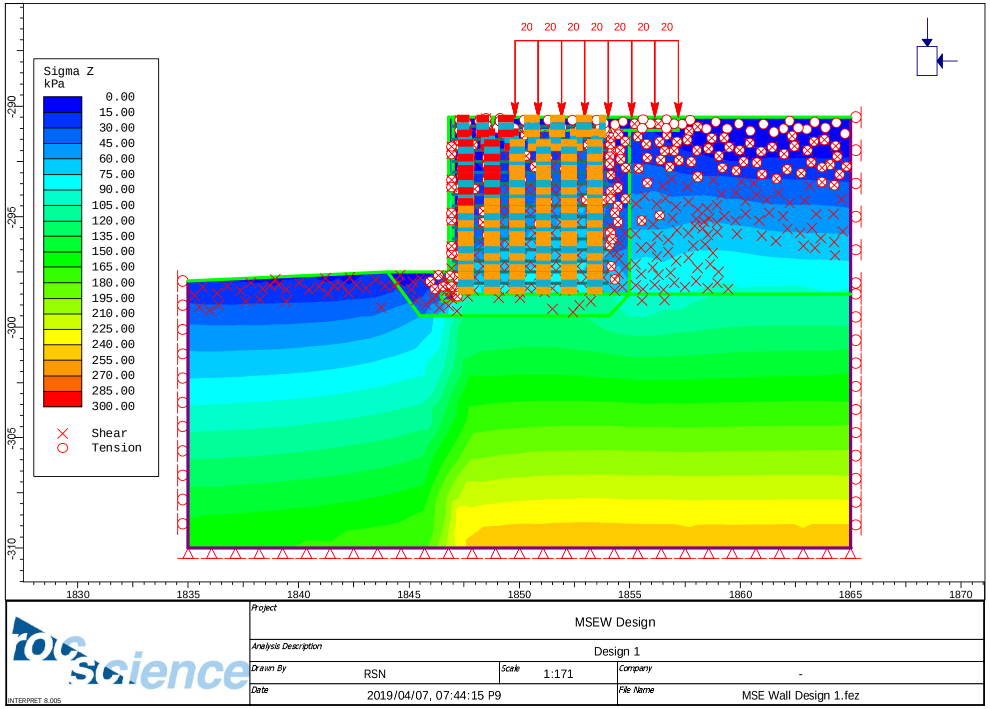
8						
Effective Depth	Length of Reinforcement	Reinforcement Design Strength				
H	L	Design Strength of Paraweb Strap	Width of Paraweb x four Straps (Across a Facing Panel)	Width of the Facing Panel	Paraweb Coverage Ratio	Design Strength (Factoring Coverage)
$H = z = h_j$		$T_D = T_{cs} / f_m$				
m	m	kN	m	m	%	kN/m
0,4	7	185,53	0,36	1,5	0,24	44,53
1	7	185,53	0,36	1,5	0,24	44,53
1,5	7	185,53	0,36	1,5	0,24	44,53
2	7	185,53	0,36	1,5	0,24	44,53
2,5	7	185,53	0,36	1,5	0,24	44,53
3	7	185,53	0,36	1,5	0,24	44,53
3,5	7	185,53	0,36	1,5	0,24	44,53
4	7	185,53	0,36	1,5	0,24	44,53
4,5	7	185,53	0,36	1,5	0,24	44,53
5	7	185,53	0,36	1,5	0,24	44,53
5,5	7	185,53	0,36	1,5	0,24	44,53
6	7	185,53	0,36	1,5	0,24	44,53
6,5	7	185,53	0,36	1,5	0,24	44,53
7	7	185,53	0,36	1,5	0,24	44,53
7,5	7	185,53	0,36	1,5	0,24	44,53
8	7	185,53	0,36	1,5	0,24	44,53

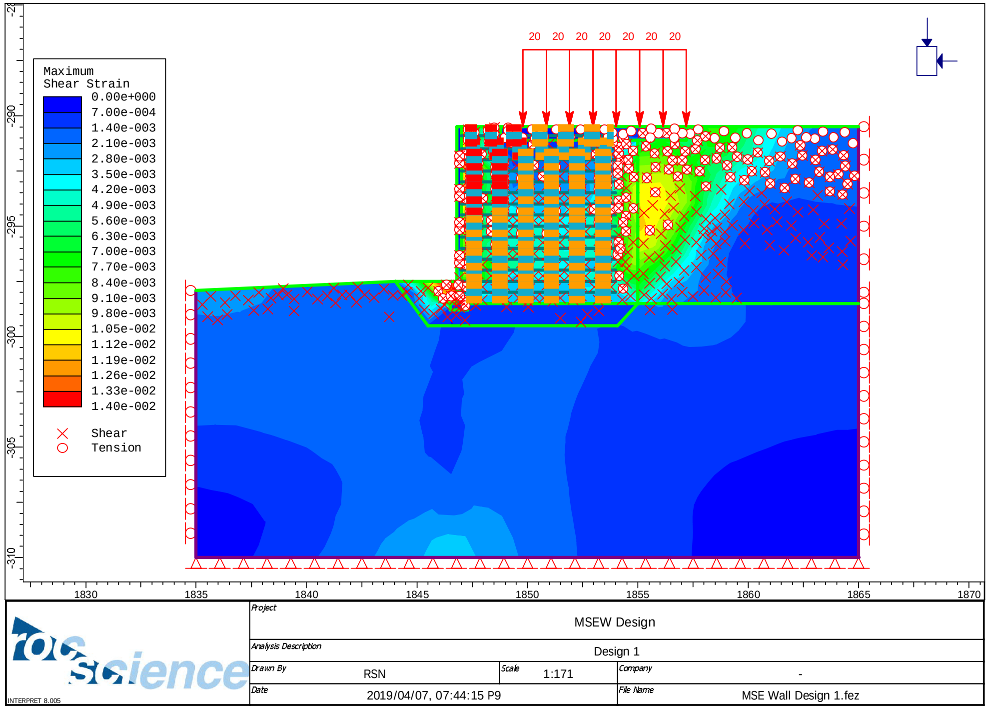
APPENDIX B

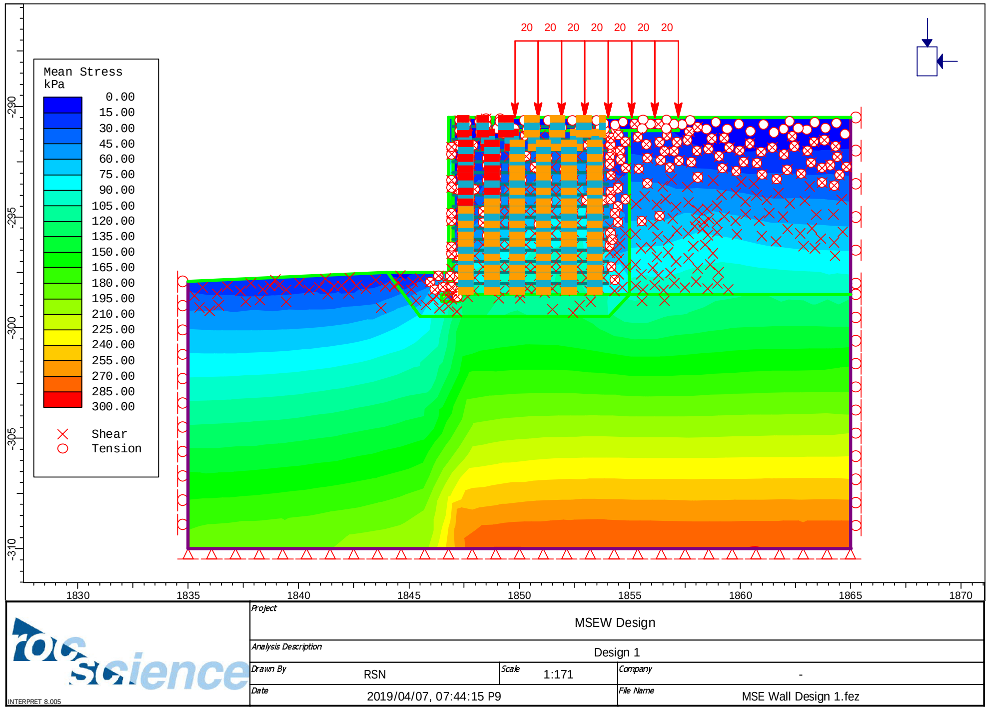
RESULTS OF THE FINITE ELEMENT ANALYSIS FOR ALL DESIGN CONFIGURATIONS

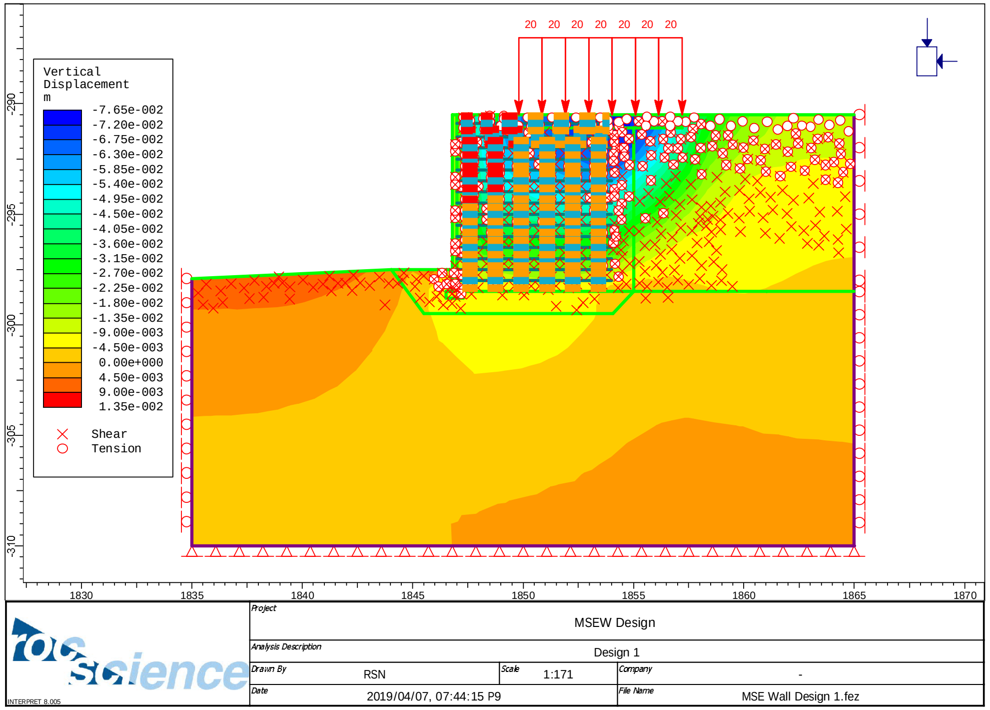
Contour plots of the following results are presented from designs 1 to 72:

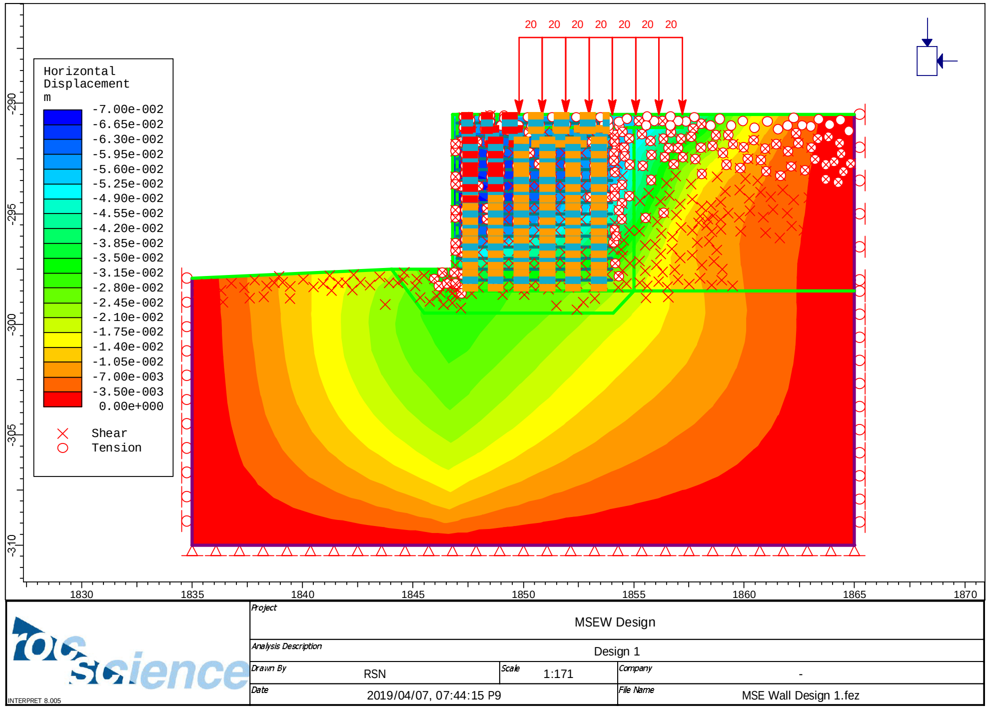
- **Stress in the Z Direction (Sigma z)**
- **Mean Stress**
- **Shear Strain**
- **Vertical Displacement**
- **Horizontal Displacement**
- **Total Displacement**
- **Shear Strength Reduction (Factor of Safety) - Shear Strain**

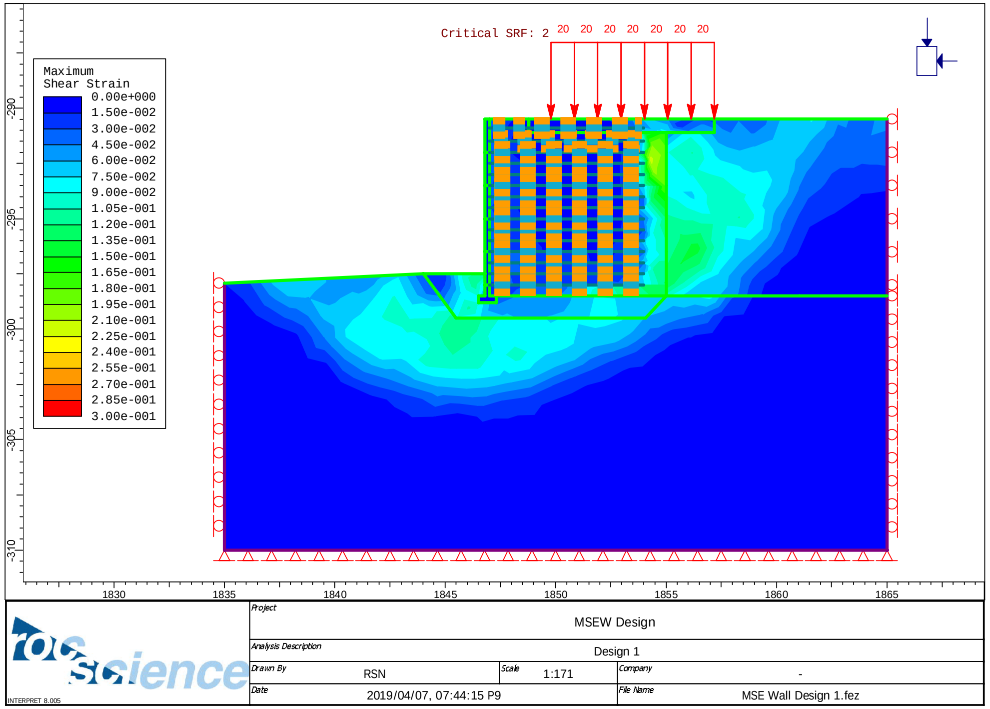

Sigma Z
kPa
0.00
15.00
30.00
45.00
60.00
75.00
90.00
105.00
120.00
135.00
150.00
165.00
180.00
195.00
210.00
225.00
240.00
255.00
270.00
285.00
300.00
Shear
Tension
20 20 20 20 20 20 20
1830 1835 1840 1845 1850 1855 1860 1865 1870
-290 -295 -300 -305 -310
Project
MSEW Design
Analysis Description
Design 1
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/04/07, 07:44:15 P9
File Name
MSE Wall Design 1.fez
INTERPRET 8.005

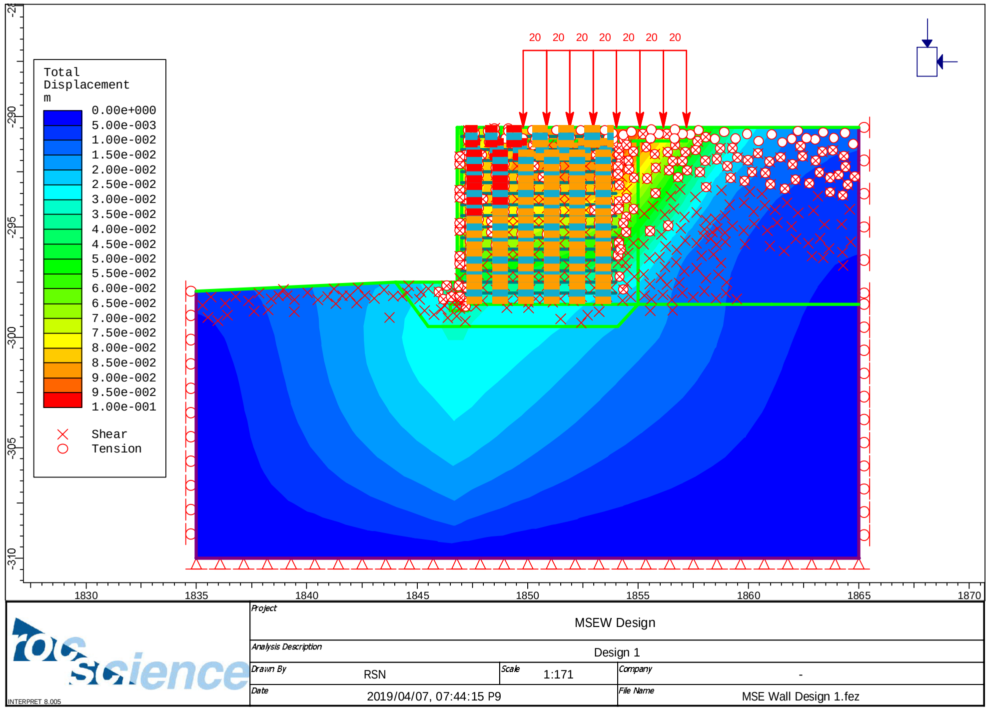

Maximum
Shear Strain
0.00e+000
7.00e-004
1.40e-003
2.10e-003
2.80e-003
3.50e-003
4.20e-003
4.90e-003
5.60e-003
6.30e-003
7.00e-003
7.70e-003
8.40e-003
9.10e-003
9.80e-003
1.05e-002
1.12e-002
1.19e-002
1.26e-002
1.33e-002
1.40e-002
Shear
Tension
20 20 20 20 20 20 20
1830 1835 1840 1845 1850 1855 1860 1865 1870
-290 -295 -300 -305 -310
Project
MSEW Design
Analysis Description
Design 1
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/04/07, 07:44:15 P9
File Name
MSE Wall Design 1.fez
INTERPRET 8.005

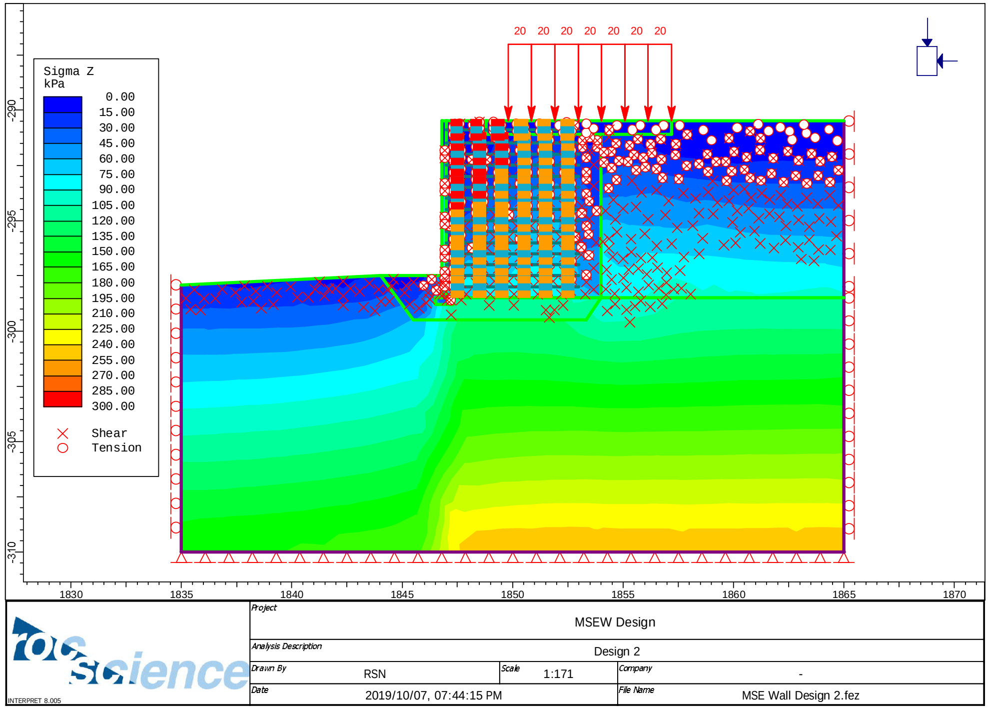

Mean Stress
kPa
0.00
15.00
30.00
45.00
60.00
75.00
90.00
105.00
120.00
135.00
150.00
165.00
180.00
195.00
210.00
225.00
240.00
255.00
270.00
285.00
300.00
Shear
Tension
20 20 20 20 20 20 20
1830 1835 1840 1845 1850 1855 1860 1865 1870
-290 -295 -300 -305 -310
Project
MSEW Design
Analysis Description
Design 1
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/04/07, 07:44:15 P9
File Name
MSE Wall Design 1.fez
INTERPRET 8.005

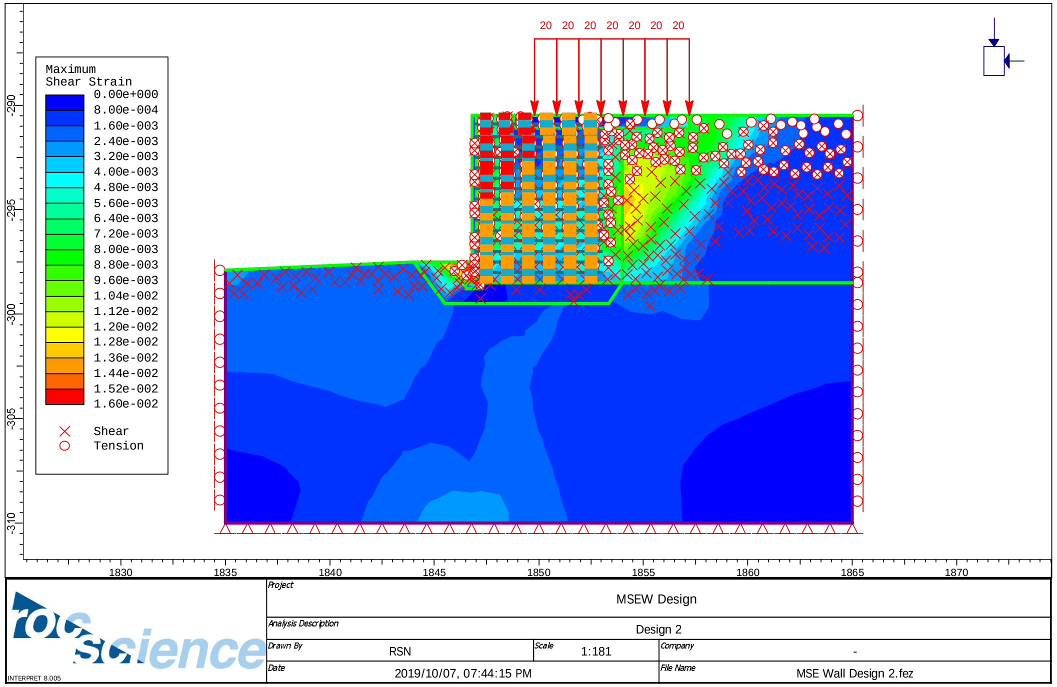

Vertical
Displacement
m
-7.65e-002
-7.20e-002
-6.75e-002
-6.30e-002
-5.85e-002
-5.40e-002
-4.95e-002
-4.50e-002
-4.05e-002
-3.60e-002
-3.15e-002
-2.70e-002
-2.25e-002
-1.80e-002
-1.35e-002
-9.00e-003
-4.50e-003
0.00e+000
4.50e-003
9.00e-003
1.35e-002
Shear
Tension
20 20 20 20 20 20 20
1830 1835 1840 1845 1850 1855 1860 1865 1870
-290 -295 -300 -305 -310
Project
MSEW Design
Analysis Description
Design 1
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/04/07, 07:44:15 P9
File Name
MSE Wall Design 1.fez
INTERPRET 8.005

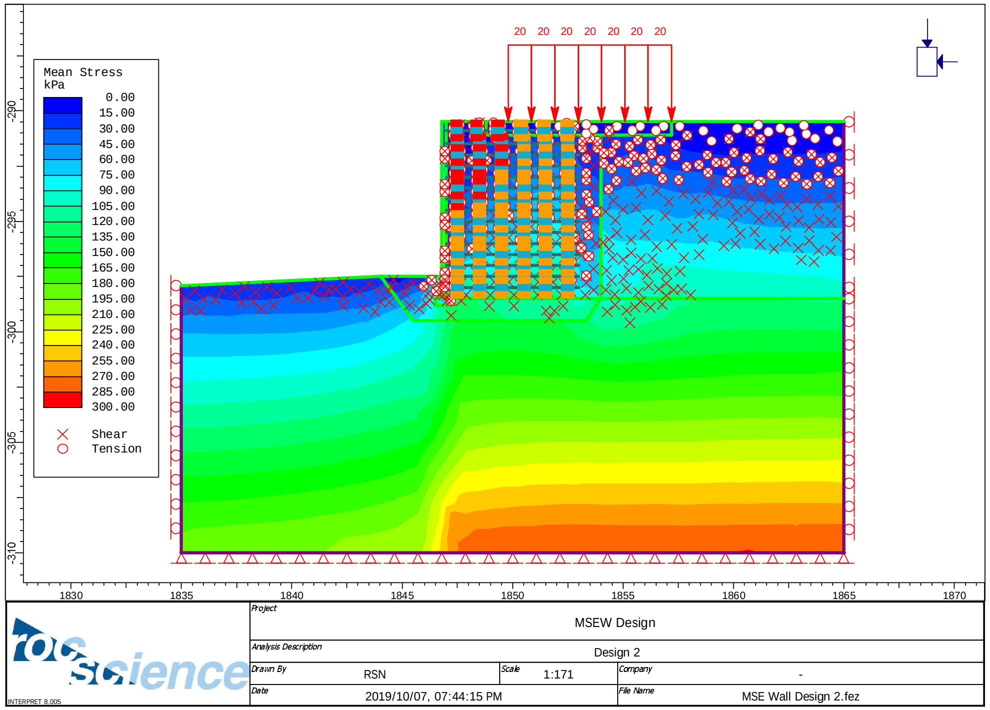

Horizontal Displacement m
-7.00e-002
-6.65e-002
-6.30e-002
-5.95e-002
-5.60e-002
-5.25e-002
-4.90e-002
-4.55e-002
-4.20e-002
-3.85e-002
-3.50e-002
-3.15e-002
-2.80e-002
-2.45e-002
-2.10e-002
-1.75e-002
-1.40e-002
-1.05e-002
-7.00e-003
-3.50e-003
0.00e+000
Shear
Tension
20 20 20 20 20 20 20
1830 1835 1840 1845 1850 1855 1860 1865 1870
-290 -295 -300 -305 -310
Project
MSEW Design
Analysis Description
Design 1
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/04/07, 07:44:15 P9
File Name
MSE Wall Design 1.fez
INTERPRET 8.005

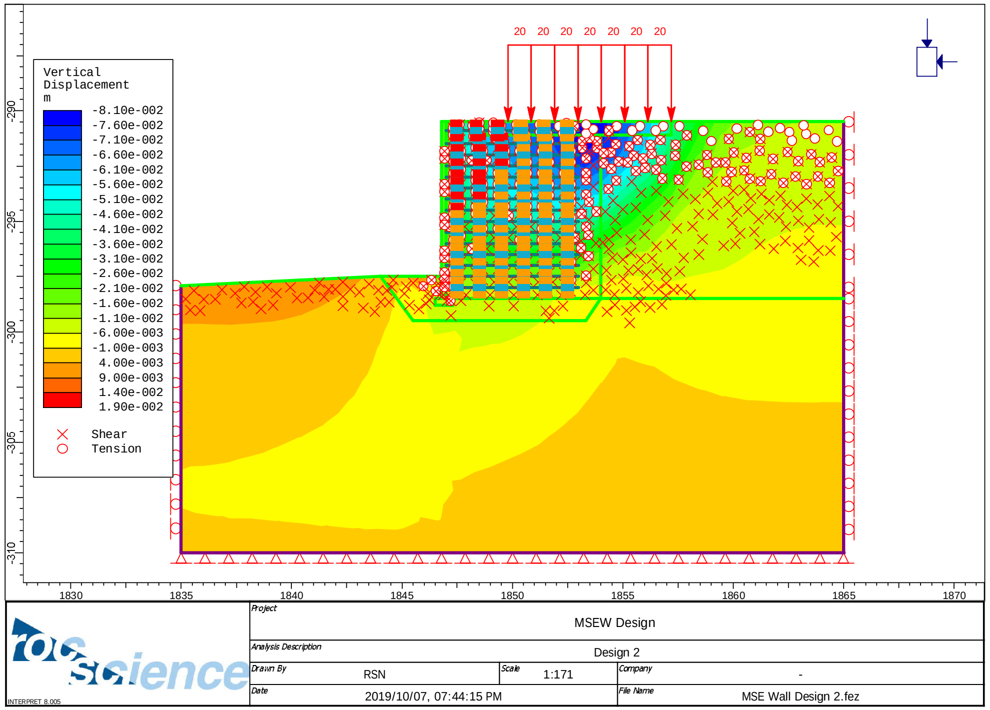

Maximum Shear Strain
0.00e+000
1.50e-002
3.00e-002
4.50e-002
6.00e-002
7.50e-002
9.00e-002
1.05e-001
1.20e-001
1.35e-001
1.50e-001
1.65e-001
1.80e-001
1.95e-001
2.10e-001
2.25e-001
2.40e-001
2.55e-001
2.70e-001
2.85e-001
3.00e-001
Critical SRF: 2
20 20 20 20 20 20 20
1830 1835 1840 1845 1850 1855 1860 1865
-290 -295 -300 -305 -310
Project
MSEW Design
Analysis Description
Design 1
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/04/07, 07:44:15 P9
File Name
MSE Wall Design 1.fez
INTERPRET 8.005

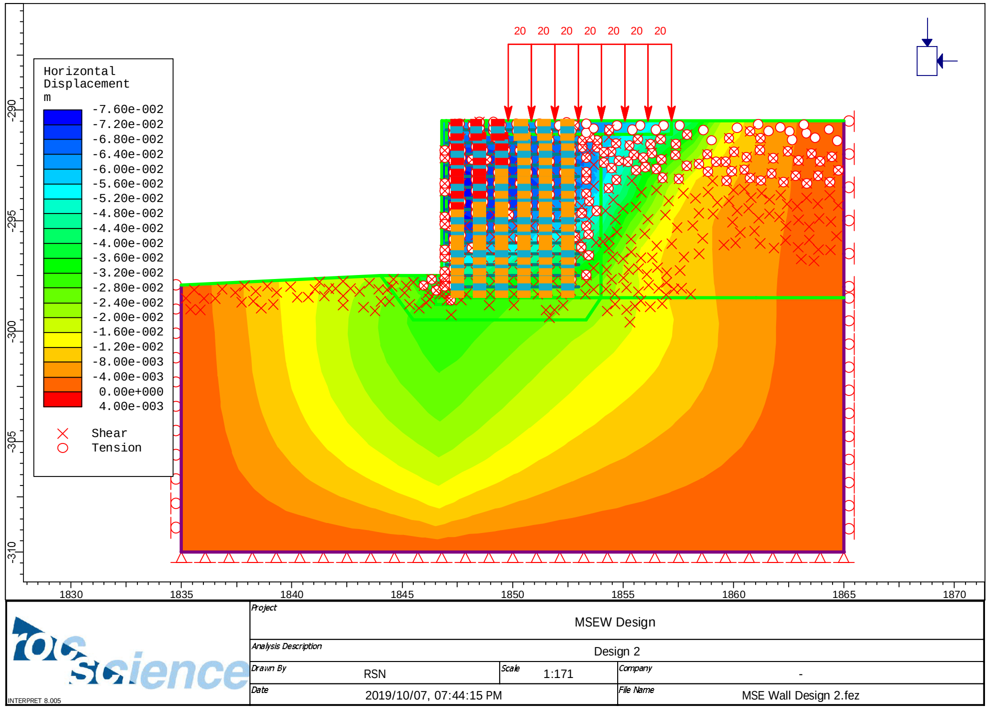

Total Displacement m
0.00e+000
5.00e-003
1.00e-002
1.50e-002
2.00e-002
2.50e-002
3.00e-002
3.50e-002
4.00e-002
4.50e-002
5.00e-002
5.50e-002
6.00e-002
6.50e-002
7.00e-002
7.50e-002
8.00e-002
8.50e-002
9.00e-002
9.50e-002
1.00e-001
Shear
Tension
20 20 20 20 20 20 20
1830 1835 1840 1845 1850 1855 1860 1865 1870
-290 -295 -300 -305 -310
Project
MSEW Design
Analysis Description
Design 1
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/04/07, 07:44:15 P9
File Name
MSE Wall Design 1.fez
INTERPRET 8.005

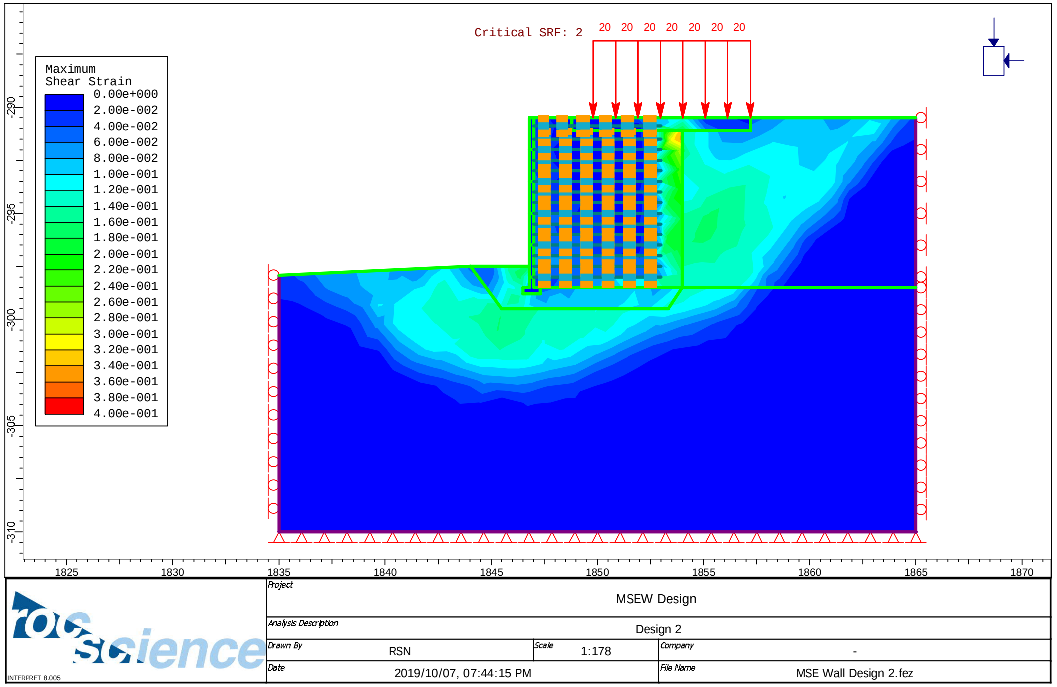

Sigma Z
kPa
0.00
15.00
30.00
45.00
60.00
75.00
90.00
105.00
120.00
135.00
150.00
165.00
180.00
195.00
210.00
225.00
240.00
255.00
270.00
285.00
300.00
Shear
Tension
20 20 20 20 20 20 20
1830 1835 1840 1845 1850 1855 1860 1865 1870
-290 -295 -300 -305 -310
Project MSEW Design
Analysis Description Design 2
Drawn By RSN
Scale 1:171
Company -
Date 2019/10/07, 07:44:15 PM
File Name MSE Wall Design 2.fez
INTERPRET 8.005

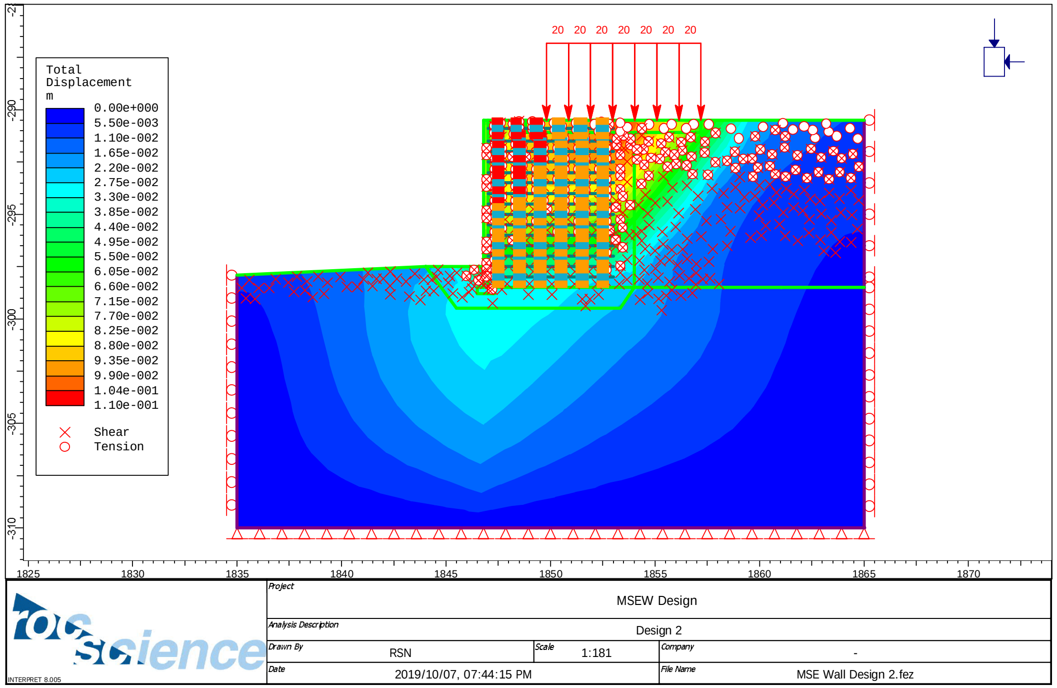

Maximum
Shear Strain
0.00e+000
8.00e-004
1.60e-003
2.40e-003
3.20e-003
4.00e-003
4.80e-003
5.60e-003
6.40e-003
7.20e-003
8.00e-003
8.80e-003
9.60e-003
1.04e-002
1.12e-002
1.20e-002
1.28e-002
1.36e-002
1.44e-002
1.52e-002
1.60e-002
Shear
Tension
20 20 20 20 20 20 20
1830 1835 1840 1845 1850 1855 1860 1865 1870
-290 -295 -300 -305 -310
Project MSEW Design
Analysis Description Design 2
Drawn By RSN
Scale 1:181
Company -
Date 2019/10/07, 07:44:15 PM
File Name MSE Wall Design 2.fez
INTERPRET 8.005

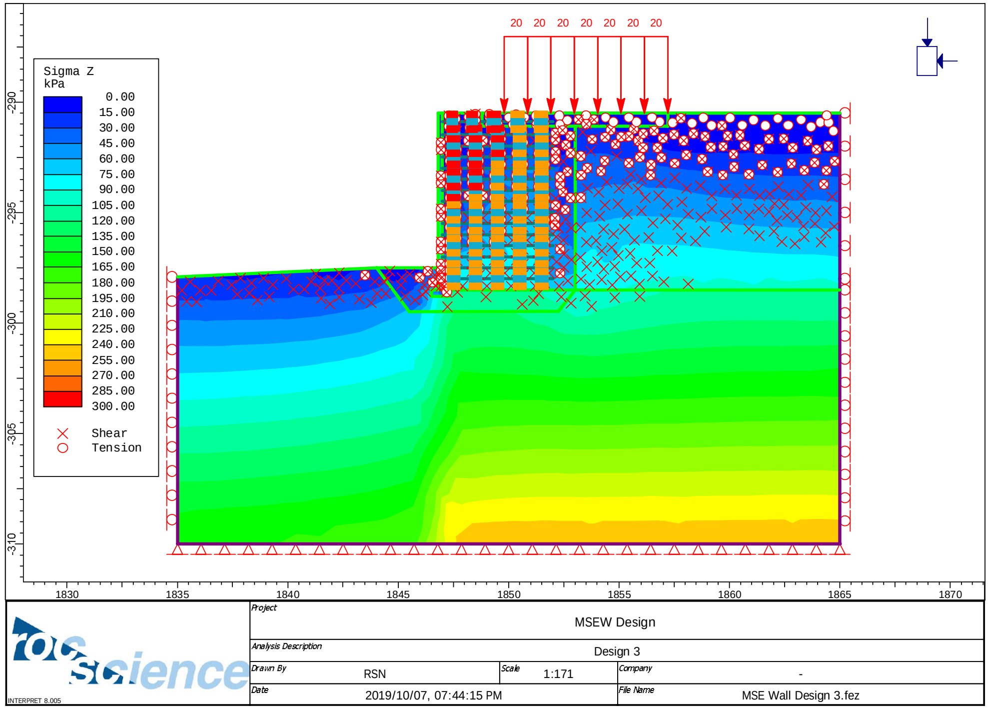

Mean Stress
kPa
0.00
15.00
30.00
45.00
60.00
75.00
90.00
105.00
120.00
135.00
150.00
165.00
180.00
195.00
210.00
225.00
240.00
255.00
270.00
285.00
300.00
Shear
Tension
20 20 20 20 20 20 20
1830 1835 1840 1845 1850 1855 1860 1865 1870
-290 -295 -300 -305 -310
Project MSEW Design
Analysis Description Design 2
Drawn By RSN
Scale 1:171
Company -
Date 2019/10/07, 07:44:15 PM
File Name MSE Wall Design 2.fez
INTERPRET 8.005

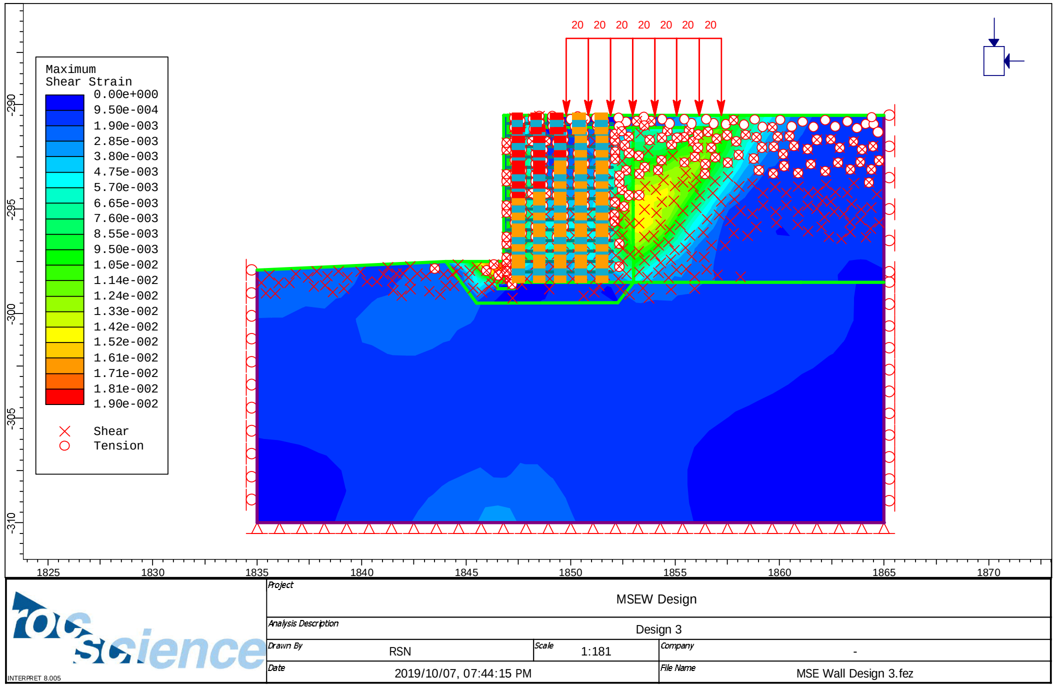

Vertical
Displacement
m
-8.10e-002
-7.60e-002
-7.10e-002
-6.60e-002
-6.10e-002
-5.60e-002
-5.10e-002
-4.60e-002
-4.10e-002
-3.60e-002
-3.10e-002
-2.60e-002
-2.10e-002
-1.60e-002
-1.10e-002
-6.00e-003
-1.00e-003
4.00e-003
9.00e-003
1.40e-002
1.90e-002
Shear
Tension
20 20 20 20 20 20 20
1830 1835 1840 1845 1850 1855 1860 1865 1870
-290 -295 -300 -305 -310
Project MSEW Design
Analysis Description Design 2
Drawn By RSN
Scale 1:171
Company -
Date 2019/10/07, 07:44:15 PM
File Name MSE Wall Design 2.fez
INTERPRET 8.005

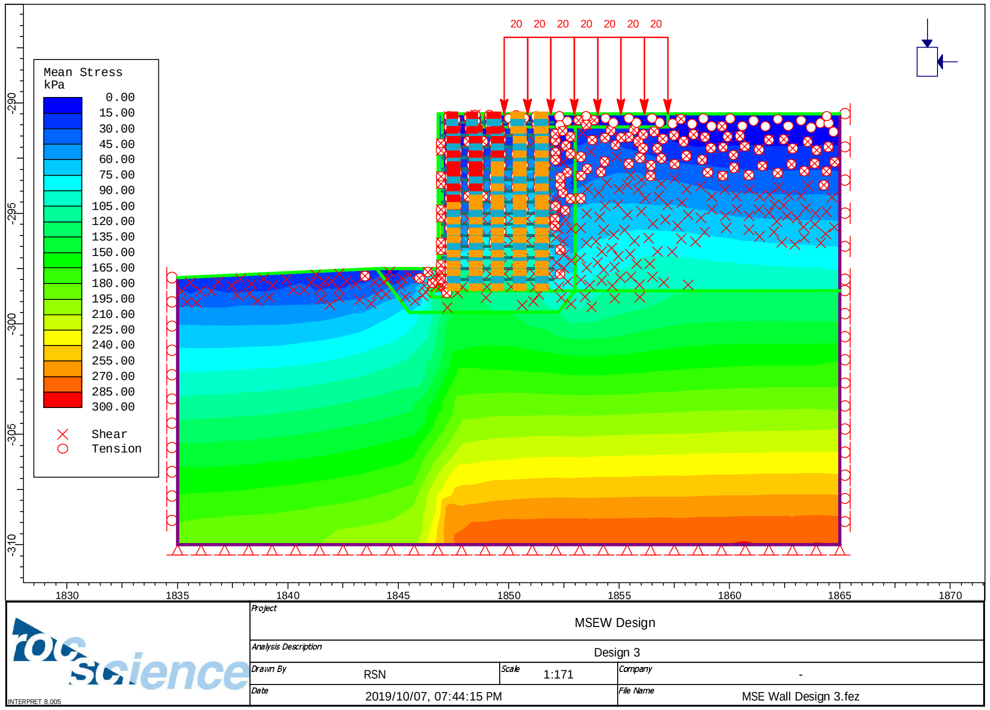

Horizontal Displacement
m
-7.60e-002
-7.20e-002
-6.80e-002
-6.40e-002
-6.00e-002
-5.60e-002
-5.20e-002
-4.80e-002
-4.40e-002
-4.00e-002
-3.60e-002
-3.20e-002
-2.80e-002
-2.40e-002
-2.00e-002
-1.60e-002
-1.20e-002
-8.00e-003
-4.00e-003
0.00e+000
4.00e-003
Shear
Tension
20 20 20 20 20 20 20
-290
-295
-300
-305
-310
1830 1835 1840 1845 1850 1855 1860 1865 1870
rocscience
INTERPRET 8.005
Project
MSEW Design
Analysis Description
Design 2
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 2.fez

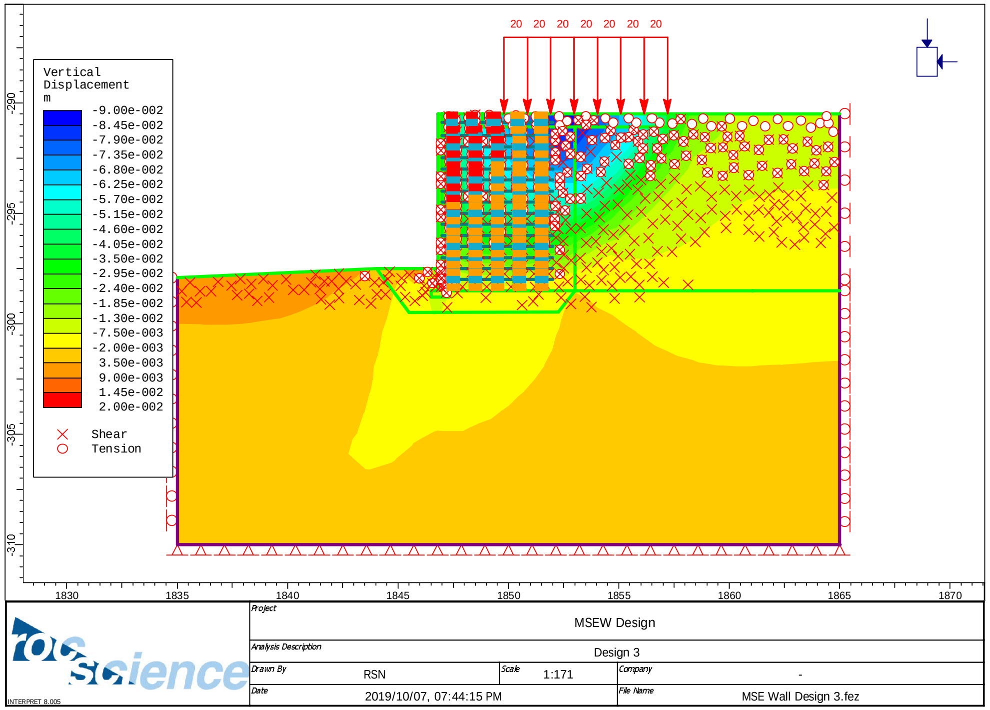

Maximum Shear Strain
0.00e+000
2.00e-002
4.00e-002
6.00e-002
8.00e-002
1.00e-001
1.20e-001
1.40e-001
1.60e-001
1.80e-001
2.00e-001
2.20e-001
2.40e-001
2.60e-001
2.80e-001
3.00e-001
3.20e-001
3.40e-001
3.60e-001
3.80e-001
4.00e-001
Critical SRF: 2
20 20 20 20 20 20 20
-290
-295
-300
-305
-310
1825 1830 1835 1840 1845 1850 1855 1860 1865 1870
rocscience
INTERPRET 8.005
Project
MSEW Design
Analysis Description
Design 2
Drawn By
RSN
Scale
1:178
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 2.fez

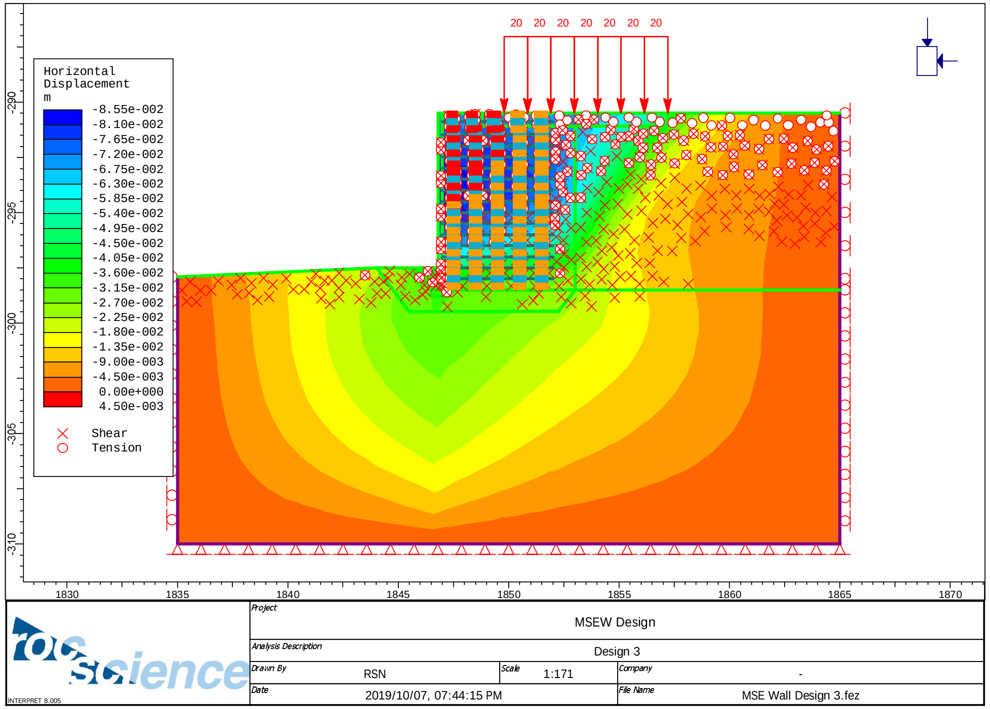

Total Displacement
m
0.00e+000
5.50e-003
1.10e-002
1.65e-002
2.20e-002
2.75e-002
3.30e-002
3.85e-002
4.40e-002
4.95e-002
5.50e-002
6.05e-002
6.60e-002
7.15e-002
7.70e-002
8.25e-002
8.80e-002
9.35e-002
9.90e-002
1.04e-001
1.10e-001
Shear
Tension
20 20 20 20 20 20 20
-290
-295
-300
-305
-310
1825 1830 1835 1840 1845 1850 1855 1860 1865 1870
rocscience
INTERPRET 8.005
Project
MSEW Design
Analysis Description
Design 2
Drawn By
RSN
Scale
1:181
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 2.fez


20 20 20 20 20 20 20
Sigma Z
kPa
0.00
15.00
30.00
45.00
60.00
75.00
90.00
105.00
120.00
135.00
150.00
165.00
180.00
195.00
210.00
225.00
240.00
255.00
270.00
285.00
300.00
Shear
Tension
1830 1835 1840 1845 1850 1855 1860 1865 1870
-290 -295 -300 -305 -310
Project
MSEW Design
Analysis Description
Design 3
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 3.fez
INTERPRET 8.005


20 20 20 20 20 20 20
Maximum
Shear Strain
0.00e+000
9.50e-004
1.90e-003
2.85e-003
3.80e-003
4.75e-003
5.70e-003
6.65e-003
7.60e-003
8.55e-003
9.50e-003
1.05e-002
1.14e-002
1.24e-002
1.33e-002
1.42e-002
1.52e-002
1.61e-002
1.71e-002
1.81e-002
1.90e-002
Shear
Tension
1825 1830 1835 1840 1845 1850 1855 1860 1865 1870
-290 -295 -300 -305 -310
Project
MSEW Design
Analysis Description
Design 3
Drawn By
RSN
Scale
1:181
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 3.fez
INTERPRET 8.005


20 20 20 20 20 20 20
Mean Stress
kPa
0.00
15.00
30.00
45.00
60.00
75.00
90.00
105.00
120.00
135.00
150.00
165.00
180.00
195.00
210.00
225.00
240.00
255.00
270.00
285.00
300.00
Shear
Tension
1830 1835 1840 1845 1850 1855 1860 1865 1870
-290 -295 -300 -305 -310
Project
MSEW Design
Analysis Description
Design 3
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 3.fez
INTERPRET 8.005


20 20 20 20 20 20 20
Vertical
Displacement
m
-9.00e-002
-8.45e-002
-7.90e-002
-7.35e-002
-6.80e-002
-6.25e-002
-5.70e-002
-5.15e-002
-4.60e-002
-4.05e-002
-3.50e-002
-2.95e-002
-2.40e-002
-1.85e-002
-1.30e-002
-7.50e-003
-2.00e-003
3.50e-003
9.00e-003
1.45e-002
2.00e-002
Shear
Tension
1830 1835 1840 1845 1850 1855 1860 1865 1870
-290 -295 -300 -305 -310
Project
MSEW Design
Analysis Description
Design 3
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 3.fez
INTERPRET 8.005


Horizontal Displacement m
-8.55e-002
-8.10e-002
-7.65e-002
-7.20e-002
-6.75e-002
-6.30e-002
-5.85e-002
-5.40e-002
-4.95e-002
-4.50e-002
-4.05e-002
-3.60e-002
-3.15e-002
-2.70e-002
-2.25e-002
-1.80e-002
-1.35e-002
-9.00e-003
-4.50e-003
0.00e+000
4.50e-003
Shear
Tension
20 20 20 20 20 20 20
Project
MSEW Design
Analysis Description
Design 3
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
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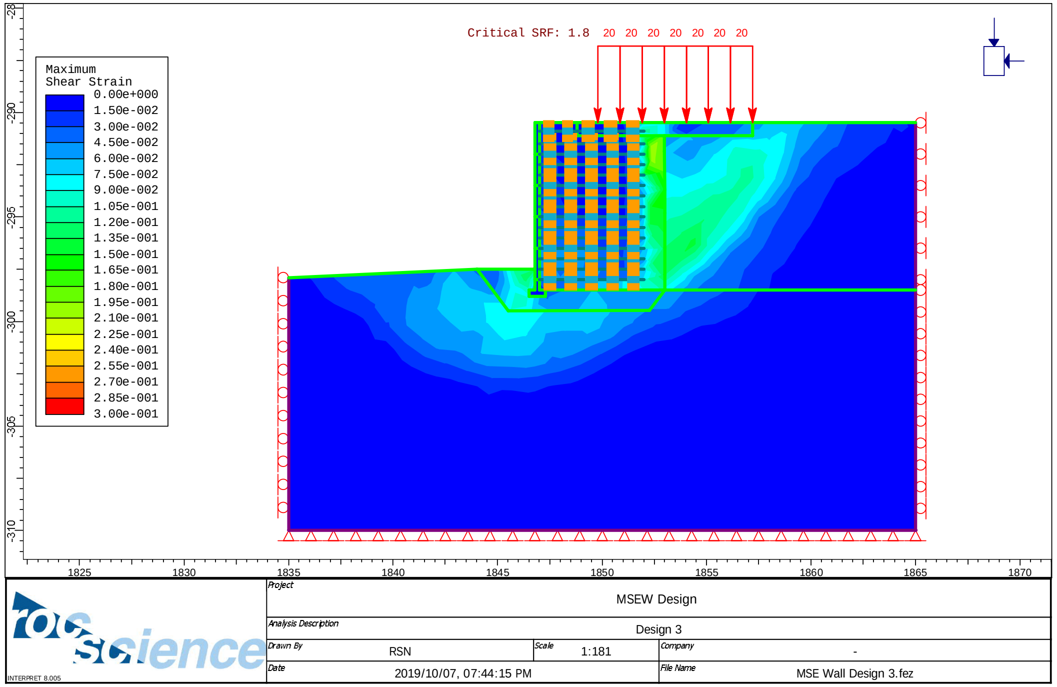
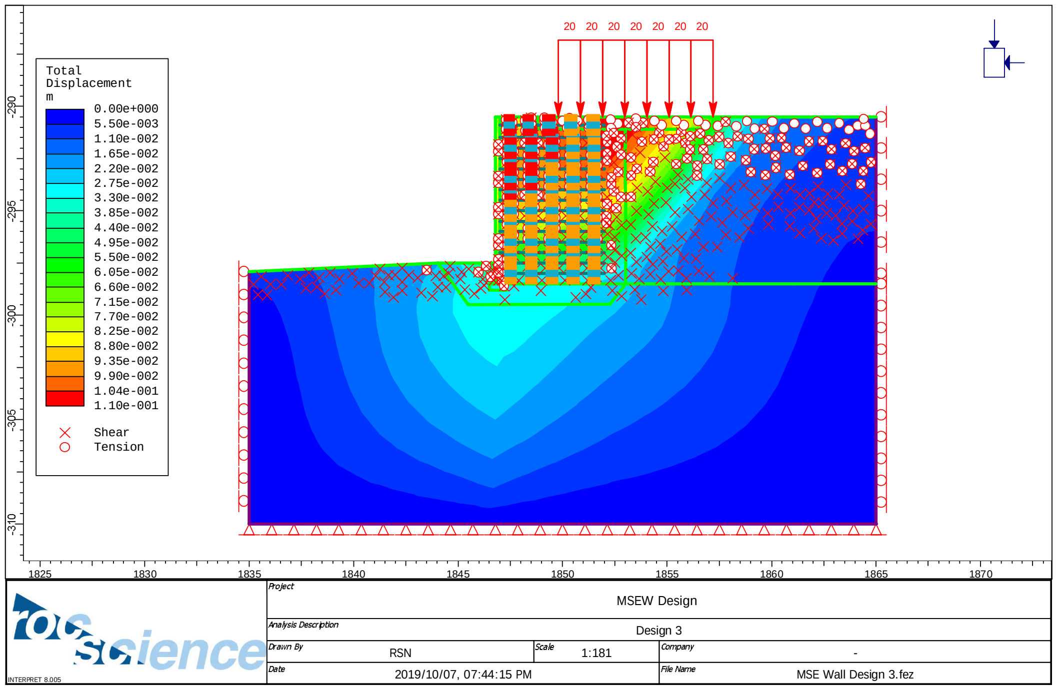
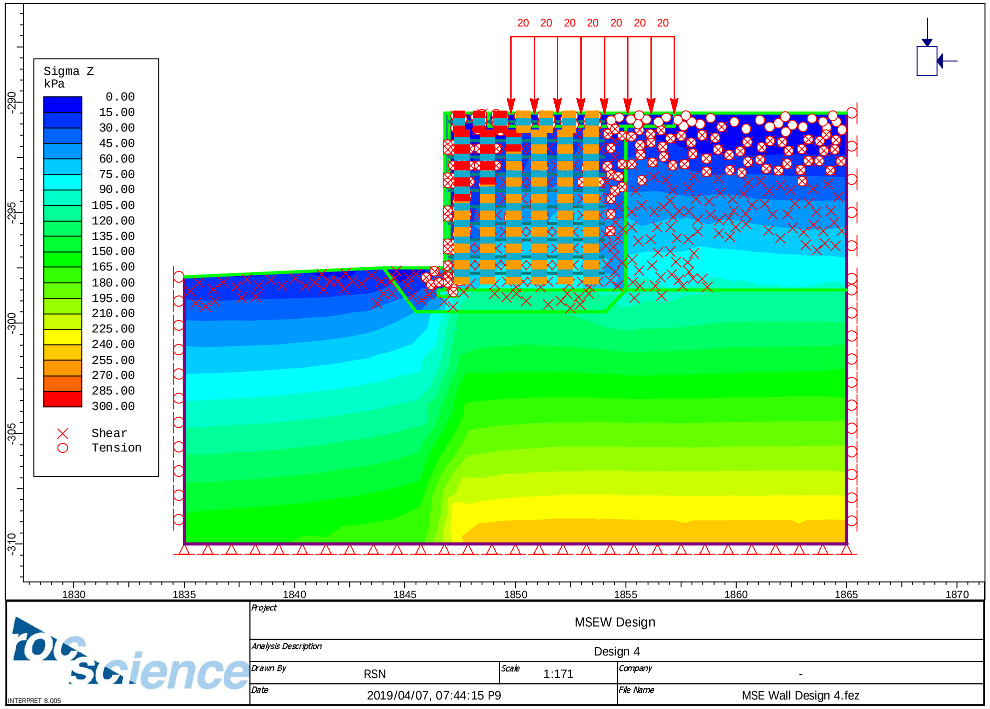
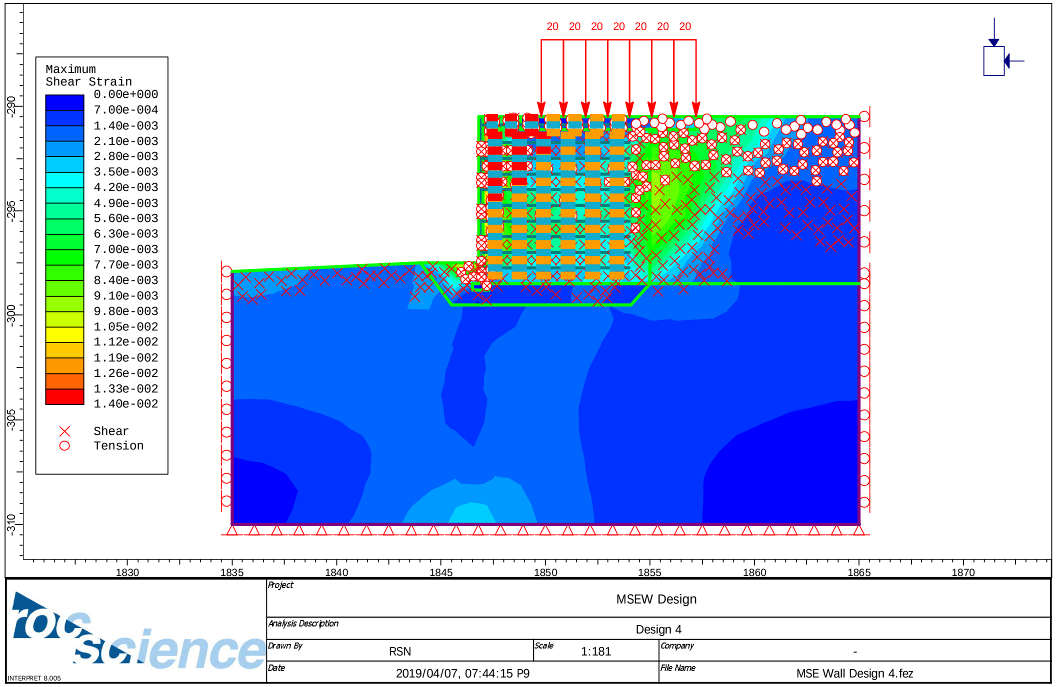
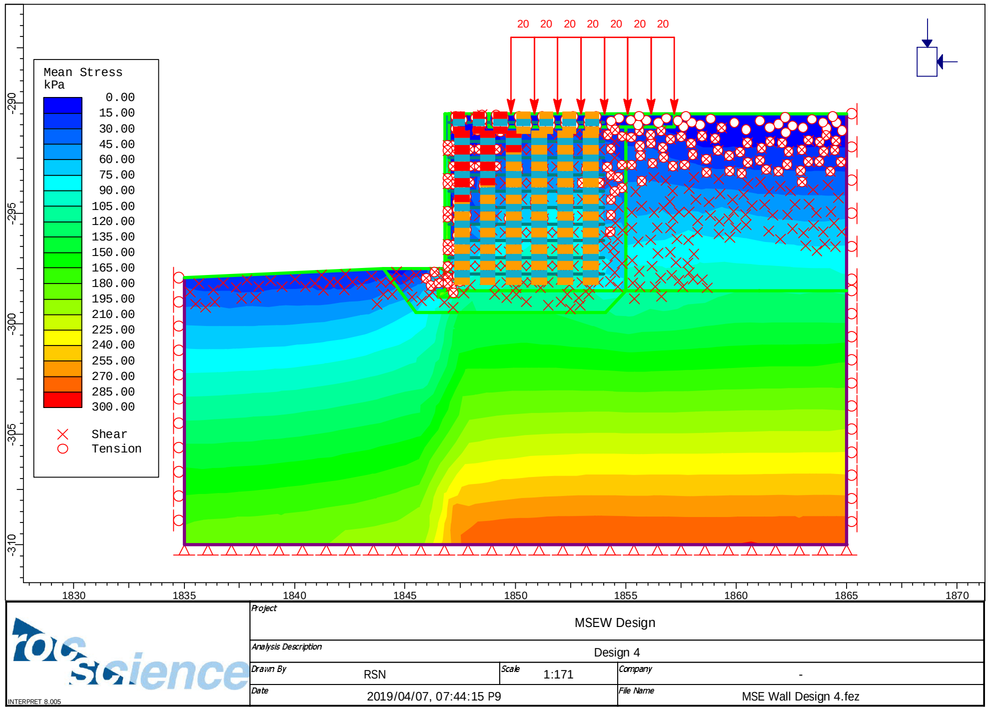
INTERPRET 8.005

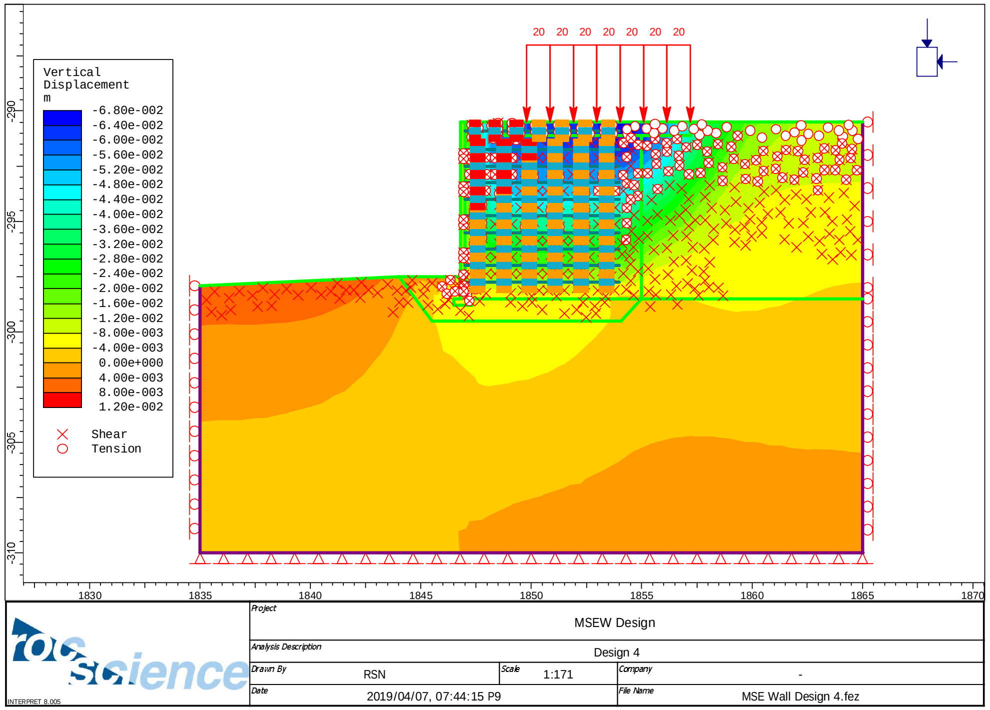

Maximum Shear Strain
0.00e+000
1.50e-002
3.00e-002
4.50e-002
6.00e-002
7.50e-002
9.00e-002
1.05e-001
1.20e-001
1.35e-001
1.50e-001
1.65e-001
1.80e-001
1.95e-001
2.10e-001
2.25e-001
2.40e-001
2.55e-001
2.70e-001
2.85e-001
3.00e-001
Critical SRF: 1.8
20 20 20 20 20 20 20
Project
MSEW Design
Analysis Description
Design 3
Drawn By
RSN
Scale
1:181
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 3.fez
INTERPRET 8.005

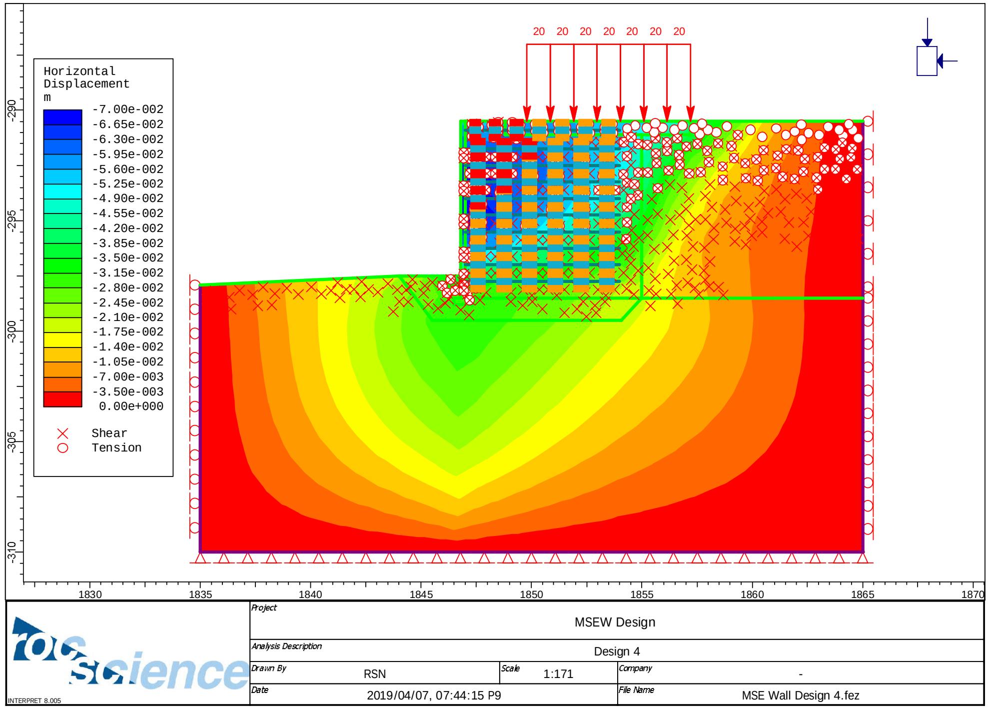

Total Displacement m
0.00e+000
5.50e-003
1.10e-002
1.65e-002
2.20e-002
2.75e-002
3.30e-002
3.85e-002
4.40e-002
4.95e-002
5.50e-002
6.05e-002
6.60e-002
7.15e-002
7.70e-002
8.25e-002
8.80e-002
9.35e-002
9.90e-002
1.04e-001
1.10e-001
Shear
Tension
20 20 20 20 20 20 20
Project
MSEW Design
Analysis Description
Design 3
Drawn By
RSN
Scale
1:181
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 3.fez
INTERPRET 8.005


Sigma Z
kPa
0.00
15.00
30.00
45.00
60.00
75.00
90.00
105.00
120.00
135.00
150.00
165.00
180.00
195.00
210.00
225.00
240.00
255.00
270.00
285.00
300.00
Shear
Tension
20 20 20 20 20 20 20
Project
MSEW Design
Analysis Description
Design 4
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/04/07, 07:44:15 P9
File Name
MSE Wall Design 4.fez
INTERPRET 8.005

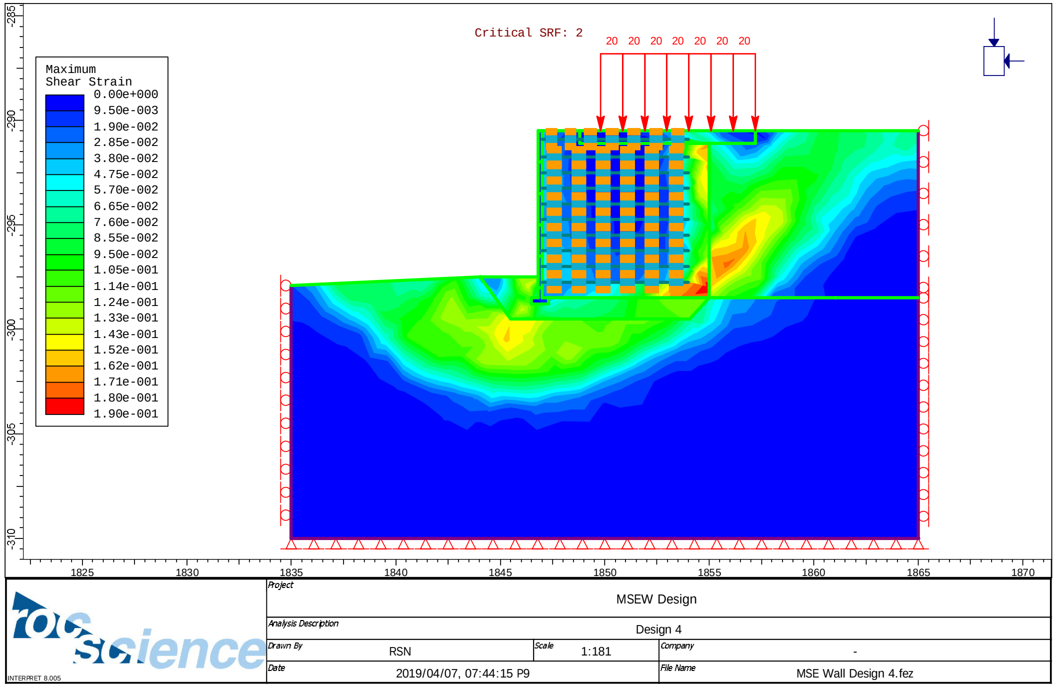

Maximum
Shear Strain
0.00e+000
7.00e-004
1.40e-003
2.10e-003
2.80e-003
3.50e-003
4.20e-003
4.90e-003
5.60e-003
6.30e-003
7.00e-003
7.70e-003
8.40e-003
9.10e-003
9.80e-003
1.05e-002
1.12e-002
1.19e-002
1.26e-002
1.33e-002
1.40e-002
Shear
Tension
20 20 20 20 20 20 20
Project
MSEW Design
Analysis Description
Design 4
Drawn By
RSN
Scale
1:181
Company
-
Date
2019/04/07, 07:44:15 P9
File Name
MSE Wall Design 4.fez
INTERPRET 8.005


Mean Stress
kPa
0.00
15.00
30.00
45.00
60.00
75.00
90.00
105.00
120.00
135.00
150.00
165.00
180.00
195.00
210.00
225.00
240.00
255.00
270.00
285.00
300.00
Shear
Tension
20 20 20 20 20 20 20
Project
MSEW Design
Analysis Description
Design 4
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/04/07, 07:44:15 P9
File Name
MSE Wall Design 4.fez
INTERPRET 8.005


Vertical
Displacement
m
-6.80e-002
-6.40e-002
-6.00e-002
-5.60e-002
-5.20e-002
-4.80e-002
-4.40e-002
-4.00e-002
-3.60e-002
-3.20e-002
-2.80e-002
-2.40e-002
-2.00e-002
-1.60e-002
-1.20e-002
-8.00e-003
-4.00e-003
0.00e+000
4.00e-003
8.00e-003
1.20e-002
Shear
Tension
20 20 20 20 20 20 20
Project
MSEW Design
Analysis Description
Design 4
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/04/07, 07:44:15 P9
File Name
MSE Wall Design 4.fez
INTERPRET 8.005



Horizontal Displacement
m
-7.00e-002
-6.65e-002
-6.30e-002
-5.95e-002
-5.60e-002
-5.25e-002
-4.90e-002
-4.55e-002
-4.20e-002
-3.85e-002
-3.50e-002
-3.15e-002
-2.80e-002
-2.45e-002
-2.10e-002
-1.75e-002
-1.40e-002
-1.05e-002
-7.00e-003
-3.50e-003
0.00e+000
Shear
Tension
20 20 20 20 20 20 20
-290
-295
-300
-305
-310
1830
1835
1840
1845
1850
1855
1860
1865
1870
Project
MSEW Design
Analysis Description
Design 4
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/04/07, 07:44:15 P9
File Name
MSE Wall Design 4.fez
INTERPRET 8.005



Critical SRF: 2
Maximum Shear Strain
0.00e+000
9.50e-003
1.90e-002
2.85e-002
3.80e-002
4.75e-002
5.70e-002
6.65e-002
7.60e-002
8.55e-002
9.50e-002
1.05e-001
1.14e-001
1.24e-001
1.33e-001
1.43e-001
1.52e-001
1.62e-001
1.71e-001
1.80e-001
1.90e-001
20 20 20 20 20 20 20
-285
-290
-295
-300
-305
-310
1825
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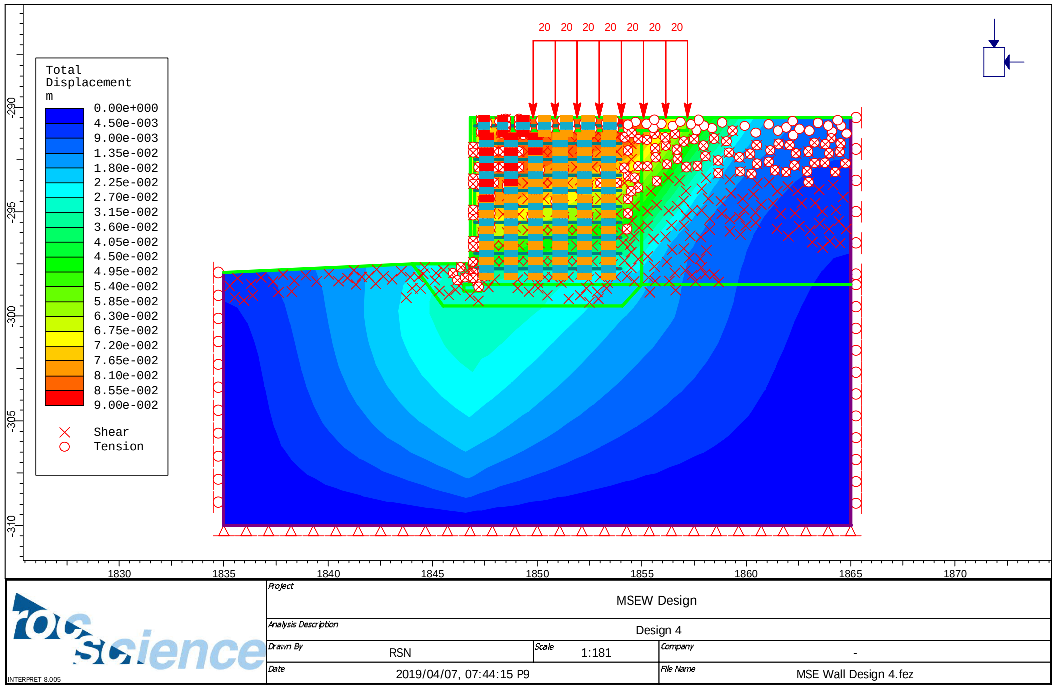
1870
Project
MSEW Design
Analysis Description
Design 4
Drawn By
RSN
Scale
1:181
Company
-
Date
2019/04/07, 07:44:15 P9
File Name
MSE Wall Design 4.fez
INTERPRET 8.005



Total Displacement
m
0.00e+000
4.50e-003
9.00e-003
1.35e-002
1.80e-002
2.25e-002
2.70e-002
3.15e-002
3.60e-002
4.05e-002
4.50e-002
4.95e-002
5.40e-002
5.85e-002
6.30e-002
6.75e-002
7.20e-002
7.65e-002
8.10e-002
8.55e-002
9.00e-002
Shear
Tension
20 20 20 20 20 20 20
-290
-295
-300
-305
-310
1830
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1855
1860
1865
1870
Project
MSEW Design
Analysis Description
Design 4
Drawn By
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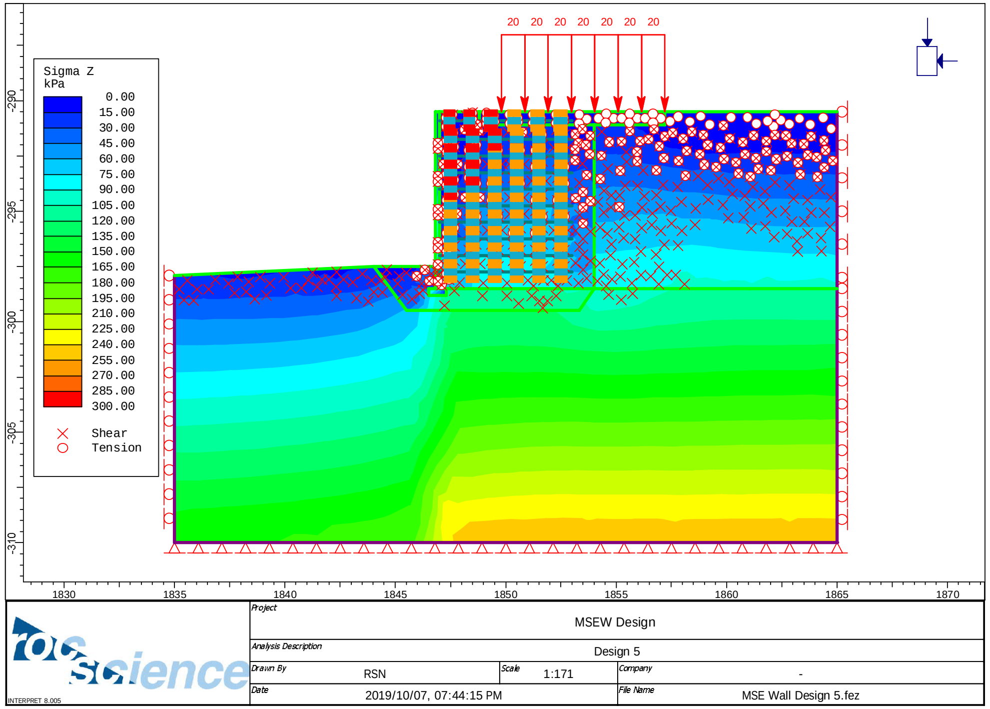
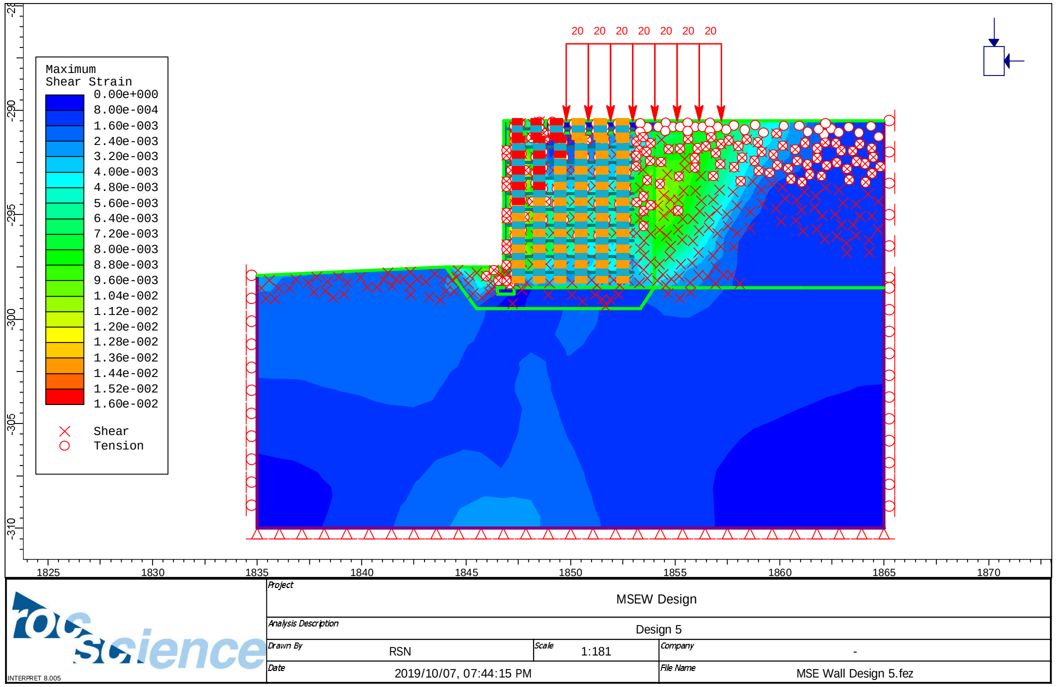
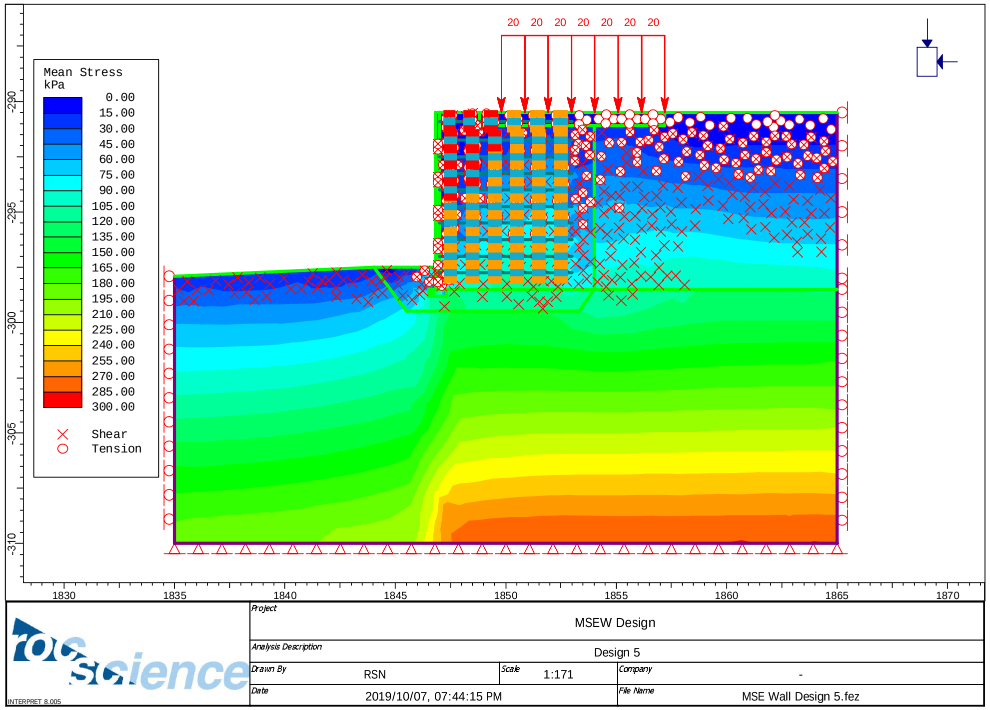
Scale
1:181
Company
-
Date
2019/04/07, 07:44:15 P9
File Name
MSE Wall Design 4.fez
INTERPRET 8.005


Sigma Z
kPa
0.00
15.00
30.00
45.00
60.00
75.00
90.00
105.00
120.00
135.00
150.00
165.00
180.00
195.00
210.00
225.00
240.00
255.00
270.00
285.00
300.00
Shear
Tension
20 20 20 20 20 20 20
1830 1835 1840 1845 1850 1855 1860 1865 1870
-290 -295 -300 -305 -310
Project
MSEW Design
Analysis Description
Design 5
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 5.fez
INTERPRET 8.005


Maximum
Shear Strain
0.00e+000
8.00e-004
1.60e-003
2.40e-003
3.20e-003
4.00e-003
4.80e-003
5.60e-003
6.40e-003
7.20e-003
8.00e-003
8.80e-003
9.60e-003
1.04e-002
1.12e-002
1.20e-002
1.28e-002
1.36e-002
1.44e-002
1.52e-002
1.60e-002
Shear
Tension
20 20 20 20 20 20 20
1825 1830 1835 1840 1845 1850 1855 1860 1865 1870
-290 -295 -300 -305 -310
Project
MSEW Design
Analysis Description
Design 5
Drawn By
RSN
Scale
1:181
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 5.fez
INTERPRET 8.005


Mean Stress
kPa
0.00
15.00
30.00
45.00
60.00
75.00
90.00
105.00
120.00
135.00
150.00
165.00
180.00
195.00
210.00
225.00
240.00
255.00
270.00
285.00
300.00
Shear
Tension
20 20 20 20 20 20 20
1830 1835 1840 1845 1850 1855 1860 1865 1870
-290 -295 -300 -305 -310
Project
MSEW Design
Analysis Description
Design 5
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Company
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Date
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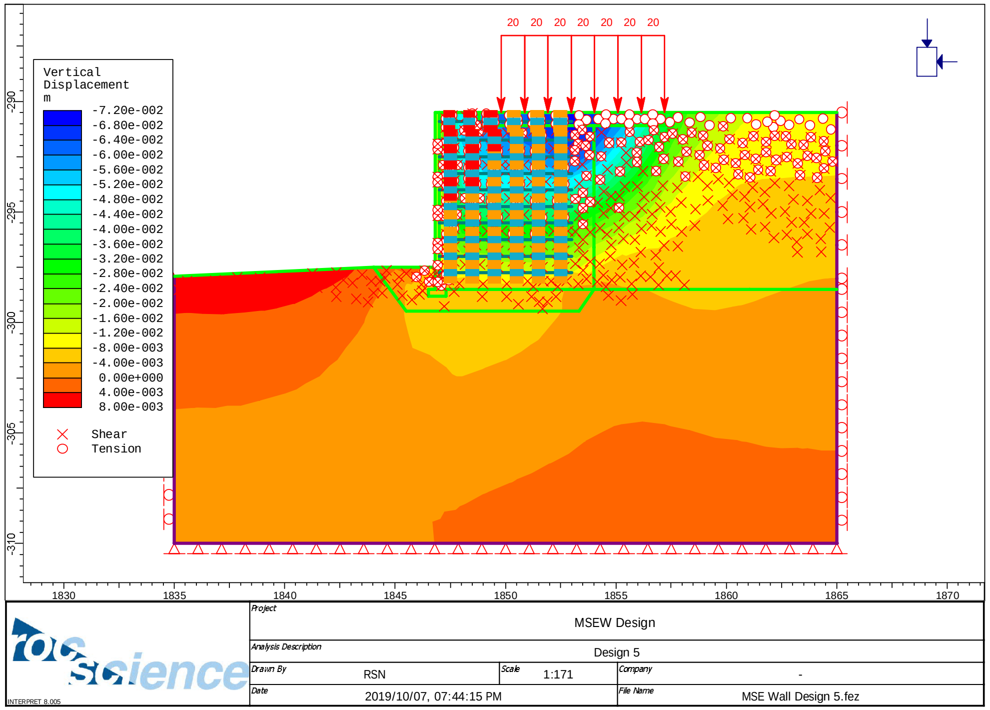
MSE Wall Design 5.fez
INTERPRET 8.005


Vertical
Displacement
m
-7.20e-002
-6.80e-002
-6.40e-002
-6.00e-002
-5.60e-002
-5.20e-002
-4.80e-002
-4.40e-002
-4.00e-002
-3.60e-002
-3.20e-002
-2.80e-002
-2.40e-002
-2.00e-002
-1.60e-002
-1.20e-002
-8.00e-003
-4.00e-003
0.00e+000
4.00e-003
8.00e-003
Shear
Tension
20 20 20 20 20 20 20
1830 1835 1840 1845 1850 1855 1860 1865 1870
-290 -295 -300 -305 -310
Project
MSEW Design
Analysis Description
Design 5
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Company
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Date
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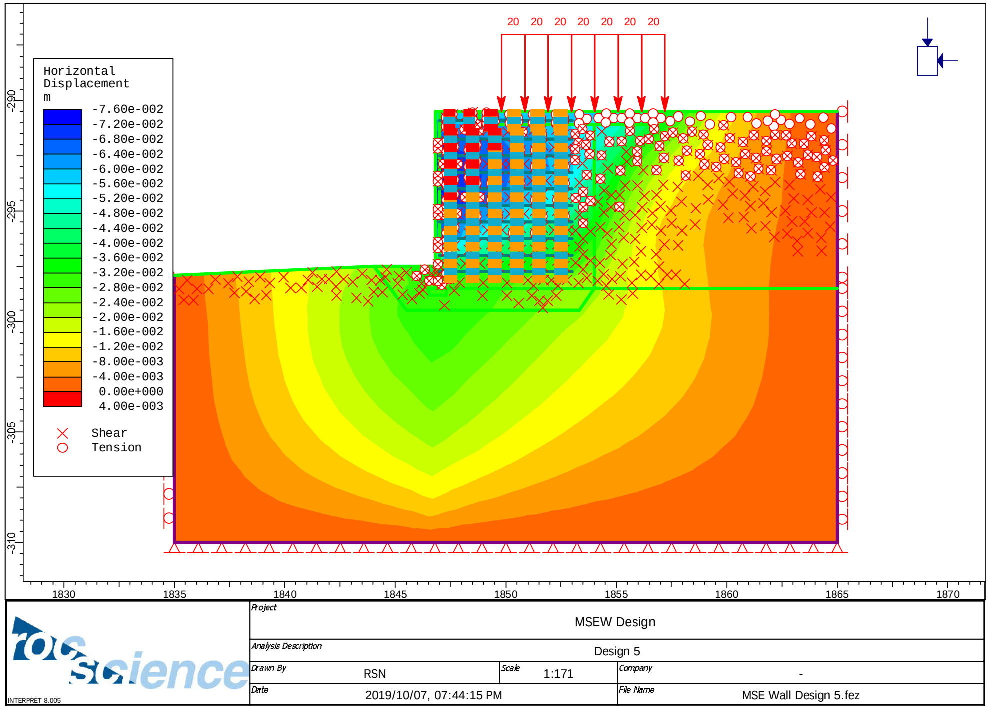
INTERPRET 8.005


20 20 20 20 20 20 20
Horizontal Displacement m
-7.60e-002
-7.20e-002
-6.80e-002
-6.40e-002
-6.00e-002
-5.60e-002
-5.20e-002
-4.80e-002
-4.40e-002
-4.00e-002
-3.60e-002
-3.20e-002
-2.80e-002
-2.40e-002
-2.00e-002
-1.60e-002
-1.20e-002
-8.00e-003
-4.00e-003
0.00e+000
4.00e-003
Shear
Tension
-290
-295
-300
-305
-310
1830
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rocscience
INTERPRET 8.005
Project
MSEW Design
Analysis Description
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Company
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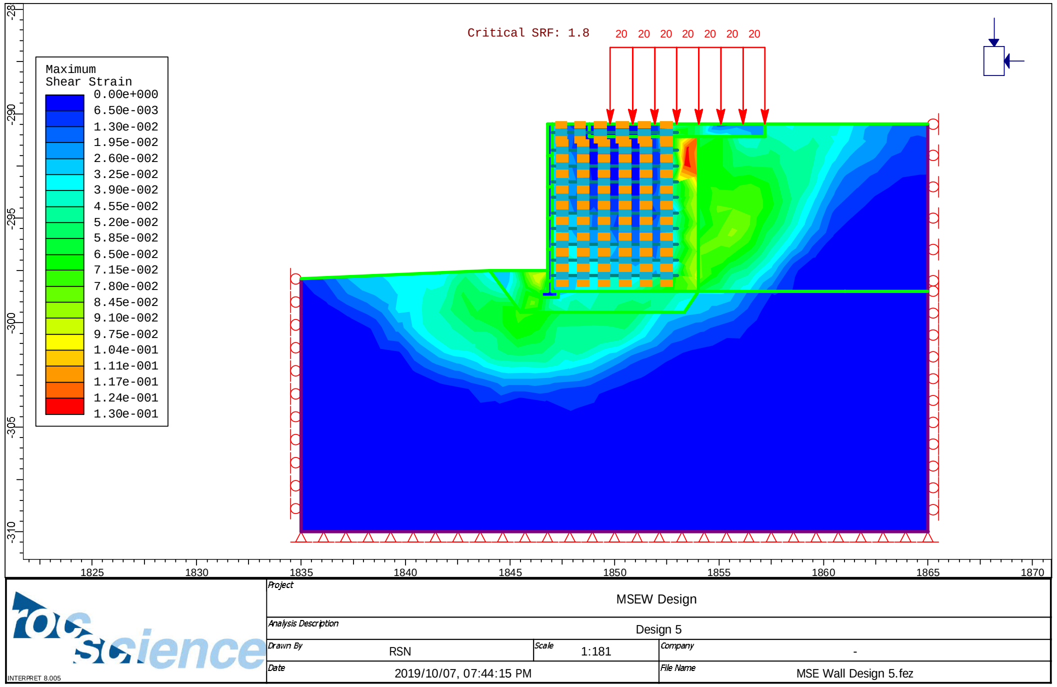
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 5.fez


Critical SRF: 1.8
20 20 20 20 20 20 20
Maximum Shear Strain
0.00e+000
6.50e-003
1.30e-002
1.95e-002
2.60e-002
3.25e-002
3.90e-002
4.55e-002
5.20e-002
5.85e-002
6.50e-002
7.15e-002
7.80e-002
8.45e-002
9.10e-002
9.75e-002
1.04e-001
1.11e-001
1.17e-001
1.24e-001
1.30e-001
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rocscience
INTERPRET 8.005
Project
MSEW Design
Analysis Description
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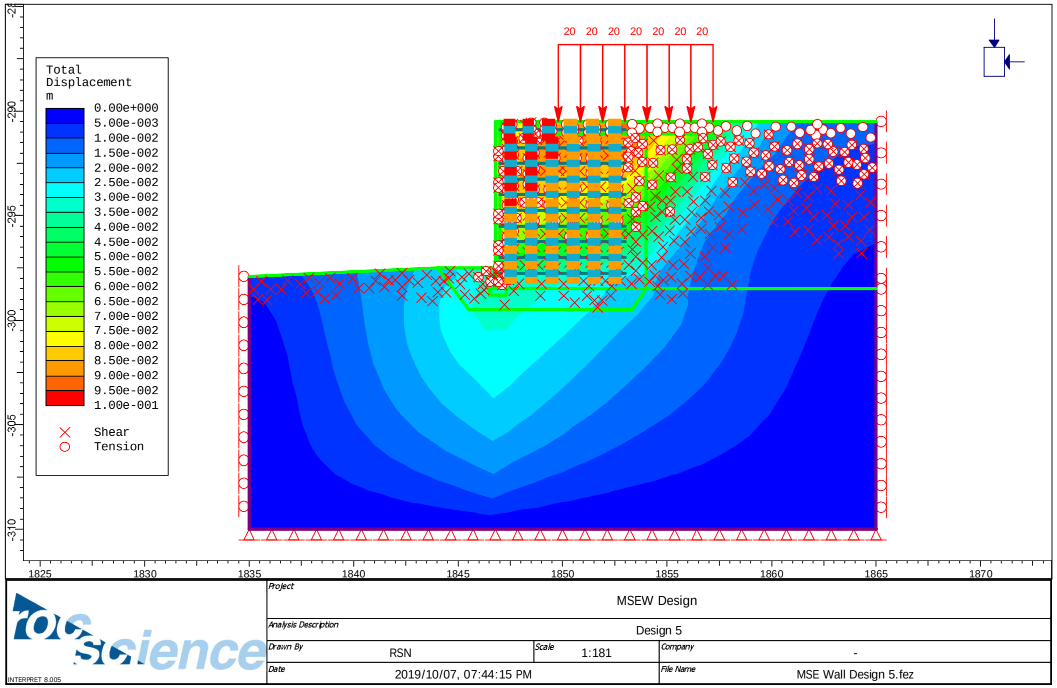
MSE Wall Design 5.fez


20 20 20 20 20 20 20
Total Displacement m
0.00e+000
5.00e-003
1.00e-002
1.50e-002
2.00e-002
2.50e-002
3.00e-002
3.50e-002
4.00e-002
4.50e-002
5.00e-002
5.50e-002
6.00e-002
6.50e-002
7.00e-002
7.50e-002
8.00e-002
8.50e-002
9.00e-002
9.50e-002
1.00e-001
Shear
Tension
-290
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-310
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1865
1870
rocscience
INTERPRET 8.005
Project
MSEW Design
Analysis Description
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Date
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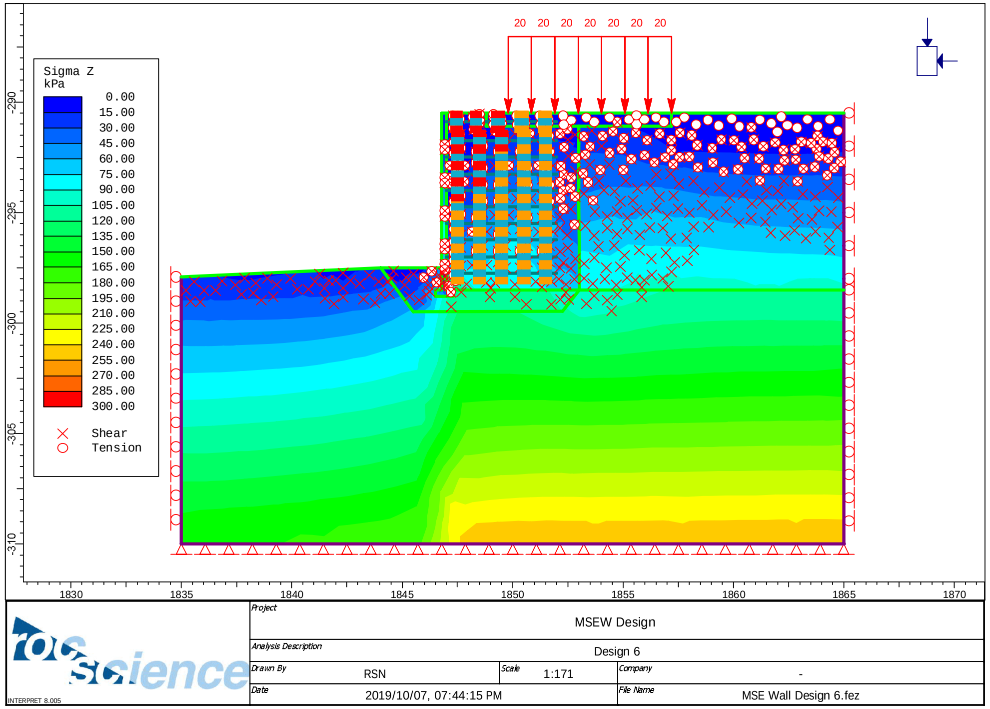

Sigma Z
kPa
0.00
15.00
30.00
45.00
60.00
75.00
90.00
105.00
120.00
135.00
150.00
165.00
180.00
195.00
210.00
225.00
240.00
255.00
270.00
285.00
300.00
Shear
Tension
20 20 20 20 20 20 20
1830 1835 1840 1845 1850 1855 1860 1865 1870
-290 -295 -300 -305 -310
Project
MSEW Design
Analysis Description
Design 6
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
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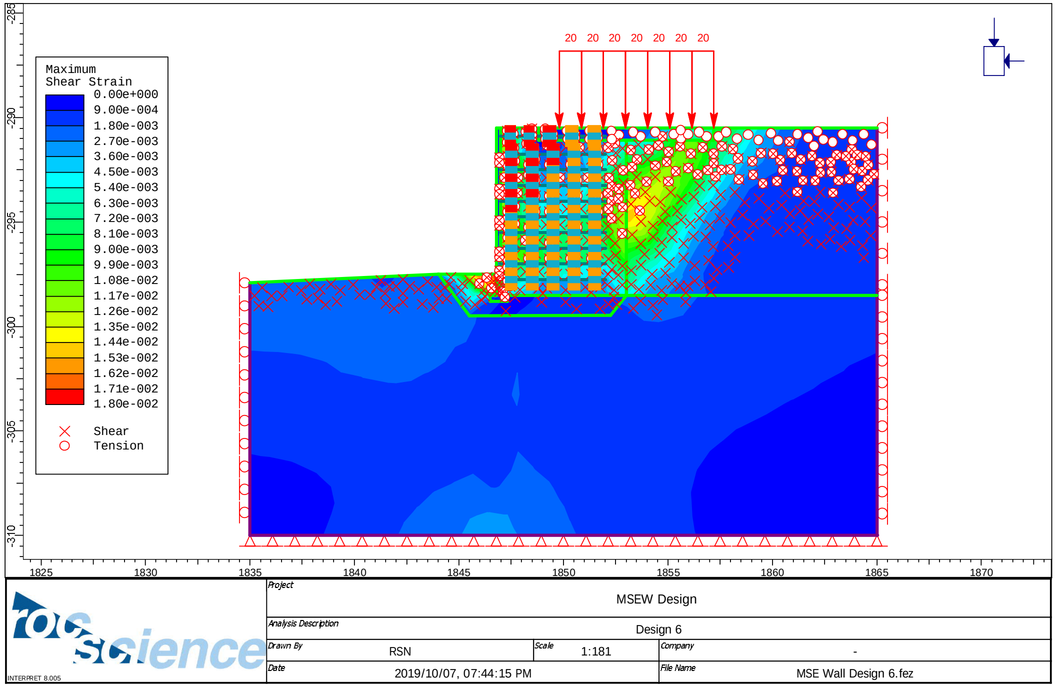
MSE Wall Design 6.fez
INTERPRET 8.005



Maximum
Shear Strain
0.00e+000
9.00e-004
1.80e-003
2.70e-003
3.60e-003
4.50e-003
5.40e-003
6.30e-003
7.20e-003
8.10e-003
9.00e-003
9.90e-003
1.08e-002
1.17e-002
1.26e-002
1.35e-002
1.44e-002
1.53e-002
1.62e-002
1.71e-002
1.80e-002
Shear
Tension
20 20 20 20 20 20 20
1825 1830 1835 1840 1845 1850 1855 1860 1865 1870
-285 -290 -295 -300 -305 -310
Project
MSEW Design
Analysis Description
Design 6
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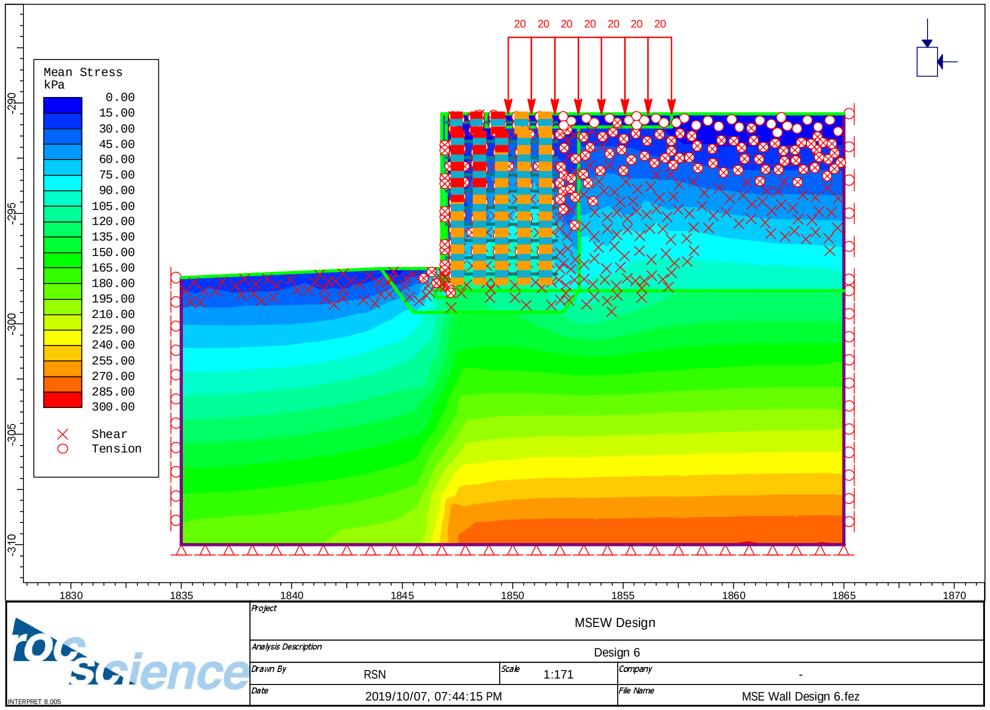
INTERPRET 8.005



Mean Stress
kPa
0.00
15.00
30.00
45.00
60.00
75.00
90.00
105.00
120.00
135.00
150.00
165.00
180.00
195.00
210.00
225.00
240.00
255.00
270.00
285.00
300.00
Shear
Tension
20 20 20 20 20 20 20
1830 1835 1840 1845 1850 1855 1860 1865 1870
-290 -295 -300 -305 -310
Project
MSEW Design
Analysis Description
Design 6
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Company
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Date
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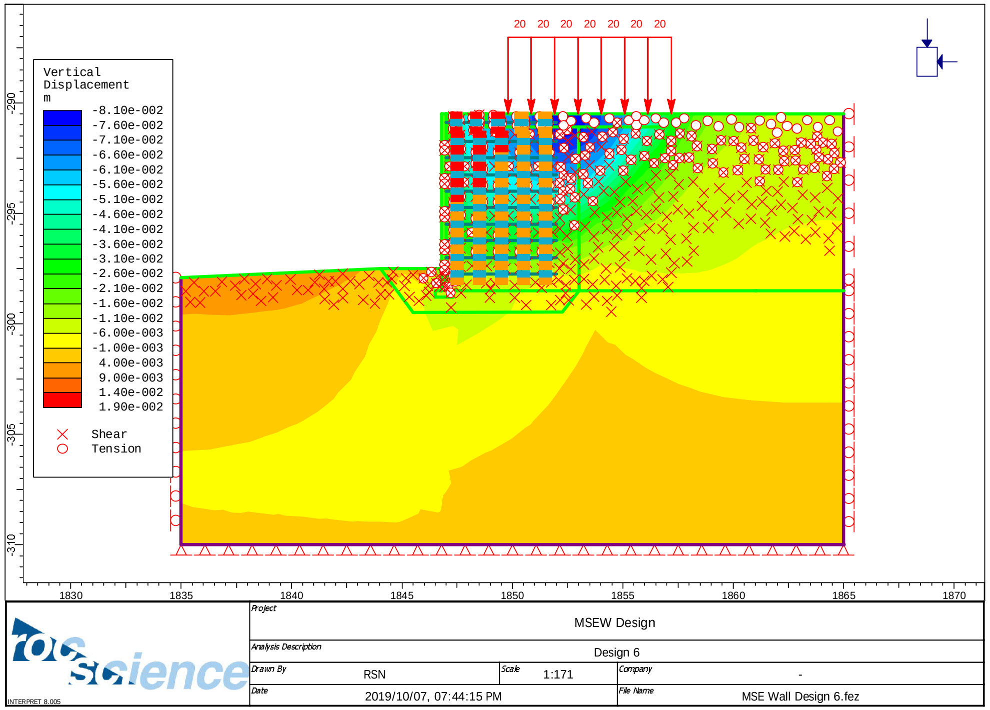
MSE Wall Design 6.fez
INTERPRET 8.005



Vertical
Displacement
m
-8.10e-002
-7.60e-002
-7.10e-002
-6.60e-002
-6.10e-002
-5.60e-002
-5.10e-002
-4.60e-002
-4.10e-002
-3.60e-002
-3.10e-002
-2.60e-002
-2.10e-002
-1.60e-002
-1.10e-002
-6.00e-003
-1.00e-003
4.00e-003
9.00e-003
1.40e-002
1.90e-002
Shear
Tension
20 20 20 20 20 20 20
1830 1835 1840 1845 1850 1855 1860 1865 1870
-290 -295 -300 -305 -310
Project
MSEW Design
Analysis Description
Design 6
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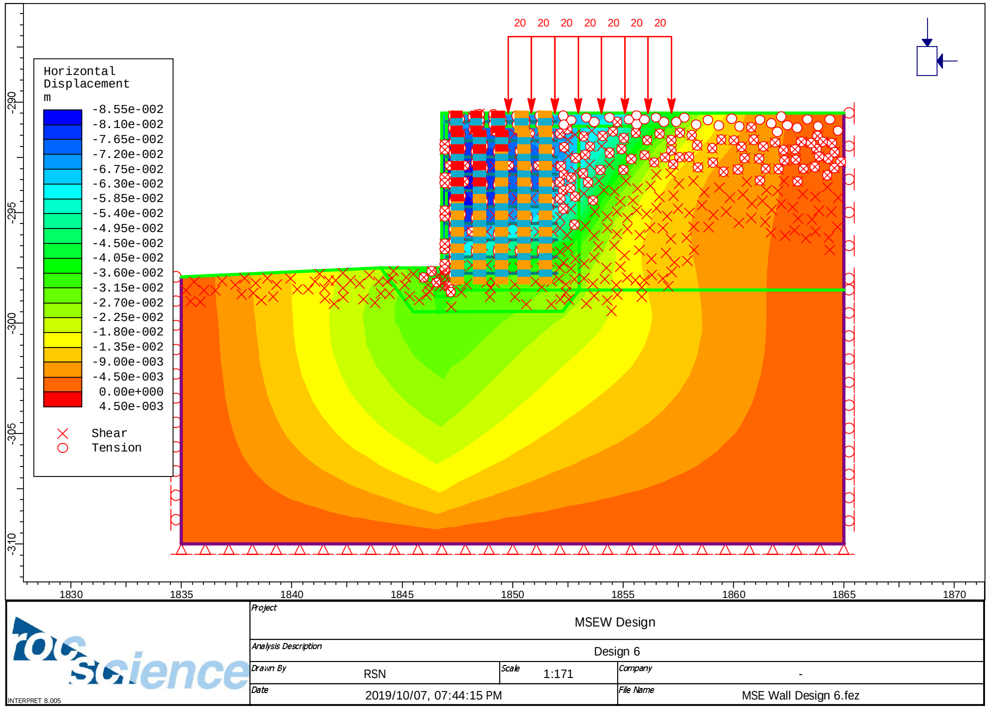
INTERPRET 8.005


20 20 20 20 20 20 20
Horizontal Displacement m
-8.55e-002
-8.10e-002
-7.65e-002
-7.20e-002
-6.75e-002
-6.30e-002
-5.85e-002
-5.40e-002
-4.95e-002
-4.50e-002
-4.05e-002
-3.60e-002
-3.15e-002
-2.70e-002
-2.25e-002
-1.80e-002
-1.35e-002
-9.00e-003
-4.50e-003
0.00e+000
4.50e-003
Shear
Tension
-290
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1830
1835
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1865
1870
rocscience
INTERPRET 8.005
Project
MSEW Design
Analysis Description
Design 6
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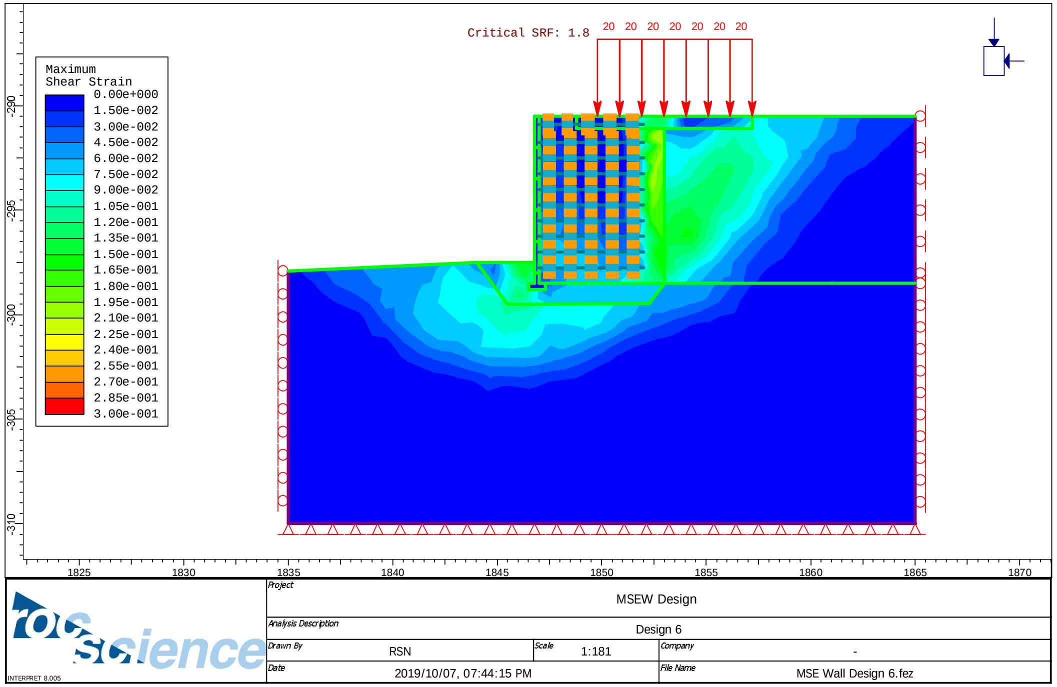
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 6.fez


Critical SRF: 1.8
20 20 20 20 20 20 20
Maximum Shear Strain
0.00e+000
1.50e-002
3.00e-002
4.50e-002
6.00e-002
7.50e-002
9.00e-002
1.05e-001
1.20e-001
1.35e-001
1.50e-001
1.65e-001
1.80e-001
1.95e-001
2.10e-001
2.25e-001
2.40e-001
2.55e-001
2.70e-001
2.85e-001
3.00e-001
-290
-295
-300
-305
-310
1825
1830
1835
1840
1845
1850
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1860
1865
1870
rocscience
INTERPRET 8.005
Project
MSEW Design
Analysis Description
Design 6
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Scale
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Company
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Date
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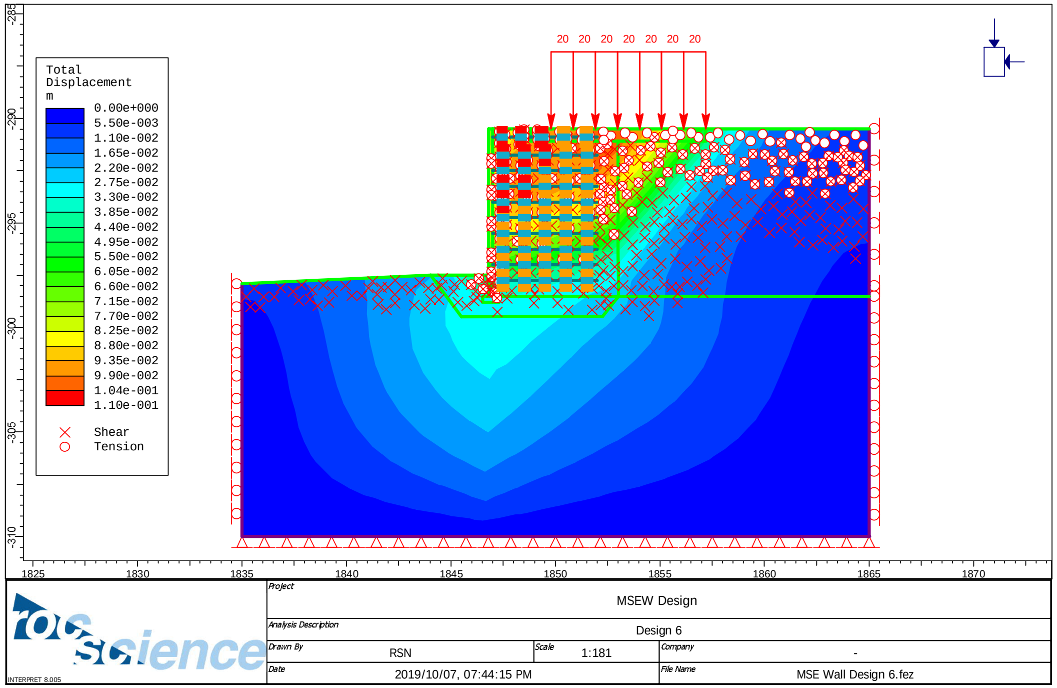
MSE Wall Design 6.fez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1.10e-002
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2.75e-002
3.30e-002
3.85e-002
4.40e-002
4.95e-002
5.50e-002
6.05e-002
6.60e-002
7.15e-002
7.70e-002
8.25e-002
8.80e-002
9.35e-002
9.90e-002
1.04e-001
1.10e-001
Shear
Tension
-285
-290
-295
-300
-305
-310
1825
1830
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1870
rocscience
INTERPRET 8.005
Project
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Analysis Description
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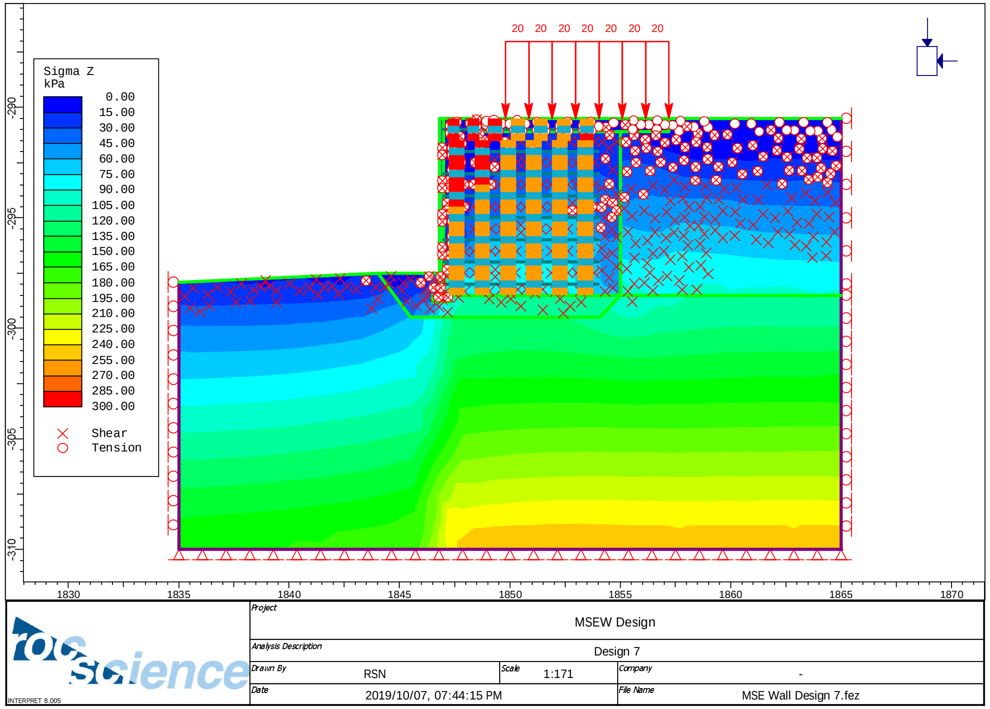
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kPa
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30.00
45.00
60.00
75.00
90.00
105.00
120.00
135.00
150.00
165.00
180.00
195.00
210.00
225.00
240.00
255.00
270.00
285.00
300.00
Shear
Tension
20 20 20 20 20 20 20
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-295
-300
-305
-310
1830 1835 1840 1845 1850 1855 1860 1865 1870
Project
MSEW Design
Analysis Description
Design 7
Drawn By
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Company
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Date
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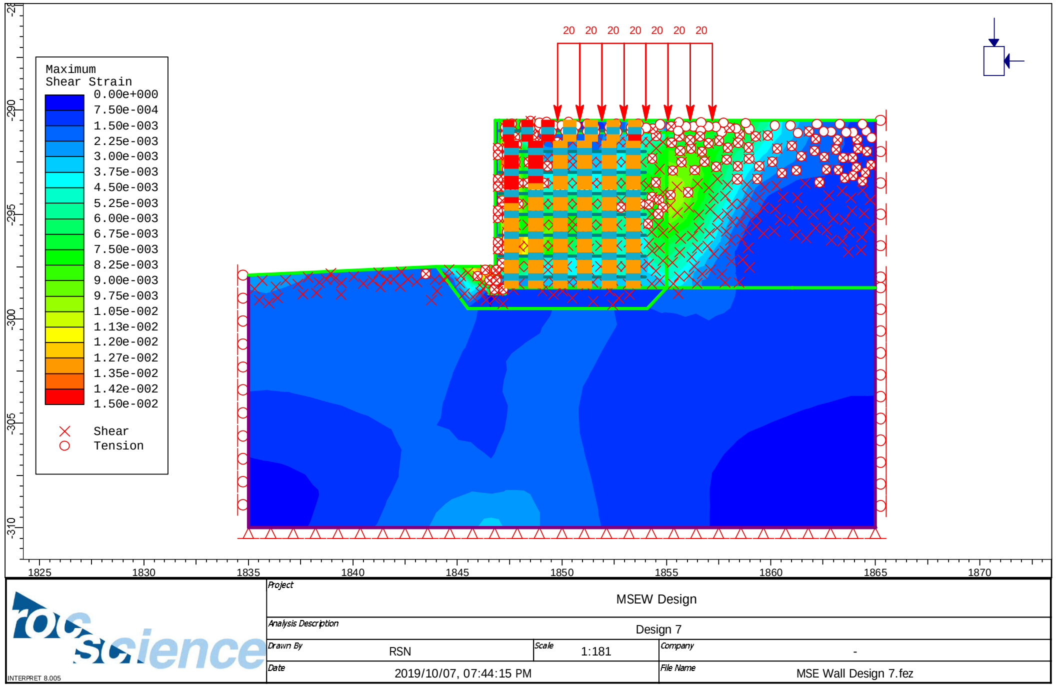
INTERPRET 8.005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1.50e-003
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3.75e-003
4.50e-003
5.25e-003
6.00e-003
6.75e-003
7.50e-003
8.25e-003
9.00e-003
9.75e-003
1.05e-002
1.13e-002
1.20e-002
1.27e-002
1.35e-002
1.42e-002
1.50e-002
Shear
Tension
20 20 20 20 20 20 20
-290
-295
-300
-305
-310
1825 1830 1835 1840 1845 1850 1855 1860 1865 1870
Project
MSEW Design
Analysis Description
Design 7
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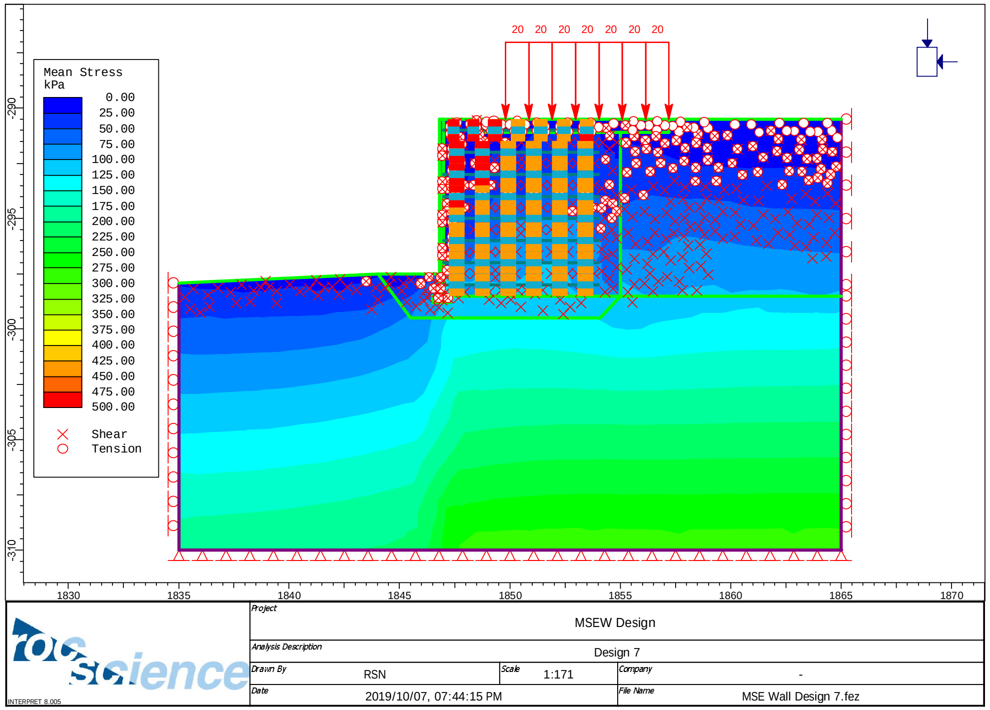
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kPa
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50.00
75.00
100.00
125.00
150.00
175.00
200.00
225.00
250.00
275.00
300.00
325.00
350.00
375.00
400.00
425.00
450.00
475.00
500.00
Shear
Tension
20 20 20 20 20 20 20
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-295
-300
-305
-310
1830 1835 1840 1845 1850 1855 1860 1865 1870
Project
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Analysis Description
Design 7
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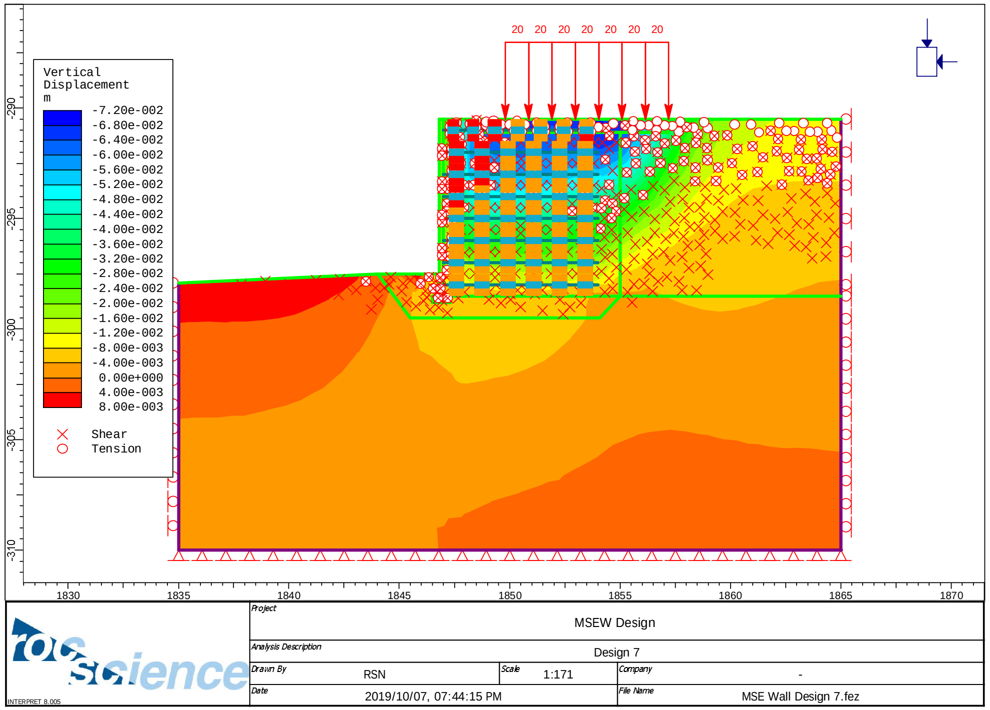
INTERPRET 8.005


Vertical
Displacement
m
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-6.80e-002
-6.40e-002
-6.00e-002
-5.60e-002
-5.20e-002
-4.80e-002
-4.40e-002
-4.00e-002
-3.60e-002
-3.20e-002
-2.80e-002
-2.40e-002
-2.00e-002
-1.60e-002
-1.20e-002
-8.00e-003
-4.00e-003
0.00e+000
4.00e-003
8.00e-003
Shear
Tension
20 20 20 20 20 20 20
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-295
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-305
-310
1830 1835 1840 1845 1850 1855 1860 1865 1870
Project
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Analysis Description
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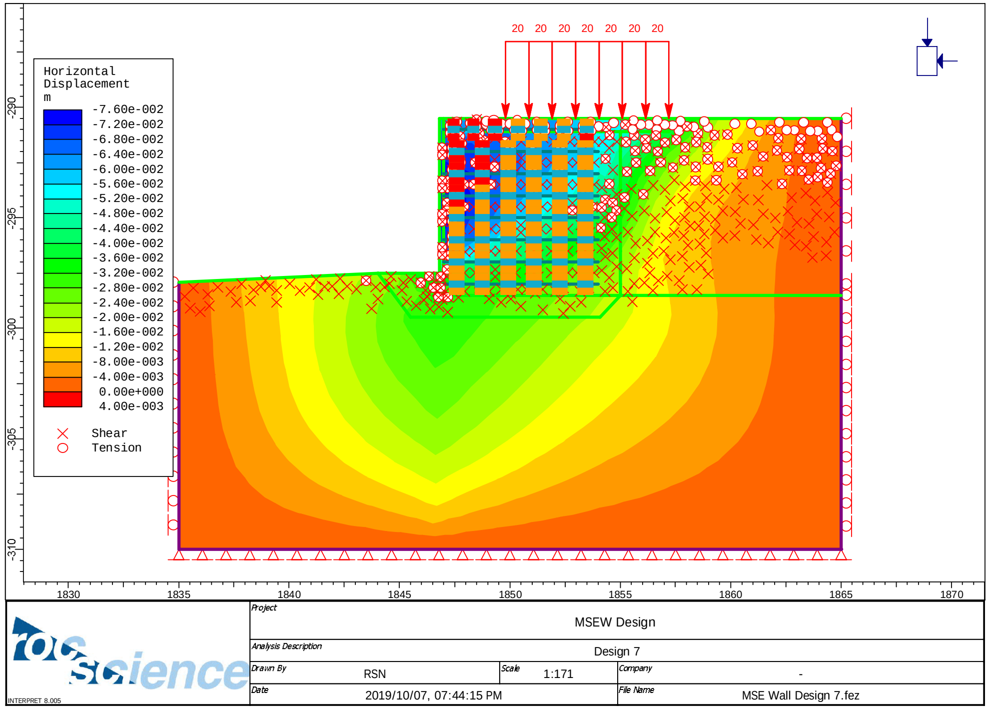
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-7.20e-002
-6.80e-002
-6.40e-002
-6.00e-002
-5.60e-002
-5.20e-002
-4.80e-002
-4.40e-002
-4.00e-002
-3.60e-002
-3.20e-002
-2.80e-002
-2.40e-002
-2.00e-002
-1.60e-002
-1.20e-002
-8.00e-003
-4.00e-003
0.00e+000
4.00e-003
Shear
Tension
20 20 20 20 20 20 20
1830 1835 1840 1845 1850 1855 1860 1865 1870
-290 -295 -300 -305 -310
Project
MSEW Design
Analysis Description
Design 7
Drawn By
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Company
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Date
2019/10/07, 07:44:15 PM
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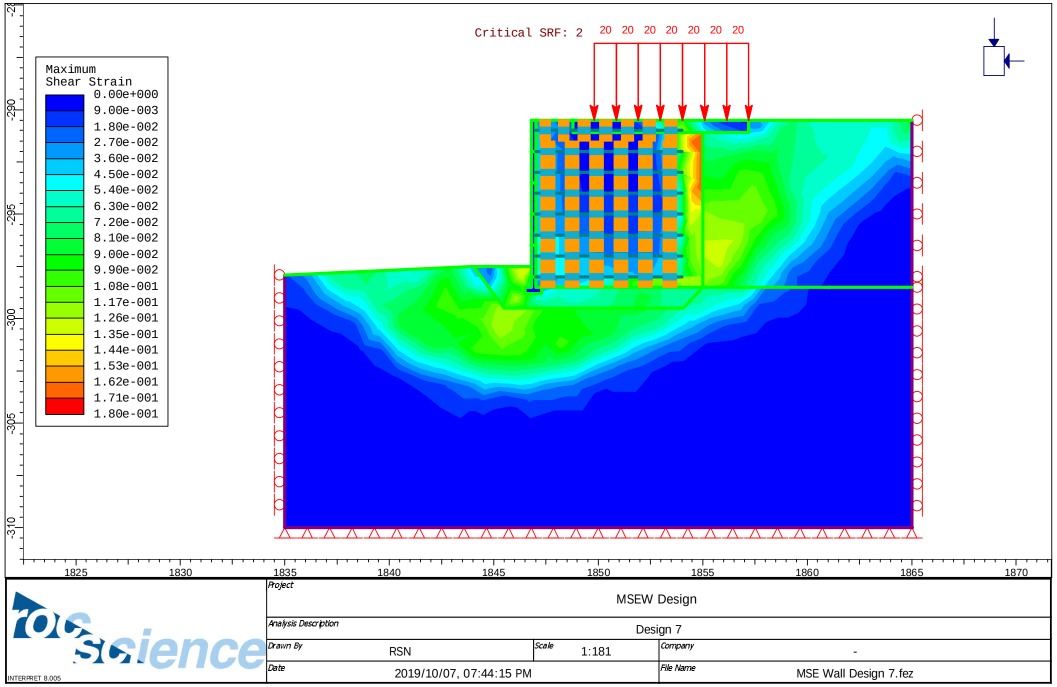
INTERPRET 8.005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9.00e-003
1.80e-002
2.70e-002
3.60e-002
4.50e-002
5.40e-002
6.30e-002
7.20e-002
8.10e-002
9.00e-002
9.90e-002
1.08e-001
1.17e-001
1.26e-001
1.35e-001
1.44e-001
1.53e-001
1.62e-001
1.71e-001
1.80e-001
Critical SRF: 2
20 20 20 20 20 20 20
1825 1830 1835 1840 1845 1850 1855 1860 1865 1870
-290 -295 -300 -305 -310
Project
MSEW Design
Analysis Description
Design 7
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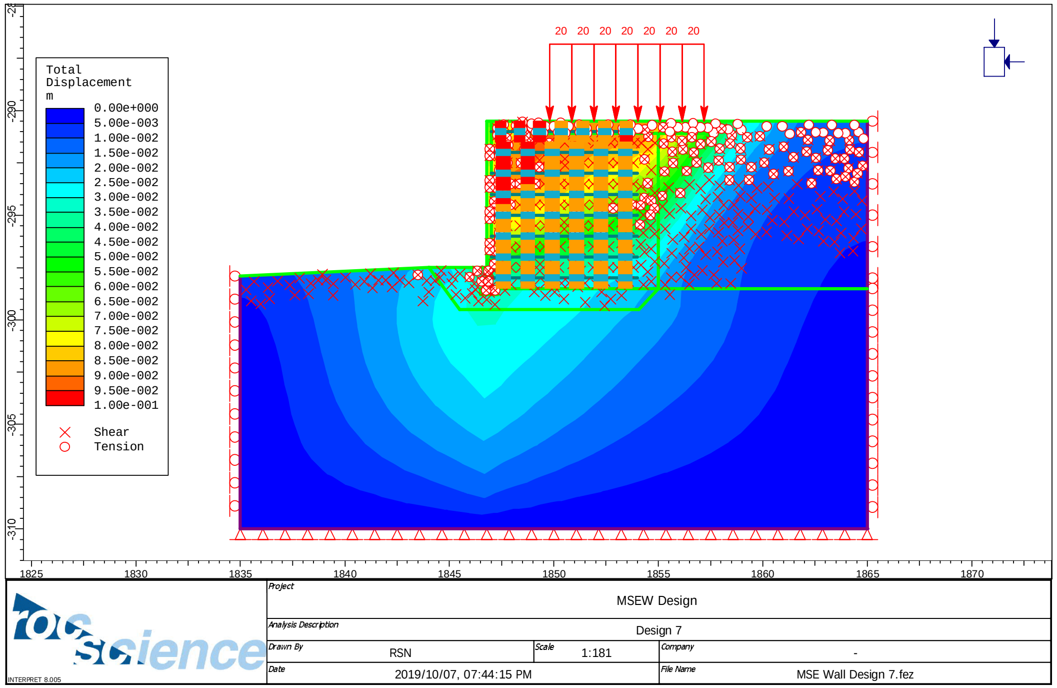
INTERPRET 8.005


Total Displacement m
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1.00e-002
1.50e-002
2.00e-002
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3.50e-002
4.00e-002
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7.50e-002
8.00e-002
8.50e-002
9.00e-002
9.50e-002
1.00e-001
Shear
Tension
20 20 20 20 20 20 20
1825 1830 1835 1840 1845 1850 1855 1860 1865 1870
-290 -295 -300 -305 -310
Project
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Analysis Description
Design 7
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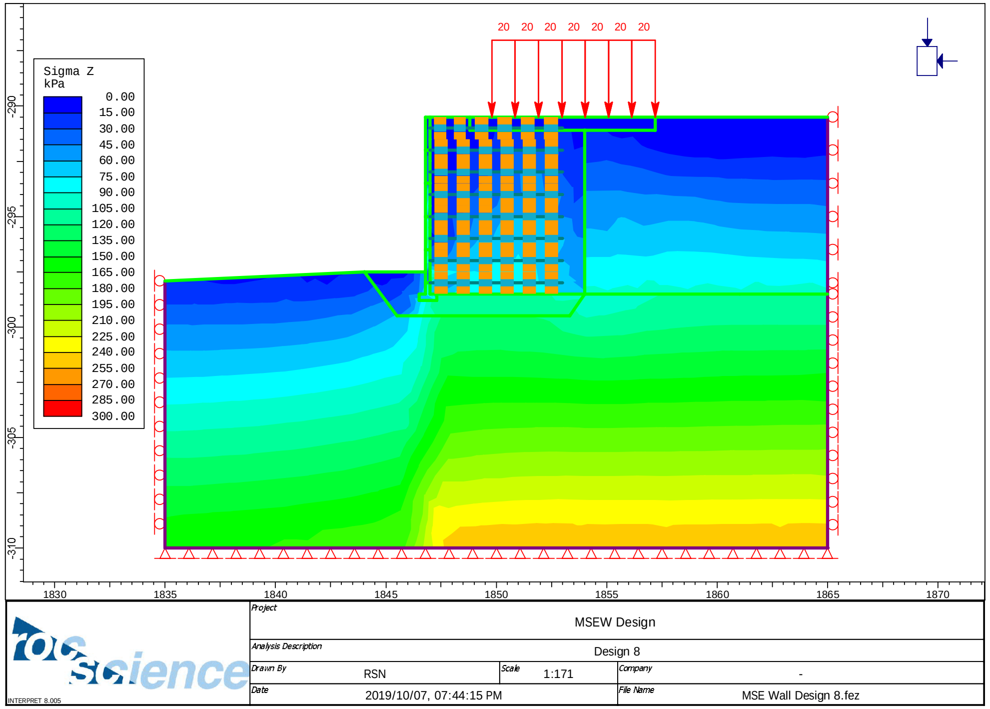
Sigma Z
kPa
0.00
15.00
30.00
45.00
60.00
75.00
90.00
105.00
120.00
135.00
150.00
165.00
180.00
195.00
210.00
225.00
240.00
255.00
270.00
285.00
300.00
20 20 20 20 20 20 20
Project
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Analysis Description
Design 8
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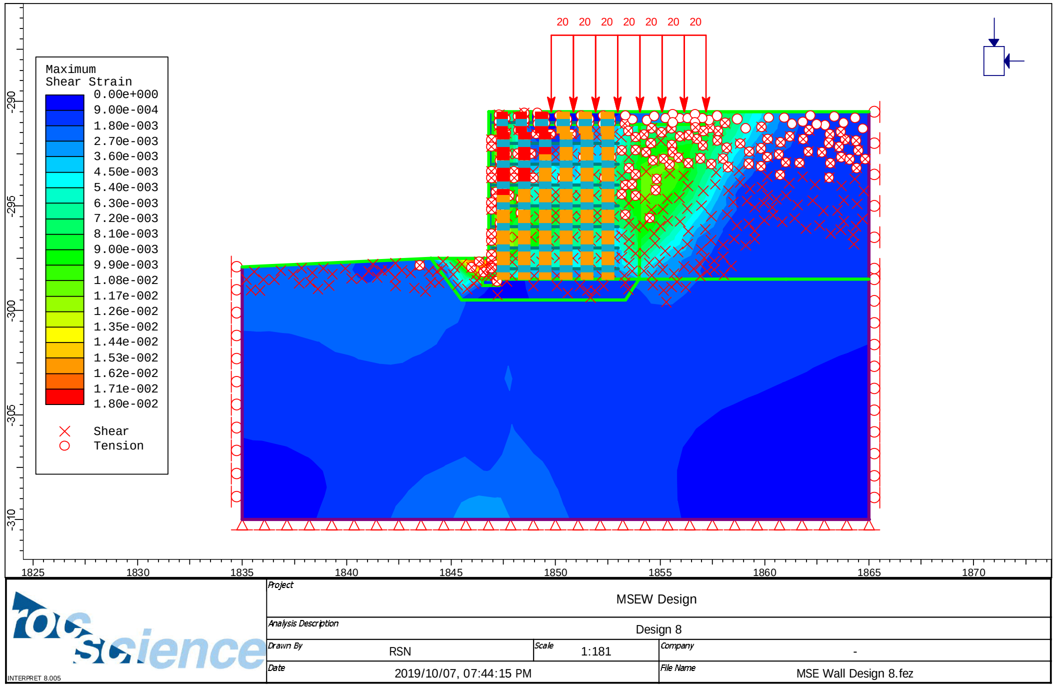
Maximum
Shear Strain
0.00e+000
9.00e-004
1.80e-003
2.70e-003
3.60e-003
4.50e-003
5.40e-003
6.30e-003
7.20e-003
8.10e-003
9.00e-003
9.90e-003
1.08e-002
1.17e-002
1.26e-002
1.35e-002
1.44e-002
1.53e-002
1.62e-002
1.71e-002
1.80e-002
Shear
Tension
20 20 20 20 20 20 20
Project
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Analysis Description
Design 8
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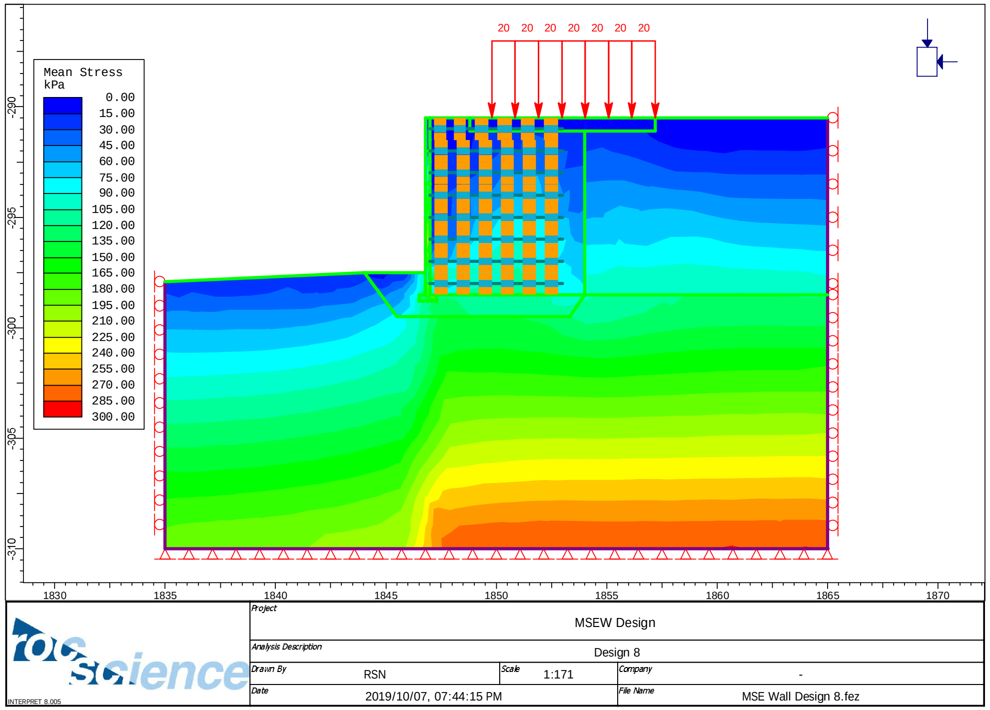
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kPa
0.00
15.00
30.00
45.00
60.00
75.00
90.00
105.00
120.00
135.00
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165.00
180.00
195.00
210.00
225.00
240.00
255.00
270.00
285.00
300.00
20 20 20 20 20 20 20
Project
MSEW Design
Analysis Description
Design 8
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Company
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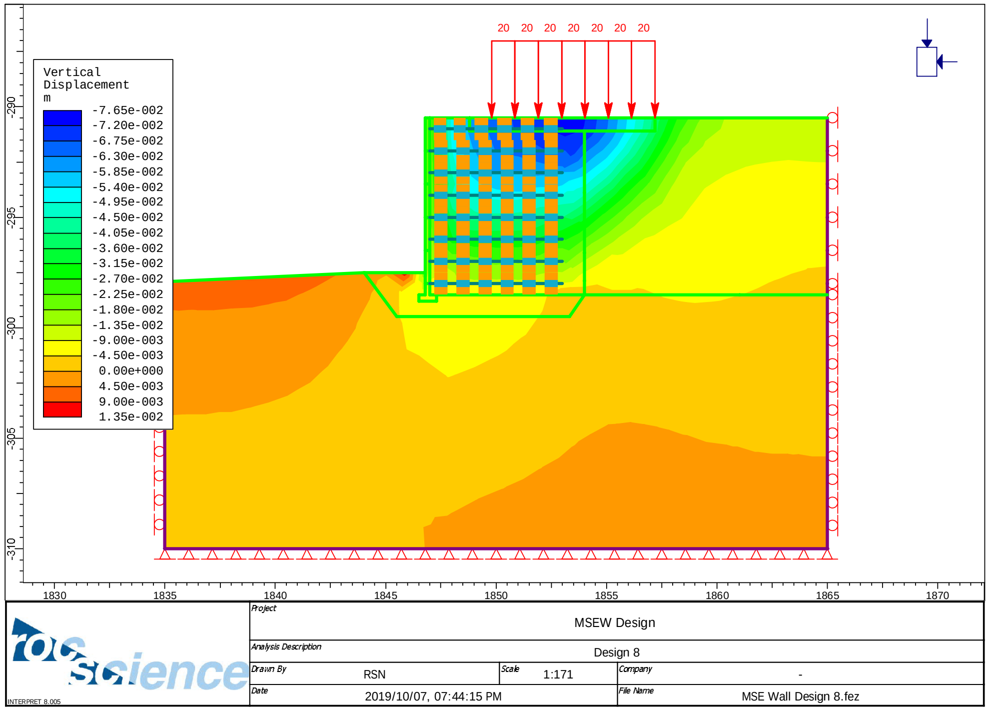
INTERPRET 8.005


Vertical
Displacement
m
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-7.20e-002
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-6.30e-002
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-4.50e-003
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4.50e-003
9.00e-003
1.35e-002
20 20 20 20 20 20 20
Project
MSEW Design
Analysis Description
Design 8
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
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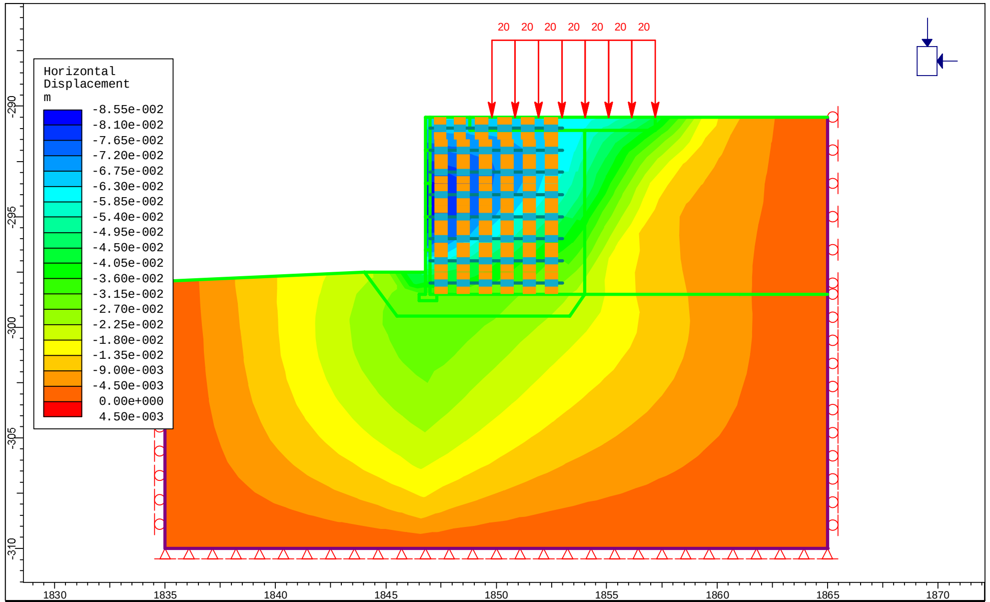

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	Analysis Description: Design 8		
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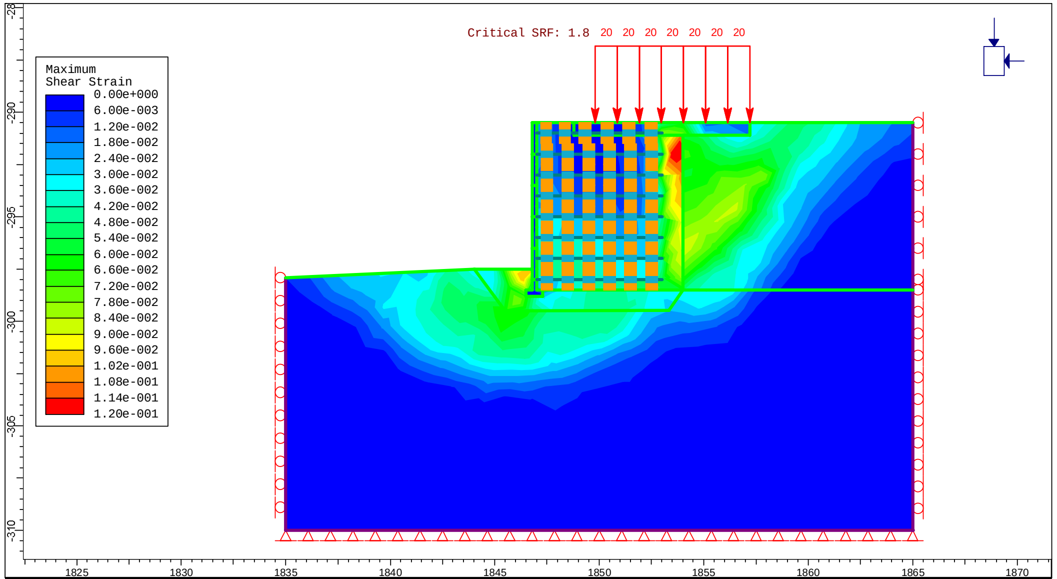
INTERPRET 8.005	Date: 2019/10/07, 07:44:15 PM		File Name: MSE Wall Design 8.fez



rocscience	Project: MSEW Design		
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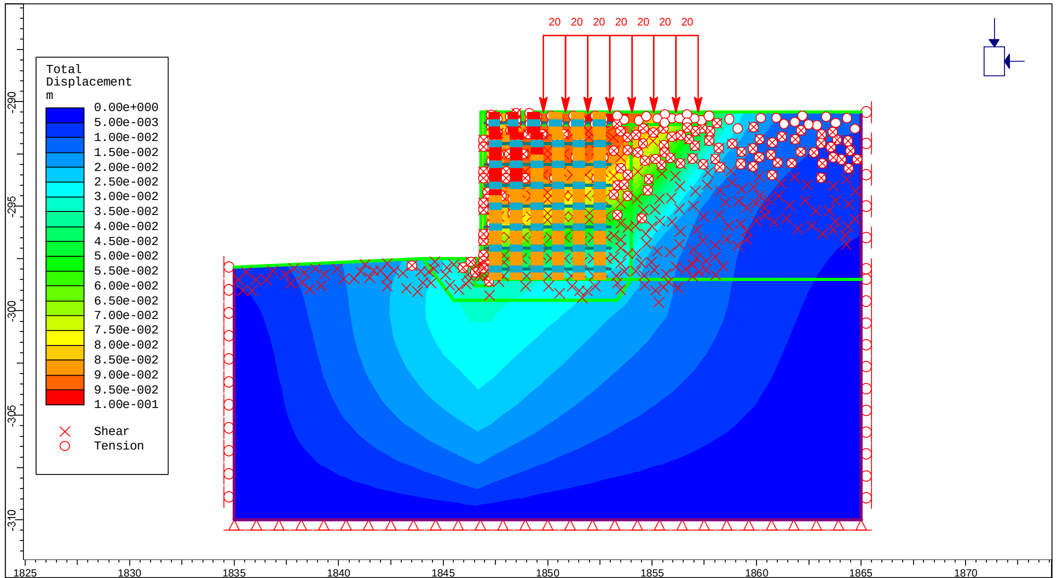

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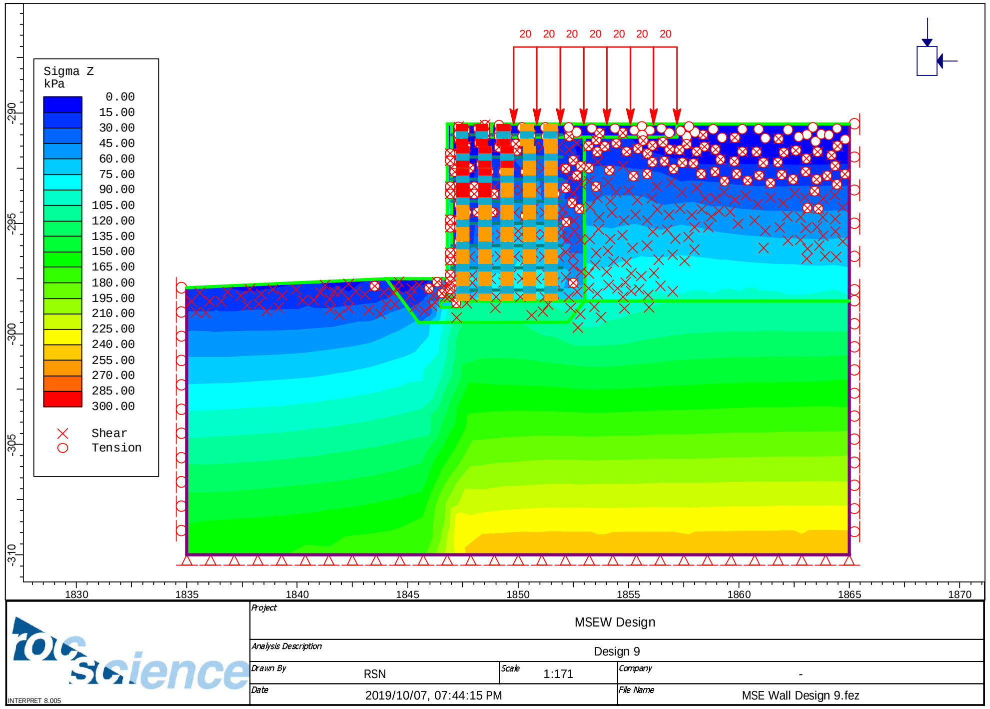
Sigma Z
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0.00
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30.00
45.00
60.00
75.00
90.00
105.00
120.00
135.00
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165.00
180.00
195.00
210.00
225.00
240.00
255.00
270.00
285.00
300.00
Shear
Tension
Project
MSEW Design
Analysis Description
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Date
2019/10/07, 07:44:15 PM
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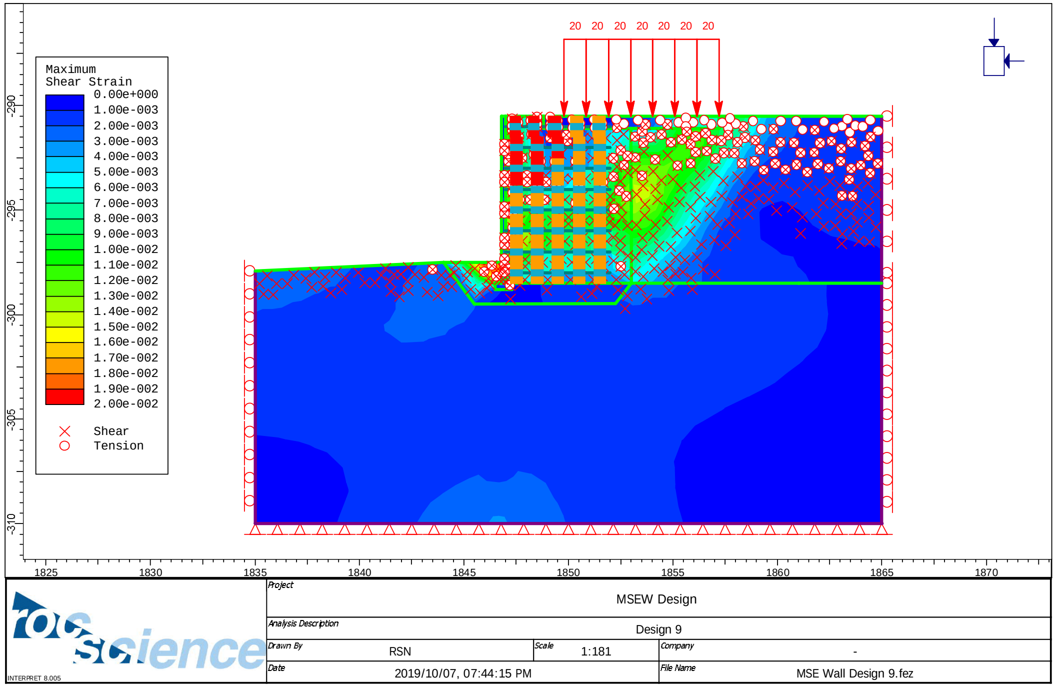
MSE Wall Design 9.fez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3.00e-003
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5.00e-003
6.00e-003
7.00e-003
8.00e-003
9.00e-003
1.00e-002
1.10e-002
1.20e-002
1.30e-002
1.40e-002
1.50e-002
1.60e-002
1.70e-002
1.80e-002
1.90e-002
2.00e-002
Shear
Tension
Project
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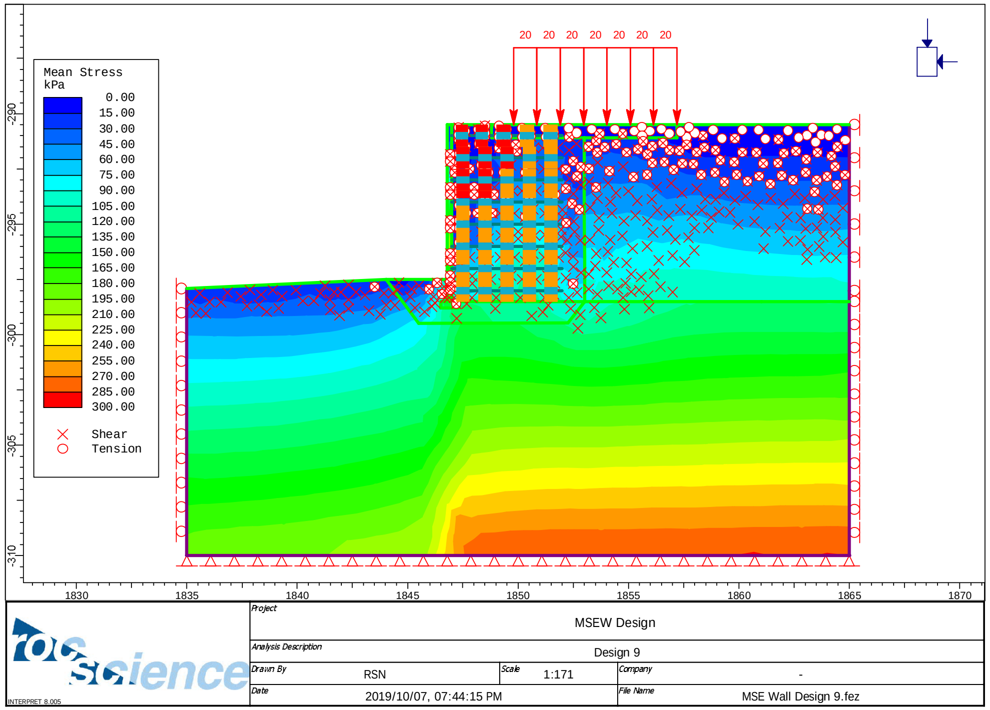
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165.00
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285.00
300.00
Shear
Tension
Project
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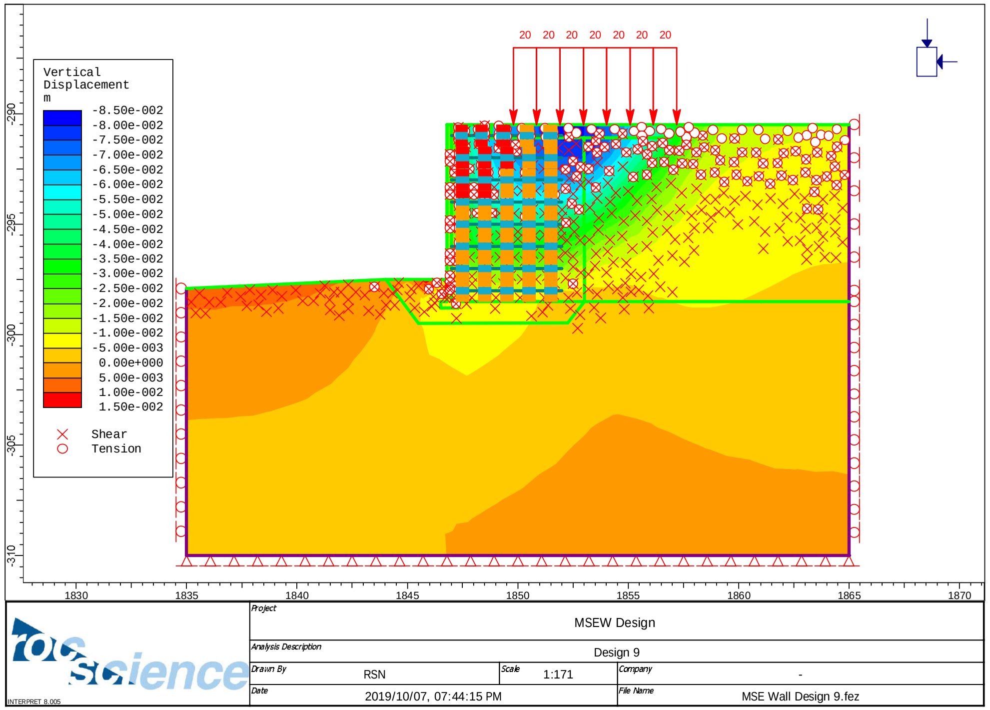
Vertical
Displacement
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0.00e+000
5.00e-003
1.00e-002
1.50e-002
Shear
Tension
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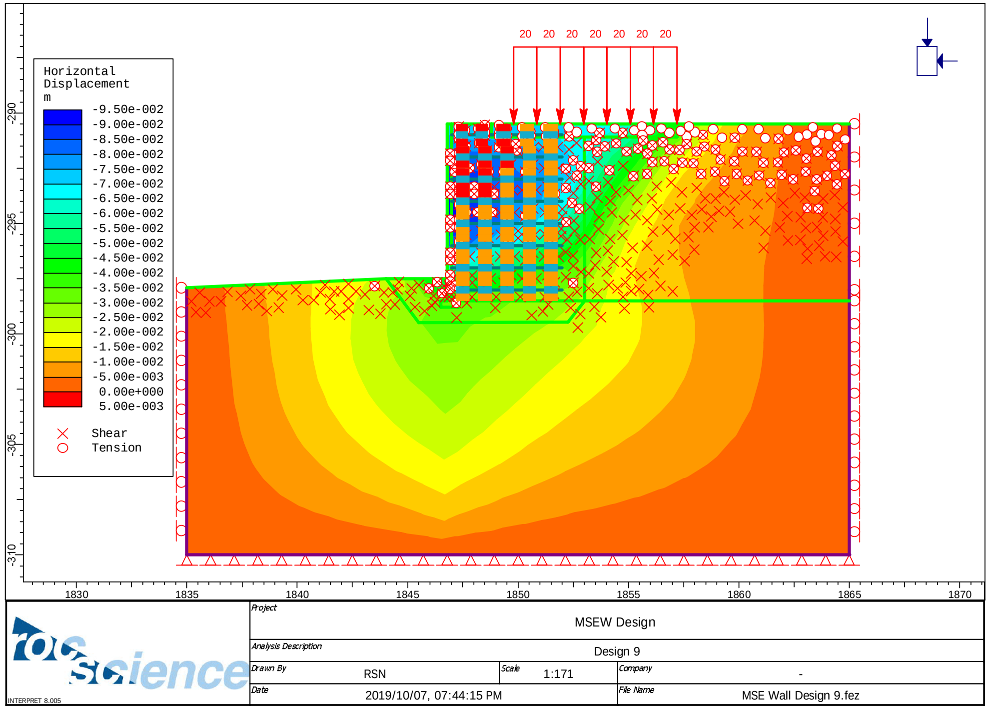
Horizontal Displacement m
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0.00e+000
5.00e-003
Shear
Tension
20 20 20 20 20 20 20
Project
MSEW Design
Analysis Description
Design 9
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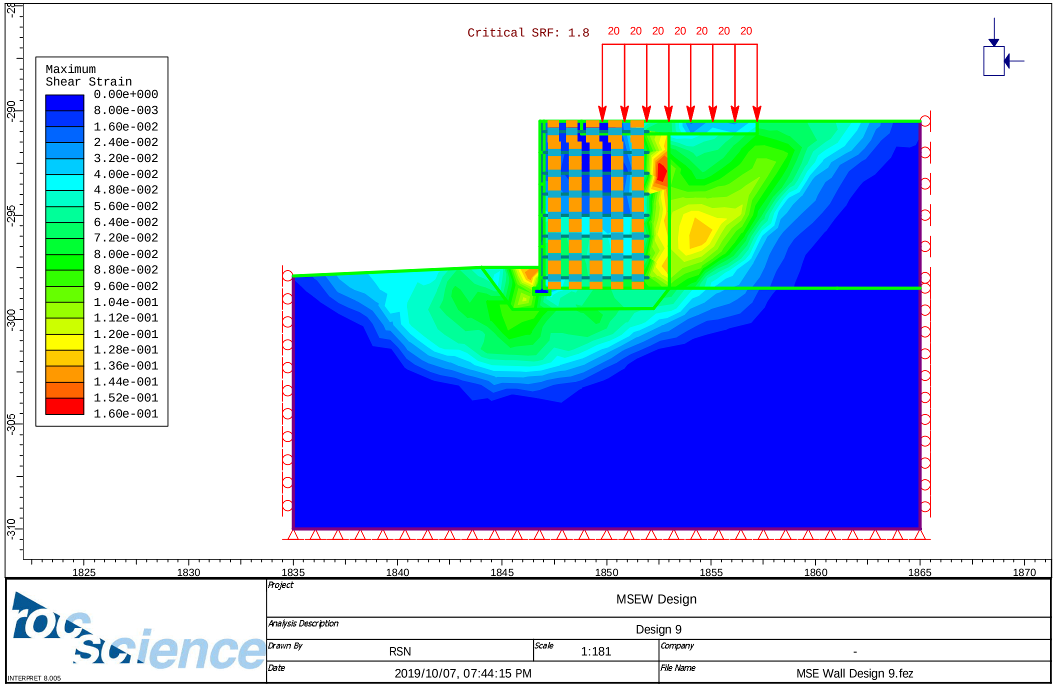
INTERPRET 8.005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4.00e-002
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5.60e-002
6.40e-002
7.20e-002
8.00e-002
8.80e-002
9.60e-002
1.04e-001
1.12e-001
1.20e-001
1.28e-001
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1.52e-001
1.60e-001
Project
MSEW Design
Analysis Description
Design 9
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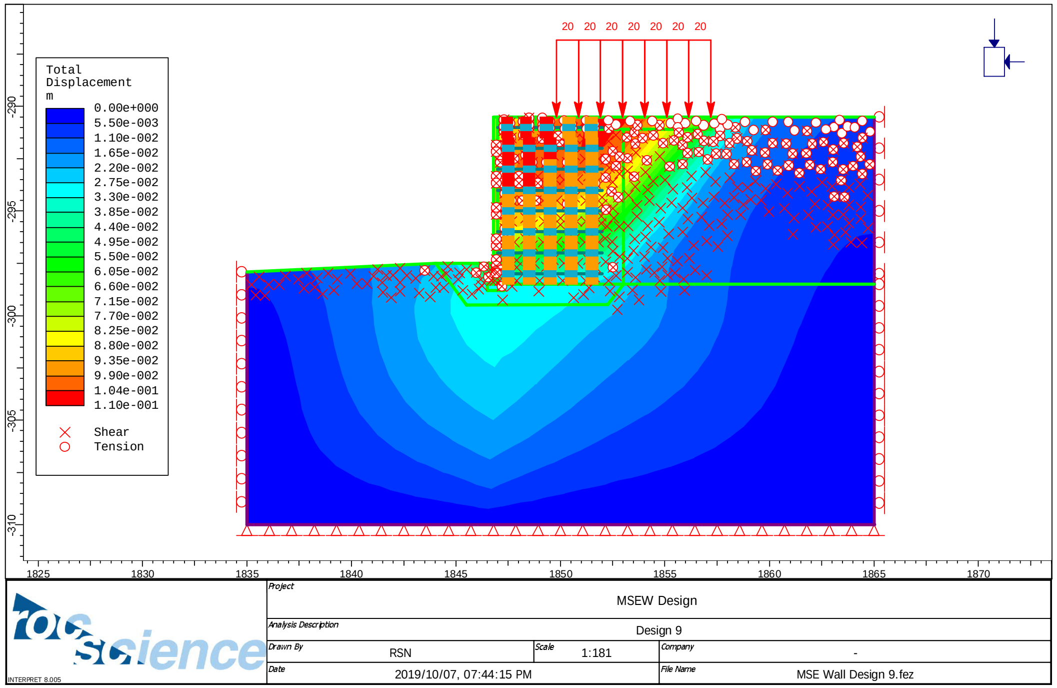
INTERPRET 8.005


Total Displacement m
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1.10e-002
1.65e-002
2.20e-002
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8.25e-002
8.80e-002
9.35e-002
9.90e-002
1.04e-001
1.10e-001
Shear
Tension
20 20 20 20 20 20 20
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Company
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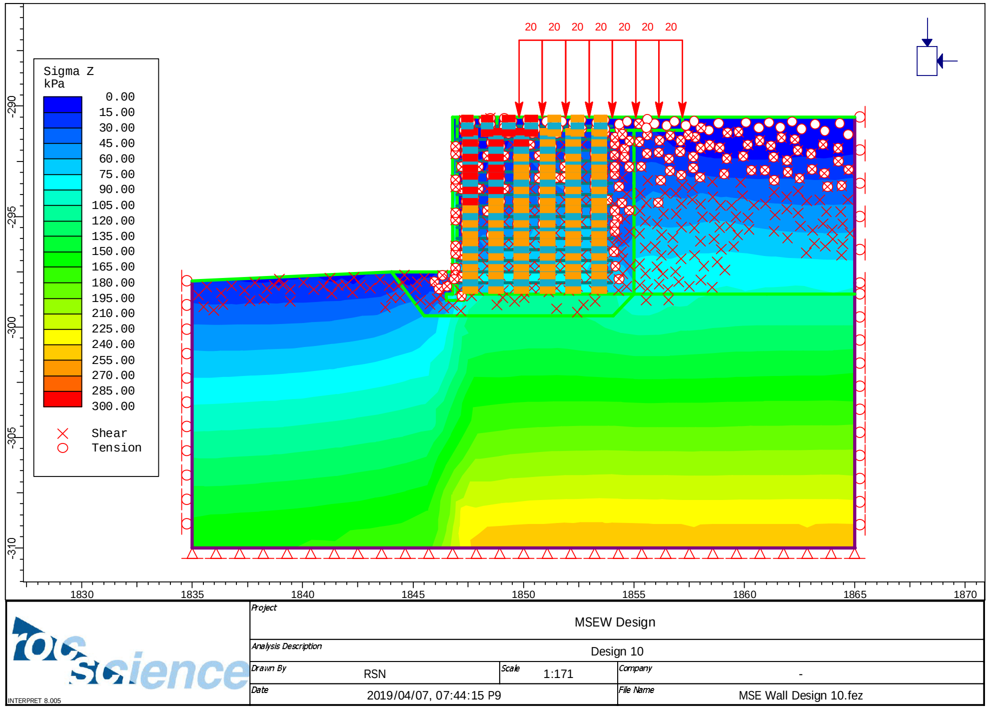
INTERPRET 8.005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240.00
255.00
270.00
285.00
300.00
Shear
Tension
20 20 20 20 20 20 20
1830 1835 1840 1845 1850 1855 1860 1865 1870
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rocscience
INTERPRET 8.005
Project
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Analysis Description
Design 10
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Date
2019/04/07, 07:44:15 P9
File Name
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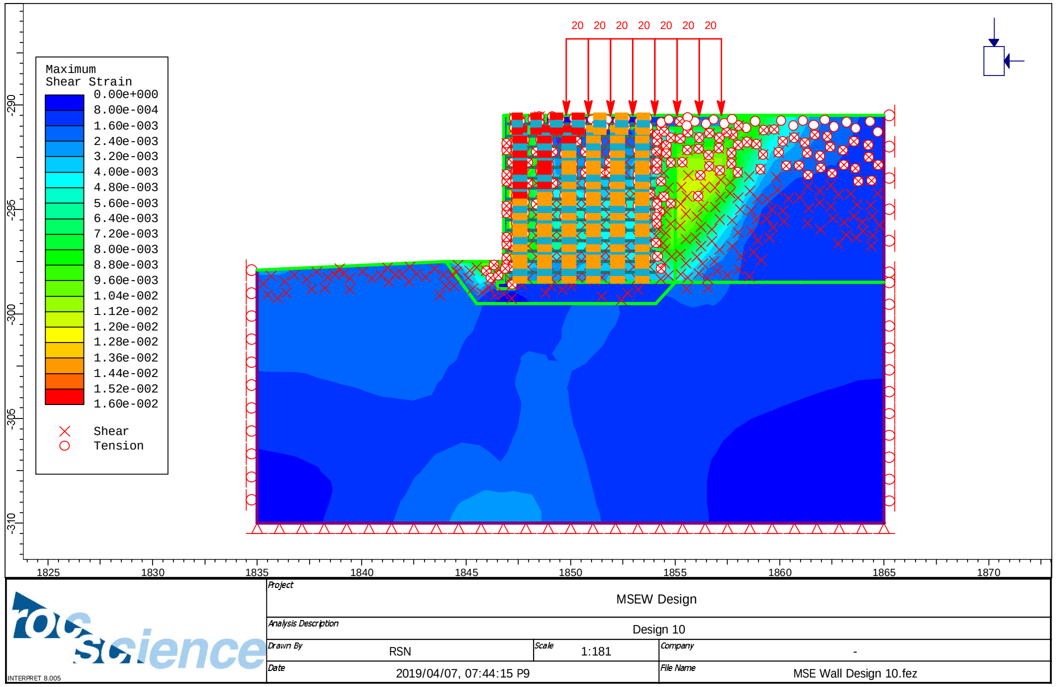
Maximum
Shear Strain
0.00e+000
8.00e-004
1.60e-003
2.40e-003
3.20e-003
4.00e-003
4.80e-003
5.60e-003
6.40e-003
7.20e-003
8.00e-003
8.80e-003
9.60e-003
1.04e-002
1.12e-002
1.20e-002
1.28e-002
1.36e-002
1.44e-002
1.52e-002
1.60e-002
Shear
Tension
20 20 20 20 20 20 20
1825 1830 1835 1840 1845 1850 1855 1860 1865 1870
-290 -295 -300 -305 -310
rocscience
INTERPRET 8.005
Project
MSEW Design
Analysis Description
Design 10
Drawn By
RSN
Scale
1:181
Company
-
Date
2019/04/07, 07:44:15 P9
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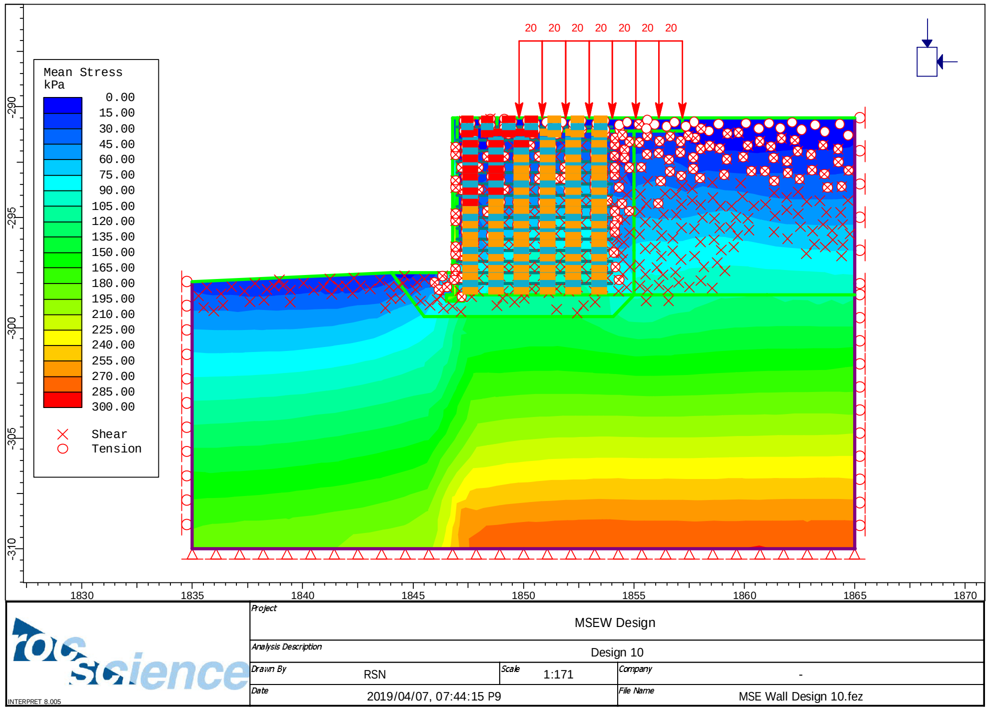
Mean Stress
kPa
0.00
15.00
30.00
45.00
60.00
75.00
90.00
105.00
120.00
135.00
150.00
165.00
180.00
195.00
210.00
225.00
240.00
255.00
270.00
285.00
300.00
Shear
Tension
20 20 20 20 20 20 20
1830 1835 1840 1845 1850 1855 1860 1865 1870
-290 -295 -300 -305 -310
rocscience
INTERPRET 8.005
Project
MSEW Design
Analysis Description
Design 10
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/04/07, 07:44:15 P9
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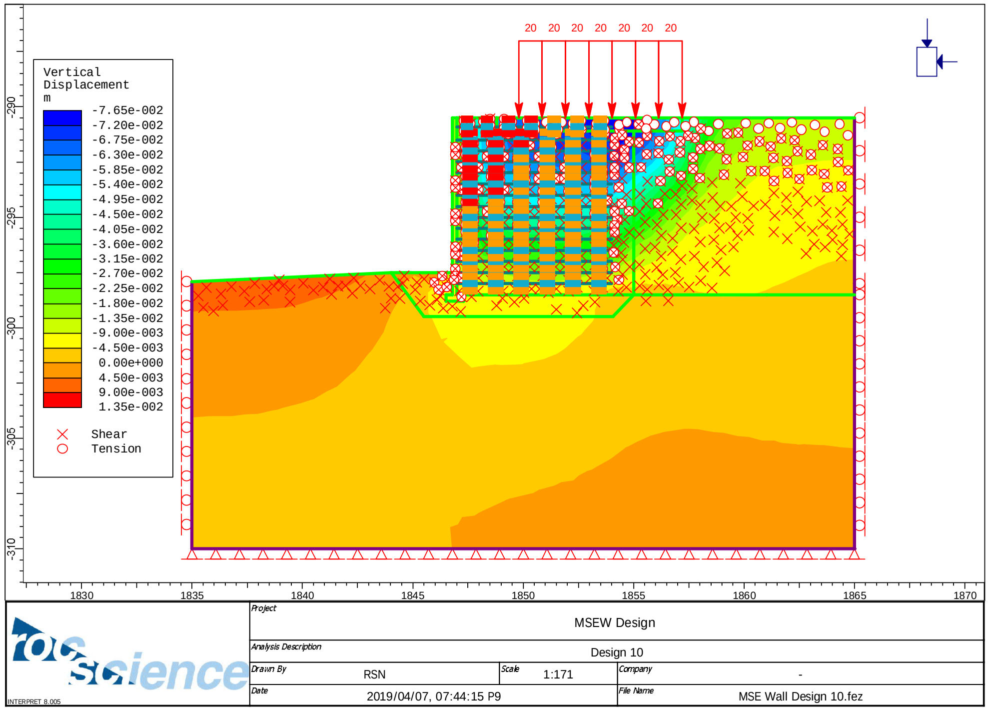
Vertical
Displacement
m
-7.65e-002
-7.20e-002
-6.75e-002
-6.30e-002
-5.85e-002
-5.40e-002
-4.95e-002
-4.50e-002
-4.05e-002
-3.60e-002
-3.15e-002
-2.70e-002
-2.25e-002
-1.80e-002
-1.35e-002
-9.00e-003
-4.50e-003
0.00e+000
4.50e-003
9.00e-003
1.35e-002
Shear
Tension
20 20 20 20 20 20 20
1830 1835 1840 1845 1850 1855 1860 1865 1870
-290 -295 -300 -305 -310
rocscience
INTERPRET 8.005
Project
MSEW Design
Analysis Description
Design 10
Drawn By
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Scale
1:171
Company
-
Date
2019/04/07, 07:44:15 P9
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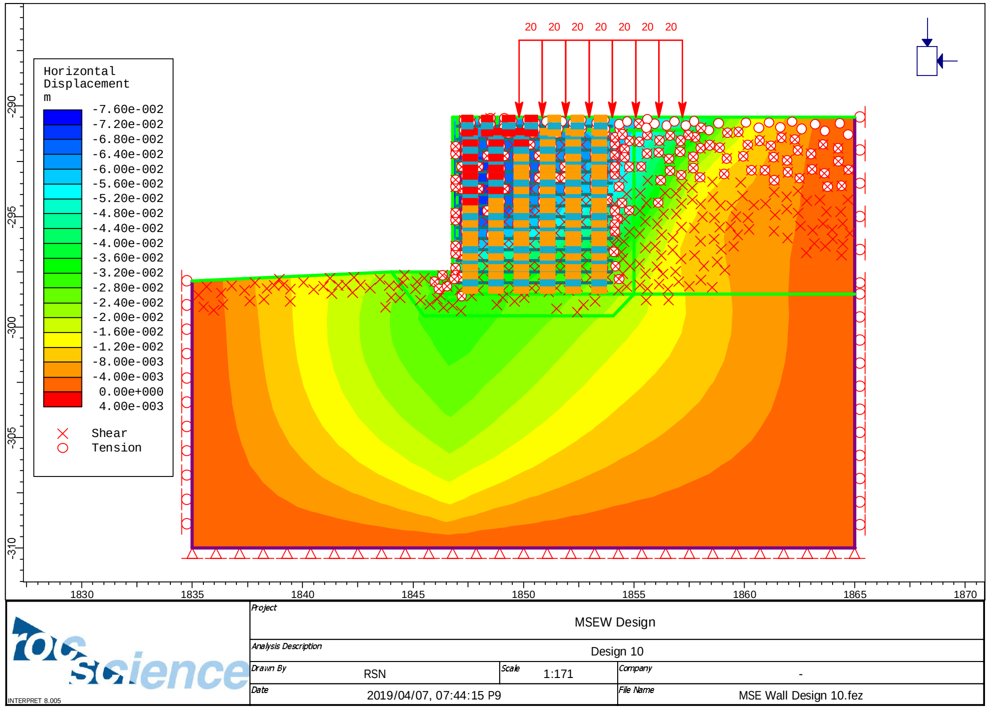
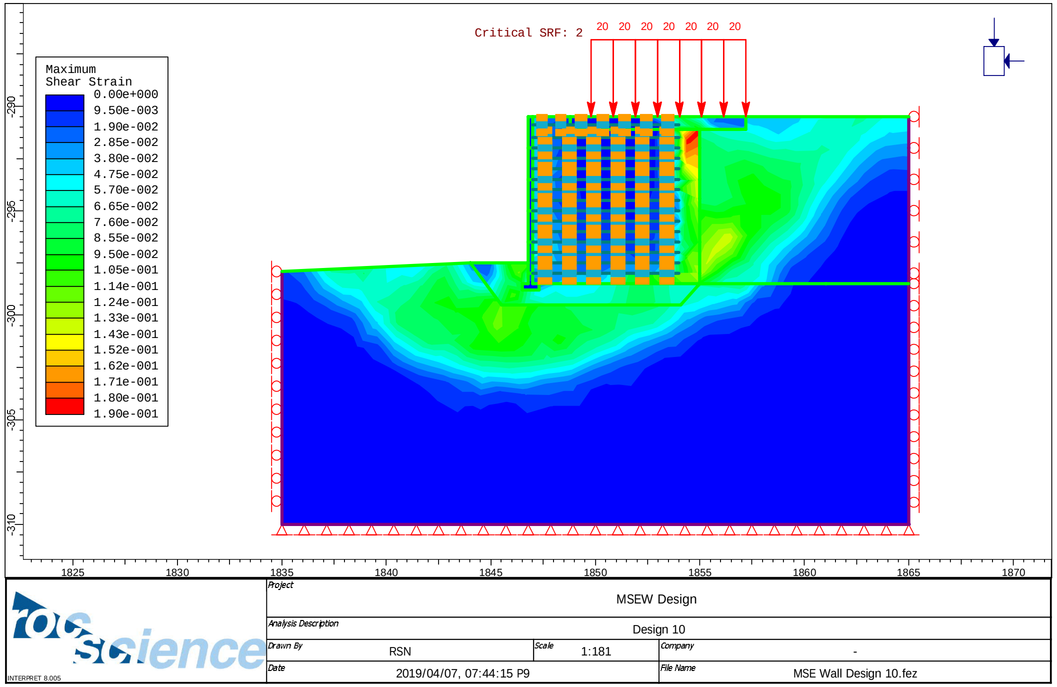
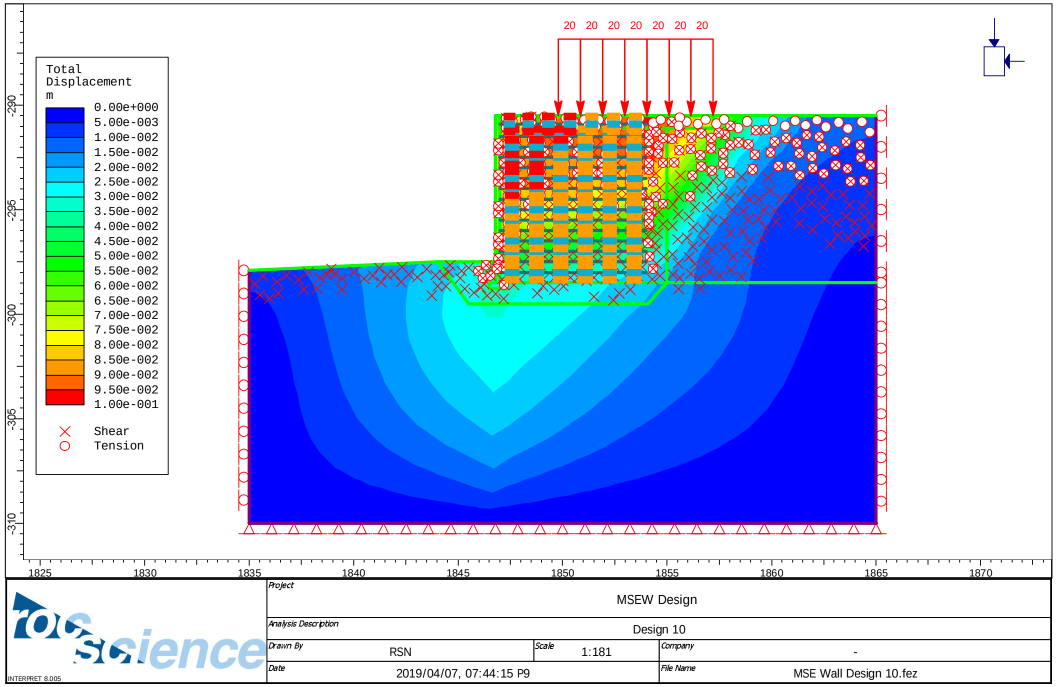
MSE Wall Design 10.fez



Horizontal Displacement m
-7.60e-002
-7.20e-002
-6.80e-002
-6.40e-002
-6.00e-002
-5.60e-002
-5.20e-002
-4.80e-002
-4.40e-002
-4.00e-002
-3.60e-002
-3.20e-002
-2.80e-002
-2.40e-002
-2.00e-002
-1.60e-002
-1.20e-002
-8.00e-003
-4.00e-003
0.00e+000
4.00e-003
Shear
Tension
20 20 20 20 20 20 20
1830 1835 1840 1845 1850 1855 1860 1865 1870
-290 -295 -300 -305 -310
Project
MSEW Design
Analysis Description
Design 10
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/04/07, 07:44:15 P9
File Name
MSE Wall Design 10.fez
INTERPRET 8.005



Critical SRF: 2
20 20 20 20 20 20 20
Maximum Shear Strain
0.00e+000
9.50e-003
1.90e-002
2.85e-002
3.80e-002
4.75e-002
5.70e-002
6.65e-002
7.60e-002
8.55e-002
9.50e-002
1.05e-001
1.14e-001
1.24e-001
1.33e-001
1.43e-001
1.52e-001
1.62e-001
1.71e-001
1.80e-001
1.90e-001
1825 1830 1835 1840 1845 1850 1855 1860 1865 1870
-290 -295 -300 -305 -310
Project
MSEW Design
Analysis Description
Design 10
Drawn By
RSN
Scale
1:181
Company
-
Date
2019/04/07, 07:44:15 P9
File Name
MSE Wall Design 10.fez
INTERPRET 8.005



Total Displacement m
0.00e+000
5.00e-003
1.00e-002
1.50e-002
2.00e-002
2.50e-002
3.00e-002
3.50e-002
4.00e-002
4.50e-002
5.00e-002
5.50e-002
6.00e-002
6.50e-002
7.00e-002
7.50e-002
8.00e-002
8.50e-002
9.00e-002
9.50e-002
1.00e-001
Shear
Tension
20 20 20 20 20 20 20
1825 1830 1835 1840 1845 1850 1855 1860 1865 1870
-290 -295 -300 -305 -310
Project
MSEW Design
Analysis Description
Design 10
Drawn By
RSN
Scale
1:181
Company
-
Date
2019/04/07, 07:44:15 P9
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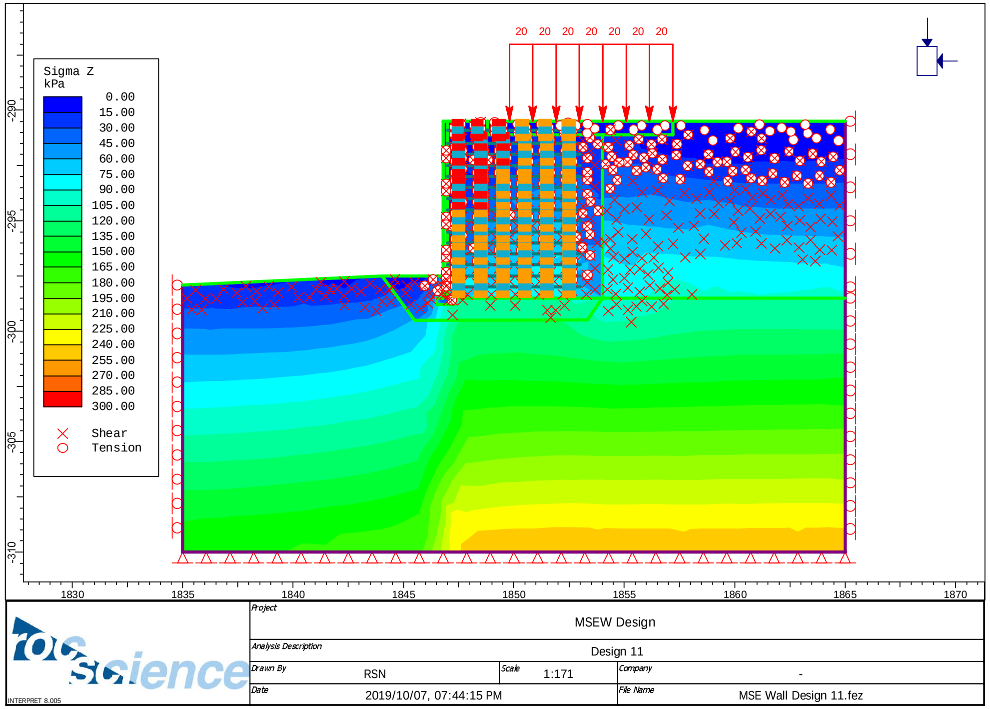
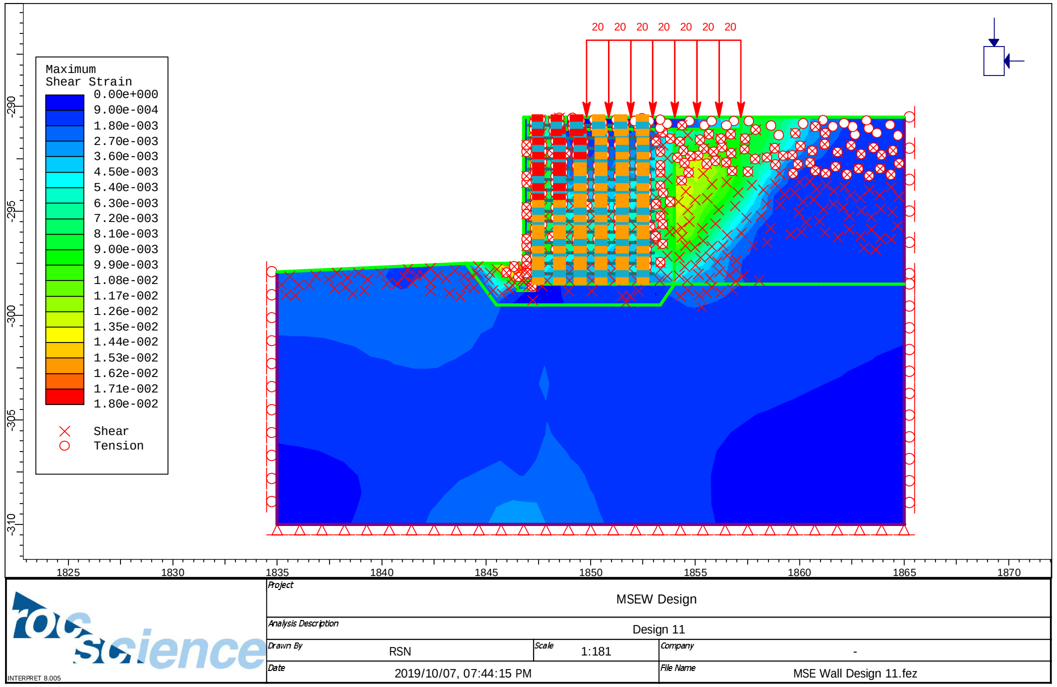
INTERPRET 8.005


Sigma Z
kPa
0.00
15.00
30.00
45.00
60.00
75.00
90.00
105.00
120.00
135.00
150.00
165.00
180.00
195.00
210.00
225.00
240.00
255.00
270.00
285.00
300.00
Shear
Tension
20 20 20 20 20 20 20
Project MSEW Design
Analysis Description Design 11
Drawn By RSN
Scale 1:171
Company -
Date 2019/10/07, 07:44:15 PM
File Name MSE Wall Design 11.fez
INTERPRET 8.005


Maximum
Shear Strain
0.00e+000
9.00e-004
1.80e-003
2.70e-003
3.60e-003
4.50e-003
5.40e-003
6.30e-003
7.20e-003
8.10e-003
9.00e-003
9.90e-003
1.08e-002
1.17e-002
1.26e-002
1.35e-002
1.44e-002
1.53e-002
1.62e-002
1.71e-002
1.80e-002
Shear
Tension
20 20 20 20 20 20 20
Project MSEW Design
Analysis Description Design 11
Drawn By RSN
Scale 1:181
Company -
Date 2019/10/07, 07:44:15 PM
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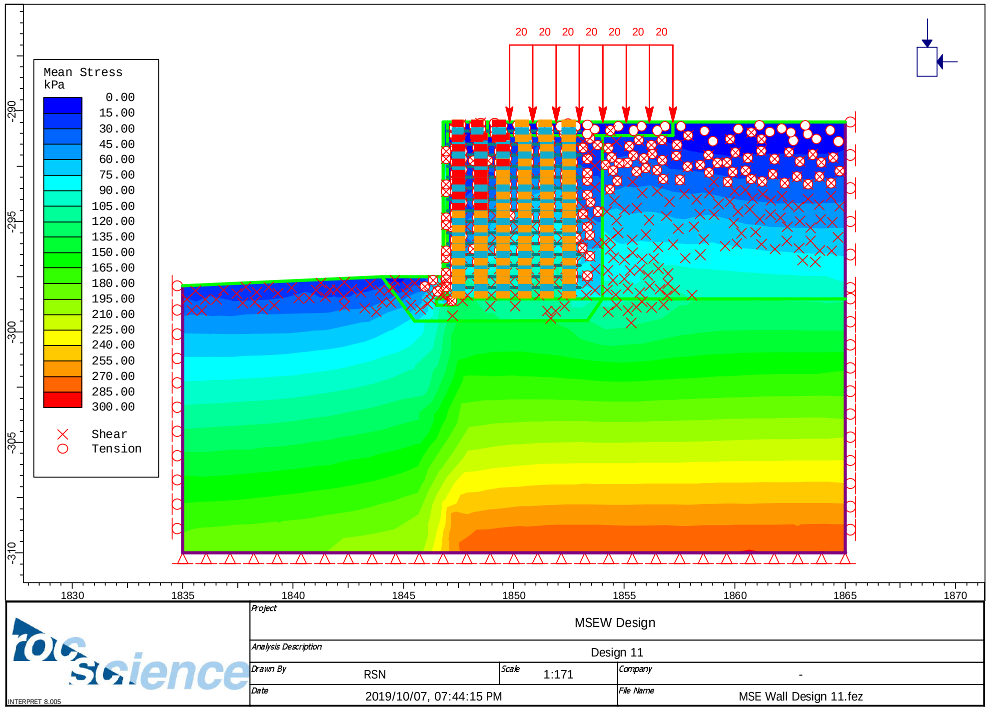
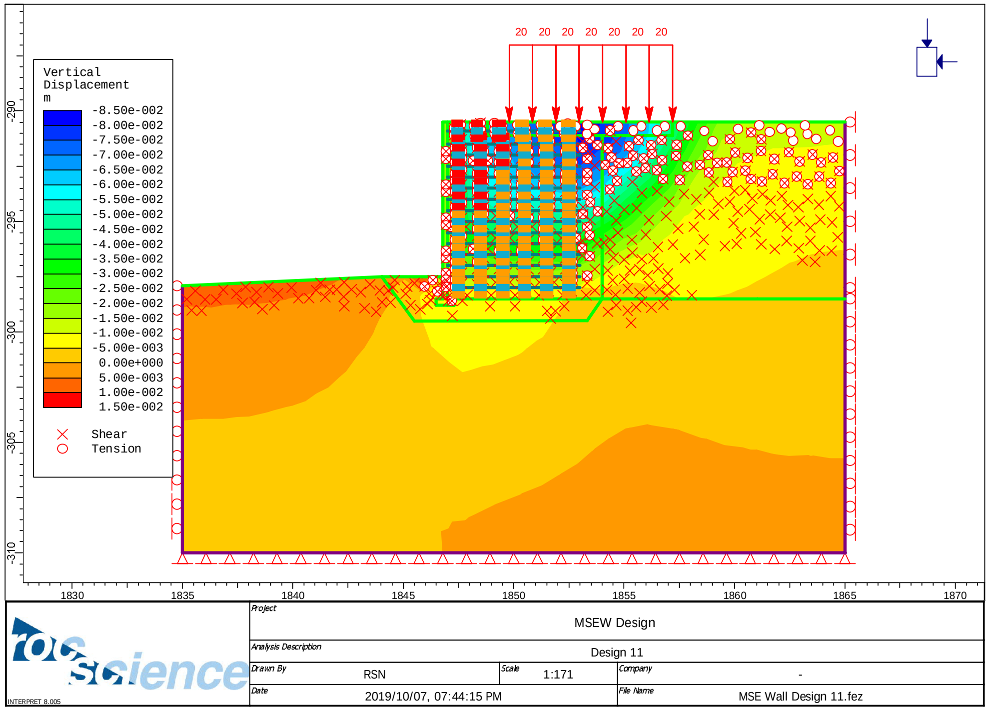
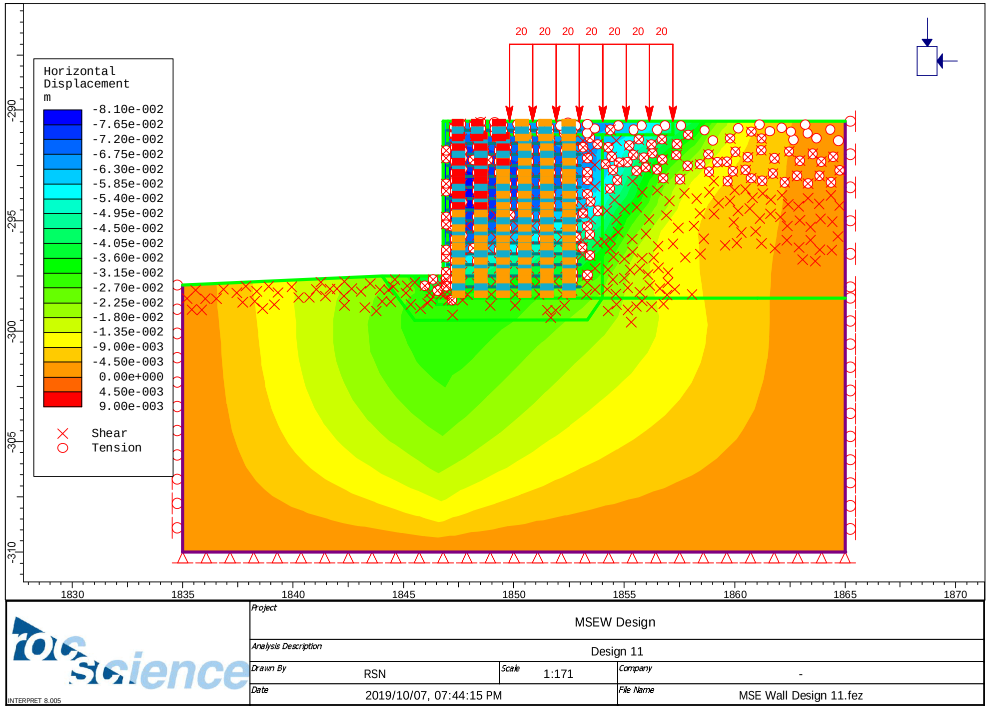
INTERPRET 8.005


Mean Stress
kPa
0.00
15.00
30.00
45.00
60.00
75.00
90.00
105.00
120.00
135.00
150.00
165.00
180.00
195.00
210.00
225.00
240.00
255.00
270.00
285.00
300.00
Shear
Tension
20 20 20 20 20 20 20
Project MSEW Design
Analysis Description Design 11
Drawn By RSN
Scale 1:171
Company -
Date 2019/10/07, 07:44:15 PM
File Name MSE Wall Design 11.fez
INTERPRET 8.005


Vertical
Displacement
m
-8.50e-002
-8.00e-002
-7.50e-002
-7.00e-002
-6.50e-002
-6.00e-002
-5.50e-002
-5.00e-002
-4.50e-002
-4.00e-002
-3.50e-002
-3.00e-002
-2.50e-002
-2.00e-002
-1.50e-002
-1.00e-002
-5.00e-003
0.00e+000
5.00e-003
1.00e-002
1.50e-002
Shear
Tension
20 20 20 20 20 20 20
Project MSEW Design
Analysis Description Design 11
Drawn By RSN
Scale 1:171
Company -
Date 2019/10/07, 07:44:15 PM
File Name MSE Wall Design 11.fez
INTERPRET 8.005


Horizontal Displacement m
-8.10e-002
-7.65e-002
-7.20e-002
-6.75e-002
-6.30e-002
-5.85e-002
-5.40e-002
-4.95e-002
-4.50e-002
-4.05e-002
-3.60e-002
-3.15e-002
-2.70e-002
-2.25e-002
-1.80e-002
-1.35e-002
-9.00e-003
-4.50e-003
0.00e+000
4.50e-003
9.00e-003
Shear
Tension
20 20 20 20 20 20 20
Project
MSEW Design
Analysis Description
Design 11
Drawn By
RSN
Scale
1:171
Company
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Date
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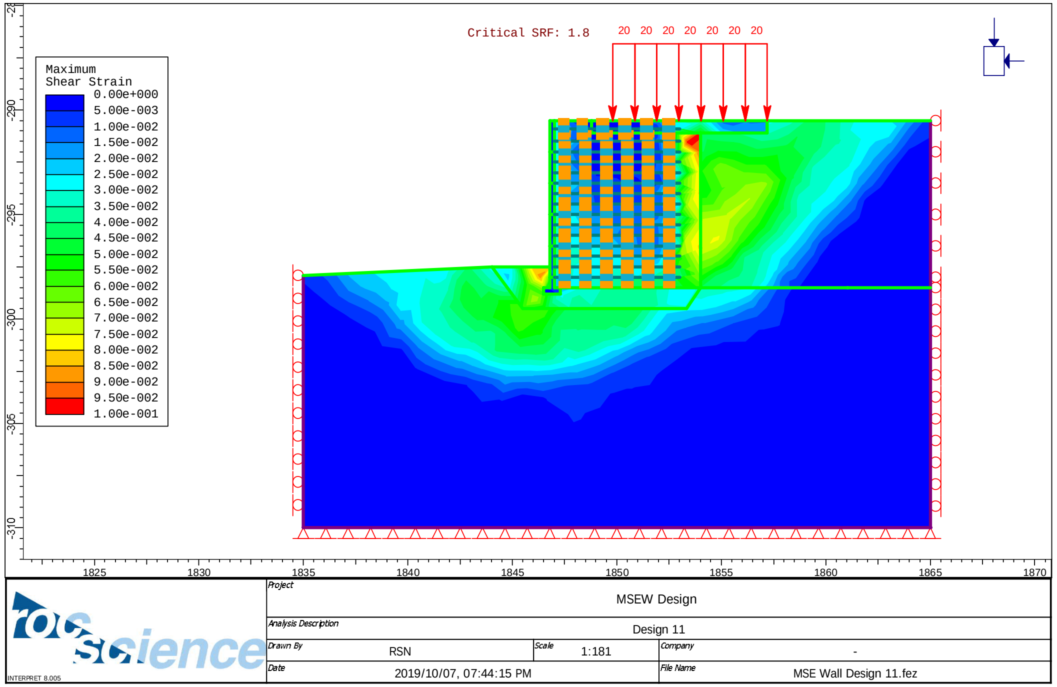
INTERPRET 8.005


Critical SRF: 1.8
Maximum Shear Strain
0.00e+000
5.00e-003
1.00e-002
1.50e-002
2.00e-002
2.50e-002
3.00e-002
3.50e-002
4.00e-002
4.50e-002
5.00e-002
5.50e-002
6.00e-002
6.50e-002
7.00e-002
7.50e-002
8.00e-002
8.50e-002
9.00e-002
9.50e-002
1.00e-001
20 20 20 20 20 20 20
Project
MSEW Design
Analysis Description
Design 11
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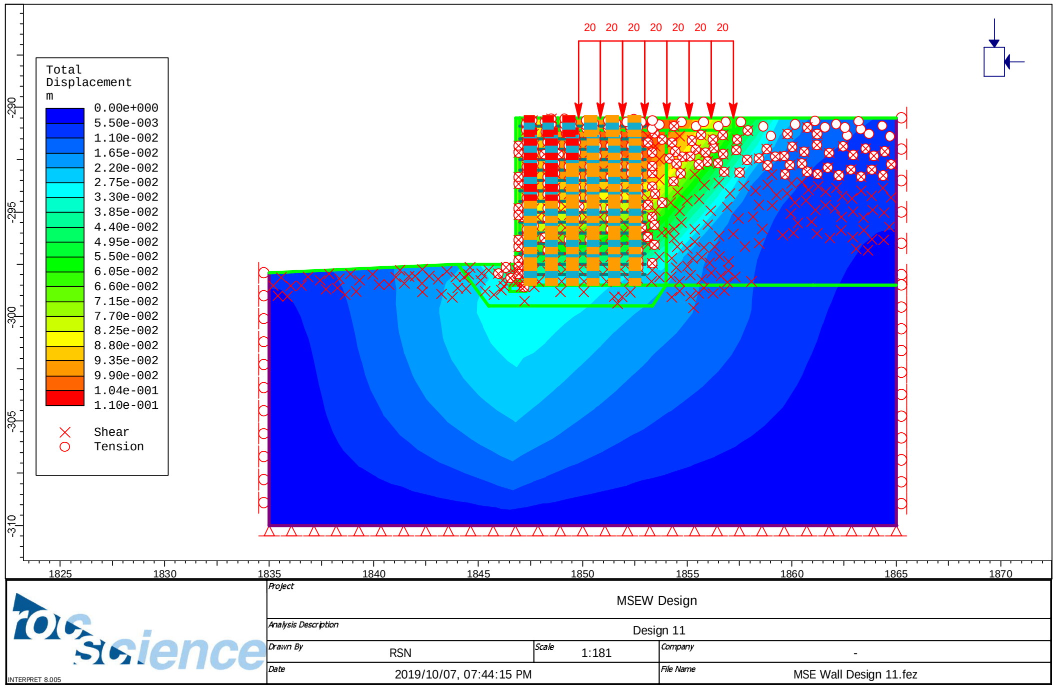
Total Displacement m
0.00e+000
5.50e-003
1.10e-002
1.65e-002
2.20e-002
2.75e-002
3.30e-002
3.85e-002
4.40e-002
4.95e-002
5.50e-002
6.05e-002
6.60e-002
7.15e-002
7.70e-002
8.25e-002
8.80e-002
9.35e-002
9.90e-002
1.04e-001
1.10e-001
Shear
Tension
20 20 20 20 20 20 20
Project
MSEW Design
Analysis Description
Design 11
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Date
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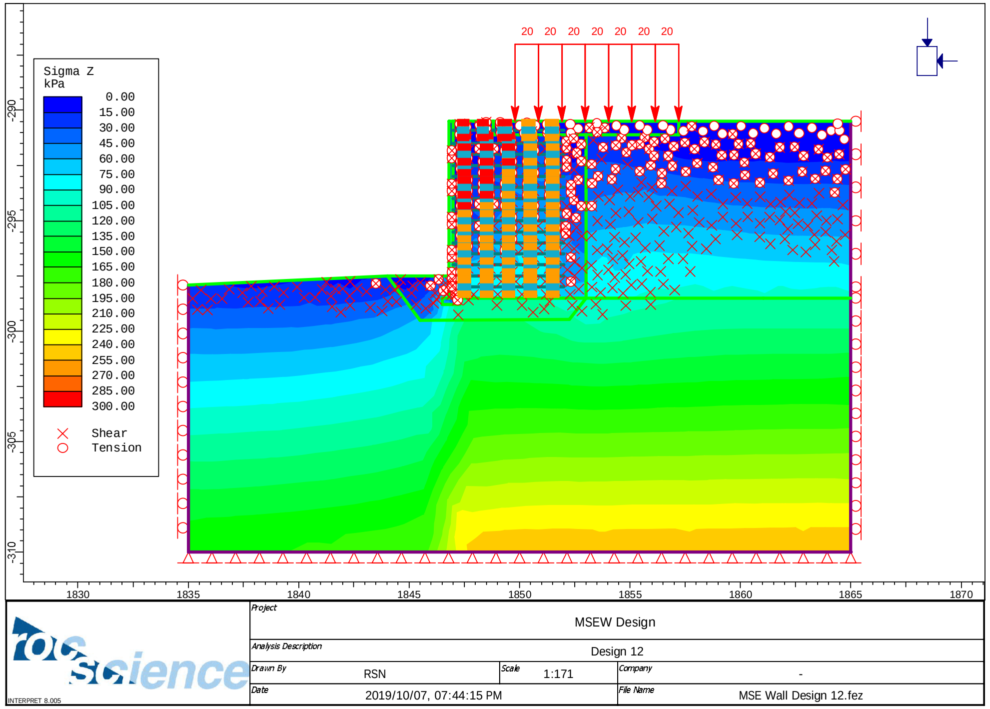

Sigma Z
kPa
0.00
15.00
30.00
45.00
60.00
75.00
90.00
105.00
120.00
135.00
150.00
165.00
180.00
195.00
210.00
225.00
240.00
255.00
270.00
285.00
300.00
Shear
Tension
20 20 20 20 20 20 20
Project
MSEW Design
Analysis Description
Design 12
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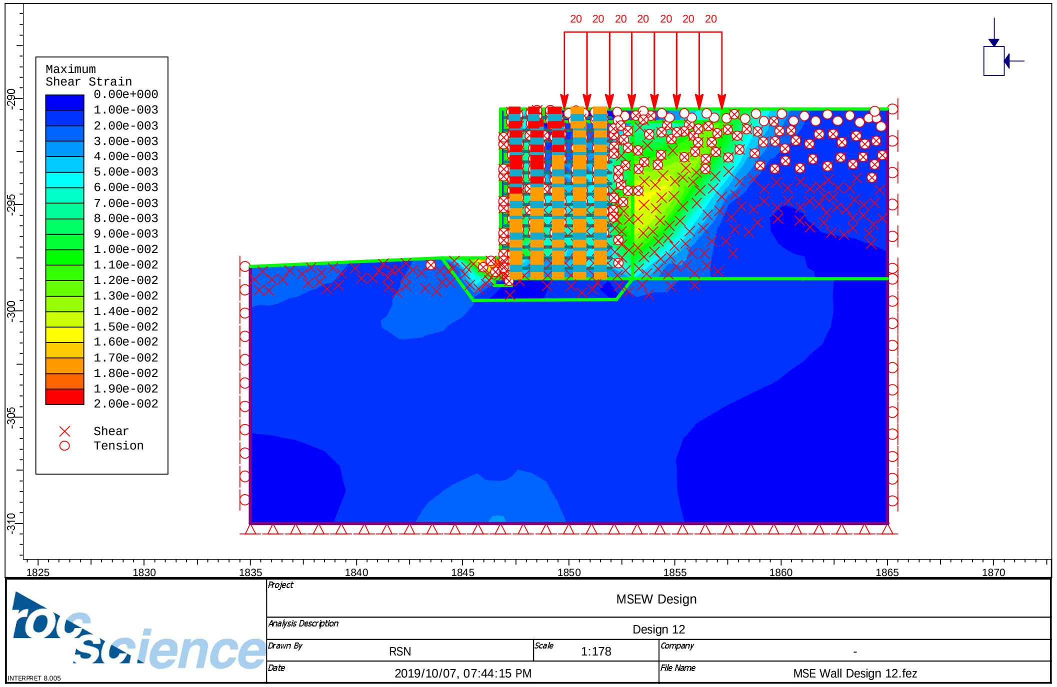

Maximum
Shear Strain
0.00e+000
1.00e-003
2.00e-003
3.00e-003
4.00e-003
5.00e-003
6.00e-003
7.00e-003
8.00e-003
9.00e-003
1.00e-002
1.10e-002
1.20e-002
1.30e-002
1.40e-002
1.50e-002
1.60e-002
1.70e-002
1.80e-002
1.90e-002
2.00e-002
Shear
Tension
20 20 20 20 20 20 20
Project
MSEW Design
Analysis Description
Design 12
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1:178
Company
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Date
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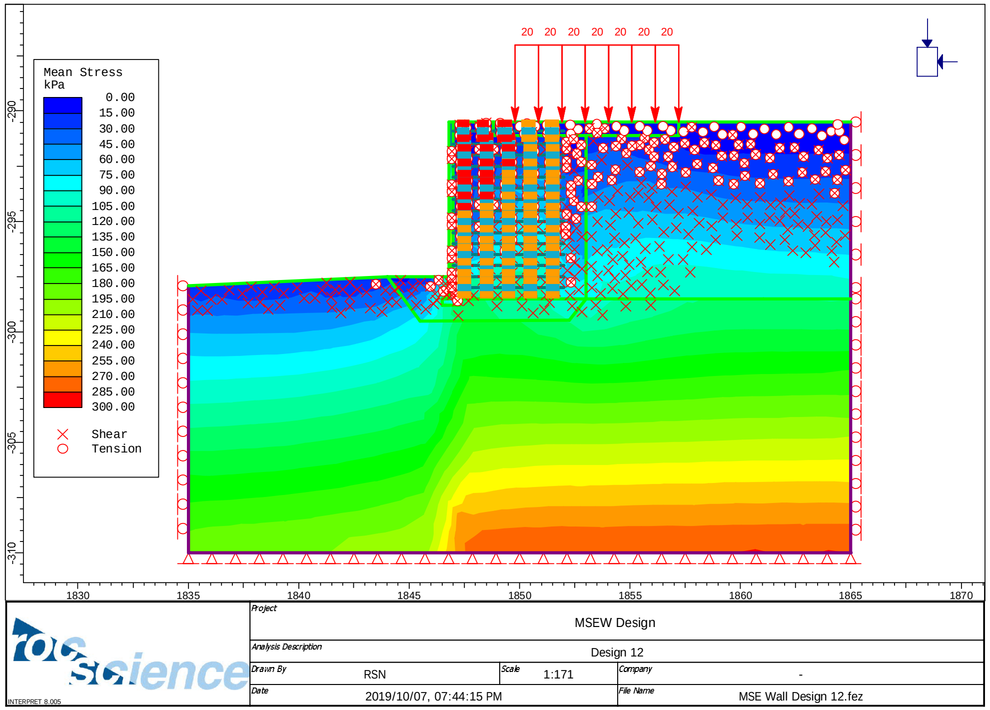
INTERPRET 8.005



Mean Stress
kPa
0.00
15.00
30.00
45.00
60.00
75.00
90.00
105.00
120.00
135.00
150.00
165.00
180.00
195.00
210.00
225.00
240.00
255.00
270.00
285.00
300.00
Shear
Tension
20 20 20 20 20 20 20
Project
MSEW Design
Analysis Description
Design 12
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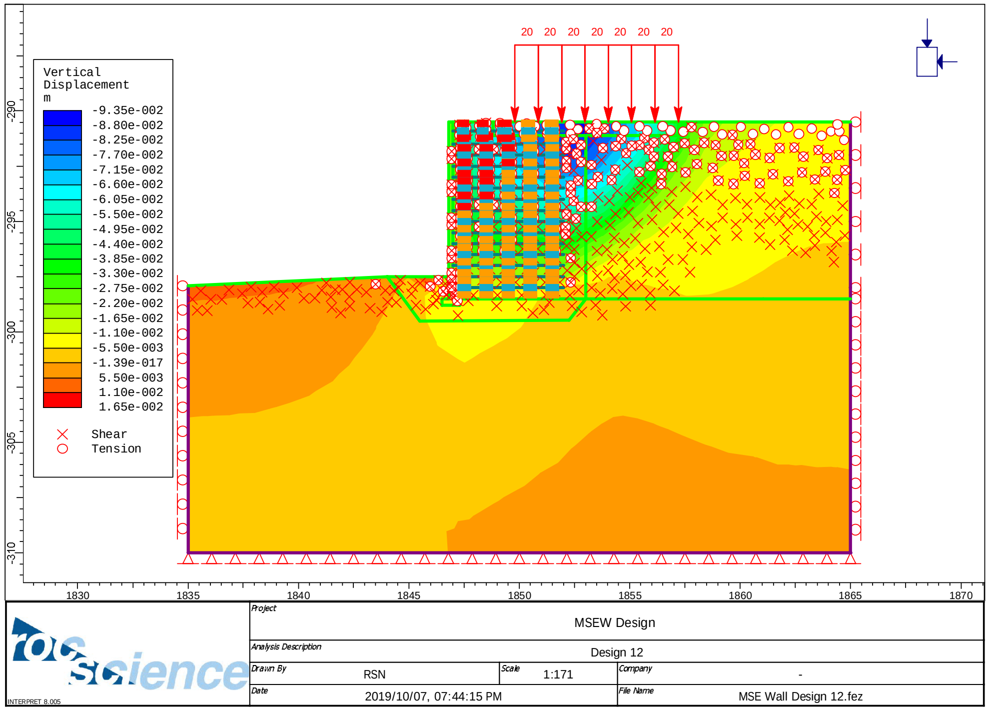

Vertical
Displacement
m
-9.35e-002
-8.80e-002
-8.25e-002
-7.70e-002
-7.15e-002
-6.60e-002
-6.05e-002
-5.50e-002
-4.95e-002
-4.40e-002
-3.85e-002
-3.30e-002
-2.75e-002
-2.20e-002
-1.65e-002
-1.10e-002
-5.50e-003
-1.39e-017
5.50e-003
1.10e-002
1.65e-002
Shear
Tension
20 20 20 20 20 20 20
Project
MSEW Design
Analysis Description
Design 12
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RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
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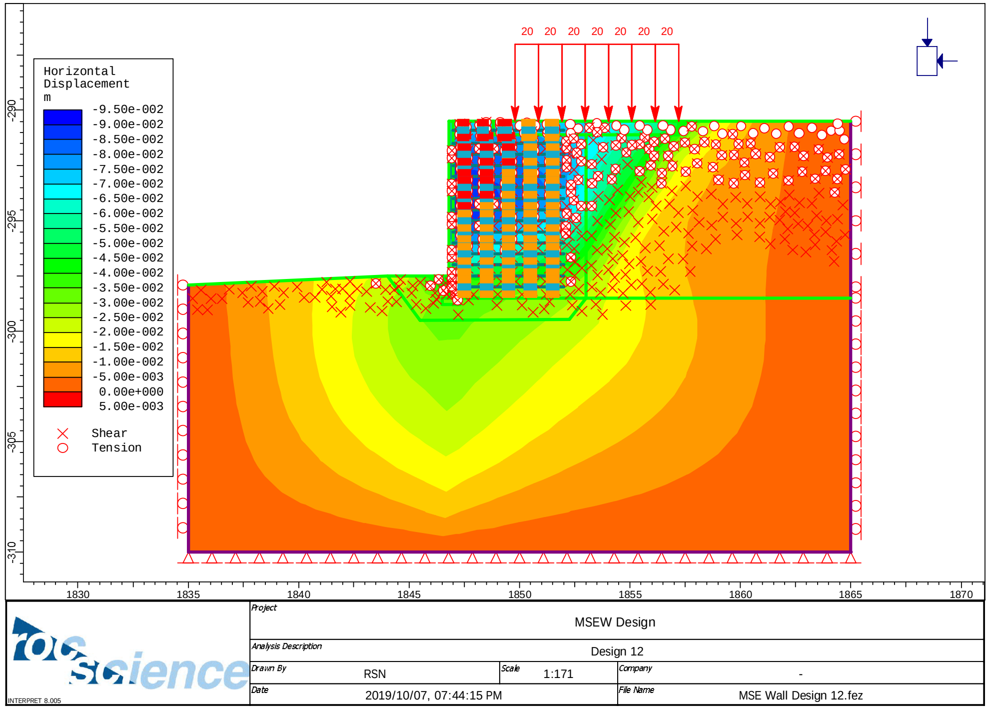
INTERPRET 8.005


Horizontal Displacement m
-9.50e-002
-9.00e-002
-8.50e-002
-8.00e-002
-7.50e-002
-7.00e-002
-6.50e-002
-6.00e-002
-5.50e-002
-5.00e-002
-4.50e-002
-4.00e-002
-3.50e-002
-3.00e-002
-2.50e-002
-2.00e-002
-1.50e-002
-1.00e-002
-5.00e-003
0.00e+000
5.00e-003
Shear
Tension
20 20 20 20 20 20 20
Project
MSEW Design
Analysis Description
Design 12
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RSN
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1:171
Company
-
Date
2019/10/07, 07:44:15 PM
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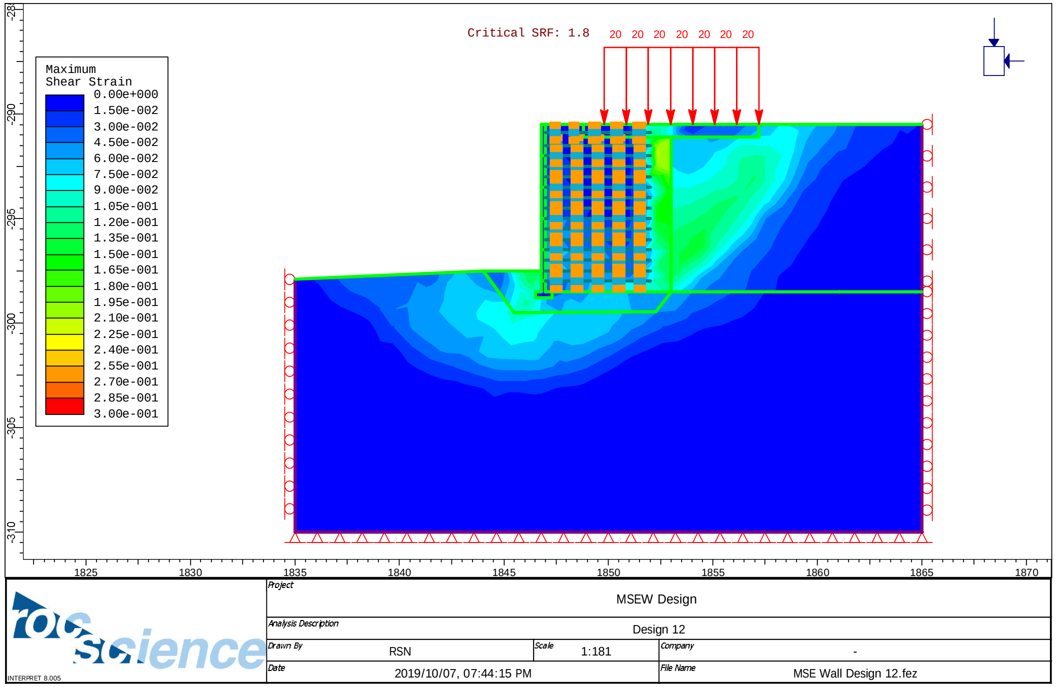
Critical SRF: 1.8
20 20 20 20 20 20 20
Maximum Shear Strain
0.00e+000
1.50e-002
3.00e-002
4.50e-002
6.00e-002
7.50e-002
9.00e-002
1.05e-001
1.20e-001
1.35e-001
1.50e-001
1.65e-001
1.80e-001
1.95e-001
2.10e-001
2.25e-001
2.40e-001
2.55e-001
2.70e-001
2.85e-001
3.00e-001
Project
MSEW Design
Analysis Description
Design 12
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Company
-
Date
2019/10/07, 07:44:15 PM
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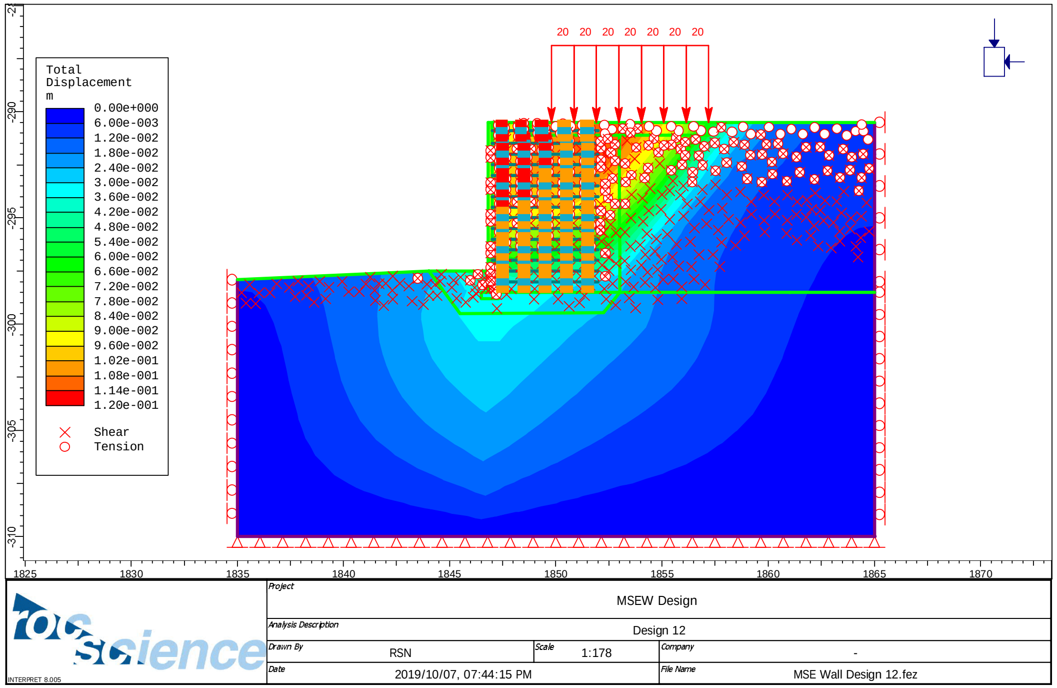
INTERPRET 8.005


Total Displacement m
0.00e+000
6.00e-003
1.20e-002
1.80e-002
2.40e-002
3.00e-002
3.60e-002
4.20e-002
4.80e-002
5.40e-002
6.00e-002
6.60e-002
7.20e-002
7.80e-002
8.40e-002
9.00e-002
9.60e-002
1.02e-001
1.08e-001
1.14e-001
1.20e-001
Shear
Tension
20 20 20 20 20 20 20
Project
MSEW Design
Analysis Description
Design 12
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1:178
Company
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Date
2019/10/07, 07:44:15 PM
File Name
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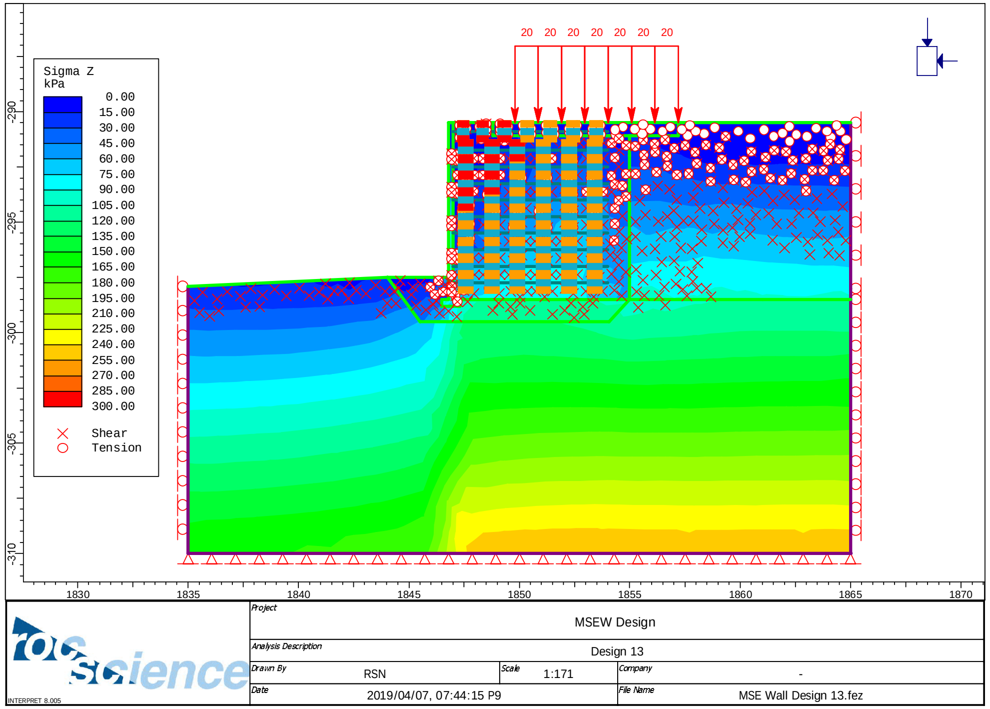
INTERPRET 8.005


Sigma Z
kPa
0.00
15.00
30.00
45.00
60.00
75.00
90.00
105.00
120.00
135.00
150.00
165.00
180.00
195.00
210.00
225.00
240.00
255.00
270.00
285.00
300.00
Shear
Tension
Project
MSEW Design
Analysis Description
Design 13
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/04/07, 07:44:15 P9
File Name
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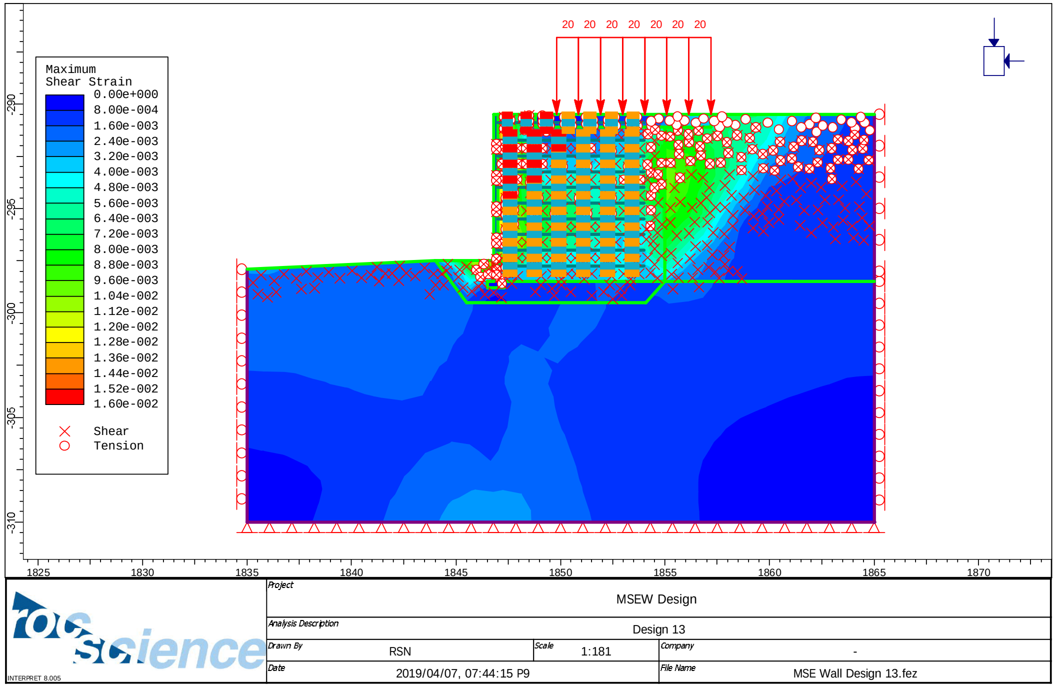
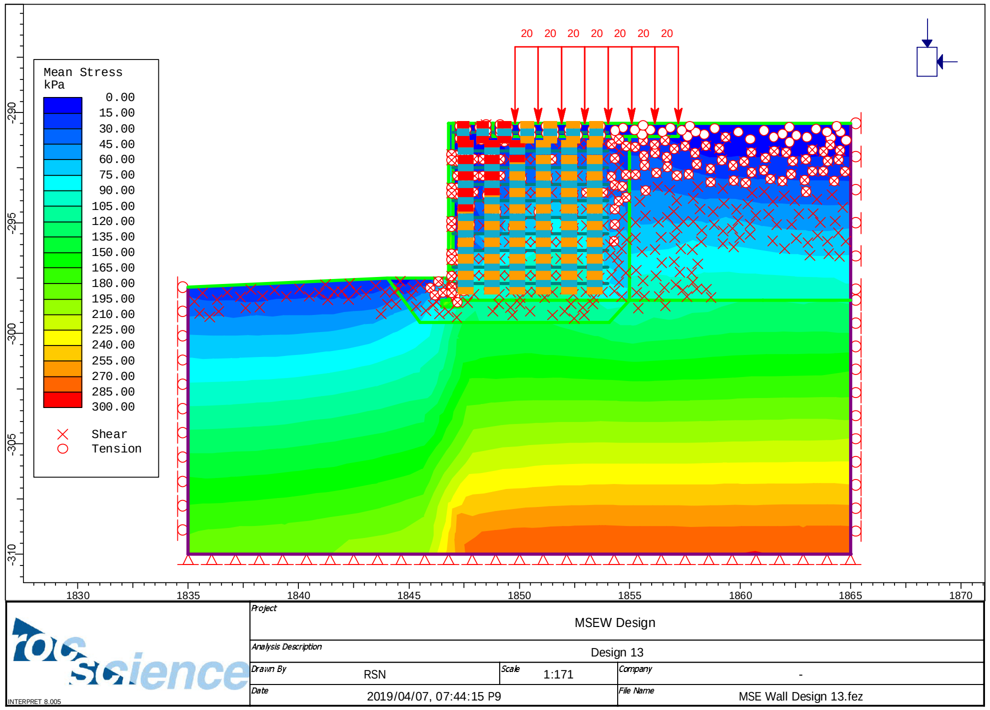
INTERPRET 8.005


Maximum
Shear Strain
0.00e+000
8.00e-004
1.60e-003
2.40e-003
3.20e-003
4.00e-003
4.80e-003
5.60e-003
6.40e-003
7.20e-003
8.00e-003
8.80e-003
9.60e-003
1.04e-002
1.12e-002
1.20e-002
1.28e-002
1.36e-002
1.44e-002
1.52e-002
1.60e-002
Shear
Tension
Project
MSEW Design
Analysis Description
Design 13
Drawn By
RSN
Scale
1:181
Company
-
Date
2019/04/07, 07:44:15 P9
File Name
MSE Wall Design 13.fez
INTERPRET 8.005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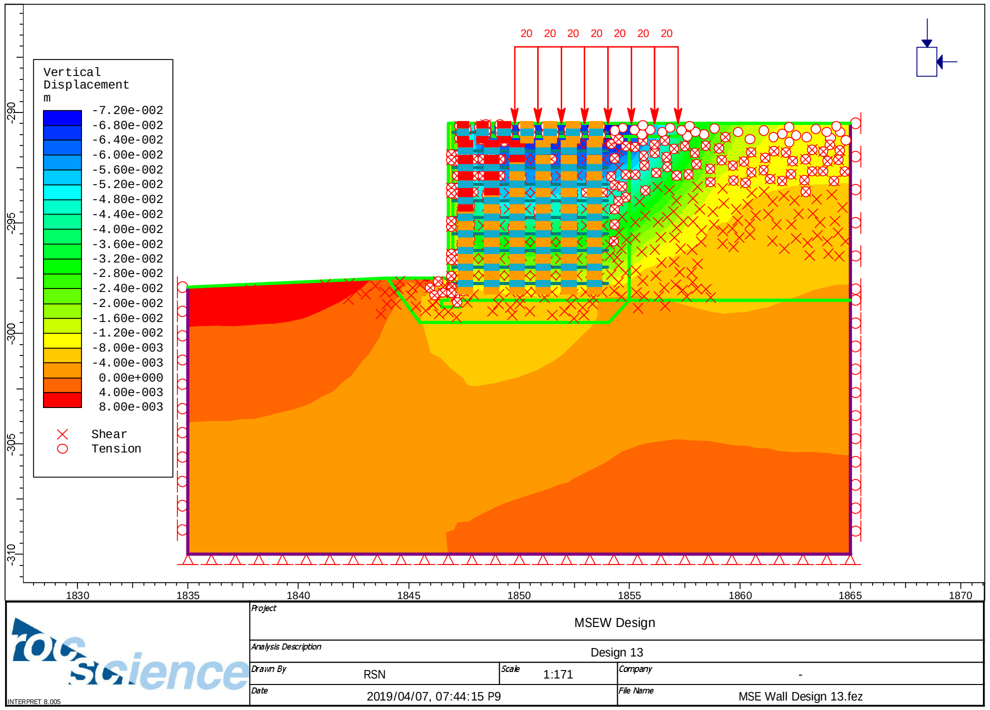
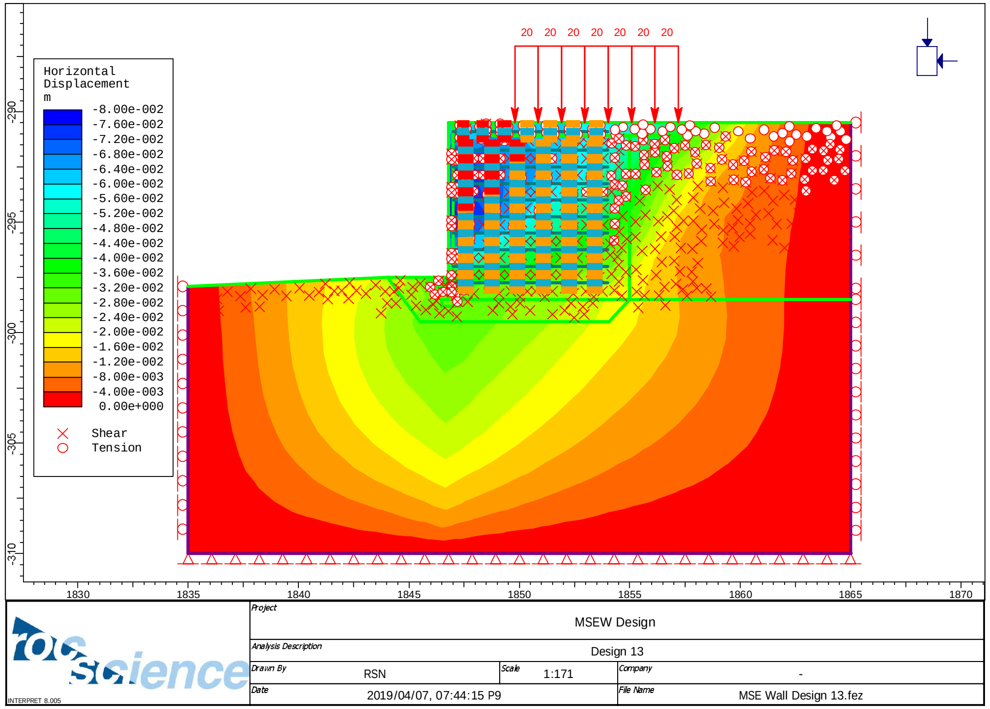
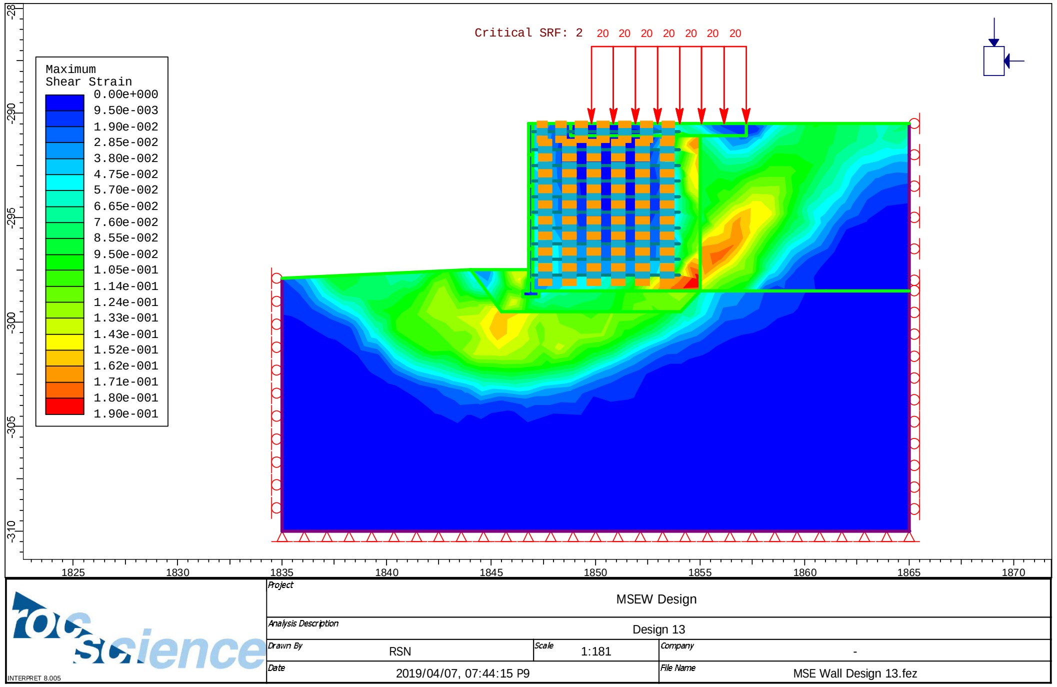
kPa
0.00
15.00
30.00
45.00
60.00
75.00
90.00
105.00
120.00
135.00
150.00
165.00
180.00
195.00
210.00
225.00
240.00
255.00
270.00
285.00
300.00
Shear
Tension
Project
MSEW Design
Analysis Description
Design 13
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/04/07, 07:44:15 P9
File Name
MSE Wall Design 13.fez
INTERPRET 8.005


Vertical
Displacement
m
-7.20e-002
-6.80e-002
-6.40e-002
-6.00e-002
-5.60e-002
-5.20e-002
-4.80e-002
-4.40e-002
-4.00e-002
-3.60e-002
-3.20e-002
-2.80e-002
-2.40e-002
-2.00e-002
-1.60e-002
-1.20e-002
-8.00e-003
-4.00e-003
0.00e+000
4.00e-003
8.00e-003
Shear
Tension
Project
MSEW Design
Analysis Description
Design 13
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/04/07, 07:44:15 P9
File Name
MSE Wall Design 13.fez
INTERPRET 8.005



20 20 20 20 20 20 20
Horizontal Displacement m
-8.00e-002
-7.60e-002
-7.20e-002
-6.80e-002
-6.40e-002
-6.00e-002
-5.60e-002
-5.20e-002
-4.80e-002
-4.40e-002
-4.00e-002
-3.60e-002
-3.20e-002
-2.80e-002
-2.40e-002
-2.00e-002
-1.60e-002
-1.20e-002
-8.00e-003
-4.00e-003
0.00e+000
Shear
Tension
1830 1835 1840 1845 1850 1855 1860 1865 1870
-290 -295 -300 -305 -310
Project: MSEW Design
Analysis Description: Design 13
Drawn By: RSN
Scale: 1:171
Company: -
Date: 2019/04/07, 07:44:15 P9
File Name: MSE Wall Design 13.fez
INTERPRET 8.005



Critical SRF: 2
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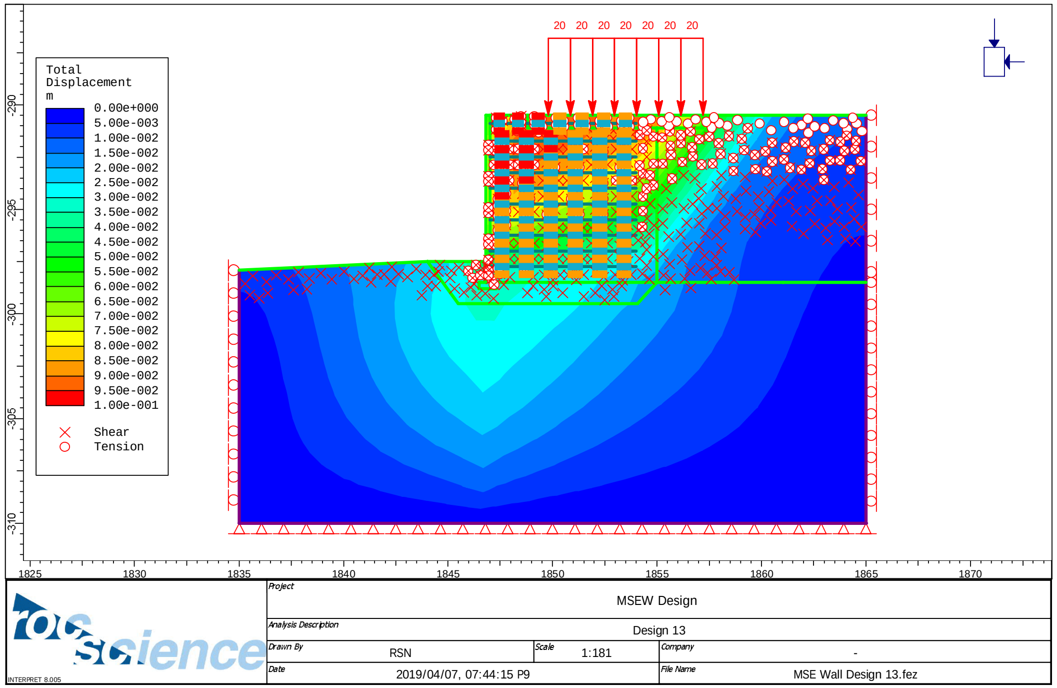
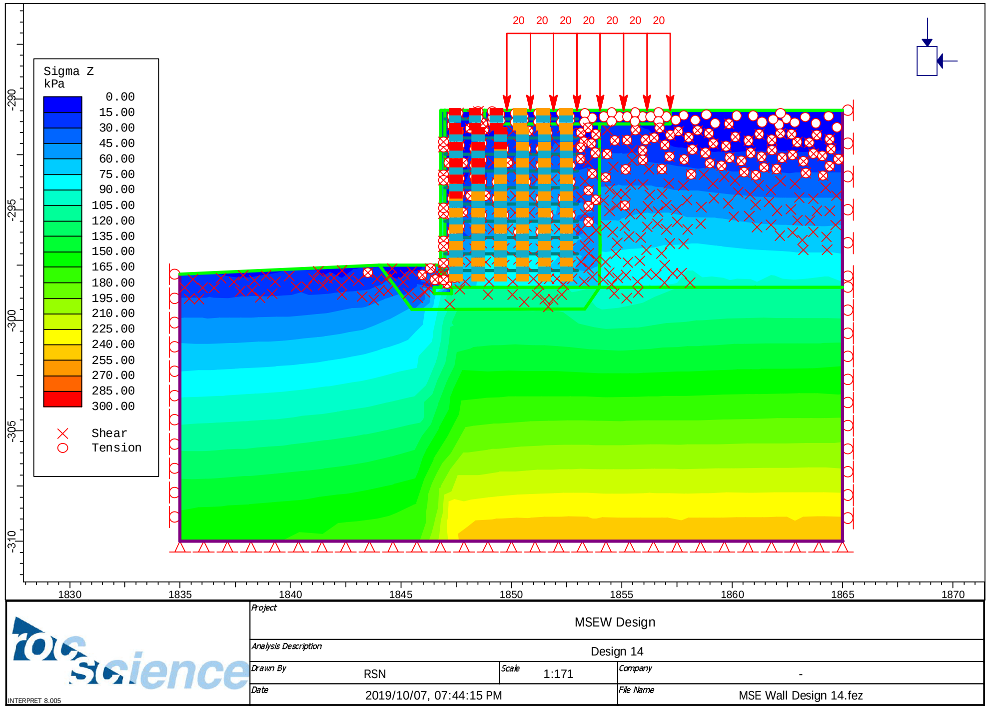
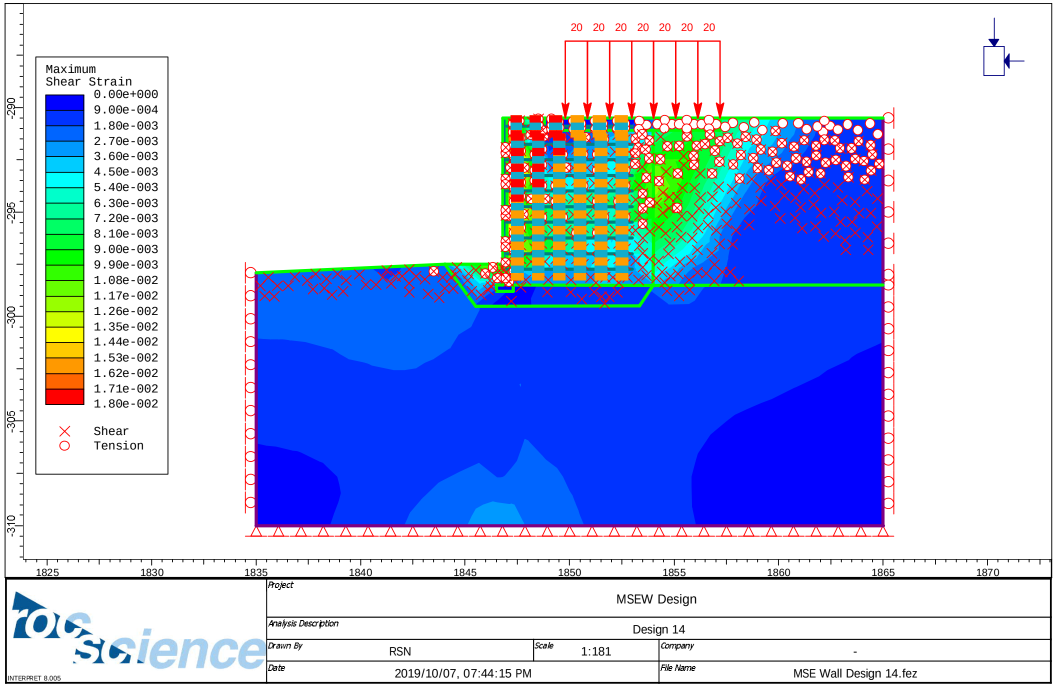
Maximum Shear Strain
0.00e+000
9.50e-003
1.90e-002
2.85e-002
3.80e-002
4.75e-002
5.70e-002
6.65e-002
7.60e-002
8.55e-002
9.50e-002
1.05e-001
1.14e-001
1.24e-001
1.33e-001
1.43e-001
1.52e-001
1.62e-001
1.71e-001
1.80e-001
1.90e-001
1825 1830 1835 1840 1845 1850 1855 1860 1865 1870
-290 -295 -300 -305 -310
Project: MSEW Design
Analysis Description: Design 13
Drawn By: RSN
Scale: 1:181
Company: -
Date: 2019/04/07, 07:44:15 P9
File Name: MSE Wall Design 13.fez
INTERPRET 8.005



20 20 20 20 20 20 20
Total Displacement m
0.00e+000
5.00e-003
1.00e-002
1.50e-002
2.00e-002
2.50e-002
3.00e-002
3.50e-002
4.00e-002
4.50e-002
5.00e-002
5.50e-002
6.00e-002
6.50e-002
7.00e-002
7.50e-002
8.00e-002
8.50e-002
9.00e-002
9.50e-002
1.00e-001
Shear
Tension
1825 1830 1835 1840 1845 1850 1855 1860 1865 1870
-290 -295 -300 -305 -310
Project: MSEW Design
Analysis Description: Design 13
Drawn By: RSN
Scale: 1:181
Company: -
Date: 2019/04/07, 07:44:15 P9
File Name: MSE Wall Design 13.fez
INTERPRET 8.005


20 20 20 20 20 20 20
Sigma Z
kPa
0.00
15.00
30.00
45.00
60.00
75.00
90.00
105.00
120.00
135.00
150.00
165.00
180.00
195.00
210.00
225.00
240.00
255.00
270.00
285.00
300.00
Shear
Tension
-290
-295
-300
-305
-310
1830
1835
1840
1845
1850
1855
1860
1865
1870
Project
MSEW Design
Analysis Description
Design 14
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 14.fez
INTERPRET 8.005


20 20 20 20 20 20 20
Maximum
Shear Strain
0.00e+000
9.00e-004
1.80e-003
2.70e-003
3.60e-003
4.50e-003
5.40e-003
6.30e-003
7.20e-003
8.10e-003
9.00e-003
9.90e-003
1.08e-002
1.17e-002
1.26e-002
1.35e-002
1.44e-002
1.53e-002
1.62e-002
1.71e-002
1.80e-002
Shear
Tension
-290
-295
-300
-305
-310
1825
1830
1835
1840
1845
1850
1855
1860
1865
1870
Project
MSEW Design
Analysis Description
Design 14
Drawn By
RSN
Scale
1:181
Company
-
Date
2019/10/07, 07:44:15 PM
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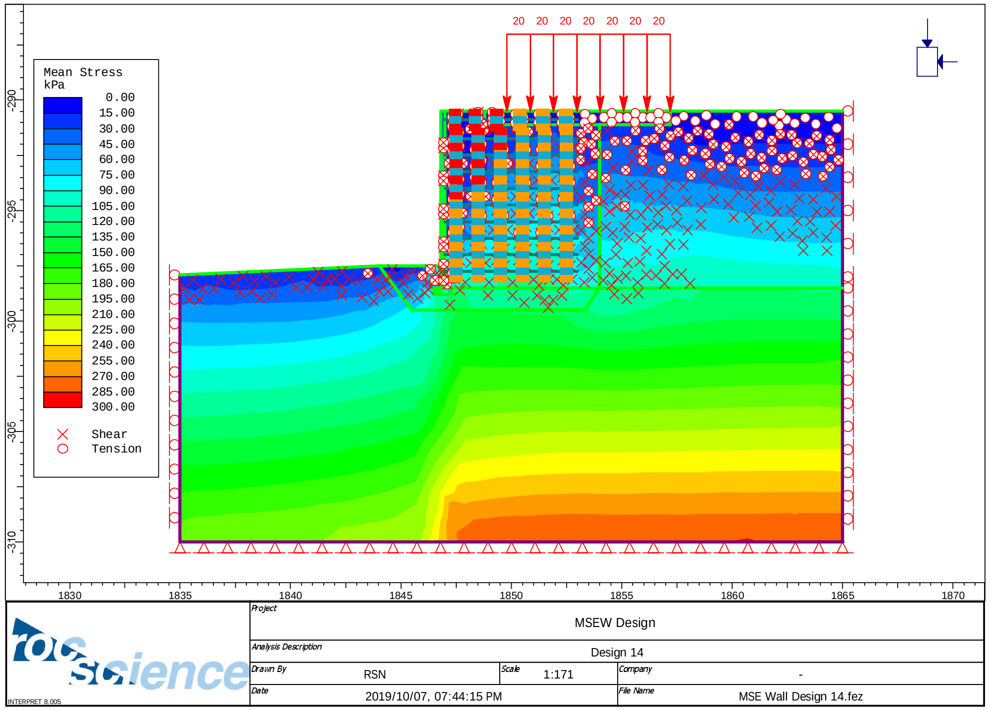
INTERPRET 8.005


20 20 20 20 20 20 20
Mean Stress
kPa
0.00
15.00
30.00
45.00
60.00
75.00
90.00
105.00
120.00
135.00
150.00
165.00
180.00
195.00
210.00
225.00
240.00
255.00
270.00
285.00
300.00
Shear
Tension
-290
-295
-300
-305
-310
1830
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1845
1850
1855
1860
1865
1870
Project
MSEW Design
Analysis Description
Design 14
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Company
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Date
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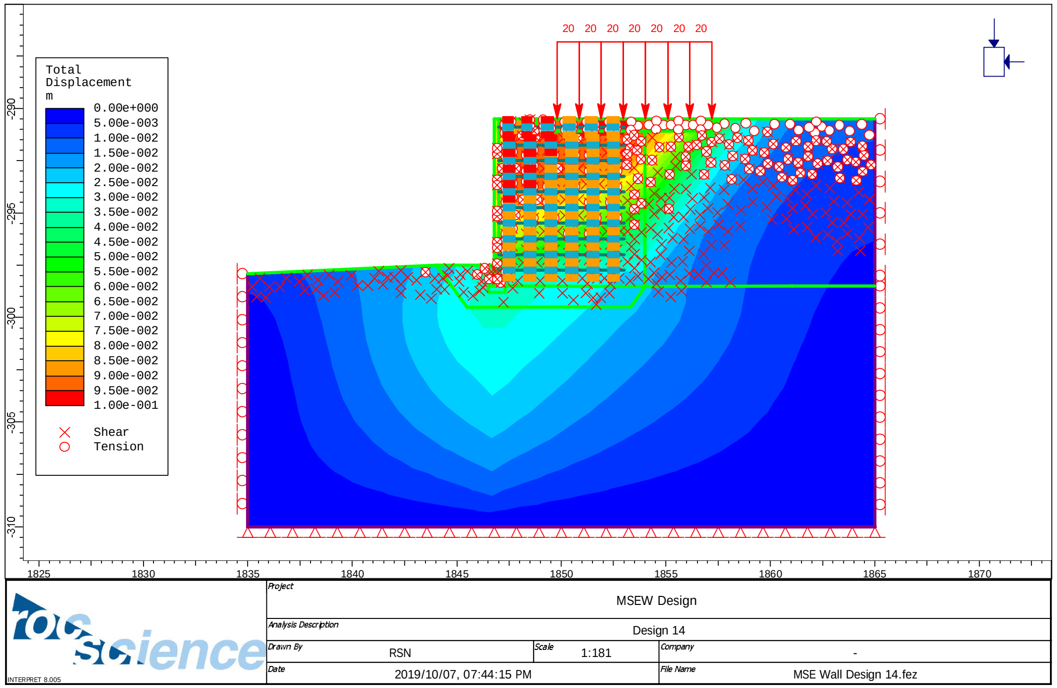
INTERPRET 8.005


20 20 20 20 20 20 20
Total
Displacement
m
0.00e+000
5.00e-003
1.00e-002
1.50e-002
2.00e-002
2.50e-002
3.00e-002
3.50e-002
4.00e-002
4.50e-002
5.00e-002
5.50e-002
6.00e-002
6.50e-002
7.00e-002
7.50e-002
8.00e-002
8.50e-002
9.00e-002
9.50e-002
1.00e-001
Shear
Tension
-290
-295
-300
-305
-310
1825
1830
1835
1840
1845
1850
1855
1860
1865
1870
Project
MSEW Design
Analysis Description
Design 14
Drawn By
RSN
Scale
1:181
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
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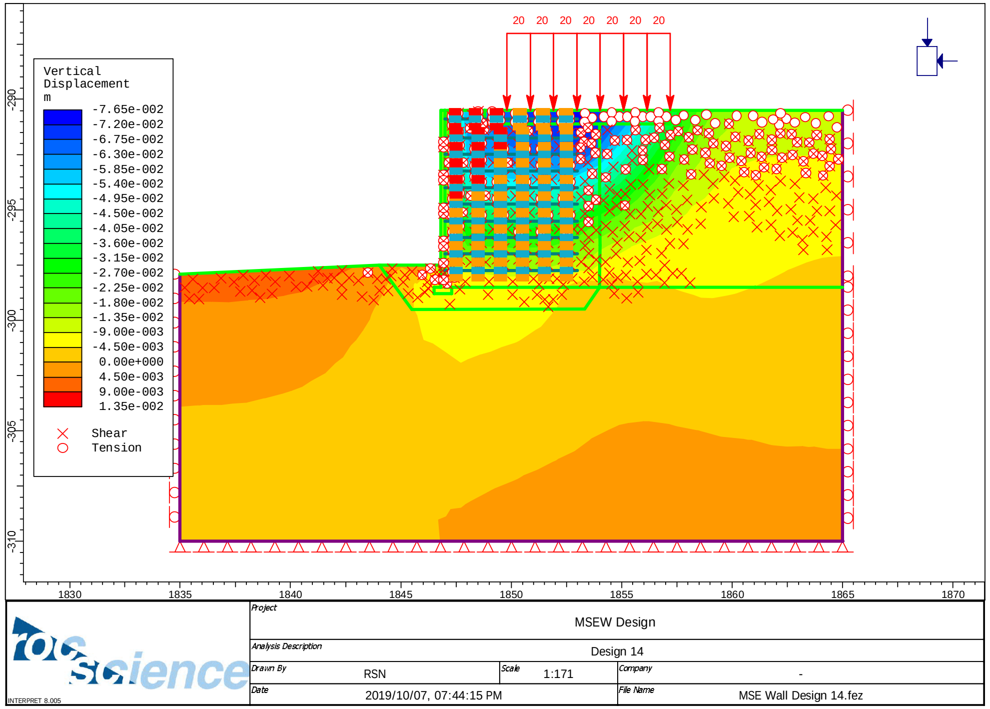
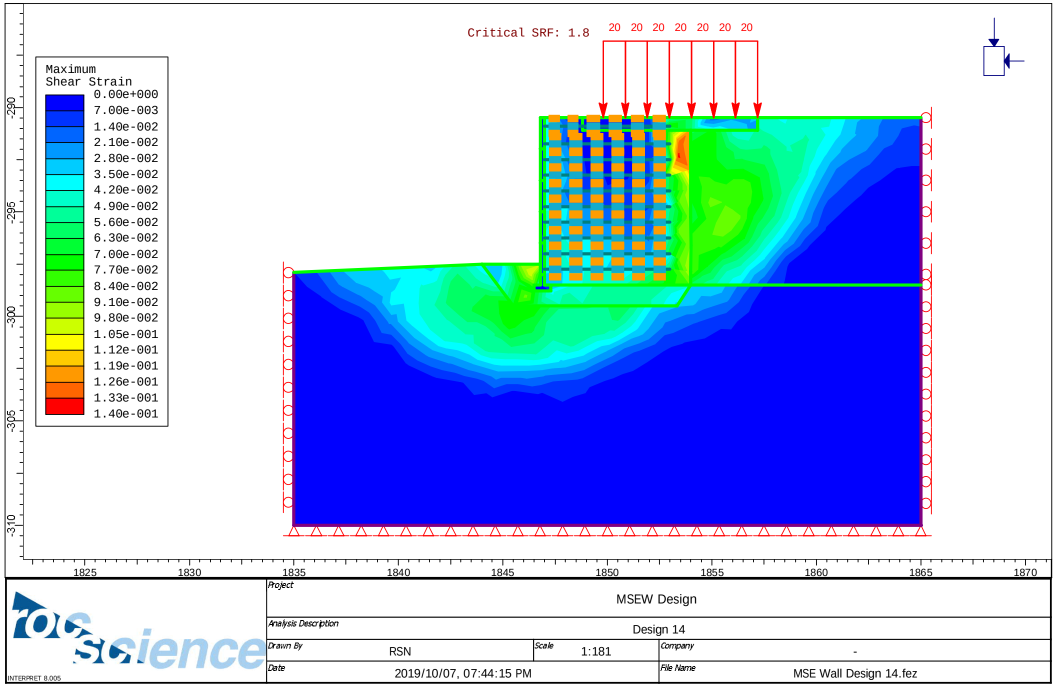
INTERPRET 8.005



Vertical Displacement
m
-7.65e-002
-7.20e-002
-6.75e-002
-6.30e-002
-5.85e-002
-5.40e-002
-4.95e-002
-4.50e-002
-4.05e-002
-3.60e-002
-3.15e-002
-2.70e-002
-2.25e-002
-1.80e-002
-1.35e-002
-9.00e-003
-4.50e-003
0.00e+000
4.50e-003
9.00e-003
1.35e-002
Shear
Tension
20 20 20 20 20 20 20
Project
MSEW Design
Analysis Description
Design 14
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 14.fez
INTERPRET 8.005



Maximum Shear Strain
0.00e+000
7.00e-003
1.40e-002
2.10e-002
2.80e-002
3.50e-002
4.20e-002
4.90e-002
5.60e-002
6.30e-002
7.00e-002
7.70e-002
8.40e-002
9.10e-002
9.80e-002
1.05e-001
1.12e-001
1.19e-001
1.26e-001
1.33e-001
1.40e-001
Critical SRF: 1.8
20 20 20 20 20 20 20
Project
MSEW Design
Analysis Description
Design 14
Drawn By
RSN
Scale
1:181
Company
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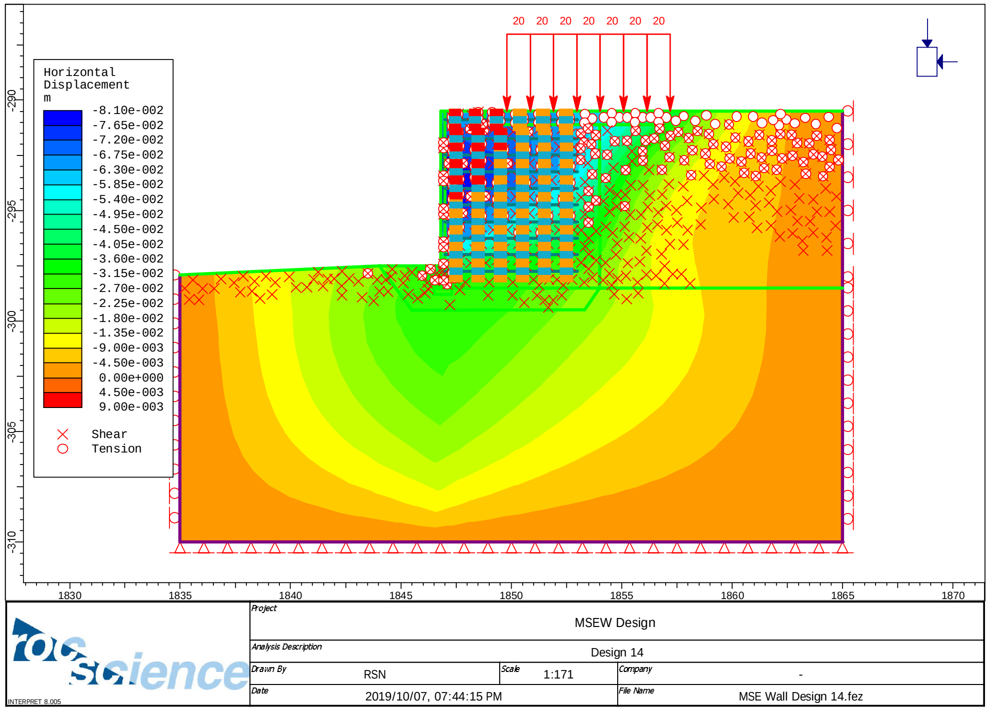
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 14.fez
INTERPRET 8.005



Horizontal Displacement
m
-8.10e-002
-7.65e-002
-7.20e-002
-6.75e-002
-6.30e-002
-5.85e-002
-5.40e-002
-4.95e-002
-4.50e-002
-4.05e-002
-3.60e-002
-3.15e-002
-2.70e-002
-2.25e-002
-1.80e-002
-1.35e-002
-9.00e-003
-4.50e-003
0.00e+000
4.50e-003
9.00e-003
Shear
Tension
20 20 20 20 20 20 20
Project
MSEW Design
Analysis Description
Design 14
Drawn By
RSN
Scale
1:171
Company
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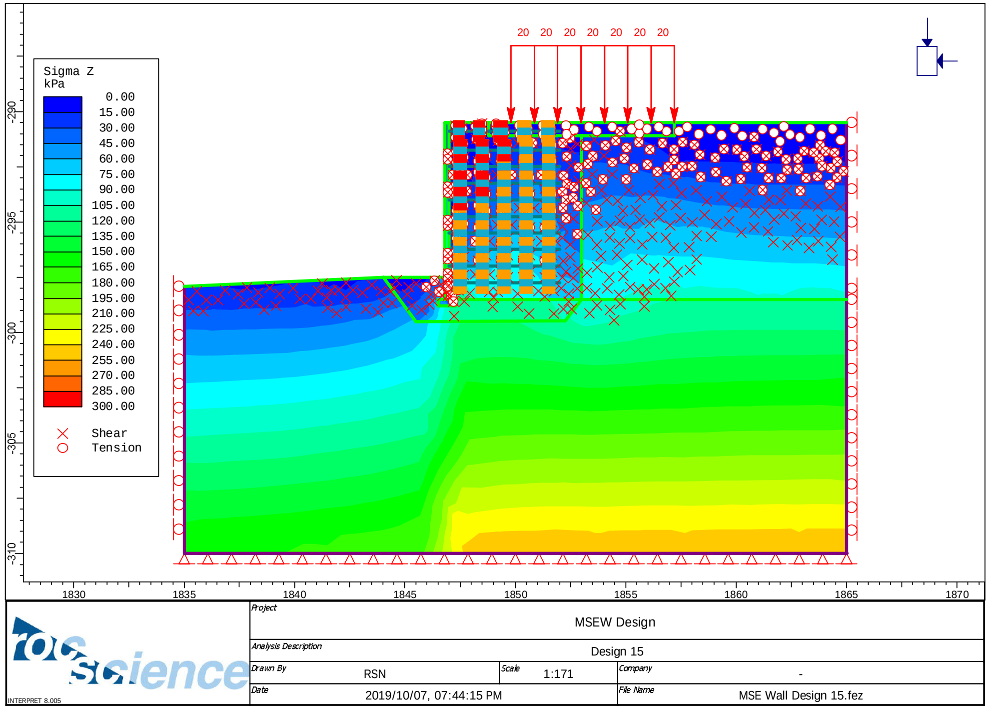
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 14.fez
INTERPRET 8.005


Sigma Z
kPa
0.00
15.00
30.00
45.00
60.00
75.00
90.00
105.00
120.00
135.00
150.00
165.00
180.00
195.00
210.00
225.00
240.00
255.00
270.00
285.00
300.00
Shear
Tension
20 20 20 20 20 20 20
-290
-295
-300
-305
-310
1830 1835 1840 1845 1850 1855 1860 1865 1870
Project
MSEW Design
Analysis Description
Design 15
Drawn By
RSN
Scale
1:171
Company
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Date
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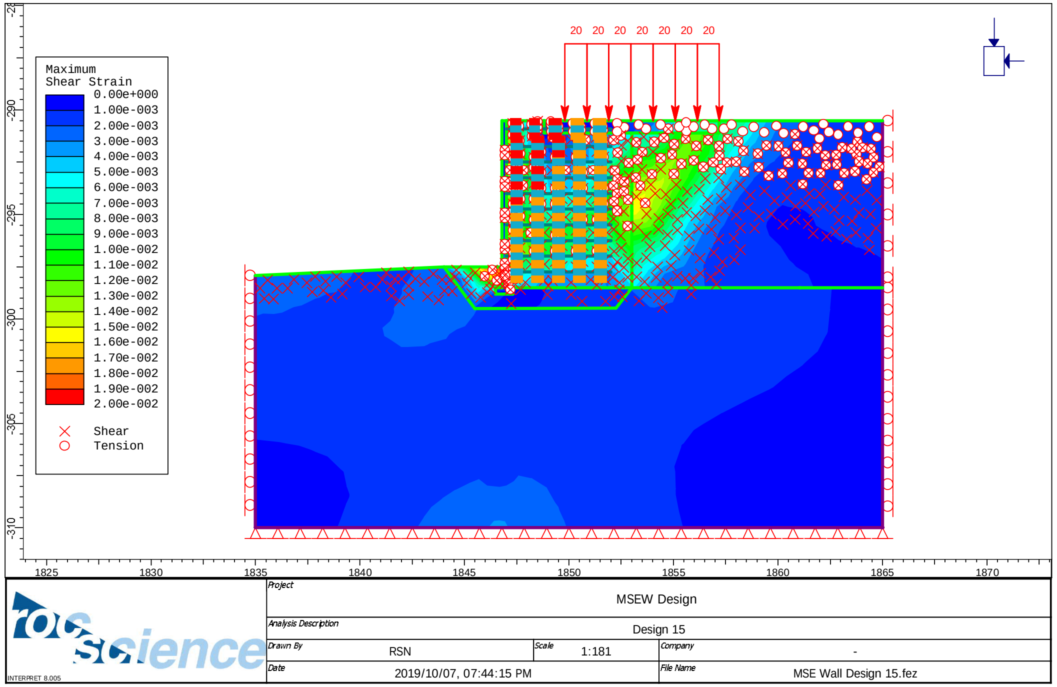
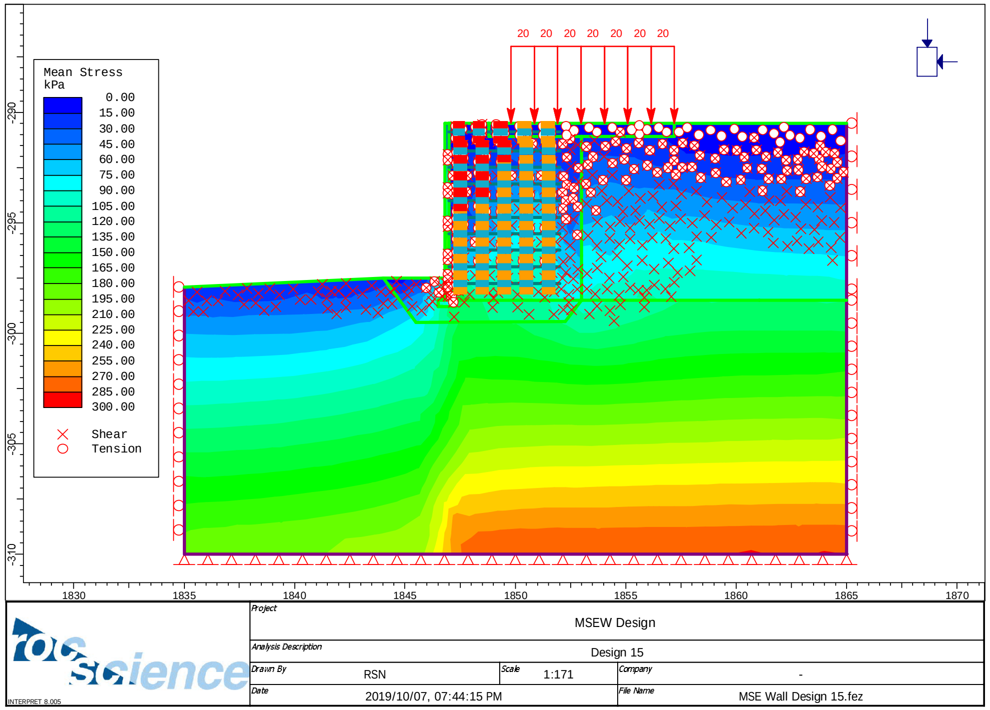
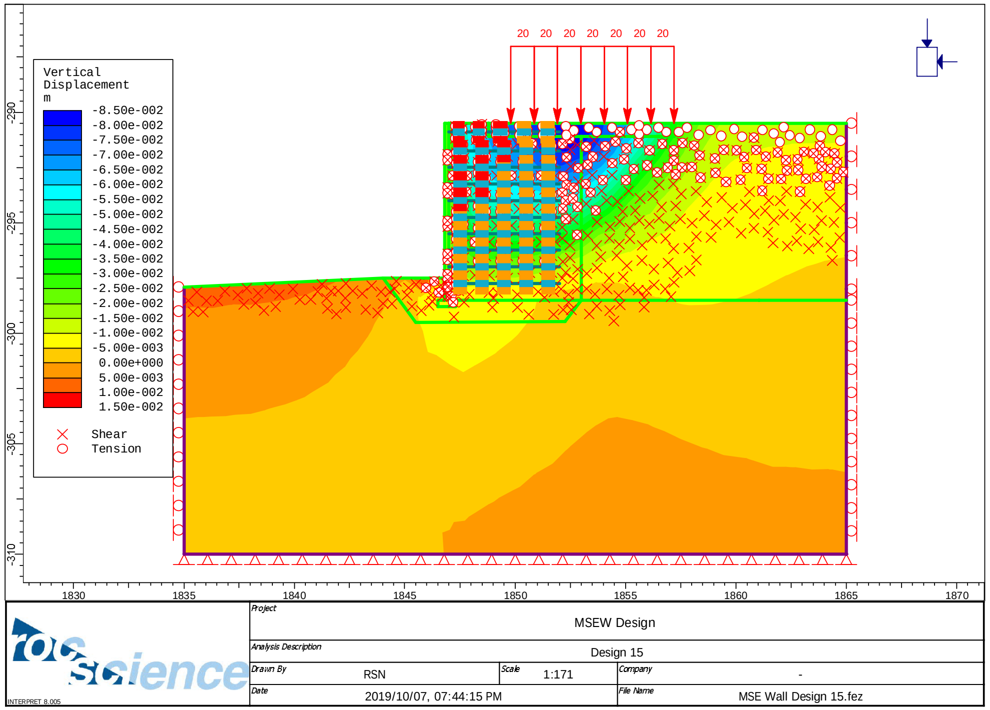
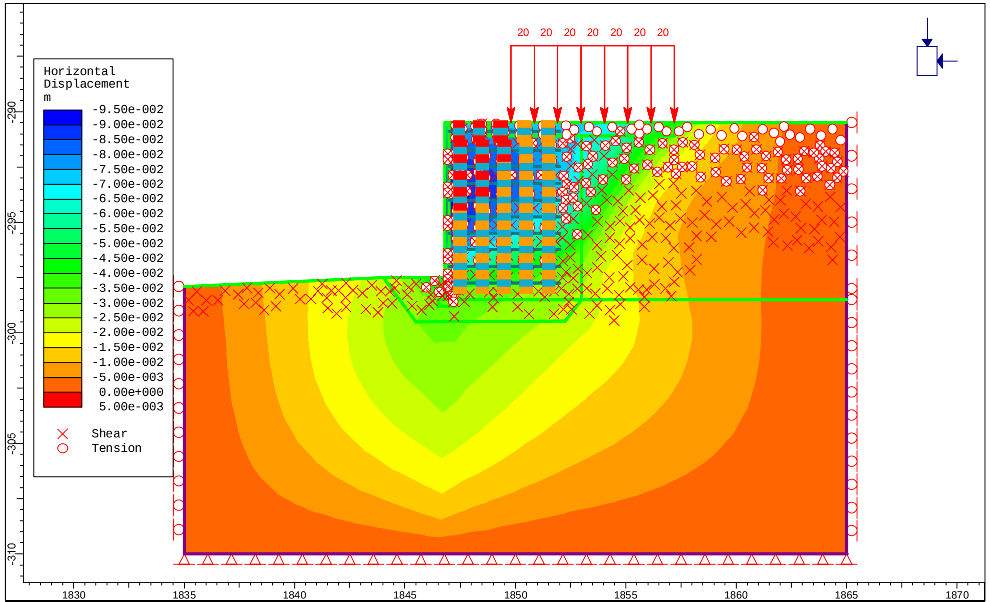
MSE Wall Design 15.fez
INTERPRET 8.005


Maximum
Shear Strain
0.00e+000
1.00e-003
2.00e-003
3.00e-003
4.00e-003
5.00e-003
6.00e-003
7.00e-003
8.00e-003
9.00e-003
1.00e-002
1.10e-002
1.20e-002
1.30e-002
1.40e-002
1.50e-002
1.60e-002
1.70e-002
1.80e-002
1.90e-002
2.00e-002
Shear
Tension
20 20 20 20 20 20 20
-290
-295
-300
-305
-310
1825 1830 1835 1840 1845 1850 1855 1860 1865 1870
Project
MSEW Design
Analysis Description
Design 15
Drawn By
RSN
Scale
1:181
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 15.fez
INTERPRET 8.005

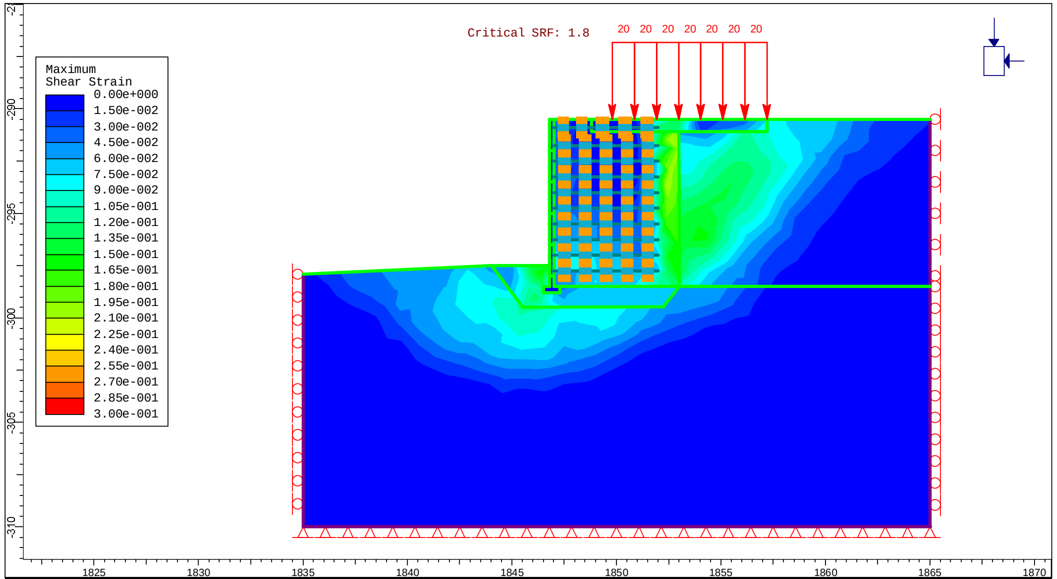

Mean Stress
kPa
0.00
15.00
30.00
45.00
60.00
75.00
90.00
105.00
120.00
135.00
150.00
165.00
180.00
195.00
210.00
225.00
240.00
255.00
270.00
285.00
300.00
Shear
Tension
20 20 20 20 20 20 20
-290
-295
-300
-305
-310
1830 1835 1840 1845 1850 1855 1860 1865 1870
Project
MSEW Design
Analysis Description
Design 15
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 15.fez
INTERPRET 8.005


Vertical
Displacement
m
-8.50e-002
-8.00e-002
-7.50e-002
-7.00e-002
-6.50e-002
-6.00e-002
-5.50e-002
-5.00e-002
-4.50e-002
-4.00e-002
-3.50e-002
-3.00e-002
-2.50e-002
-2.00e-002
-1.50e-002
-1.00e-002
-5.00e-003
0.00e+000
5.00e-003
1.00e-002
1.50e-002
Shear
Tension
20 20 20 20 20 20 20
-290
-295
-300
-305
-310
1830 1835 1840 1845 1850 1855 1860 1865 1870
Project
MSEW Design
Analysis Description
Design 15
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 15.fez
INTERPRET 8.005



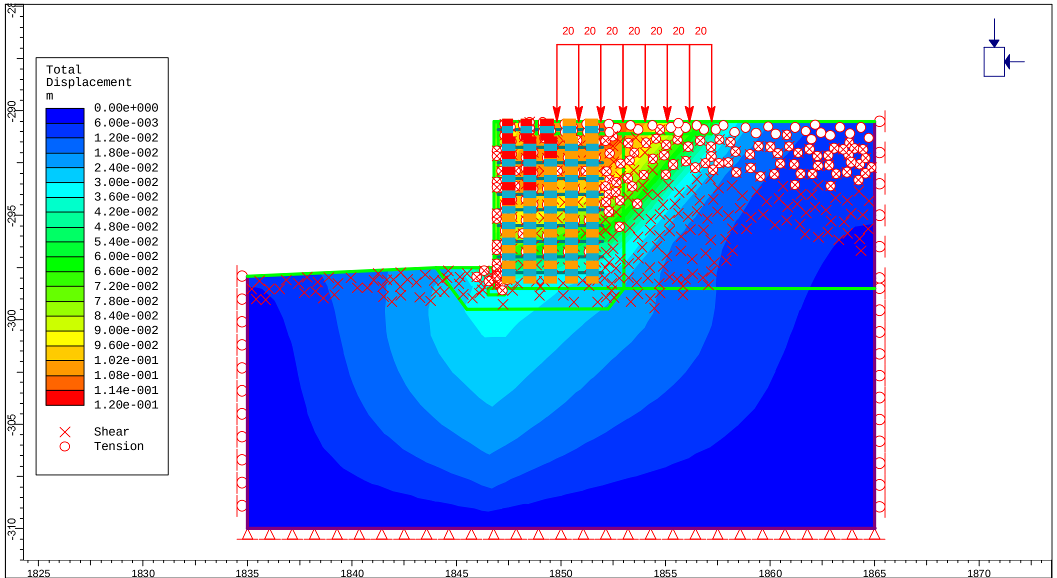
INTERPRET 8.005

Project	MSEW Design		
Analysis Description	Design 15		
Drawn By	RSN	Scale	1:171
Company	-		
Date	2019/10/07, 07:44:15 PM	File Name	MSE Wall Design 15.fez



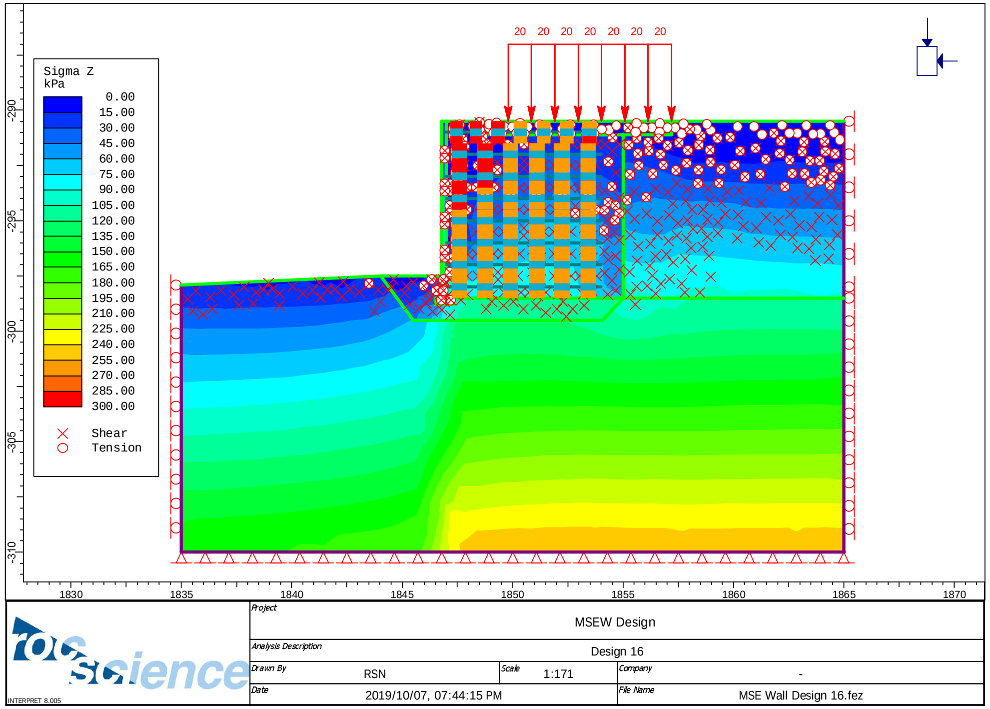
INTERPRET 8.005

Project	MSEW Design		
Analysis Description	Design 15		
Drawn By	RSN	Scale	1:181
Company	-		
Date	2019/10/07, 07:44:15 PM	File Name	MSE Wall Design 15.fez



INTERPRET 8.005

Project	MSEW Design		
Analysis Description	Design 15		
Drawn By	RSN	Scale	1:181
Company	-		
Date	2019/10/07, 07:44:15 PM	File Name	MSE Wall Design 15.fez


Sigma Z
kPa
0.00
15.00
30.00
45.00
60.00
75.00
90.00
105.00
120.00
135.00
150.00
165.00
180.00
195.00
210.00
225.00
240.00
255.00
270.00
285.00
300.00
Shear
Tension
20 20 20 20 20 20 20
Project
MSEW Design
Analysis Description
Design 16
Drawn By
RSN
Scale
1:171
Company
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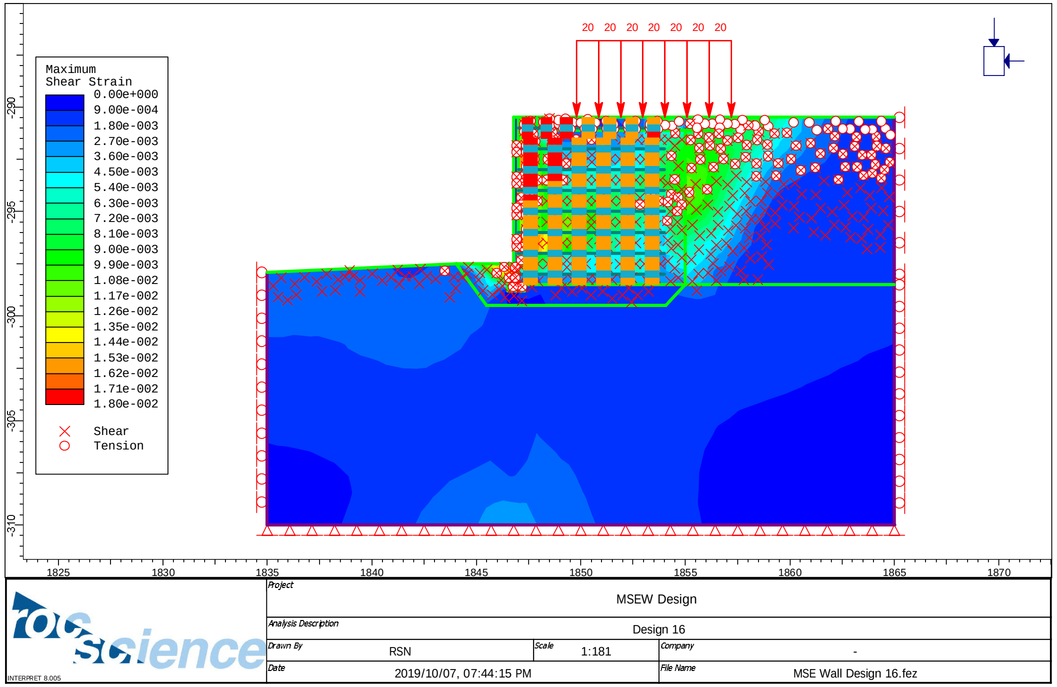
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 16.fez
INTERPRET 8.005


Maximum
Shear Strain
0.00e+000
9.00e-004
1.80e-003
2.70e-003
3.60e-003
4.50e-003
5.40e-003
6.30e-003
7.20e-003
8.10e-003
9.00e-003
9.90e-003
1.08e-002
1.17e-002
1.26e-002
1.35e-002
1.44e-002
1.53e-002
1.62e-002
1.71e-002
1.80e-002
Shear
Tension
20 20 20 20 20 20 20
Project
MSEW Design
Analysis Description
Design 16
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RSN
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Company
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Date
2019/10/07, 07:44:15 PM
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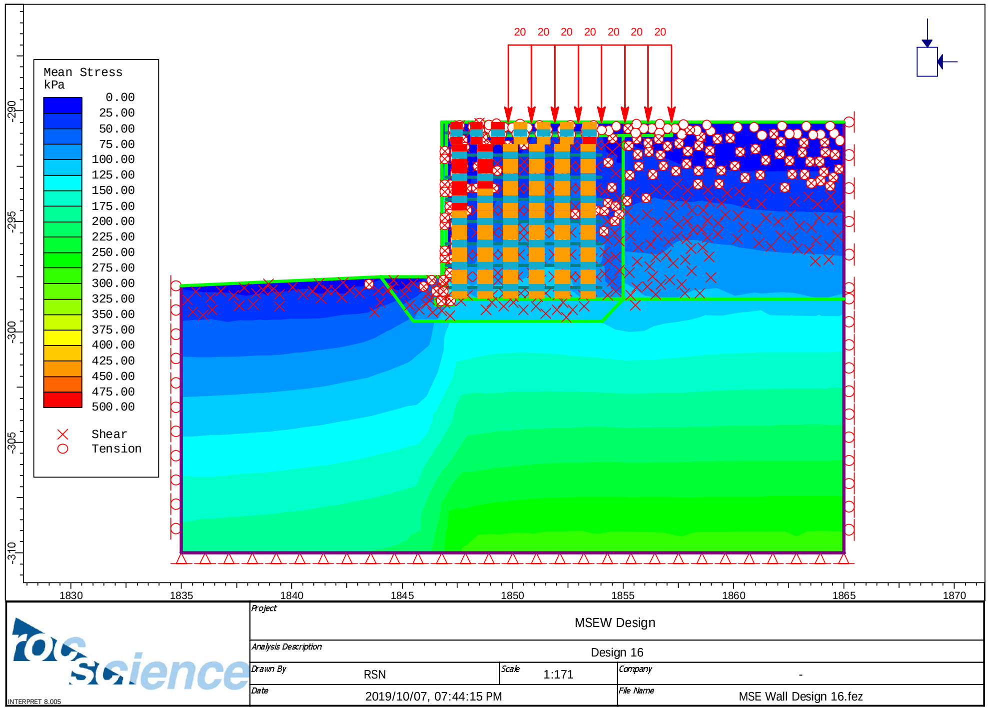
MSE Wall Design 16.fez
INTERPRET 8.005


Mean Stress
kPa
0.00
25.00
50.00
75.00
100.00
125.00
150.00
175.00
200.00
225.00
250.00
275.00
300.00
325.00
350.00
375.00
400.00
425.00
450.00
475.00
500.00
Shear
Tension
20 20 20 20 20 20 20
Project
MSEW Design
Analysis Description
Design 16
Drawn By
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1:171
Company
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Date
2019/10/07, 07:44:15 PM
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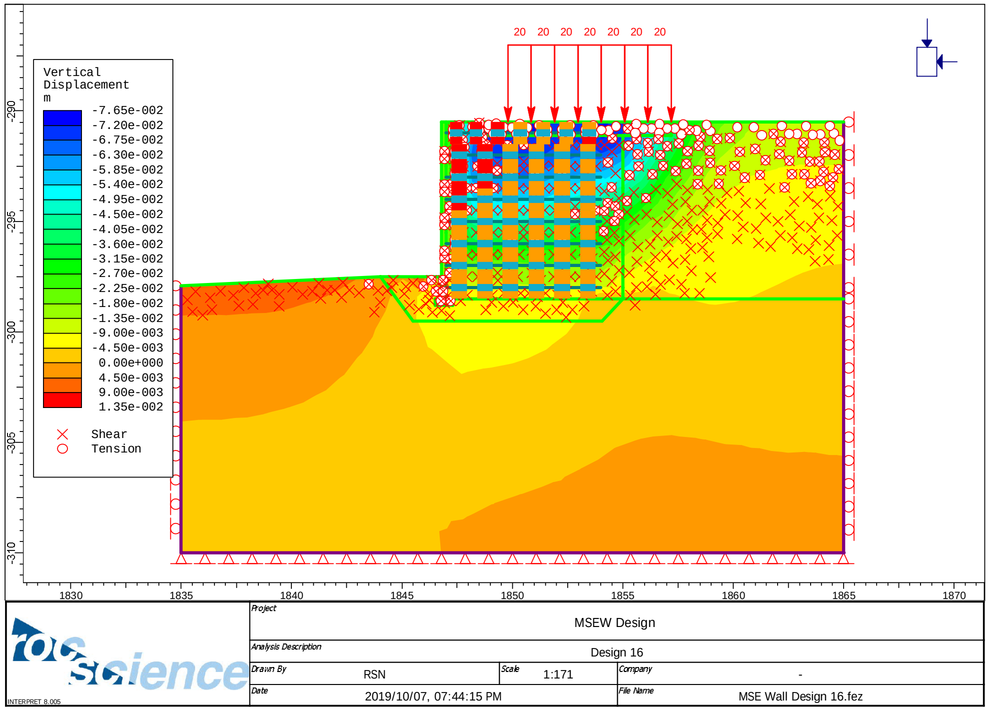
INTERPRET 8.005


Vertical
Displacement
m
-7.65e-002
-7.20e-002
-6.75e-002
-6.30e-002
-5.85e-002
-5.40e-002
-4.95e-002
-4.50e-002
-4.05e-002
-3.60e-002
-3.15e-002
-2.70e-002
-2.25e-002
-1.80e-002
-1.35e-002
-9.00e-003
-4.50e-003
0.00e+000
4.50e-003
9.00e-003
1.35e-002
Shear
Tension
20 20 20 20 20 20 20
Project
MSEW Design
Analysis Description
Design 16
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RSN
Scale
1:171
Company
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Date
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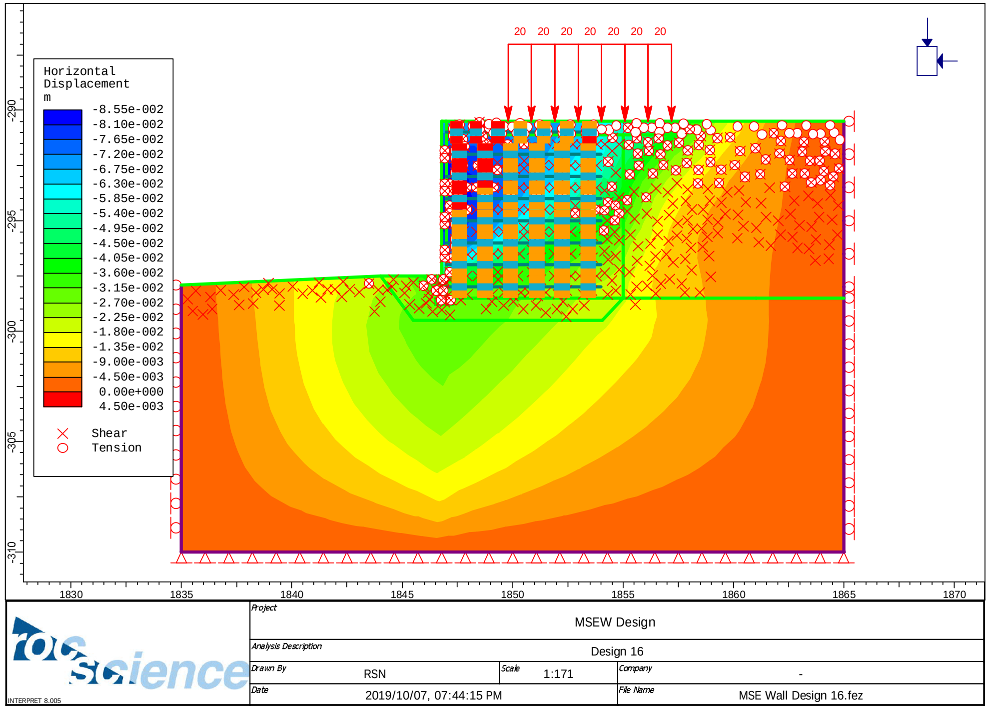
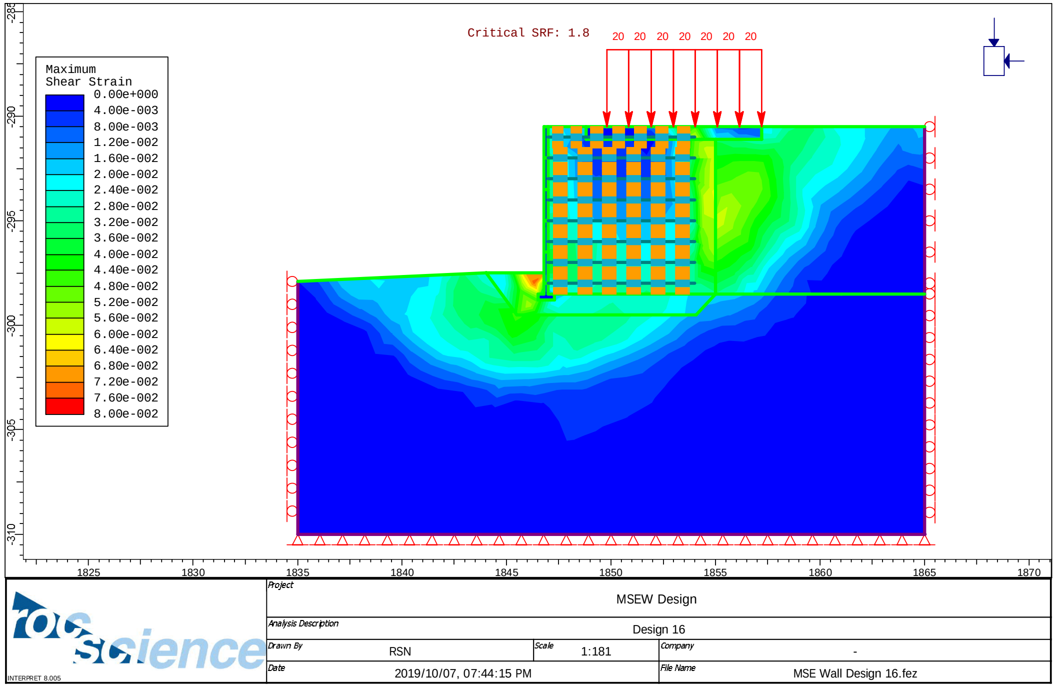
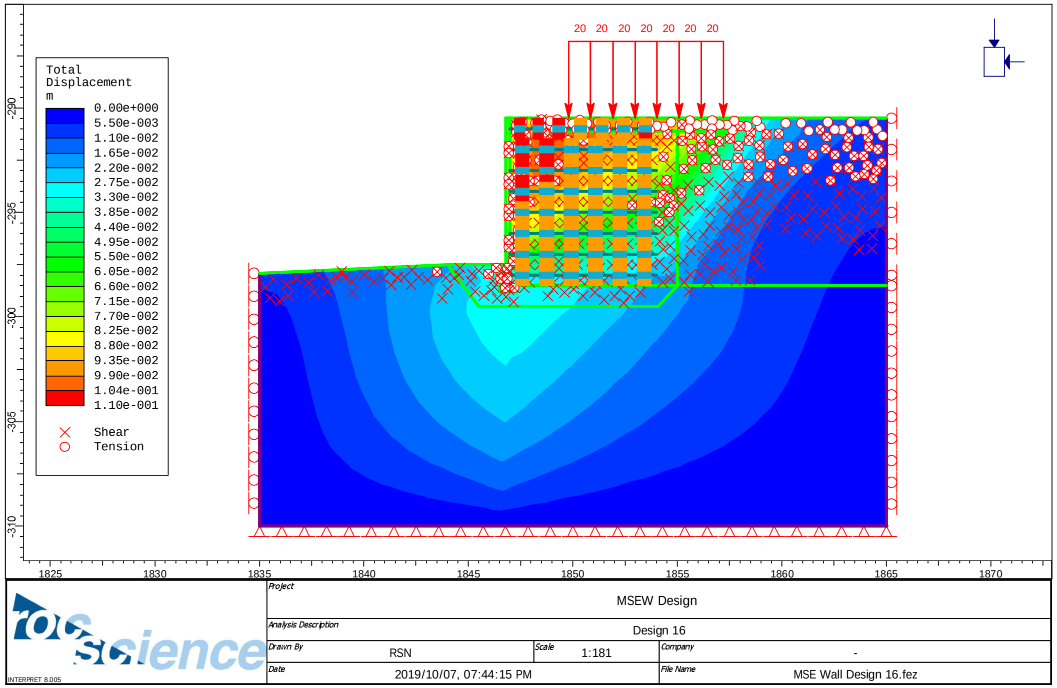
MSE Wall Design 16.fez
INTERPRET 8.005



Horizontal Displacement m
-8.55e-002
-8.10e-002
-7.65e-002
-7.20e-002
-6.75e-002
-6.30e-002
-5.85e-002
-5.40e-002
-4.95e-002
-4.50e-002
-4.05e-002
-3.60e-002
-3.15e-002
-2.70e-002
-2.25e-002
-1.80e-002
-1.35e-002
-9.00e-003
-4.50e-003
0.00e+000
4.50e-003
Shear
Tension
20 20 20 20 20 20 20
1830 1835 1840 1845 1850 1855 1860 1865 1870
-290 -295 -300 -305 -310
rocscience
INTERPRET 8.005
Project
MSEW Design
Analysis Description
Design 16
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 16.fez



Critical SRF: 1.8
Maximum Shear Strain
0.00e+000
4.00e-003
8.00e-003
1.20e-002
1.60e-002
2.00e-002
2.40e-002
2.80e-002
3.20e-002
3.60e-002
4.00e-002
4.40e-002
4.80e-002
5.20e-002
5.60e-002
6.00e-002
6.40e-002
6.80e-002
7.20e-002
7.60e-002
8.00e-002
20 20 20 20 20 20 20 20
1825 1830 1835 1840 1845 1850 1855 1860 1865 1870
-285 -290 -295 -300 -305 -310
rocscience
INTERPRET 8.005
Project
MSEW Design
Analysis Description
Design 16
Drawn By
RSN
Scale
1:181
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 16.fez



Total Displacement m
0.00e+000
5.50e-003
1.10e-002
1.65e-002
2.20e-002
2.75e-002
3.30e-002
3.85e-002
4.40e-002
4.95e-002
5.50e-002
6.05e-002
6.60e-002
7.15e-002
7.70e-002
8.25e-002
8.80e-002
9.35e-002
9.90e-002
1.04e-001
1.10e-001
Shear
Tension
20 20 20 20 20 20 20
1825 1830 1835 1840 1845 1850 1855 1860 1865 1870
-290 -295 -300 -305 -310
rocscience
INTERPRET 8.005
Project
MSEW Design
Analysis Description
Design 16
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Scale
1:181
Company
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Date
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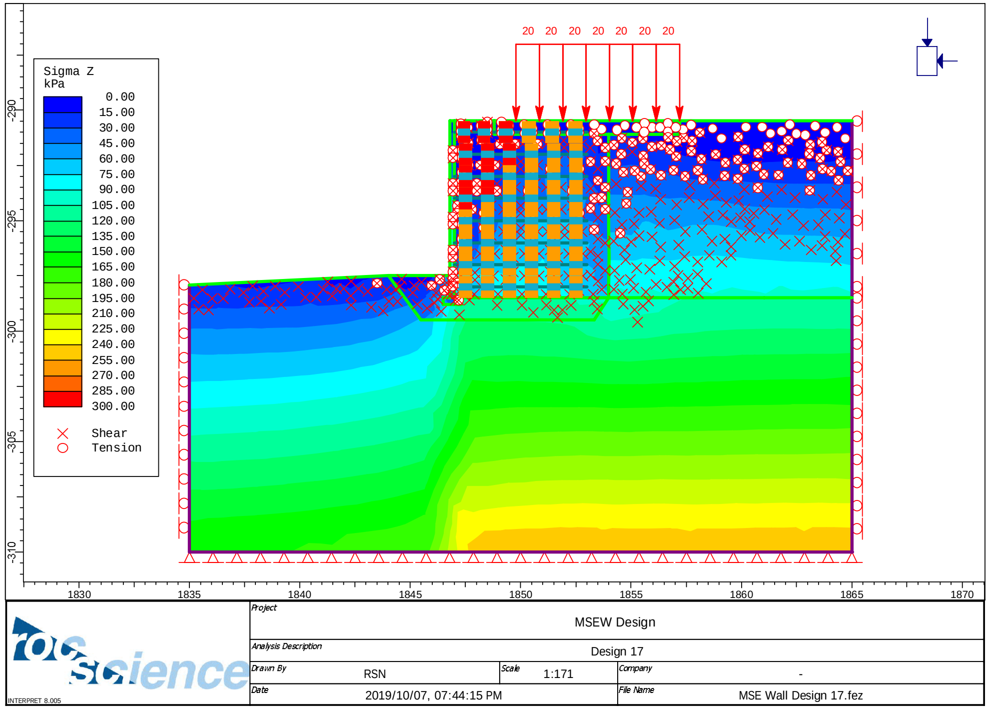
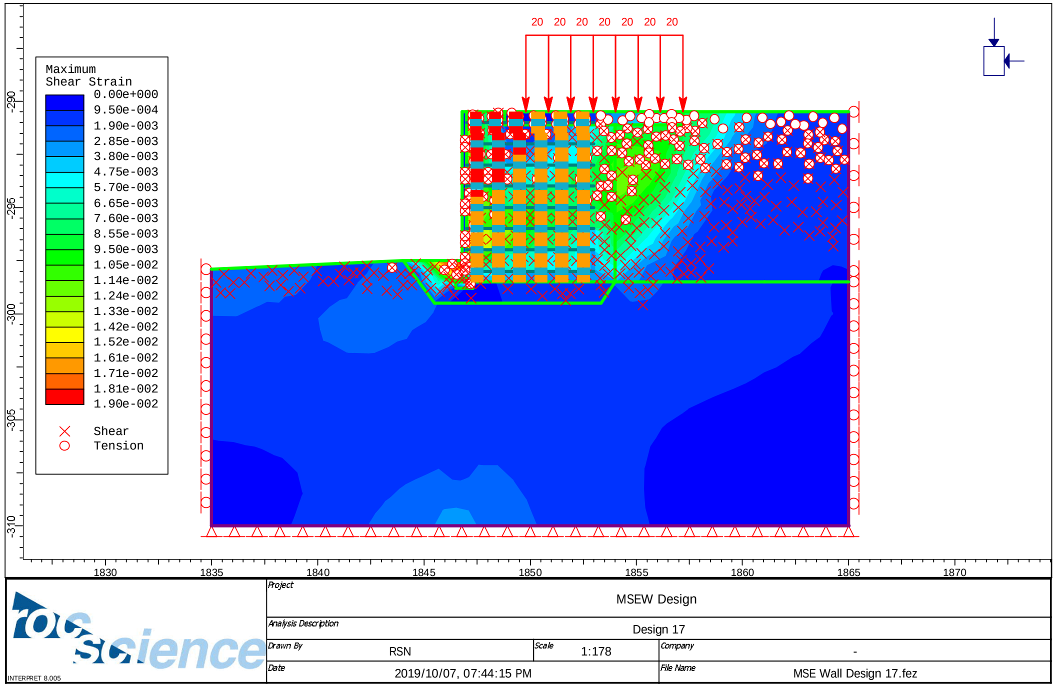

Sigma Z
kPa
0.00
15.00
30.00
45.00
60.00
75.00
90.00
105.00
120.00
135.00
150.00
165.00
180.00
195.00
210.00
225.00
240.00
255.00
270.00
285.00
300.00
Shear
Tension
Project
MSEW Design
Analysis Description
Design 17
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 17.fez
INTERPRET 8.005


Maximum
Shear Strain
0.00e+000
9.50e-004
1.90e-003
2.85e-003
3.80e-003
4.75e-003
5.70e-003
6.65e-003
7.60e-003
8.55e-003
9.50e-003
1.05e-002
1.14e-002
1.24e-002
1.33e-002
1.42e-002
1.52e-002
1.61e-002
1.71e-002
1.81e-002
1.90e-002
Shear
Tension
Project
MSEW Design
Analysis Description
Design 17
Drawn By
RSN
Scale
1:178
Company
-
Date
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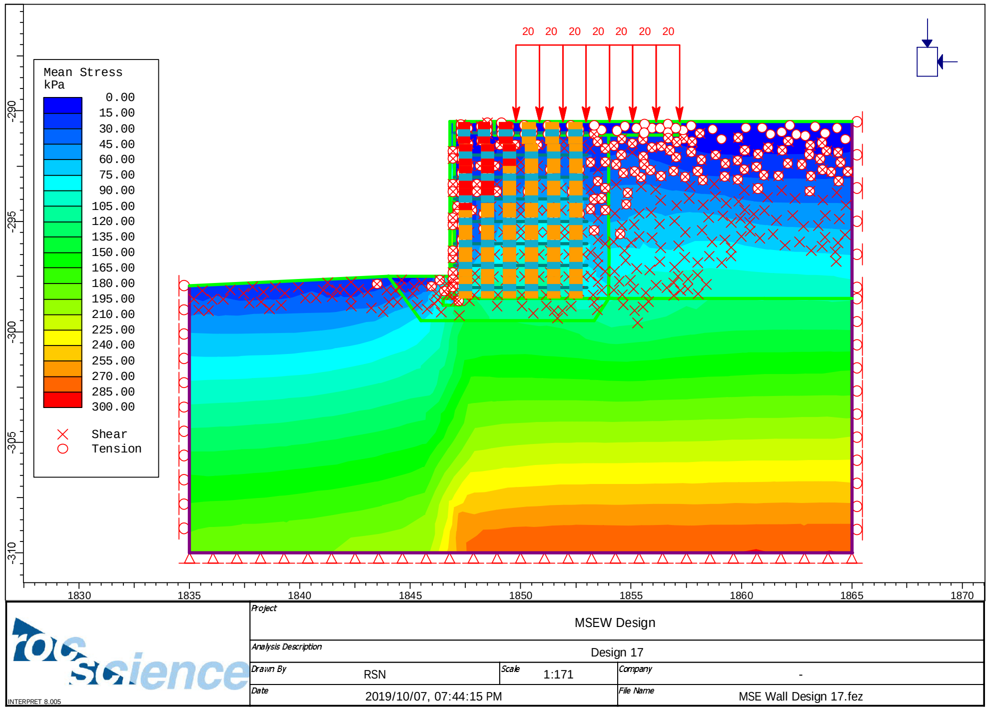
File Name
MSE Wall Design 17.fez
INTERPRET 8.005


Mean Stress
kPa
0.00
15.00
30.00
45.00
60.00
75.00
90.00
105.00
120.00
135.00
150.00
165.00
180.00
195.00
210.00
225.00
240.00
255.00
270.00
285.00
300.00
Shear
Tension
Project
MSEW Design
Analysis Description
Design 17
Drawn By
RSN
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Company
-
Date
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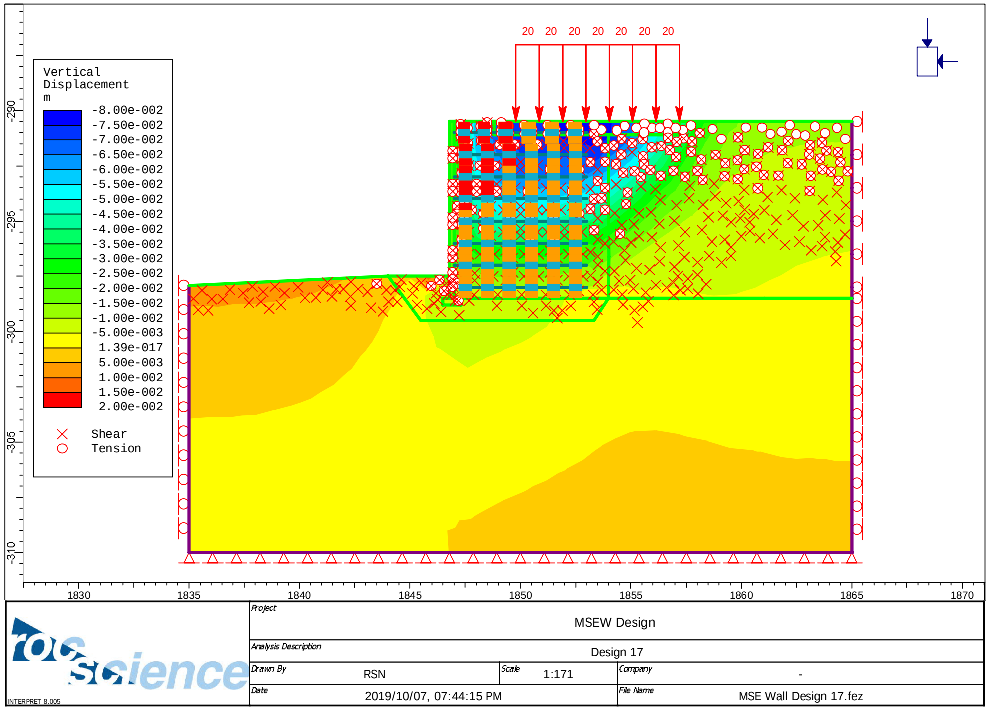
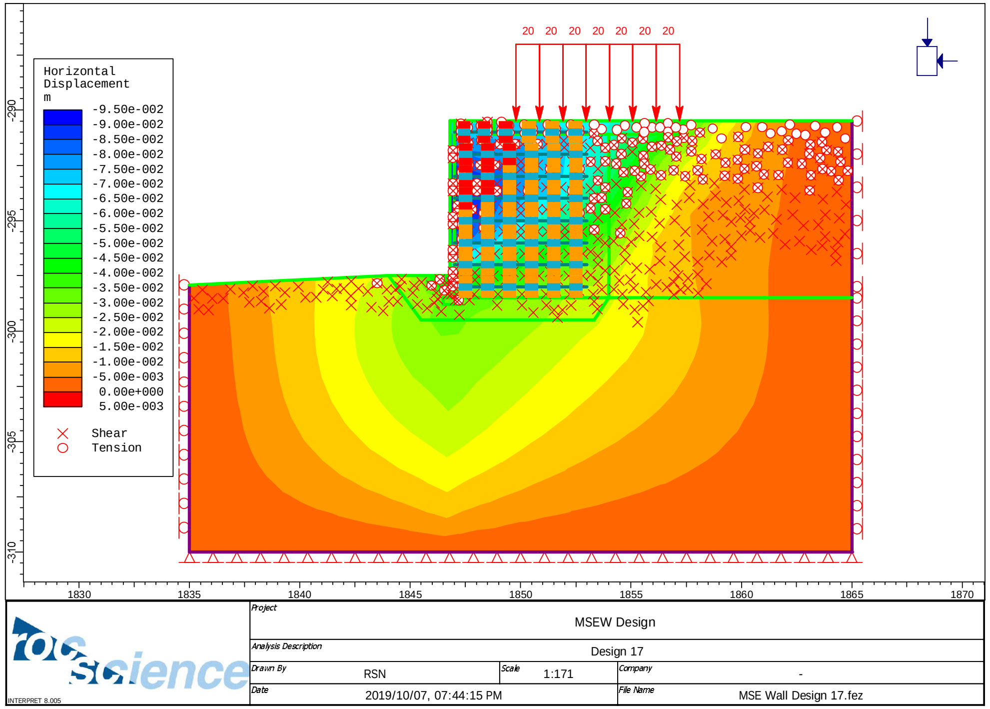
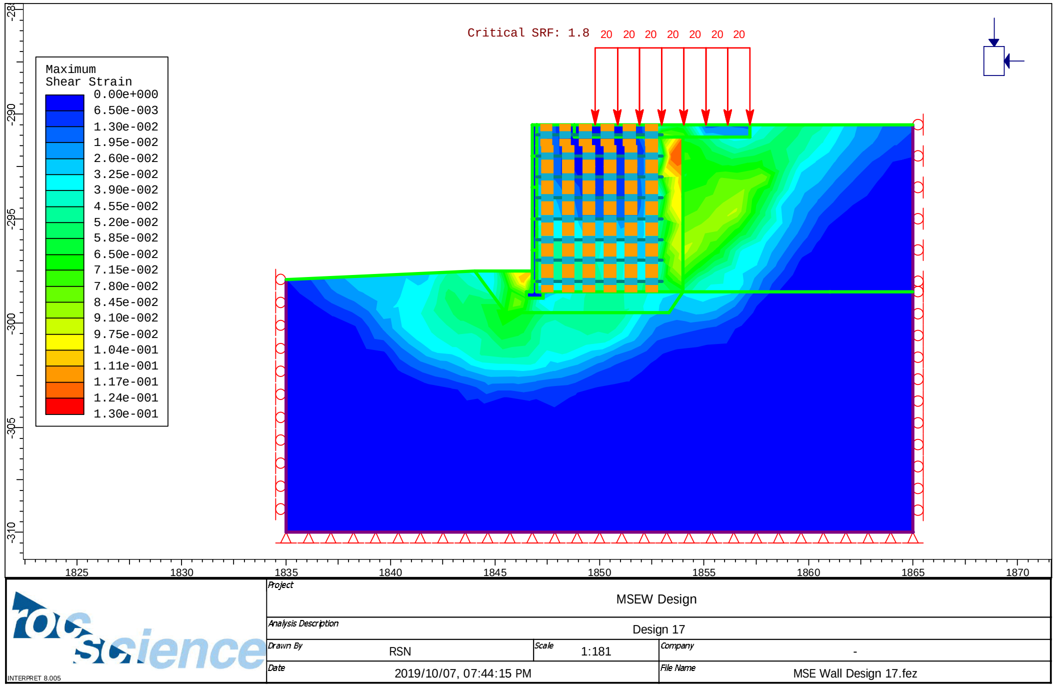
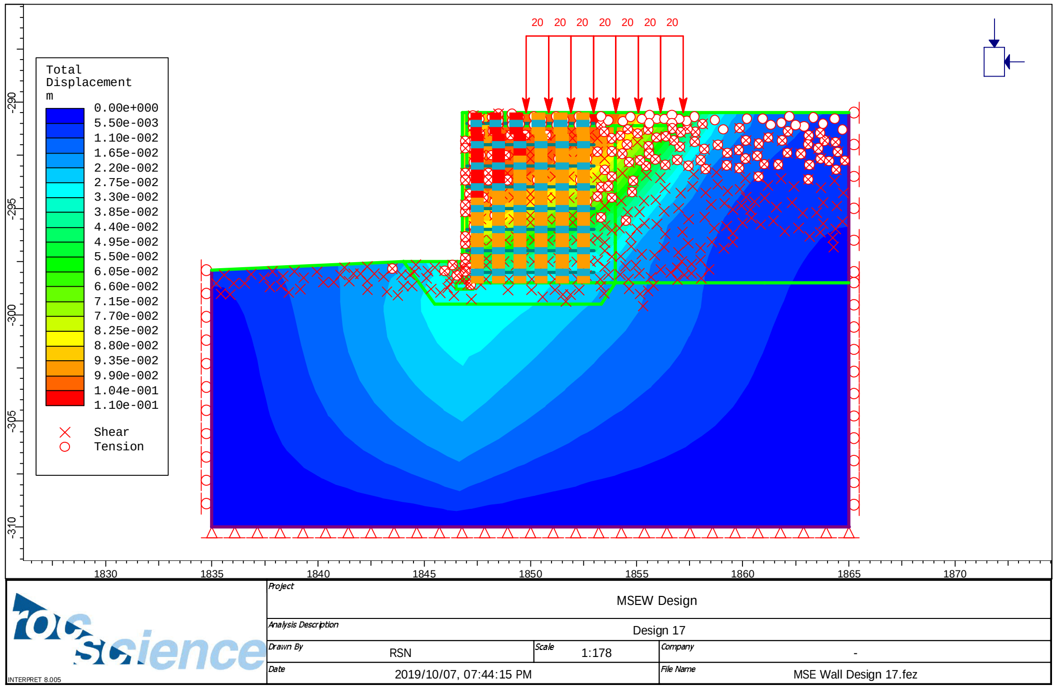
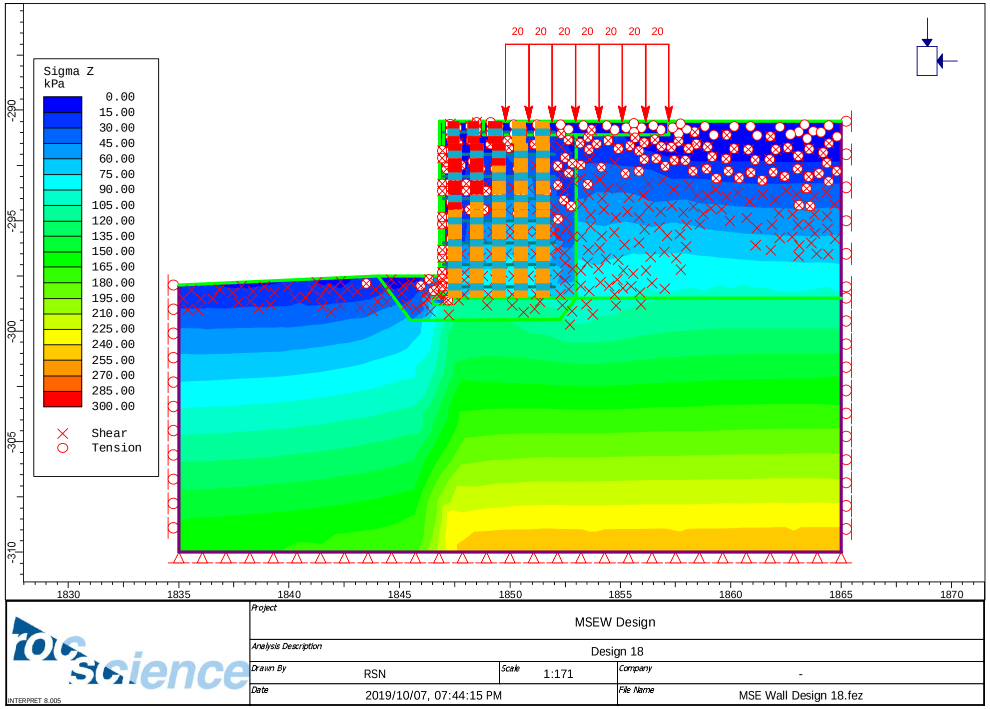
File Name
MSE Wall Design 17.fez
INTERPRET 8.005

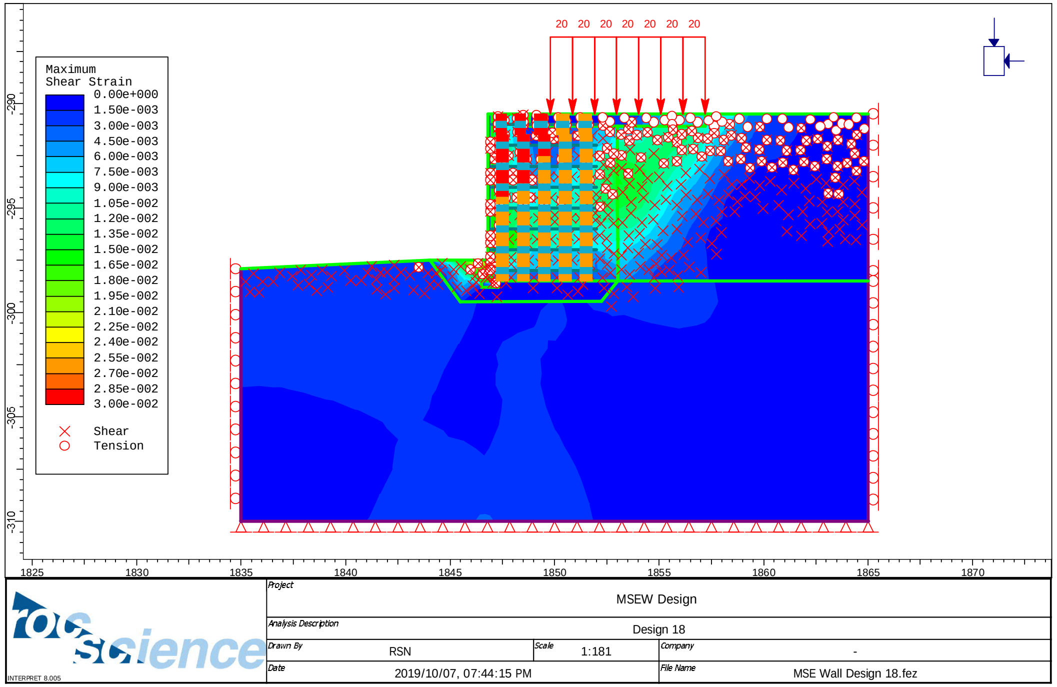

Vertical
Displacement
m
-8.00e-002
-7.50e-002
-7.00e-002
-6.50e-002
-6.00e-002
-5.50e-002
-5.00e-002
-4.50e-002
-4.00e-002
-3.50e-002
-3.00e-002
-2.50e-002
-2.00e-002
-1.50e-002
-1.00e-002
-5.00e-003
1.39e-017
5.00e-003
1.00e-002
1.50e-002
2.00e-002
Shear
Tension
Project
MSEW Design
Analysis Description
Design 17
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 17.fez
INTERPRET 8.005

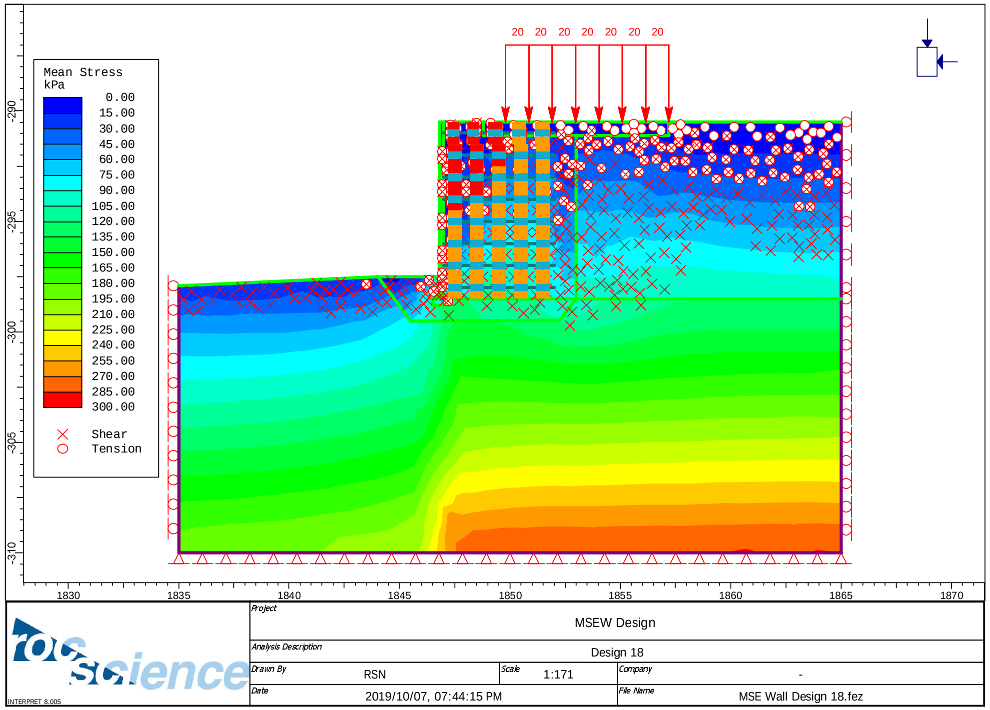

Horizontal Displacement m
-9.50e-002
-9.00e-002
-8.50e-002
-8.00e-002
-7.50e-002
-7.00e-002
-6.50e-002
-6.00e-002
-5.50e-002
-5.00e-002
-4.50e-002
-4.00e-002
-3.50e-002
-3.00e-002
-2.50e-002
-2.00e-002
-1.50e-002
-1.00e-002
-5.00e-003
0.00e+000
5.00e-003
Shear
Tension
20 20 20 20 20 20 20
Project
MSEW Design
Analysis Description
Design 17
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 17.fez
INTERPRET 8.005


Critical SRF: 1.8
20 20 20 20 20 20 20
Maximum Shear Strain
0.00e+000
6.50e-003
1.30e-002
1.95e-002
2.60e-002
3.25e-002
3.90e-002
4.55e-002
5.20e-002
5.85e-002
6.50e-002
7.15e-002
7.80e-002
8.45e-002
9.10e-002
9.75e-002
1.04e-001
1.11e-001
1.17e-001
1.24e-001
1.30e-001
Project
MSEW Design
Analysis Description
Design 17
Drawn By
RSN
Scale
1:181
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 17.fez
INTERPRET 8.005


Total Displacement m
0.00e+000
5.50e-003
1.10e-002
1.65e-002
2.20e-002
2.75e-002
3.30e-002
3.85e-002
4.40e-002
4.95e-002
5.50e-002
6.05e-002
6.60e-002
7.15e-002
7.70e-002
8.25e-002
8.80e-002
9.35e-002
9.90e-002
1.04e-001
1.10e-001
Shear
Tension
20 20 20 20 20 20 20
Project
MSEW Design
Analysis Description
Design 17
Drawn By
RSN
Scale
1:178
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 17.fez
INTERPRET 8.005


Sigma Z
kPa
0.00
15.00
30.00
45.00
60.00
75.00
90.00
105.00
120.00
135.00
150.00
165.00
180.00
195.00
210.00
225.00
240.00
255.00
270.00
285.00
300.00
Shear
Tension
20 20 20 20 20 20 20
-290
-295
-300
-305
-310
1830 1835 1840 1845 1850 1855 1860 1865 1870
Project
MSEW Design
Analysis Description
Design 18
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 18.fez
INTERPRET 8.005


Maximum
Shear Strain
0.00e+000
1.50e-003
3.00e-003
4.50e-003
6.00e-003
7.50e-003
9.00e-003
1.05e-002
1.20e-002
1.35e-002
1.50e-002
1.65e-002
1.80e-002
1.95e-002
2.10e-002
2.25e-002
2.40e-002
2.55e-002
2.70e-002
2.85e-002
3.00e-002
Shear
Tension
20 20 20 20 20 20 20
-290
-295
-300
-305
-310
1825 1830 1835 1840 1845 1850 1855 1860 1865 1870
Project
MSEW Design
Analysis Description
Design 18
Drawn By
RSN
Scale
1:181
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 18.fez
INTERPRET 8.005


Mean Stress
kPa
0.00
15.00
30.00
45.00
60.00
75.00
90.00
105.00
120.00
135.00
150.00
165.00
180.00
195.00
210.00
225.00
240.00
255.00
270.00
285.00
300.00
Shear
Tension
20 20 20 20 20 20 20
-290
-295
-300
-305
-310
1830 1835 1840 1845 1850 1855 1860 1865 1870
Project
MSEW Design
Analysis Description
Design 18
Drawn By
RSN
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1:171
Company
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Date
2019/10/07, 07:44:15 PM
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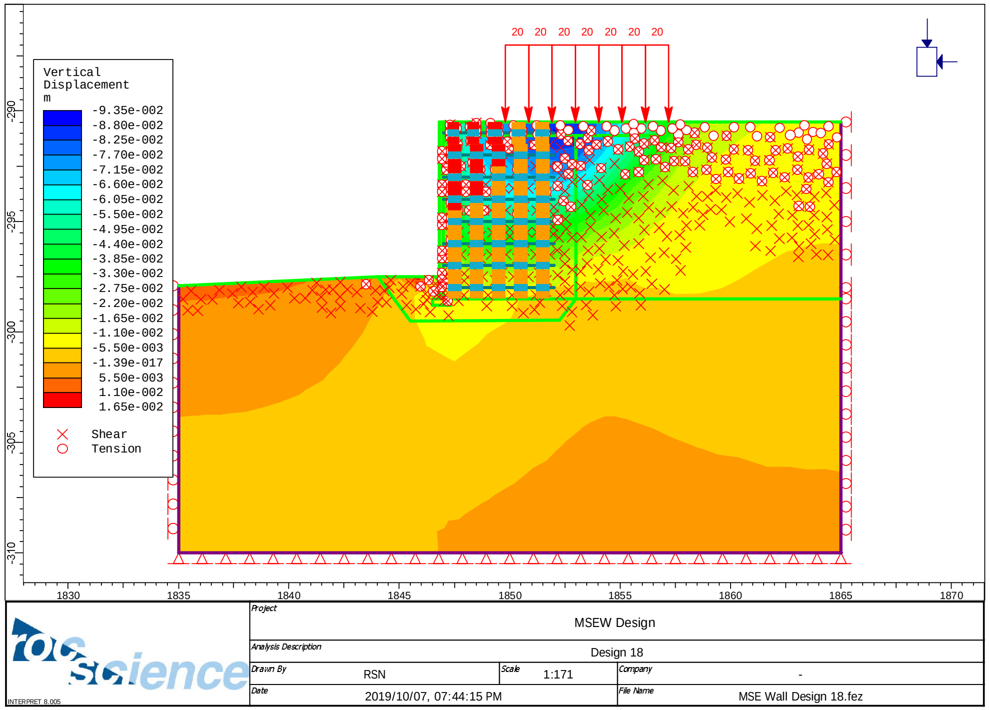
MSE Wall Design 18.fez
INTERPRET 8.005


Vertical
Displacement
m
-9.35e-002
-8.80e-002
-8.25e-002
-7.70e-002
-7.15e-002
-6.60e-002
-6.05e-002
-5.50e-002
-4.95e-002
-4.40e-002
-3.85e-002
-3.30e-002
-2.75e-002
-2.20e-002
-1.65e-002
-1.10e-002
-5.50e-003
-1.39e-017
5.50e-003
1.10e-002
1.65e-002
Shear
Tension
20 20 20 20 20 20 20
-290
-295
-300
-305
-310
1830 1835 1840 1845 1850 1855 1860 1865 1870
Project
MSEW Design
Analysis Description
Design 18
Drawn By
RSN
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1:171
Company
-
Date
2019/10/07, 07:44:15 PM
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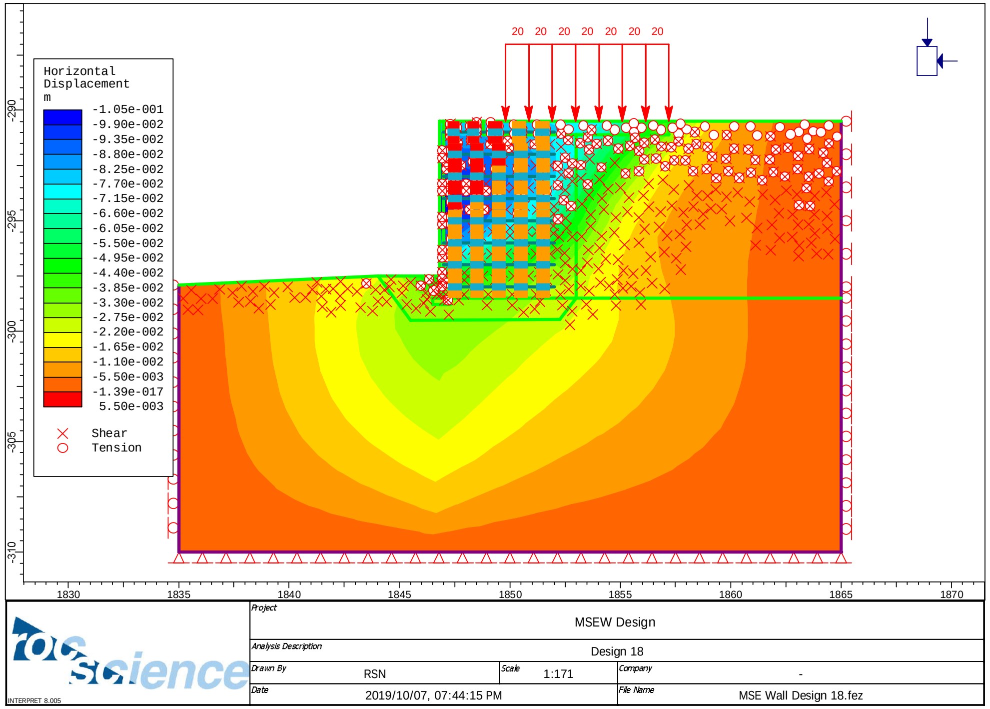
MSE Wall Design 18.fez
INTERPRET 8.005



Horizontal Displacement m
-1.05e-001
-9.90e-002
-9.35e-002
-8.80e-002
-8.25e-002
-7.70e-002
-7.15e-002
-6.60e-002
-6.05e-002
-5.50e-002
-4.95e-002
-4.40e-002
-3.85e-002
-3.30e-002
-2.75e-002
-2.20e-002
-1.65e-002
-1.10e-002
-5.50e-003
-1.39e-017
5.50e-003
Shear
Tension
20 20 20 20 20 20 20
-290
-295
-300
-305
-310
1830 1835 1840 1845 1850 1855 1860 1865 1870
Project
MSEW Design
Analysis Description
Design 18
Drawn By
RSN
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1:171
Company
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Date
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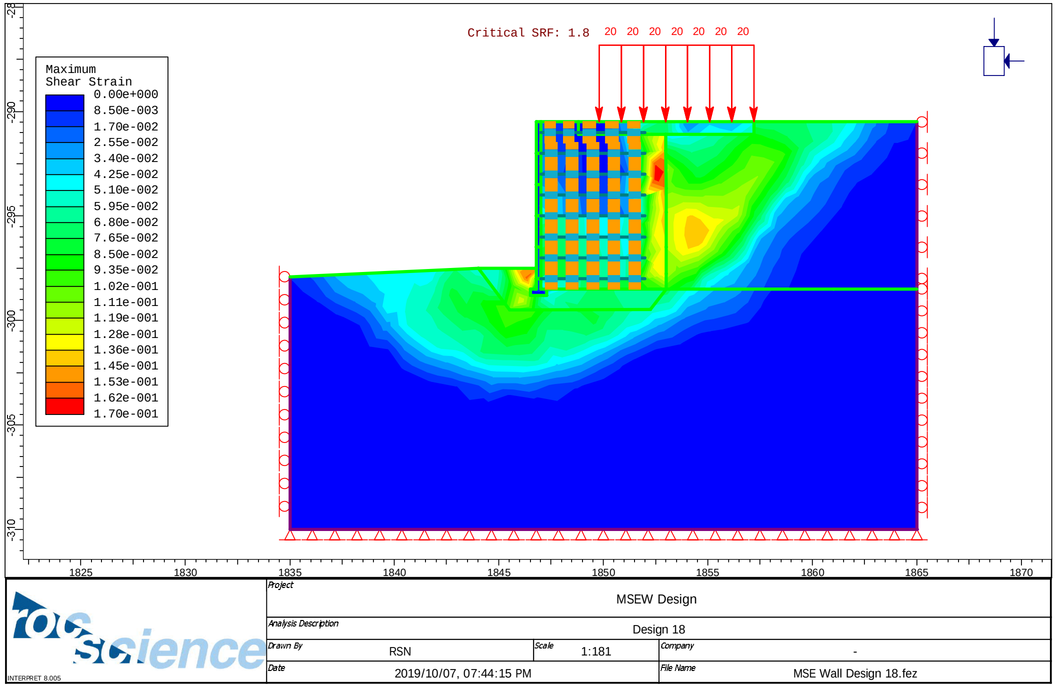
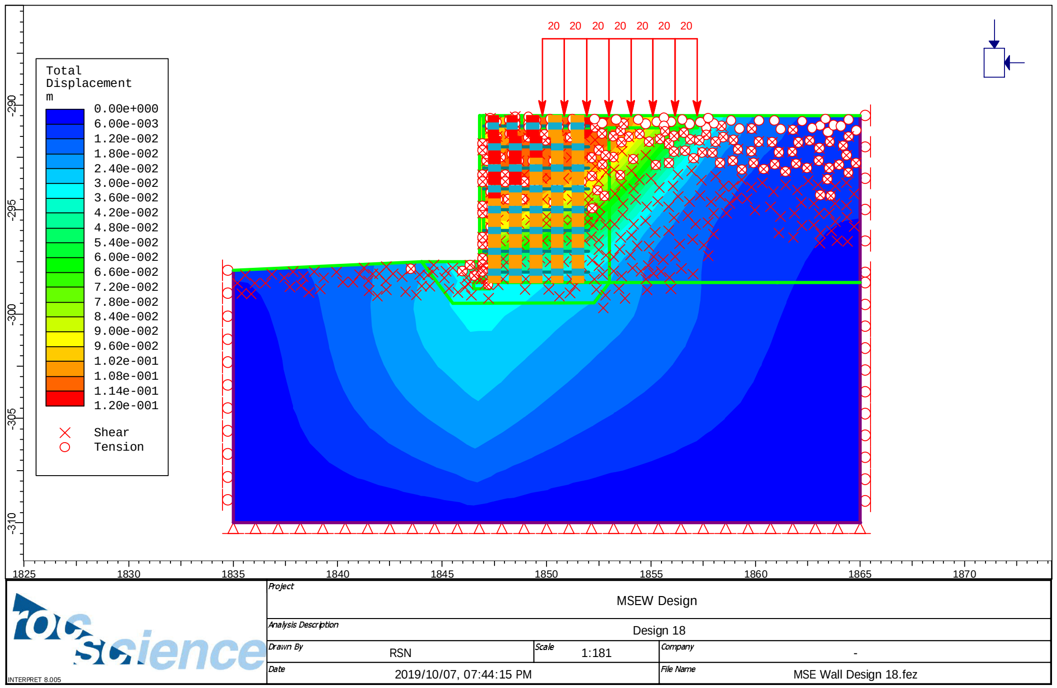
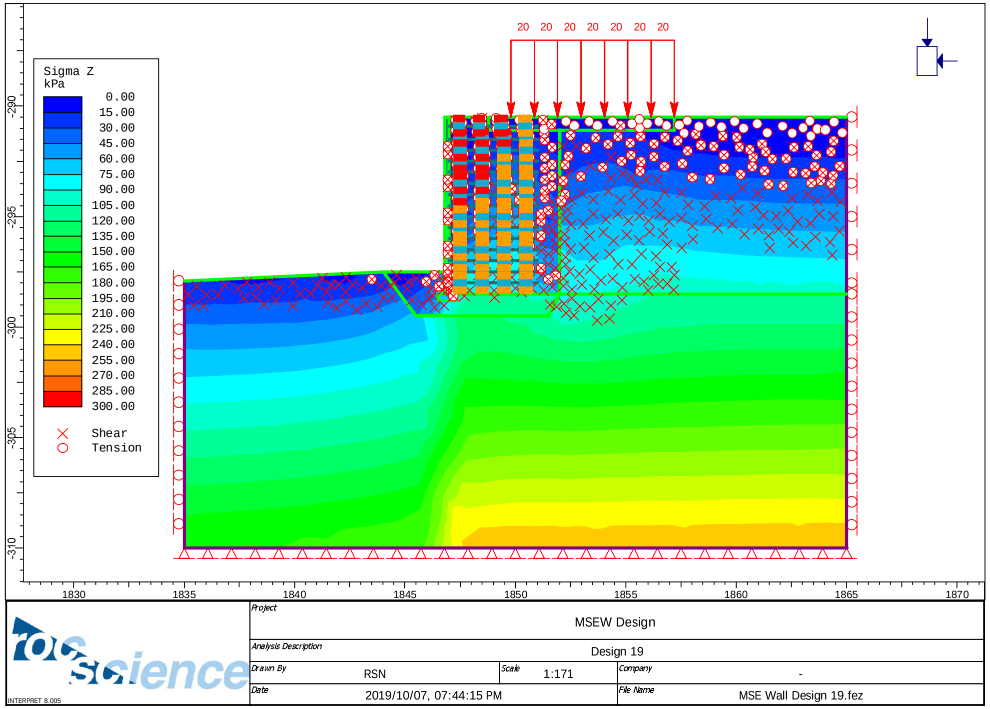
INTERPRET 8.005



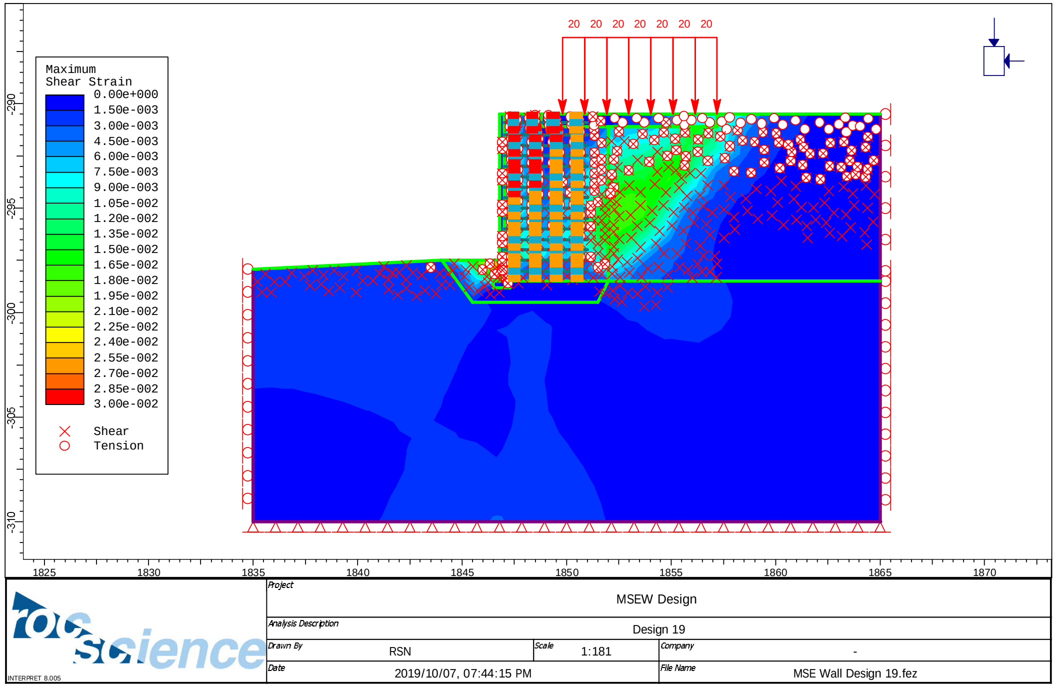
Maximum Shear Strain
0.00e+000
8.50e-003
1.70e-002
2.55e-002
3.40e-002
4.25e-002
5.10e-002
5.95e-002
6.80e-002
7.65e-002
8.50e-002
9.35e-002
1.02e-001
1.11e-001
1.19e-001
1.28e-001
1.36e-001
1.45e-001
1.53e-001
1.62e-001
1.70e-001
Critical SRF: 1.8
20 20 20 20 20 20 20
-290
-295
-300
-305
-310
1825 1830 1835 1840 1845 1850 1855 1860 1865 1870
Project
MSEW Design
Analysis Description
Design 18
Drawn By
RSN
Scale
1:181
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 18.fez
INTERPRET 8.005



Total Displacement m
0.00e+000
6.00e-003
1.20e-002
1.80e-002
2.40e-002
3.00e-002
3.60e-002
4.20e-002
4.80e-002
5.40e-002
6.00e-002
6.60e-002
7.20e-002
7.80e-002
8.40e-002
9.00e-002
9.60e-002
1.02e-001
1.08e-001
1.14e-001
1.20e-001
Shear
Tension
20 20 20 20 20 20 20
-290
-295
-300
-305
-310
1825 1830 1835 1840 1845 1850 1855 1860 1865 1870
Project
MSEW Design
Analysis Description
Design 18
Drawn By
RSN
Scale
1:181
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 18.fez
INTERPRET 8.005



Sigma Z
kPa
0.00
15.00
30.00
45.00
60.00
75.00
90.00
105.00
120.00
135.00
150.00
165.00
180.00
195.00
210.00
225.00
240.00
255.00
270.00
285.00
300.00
Shear
Tension
20 20 20 20 20 20 20
Project
MSEW Design
Analysis Description
Design 19
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 19.fez
INTERPRET 8.005



Maximum
Shear Strain
0.00e+000
1.50e-003
3.00e-003
4.50e-003
6.00e-003
7.50e-003
9.00e-003
1.05e-002
1.20e-002
1.35e-002
1.50e-002
1.65e-002
1.80e-002
1.95e-002
2.10e-002
2.25e-002
2.40e-002
2.55e-002
2.70e-002
2.85e-002
3.00e-002
Shear
Tension
20 20 20 20 20 20 20
Project
MSEW Design
Analysis Description
Design 19
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Scale
1:181
Company
-
Date
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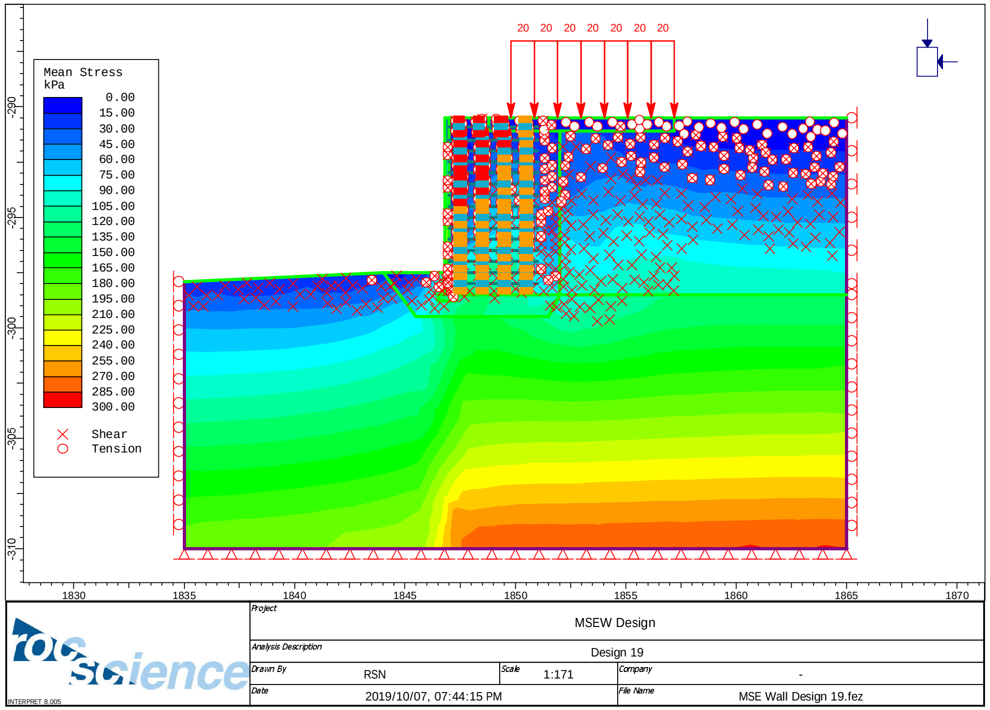
MSE Wall Design 19.fez
INTERPRET 8.005



Mean Stress
kPa
0.00
15.00
30.00
45.00
60.00
75.00
90.00
105.00
120.00
135.00
150.00
165.00
180.00
195.00
210.00
225.00
240.00
255.00
270.00
285.00
300.00
Shear
Tension
20 20 20 20 20 20 20
Project
MSEW Design
Analysis Description
Design 19
Drawn By
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1:171
Company
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Date
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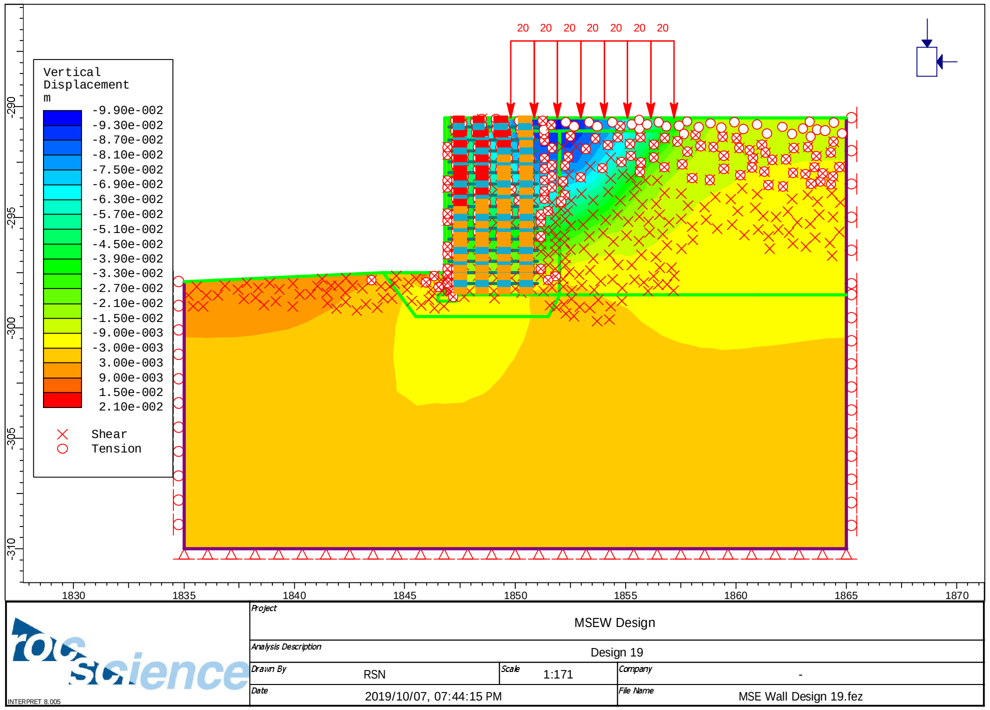
INTERPRET 8.005



Vertical
Displacement
m
-9.90e-002
-9.30e-002
-8.70e-002
-8.10e-002
-7.50e-002
-6.90e-002
-6.30e-002
-5.70e-002
-5.10e-002
-4.50e-002
-3.90e-002
-3.30e-002
-2.70e-002
-2.10e-002
-1.50e-002
-9.00e-003
-3.00e-003
3.00e-003
9.00e-003
1.50e-002
2.10e-002
Shear
Tension
20 20 20 20 20 20 20
Project
MSEW Design
Analysis Description
Design 19
Drawn By
RSN
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1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
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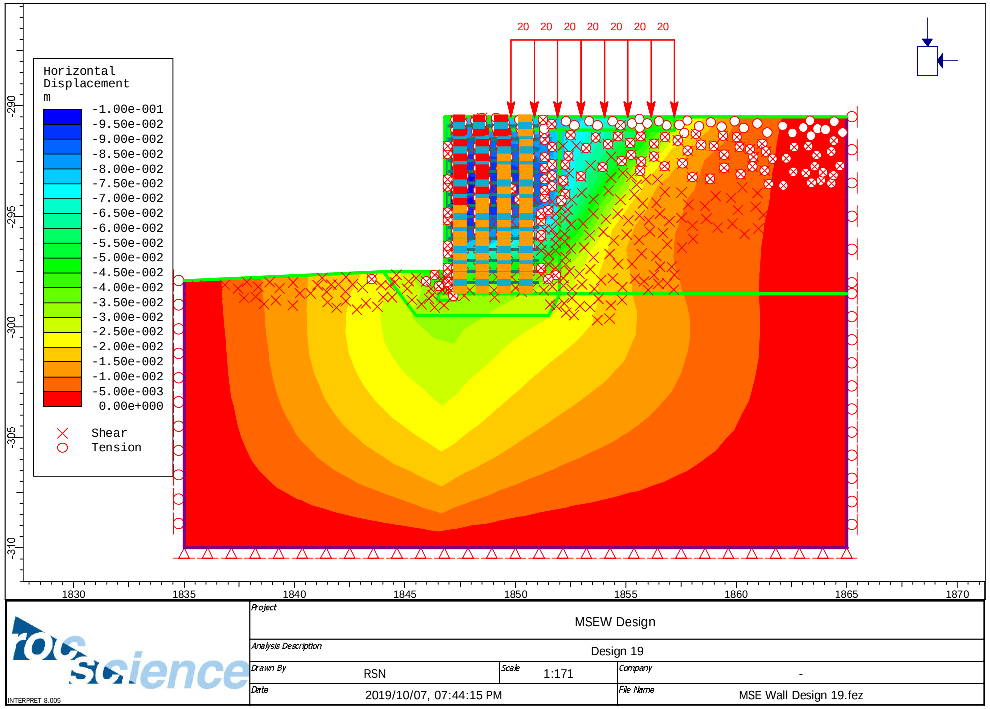
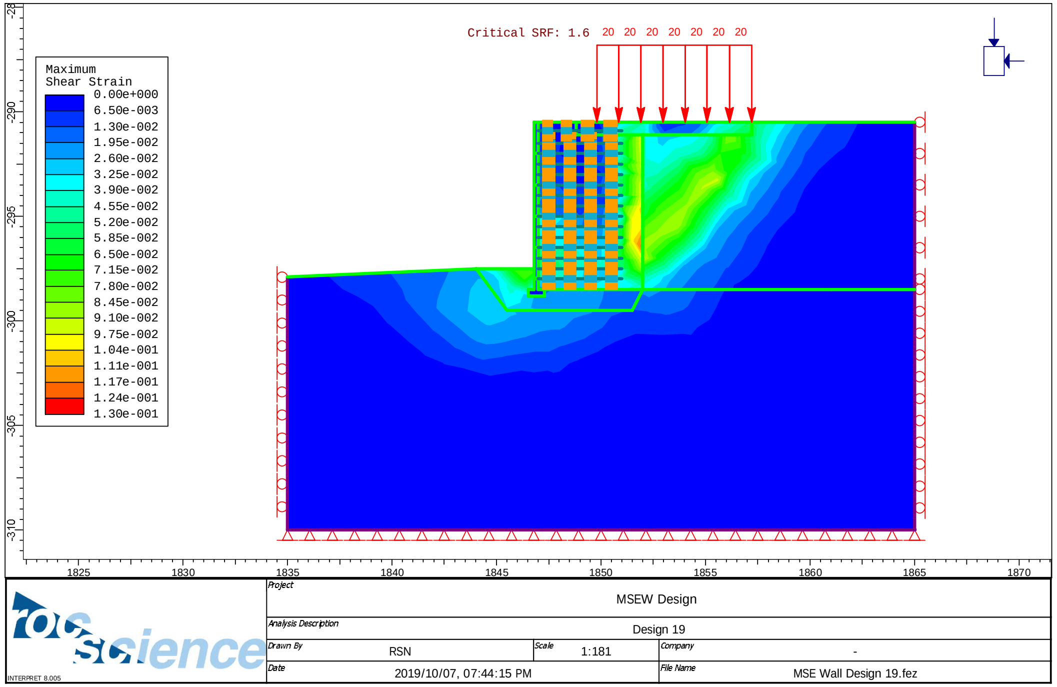
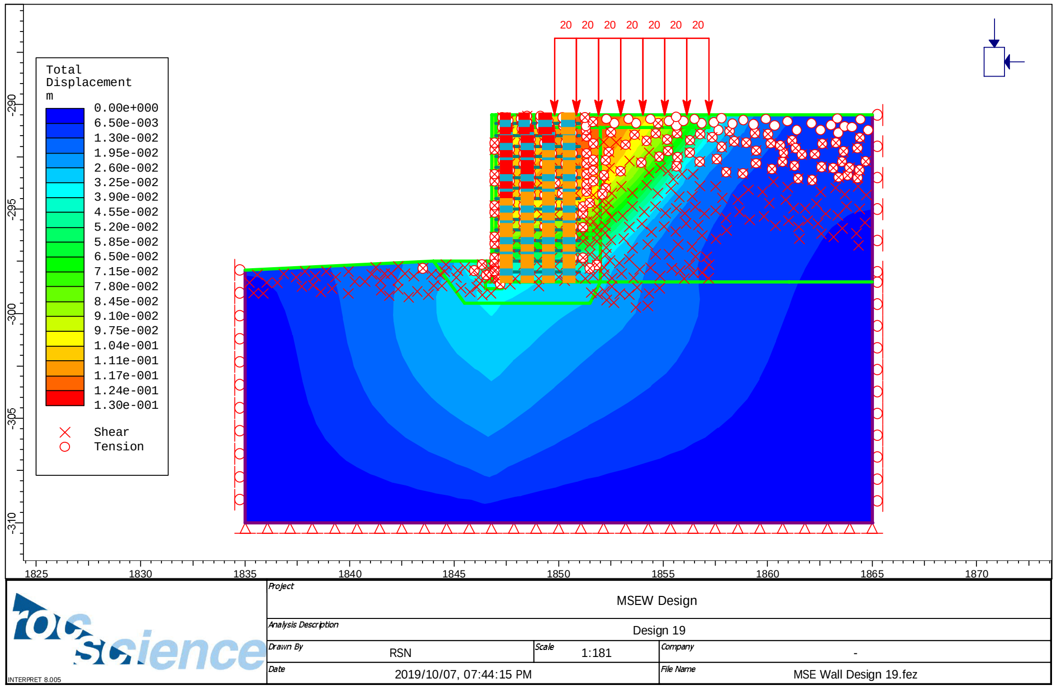
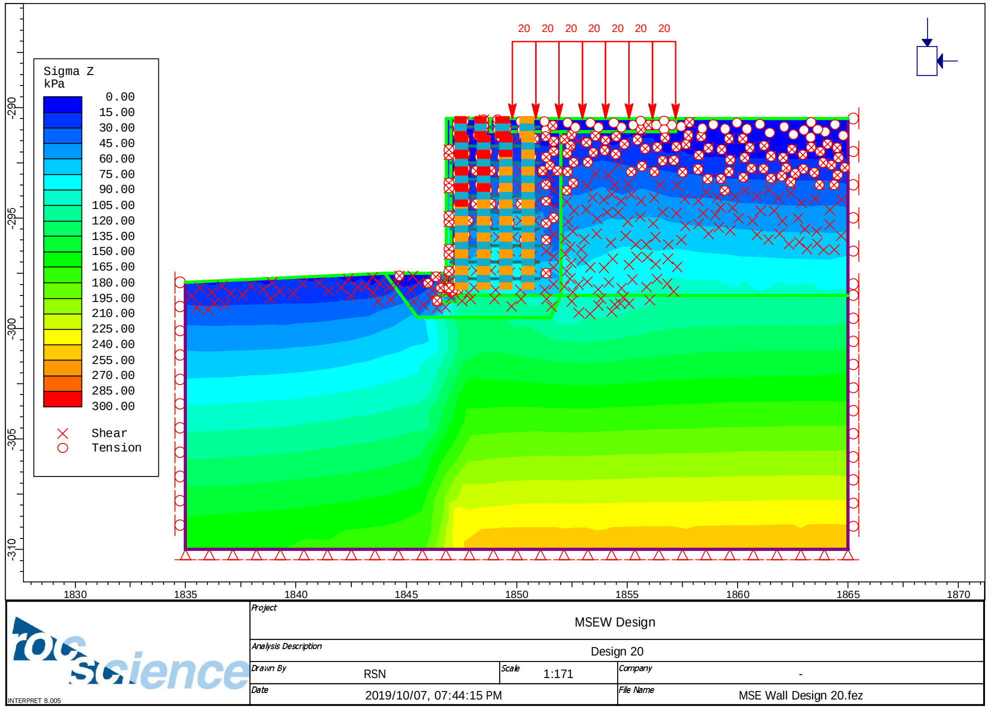
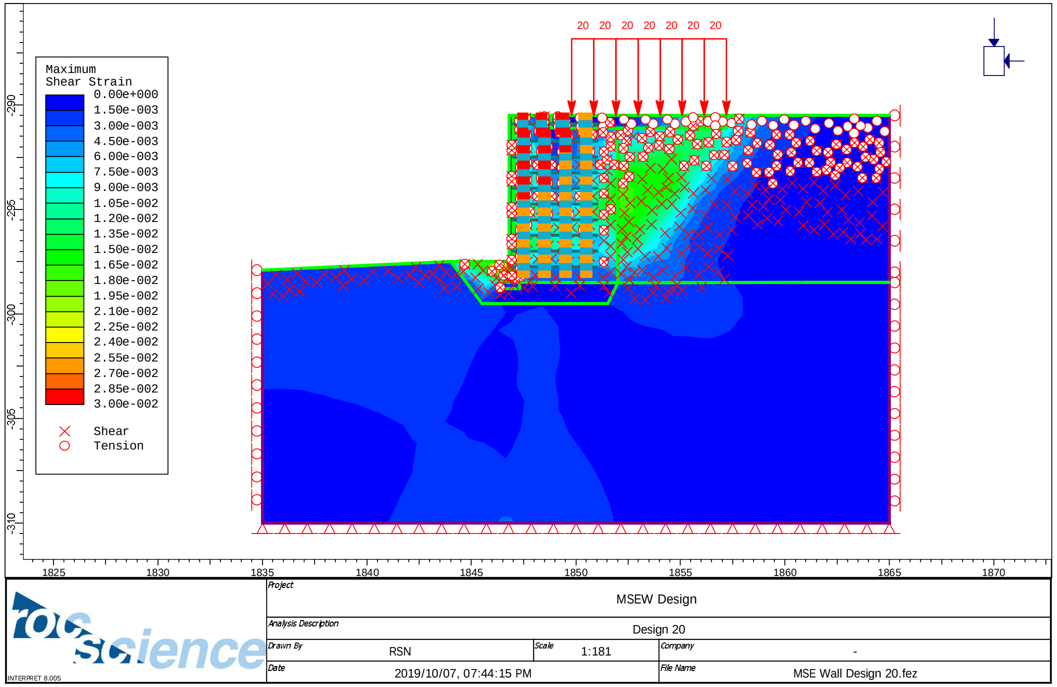
INTERPRET 8.005

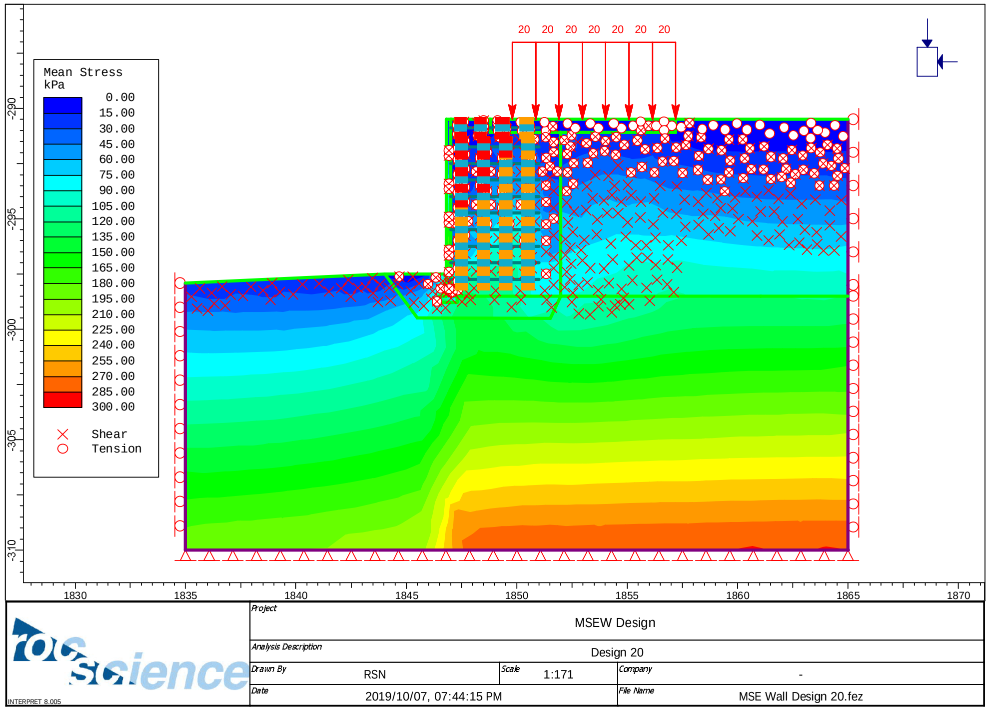

20 20 20 20 20 20 20
Horizontal Displacement m
-1.00e-001
-9.50e-002
-9.00e-002
-8.50e-002
-8.00e-002
-7.50e-002
-7.00e-002
-6.50e-002
-6.00e-002
-5.50e-002
-5.00e-002
-4.50e-002
-4.00e-002
-3.50e-002
-3.00e-002
-2.50e-002
-2.00e-002
-1.50e-002
-1.00e-002
-5.00e-003
0.00e+000
Shear
Tension
-290
-295
-300
-305
-310
1830
1835
1840
1845
1850
1855
1860
1865
1870
Project
MSEW Design
Analysis Description
Design 19
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 19.fez
INTERPRET 8.005

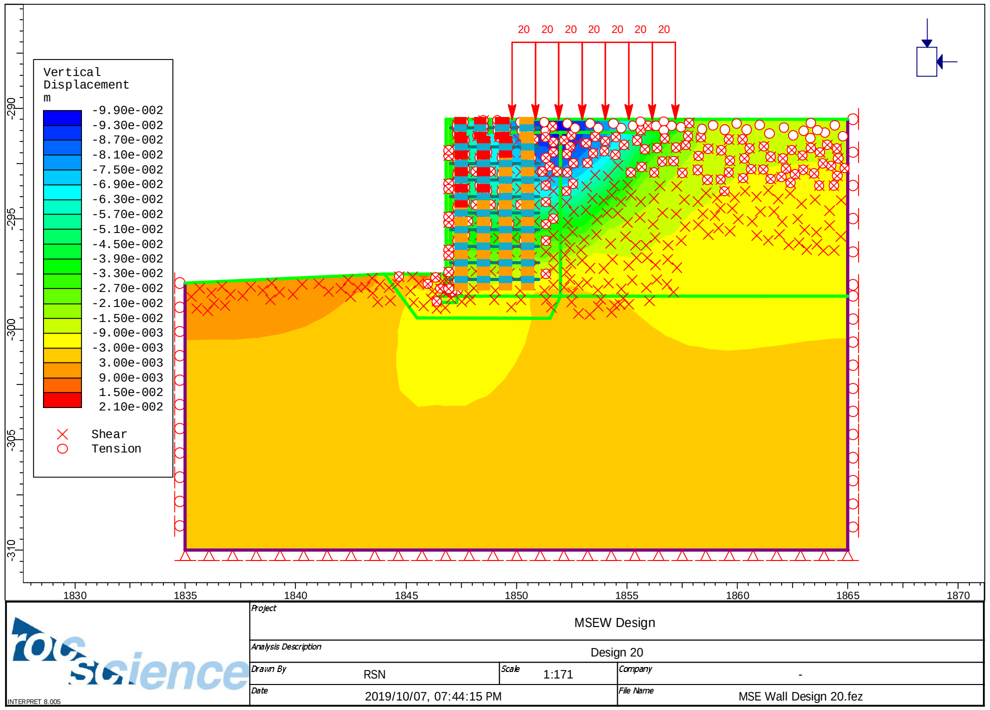

Critical SRF: 1.6 20 20 20 20 20 20 20
Maximum Shear Strain
0.00e+000
6.50e-003
1.30e-002
1.95e-002
2.60e-002
3.25e-002
3.90e-002
4.55e-002
5.20e-002
5.85e-002
6.50e-002
7.15e-002
7.80e-002
8.45e-002
9.10e-002
9.75e-002
1.04e-001
1.11e-001
1.17e-001
1.24e-001
1.30e-001
-290
-295
-300
-305
-310
1825
1830
1835
1840
1845
1850
1855
1860
1865
1870
Project
MSEW Design
Analysis Description
Design 19
Drawn By
RSN
Scale
1:181
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 19.fez
INTERPRET 8.005

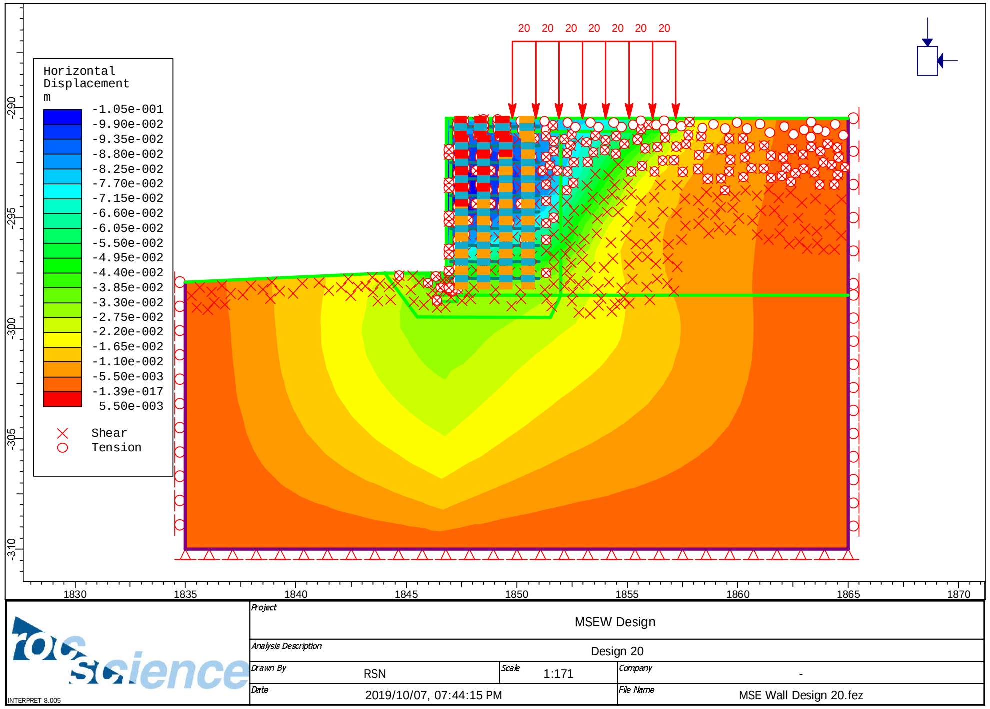

20 20 20 20 20 20 20
Total Displacement m
0.00e+000
6.50e-003
1.30e-002
1.95e-002
2.60e-002
3.25e-002
3.90e-002
4.55e-002
5.20e-002
5.85e-002
6.50e-002
7.15e-002
7.80e-002
8.45e-002
9.10e-002
9.75e-002
1.04e-001
1.11e-001
1.17e-001
1.24e-001
1.30e-001
Shear
Tension
-290
-295
-300
-305
-310
1825
1830
1835
1840
1845
1850
1855
1860
1865
1870
Project
MSEW Design
Analysis Description
Design 19
Drawn By
RSN
Scale
1:181
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 19.fez
INTERPRET 8.005

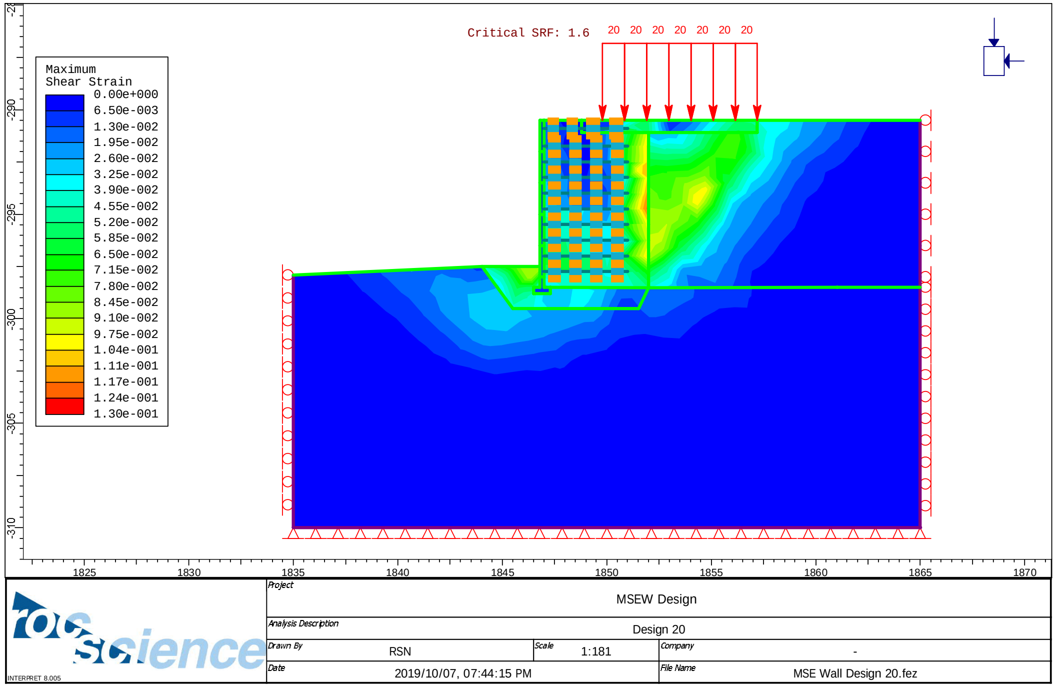

Sigma Z
kPa
0.00
15.00
30.00
45.00
60.00
75.00
90.00
105.00
120.00
135.00
150.00
165.00
180.00
195.00
210.00
225.00
240.00
255.00
270.00
285.00
300.00
Shear
Tension
20 20 20 20 20 20 20
1830 1835 1840 1845 1850 1855 1860 1865 1870
-290 -295 -300 -305 -310
Project
MSEW Design
Analysis Description
Design 20
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 20.fez
INTERPRET 8.005

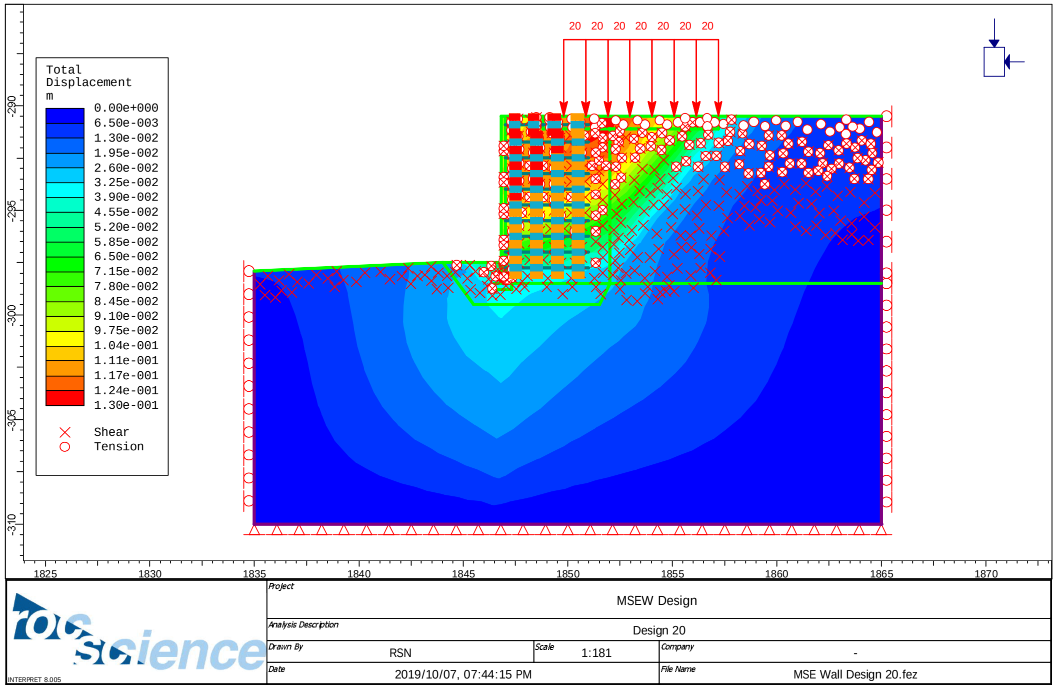

Maximum
Shear Strain
0.00e+000
1.50e-003
3.00e-003
4.50e-003
6.00e-003
7.50e-003
9.00e-003
1.05e-002
1.20e-002
1.35e-002
1.50e-002
1.65e-002
1.80e-002
1.95e-002
2.10e-002
2.25e-002
2.40e-002
2.55e-002
2.70e-002
2.85e-002
3.00e-002
Shear
Tension
20 20 20 20 20 20 20
1825 1830 1835 1840 1845 1850 1855 1860 1865 1870
-290 -295 -300 -305 -310
Project
MSEW Design
Analysis Description
Design 20
Drawn By
RSN
Scale
1:181
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 20.fez
INTERPRET 8.005

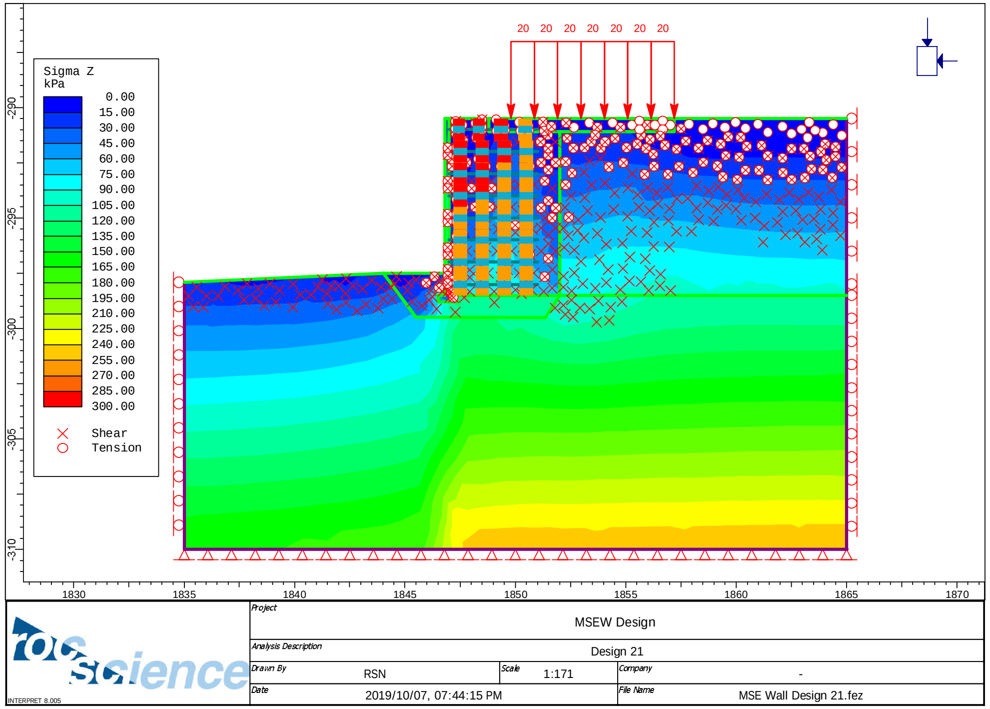

Mean Stress
kPa
0.00
15.00
30.00
45.00
60.00
75.00
90.00
105.00
120.00
135.00
150.00
165.00
180.00
195.00
210.00
225.00
240.00
255.00
270.00
285.00
300.00
Shear
Tension
20 20 20 20 20 20 20
1830 1835 1840 1845 1850 1855 1860 1865 1870
-290 -295 -300 -305 -310
Project
MSEW Design
Analysis Description
Design 20
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 20.fez
INTERPRET 8.005


Vertical
Displacement
m
-9.90e-002
-9.30e-002
-8.70e-002
-8.10e-002
-7.50e-002
-6.90e-002
-6.30e-002
-5.70e-002
-5.10e-002
-4.50e-002
-3.90e-002
-3.30e-002
-2.70e-002
-2.10e-002
-1.50e-002
-9.00e-003
-3.00e-003
3.00e-003
9.00e-003
1.50e-002
2.10e-002
Shear
Tension
20 20 20 20 20 20 20
1830 1835 1840 1845 1850 1855 1860 1865 1870
-290 -295 -300 -305 -310
Project
MSEW Design
Analysis Description
Design 20
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 20.fez
INTERPRET 8.005

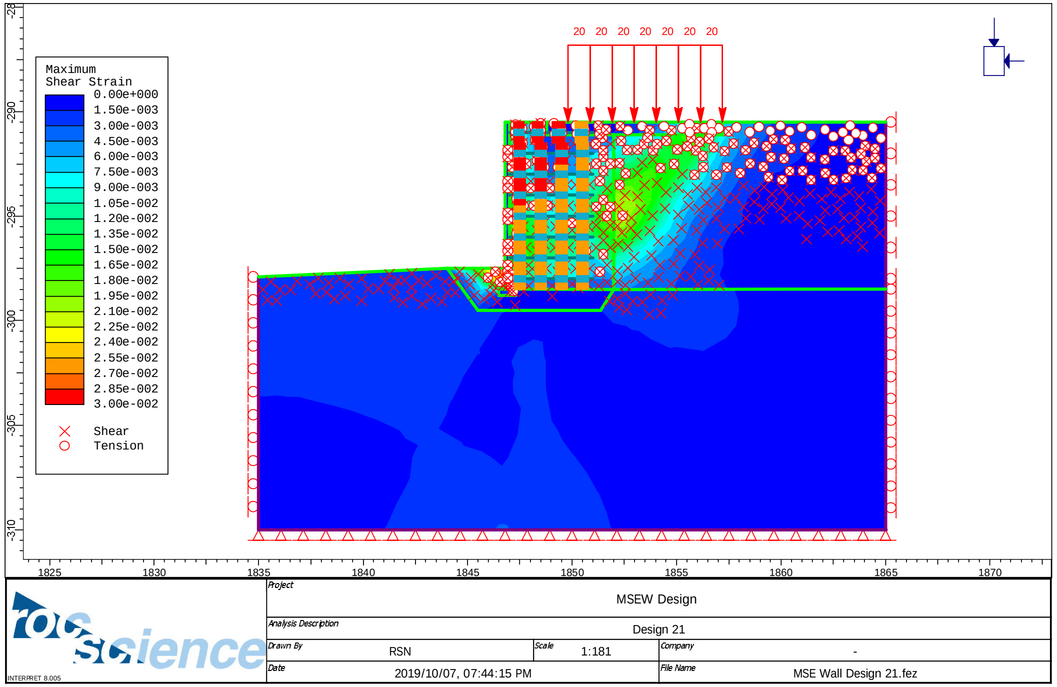

Horizontal Displacement m
-1.05e-001
-9.90e-002
-9.35e-002
-8.80e-002
-8.25e-002
-7.70e-002
-7.15e-002
-6.60e-002
-6.05e-002
-5.50e-002
-4.95e-002
-4.40e-002
-3.85e-002
-3.30e-002
-2.75e-002
-2.20e-002
-1.65e-002
-1.10e-002
-5.50e-003
-1.39e-017
5.50e-003
Shear
Tension
20 20 20 20 20 20 20
Project MSEW Design
Analysis Description Design 20
Drawn By RSN
Scale 1:171
Company -
Date 2019/10/07, 07:44:15 PM
File Name MSE Wall Design 20.fez
INTERPRET 8.005


Maximum Shear Strain
0.00e+000
6.50e-003
1.30e-002
1.95e-002
2.60e-002
3.25e-002
3.90e-002
4.55e-002
5.20e-002
5.85e-002
6.50e-002
7.15e-002
7.80e-002
8.45e-002
9.10e-002
9.75e-002
1.04e-001
1.11e-001
1.17e-001
1.24e-001
1.30e-001
Critical SRF: 1.6
20 20 20 20 20 20 20
Project MSEW Design
Analysis Description Design 20
Drawn By RSN
Scale 1:181
Company -
Date 2019/10/07, 07:44:15 PM
File Name MSE Wall Design 20.fez
INTERPRET 8.005

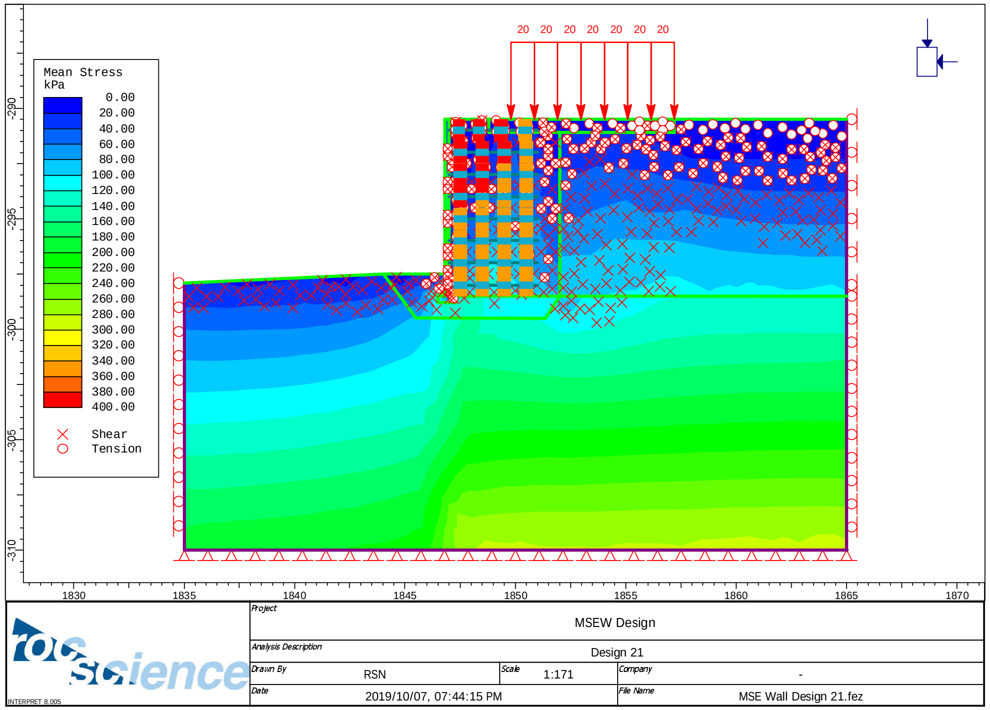

Total Displacement m
0.00e+000
6.50e-003
1.30e-002
1.95e-002
2.60e-002
3.25e-002
3.90e-002
4.55e-002
5.20e-002
5.85e-002
6.50e-002
7.15e-002
7.80e-002
8.45e-002
9.10e-002
9.75e-002
1.04e-001
1.11e-001
1.17e-001
1.24e-001
1.30e-001
Shear
Tension
20 20 20 20 20 20 20
Project MSEW Design
Analysis Description Design 20
Drawn By RSN
Scale 1:181
Company -
Date 2019/10/07, 07:44:15 PM
File Name MSE Wall Design 20.fez
INTERPRET 8.005



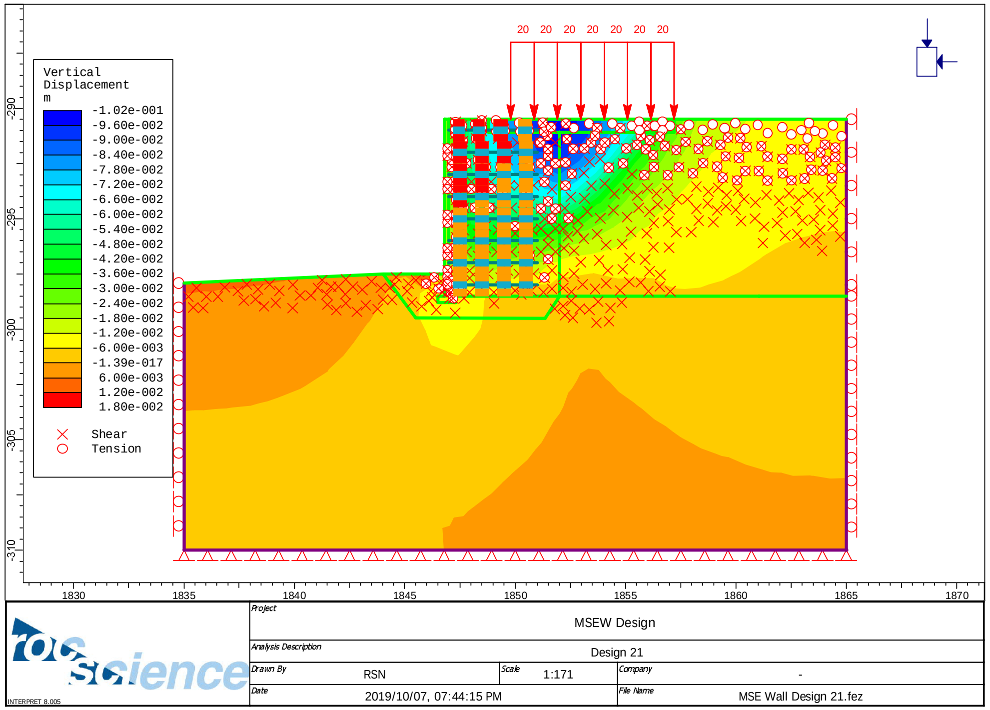
20 20 20 20 20 20 20
Sigma Z
kPa
0.00
15.00
30.00
45.00
60.00
75.00
90.00
105.00
120.00
135.00
150.00
165.00
180.00
195.00
210.00
225.00
240.00
255.00
270.00
285.00
300.00
Shear
Tension
-290
-295
-300
-305
-310
1830 1835 1840 1845 1850 1855 1860 1865 1870
Project
MSEW Design
Analysis Description
Design 21
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 21.fez
INTERPRET 8.005



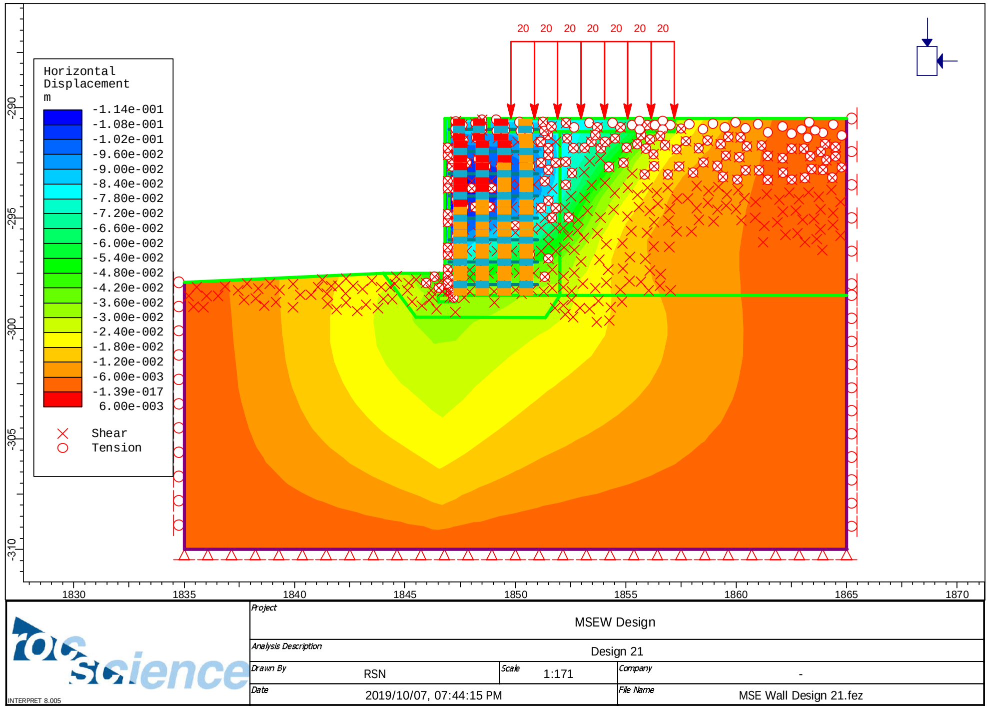
20 20 20 20 20 20 20
Maximum
Shear Strain
0.00e+000
1.50e-003
3.00e-003
4.50e-003
6.00e-003
7.50e-003
9.00e-003
1.05e-002
1.20e-002
1.35e-002
1.50e-002
1.65e-002
1.80e-002
1.95e-002
2.10e-002
2.25e-002
2.40e-002
2.55e-002
2.70e-002
2.85e-002
3.00e-002
Shear
Tension
-285
-290
-295
-300
-305
-310
1825 1830 1835 1840 1845 1850 1855 1860 1865 1870
Project
MSEW Design
Analysis Description
Design 21
Drawn By
RSN
Scale
1:181
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 21.fez
INTERPRET 8.005

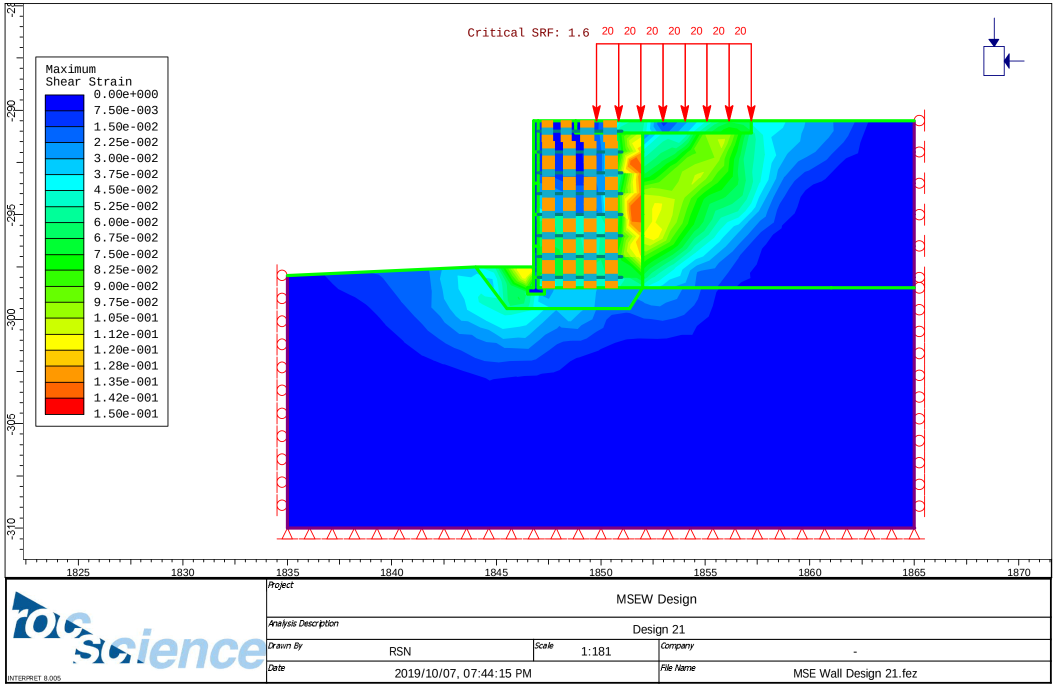


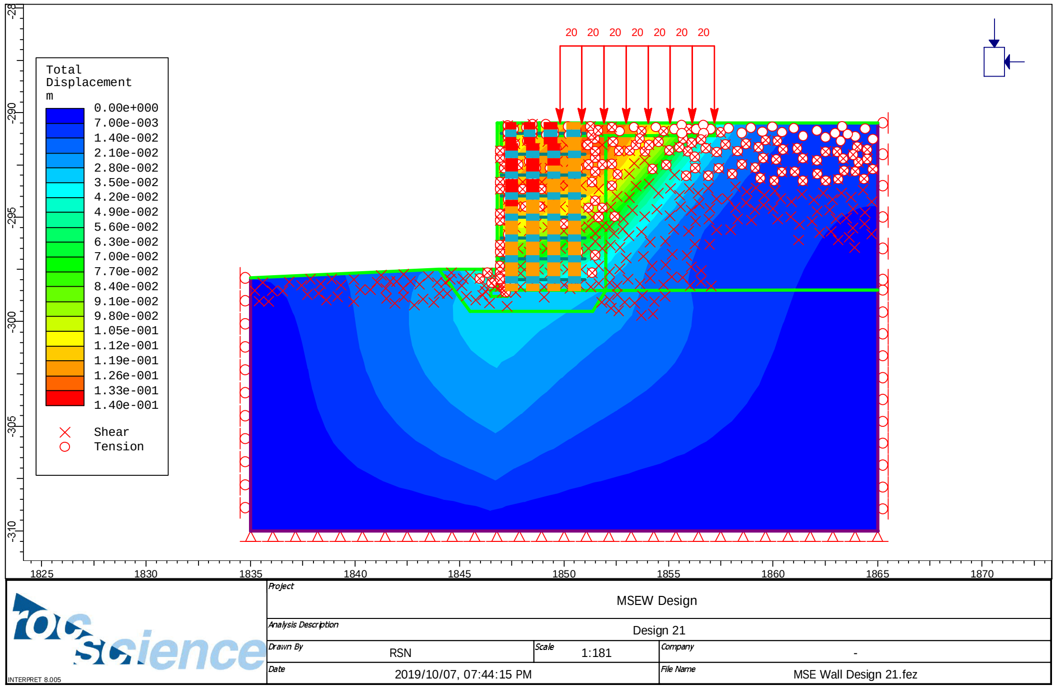
20 20 20 20 20 20 20
Mean Stress
kPa
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
160.00
180.00
200.00
220.00
240.00
260.00
280.00
300.00
320.00
340.00
360.00
380.00
400.00
Shear
Tension
-290
-295
-300
-305
-310
1830 1835 1840 1845 1850 1855 1860 1865 1870
Project
MSEW Design
Analysis Description
Design 21
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 21.fez
INTERPRET 8.005

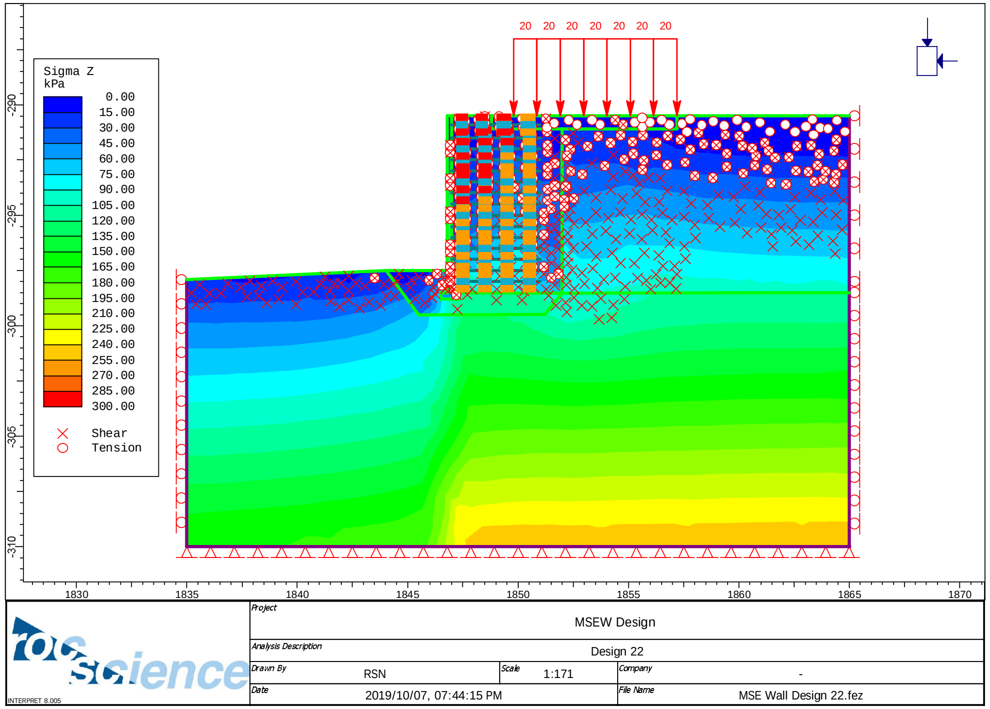


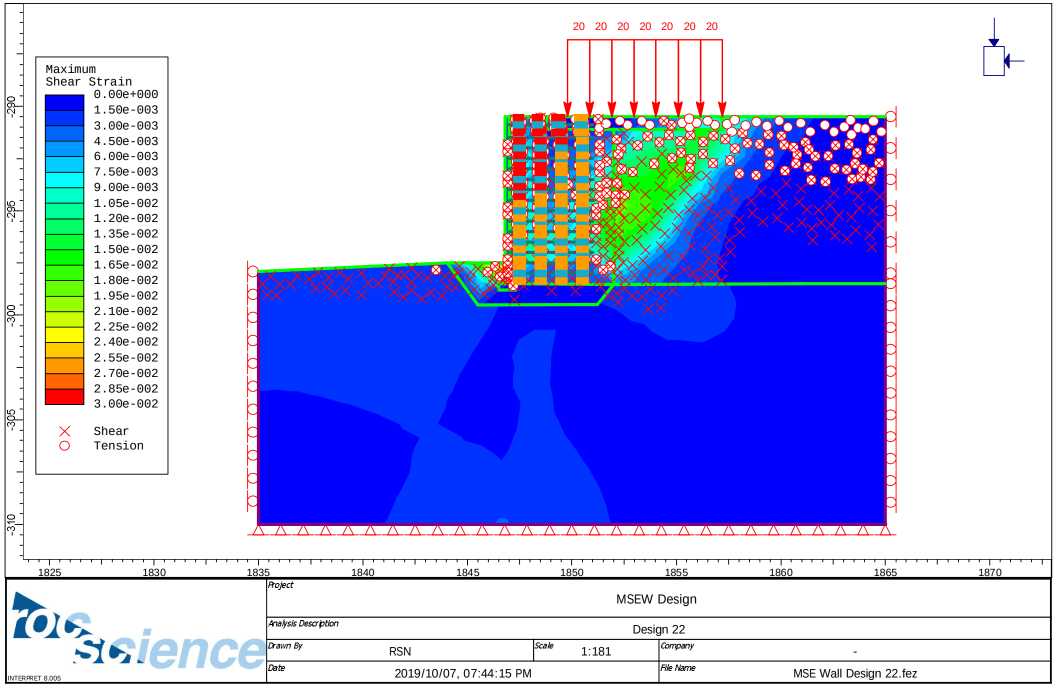
20 20 20 20 20 20 20
Vertical
Displacement
m
-1.02e-001
-9.60e-002
-9.00e-002
-8.40e-002
-7.80e-002
-7.20e-002
-6.60e-002
-6.00e-002
-5.40e-002
-4.80e-002
-4.20e-002
-3.60e-002
-3.00e-002
-2.40e-002
-1.80e-002
-1.20e-002
-6.00e-003
-1.39e-017
6.00e-003
1.20e-002
1.80e-002
Shear
Tension
-290
-295
-300
-305
-310
1830 1835 1840 1845 1850 1855 1860 1865 1870
Project
MSEW Design
Analysis Description
Design 21
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 21.fez
INTERPRET 8.005

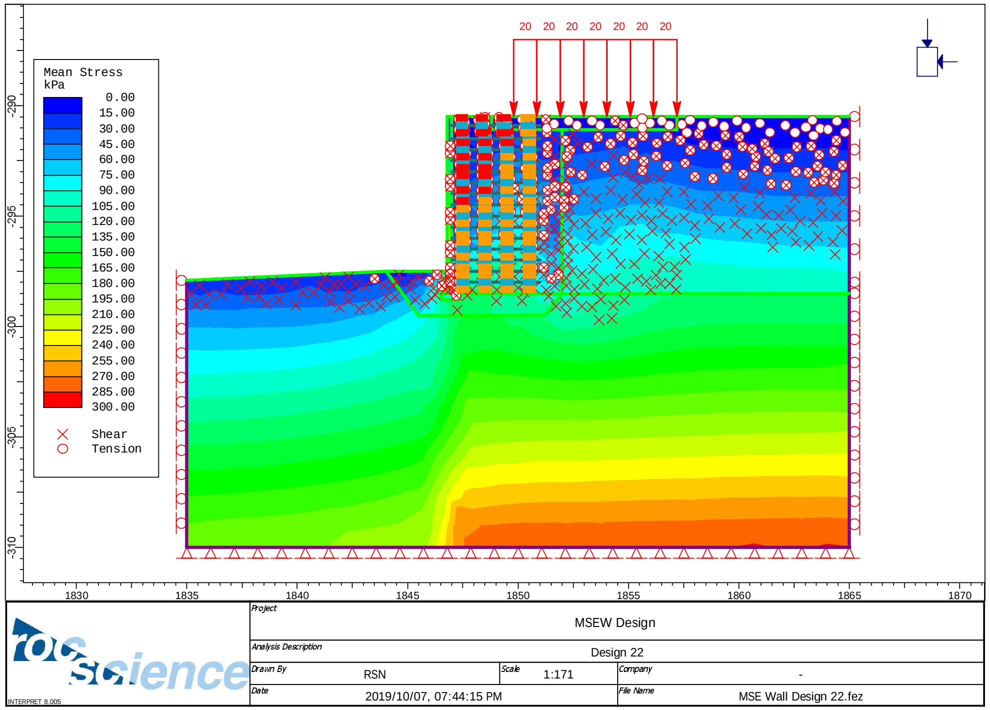

Horizontal Displacement m
-1.14e-001
-1.08e-001
-1.02e-001
-9.60e-002
-9.00e-002
-8.40e-002
-7.80e-002
-7.20e-002
-6.60e-002
-6.00e-002
-5.40e-002
-4.80e-002
-4.20e-002
-3.60e-002
-3.00e-002
-2.40e-002
-1.80e-002
-1.20e-002
-6.00e-003
-1.39e-017
6.00e-003
Shear
Tension
20 20 20 20 20 20 20
1830 1835 1840 1845 1850 1855 1860 1865 1870
-290 -295 -300 -305 -310
Project
MSEW Design
Analysis Description
Design 21
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 21.fez
INTERPRET 8.005

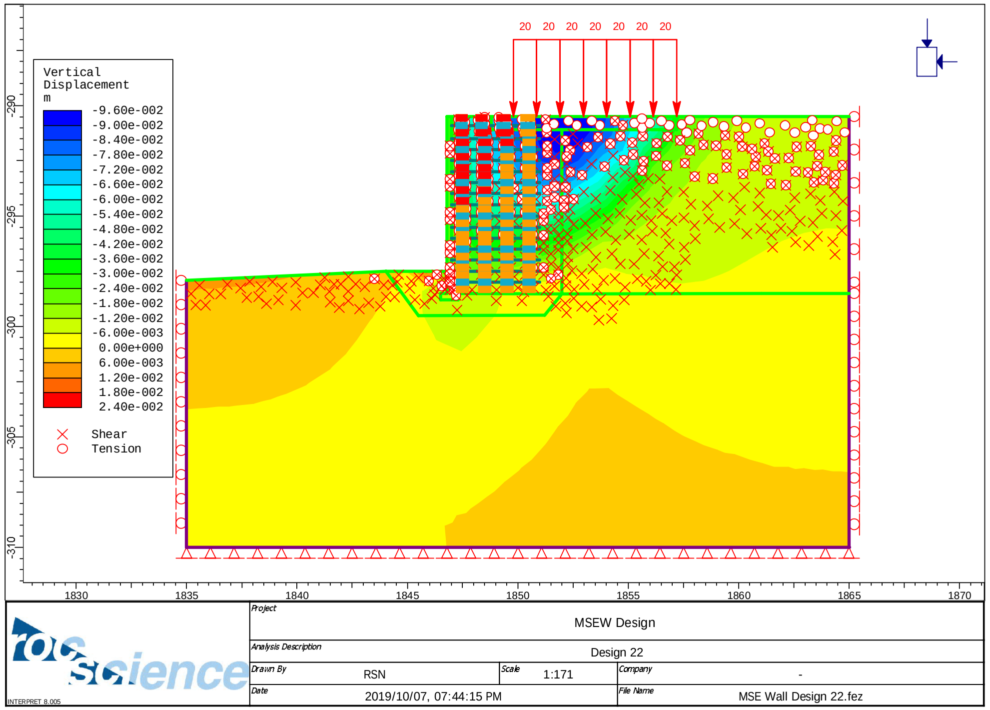

Critical SRF: 1.6
Maximum Shear Strain
0.00e+000
7.50e-003
1.50e-002
2.25e-002
3.00e-002
3.75e-002
4.50e-002
5.25e-002
6.00e-002
6.75e-002
7.50e-002
8.25e-002
9.00e-002
9.75e-002
1.05e-001
1.12e-001
1.20e-001
1.28e-001
1.35e-001
1.42e-001
1.50e-001
20 20 20 20 20 20 20
1825 1830 1835 1840 1845 1850 1855 1860 1865 1870
-290 -295 -300 -305 -310
Project
MSEW Design
Analysis Description
Design 21
Drawn By
RSN
Scale
1:181
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 21.fez
INTERPRET 8.005

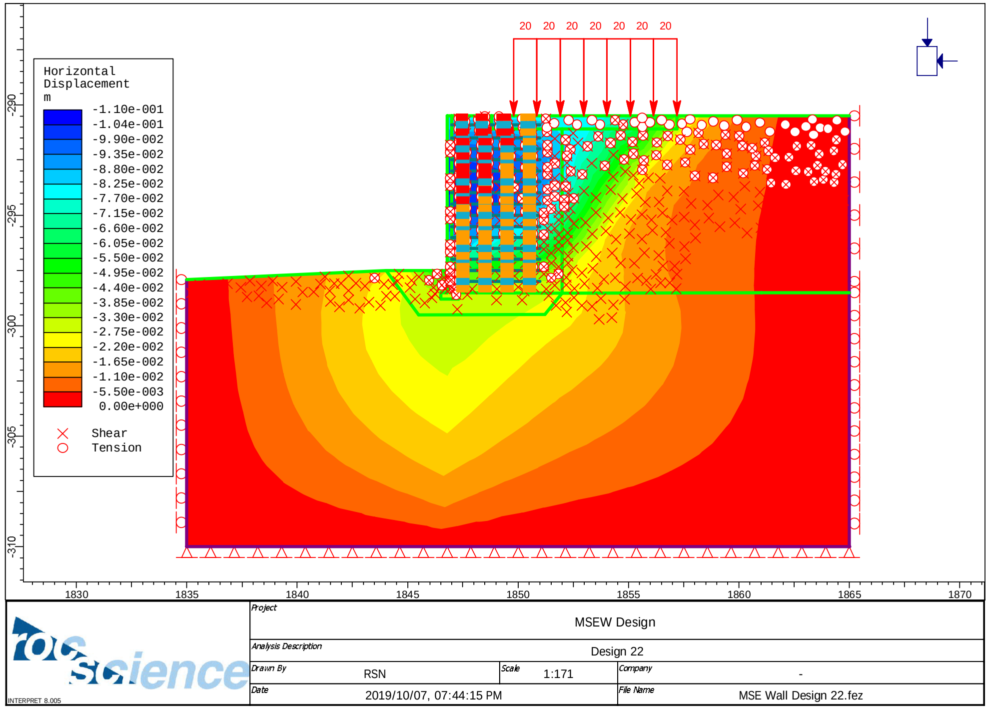

Total Displacement m
0.00e+000
7.00e-003
1.40e-002
2.10e-002
2.80e-002
3.50e-002
4.20e-002
4.90e-002
5.60e-002
6.30e-002
7.00e-002
7.70e-002
8.40e-002
9.10e-002
9.80e-002
1.05e-001
1.12e-001
1.19e-001
1.26e-001
1.33e-001
1.40e-001
Shear
Tension
20 20 20 20 20 20 20
1825 1830 1835 1840 1845 1850 1855 1860 1865 1870
-290 -295 -300 -305 -310
Project
MSEW Design
Analysis Description
Design 21
Drawn By
RSN
Scale
1:181
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 21.fez
INTERPRET 8.005


Sigma Z
kPa
0.00
15.00
30.00
45.00
60.00
75.00
90.00
105.00
120.00
135.00
150.00
165.00
180.00
195.00
210.00
225.00
240.00
255.00
270.00
285.00
300.00
Shear
Tension
20 20 20 20 20 20 20
Project
MSEW Design
Analysis Description
Design 22
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 22.fez
INTERPRET 8.005

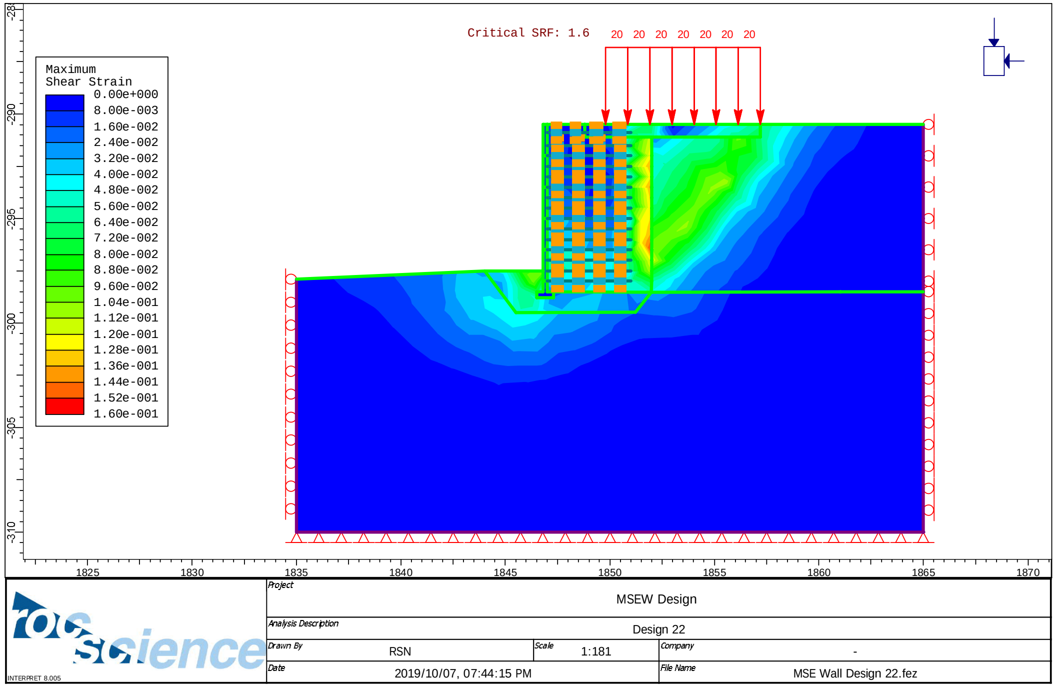

Maximum
Shear Strain
0.00e+000
1.50e-003
3.00e-003
4.50e-003
6.00e-003
7.50e-003
9.00e-003
1.05e-002
1.20e-002
1.35e-002
1.50e-002
1.65e-002
1.80e-002
1.95e-002
2.10e-002
2.25e-002
2.40e-002
2.55e-002
2.70e-002
2.85e-002
3.00e-002
Shear
Tension
20 20 20 20 20 20 20
Project
MSEW Design
Analysis Description
Design 22
Drawn By
RSN
Scale
1:181
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 22.fez
INTERPRET 8.005


Mean Stress
kPa
0.00
15.00
30.00
45.00
60.00
75.00
90.00
105.00
120.00
135.00
150.00
165.00
180.00
195.00
210.00
225.00
240.00
255.00
270.00
285.00
300.00
Shear
Tension
20 20 20 20 20 20 20
Project
MSEW Design
Analysis Description
Design 22
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 22.fez
INTERPRET 8.005


Vertical
Displacement
m
-9.60e-002
-9.00e-002
-8.40e-002
-7.80e-002
-7.20e-002
-6.60e-002
-6.00e-002
-5.40e-002
-4.80e-002
-4.20e-002
-3.60e-002
-3.00e-002
-2.40e-002
-1.80e-002
-1.20e-002
-6.00e-003
0.00e+000
6.00e-003
1.20e-002
1.80e-002
2.40e-002
Shear
Tension
20 20 20 20 20 20 20
Project
MSEW Design
Analysis Description
Design 22
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 22.fez
INTERPRET 8.005



Horizontal Displacement m
-1.10e-001
-1.04e-001
-9.90e-002
-9.35e-002
-8.80e-002
-8.25e-002
-7.70e-002
-7.15e-002
-6.60e-002
-6.05e-002
-5.50e-002
-4.95e-002
-4.40e-002
-3.85e-002
-3.30e-002
-2.75e-002
-2.20e-002
-1.65e-002
-1.10e-002
-5.50e-003
0.00e+000
Shear
Tension
20 20 20 20 20 20 20
Project MSEW Design
Analysis Description Design 22
Drawn By RSN
Scale 1:171
Company -
Date 2019/10/07, 07:44:15 PM
File Name MSE Wall Design 22.fez



Critical SRF: 1.6
Maximum Shear Strain
0.00e+000
8.00e-003
1.60e-002
2.40e-002
3.20e-002
4.00e-002
4.80e-002
5.60e-002
6.40e-002
7.20e-002
8.00e-002
8.80e-002
9.60e-002
1.04e-001
1.12e-001
1.20e-001
1.28e-001
1.36e-001
1.44e-001
1.52e-001
1.60e-001
20 20 20 20 20 20 20
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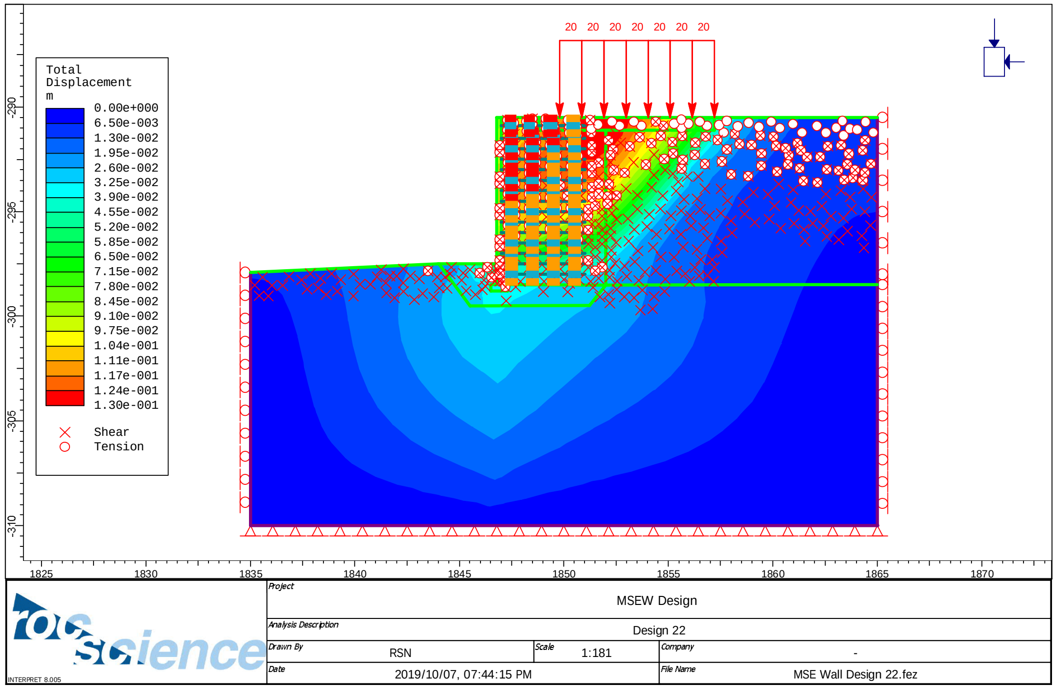
Analysis Description Design 22
Drawn By RSN
Scale 1:181
Company -
Date 2019/10/07, 07:44:15 PM
File Name MSE Wall Design 22.fez



Total Displacement m
0.00e+000
6.50e-003
1.30e-002
1.95e-002
2.60e-002
3.25e-002
3.90e-002
4.55e-002
5.20e-002
5.85e-002
6.50e-002
7.15e-002
7.80e-002
8.45e-002
9.10e-002
9.75e-002
1.04e-001
1.11e-001
1.17e-001
1.24e-001
1.30e-001
Shear
Tension
20 20 20 20 20 20 20
Project MSEW Design
Analysis Description Design 22
Drawn By RSN
Scale 1:181
Company -
Date 2019/10/07, 07:44:15 PM
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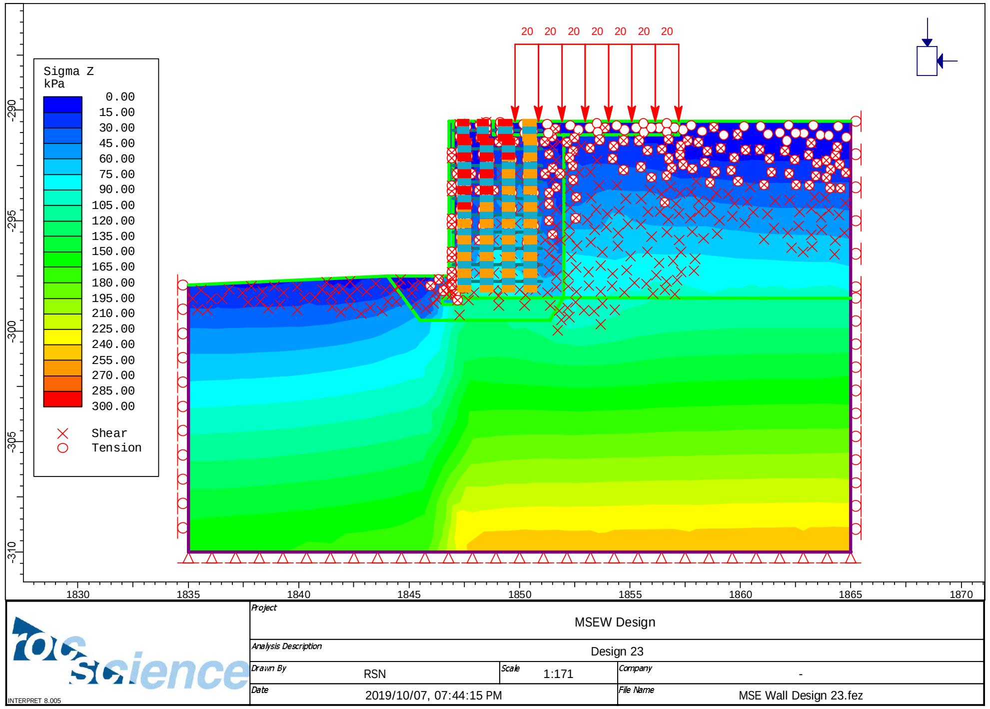
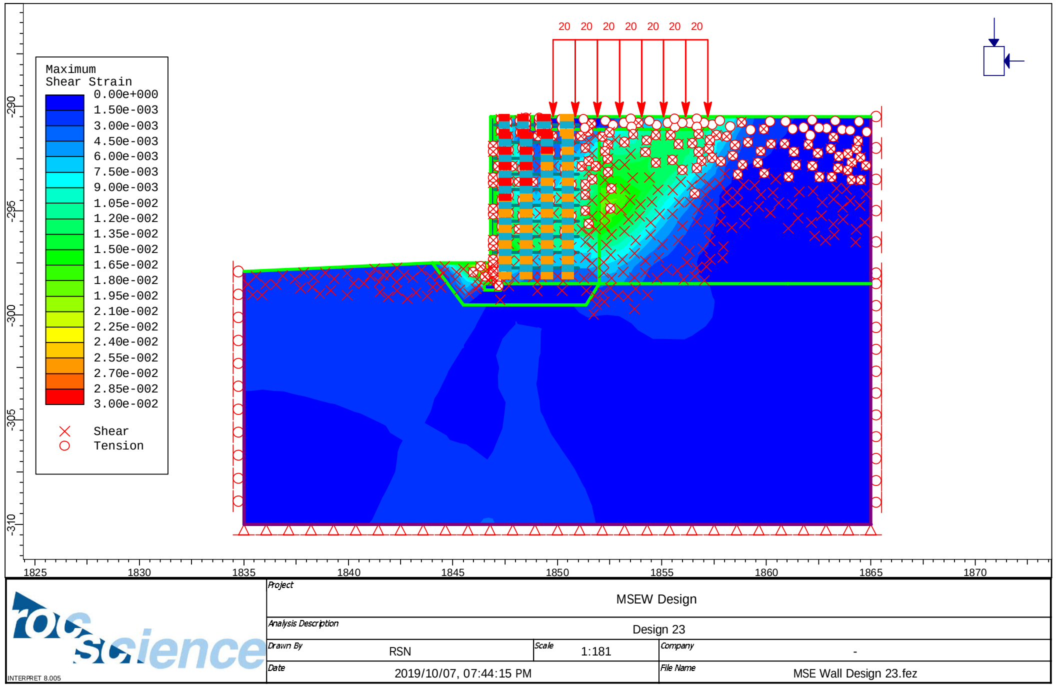

Sigma Z
kPa
0.00
15.00
30.00
45.00
60.00
75.00
90.00
105.00
120.00
135.00
150.00
165.00
180.00
195.00
210.00
225.00
240.00
255.00
270.00
285.00
300.00
Shear
Tension
20 20 20 20 20 20 20
Project
MSEW Design
Analysis Description
Design 23
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 23.fez
INTERPRET 8.005


Maximum
Shear Strain
0.00e+000
1.50e-003
3.00e-003
4.50e-003
6.00e-003
7.50e-003
9.00e-003
1.05e-002
1.20e-002
1.35e-002
1.50e-002
1.65e-002
1.80e-002
1.95e-002
2.10e-002
2.25e-002
2.40e-002
2.55e-002
2.70e-002
2.85e-002
3.00e-002
Shear
Tension
20 20 20 20 20 20 20
Project
MSEW Design
Analysis Description
Design 23
Drawn By
RSN
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1:181
Company
-
Date
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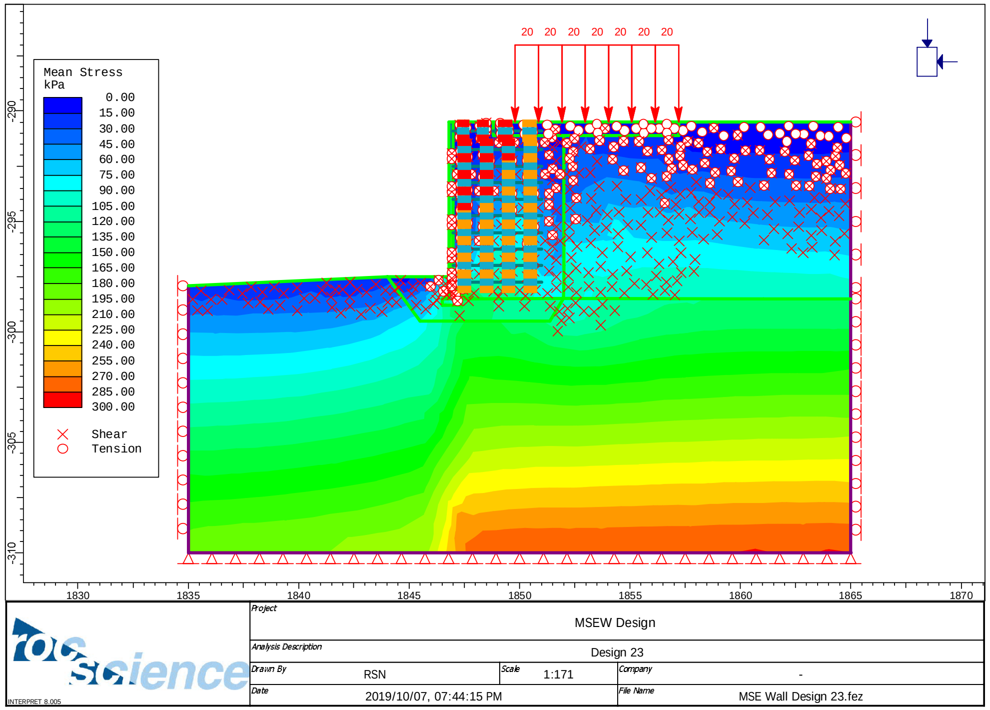
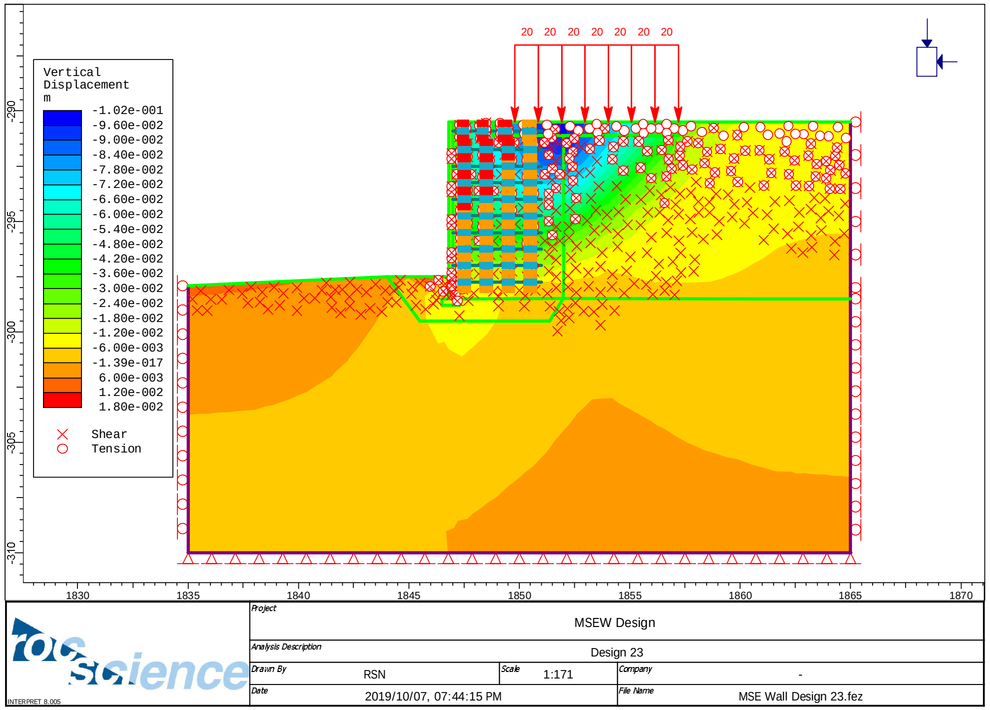
File Name
MSE Wall Design 23.fez
INTERPRET 8.005


Mean Stress
kPa
0.00
15.00
30.00
45.00
60.00
75.00
90.00
105.00
120.00
135.00
150.00
165.00
180.00
195.00
210.00
225.00
240.00
255.00
270.00
285.00
300.00
Shear
Tension
20 20 20 20 20 20 20
Project
MSEW Design
Analysis Description
Design 23
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 23.fez
INTERPRET 8.005


Vertical
Displacement
m
-1.02e-001
-9.60e-002
-9.00e-002
-8.40e-002
-7.80e-002
-7.20e-002
-6.60e-002
-6.00e-002
-5.40e-002
-4.80e-002
-4.20e-002
-3.60e-002
-3.00e-002
-2.40e-002
-1.80e-002
-1.20e-002
-6.00e-003
-1.39e-017
6.00e-003
1.20e-002
1.80e-002
Shear
Tension
20 20 20 20 20 20 20
Project
MSEW Design
Analysis Description
Design 23
Drawn By
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1:171
Company
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Date
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File Name
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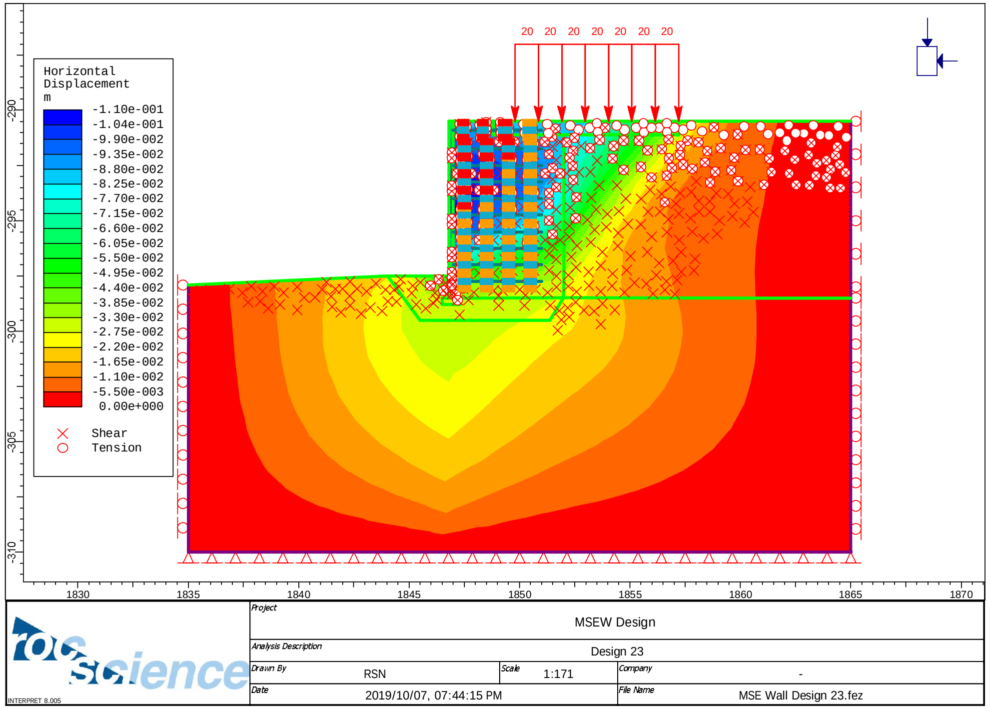
INTERPRET 8.005


20 20 20 20 20 20 20
Horizontal Displacement m
-1.10e-001
-1.04e-001
-9.90e-002
-9.35e-002
-8.80e-002
-8.25e-002
-7.70e-002
-7.15e-002
-6.60e-002
-6.05e-002
-5.50e-002
-4.95e-002
-4.40e-002
-3.85e-002
-3.30e-002
-2.75e-002
-2.20e-002
-1.65e-002
-1.10e-002
-5.50e-003
0.00e+000
Shear
Tension
-290
-295
-300
-305
-310
1830
1835
1840
1845
1850
1855
1860
1865
1870
INTERPRET 8.005
Project
MSEW Design
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Design 23
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RSN
Scale
1:171
Company
-
Date
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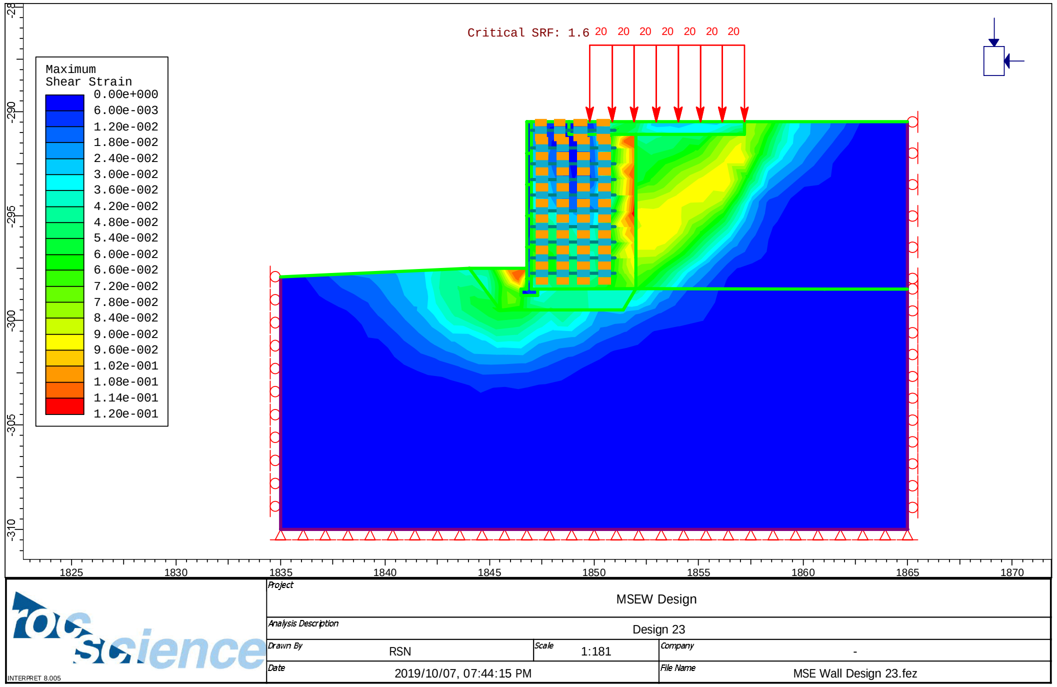
Critical SRF: 1.6
20 20 20 20 20 20 20
Maximum Shear Strain
0.00e+000
6.00e-003
1.20e-002
1.80e-002
2.40e-002
3.00e-002
3.60e-002
4.20e-002
4.80e-002
5.40e-002
6.00e-002
6.60e-002
7.20e-002
7.80e-002
8.40e-002
9.00e-002
9.60e-002
1.02e-001
1.08e-001
1.14e-001
1.20e-001
-290
-295
-300
-305
-310
1825
1830
1835
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1845
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1855
1860
1865
1870
INTERPRET 8.005
Project
MSEW Design
Analysis Description
Design 23
Drawn By
RSN
Scale
1:181
Company
-
Date
2019/10/07, 07:44:15 PM
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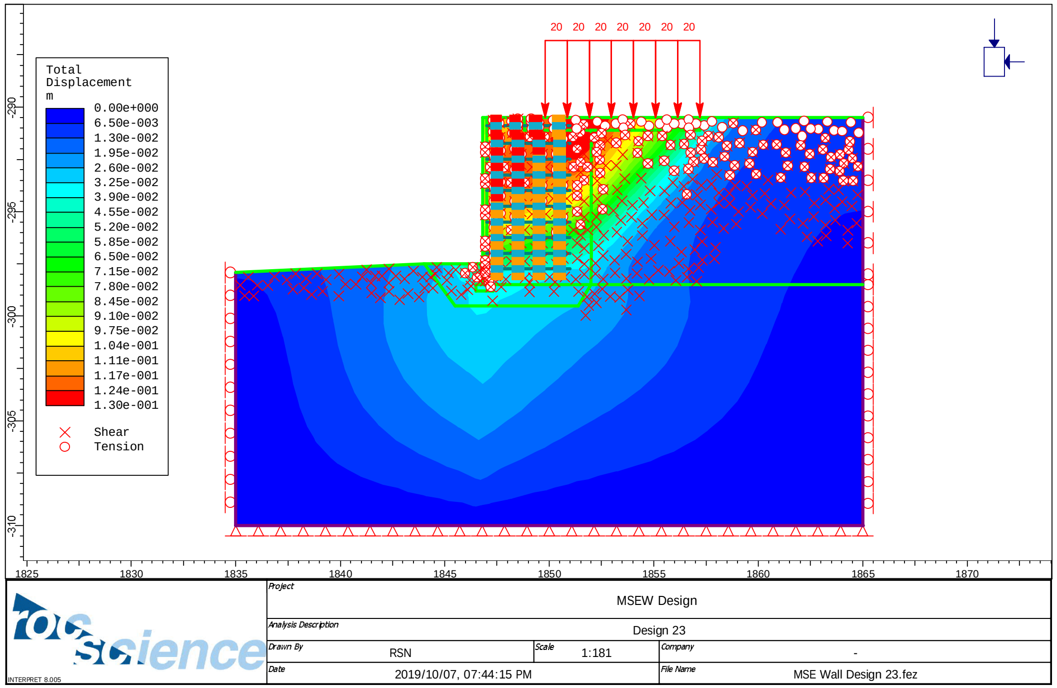
MSE Wall Design 23.fez


20 20 20 20 20 20 20
Total Displacement m
0.00e+000
6.50e-003
1.30e-002
1.95e-002
2.60e-002
3.25e-002
3.90e-002
4.55e-002
5.20e-002
5.85e-002
6.50e-002
7.15e-002
7.80e-002
8.45e-002
9.10e-002
9.75e-002
1.04e-001
1.11e-001
1.17e-001
1.24e-001
1.30e-001
Shear
Tension
-290
-295
-300
-305
-310
1825
1830
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1845
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1870
INTERPRET 8.005
Project
MSEW Design
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RSN
Scale
1:181
Company
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Date
2019/10/07, 07:44:15 PM
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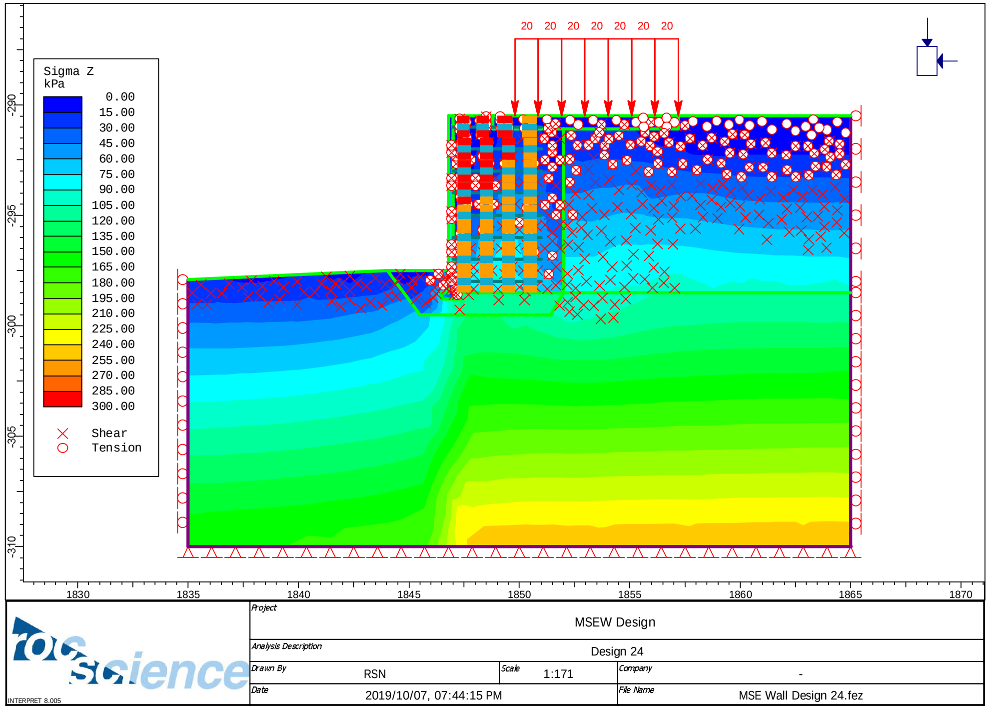
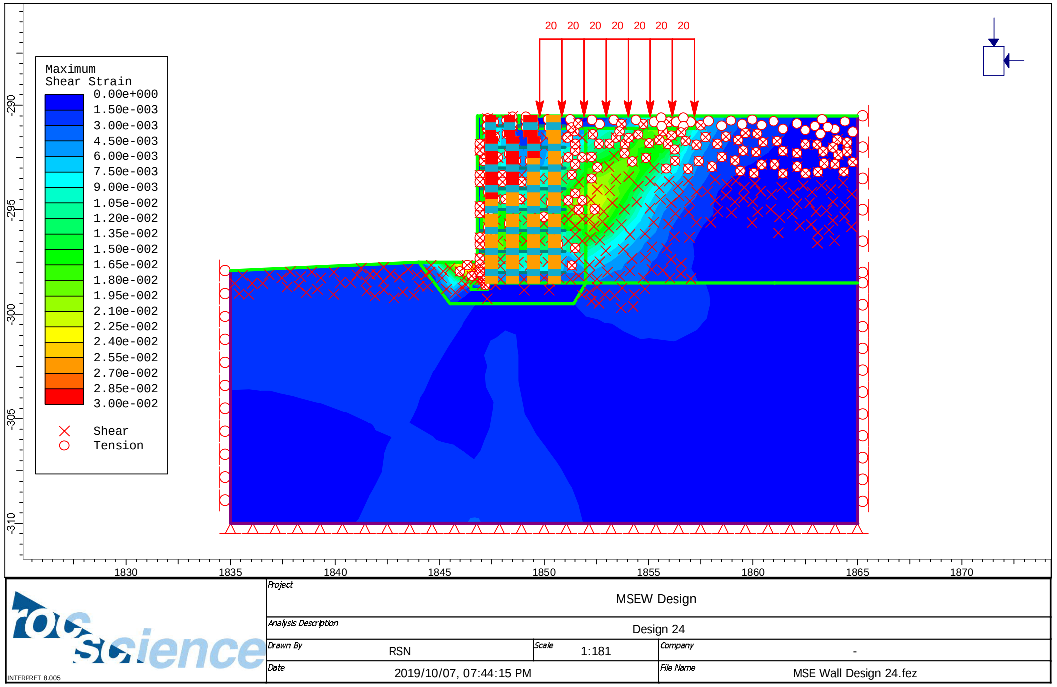

Sigma Z
kPa
0.00
15.00
30.00
45.00
60.00
75.00
90.00
105.00
120.00
135.00
150.00
165.00
180.00
195.00
210.00
225.00
240.00
255.00
270.00
285.00
300.00
Shear
Tension
Project
MSEW Design
Analysis Description
Design 24
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 24.fez
INTERPRET 8.005


Maximum
Shear Strain
0.00e+000
1.50e-003
3.00e-003
4.50e-003
6.00e-003
7.50e-003
9.00e-003
1.05e-002
1.20e-002
1.35e-002
1.50e-002
1.65e-002
1.80e-002
1.95e-002
2.10e-002
2.25e-002
2.40e-002
2.55e-002
2.70e-002
2.85e-002
3.00e-002
Shear
Tension
Project
MSEW Design
Analysis Description
Design 24
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RSN
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1:181
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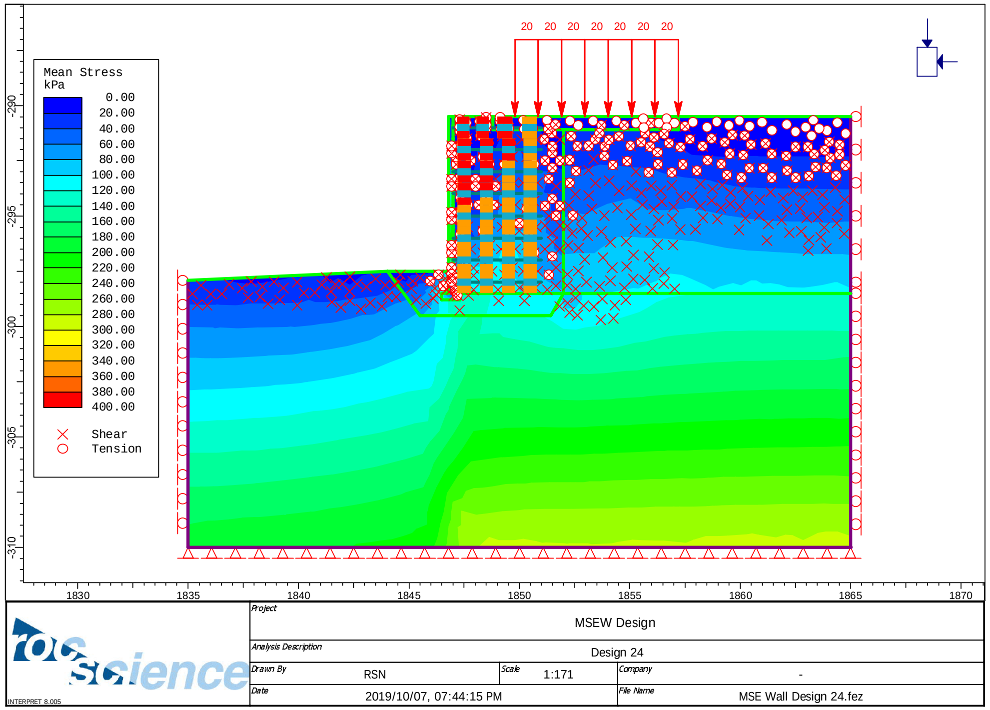
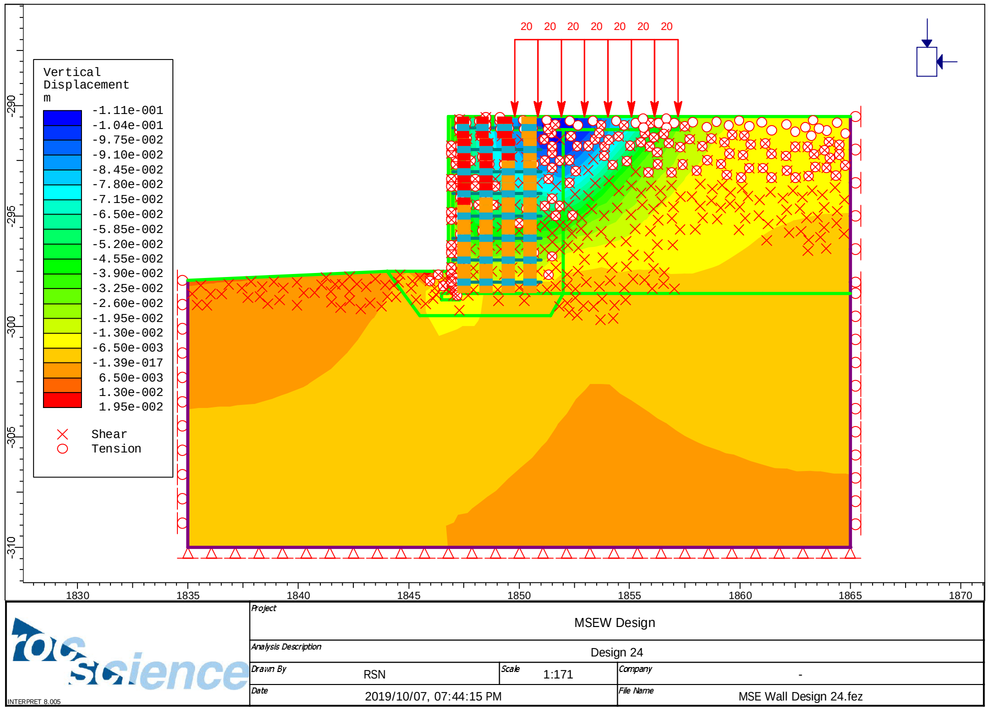
INTERPRET 8.005


Mean Stress
kPa
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
160.00
180.00
200.00
220.00
240.00
260.00
280.00
300.00
320.00
340.00
360.00
380.00
400.00
Shear
Tension
Project
MSEW Design
Analysis Description
Design 24
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 24.fez
INTERPRET 8.005


Vertical
Displacement
m
-1.11e-001
-1.04e-001
-9.75e-002
-9.10e-002
-8.45e-002
-7.80e-002
-7.15e-002
-6.50e-002
-5.85e-002
-5.20e-002
-4.55e-002
-3.90e-002
-3.25e-002
-2.60e-002
-1.95e-002
-1.30e-002
-6.50e-003
-1.39e-017
6.50e-003
1.30e-002
1.95e-002
Shear
Tension
Project
MSEW Design
Analysis Description
Design 24
Drawn By
RSN
Scale
1:171
Company
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Date
2019/10/07, 07:44:15 PM
File Name
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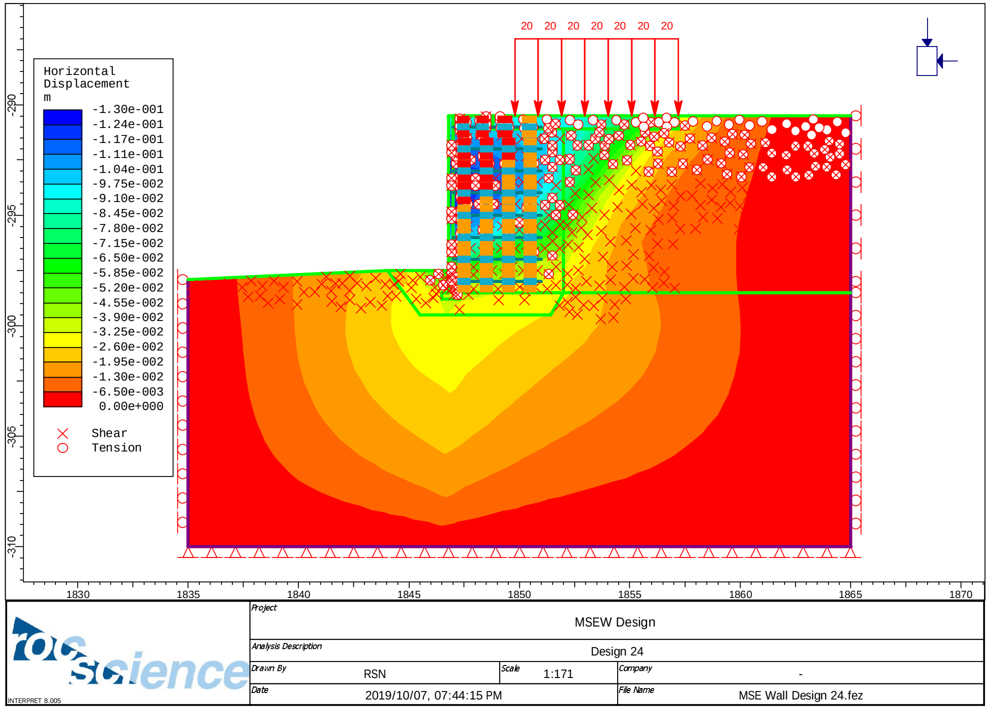
INTERPRET 8.005


20 20 20 20 20 20 20
Horizontal Displacement m
-1.30e-001
-1.24e-001
-1.17e-001
-1.11e-001
-1.04e-001
-9.75e-002
-9.10e-002
-8.45e-002
-7.80e-002
-7.15e-002
-6.50e-002
-5.85e-002
-5.20e-002
-4.55e-002
-3.90e-002
-3.25e-002
-2.60e-002
-1.95e-002
-1.30e-002
-6.50e-003
0.00e+000
Shear
Tension
-290
-295
-300
-305
-310
1830
1835
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1865
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Project
MSEW Design
Analysis Description
Design 24
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Company
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Date
2019/10/07, 07:44:15 PM
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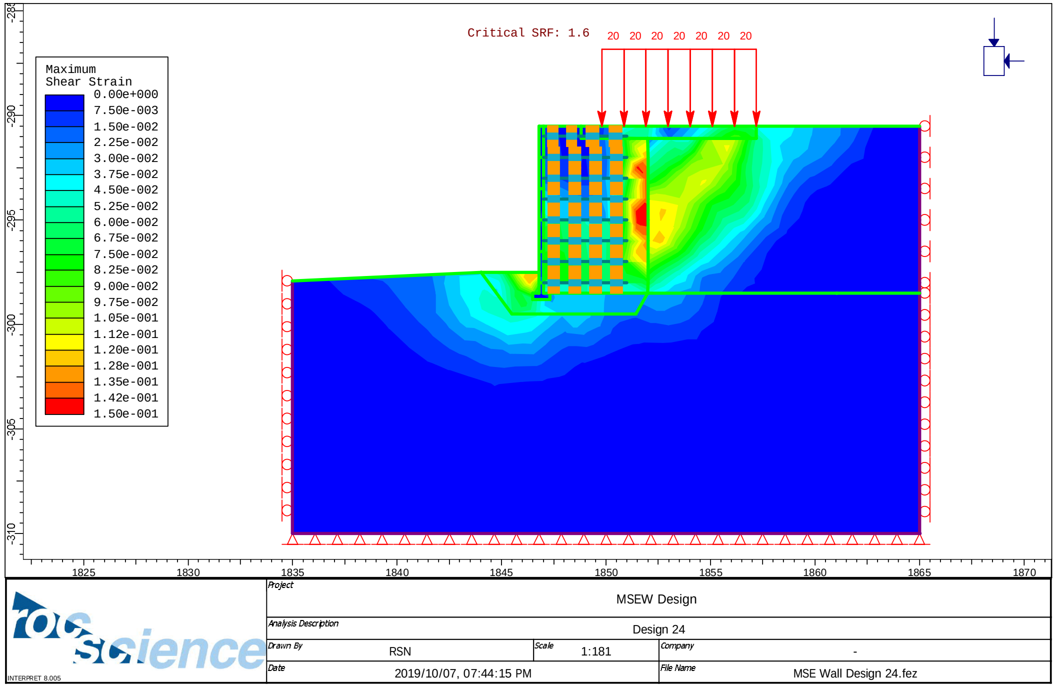
MSE Wall Design 24.fez
INTERPRET 8.005


Critical SRF: 1.6
20 20 20 20 20 20 20
Maximum Shear Strain
0.00e+000
7.50e-003
1.50e-002
2.25e-002
3.00e-002
3.75e-002
4.50e-002
5.25e-002
6.00e-002
6.75e-002
7.50e-002
8.25e-002
9.00e-002
9.75e-002
1.05e-001
1.12e-001
1.20e-001
1.28e-001
1.35e-001
1.42e-001
1.50e-001
-290
-295
-300
-305
-310
1825
1830
1835
1840
1845
1850
1855
1860
1865
1870
Project
MSEW Design
Analysis Description
Design 24
Drawn By
RSN
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1:181
Company
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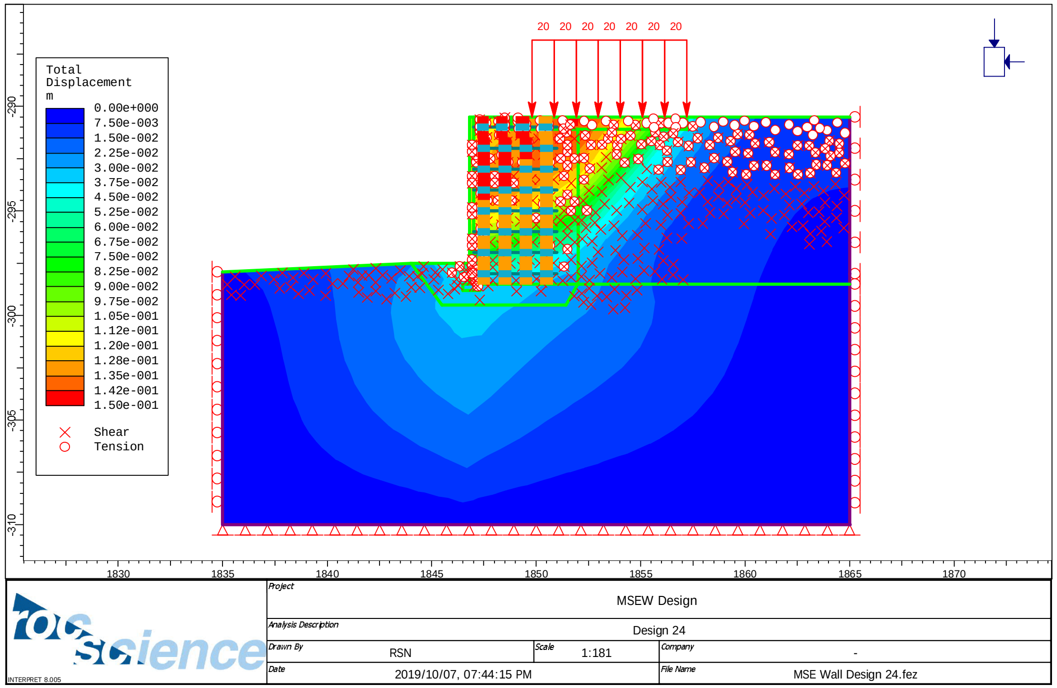
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 24.fez
INTERPRET 8.005


20 20 20 20 20 20 20
Total Displacement m
0.00e+000
7.50e-003
1.50e-002
2.25e-002
3.00e-002
3.75e-002
4.50e-002
5.25e-002
6.00e-002
6.75e-002
7.50e-002
8.25e-002
9.00e-002
9.75e-002
1.05e-001
1.12e-001
1.20e-001
1.28e-001
1.35e-001
1.42e-001
1.50e-001
Shear
Tension
-290
-295
-300
-305
-310
1830
1835
1840
1845
1850
1855
1860
1865
1870
Project
MSEW Design
Analysis Description
Design 24
Drawn By
RSN
Scale
1:181
Company
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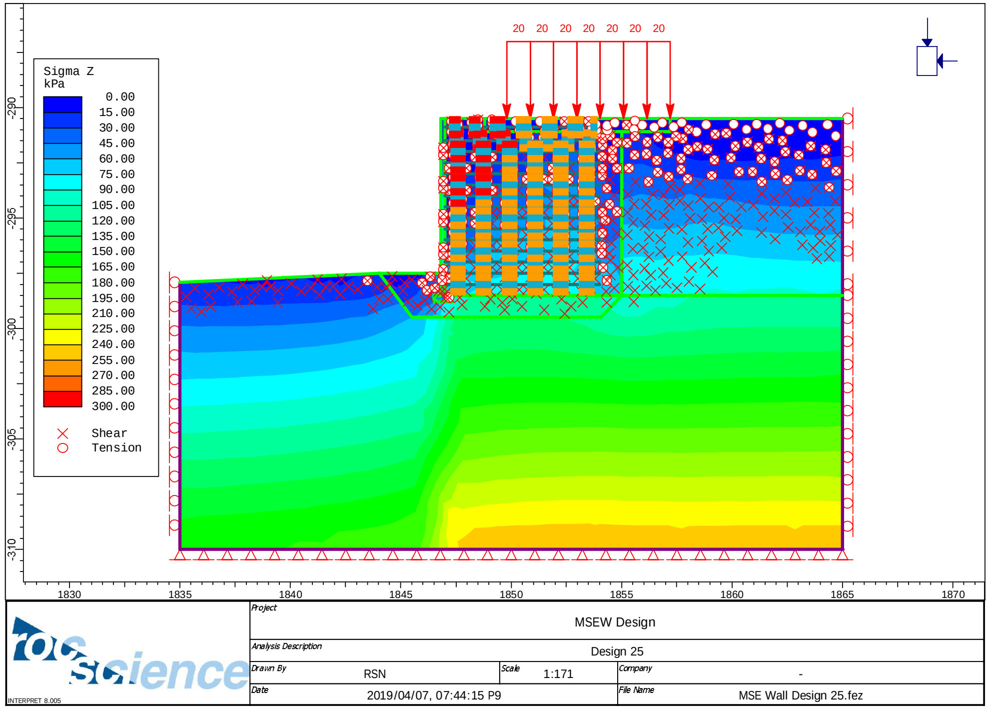
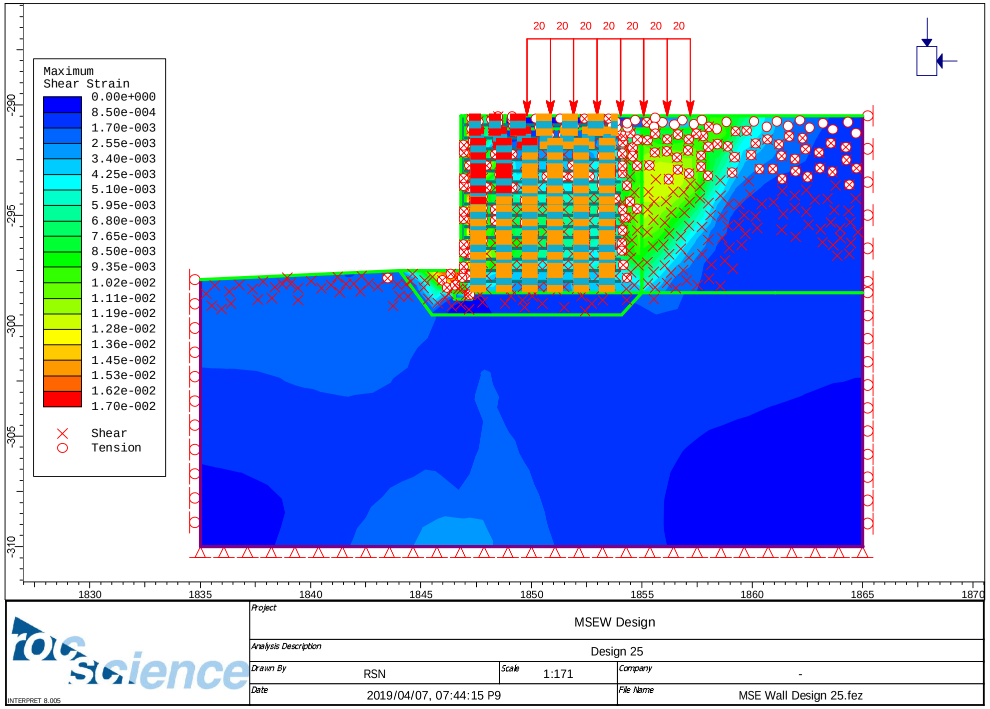
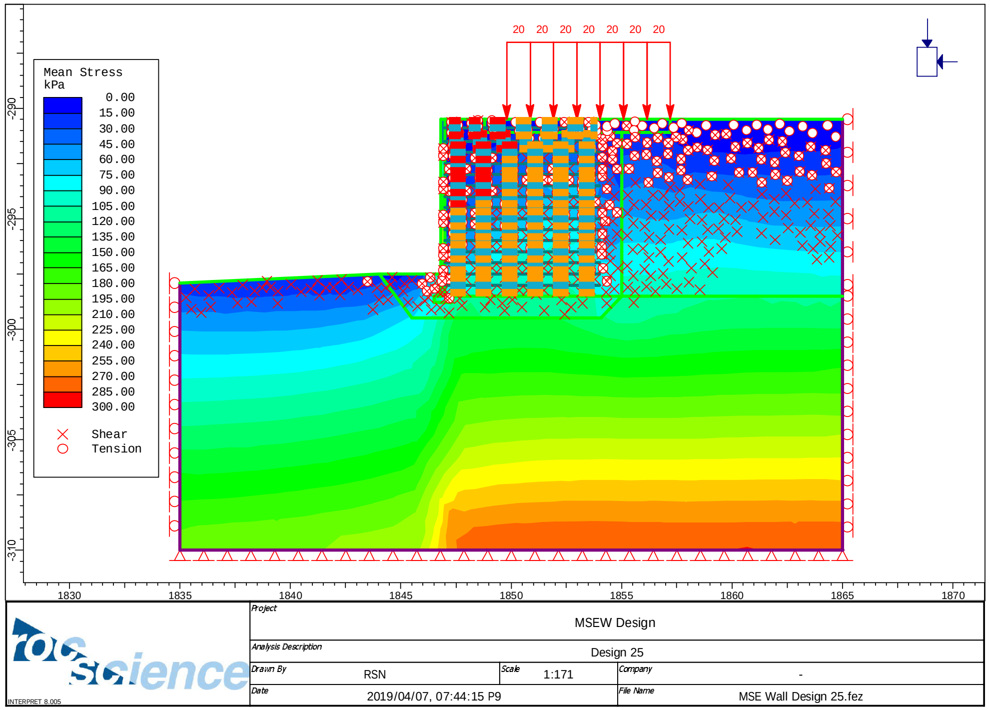
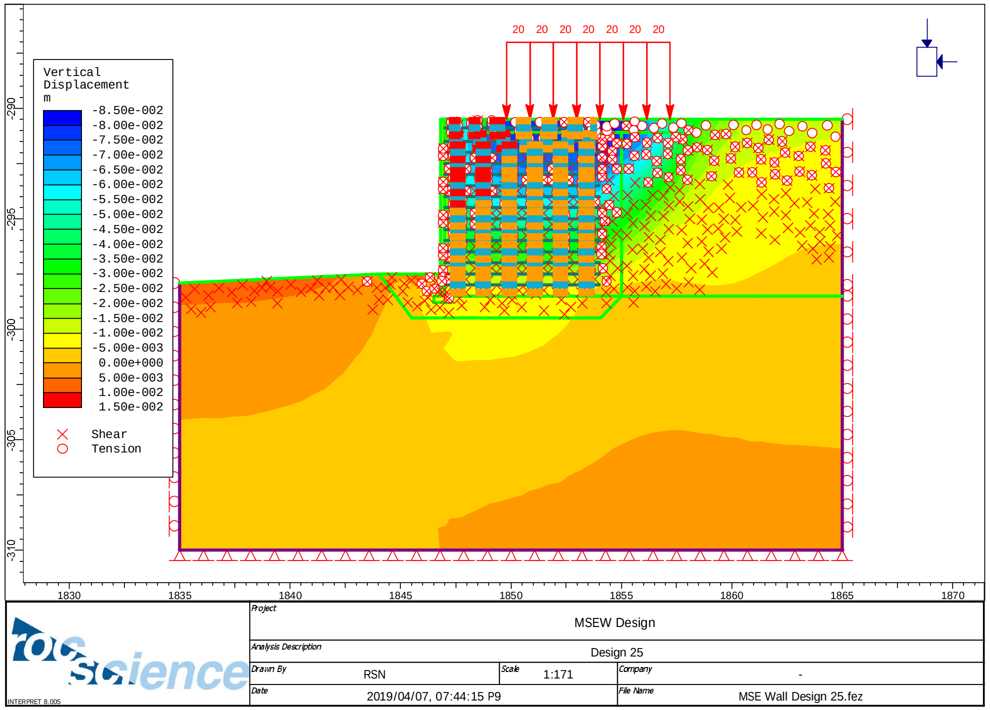
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 24.fez
INTERPRET 8.005


Sigma Z
kPa
0.00
15.00
30.00
45.00
60.00
75.00
90.00
105.00
120.00
135.00
150.00
165.00
180.00
195.00
210.00
225.00
240.00
255.00
270.00
285.00
300.00
Shear
Tension
20 20 20 20 20 20 20
Project
MSEW Design
Analysis Description
Design 25
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/04/07, 07:44:15 P9
File Name
MSE Wall Design 25.fez
INTERPRET 8.005


Maximum
Shear Strain
0.00e+000
8.50e-004
1.70e-003
2.55e-003
3.40e-003
4.25e-003
5.10e-003
5.95e-003
6.80e-003
7.65e-003
8.50e-003
9.35e-003
1.02e-002
1.11e-002
1.19e-002
1.28e-002
1.36e-002
1.45e-002
1.53e-002
1.62e-002
1.70e-002
Shear
Tension
20 20 20 20 20 20 20
Project
MSEW Design
Analysis Description
Design 25
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/04/07, 07:44:15 P9
File Name
MSE Wall Design 25.fez
INTERPRET 8.005


Mean Stress
kPa
0.00
15.00
30.00
45.00
60.00
75.00
90.00
105.00
120.00
135.00
150.00
165.00
180.00
195.00
210.00
225.00
240.00
255.00
270.00
285.00
300.00
Shear
Tension
20 20 20 20 20 20 20
Project
MSEW Design
Analysis Description
Design 25
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/04/07, 07:44:15 P9
File Name
MSE Wall Design 25.fez
INTERPRET 8.005


Vertical
Displacement
m
-8.50e-002
-8.00e-002
-7.50e-002
-7.00e-002
-6.50e-002
-6.00e-002
-5.50e-002
-5.00e-002
-4.50e-002
-4.00e-002
-3.50e-002
-3.00e-002
-2.50e-002
-2.00e-002
-1.50e-002
-1.00e-002
-5.00e-003
0.00e+000
5.00e-003
1.00e-002
1.50e-002
Shear
Tension
20 20 20 20 20 20 20
Project
MSEW Design
Analysis Description
Design 25
Drawn By
RSN
Scale
1:171
Company
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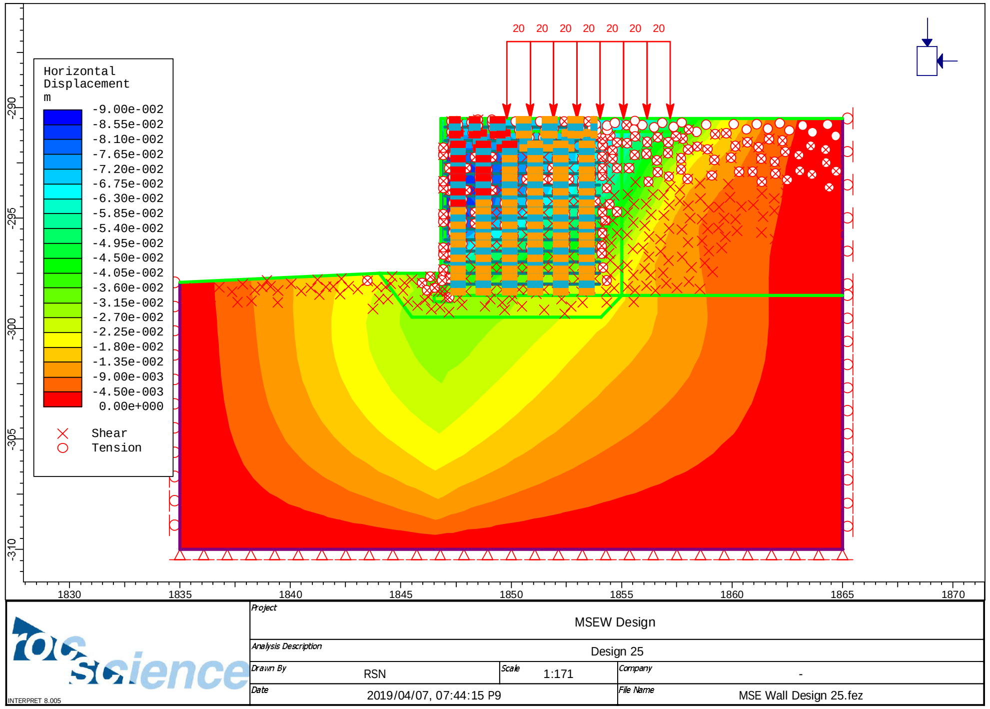
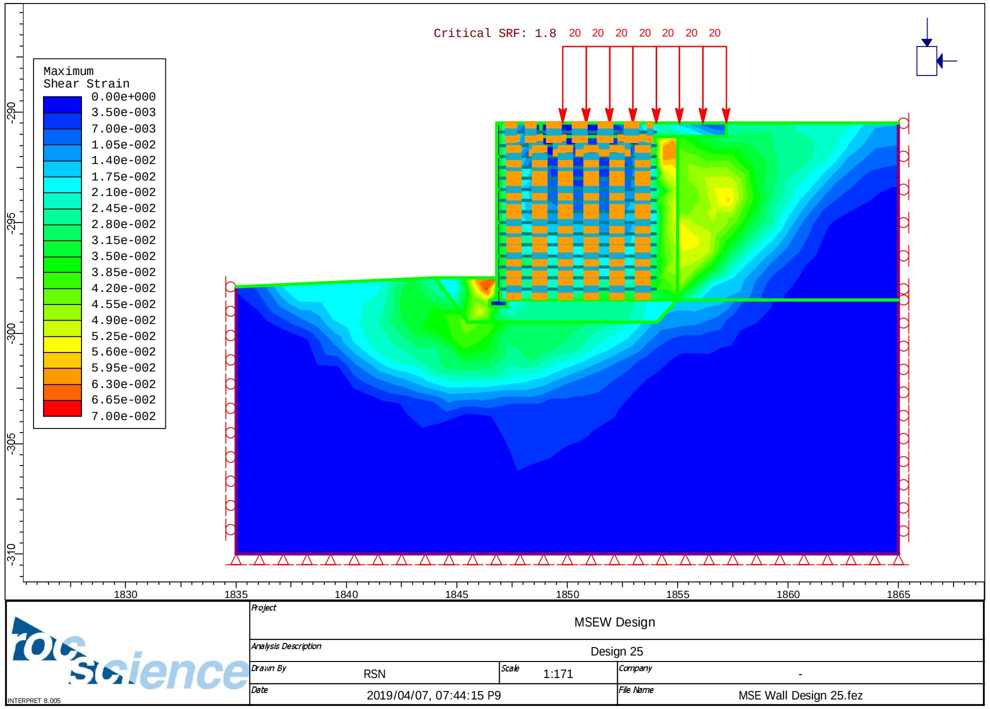
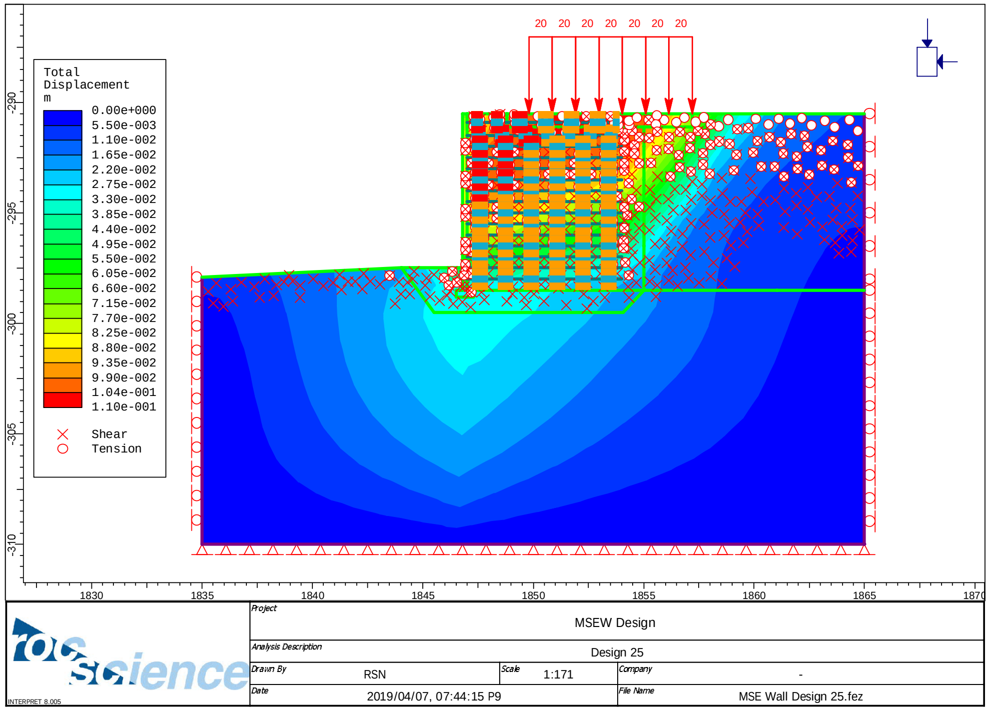
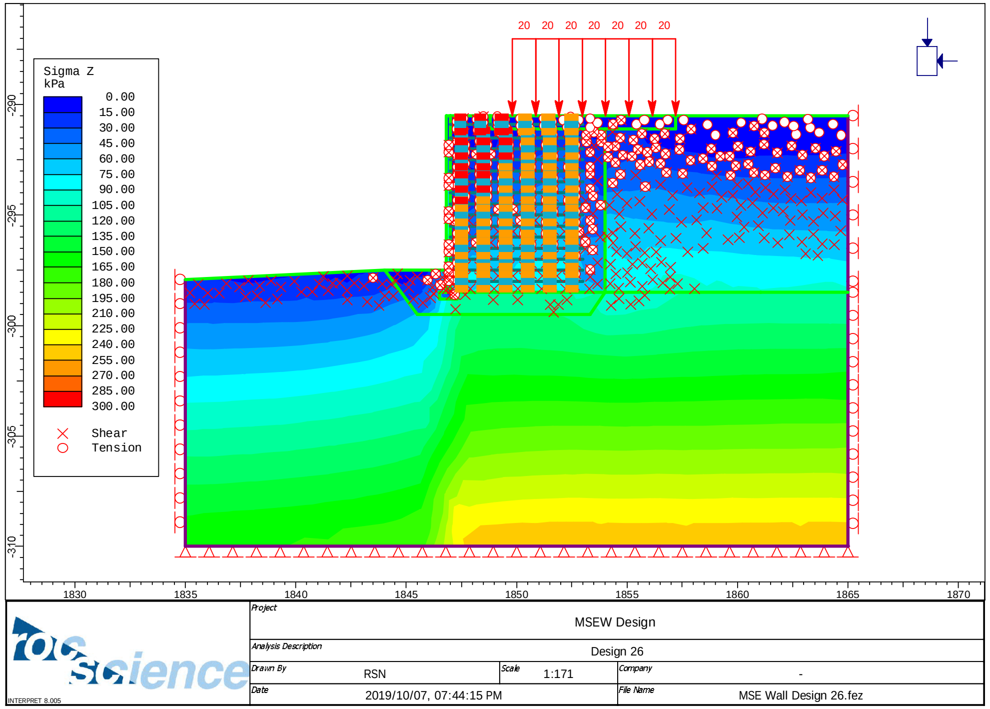
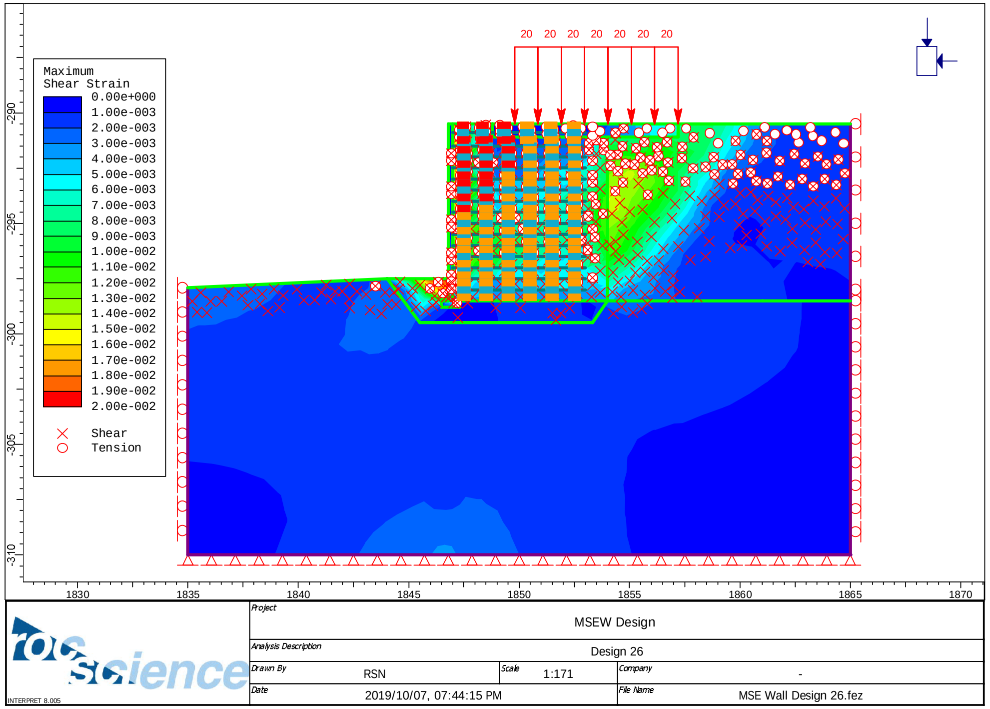
Date
2019/04/07, 07:44:15 P9
File Name
MSE Wall Design 25.fez
INTERPRET 8.005

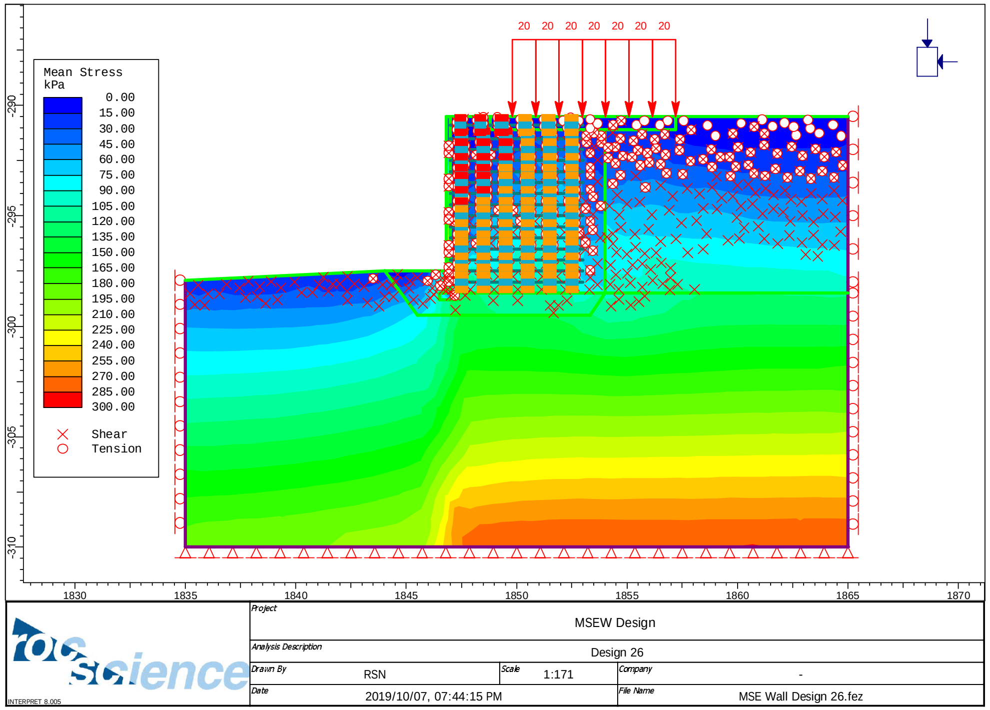

Horizontal Displacement m
-9.00e-002
-8.55e-002
-8.10e-002
-7.65e-002
-7.20e-002
-6.75e-002
-6.30e-002
-5.85e-002
-5.40e-002
-4.95e-002
-4.50e-002
-4.05e-002
-3.60e-002
-3.15e-002
-2.70e-002
-2.25e-002
-1.80e-002
-1.35e-002
-9.00e-003
-4.50e-003
0.00e+000
Shear
Tension
20 20 20 20 20 20 20
-290
-295
-300
-305
-310
1830 1835 1840 1845 1850 1855 1860 1865 1870
Project MSEW Design
Analysis Description Design 25
Drawn By RSN
Scale 1:171
Company -
Date 2019/04/07, 07:44:15 P9
File Name MSE Wall Design 25.fez
INTERPRET 8.005


Maximum Shear Strain
0.00e+000
3.50e-003
7.00e-003
1.05e-002
1.40e-002
1.75e-002
2.10e-002
2.45e-002
2.80e-002
3.15e-002
3.50e-002
3.85e-002
4.20e-002
4.55e-002
4.90e-002
5.25e-002
5.60e-002
5.95e-002
6.30e-002
6.65e-002
7.00e-002
Critical SRF: 1.8
20 20 20 20 20 20 20
-290
-295
-300
-305
-310
1830 1835 1840 1845 1850 1855 1860 1865
Project MSEW Design
Analysis Description Design 25
Drawn By RSN
Scale 1:171
Company -
Date 2019/04/07, 07:44:15 P9
File Name MSE Wall Design 25.fez
INTERPRET 8.005


Total Displacement m
0.00e+000
5.50e-003
1.10e-002
1.65e-002
2.20e-002
2.75e-002
3.30e-002
3.85e-002
4.40e-002
4.95e-002
5.50e-002
6.05e-002
6.60e-002
7.15e-002
7.70e-002
8.25e-002
8.80e-002
9.35e-002
9.90e-002
1.04e-001
1.10e-001
Shear
Tension
20 20 20 20 20 20 20
-290
-295
-300
-305
-310
1830 1835 1840 1845 1850 1855 1860 1865 1870
Project MSEW Design
Analysis Description Design 25
Drawn By RSN
Scale 1:171
Company -
Date 2019/04/07, 07:44:15 P9
File Name MSE Wall Design 25.fez
INTERPRET 8.005


Sigma Z
kPa
0.00
15.00
30.00
45.00
60.00
75.00
90.00
105.00
120.00
135.00
150.00
165.00
180.00
195.00
210.00
225.00
240.00
255.00
270.00
285.00
300.00
Shear
Tension
20 20 20 20 20 20 20
1830 1835 1840 1845 1850 1855 1860 1865 1870
-290 -295 -300 -305 -310
Project
MSEW Design
Analysis Description
Design 26
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 26.fez
INTERPRET 8.005


Maximum
Shear Strain
0.00e+000
1.00e-003
2.00e-003
3.00e-003
4.00e-003
5.00e-003
6.00e-003
7.00e-003
8.00e-003
9.00e-003
1.00e-002
1.10e-002
1.20e-002
1.30e-002
1.40e-002
1.50e-002
1.60e-002
1.70e-002
1.80e-002
1.90e-002
2.00e-002
Shear
Tension
20 20 20 20 20 20 20
1830 1835 1840 1845 1850 1855 1860 1865 1870
-290 -295 -300 -305 -310
Project
MSEW Design
Analysis Description
Design 26
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 26.fez
INTERPRET 8.005


Mean Stress
kPa
0.00
15.00
30.00
45.00
60.00
75.00
90.00
105.00
120.00
135.00
150.00
165.00
180.00
195.00
210.00
225.00
240.00
255.00
270.00
285.00
300.00
Shear
Tension
20 20 20 20 20 20 20
1830 1835 1840 1845 1850 1855 1860 1865 1870
-290 -295 -300 -305 -310
Project
MSEW Design
Analysis Description
Design 26
Drawn By
RSN
Scale
1:171
Company
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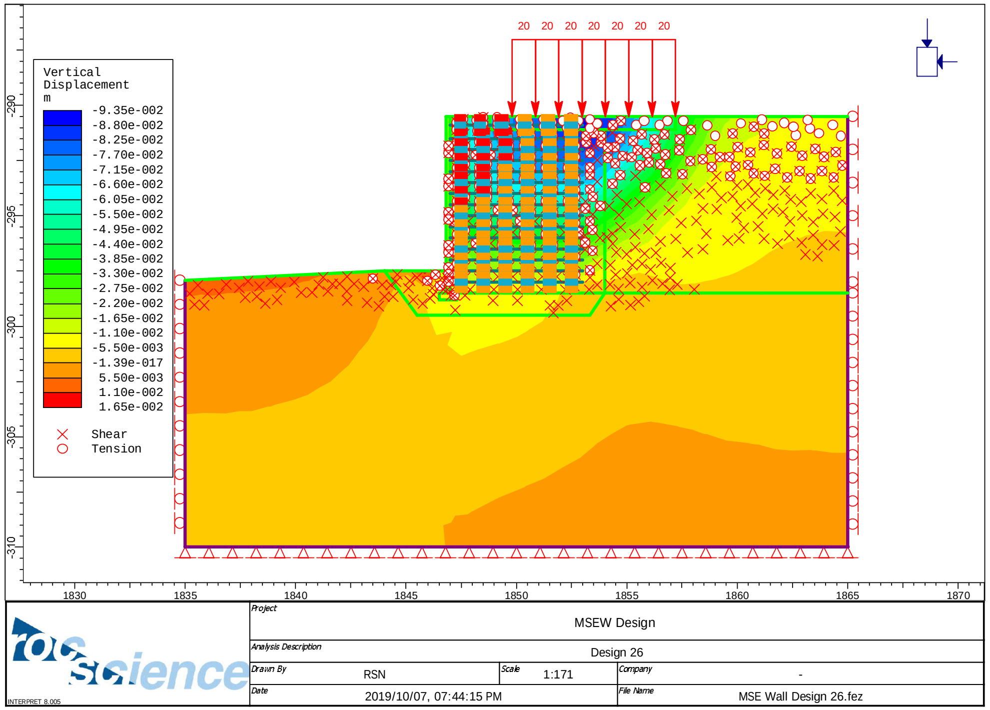
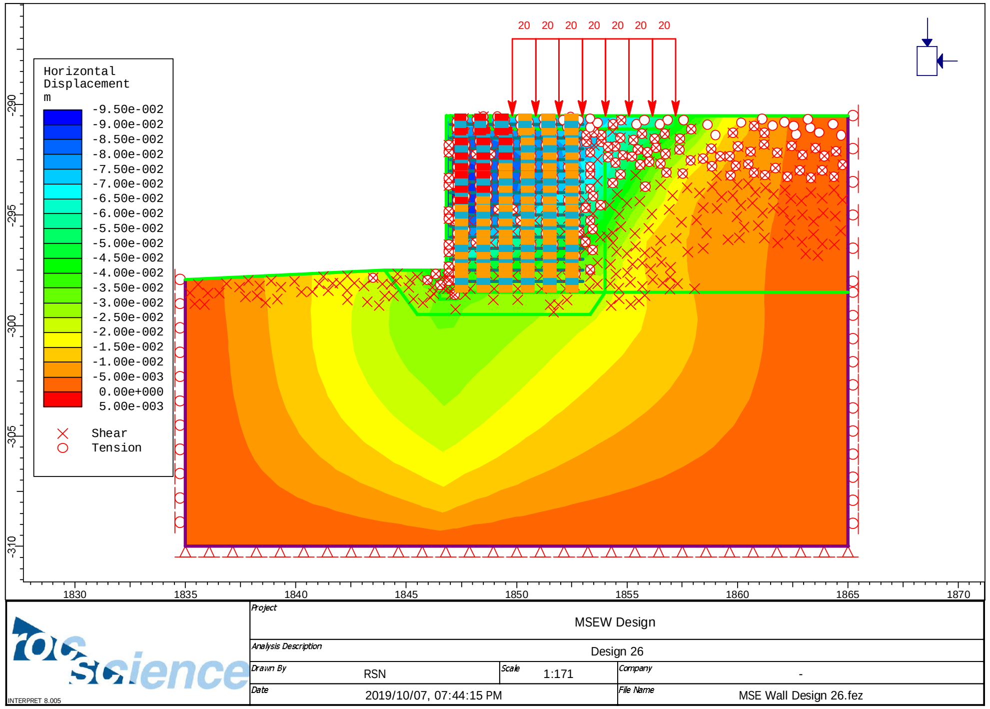
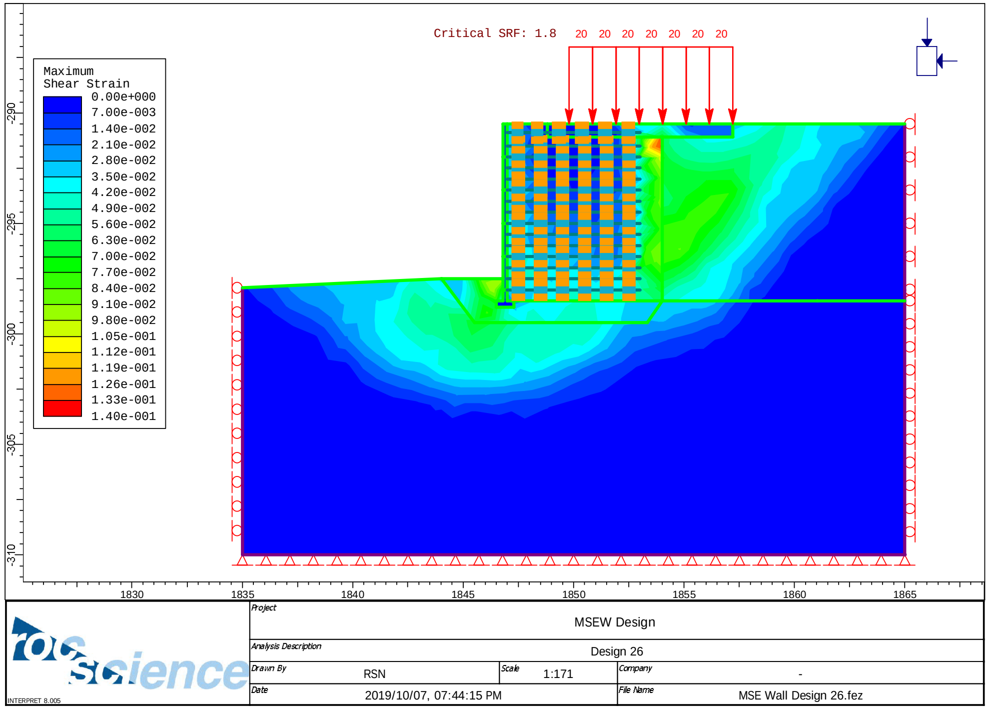
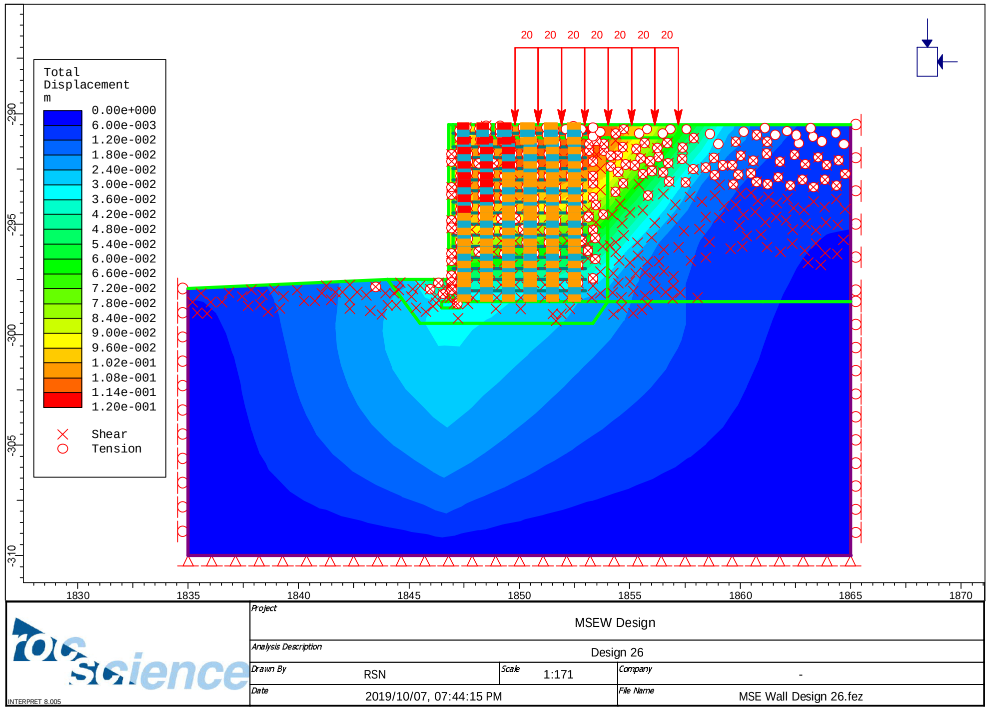
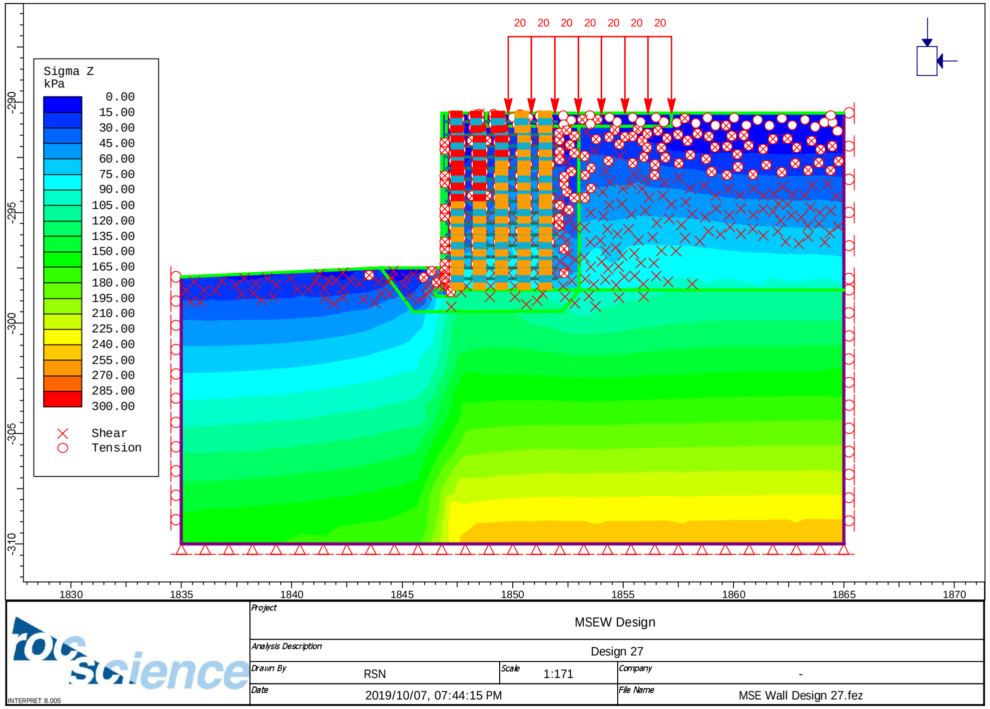
MSE Wall Design 26.fez
INTERPRET 8.005

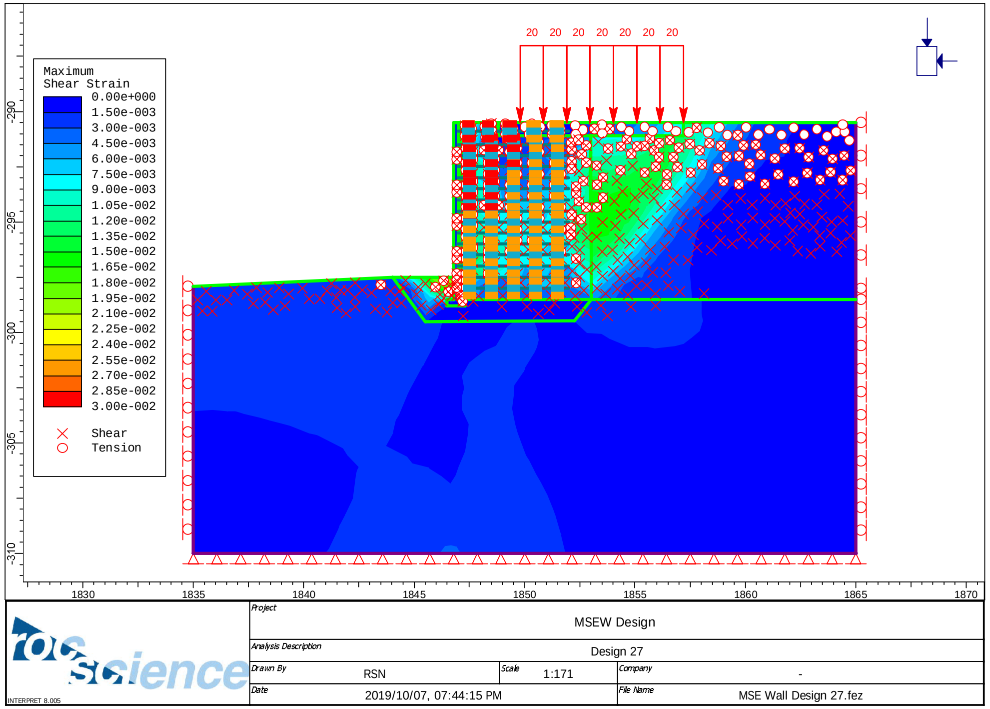

Vertical
Displacement
m
-9.35e-002
-8.80e-002
-8.25e-002
-7.70e-002
-7.15e-002
-6.60e-002
-6.05e-002
-5.50e-002
-4.95e-002
-4.40e-002
-3.85e-002
-3.30e-002
-2.75e-002
-2.20e-002
-1.65e-002
-1.10e-002
-5.50e-003
-1.39e-017
5.50e-003
1.10e-002
1.65e-002
Shear
Tension
20 20 20 20 20 20 20
1830 1835 1840 1845 1850 1855 1860 1865 1870
-290 -295 -300 -305 -310
Project
MSEW Design
Analysis Description
Design 26
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 26.fez
INTERPRET 8.005

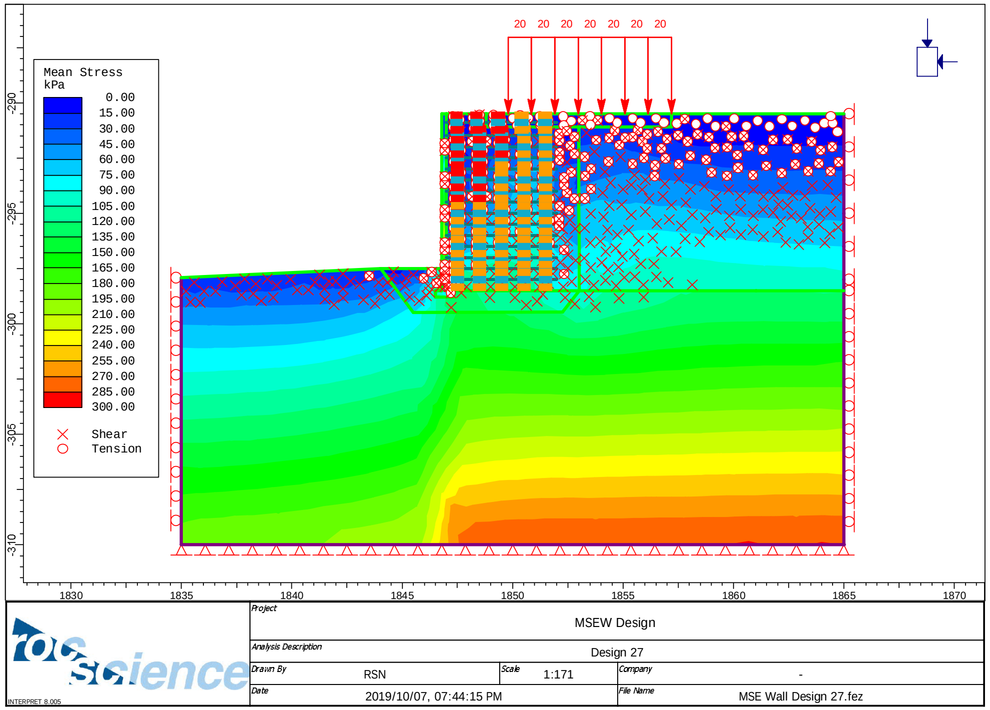

Horizontal Displacement m
-9.50e-002
-9.00e-002
-8.50e-002
-8.00e-002
-7.50e-002
-7.00e-002
-6.50e-002
-6.00e-002
-5.50e-002
-5.00e-002
-4.50e-002
-4.00e-002
-3.50e-002
-3.00e-002
-2.50e-002
-2.00e-002
-1.50e-002
-1.00e-002
-5.00e-003
0.00e+000
5.00e-003
Shear
Tension
20 20 20 20 20 20 20
Project
MSEW Design
Analysis Description
Design 26
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 26.fez
INTERPRET 8.005

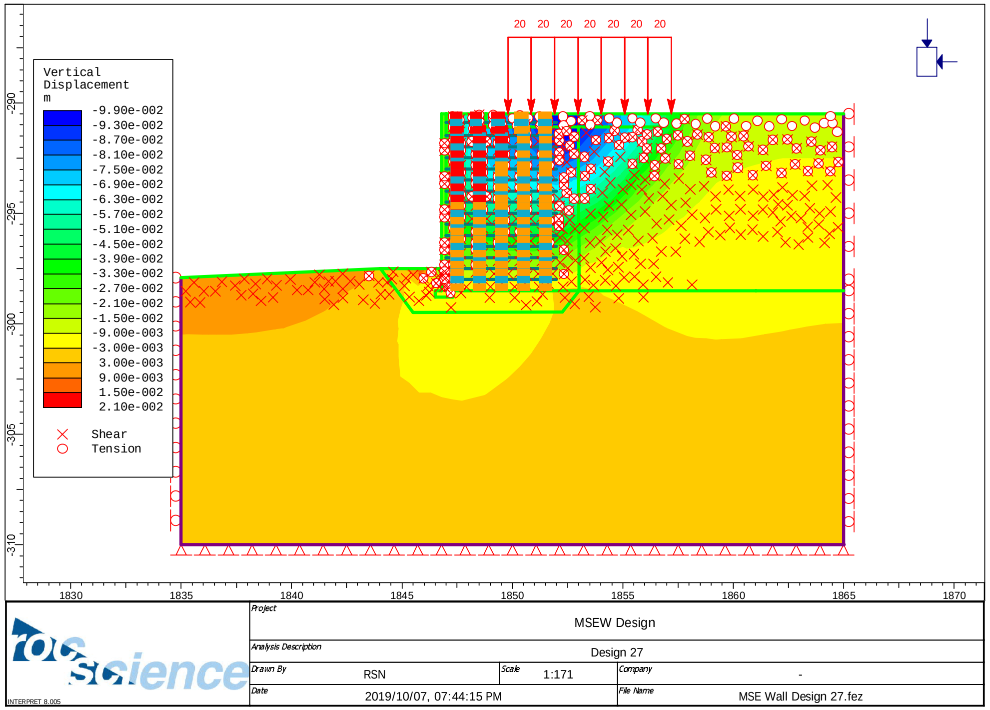

Maximum Shear Strain
0.00e+000
7.00e-003
1.40e-002
2.10e-002
2.80e-002
3.50e-002
4.20e-002
4.90e-002
5.60e-002
6.30e-002
7.00e-002
7.70e-002
8.40e-002
9.10e-002
9.80e-002
1.05e-001
1.12e-001
1.19e-001
1.26e-001
1.33e-001
1.40e-001
Critical SRF: 1.8
20 20 20 20 20 20 20
Project
MSEW Design
Analysis Description
Design 26
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 26.fez
INTERPRET 8.005

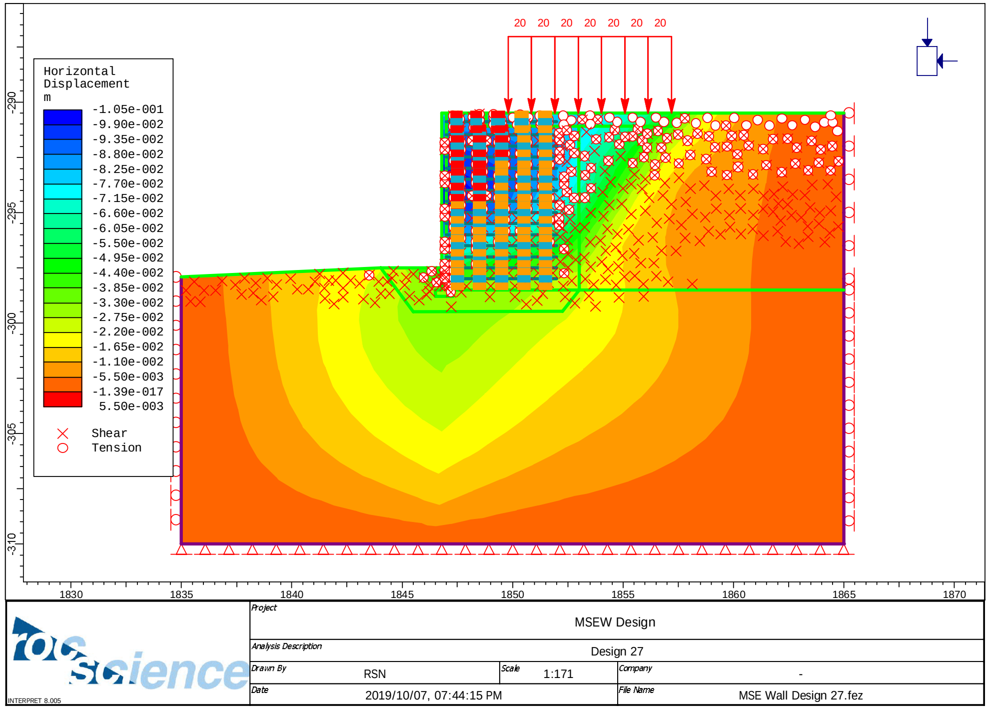

Total Displacement m
0.00e+000
6.00e-003
1.20e-002
1.80e-002
2.40e-002
3.00e-002
3.60e-002
4.20e-002
4.80e-002
5.40e-002
6.00e-002
6.60e-002
7.20e-002
7.80e-002
8.40e-002
9.00e-002
9.60e-002
1.02e-001
1.08e-001
1.14e-001
1.20e-001
Shear
Tension
20 20 20 20 20 20 20
Project
MSEW Design
Analysis Description
Design 26
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 26.fez
INTERPRET 8.005


Sigma Z
kPa
0.00
15.00
30.00
45.00
60.00
75.00
90.00
105.00
120.00
135.00
150.00
165.00
180.00
195.00
210.00
225.00
240.00
255.00
270.00
285.00
300.00
Shear
Tension
20 20 20 20 20 20 20
-290
-295
-300
-305
-310
1830 1835 1840 1845 1850 1855 1860 1865 1870
Project
MSEW Design
Analysis Description
Design 27
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 27.fez
INTERPRET 8.005

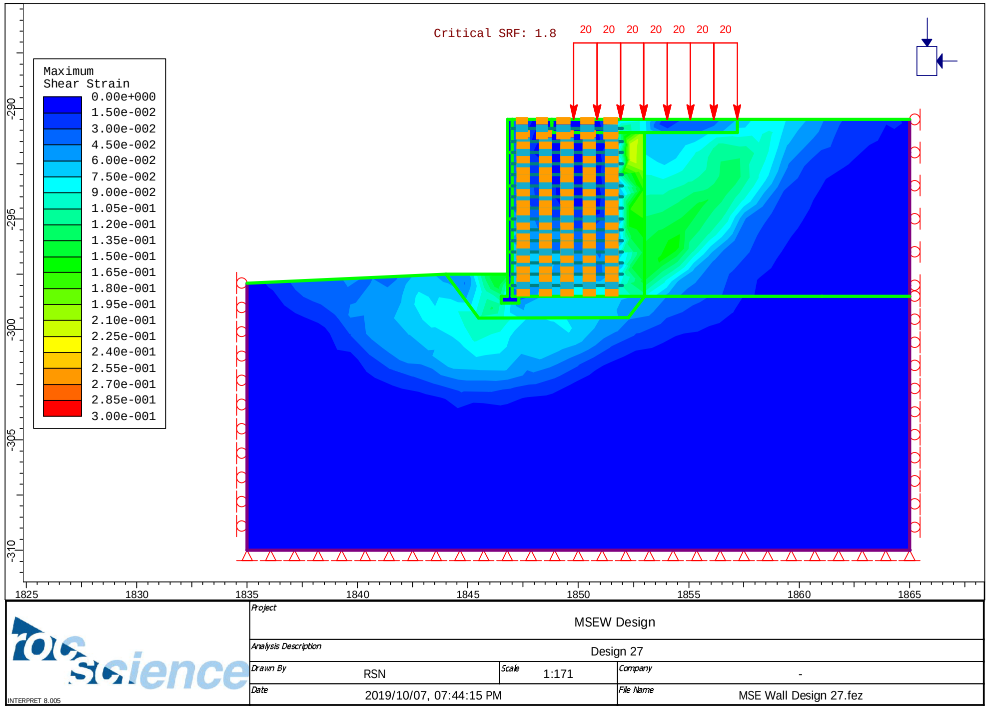

Maximum
Shear Strain
0.00e+000
1.50e-003
3.00e-003
4.50e-003
6.00e-003
7.50e-003
9.00e-003
1.05e-002
1.20e-002
1.35e-002
1.50e-002
1.65e-002
1.80e-002
1.95e-002
2.10e-002
2.25e-002
2.40e-002
2.55e-002
2.70e-002
2.85e-002
3.00e-002
Shear
Tension
20 20 20 20 20 20 20
-290
-295
-300
-305
-310
1830 1835 1840 1845 1850 1855 1860 1865 1870
Project
MSEW Design
Analysis Description
Design 27
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 27.fez
INTERPRET 8.005


Mean Stress
kPa
0.00
15.00
30.00
45.00
60.00
75.00
90.00
105.00
120.00
135.00
150.00
165.00
180.00
195.00
210.00
225.00
240.00
255.00
270.00
285.00
300.00
Shear
Tension
20 20 20 20 20 20 20
-290
-295
-300
-305
-310
1830 1835 1840 1845 1850 1855 1860 1865 1870
Project
MSEW Design
Analysis Description
Design 27
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 27.fez
INTERPRET 8.005

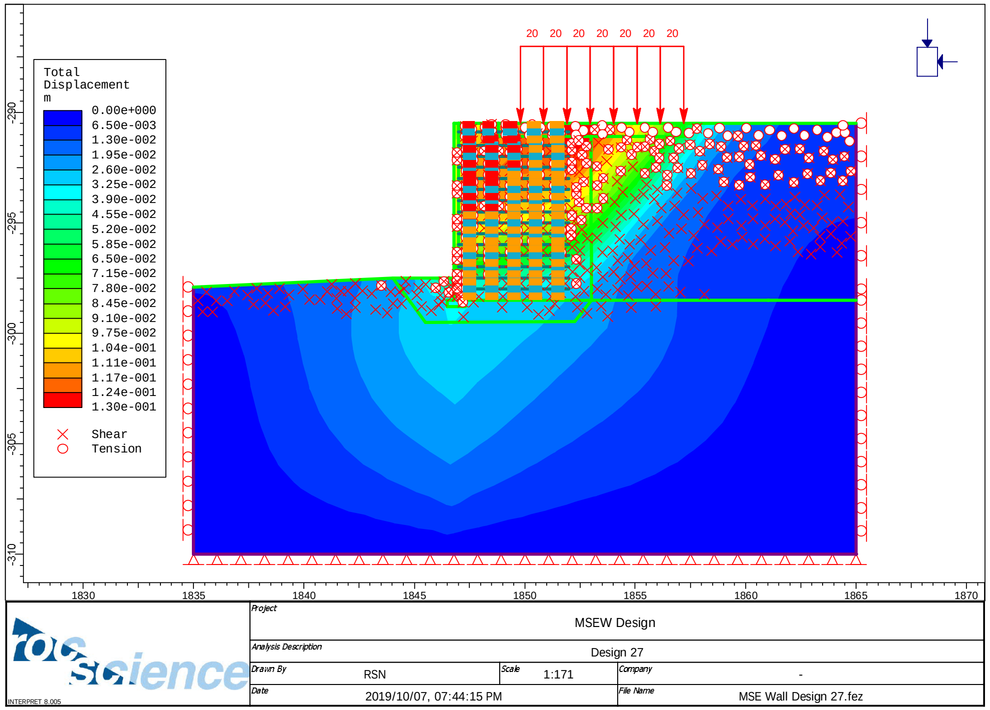

Vertical
Displacement
m
-9.90e-002
-9.30e-002
-8.70e-002
-8.10e-002
-7.50e-002
-6.90e-002
-6.30e-002
-5.70e-002
-5.10e-002
-4.50e-002
-3.90e-002
-3.30e-002
-2.70e-002
-2.10e-002
-1.50e-002
-9.00e-003
-3.00e-003
3.00e-003
9.00e-003
1.50e-002
2.10e-002
Shear
Tension
20 20 20 20 20 20 20
-290
-295
-300
-305
-310
1830 1835 1840 1845 1850 1855 1860 1865 1870
Project
MSEW Design
Analysis Description
Design 27
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 27.fez
INTERPRET 8.005



Horizontal Displacement m
-1.05e-001
-9.90e-002
-9.35e-002
-8.80e-002
-8.25e-002
-7.70e-002
-7.15e-002
-6.60e-002
-6.05e-002
-5.50e-002
-4.95e-002
-4.40e-002
-3.85e-002
-3.30e-002
-2.75e-002
-2.20e-002
-1.65e-002
-1.10e-002
-5.50e-003
-1.39e-017
5.50e-003
Shear
Tension
20 20 20 20 20 20 20
Project: MSEW Design
Analysis Description: Design 27
Drawn By: RSN
Scale: 1:171
Company: -
Date: 2019/10/07, 07:44:15 PM
File Name: MSE Wall Design 27.fez
INTERPRET 8.005



Critical SRF: 1.8
Maximum Shear Strain
0.00e+000
1.50e-002
3.00e-002
4.50e-002
6.00e-002
7.50e-002
9.00e-002
1.05e-001
1.20e-001
1.35e-001
1.50e-001
1.65e-001
1.80e-001
1.95e-001
2.10e-001
2.25e-001
2.40e-001
2.55e-001
2.70e-001
2.85e-001
3.00e-001
20 20 20 20 20 20 20
Project: MSEW Design
Analysis Description: Design 27
Drawn By: RSN
Scale: 1:171
Company: -
Date: 2019/10/07, 07:44:15 PM
File Name: MSE Wall Design 27.fez
INTERPRET 8.005



Total Displacement m
0.00e+000
6.50e-003
1.30e-002
1.95e-002
2.60e-002
3.25e-002
3.90e-002
4.55e-002
5.20e-002
5.85e-002
6.50e-002
7.15e-002
7.80e-002
8.45e-002
9.10e-002
9.75e-002
1.04e-001
1.11e-001
1.17e-001
1.24e-001
1.30e-001
Shear
Tension
20 20 20 20 20 20 20
Project: MSEW Design
Analysis Description: Design 27
Drawn By: RSN
Scale: 1:171
Company: -
Date: 2019/10/07, 07:44:15 PM
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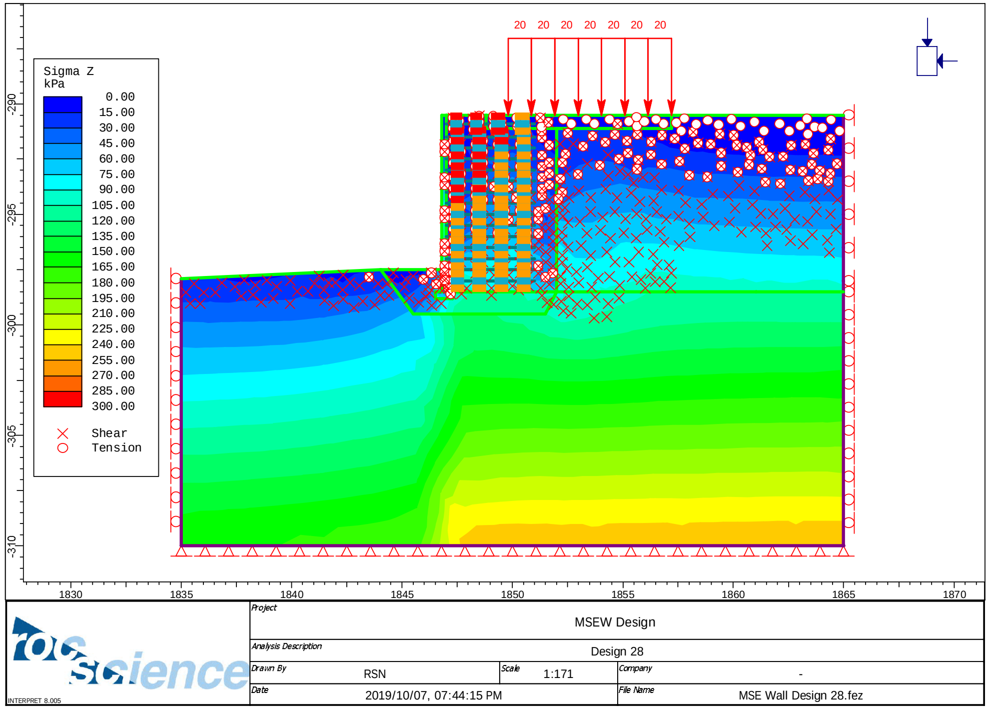
INTERPRET 8.005


Sigma Z
kPa
0.00
15.00
30.00
45.00
60.00
75.00
90.00
105.00
120.00
135.00
150.00
165.00
180.00
195.00
210.00
225.00
240.00
255.00
270.00
285.00
300.00
Shear
Tension
20 20 20 20 20 20 20
1830 1835 1840 1845 1850 1855 1860 1865 1870
-290 -295 -300 -305 -310
Project
MSEW Design
Analysis Description
Design 28
Drawn By
RSN
Scale
1:171
Company
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Date
2019/10/07, 07:44:15 PM
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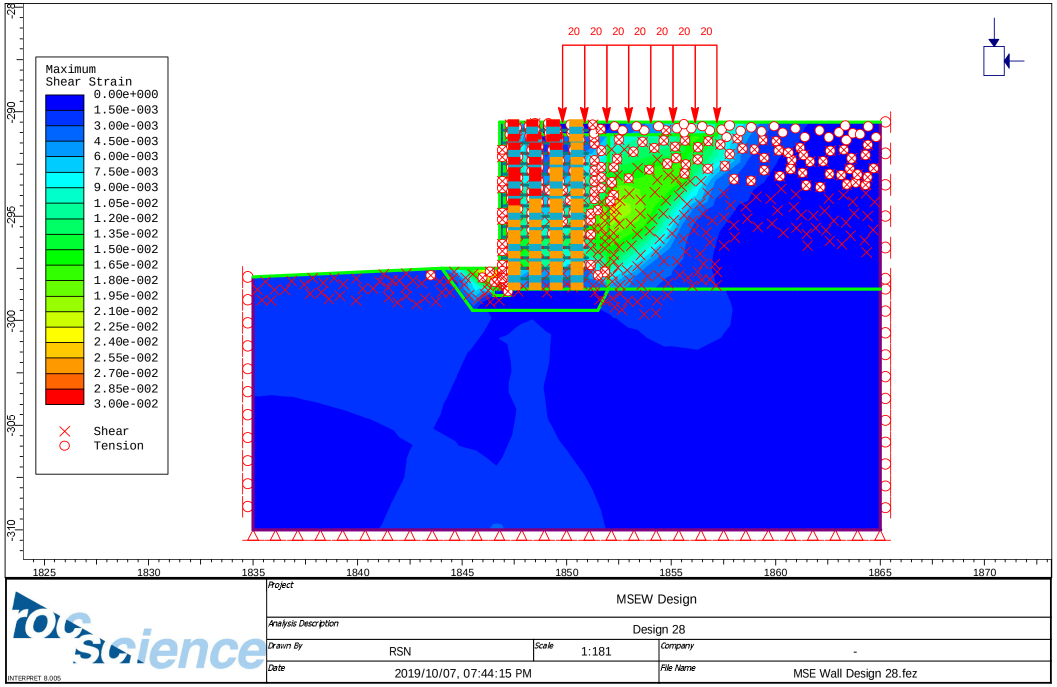
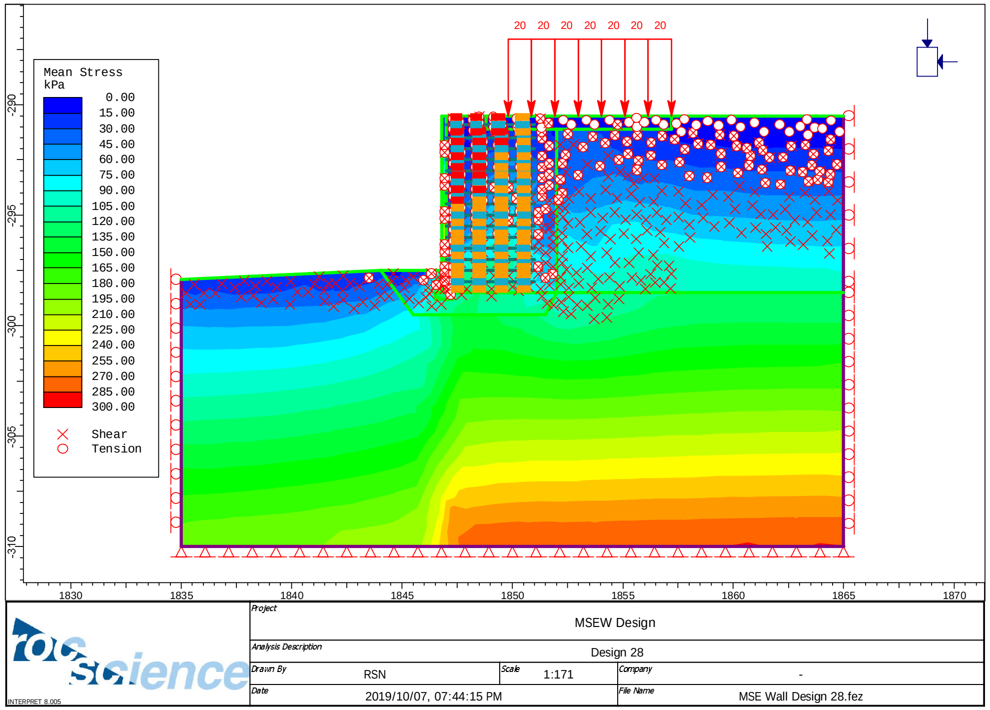
INTERPRET 8.005


Maximum
Shear Strain
0.00e+000
1.50e-003
3.00e-003
4.50e-003
6.00e-003
7.50e-003
9.00e-003
1.05e-002
1.20e-002
1.35e-002
1.50e-002
1.65e-002
1.80e-002
1.95e-002
2.10e-002
2.25e-002
2.40e-002
2.55e-002
2.70e-002
2.85e-002
3.00e-002
Shear
Tension
20 20 20 20 20 20 20
1825 1830 1835 1840 1845 1850 1855 1860 1865 1870
-285 -290 -295 -300 -305 -310
Project
MSEW Design
Analysis Description
Design 28
Drawn By
RSN
Scale
1:181
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 28.fez
INTERPRET 8.005


Mean Stress
kPa
0.00
15.00
30.00
45.00
60.00
75.00
90.00
105.00
120.00
135.00
150.00
165.00
180.00
195.00
210.00
225.00
240.00
255.00
270.00
285.00
300.00
Shear
Tension
20 20 20 20 20 20 20
1830 1835 1840 1845 1850 1855 1860 1865 1870
-290 -295 -300 -305 -310
Project
MSEW Design
Analysis Description
Design 28
Drawn By
RSN
Scale
1:171
Company
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Date
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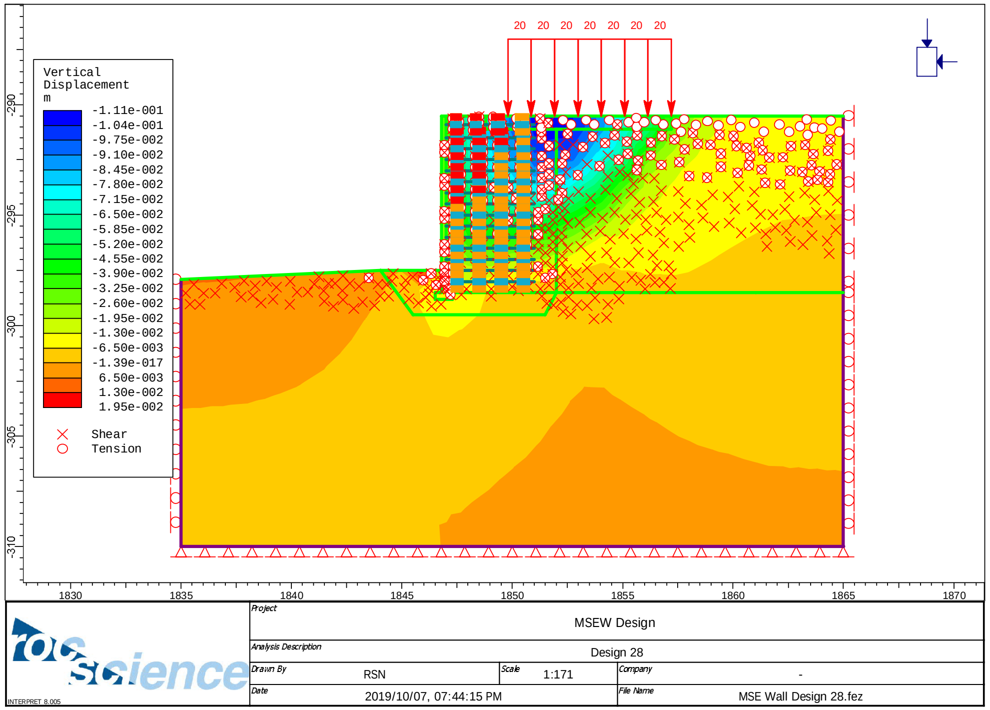
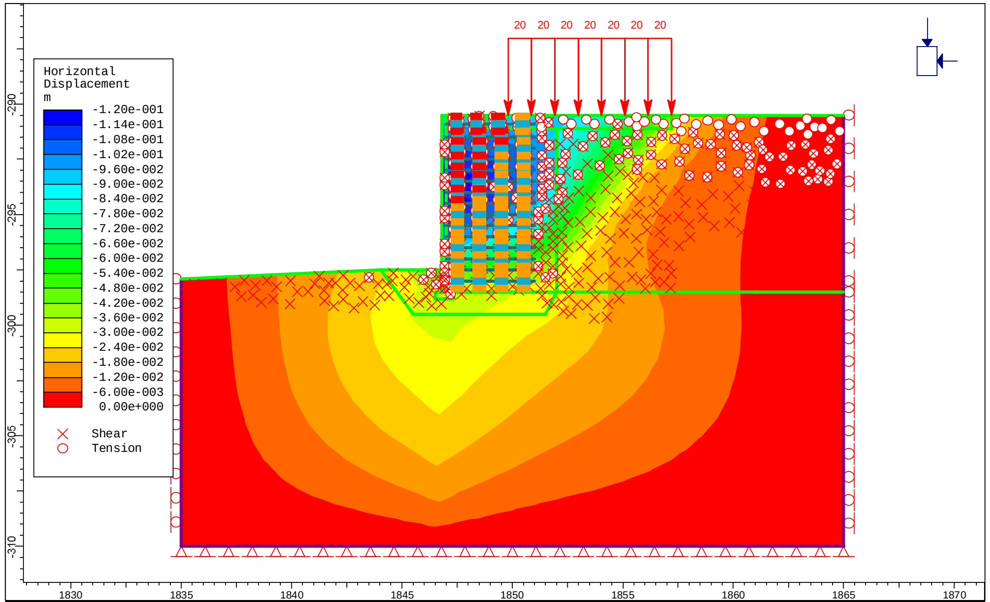
INTERPRET 8.005


Vertical
Displacement
m
-1.11e-001
-1.04e-001
-9.75e-002
-9.10e-002
-8.45e-002
-7.80e-002
-7.15e-002
-6.50e-002
-5.85e-002
-5.20e-002
-4.55e-002
-3.90e-002
-3.25e-002
-2.60e-002
-1.95e-002
-1.30e-002
-6.50e-003
-1.39e-017
6.50e-003
1.30e-002
1.95e-002
Shear
Tension
20 20 20 20 20 20 20
1830 1835 1840 1845 1850 1855 1860 1865 1870
-290 -295 -300 -305 -310
Project
MSEW Design
Analysis Description
Design 28
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 28.fez
INTERPRET 8.005



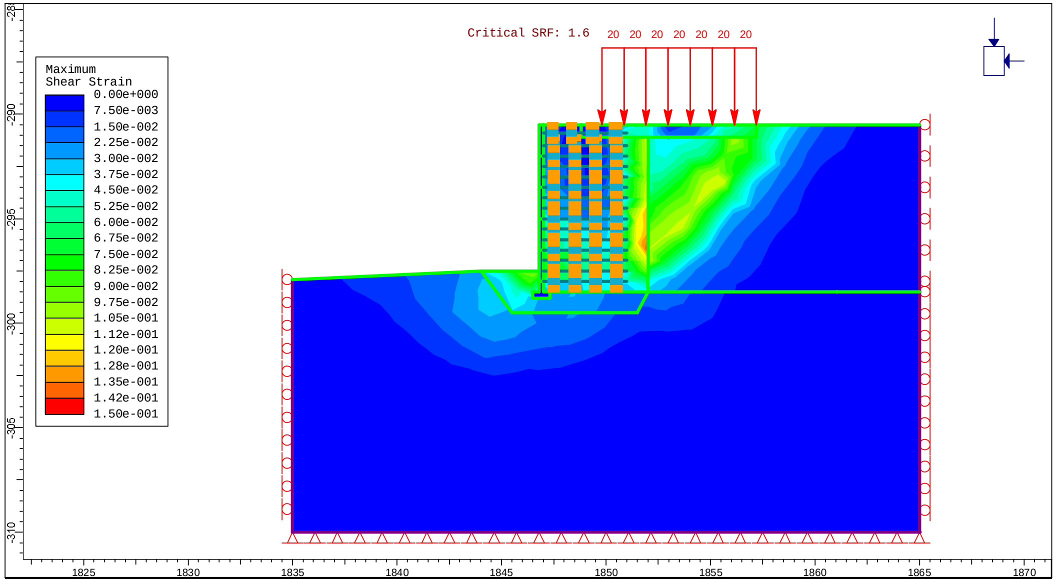
Project: MSEW Design

Analysis Description: Design 28

Drawn By: RSN | Scale: 1:171 | Company: -

Date: 2019/10/07, 07:44:15 PM | File Name: MSE Wall Design 28.fez

INTERPRET 8.005



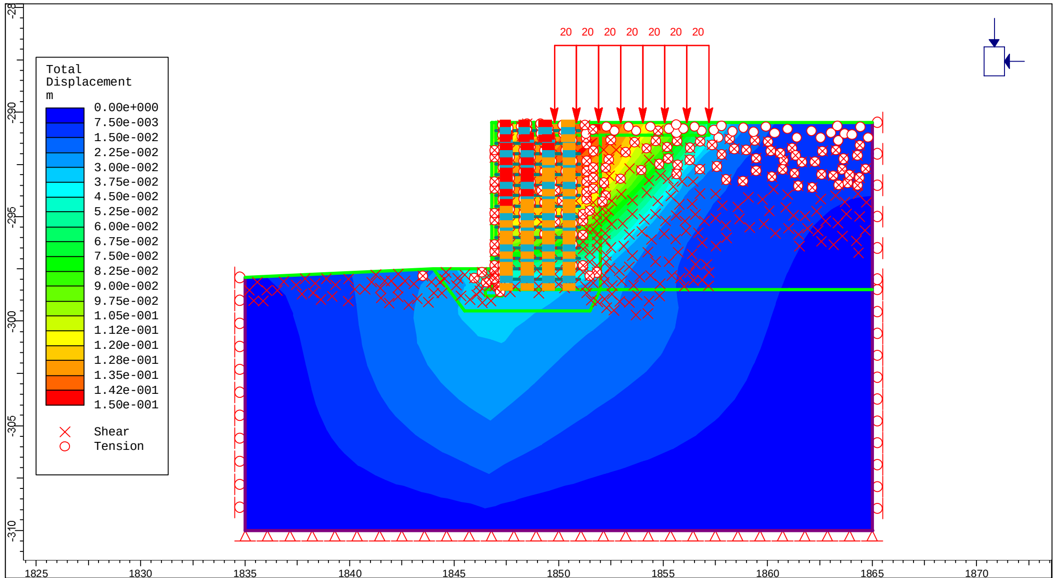
Project: MSEW Design

Analysis Description: Design 28

Drawn By: RSN | Scale: 1:181 | Company: -

Date: 2019/10/07, 07:44:15 PM | File Name: MSE Wall Design 28.fez

INTERPRET 8.005



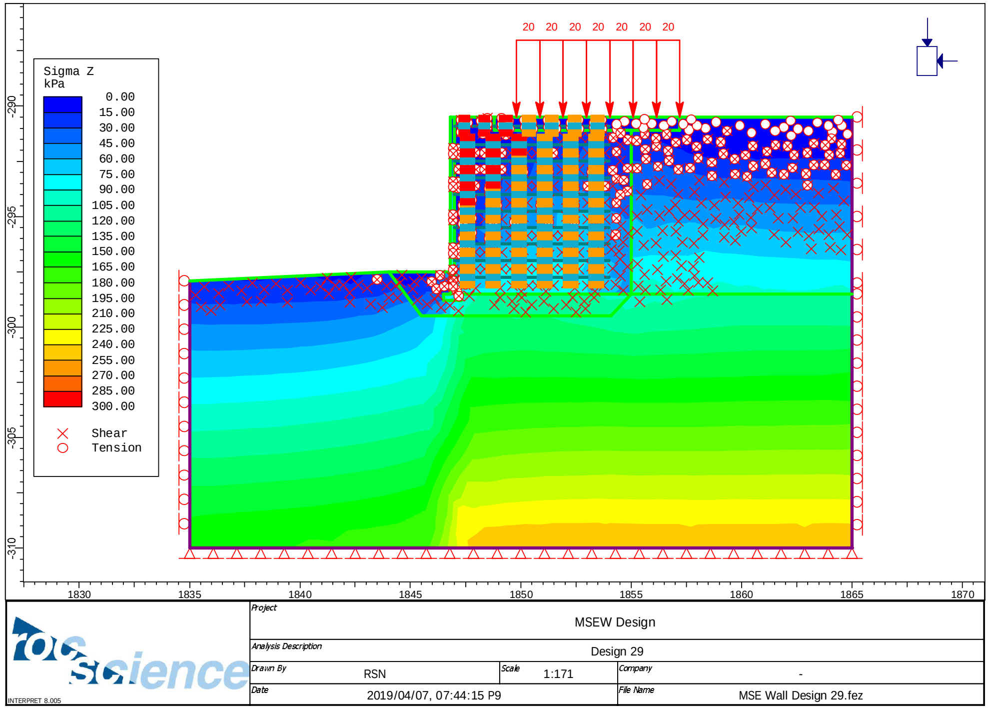
Project: MSEW Design

Analysis Description: Design 28

Drawn By: RSN | Scale: 1:181 | Company: -

Date: 2019/10/07, 07:44:15 PM | File Name: MSE Wall Design 28.fez

INTERPRET 8.005


Sigma Z
kPa
0.00
15.00
30.00
45.00
60.00
75.00
90.00
105.00
120.00
135.00
150.00
165.00
180.00
195.00
210.00
225.00
240.00
255.00
270.00
285.00
300.00
Shear
Tension
20 20 20 20 20 20 20
-290
-295
-300
-305
-310
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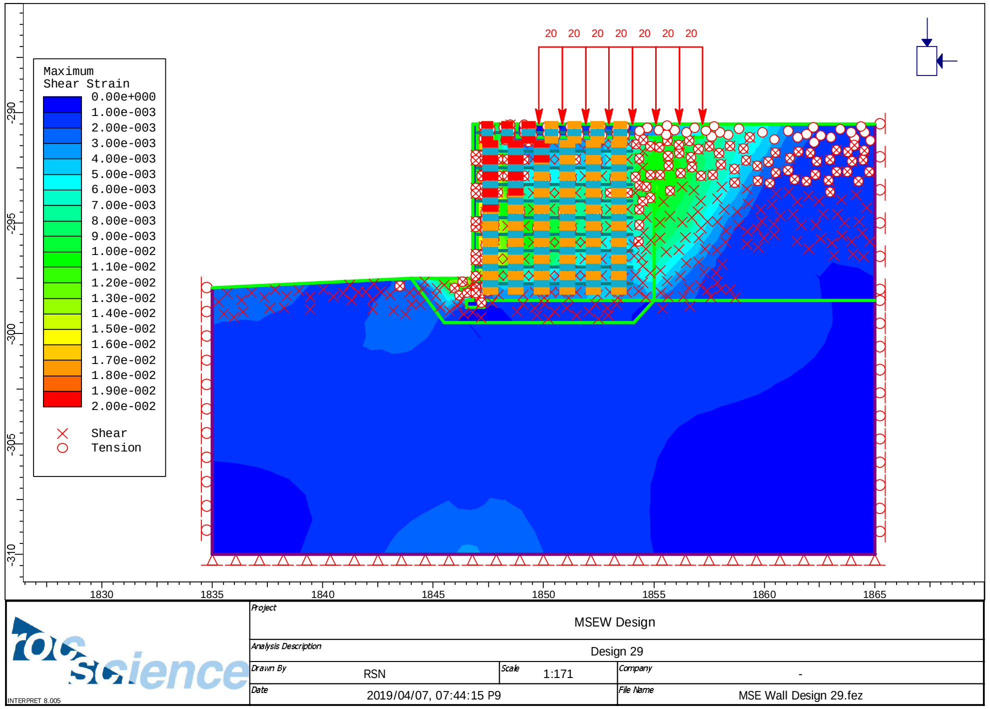
Project
MSEW Design
Analysis Description
Design 29
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/04/07, 07:44:15 P9
File Name
MSE Wall Design 29.fez
INTERPRET 8.005


Maximum
Shear Strain
0.00e+000
1.00e-003
2.00e-003
3.00e-003
4.00e-003
5.00e-003
6.00e-003
7.00e-003
8.00e-003
9.00e-003
1.00e-002
1.10e-002
1.20e-002
1.30e-002
1.40e-002
1.50e-002
1.60e-002
1.70e-002
1.80e-002
1.90e-002
2.00e-002
Shear
Tension
20 20 20 20 20 20 20
-290
-295
-300
-305
-310
1830
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1860
1865
Project
MSEW Design
Analysis Description
Design 29
Drawn By
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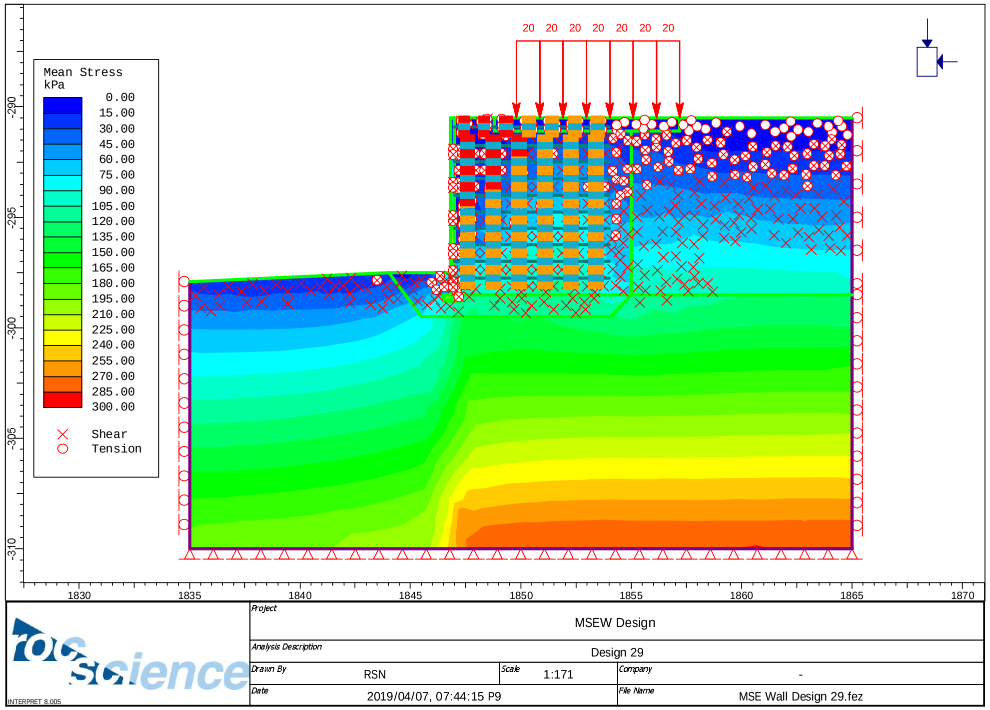
Scale
1:171
Company
-
Date
2019/04/07, 07:44:15 P9
File Name
MSE Wall Design 29.fez
INTERPRET 8.005


Mean Stress
kPa
0.00
15.00
30.00
45.00
60.00
75.00
90.00
105.00
120.00
135.00
150.00
165.00
180.00
195.00
210.00
225.00
240.00
255.00
270.00
285.00
300.00
Shear
Tension
20 20 20 20 20 20 20
-290
-295
-300
-305
-310
1830
1835
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1860
1865
1870
Project
MSEW Design
Analysis Description
Design 29
Drawn By
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1:171
Company
-
Date
2019/04/07, 07:44:15 P9
File Name
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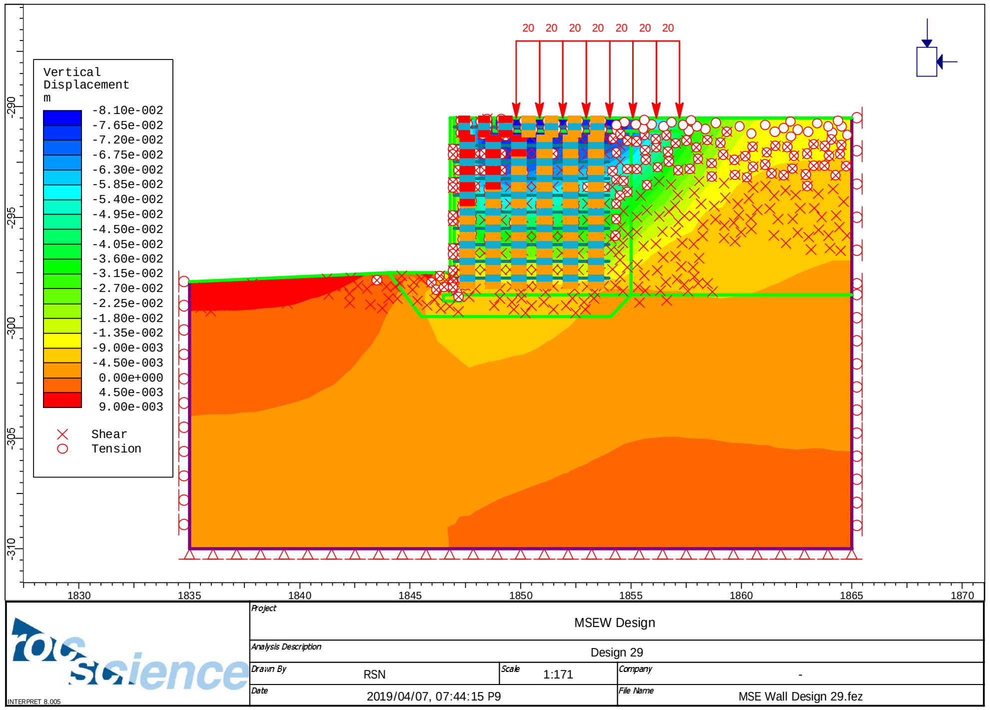
INTERPRET 8.005


Vertical
Displacement
m
-8.10e-002
-7.65e-002
-7.20e-002
-6.75e-002
-6.30e-002
-5.85e-002
-5.40e-002
-4.95e-002
-4.50e-002
-4.05e-002
-3.60e-002
-3.15e-002
-2.70e-002
-2.25e-002
-1.80e-002
-1.35e-002
-9.00e-003
-4.50e-003
0.00e+000
4.50e-003
9.00e-003
Shear
Tension
20 20 20 20 20 20 20
-290
-295
-300
-305
-310
1830
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1860
1865
1870
Project
MSEW Design
Analysis Description
Design 29
Drawn By
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Scale
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Company
-
Date
2019/04/07, 07:44:15 P9
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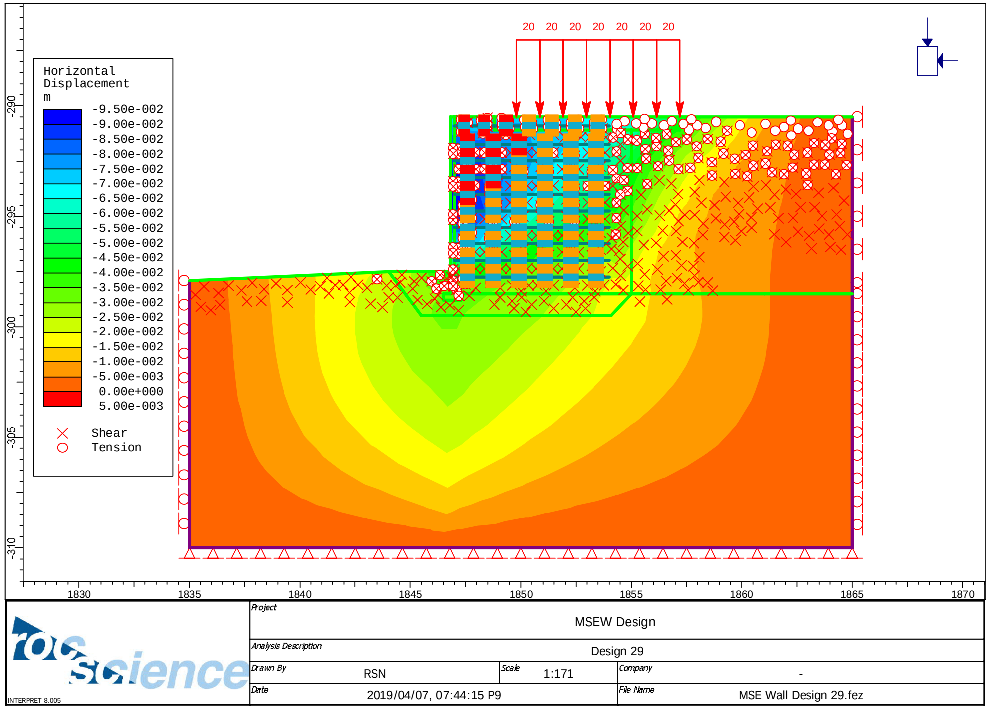
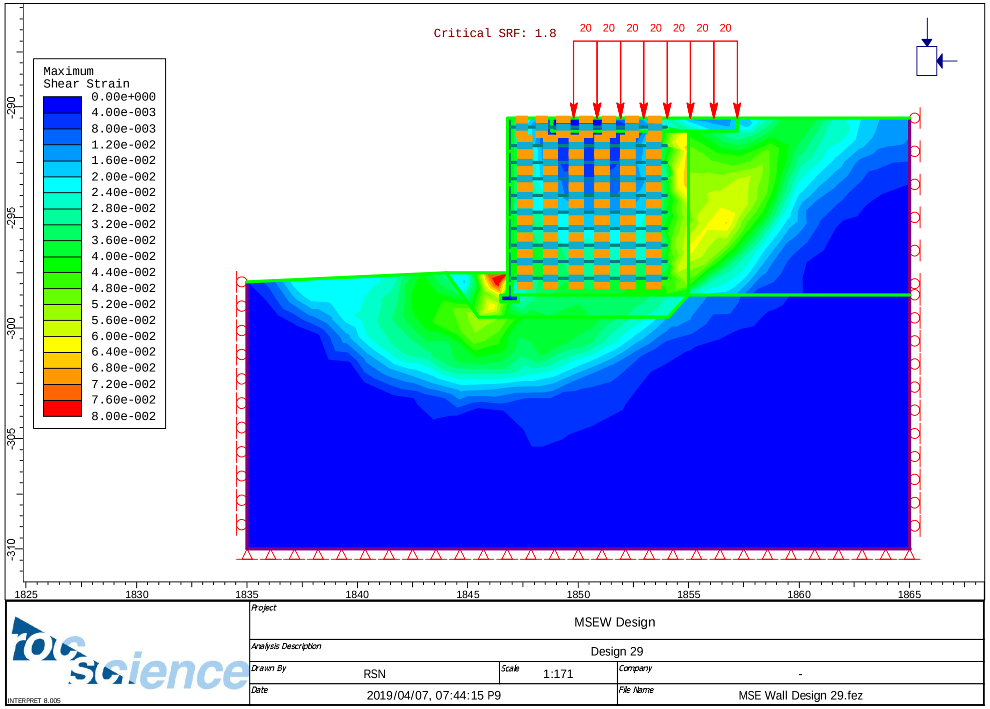
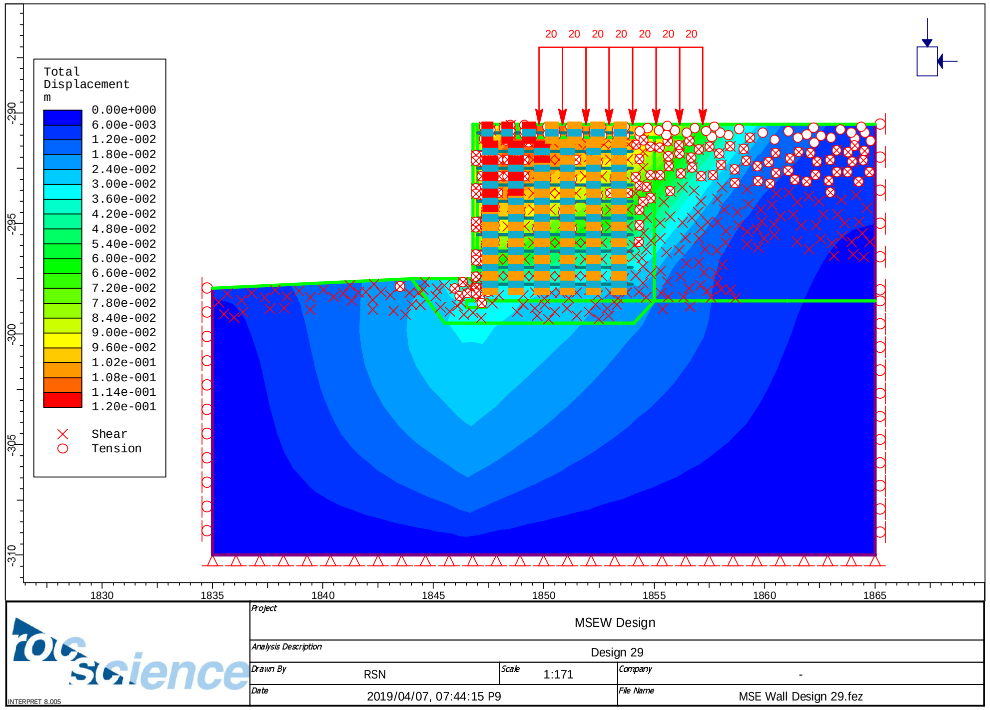
MSE Wall Design 29.fez
INTERPRET 8.005



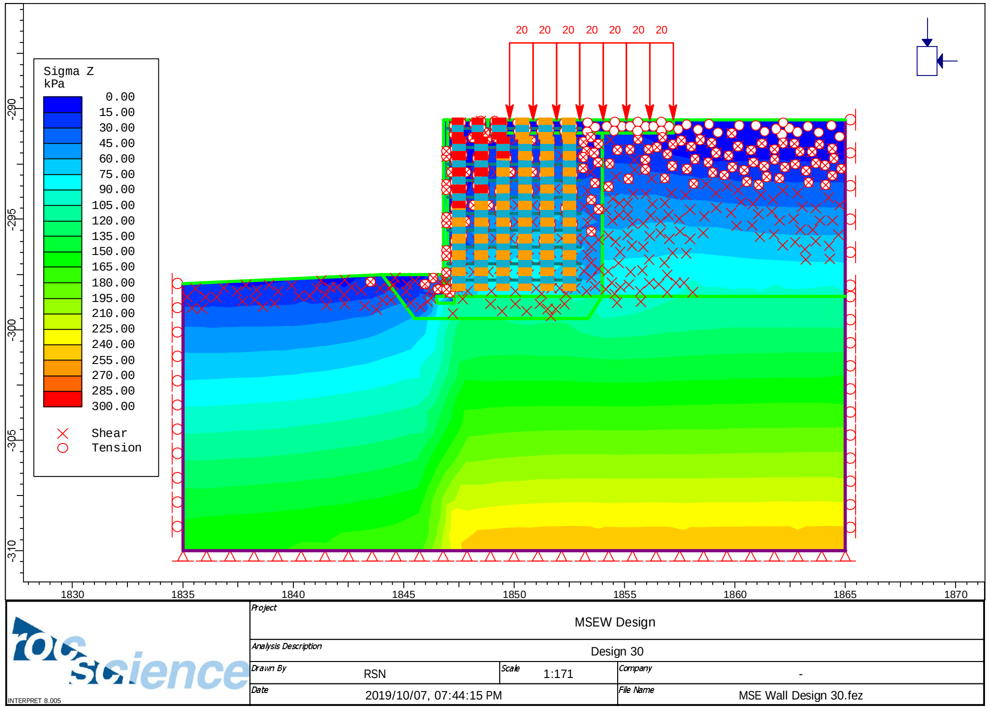
Horizontal Displacement m
-9.50e-002
-9.00e-002
-8.50e-002
-8.00e-002
-7.50e-002
-7.00e-002
-6.50e-002
-6.00e-002
-5.50e-002
-5.00e-002
-4.50e-002
-4.00e-002
-3.50e-002
-3.00e-002
-2.50e-002
-2.00e-002
-1.50e-002
-1.00e-002
-5.00e-003
0.00e+000
5.00e-003
Shear
Tension
20 20 20 20 20 20 20
Project
MSEW Design
Analysis Description
Design 29
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/04/07, 07:44:15 P9
File Name
MSE Wall Design 29.fez
INTERPRET 8.005

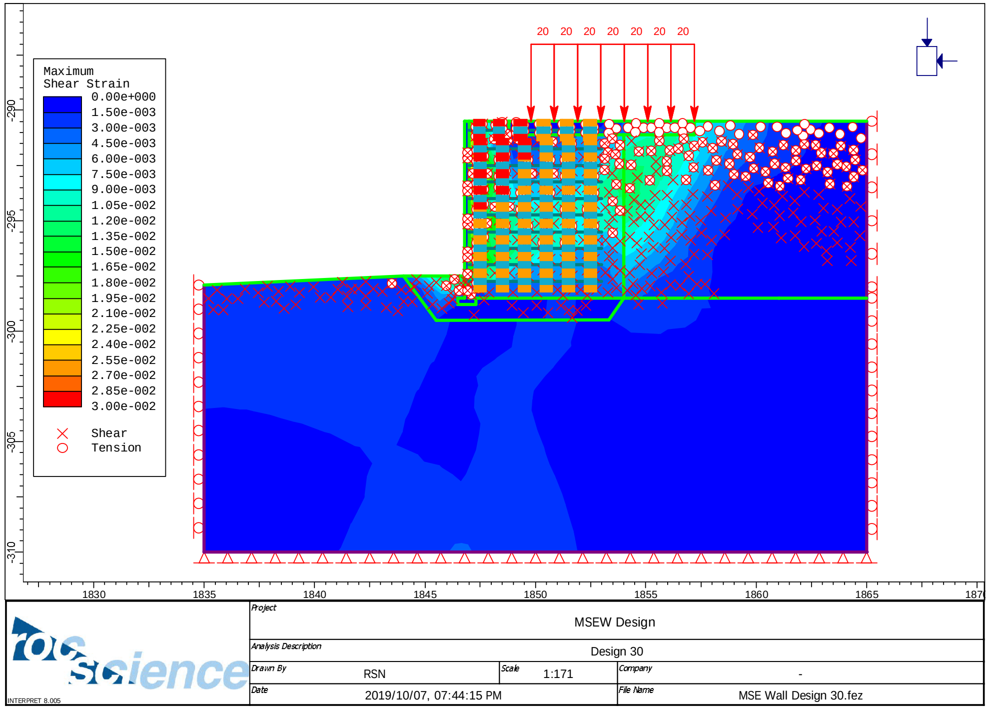


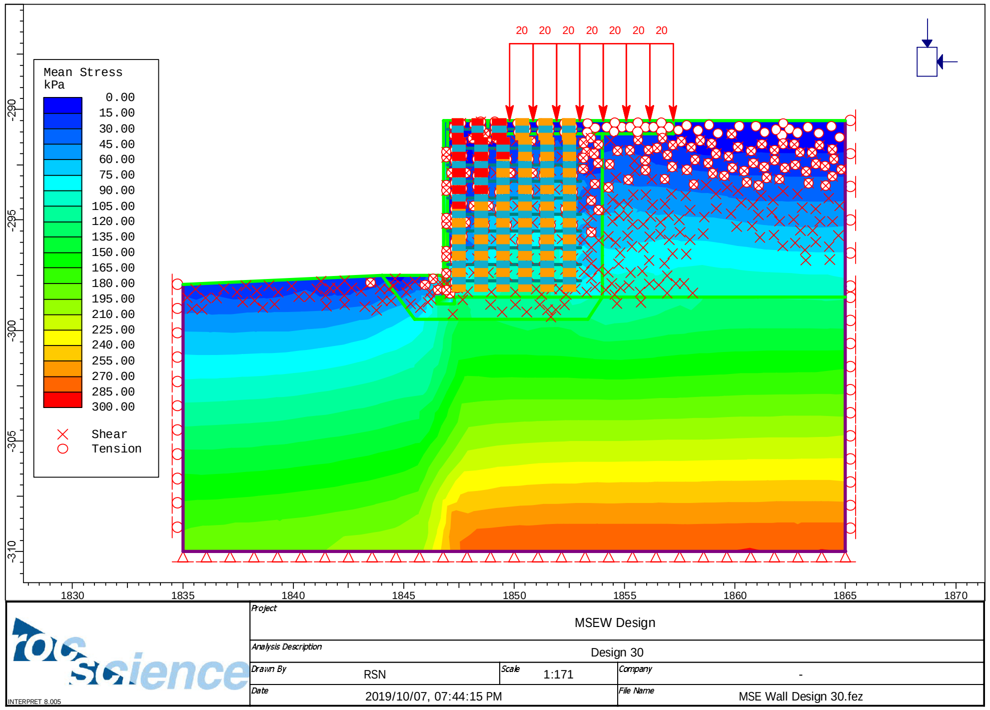
Maximum Shear Strain
0.00e+000
4.00e-003
8.00e-003
1.20e-002
1.60e-002
2.00e-002
2.40e-002
2.80e-002
3.20e-002
3.60e-002
4.00e-002
4.40e-002
4.80e-002
5.20e-002
5.60e-002
6.00e-002
6.40e-002
6.80e-002
7.20e-002
7.60e-002
8.00e-002
Critical SRF: 1.8
20 20 20 20 20 20 20
Project
MSEW Design
Analysis Description
Design 29
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/04/07, 07:44:15 P9
File Name
MSE Wall Design 29.fez
INTERPRET 8.005



Total Displacement m
0.00e+000
6.00e-003
1.20e-002
1.80e-002
2.40e-002
3.00e-002
3.60e-002
4.20e-002
4.80e-002
5.40e-002
6.00e-002
6.60e-002
7.20e-002
7.80e-002
8.40e-002
9.00e-002
9.60e-002
1.02e-001
1.08e-001
1.14e-001
1.20e-001
Shear
Tension
20 20 20 20 20 20 20
Project
MSEW Design
Analysis Description
Design 29
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/04/07, 07:44:15 P9
File Name
MSE Wall Design 29.fez
INTERPRET 8.005


Sigma Z
kPa
0.00
15.00
30.00
45.00
60.00
75.00
90.00
105.00
120.00
135.00
150.00
165.00
180.00
195.00
210.00
225.00
240.00
255.00
270.00
285.00
300.00
Shear
Tension
20 20 20 20 20 20 20
Project
MSEW Design
Analysis Description
Design 30
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 30.fez


Maximum
Shear Strain
0.00e+000
1.50e-003
3.00e-003
4.50e-003
6.00e-003
7.50e-003
9.00e-003
1.05e-002
1.20e-002
1.35e-002
1.50e-002
1.65e-002
1.80e-002
1.95e-002
2.10e-002
2.25e-002
2.40e-002
2.55e-002
2.70e-002
2.85e-002
3.00e-002
Shear
Tension
20 20 20 20 20 20 20
Project
MSEW Design
Analysis Description
Design 30
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 30.fez


Mean Stress
kPa
0.00
15.00
30.00
45.00
60.00
75.00
90.00
105.00
120.00
135.00
150.00
165.00
180.00
195.00
210.00
225.00
240.00
255.00
270.00
285.00
300.00
Shear
Tension
20 20 20 20 20 20 20
Project
MSEW Design
Analysis Description
Design 30
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
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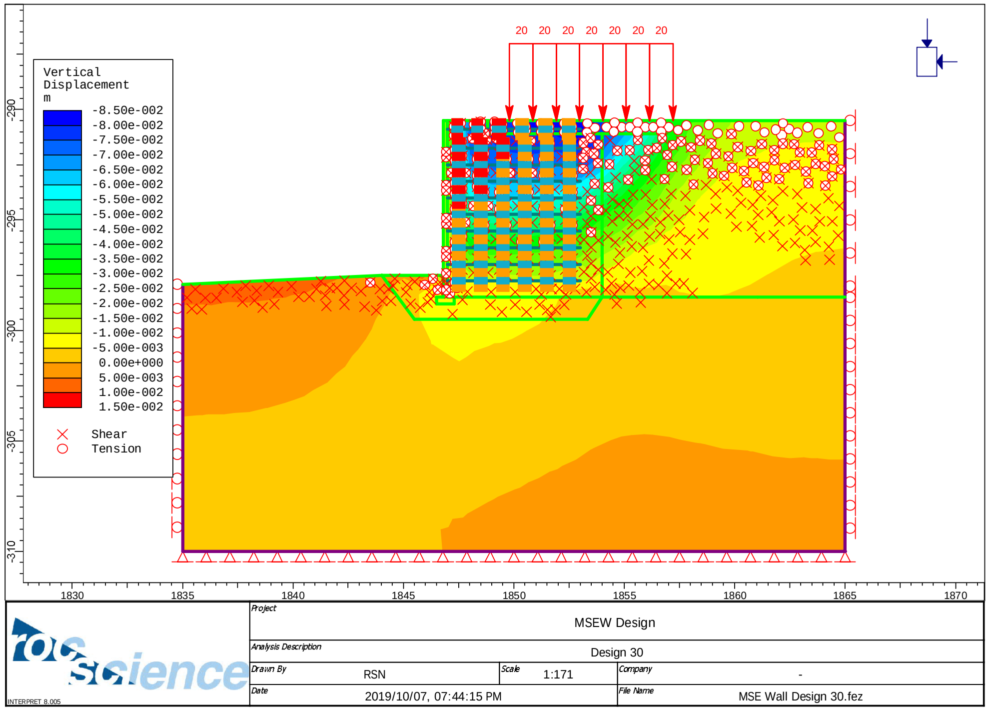
MSE Wall Design 30.fez


Vertical
Displacement
m
-8.50e-002
-8.00e-002
-7.50e-002
-7.00e-002
-6.50e-002
-6.00e-002
-5.50e-002
-5.00e-002
-4.50e-002
-4.00e-002
-3.50e-002
-3.00e-002
-2.50e-002
-2.00e-002
-1.50e-002
-1.00e-002
-5.00e-003
0.00e+000
5.00e-003
1.00e-002
1.50e-002
Shear
Tension
20 20 20 20 20 20 20
Project
MSEW Design
Analysis Description
Design 30
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RSN
Scale
1:171
Company
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Date
2019/10/07, 07:44:15 PM
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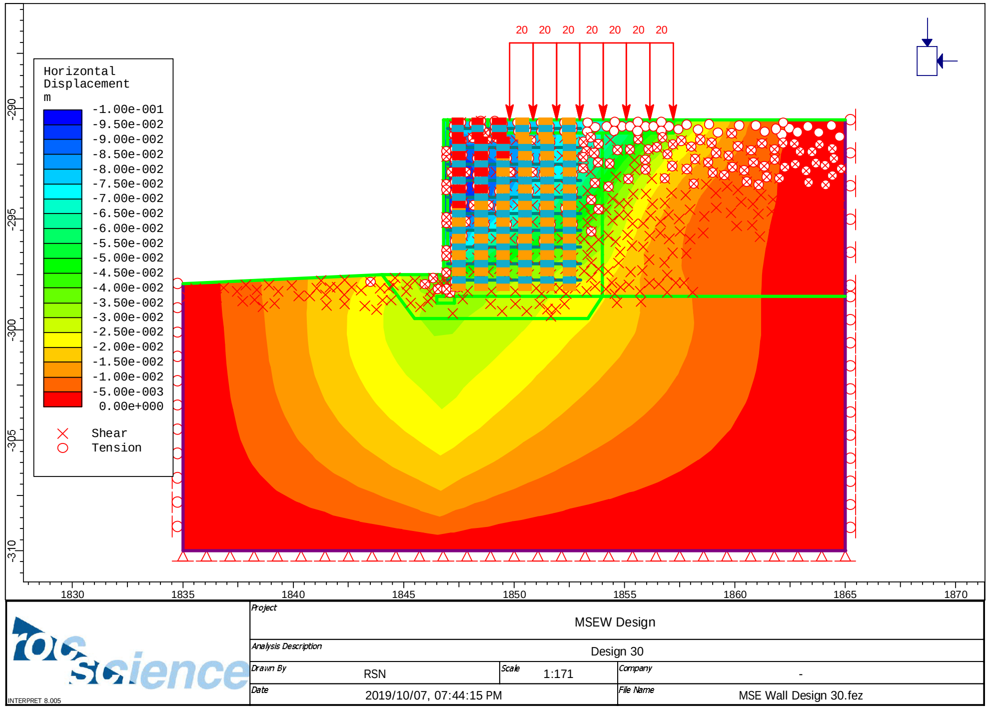
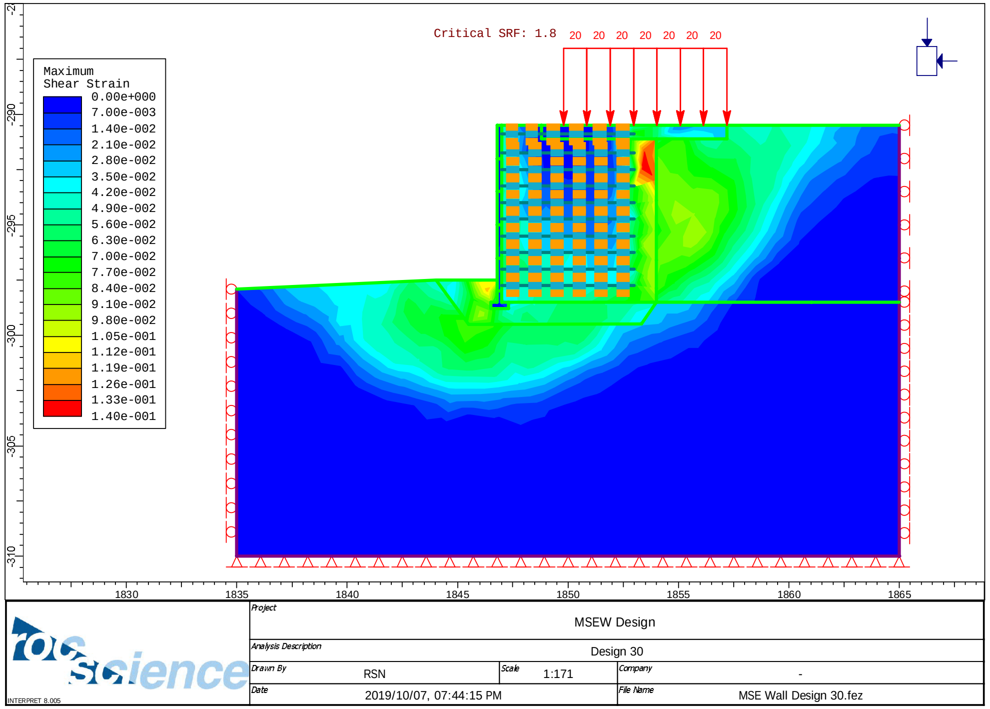


Horizontal Displacement m
-1.00e-001
-9.50e-002
-9.00e-002
-8.50e-002
-8.00e-002
-7.50e-002
-7.00e-002
-6.50e-002
-6.00e-002
-5.50e-002
-5.00e-002
-4.50e-002
-4.00e-002
-3.50e-002
-3.00e-002
-2.50e-002
-2.00e-002
-1.50e-002
-1.00e-002
-5.00e-003
0.00e+000
Shear
Tension
20 20 20 20 20 20 20
Project
MSEW Design
Analysis Description
Design 30
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 30.fez
INTERPRET 8.005



Critical SRF: 1.8
20 20 20 20 20 20 20
Maximum Shear Strain
0.00e+000
7.00e-003
1.40e-002
2.10e-002
2.80e-002
3.50e-002
4.20e-002
4.90e-002
5.60e-002
6.30e-002
7.00e-002
7.70e-002
8.40e-002
9.10e-002
9.80e-002
1.05e-001
1.12e-001
1.19e-001
1.26e-001
1.33e-001
1.40e-001
Project
MSEW Design
Analysis Description
Design 30
Drawn By
RSN
Scale
1:171
Company
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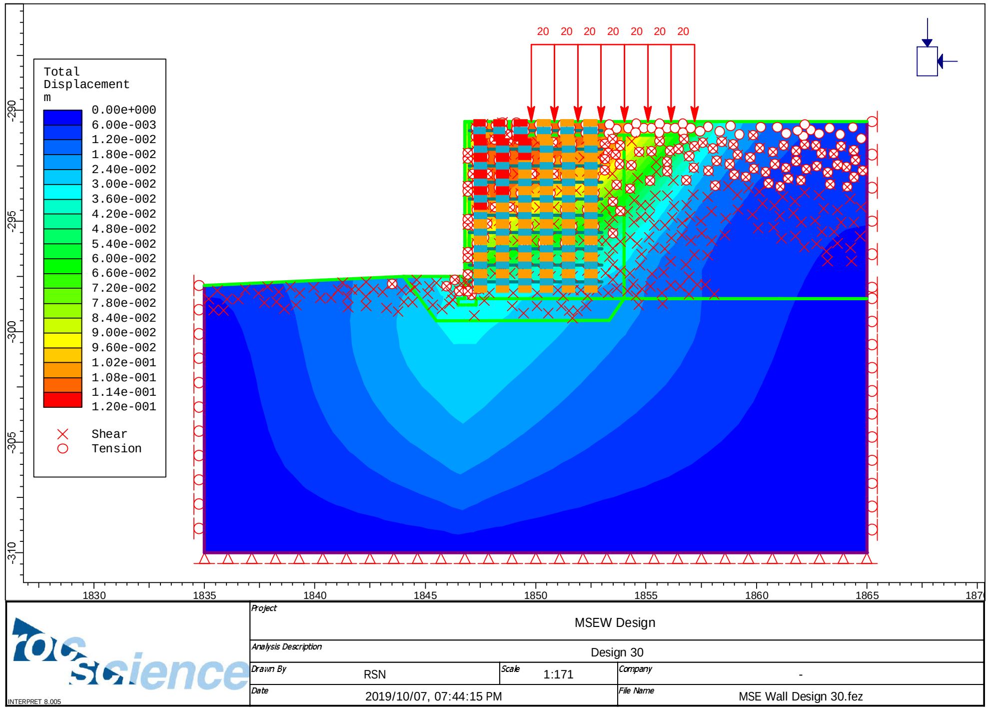
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 30.fez
INTERPRET 8.005



Total Displacement m
0.00e+000
6.00e-003
1.20e-002
1.80e-002
2.40e-002
3.00e-002
3.60e-002
4.20e-002
4.80e-002
5.40e-002
6.00e-002
6.60e-002
7.20e-002
7.80e-002
8.40e-002
9.00e-002
9.60e-002
1.02e-001
1.08e-001
1.14e-001
1.20e-001
Shear
Tension
20 20 20 20 20 20 20
Project
MSEW Design
Analysis Description
Design 30
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Company
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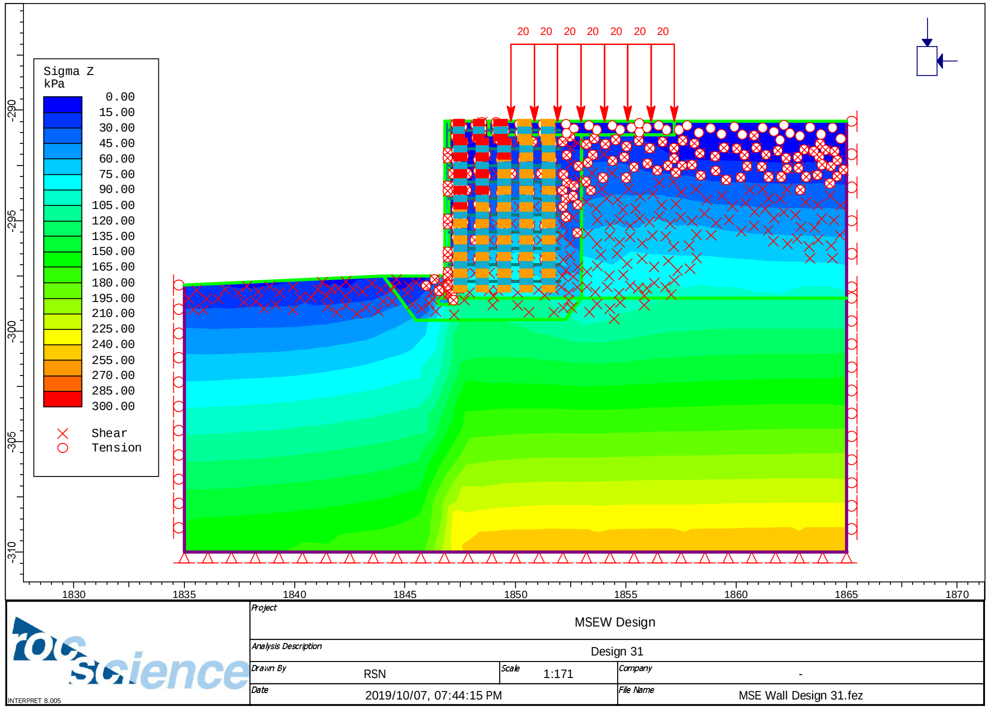
INTERPRET 8.005


20 20 20 20 20 20 20
Sigma Z
kPa
0.00
15.00
30.00
45.00
60.00
75.00
90.00
105.00
120.00
135.00
150.00
165.00
180.00
195.00
210.00
225.00
240.00
255.00
270.00
285.00
300.00
Shear
Tension
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Project
MSEW Design
Analysis Description
Design 31
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Company
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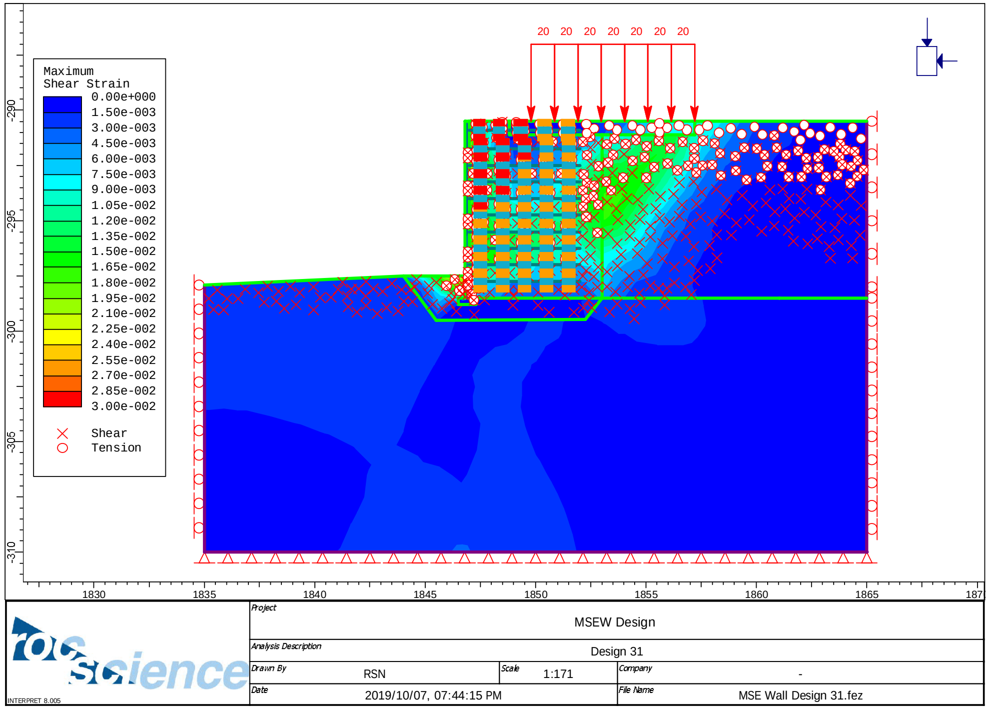
File Name
MSE Wall Design 31.fez
INTERPRET 8.005


20 20 20 20 20 20 20
Maximum
Shear Strain
0.00e+000
1.50e-003
3.00e-003
4.50e-003
6.00e-003
7.50e-003
9.00e-003
1.05e-002
1.20e-002
1.35e-002
1.50e-002
1.65e-002
1.80e-002
1.95e-002
2.10e-002
2.25e-002
2.40e-002
2.55e-002
2.70e-002
2.85e-002
3.00e-002
Shear
Tension
-290
-295
-300
-305
-310
1830
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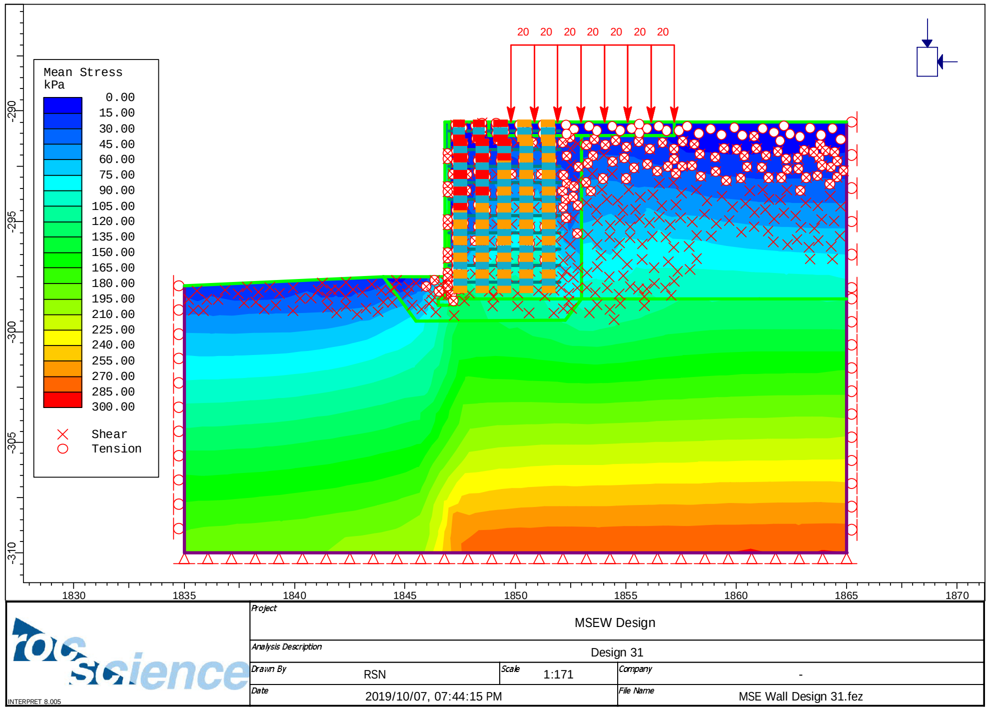
1865
187
Project
MSEW Design
Analysis Description
Design 31
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 31.fez
INTERPRET 8.005


20 20 20 20 20 20 20
Mean Stress
kPa
0.00
15.00
30.00
45.00
60.00
75.00
90.00
105.00
120.00
135.00
150.00
165.00
180.00
195.00
210.00
225.00
240.00
255.00
270.00
285.00
300.00
Shear
Tension
-290
-295
-300
-305
-310
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Project
MSEW Design
Analysis Description
Design 31
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Company
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File Name
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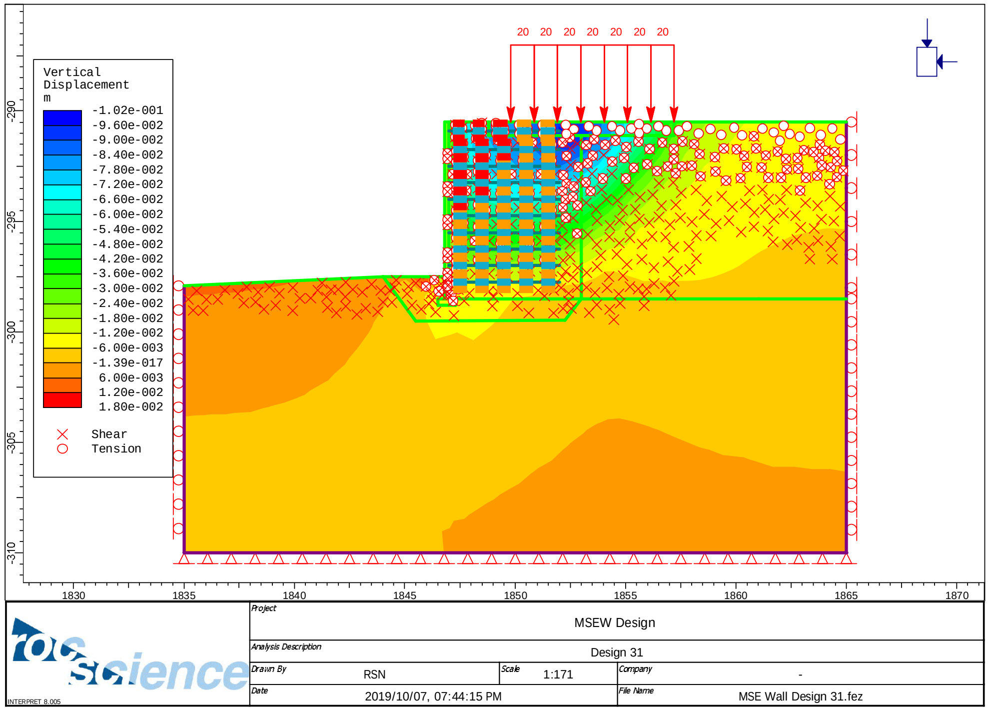
INTERPRET 8.005


20 20 20 20 20 20 20
Vertical
Displacement
m
-1.02e-001
-9.60e-002
-9.00e-002
-8.40e-002
-7.80e-002
-7.20e-002
-6.60e-002
-6.00e-002
-5.40e-002
-4.80e-002
-4.20e-002
-3.60e-002
-3.00e-002
-2.40e-002
-1.80e-002
-1.20e-002
-6.00e-003
-1.39e-017
6.00e-003
1.20e-002
1.80e-002
Shear
Tension
-290
-295
-300
-305
-310
1830
1835
1840
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1865
1870
Project
MSEW Design
Analysis Description
Design 31
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Company
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Date
2019/10/07, 07:44:15 PM
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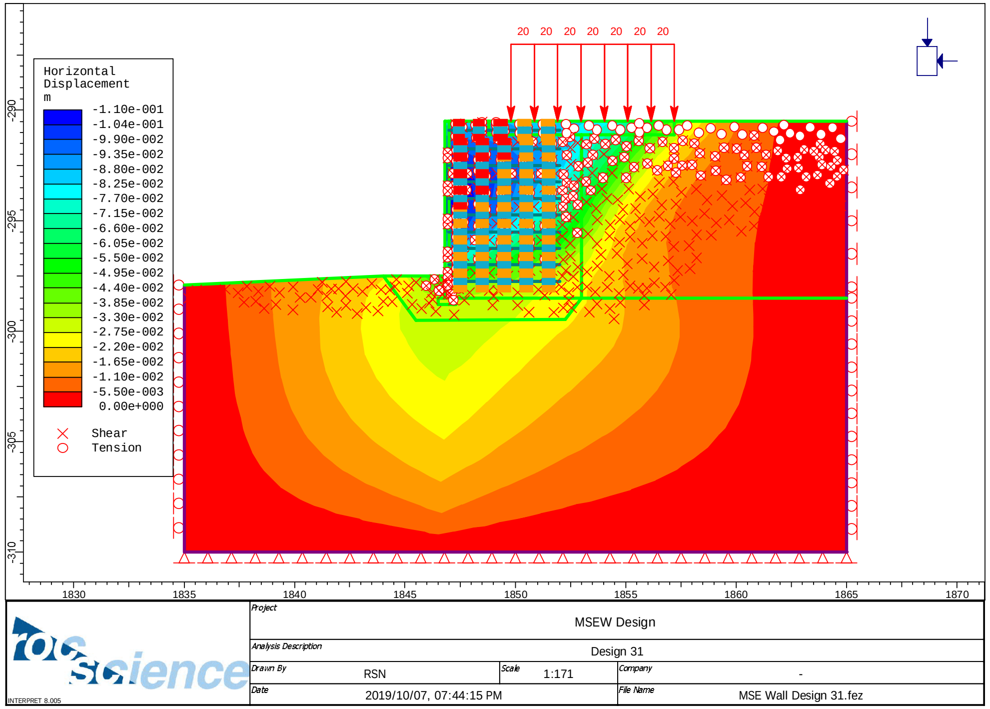
INTERPRET 8.005


Horizontal Displacement m
-1.10e-001
-1.04e-001
-9.90e-002
-9.35e-002
-8.80e-002
-8.25e-002
-7.70e-002
-7.15e-002
-6.60e-002
-6.05e-002
-5.50e-002
-4.95e-002
-4.40e-002
-3.85e-002
-3.30e-002
-2.75e-002
-2.20e-002
-1.65e-002
-1.10e-002
-5.50e-003
0.00e+000
Shear
Tension
20 20 20 20 20 20 20
Project
MSEW Design
Analysis Description
Design 31
Drawn By
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1:171
Company
-
Date
2019/10/07, 07:44:15 PM
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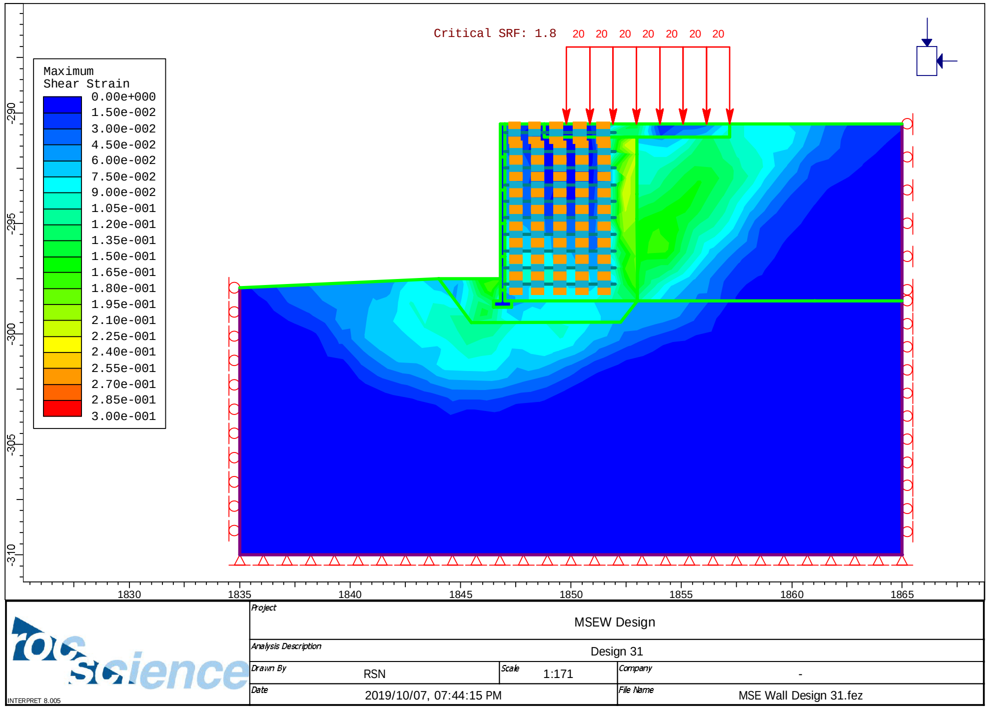
MSE Wall Design 31.fez
INTERPRET 8.005


Critical SRF: 1.8
Maximum Shear Strain
0.00e+000
1.50e-002
3.00e-002
4.50e-002
6.00e-002
7.50e-002
9.00e-002
1.05e-001
1.20e-001
1.35e-001
1.50e-001
1.65e-001
1.80e-001
1.95e-001
2.10e-001
2.25e-001
2.40e-001
2.55e-001
2.70e-001
2.85e-001
3.00e-001
20 20 20 20 20 20 20
Project
MSEW Design
Analysis Description
Design 31
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Company
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Date
2019/10/07, 07:44:15 PM
File Name
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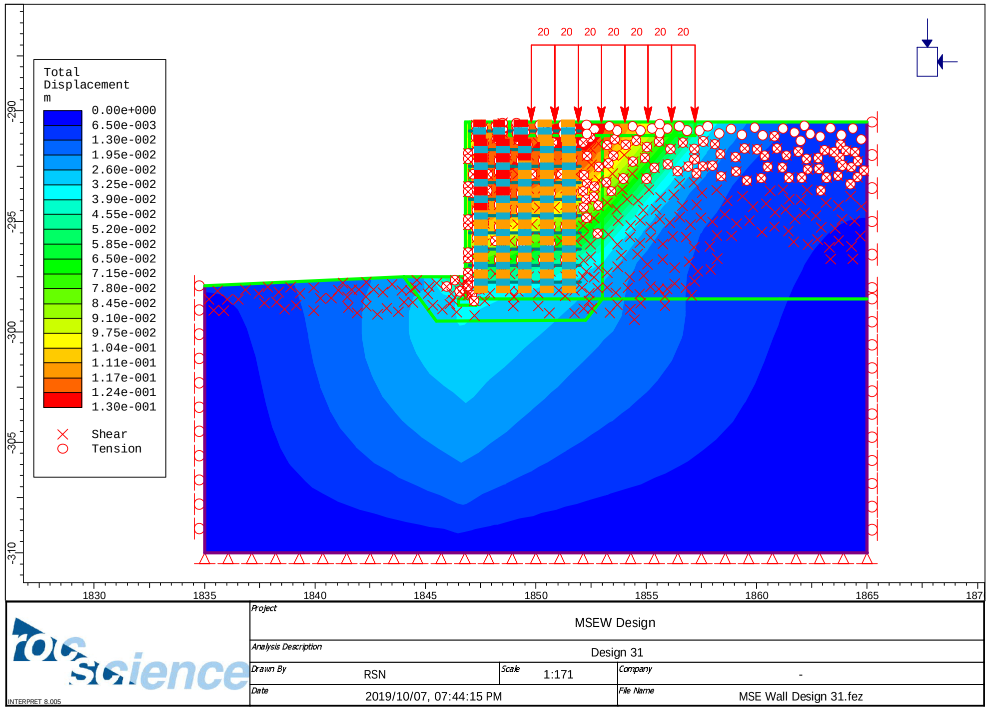
INTERPRET 8.005


Total Displacement m
0.00e+000
6.50e-003
1.30e-002
1.95e-002
2.60e-002
3.25e-002
3.90e-002
4.55e-002
5.20e-002
5.85e-002
6.50e-002
7.15e-002
7.80e-002
8.45e-002
9.10e-002
9.75e-002
1.04e-001
1.11e-001
1.17e-001
1.24e-001
1.30e-001
Shear
Tension
20 20 20 20 20 20 20
Project
MSEW Design
Analysis Description
Design 31
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1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
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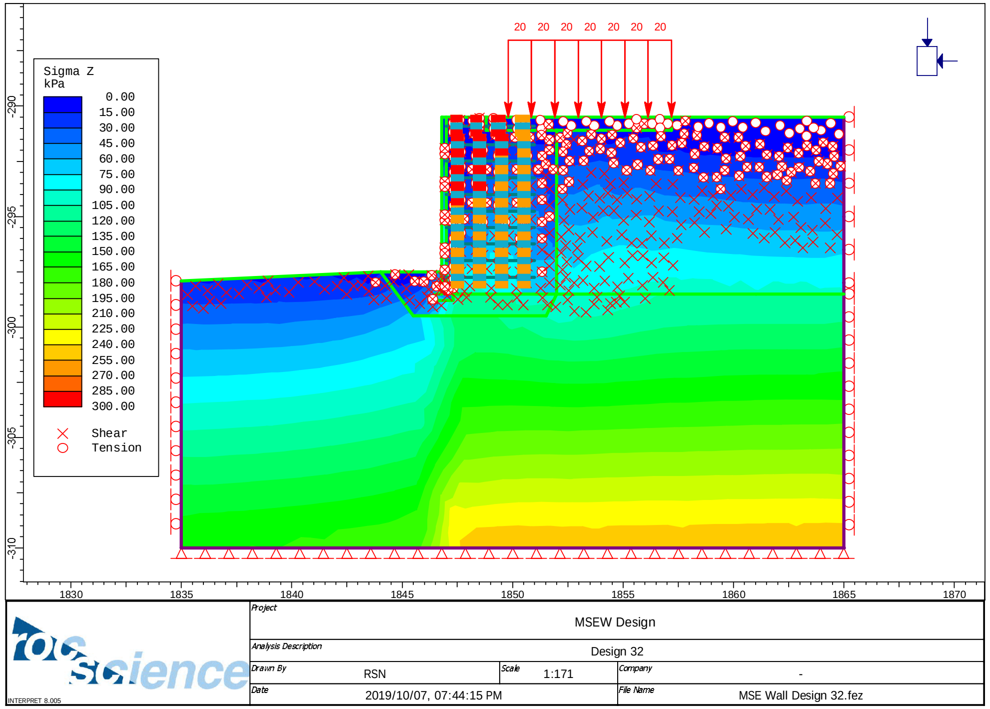
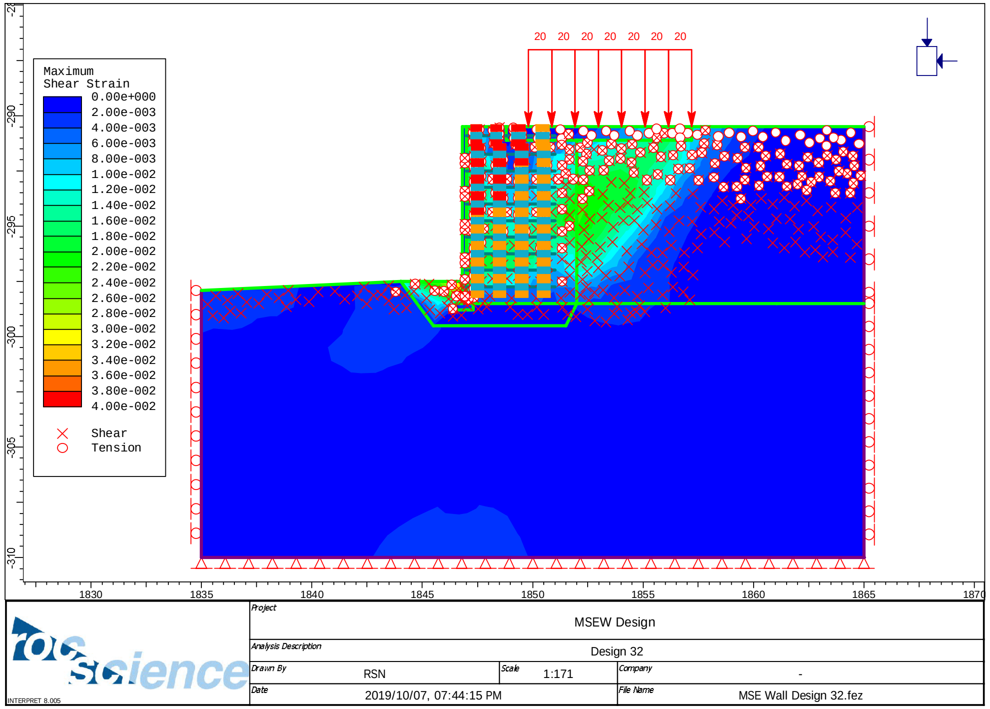
INTERPRET 8.005



Sigma Z
kPa
0.00
15.00
30.00
45.00
60.00
75.00
90.00
105.00
120.00
135.00
150.00
165.00
180.00
195.00
210.00
225.00
240.00
255.00
270.00
285.00
300.00
Shear
Tension
20 20 20 20 20 20 20
-290
-295
-300
-305
-310
1830 1835 1840 1845 1850 1855 1860 1865 1870
Project
MSEW Design
Analysis Description
Design 32
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 32.fez
INTERPRET 8.005



Maximum
Shear Strain
0.00e+000
2.00e-003
4.00e-003
6.00e-003
8.00e-003
1.00e-002
1.20e-002
1.40e-002
1.60e-002
1.80e-002
2.00e-002
2.20e-002
2.40e-002
2.60e-002
2.80e-002
3.00e-002
3.20e-002
3.40e-002
3.60e-002
3.80e-002
4.00e-002
Shear
Tension
20 20 20 20 20 20 20
-290
-295
-300
-305
-310
1830 1835 1840 1845 1850 1855 1860 1865 1870
Project
MSEW Design
Analysis Description
Design 32
Drawn By
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Scale
1:171
Company
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Date
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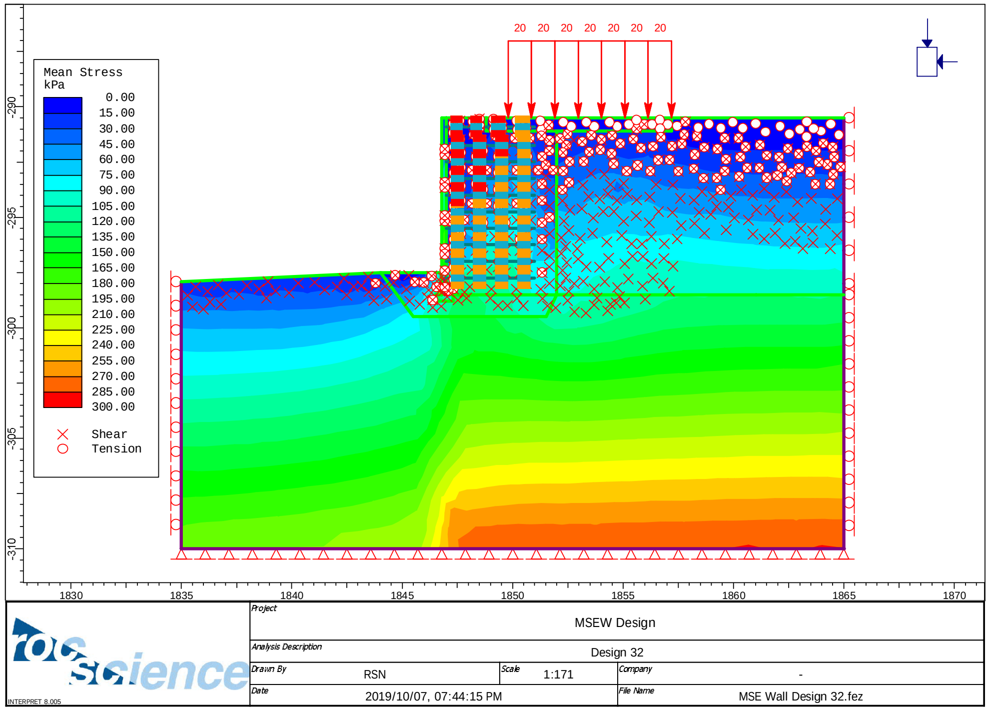
MSE Wall Design 32.fez
INTERPRET 8.005



Mean Stress
kPa
0.00
15.00
30.00
45.00
60.00
75.00
90.00
105.00
120.00
135.00
150.00
165.00
180.00
195.00
210.00
225.00
240.00
255.00
270.00
285.00
300.00
Shear
Tension
20 20 20 20 20 20 20
-290
-295
-300
-305
-310
1830 1835 1840 1845 1850 1855 1860 1865 1870
Project
MSEW Design
Analysis Description
Design 32
Drawn By
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Date
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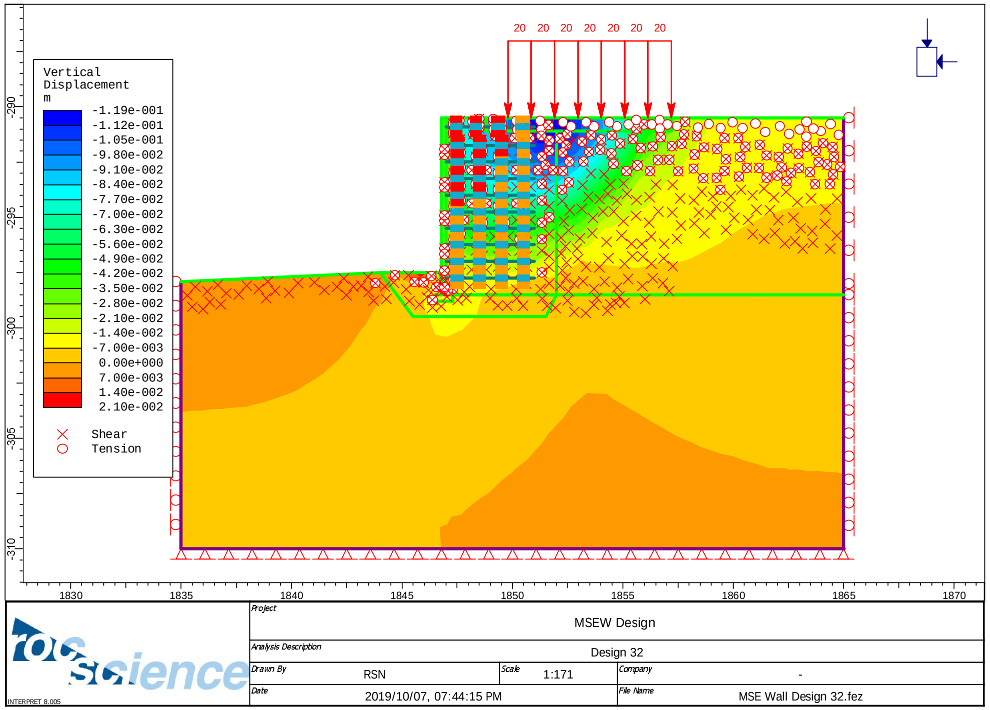
MSE Wall Design 32.fez
INTERPRET 8.005



Vertical
Displacement
m
-1.19e-001
-1.12e-001
-1.05e-001
-9.80e-002
-9.10e-002
-8.40e-002
-7.70e-002
-7.00e-002
-6.30e-002
-5.60e-002
-4.90e-002
-4.20e-002
-3.50e-002
-2.80e-002
-2.10e-002
-1.40e-002
-7.00e-003
0.00e+000
7.00e-003
1.40e-002
2.10e-002
Shear
Tension
20 20 20 20 20 20 20
-290
-295
-300
-305
-310
1830 1835 1840 1845 1850 1855 1860 1865 1870
Project
MSEW Design
Analysis Description
Design 32
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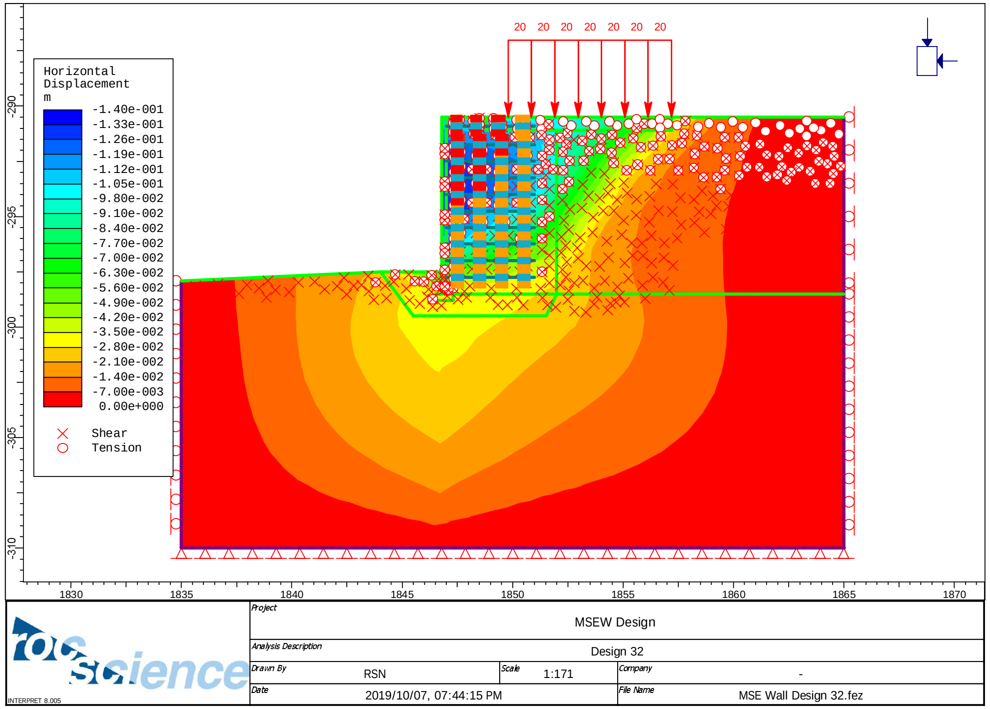
INTERPRET 8.005



Horizontal Displacement m
-1.40e-001
-1.33e-001
-1.26e-001
-1.19e-001
-1.12e-001
-1.05e-001
-9.80e-002
-9.10e-002
-8.40e-002
-7.70e-002
-7.00e-002
-6.30e-002
-5.60e-002
-4.90e-002
-4.20e-002
-3.50e-002
-2.80e-002
-2.10e-002
-1.40e-002
-7.00e-003
0.00e+000
Shear
Tension
20 20 20 20 20 20 20
1830 1835 1840 1845 1850 1855 1860 1865 1870
-290 -295 -300 -305 -310
Project
MSEW Design
Analysis Description
Design 32
Drawn By
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Company
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Date
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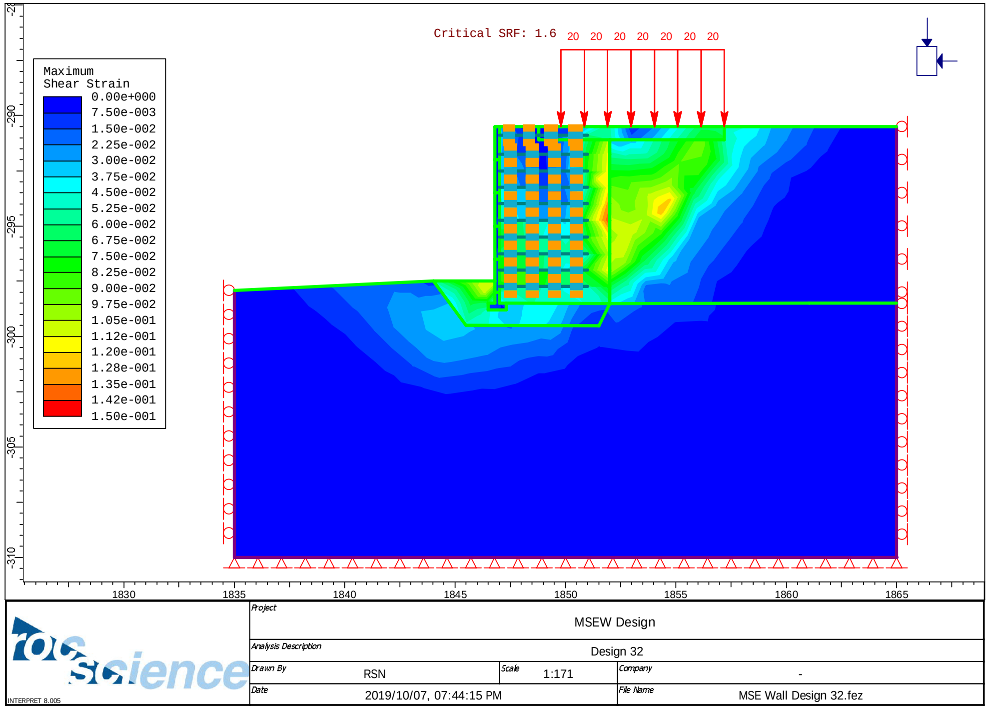
MSE Wall Design 32.fez
INTERPRET 8.005



Maximum Shear Strain
0.00e+000
7.50e-003
1.50e-002
2.25e-002
3.00e-002
3.75e-002
4.50e-002
5.25e-002
6.00e-002
6.75e-002
7.50e-002
8.25e-002
9.00e-002
9.75e-002
1.05e-001
1.12e-001
1.20e-001
1.28e-001
1.35e-001
1.42e-001
1.50e-001
Critical SRF: 1.6
20 20 20 20 20 20 20
1830 1835 1840 1845 1850 1855 1860 1865
-290 -295 -300 -305 -310
Project
MSEW Design
Analysis Description
Design 32
Drawn By
RSN
Scale
1:171
Company
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Date
2019/10/07, 07:44:15 PM
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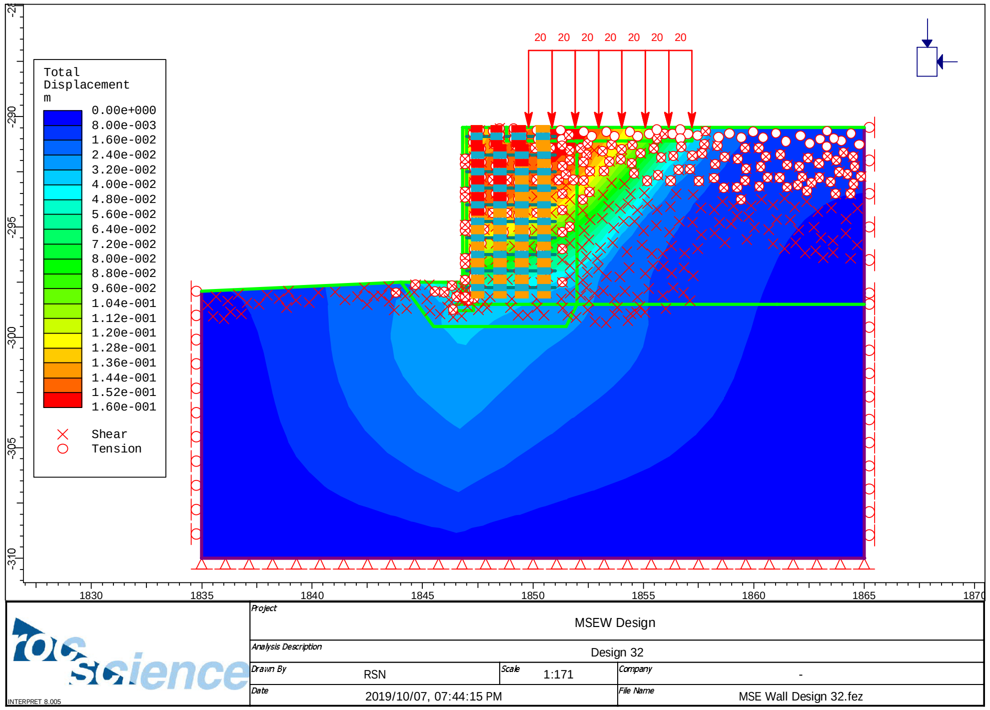
MSE Wall Design 32.fez
INTERPRET 8.005



Total Displacement m
0.00e+000
8.00e-003
1.60e-002
2.40e-002
3.20e-002
4.00e-002
4.80e-002
5.60e-002
6.40e-002
7.20e-002
8.00e-002
8.80e-002
9.60e-002
1.04e-001
1.12e-001
1.20e-001
1.28e-001
1.36e-001
1.44e-001
1.52e-001
1.60e-001
Shear
Tension
20 20 20 20 20 20 20
1830 1835 1840 1845 1850 1855 1860 1865 1870
-290 -295 -300 -305 -310
Project
MSEW Design
Analysis Description
Design 32
Drawn By
RSN
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1:171
Company
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Date
2019/10/07, 07:44:15 PM
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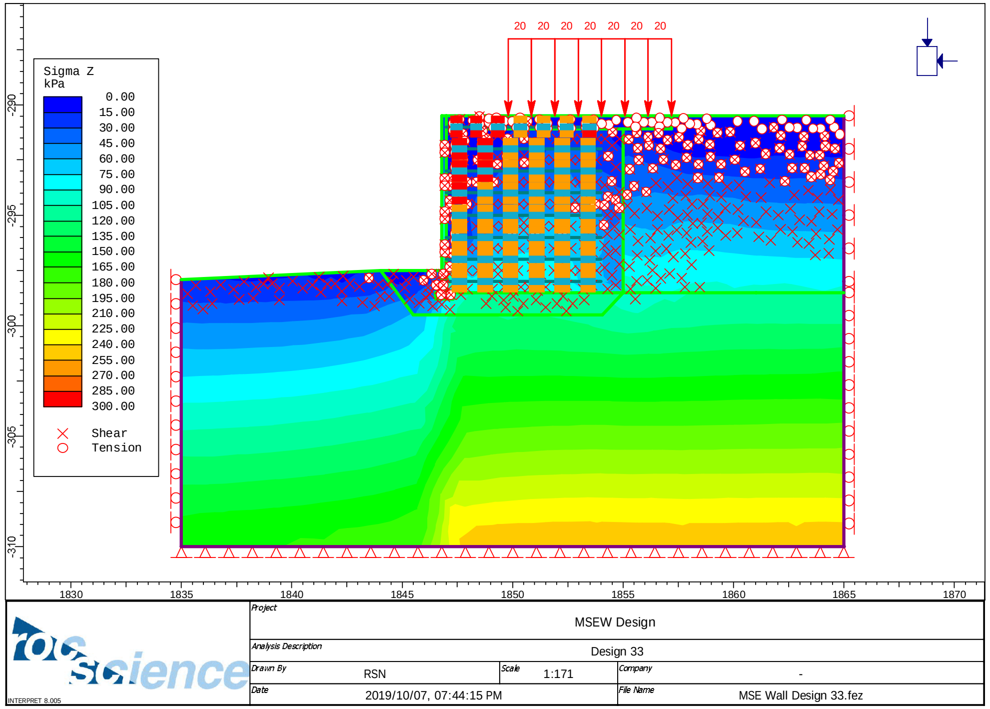
INTERPRET 8.005


20 20 20 20 20 20 20
Sigma Z
kPa
0.00
15.00
30.00
45.00
60.00
75.00
90.00
105.00
120.00
135.00
150.00
165.00
180.00
195.00
210.00
225.00
240.00
255.00
270.00
285.00
300.00
Shear
Tension
-290
-295
-300
-305
-310
1830
1835
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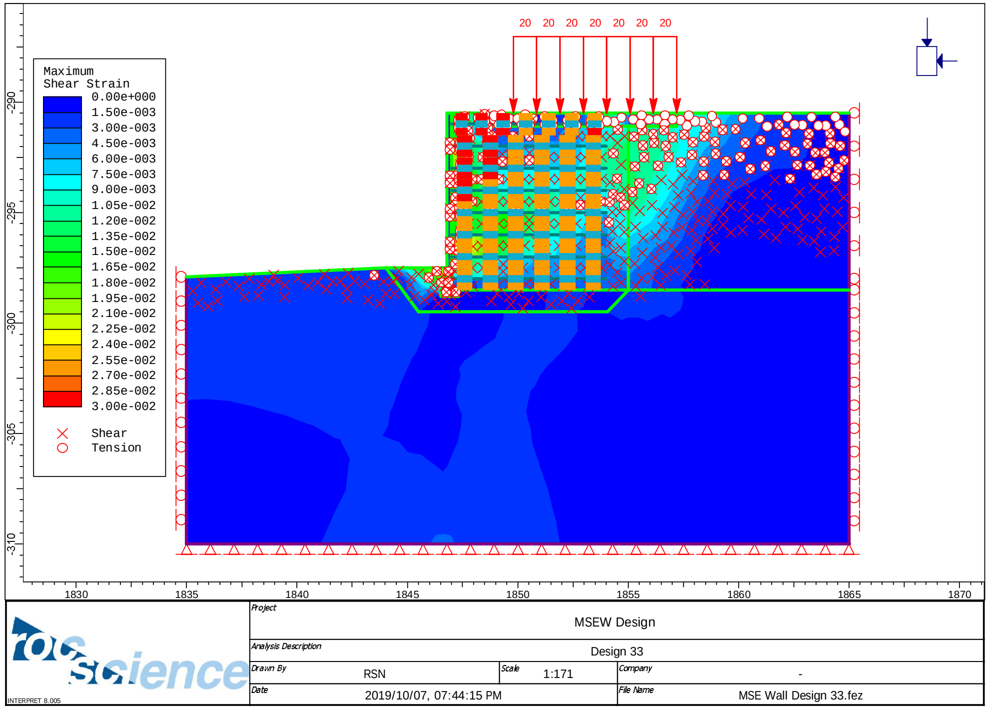
1870
Project
MSEW Design
Analysis Description
Design 33
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 33.fez
INTERPRET 8.005


20 20 20 20 20 20 20
Maximum
Shear Strain
0.00e+000
1.50e-003
3.00e-003
4.50e-003
6.00e-003
7.50e-003
9.00e-003
1.05e-002
1.20e-002
1.35e-002
1.50e-002
1.65e-002
1.80e-002
1.95e-002
2.10e-002
2.25e-002
2.40e-002
2.55e-002
2.70e-002
2.85e-002
3.00e-002
Shear
Tension
-290
-295
-300
-305
-310
1830
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1865
1870
Project
MSEW Design
Analysis Description
Design 33
Drawn By
RSN
Scale
1:171
Company
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Date
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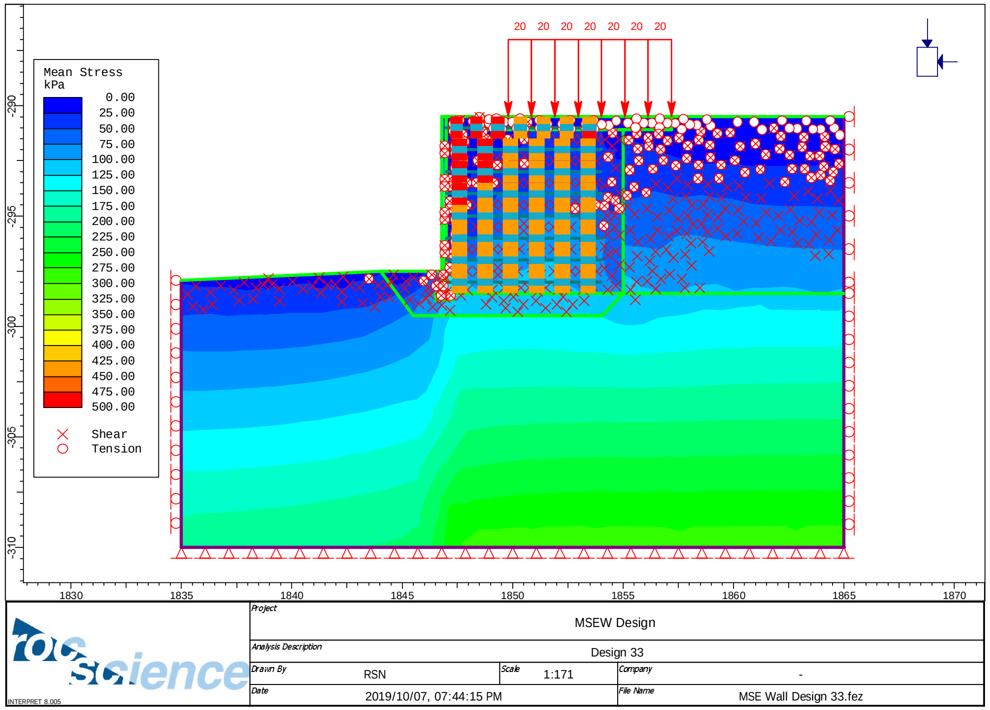
File Name
MSE Wall Design 33.fez
INTERPRET 8.005


20 20 20 20 20 20 20
Mean Stress
kPa
0.00
25.00
50.00
75.00
100.00
125.00
150.00
175.00
200.00
225.00
250.00
275.00
300.00
325.00
350.00
375.00
400.00
425.00
450.00
475.00
500.00
Shear
Tension
-290
-295
-300
-305
-310
1830
1835
1840
1845
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1870
Project
MSEW Design
Analysis Description
Design 33
Drawn By
RSN
Scale
1:171
Company
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Date
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File Name
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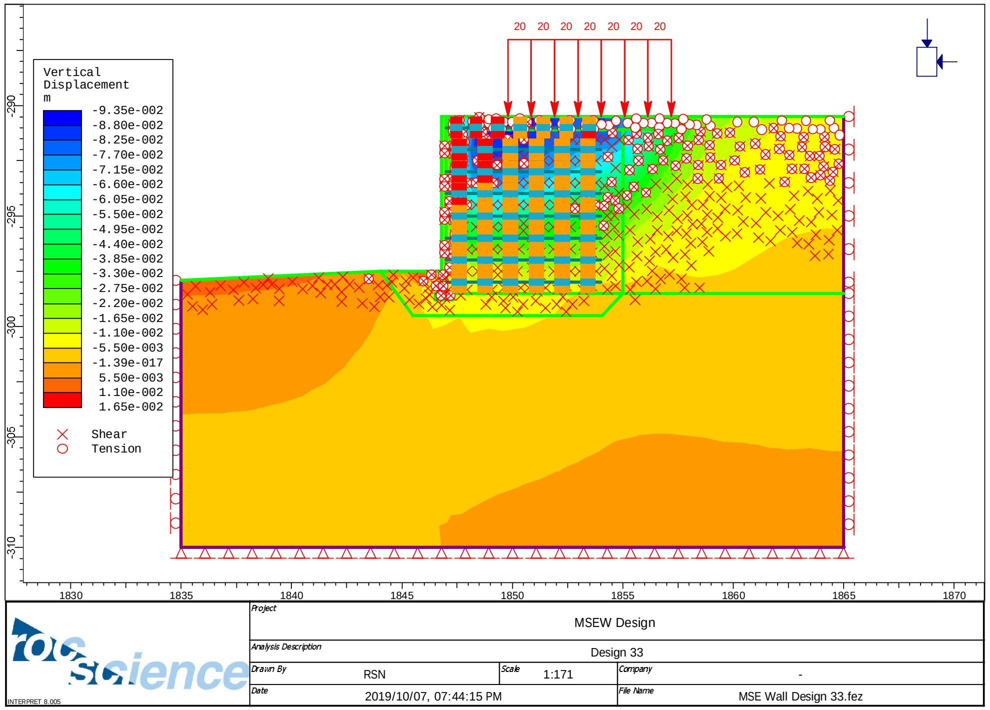
INTERPRET 8.005


20 20 20 20 20 20 20
Vertical
Displacement
m
-9.35e-002
-8.80e-002
-8.25e-002
-7.70e-002
-7.15e-002
-6.60e-002
-6.05e-002
-5.50e-002
-4.95e-002
-4.40e-002
-3.85e-002
-3.30e-002
-2.75e-002
-2.20e-002
-1.65e-002
-1.10e-002
-5.50e-003
-1.39e-017
5.50e-003
1.10e-002
1.65e-002
Shear
Tension
-290
-295
-300
-305
-310
1830
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1870
Project
MSEW Design
Analysis Description
Design 33
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Company
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Date
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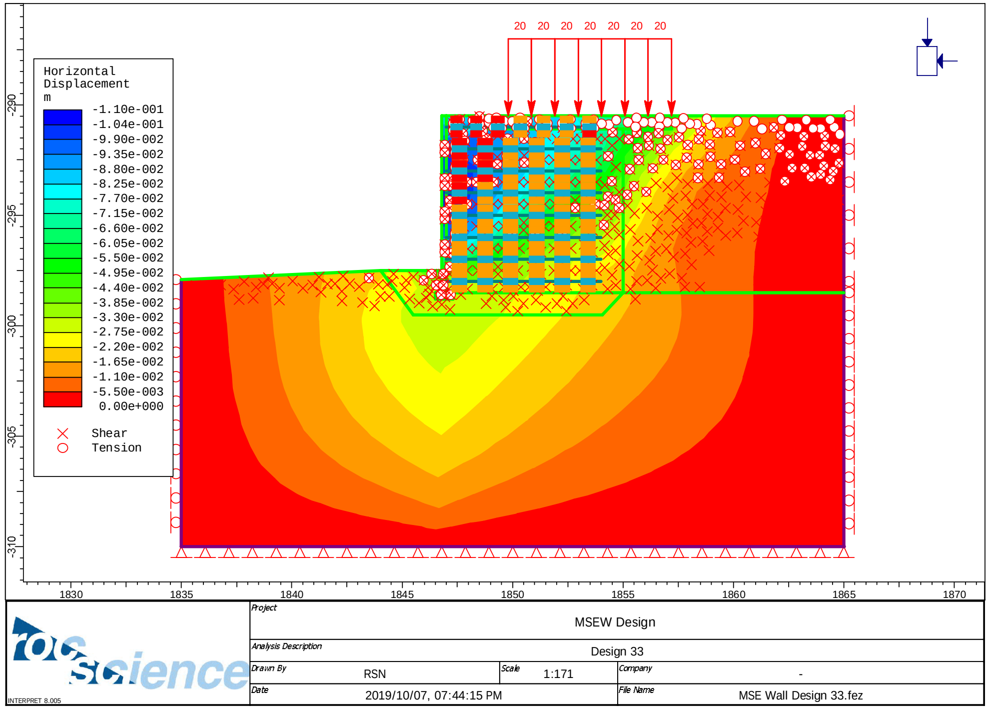
INTERPRET 8.005


20 20 20 20 20 20 20
Horizontal Displacement
m
-1.10e-001
-1.04e-001
-9.90e-002
-9.35e-002
-8.80e-002
-8.25e-002
-7.70e-002
-7.15e-002
-6.60e-002
-6.05e-002
-5.50e-002
-4.95e-002
-4.40e-002
-3.85e-002
-3.30e-002
-2.75e-002
-2.20e-002
-1.65e-002
-1.10e-002
-5.50e-003
0.00e+000
Shear
Tension
-290
-295
-300
-305
-310
1830
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Project
MSEW Design
Analysis Description
Design 33
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Date
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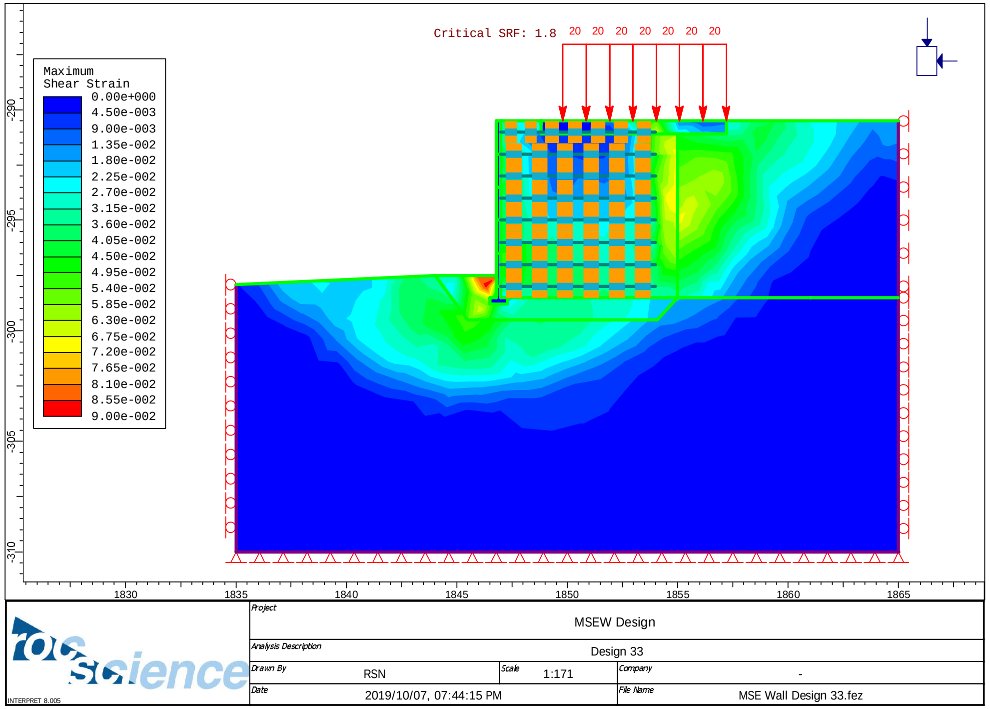
INTERPRET 8.005


Critical SRF: 1.8
20 20 20 20 20 20 20
Maximum Shear Strain
0.00e+000
4.50e-003
9.00e-003
1.35e-002
1.80e-002
2.25e-002
2.70e-002
3.15e-002
3.60e-002
4.05e-002
4.50e-002
4.95e-002
5.40e-002
5.85e-002
6.30e-002
6.75e-002
7.20e-002
7.65e-002
8.10e-002
8.55e-002
9.00e-002
-290
-295
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-305
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Project
MSEW Design
Analysis Description
Design 33
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Company
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Date
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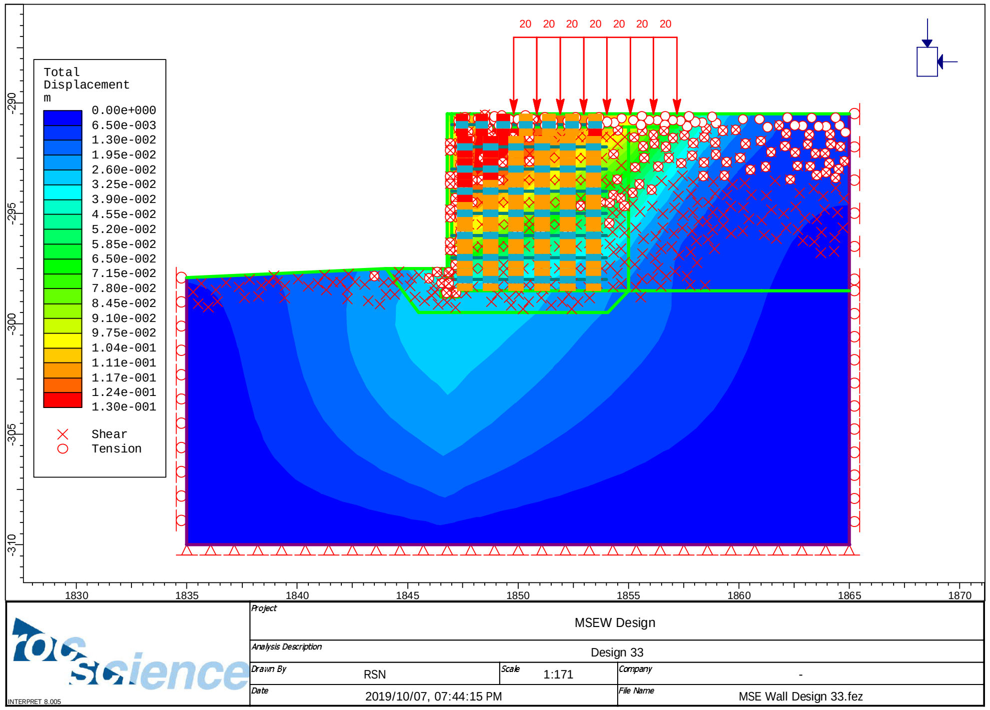
MSE Wall Design 33.fez
INTERPRET 8.005


20 20 20 20 20 20 20
Total Displacement
m
0.00e+000
6.50e-003
1.30e-002
1.95e-002
2.60e-002
3.25e-002
3.90e-002
4.55e-002
5.20e-002
5.85e-002
6.50e-002
7.15e-002
7.80e-002
8.45e-002
9.10e-002
9.75e-002
1.04e-001
1.11e-001
1.17e-001
1.24e-001
1.30e-001
Shear
Tension
-290
-295
-300
-305
-310
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Project
MSEW Design
Analysis Description
Design 33
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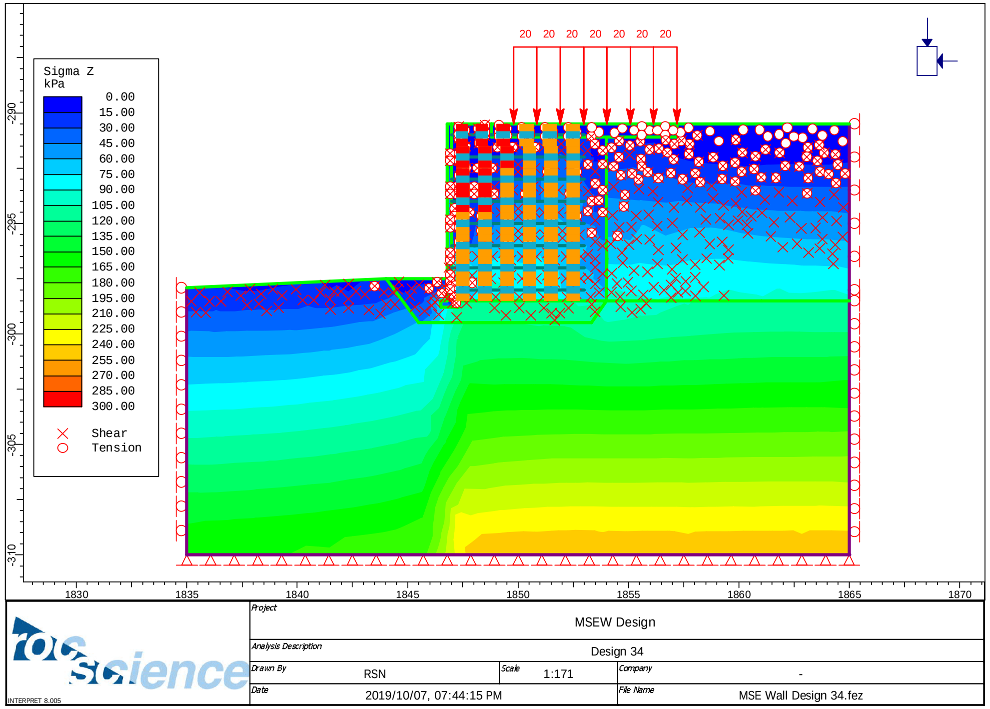
INTERPRET 8.005


Sigma Z
kPa
0.00
15.00
30.00
45.00
60.00
75.00
90.00
105.00
120.00
135.00
150.00
165.00
180.00
195.00
210.00
225.00
240.00
255.00
270.00
285.00
300.00
Shear
Tension
20 20 20 20 20 20 20
-290
-295
-300
-305
-310
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rocscience
INTERPRET 8.005
Project
MSEW Design
Analysis Description
Design 34
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Scale
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Company
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Date
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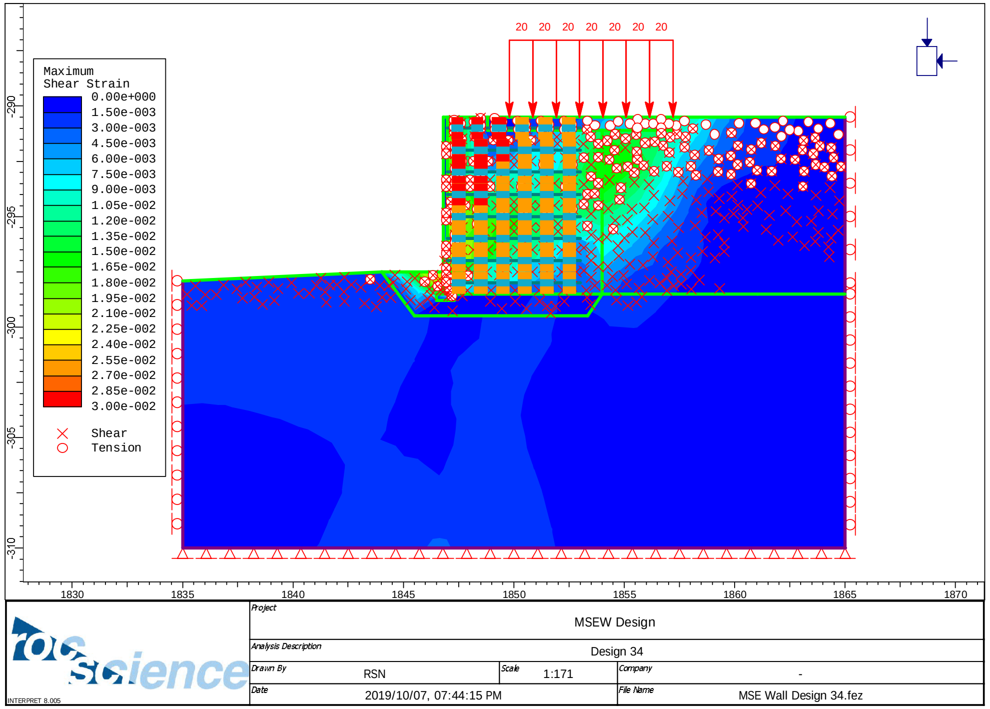
File Name
MSE Wall Design 34.fez


Maximum
Shear Strain
0.00e+000
1.50e-003
3.00e-003
4.50e-003
6.00e-003
7.50e-003
9.00e-003
1.05e-002
1.20e-002
1.35e-002
1.50e-002
1.65e-002
1.80e-002
1.95e-002
2.10e-002
2.25e-002
2.40e-002
2.55e-002
2.70e-002
2.85e-002
3.00e-002
Shear
Tension
20 20 20 20 20 20 20
-290
-295
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-305
-310
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1855
1860
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1870
rocscience
INTERPRET 8.005
Project
MSEW Design
Analysis Description
Design 34
Drawn By
RSN
Scale
1:171
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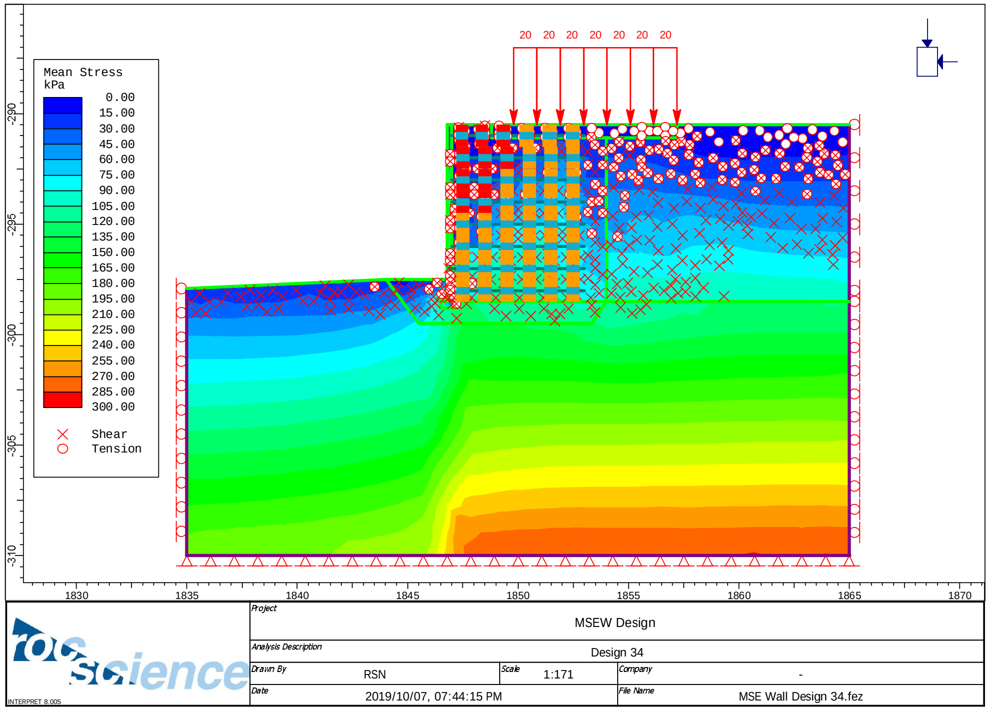
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 34.fez


Mean Stress
kPa
0.00
15.00
30.00
45.00
60.00
75.00
90.00
105.00
120.00
135.00
150.00
165.00
180.00
195.00
210.00
225.00
240.00
255.00
270.00
285.00
300.00
Shear
Tension
20 20 20 20 20 20 20
-290
-295
-300
-305
-310
1830
1835
1840
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1855
1860
1865
1870
rocscience
INTERPRET 8.005
Project
MSEW Design
Analysis Description
Design 34
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RSN
Scale
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Company
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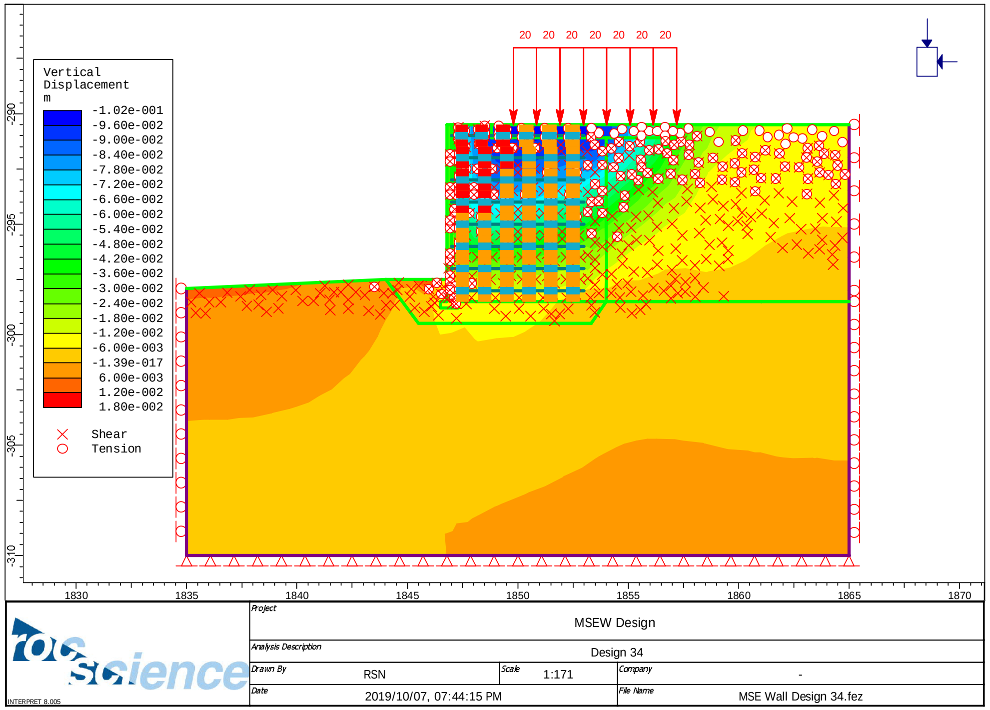
Vertical
Displacement
m
-1.02e-001
-9.60e-002
-9.00e-002
-8.40e-002
-7.80e-002
-7.20e-002
-6.60e-002
-6.00e-002
-5.40e-002
-4.80e-002
-4.20e-002
-3.60e-002
-3.00e-002
-2.40e-002
-1.80e-002
-1.20e-002
-6.00e-003
-1.39e-017
6.00e-003
1.20e-002
1.80e-002
Shear
Tension
20 20 20 20 20 20 20
-290
-295
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rocscience
INTERPRET 8.005
Project
MSEW Design
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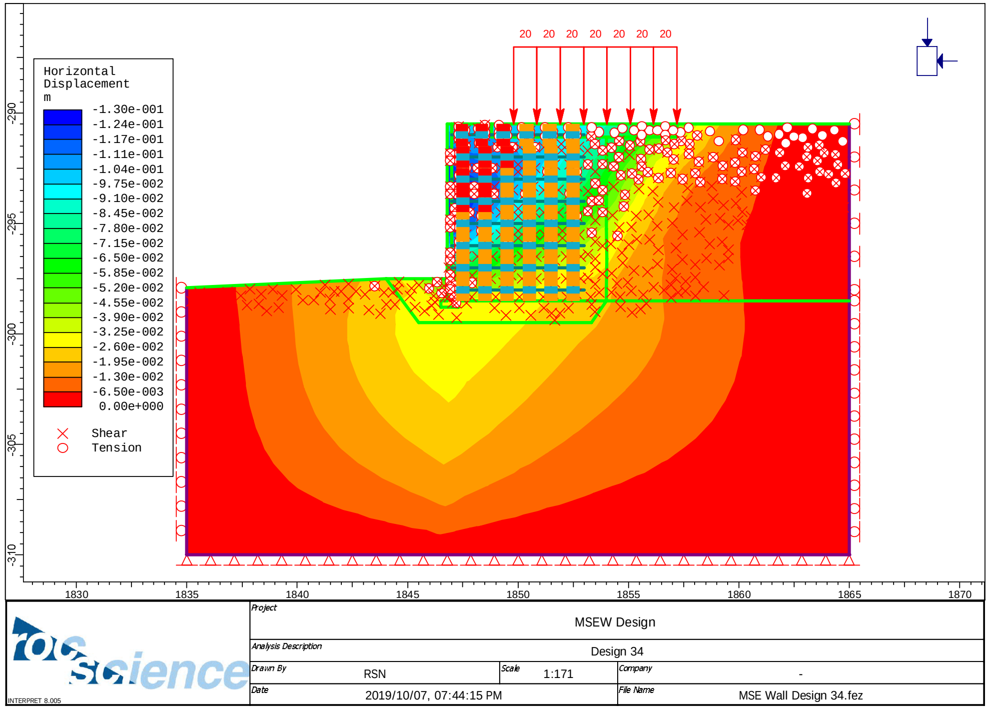
20 20 20 20 20 20 20
Horizontal Displacement m
-1.30e-001
-1.24e-001
-1.17e-001
-1.11e-001
-1.04e-001
-9.75e-002
-9.10e-002
-8.45e-002
-7.80e-002
-7.15e-002
-6.50e-002
-5.85e-002
-5.20e-002
-4.55e-002
-3.90e-002
-3.25e-002
-2.60e-002
-1.95e-002
-1.30e-002
-6.50e-003
0.00e+000
Shear
Tension
-290
-295
-300
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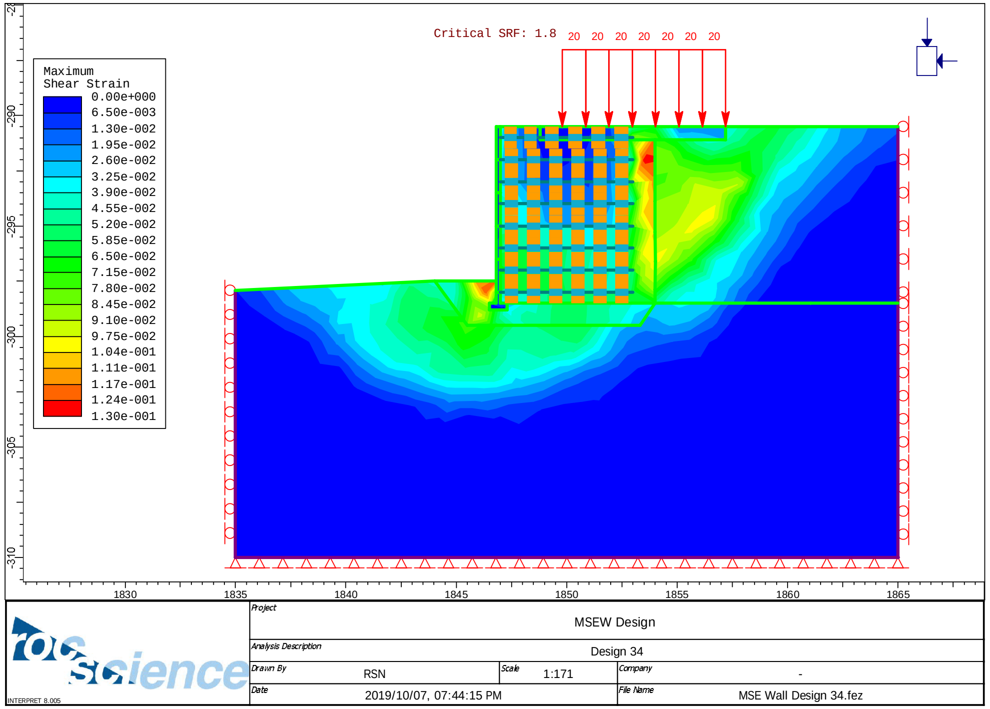
1830 1835 1840 1845 1850 1855 1860 1865 1870
rocscience
INTERPRET 8.005
Project
MSEW Design
Analysis Description
Design 34
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 34.fez


Critical SRF: 1.8
20 20 20 20 20 20 20
Maximum Shear Strain
0.00e+000
6.50e-003
1.30e-002
1.95e-002
2.60e-002
3.25e-002
3.90e-002
4.55e-002
5.20e-002
5.85e-002
6.50e-002
7.15e-002
7.80e-002
8.45e-002
9.10e-002
9.75e-002
1.04e-001
1.11e-001
1.17e-001
1.24e-001
1.30e-001
-290
-295
-300
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-310
1830 1835 1840 1845 1850 1855 1860 1865
rocscience
INTERPRET 8.005
Project
MSEW Design
Analysis Description
Design 34
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RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
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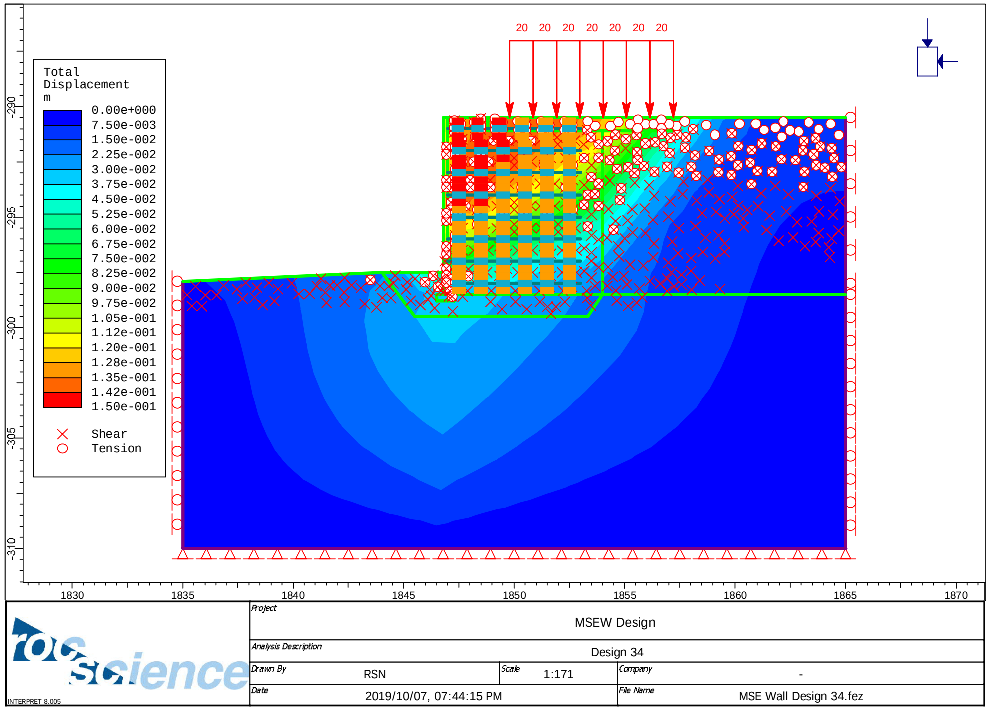
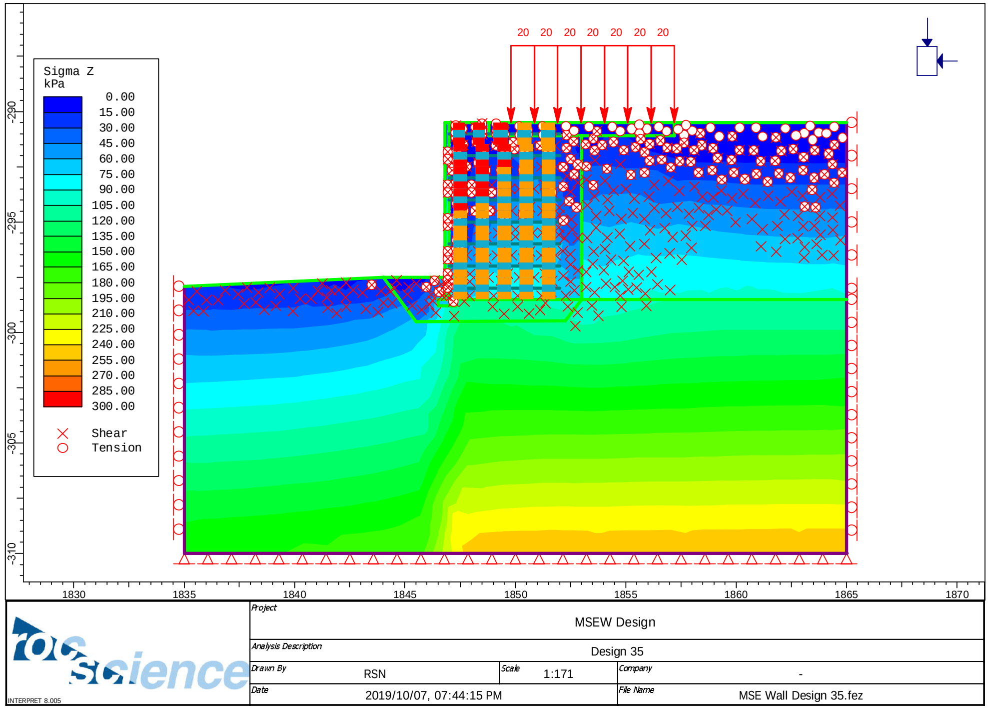
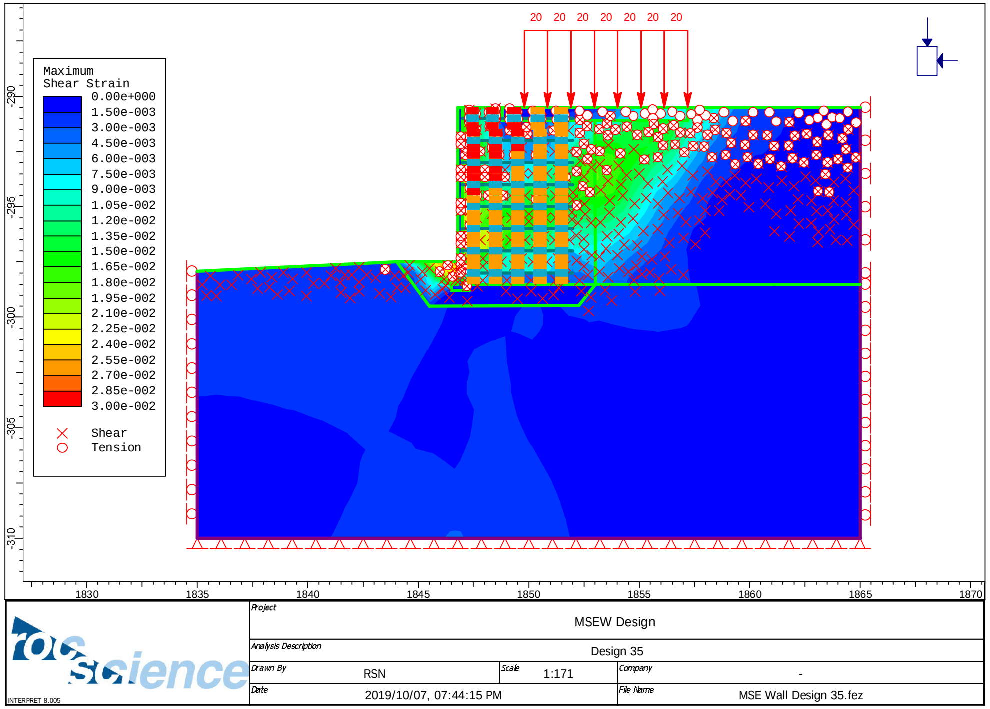
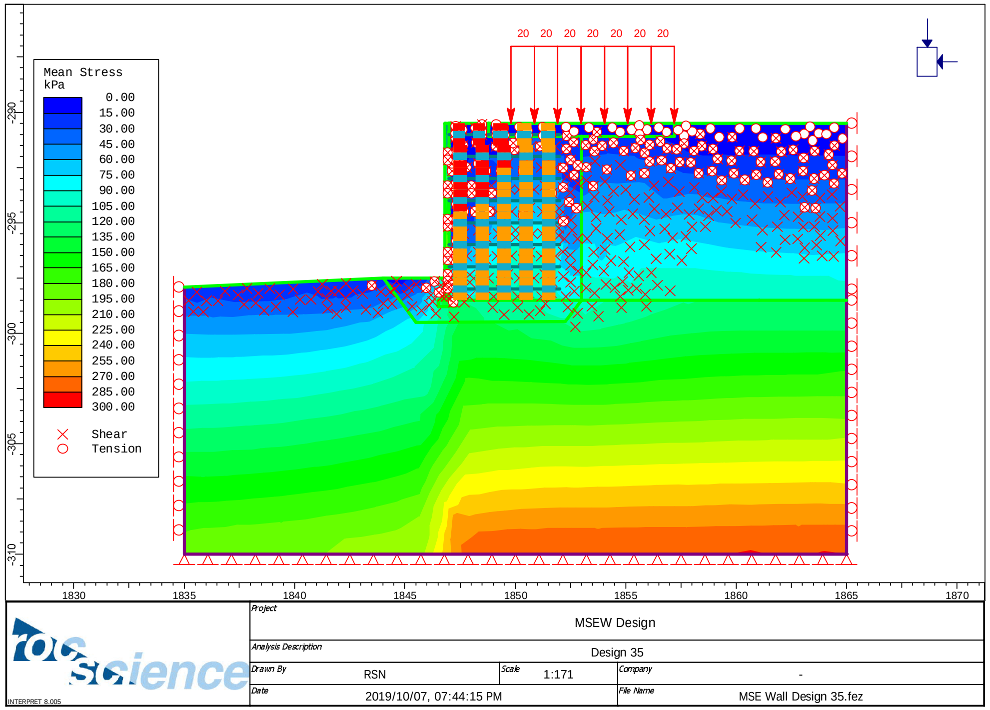
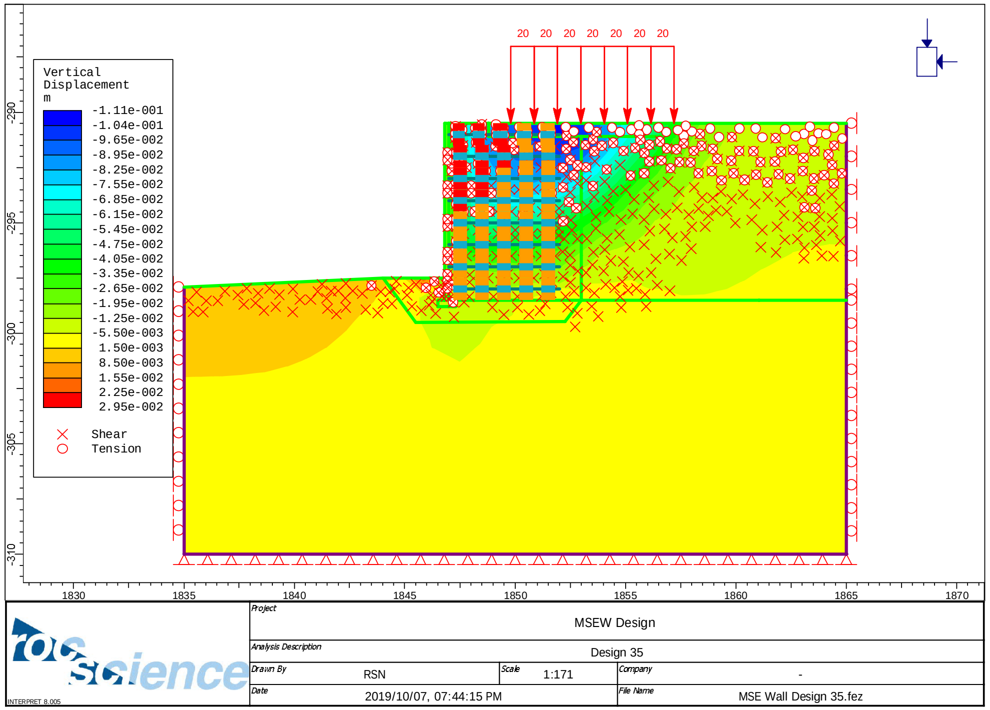
MSE Wall Design 34.fez

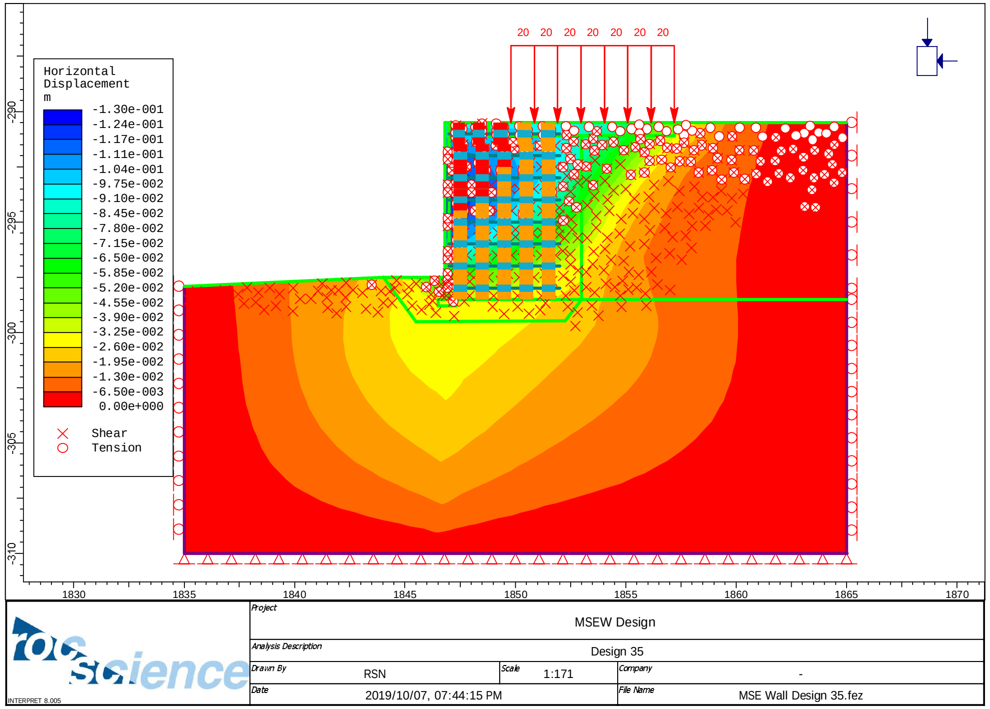

20 20 20 20 20 20 20
Total Displacement m
0.00e+000
7.50e-003
1.50e-002
2.25e-002
3.00e-002
3.75e-002
4.50e-002
5.25e-002
6.00e-002
6.75e-002
7.50e-002
8.25e-002
9.00e-002
9.75e-002
1.05e-001
1.12e-001
1.20e-001
1.28e-001
1.35e-001
1.42e-001
1.50e-001
Shear
Tension
-290
-295
-300
-305
-310
1830 1835 1840 1845 1850 1855 1860 1865 1870
rocscience
INTERPRET 8.005
Project
MSEW Design
Analysis Description
Design 34
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 34.fez

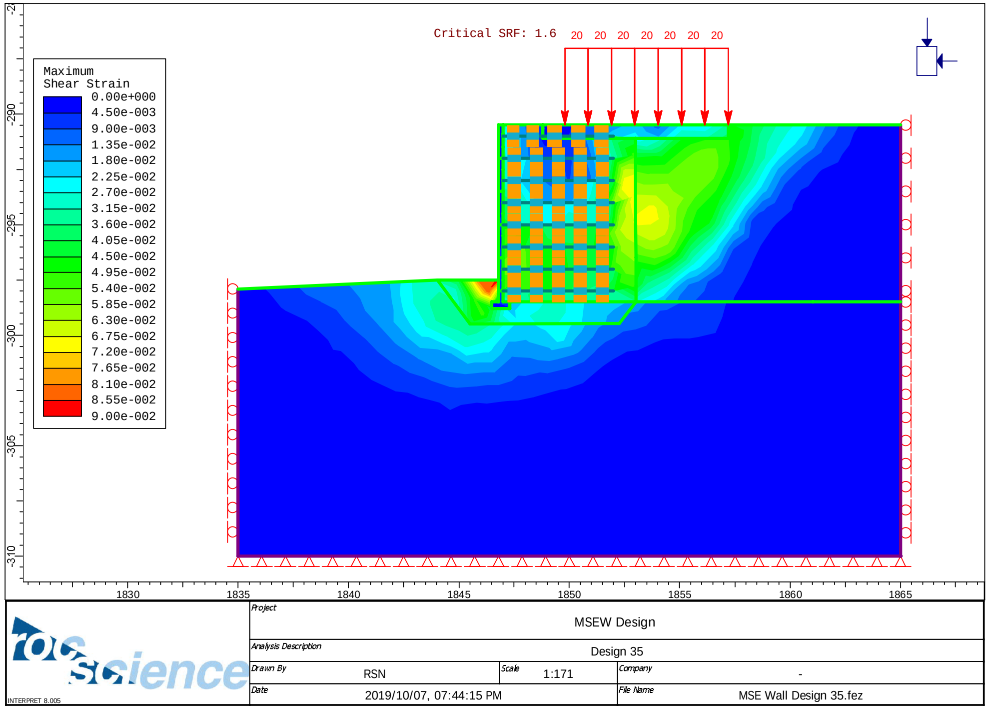

Sigma Z
kPa
0.00
15.00
30.00
45.00
60.00
75.00
90.00
105.00
120.00
135.00
150.00
165.00
180.00
195.00
210.00
225.00
240.00
255.00
270.00
285.00
300.00
Shear
Tension
20 20 20 20 20 20 20
1830 1835 1840 1845 1850 1855 1860 1865 1870
-290 -295 -300 -305 -310
Project
MSEW Design
Analysis Description
Design 35
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 35.fez
INTERPRET 8.005

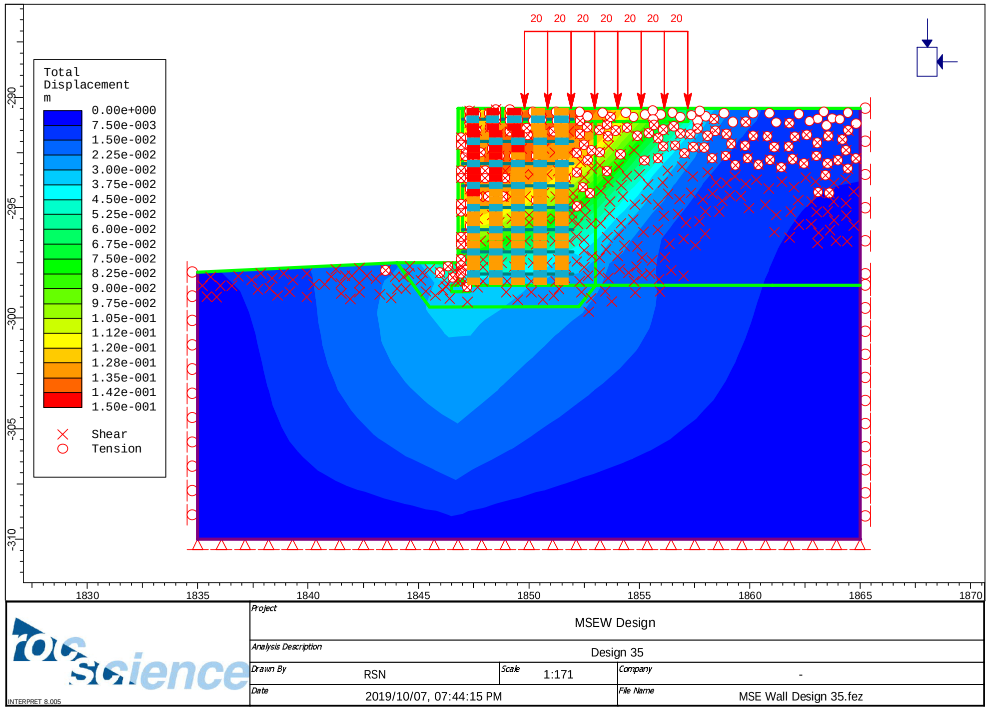

Maximum
Shear Strain
0.00e+000
1.50e-003
3.00e-003
4.50e-003
6.00e-003
7.50e-003
9.00e-003
1.05e-002
1.20e-002
1.35e-002
1.50e-002
1.65e-002
1.80e-002
1.95e-002
2.10e-002
2.25e-002
2.40e-002
2.55e-002
2.70e-002
2.85e-002
3.00e-002
Shear
Tension
20 20 20 20 20 20 20
1830 1835 1840 1845 1850 1855 1860 1865 1870
-290 -295 -300 -305 -310
Project
MSEW Design
Analysis Description
Design 35
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 35.fez
INTERPRET 8.005

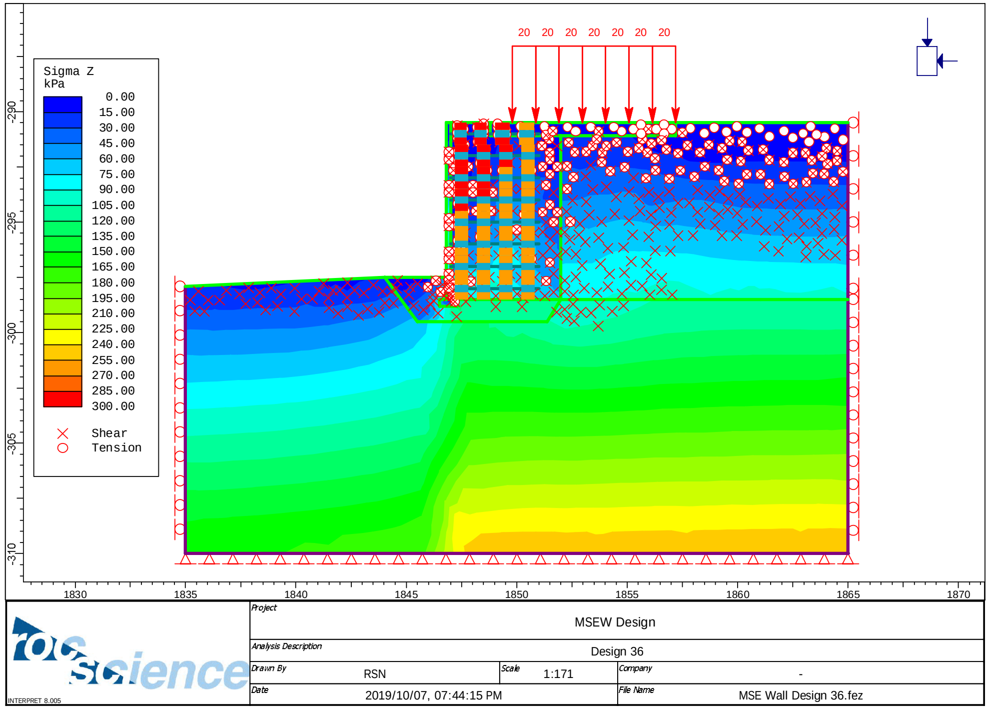

Mean Stress
kPa
0.00
15.00
30.00
45.00
60.00
75.00
90.00
105.00
120.00
135.00
150.00
165.00
180.00
195.00
210.00
225.00
240.00
255.00
270.00
285.00
300.00
Shear
Tension
20 20 20 20 20 20 20
1830 1835 1840 1845 1850 1855 1860 1865 1870
-290 -295 -300 -305 -310
Project
MSEW Design
Analysis Description
Design 35
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 35.fez
INTERPRET 8.005

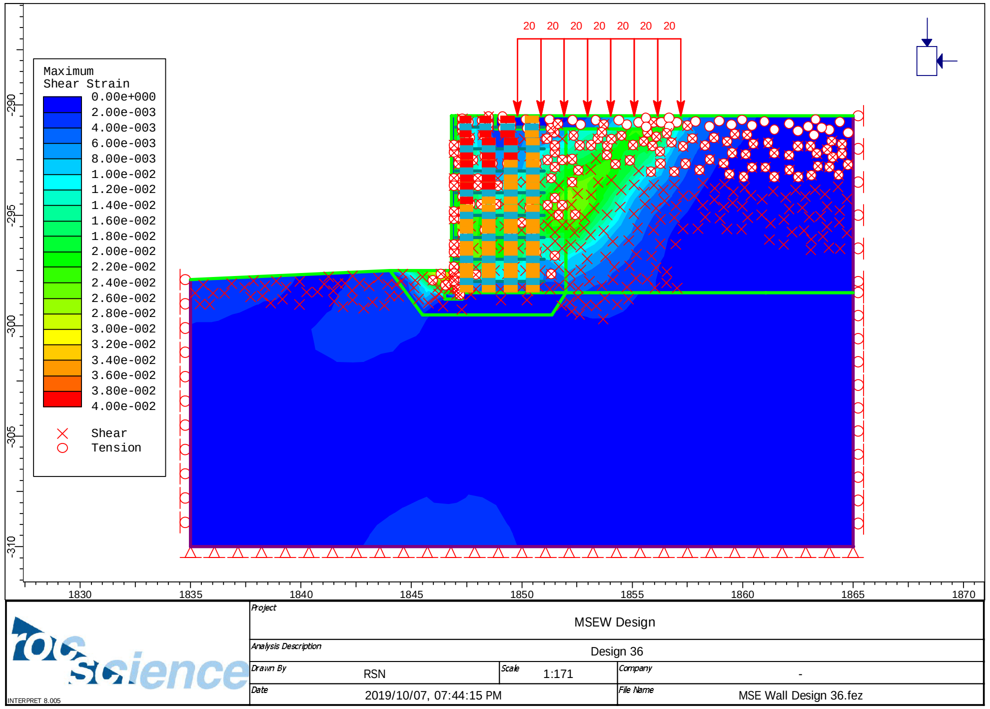

Vertical
Displacement
m
-1.11e-001
-1.04e-001
-9.65e-002
-8.95e-002
-8.25e-002
-7.55e-002
-6.85e-002
-6.15e-002
-5.45e-002
-4.75e-002
-4.05e-002
-3.35e-002
-2.65e-002
-1.95e-002
-1.25e-002
-5.50e-003
1.50e-003
8.50e-003
1.55e-002
2.25e-002
2.95e-002
Shear
Tension
20 20 20 20 20 20 20
1830 1835 1840 1845 1850 1855 1860 1865 1870
-290 -295 -300 -305 -310
Project
MSEW Design
Analysis Description
Design 35
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 35.fez
INTERPRET 8.005

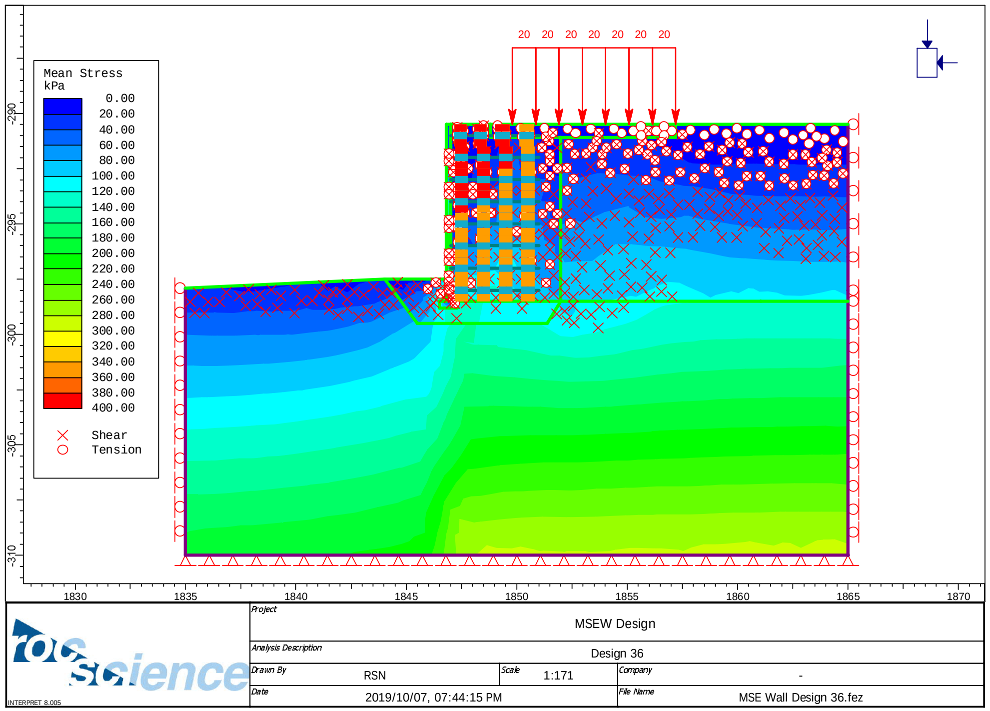

20 20 20 20 20 20 20
Horizontal Displacement m
-1.30e-001
-1.24e-001
-1.17e-001
-1.11e-001
-1.04e-001
-9.75e-002
-9.10e-002
-8.45e-002
-7.80e-002
-7.15e-002
-6.50e-002
-5.85e-002
-5.20e-002
-4.55e-002
-3.90e-002
-3.25e-002
-2.60e-002
-1.95e-002
-1.30e-002
-6.50e-003
0.00e+000
Shear
Tension
1830 1835 1840 1845 1850 1855 1860 1865 1870
-290 -295 -300 -305 -310
Project
MSEW Design
Analysis Description
Design 35
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 35.fez
INTERPRET 8.005

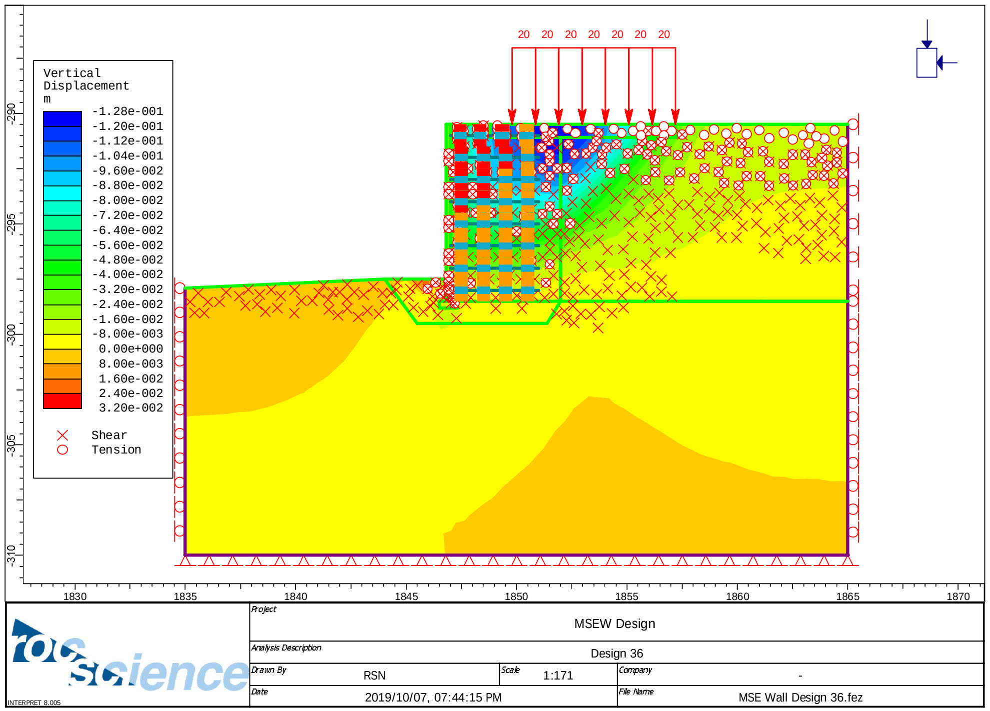

Critical SRF: 1.6
20 20 20 20 20 20 20
Maximum Shear Strain
0.00e+000
4.50e-003
9.00e-003
1.35e-002
1.80e-002
2.25e-002
2.70e-002
3.15e-002
3.60e-002
4.05e-002
4.50e-002
4.95e-002
5.40e-002
5.85e-002
6.30e-002
6.75e-002
7.20e-002
7.65e-002
8.10e-002
8.55e-002
9.00e-002
1830 1835 1840 1845 1850 1855 1860 1865
-290 -295 -300 -305 -310
Project
MSEW Design
Analysis Description
Design 35
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 35.fez
INTERPRET 8.005

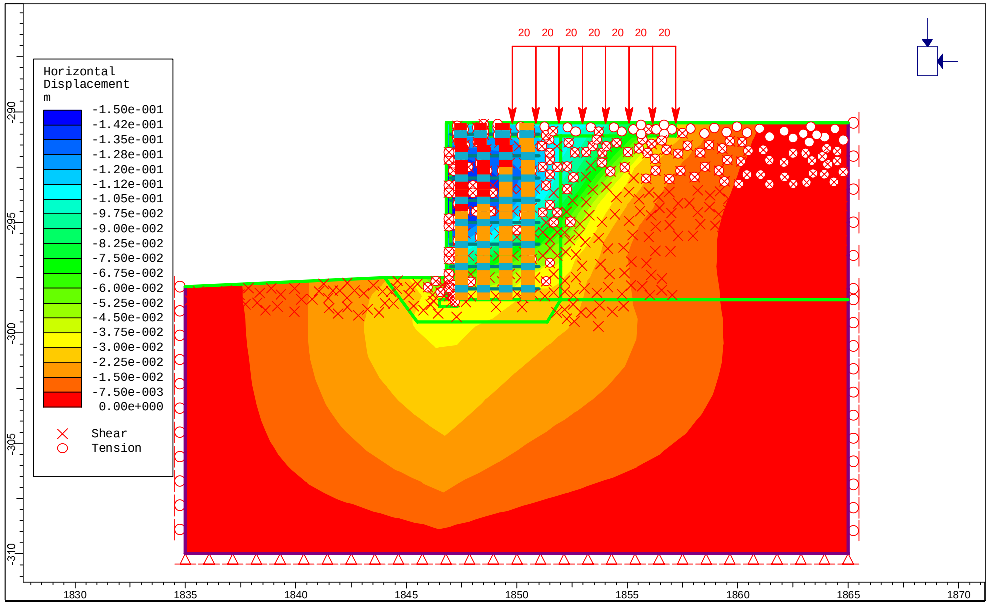

20 20 20 20 20 20 20
Total Displacement m
0.00e+000
7.50e-003
1.50e-002
2.25e-002
3.00e-002
3.75e-002
4.50e-002
5.25e-002
6.00e-002
6.75e-002
7.50e-002
8.25e-002
9.00e-002
9.75e-002
1.05e-001
1.12e-001
1.20e-001
1.28e-001
1.35e-001
1.42e-001
1.50e-001
Shear
Tension
1830 1835 1840 1845 1850 1855 1860 1865 1870
-290 -295 -300 -305 -310
Project
MSEW Design
Analysis Description
Design 35
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 35.fez
INTERPRET 8.005


20 20 20 20 20 20 20
Sigma Z
kPa
0.00
15.00
30.00
45.00
60.00
75.00
90.00
105.00
120.00
135.00
150.00
165.00
180.00
195.00
210.00
225.00
240.00
255.00
270.00
285.00
300.00
Shear
Tension
-290
-295
-300
-305
-310
1830 1835 1840 1845 1850 1855 1860 1865 1870
Project
MSEW Design
Analysis Description
Design 36
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 36.fez
INTERPRET 8.005


20 20 20 20 20 20 20 20
Maximum
Shear Strain
0.00e+000
2.00e-003
4.00e-003
6.00e-003
8.00e-003
1.00e-002
1.20e-002
1.40e-002
1.60e-002
1.80e-002
2.00e-002
2.20e-002
2.40e-002
2.60e-002
2.80e-002
3.00e-002
3.20e-002
3.40e-002
3.60e-002
3.80e-002
4.00e-002
Shear
Tension
-290
-295
-300
-305
-310
1830 1835 1840 1845 1850 1855 1860 1865 1870
Project
MSEW Design
Analysis Description
Design 36
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 36.fez
INTERPRET 8.005

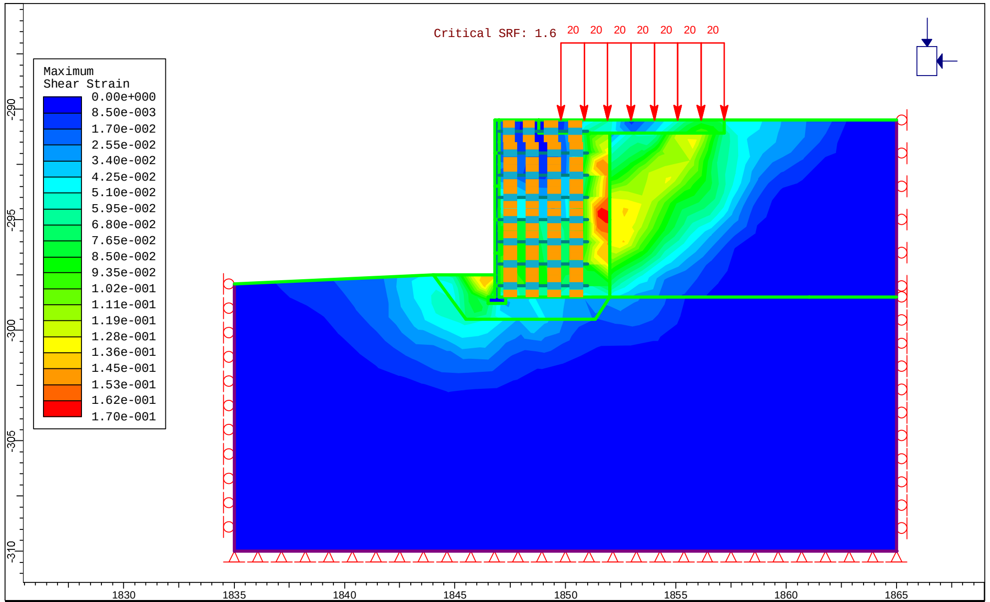

20 20 20 20 20 20 20
Mean Stress
kPa
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
160.00
180.00
200.00
220.00
240.00
260.00
280.00
300.00
320.00
340.00
360.00
380.00
400.00
Shear
Tension
-290
-295
-300
-305
-310
1830 1835 1840 1845 1850 1855 1860 1865 1870
Project
MSEW Design
Analysis Description
Design 36
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 36.fez
INTERPRET 8.005


20 20 20 20 20 20 20
Vertical
Displacement
m
-1.28e-001
-1.20e-001
-1.12e-001
-1.04e-001
-9.60e-002
-8.80e-002
-8.00e-002
-7.20e-002
-6.40e-002
-5.60e-002
-4.80e-002
-4.00e-002
-3.20e-002
-2.40e-002
-1.60e-002
-8.00e-003
0.00e+000
8.00e-003
1.60e-002
2.40e-002
3.20e-002
Shear
Tension
-290
-295
-300
-305
-310
1830 1835 1840 1845 1850 1855 1860 1865 1870
Project
MSEW Design
Analysis Description
Design 36
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 36.fez
INTERPRET 8.005



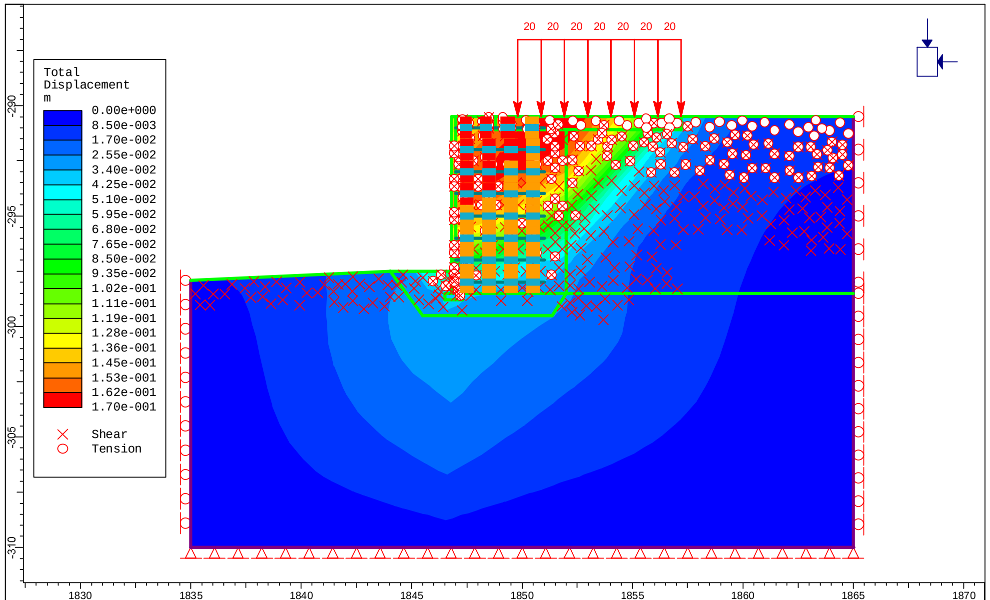
Project	MSEW Design		
Analysis Description	Design 36		
Drawn By	RSN	Scale	1:171
Company	-		
Date	2019/10/07, 07:44:15 PM	File Name	MSE Wall Design 36.fez

INTERPRET 8.005



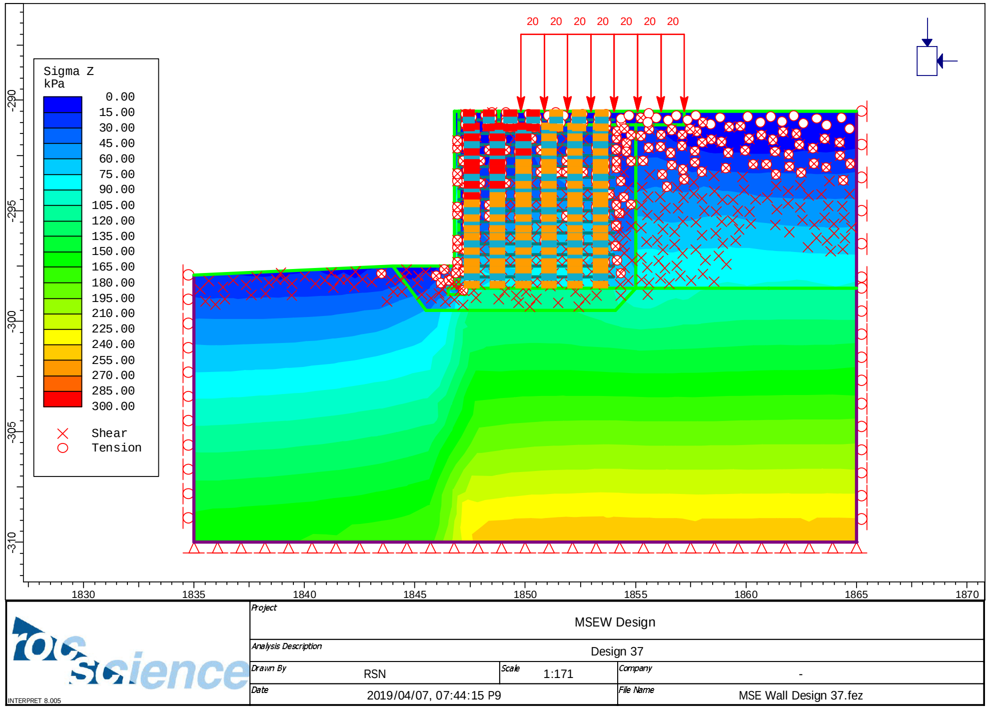
Project	MSEW Design		
Analysis Description	Design 36		
Drawn By	RSN	Scale	1:171
Company	-		
Date	2019/10/07, 07:44:15 PM	File Name	MSE Wall Design 36.fez

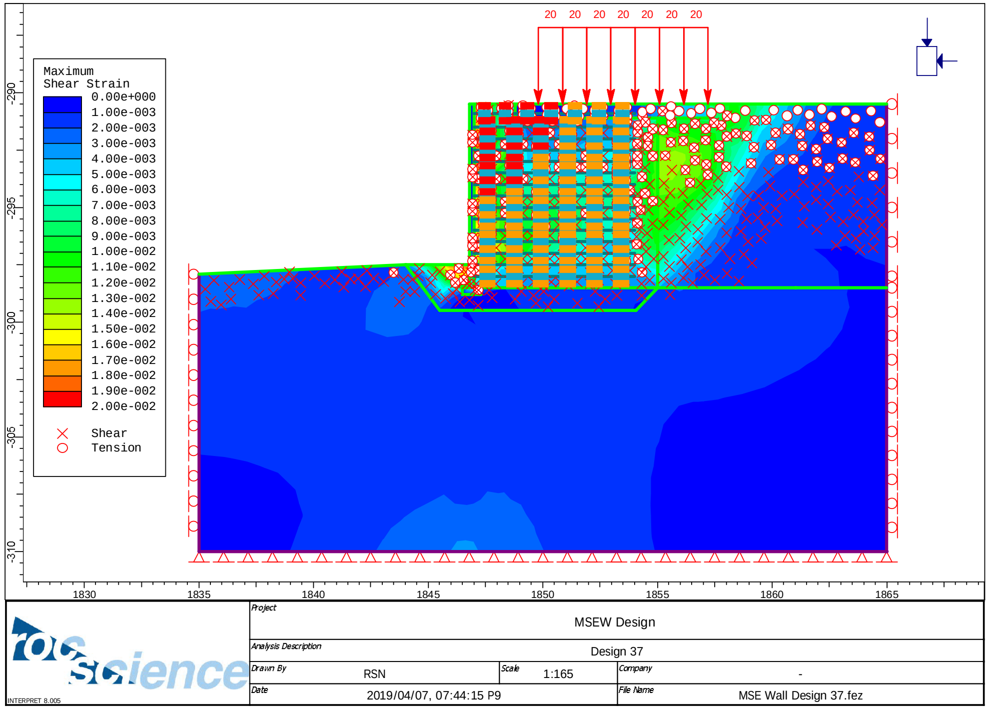
INTERPRET 8.005

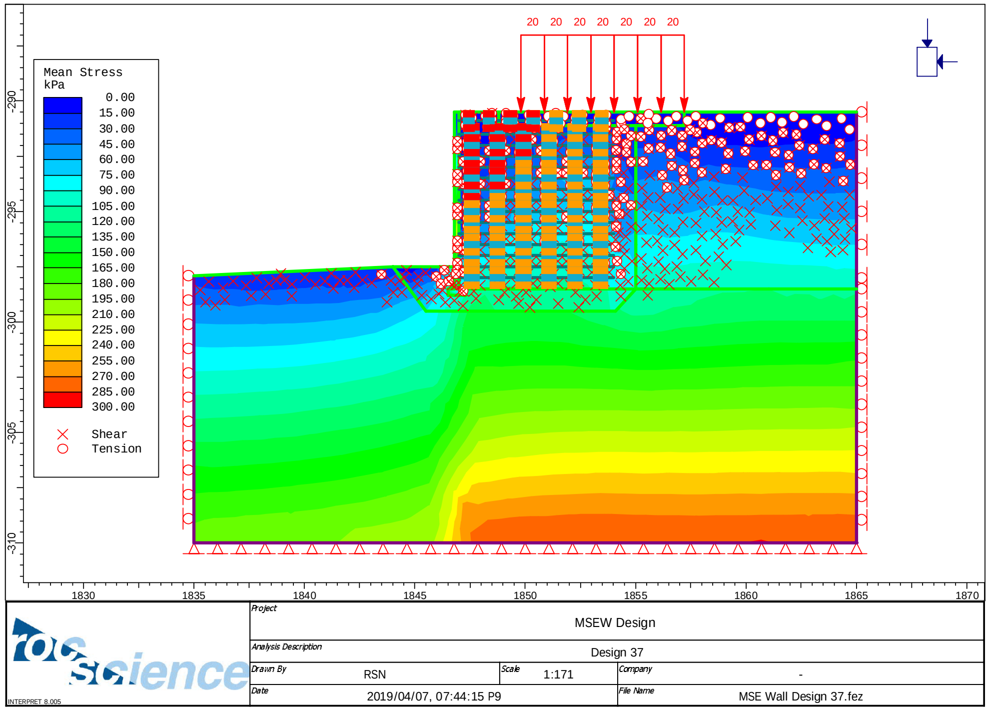


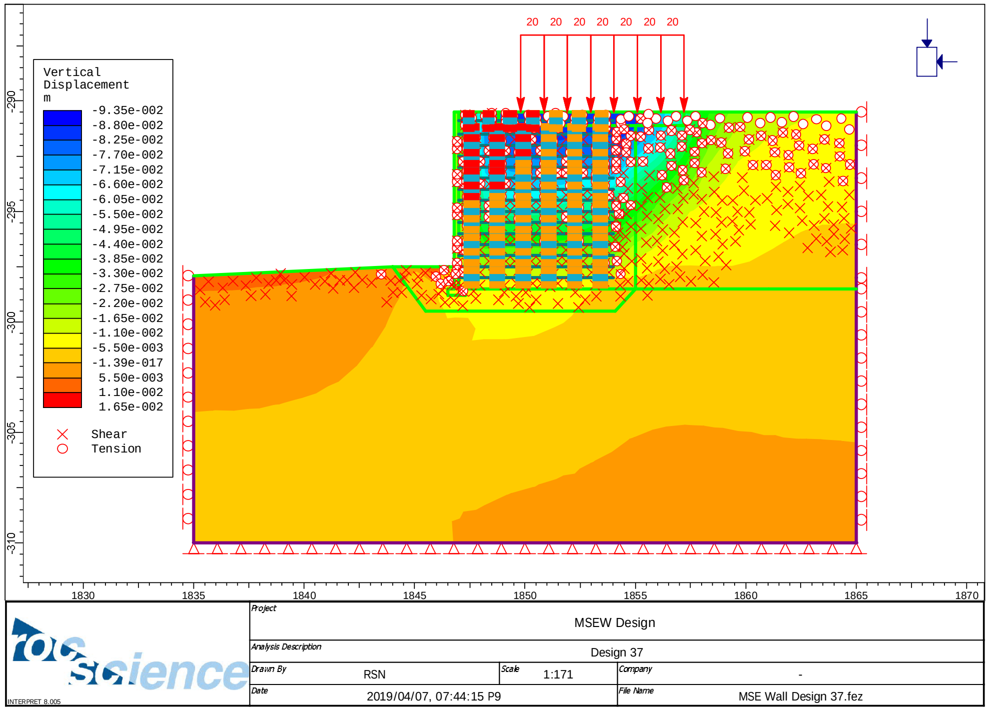
Project	MSEW Design		
Analysis Description	Design 36		
Drawn By	RSN	Scale	1:171
Company	-		
Date	2019/10/07, 07:44:15 PM	File Name	MSE Wall Design 36.fez

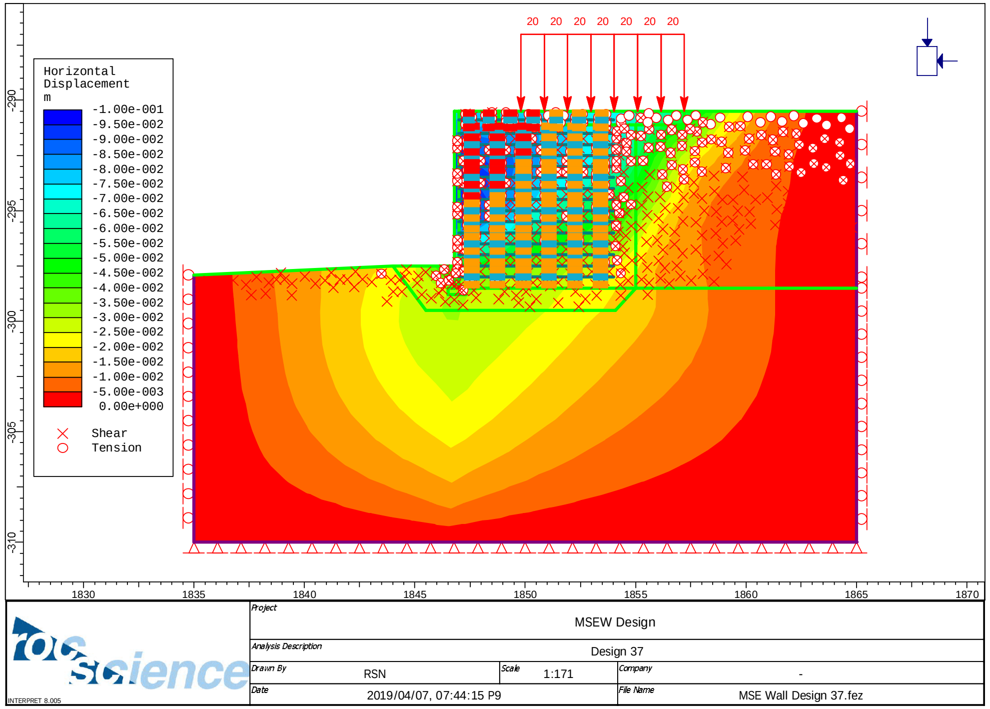
INTERPRET 8.005

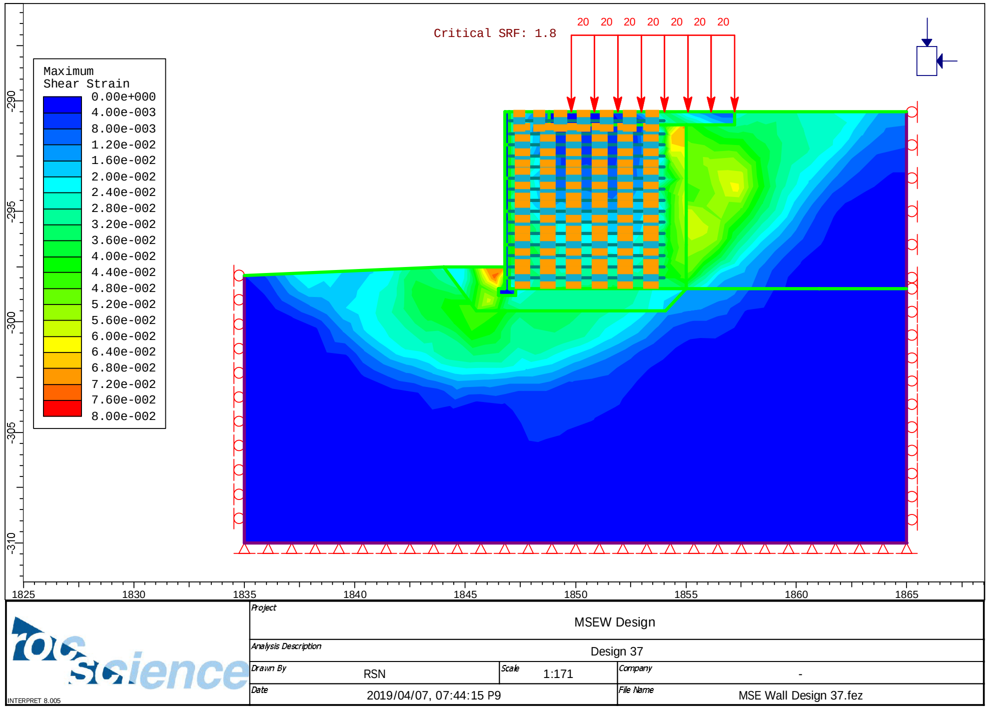

Sigma Z
kPa
0.00
15.00
30.00
45.00
60.00
75.00
90.00
105.00
120.00
135.00
150.00
165.00
180.00
195.00
210.00
225.00
240.00
255.00
270.00
285.00
300.00
Shear
Tension
Project
MSEW Design
Analysis Description
Design 37
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/04/07, 07:44:15 P9
File Name
MSE Wall Design 37.fez

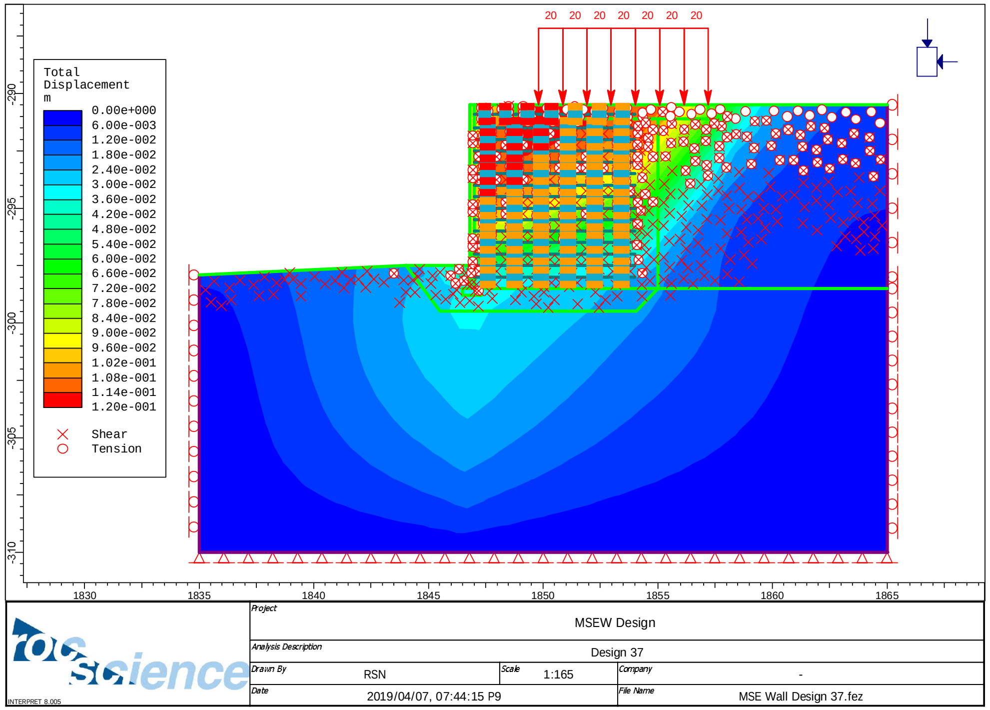

Maximum
Shear Strain
0.00e+000
1.00e-003
2.00e-003
3.00e-003
4.00e-003
5.00e-003
6.00e-003
7.00e-003
8.00e-003
9.00e-003
1.00e-002
1.10e-002
1.20e-002
1.30e-002
1.40e-002
1.50e-002
1.60e-002
1.70e-002
1.80e-002
1.90e-002
2.00e-002
Shear
Tension
Project
MSEW Design
Analysis Description
Design 37
Drawn By
RSN
Scale
1:165
Company
-
Date
2019/04/07, 07:44:15 P9
File Name
MSE Wall Design 37.fez

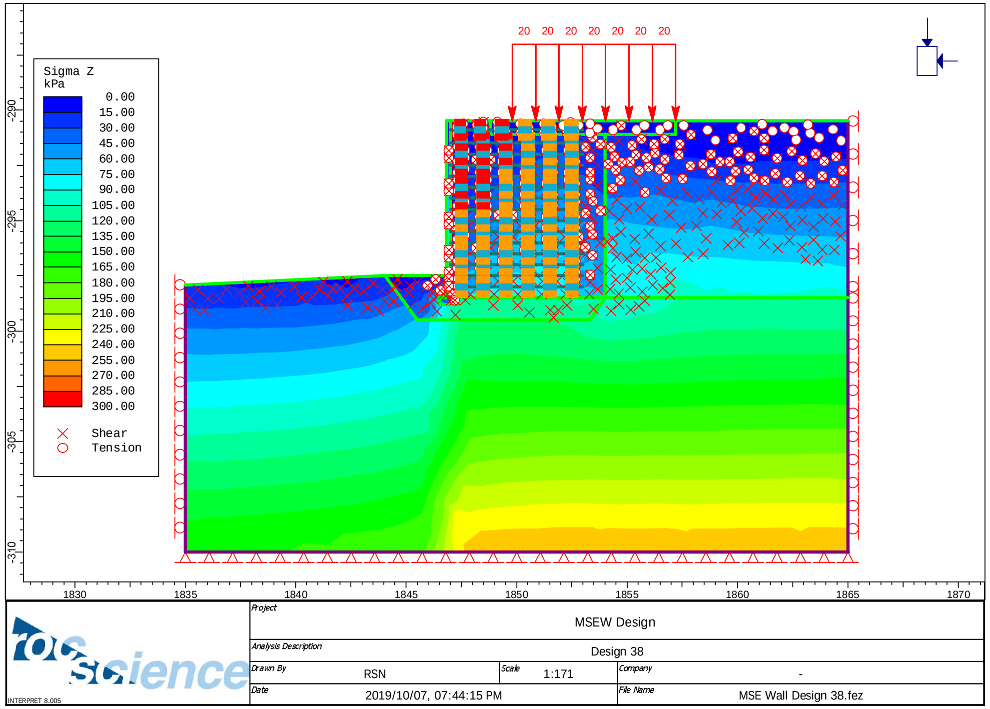

Mean Stress
kPa
0.00
15.00
30.00
45.00
60.00
75.00
90.00
105.00
120.00
135.00
150.00
165.00
180.00
195.00
210.00
225.00
240.00
255.00
270.00
285.00
300.00
Shear
Tension
Project
MSEW Design
Analysis Description
Design 37
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/04/07, 07:44:15 P9
File Name
MSE Wall Design 37.fez


Vertical
Displacement
m
-9.35e-002
-8.80e-002
-8.25e-002
-7.70e-002
-7.15e-002
-6.60e-002
-6.05e-002
-5.50e-002
-4.95e-002
-4.40e-002
-3.85e-002
-3.30e-002
-2.75e-002
-2.20e-002
-1.65e-002
-1.10e-002
-5.50e-003
-1.39e-017
5.50e-003
1.10e-002
1.65e-002
Shear
Tension
Project
MSEW Design
Analysis Description
Design 37
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/04/07, 07:44:15 P9
File Name
MSE Wall Design 37.fez

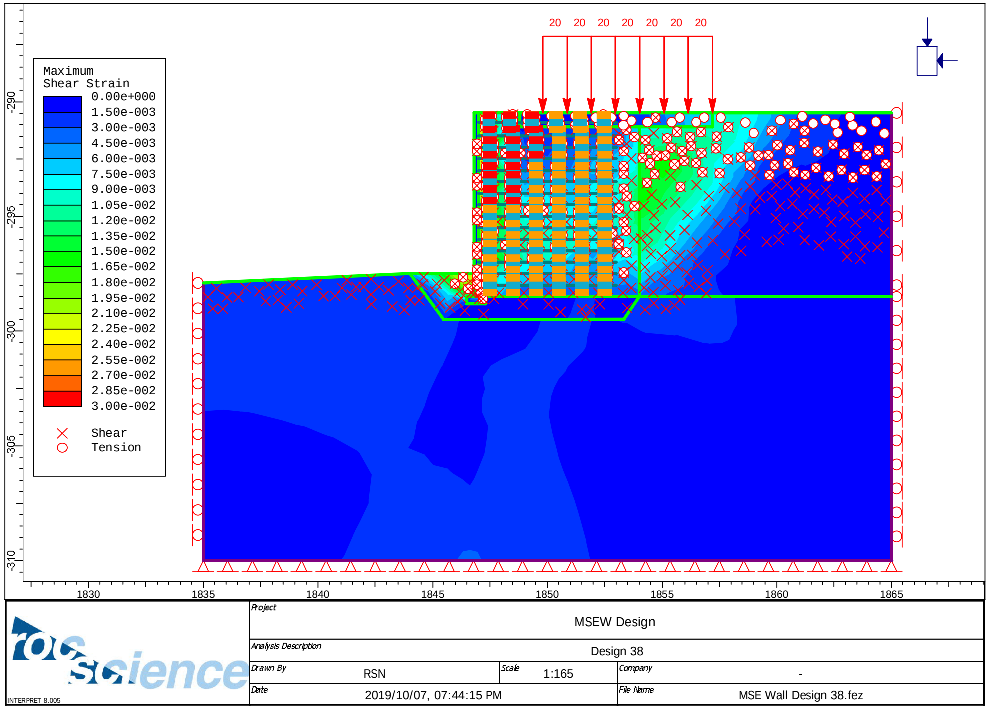

20 20 20 20 20 20 20
Horizontal Displacement m
-1.00e-001
-9.50e-002
-9.00e-002
-8.50e-002
-8.00e-002
-7.50e-002
-7.00e-002
-6.50e-002
-6.00e-002
-5.50e-002
-5.00e-002
-4.50e-002
-4.00e-002
-3.50e-002
-3.00e-002
-2.50e-002
-2.00e-002
-1.50e-002
-1.00e-002
-5.00e-003
0.00e+000
Shear
Tension
-290
-295
-300
-305
-310
1830 1835 1840 1845 1850 1855 1860 1865 1870
Project
MSEW Design
Analysis Description
Design 37
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/04/07, 07:44:15 P9
File Name
MSE Wall Design 37.fez
INTERPRET 8.005


Critical SRF: 1.8
20 20 20 20 20 20 20
Maximum Shear Strain
0.00e+000
4.00e-003
8.00e-003
1.20e-002
1.60e-002
2.00e-002
2.40e-002
2.80e-002
3.20e-002
3.60e-002
4.00e-002
4.40e-002
4.80e-002
5.20e-002
5.60e-002
6.00e-002
6.40e-002
6.80e-002
7.20e-002
7.60e-002
8.00e-002
-290
-295
-300
-305
-310
1825 1830 1835 1840 1845 1850 1855 1860 1865
Project
MSEW Design
Analysis Description
Design 37
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/04/07, 07:44:15 P9
File Name
MSE Wall Design 37.fez
INTERPRET 8.005

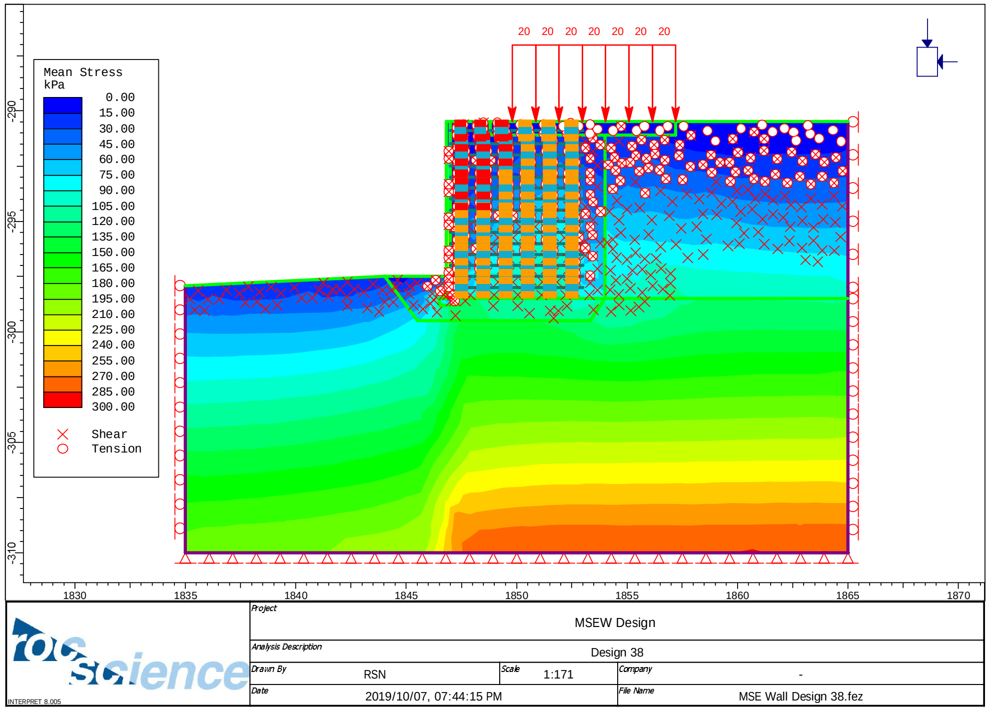

20 20 20 20 20 20 20
Total Displacement m
0.00e+000
6.00e-003
1.20e-002
1.80e-002
2.40e-002
3.00e-002
3.60e-002
4.20e-002
4.80e-002
5.40e-002
6.00e-002
6.60e-002
7.20e-002
7.80e-002
8.40e-002
9.00e-002
9.60e-002
1.02e-001
1.08e-001
1.14e-001
1.20e-001
Shear
Tension
-290
-295
-300
-305
-310
1830 1835 1840 1845 1850 1855 1860 1865
Project
MSEW Design
Analysis Description
Design 37
Drawn By
RSN
Scale
1:165
Company
-
Date
2019/04/07, 07:44:15 P9
File Name
MSE Wall Design 37.fez
INTERPRET 8.005



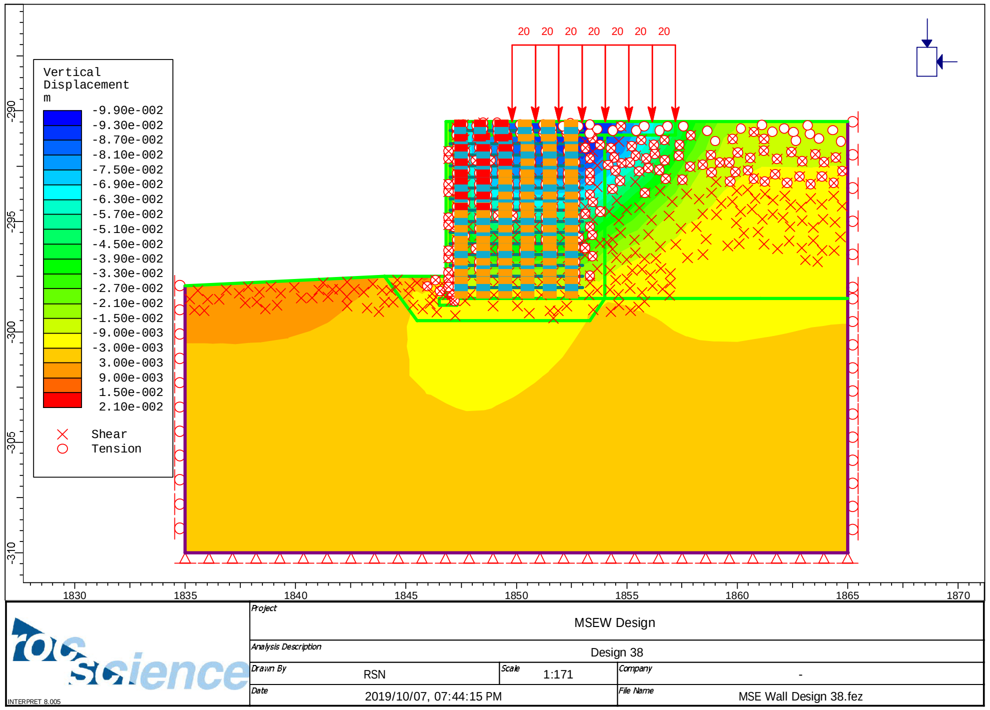
Sigma Z
kPa
0.00
15.00
30.00
45.00
60.00
75.00
90.00
105.00
120.00
135.00
150.00
165.00
180.00
195.00
210.00
225.00
240.00
255.00
270.00
285.00
300.00
Shear
Tension
20 20 20 20 20 20 20
1830 1835 1840 1845 1850 1855 1860 1865 1870
-290 -295 -300 -305 -310
rocscience
INTERPRET 8.005
Project
MSEW Design
Analysis Description
Design 38
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 38.fez



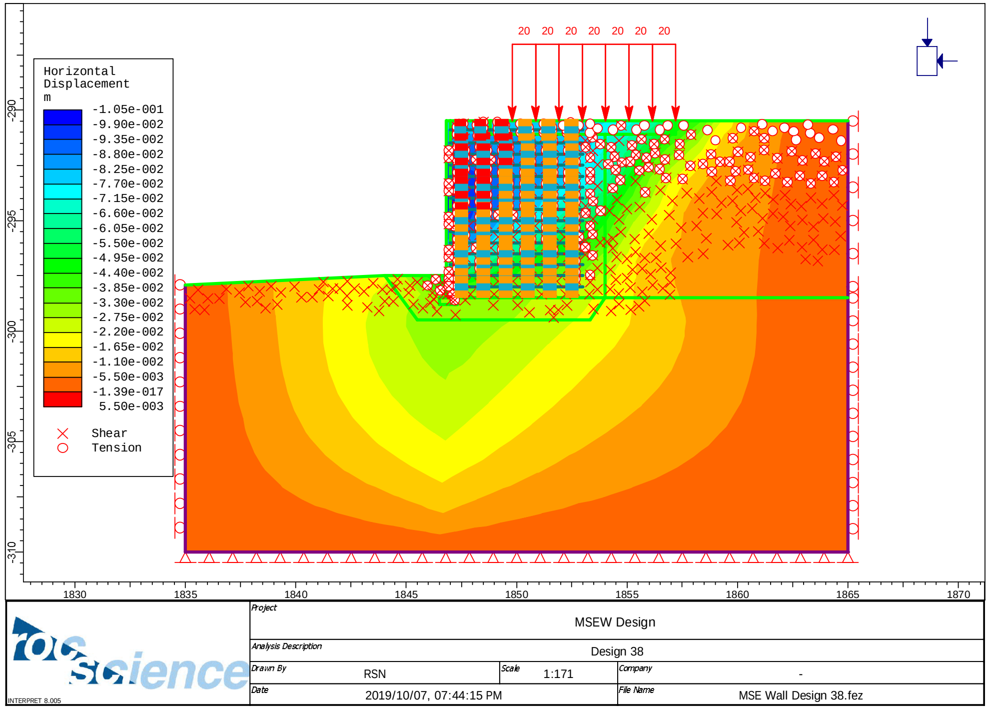
Maximum
Shear Strain
0.00e+000
1.50e-003
3.00e-003
4.50e-003
6.00e-003
7.50e-003
9.00e-003
1.05e-002
1.20e-002
1.35e-002
1.50e-002
1.65e-002
1.80e-002
1.95e-002
2.10e-002
2.25e-002
2.40e-002
2.55e-002
2.70e-002
2.85e-002
3.00e-002
Shear
Tension
20 20 20 20 20 20 20
1830 1835 1840 1845 1850 1855 1860 1865
-290 -295 -300 -305 -310
rocscience
INTERPRET 8.005
Project
MSEW Design
Analysis Description
Design 38
Drawn By
RSN
Scale
1:165
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 38.fez



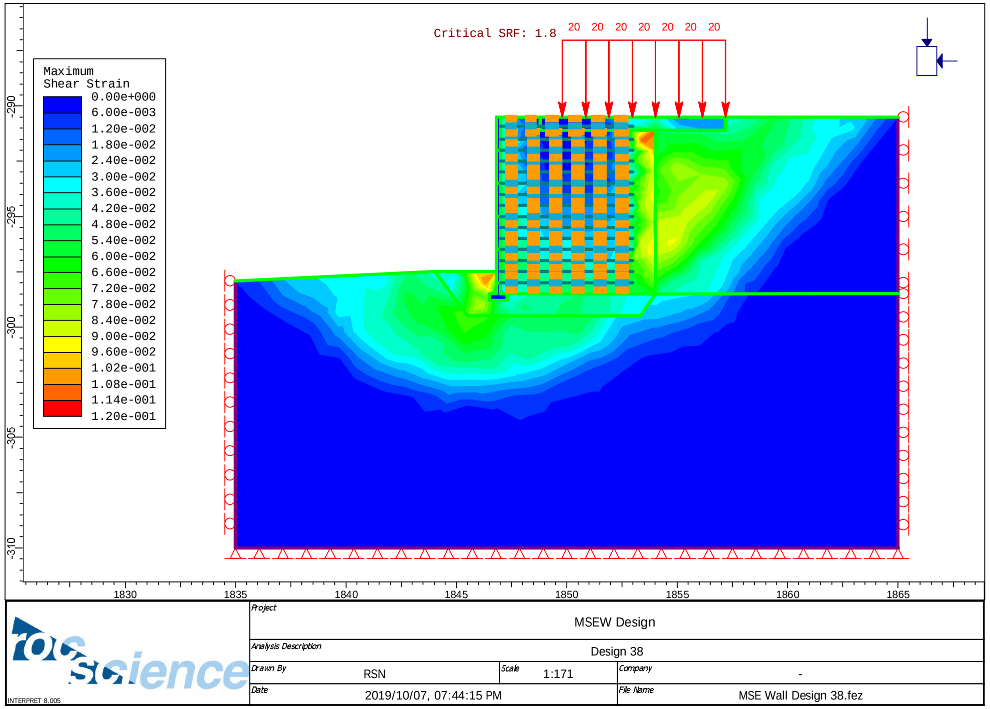
Mean Stress
kPa
0.00
15.00
30.00
45.00
60.00
75.00
90.00
105.00
120.00
135.00
150.00
165.00
180.00
195.00
210.00
225.00
240.00
255.00
270.00
285.00
300.00
Shear
Tension
20 20 20 20 20 20 20
1830 1835 1840 1845 1850 1855 1860 1865 1870
-290 -295 -300 -305 -310
rocscience
INTERPRET 8.005
Project
MSEW Design
Analysis Description
Design 38
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 38.fez



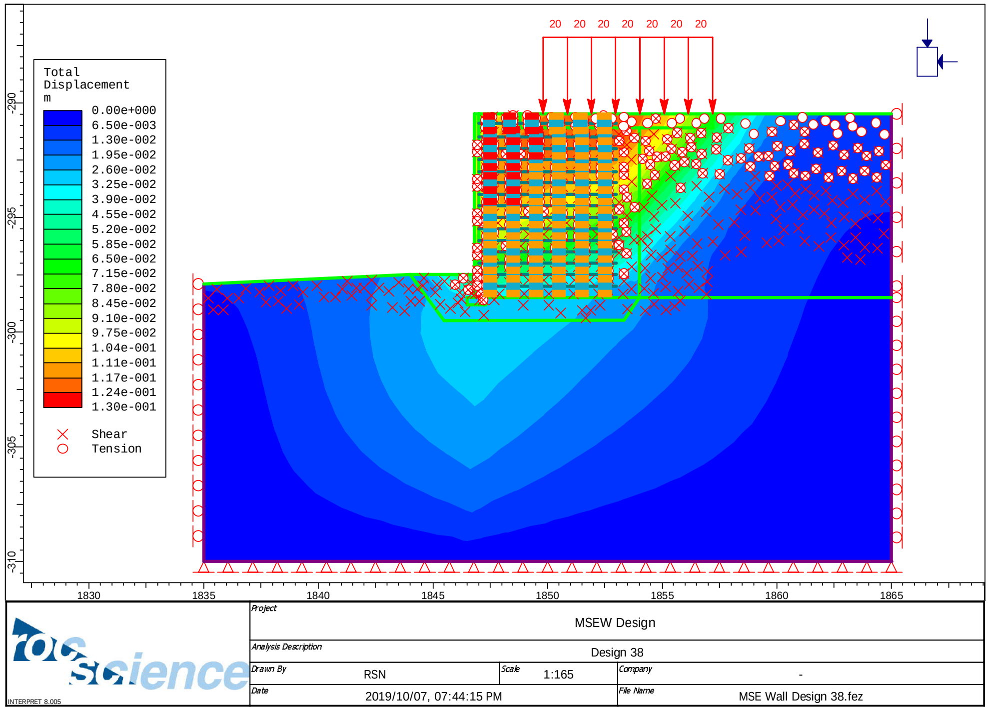
Vertical
Displacement
m
-9.90e-002
-9.30e-002
-8.70e-002
-8.10e-002
-7.50e-002
-6.90e-002
-6.30e-002
-5.70e-002
-5.10e-002
-4.50e-002
-3.90e-002
-3.30e-002
-2.70e-002
-2.10e-002
-1.50e-002
-9.00e-003
-3.00e-003
3.00e-003
9.00e-003
1.50e-002
2.10e-002
Shear
Tension
20 20 20 20 20 20 20
1830 1835 1840 1845 1850 1855 1860 1865 1870
-290 -295 -300 -305 -310
rocscience
INTERPRET 8.005
Project
MSEW Design
Analysis Description
Design 38
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 38.fez



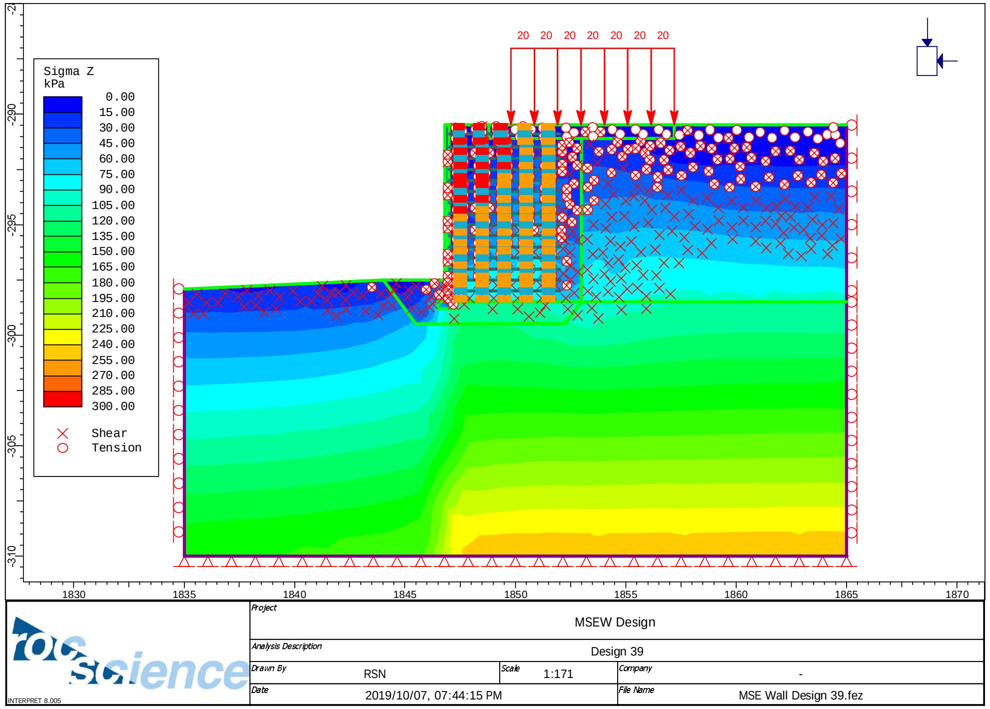
Horizontal Displacement m
-1.05e-001
-9.90e-002
-9.35e-002
-8.80e-002
-8.25e-002
-7.70e-002
-7.15e-002
-6.60e-002
-6.05e-002
-5.50e-002
-4.95e-002
-4.40e-002
-3.85e-002
-3.30e-002
-2.75e-002
-2.20e-002
-1.65e-002
-1.10e-002
-5.50e-003
-1.39e-017
5.50e-003
Shear
Tension
20 20 20 20 20 20 20
Project
MSEW Design
Analysis Description
Design 38
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 38.fez
INTERPRET 8.005



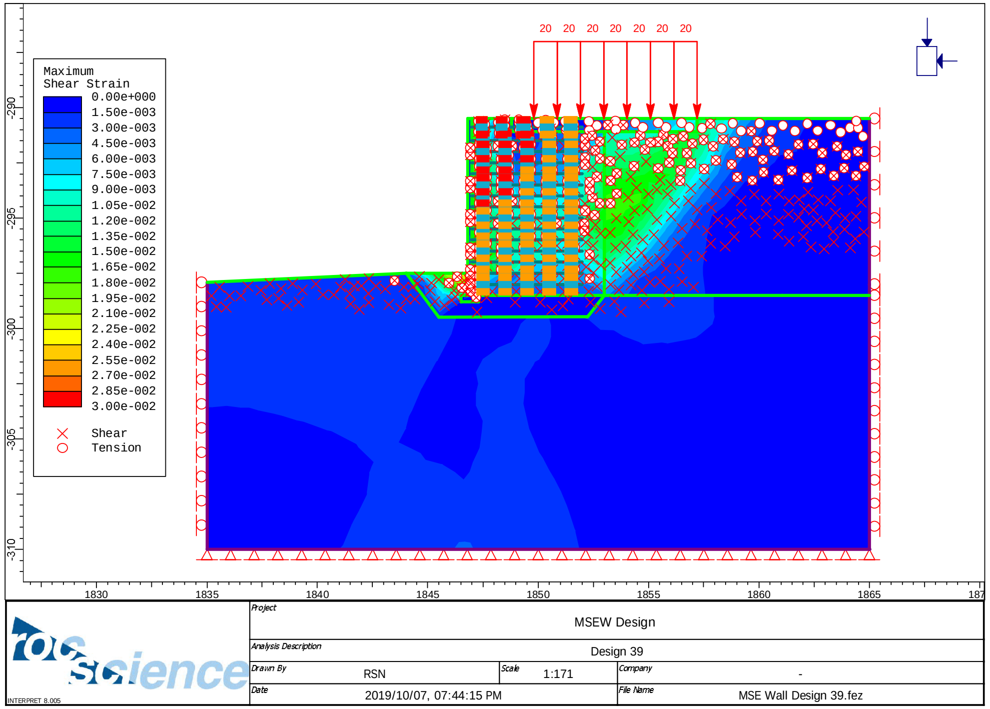
Maximum Shear Strain
0.00e+000
6.00e-003
1.20e-002
1.80e-002
2.40e-002
3.00e-002
3.60e-002
4.20e-002
4.80e-002
5.40e-002
6.00e-002
6.60e-002
7.20e-002
7.80e-002
8.40e-002
9.00e-002
9.60e-002
1.02e-001
1.08e-001
1.14e-001
1.20e-001
Critical SRF: 1.8
20 20 20 20 20 20 20
Project
MSEW Design
Analysis Description
Design 38
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 38.fez
INTERPRET 8.005



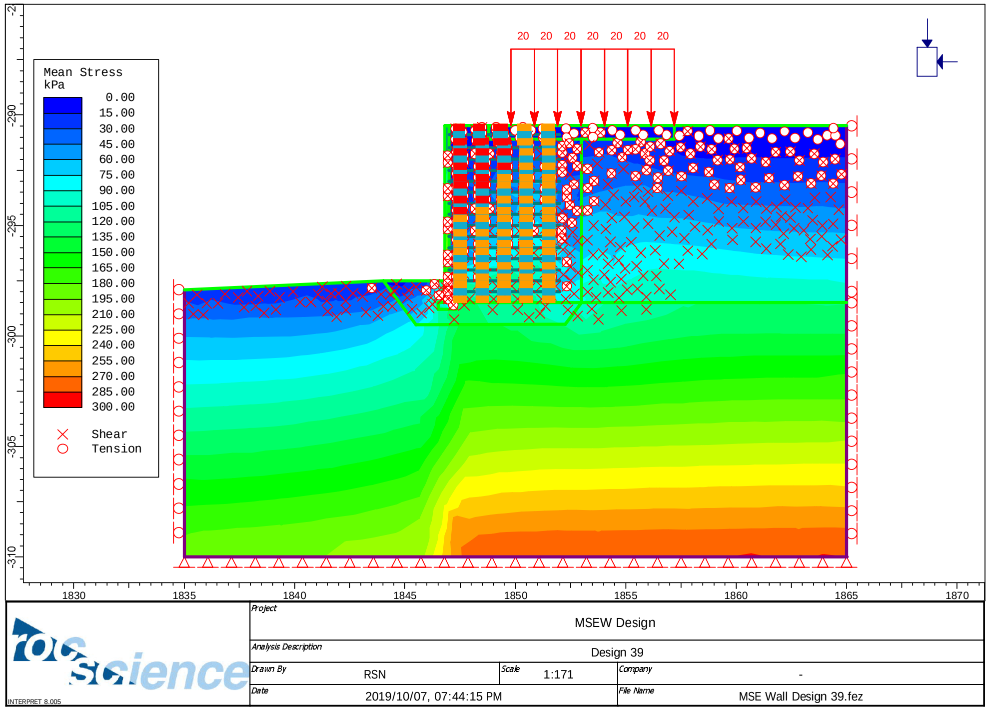
Total Displacement m
0.00e+000
6.50e-003
1.30e-002
1.95e-002
2.60e-002
3.25e-002
3.90e-002
4.55e-002
5.20e-002
5.85e-002
6.50e-002
7.15e-002
7.80e-002
8.45e-002
9.10e-002
9.75e-002
1.04e-001
1.11e-001
1.17e-001
1.24e-001
1.30e-001
Shear
Tension
20 20 20 20 20 20 20
Project
MSEW Design
Analysis Description
Design 38
Drawn By
RSN
Scale
1:165
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 38.fez
INTERPRET 8.005



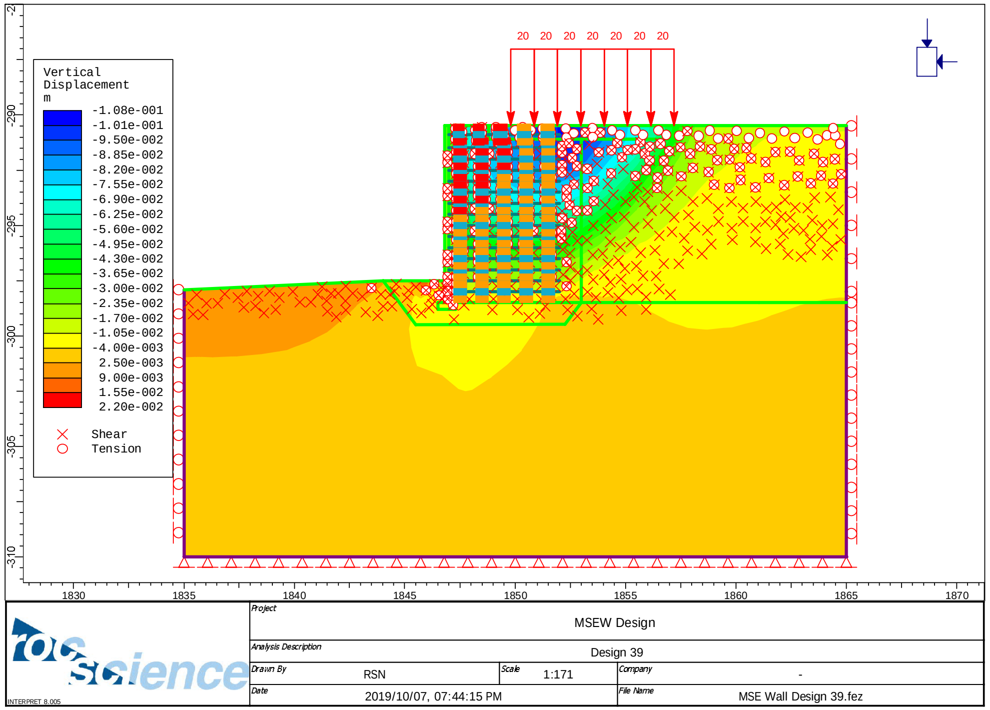
Sigma Z
kPa
0.00
15.00
30.00
45.00
60.00
75.00
90.00
105.00
120.00
135.00
150.00
165.00
180.00
195.00
210.00
225.00
240.00
255.00
270.00
285.00
300.00
Shear
Tension
20 20 20 20 20 20 20
Project
MSEW Design
Analysis Description
Design 39
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 39.fez
INTERPRET 8.005



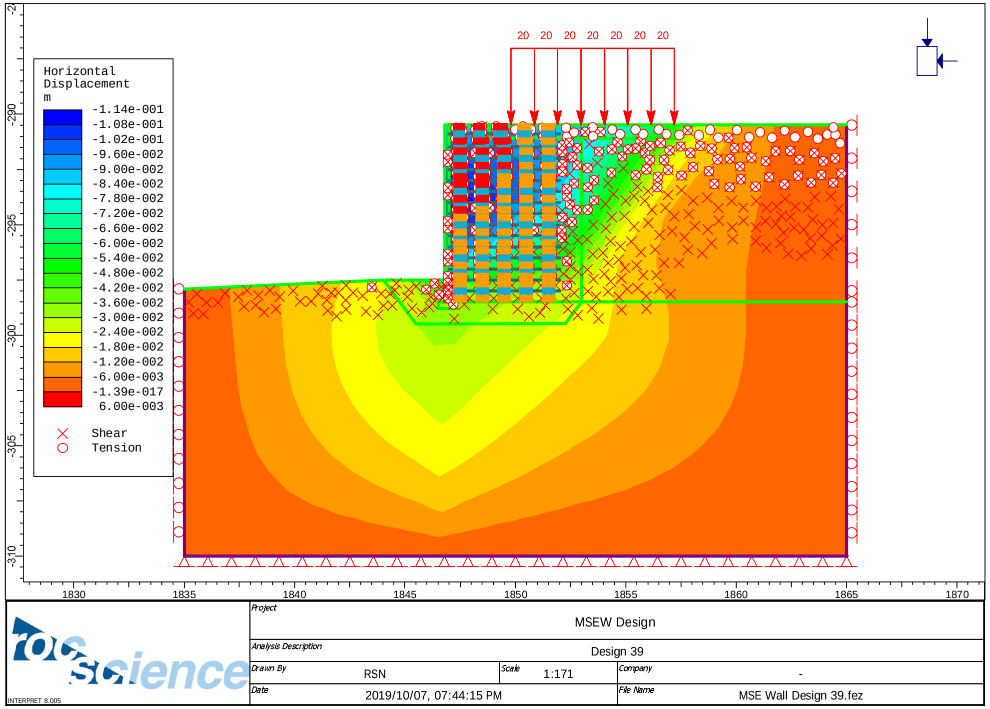
Maximum
Shear Strain
0.00e+000
1.50e-003
3.00e-003
4.50e-003
6.00e-003
7.50e-003
9.00e-003
1.05e-002
1.20e-002
1.35e-002
1.50e-002
1.65e-002
1.80e-002
1.95e-002
2.10e-002
2.25e-002
2.40e-002
2.55e-002
2.70e-002
2.85e-002
3.00e-002
Shear
Tension
20 20 20 20 20 20 20
Project
MSEW Design
Analysis Description
Design 39
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 39.fez
INTERPRET 8.005



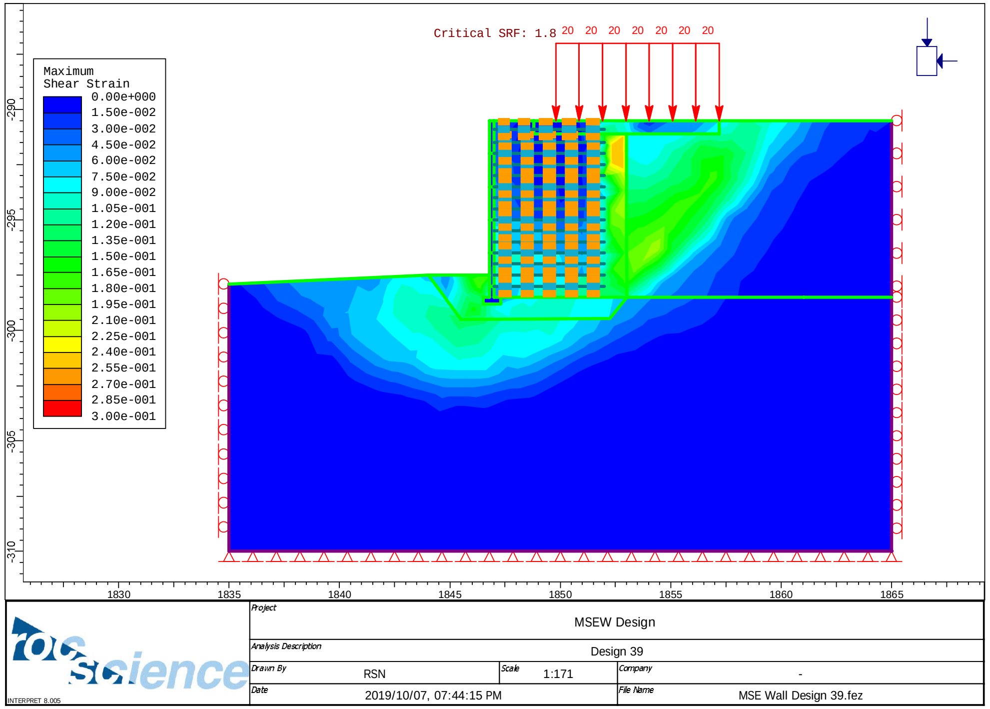
Mean Stress
kPa
0.00
15.00
30.00
45.00
60.00
75.00
90.00
105.00
120.00
135.00
150.00
165.00
180.00
195.00
210.00
225.00
240.00
255.00
270.00
285.00
300.00
Shear
Tension
20 20 20 20 20 20 20
Project
MSEW Design
Analysis Description
Design 39
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 39.fez
INTERPRET 8.005



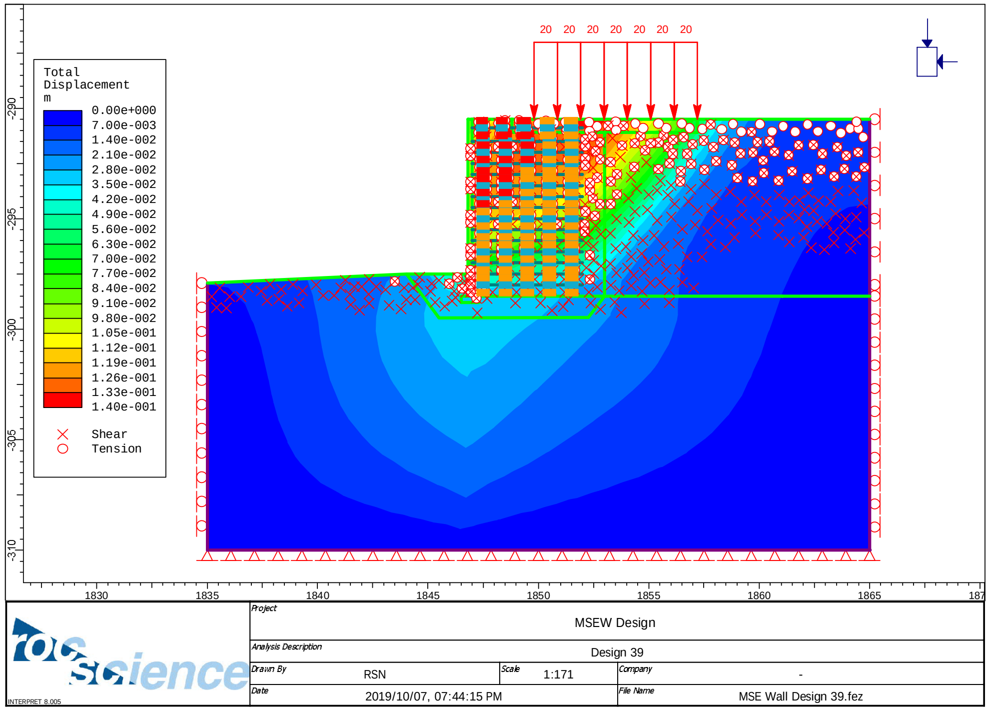
Vertical
Displacement
m
-1.08e-001
-1.01e-001
-9.50e-002
-8.85e-002
-8.20e-002
-7.55e-002
-6.90e-002
-6.25e-002
-5.60e-002
-4.95e-002
-4.30e-002
-3.65e-002
-3.00e-002
-2.35e-002
-1.70e-002
-1.05e-002
-4.00e-003
2.50e-003
9.00e-003
1.55e-002
2.20e-002
Shear
Tension
20 20 20 20 20 20 20
Project
MSEW Design
Analysis Description
Design 39
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 39.fez
INTERPRET 8.005



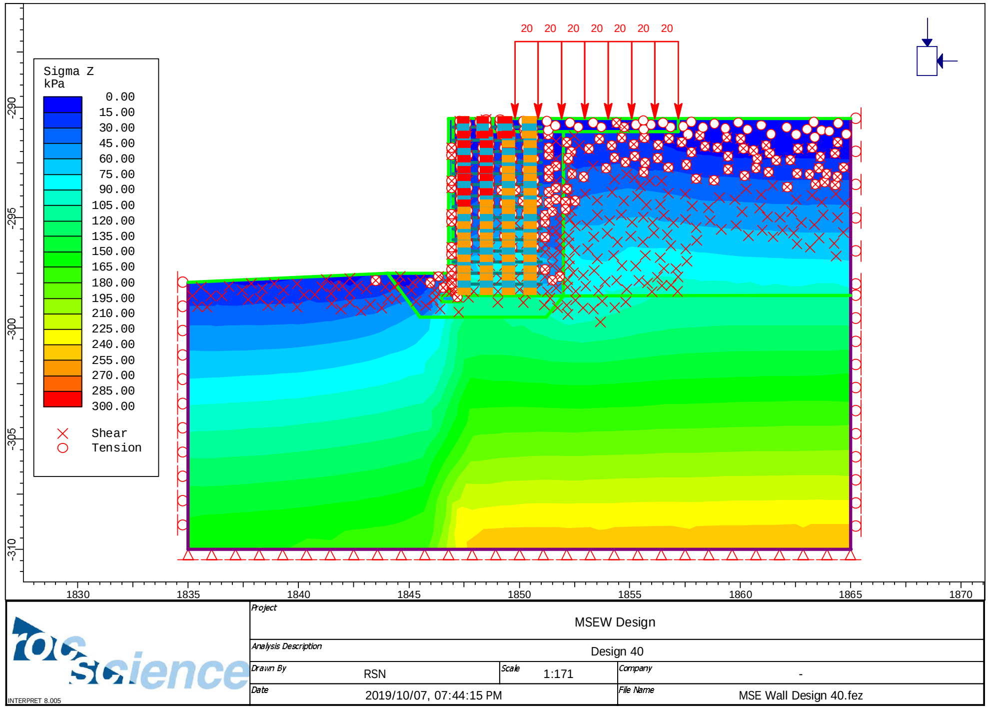
Horizontal Displacement
m
-1.14e-001
-1.08e-001
-1.02e-001
-9.60e-002
-9.00e-002
-8.40e-002
-7.80e-002
-7.20e-002
-6.60e-002
-6.00e-002
-5.40e-002
-4.80e-002
-4.20e-002
-3.60e-002
-3.00e-002
-2.40e-002
-1.80e-002
-1.20e-002
-6.00e-003
-1.39e-017
6.00e-003
Shear
Tension
20 20 20 20 20 20 20
-290
-295
-300
-305
-310
1830
1835
1840
1845
1850
1855
1860
1865
1870
Project
MSEW Design
Analysis Description
Design 39
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 39.fez
INTERPRET 8.005

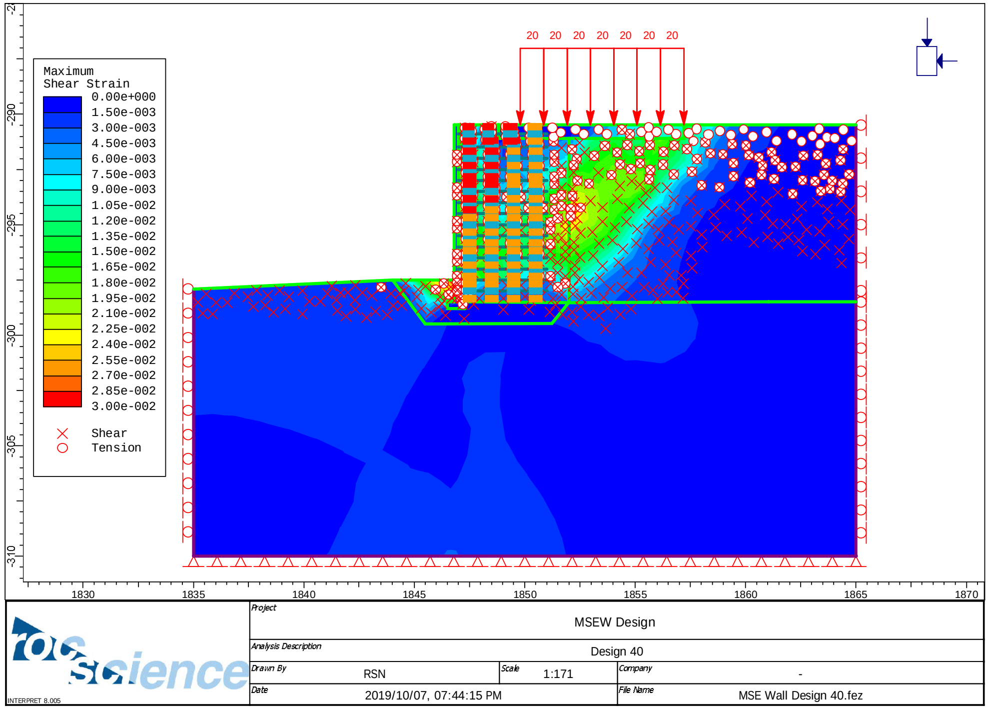


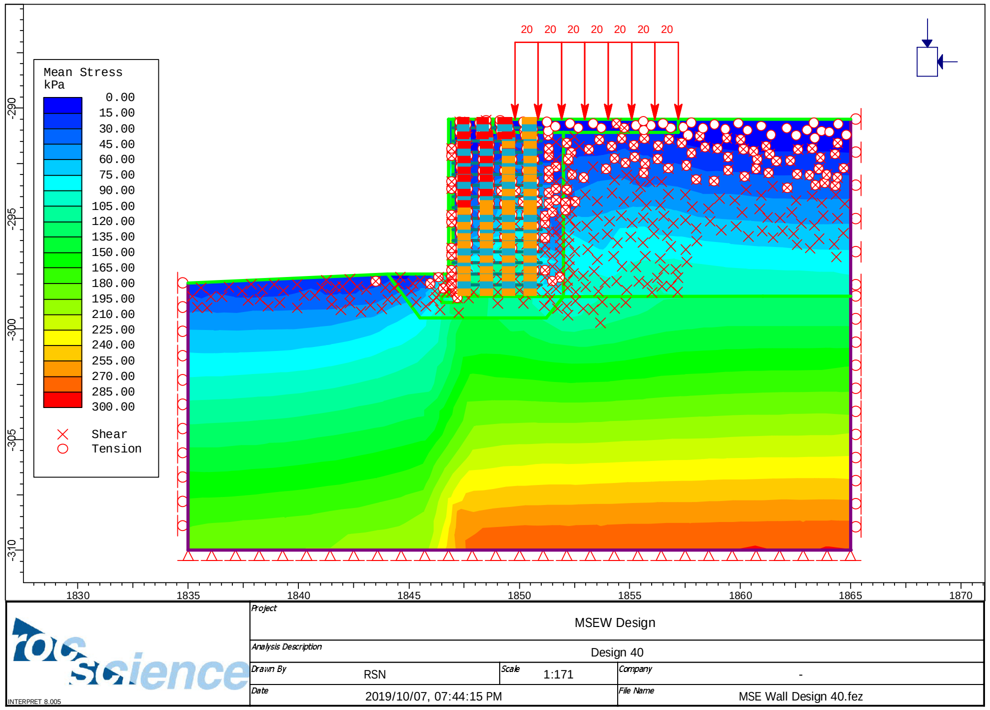
Maximum Shear Strain
0.00e+000
1.50e-002
3.00e-002
4.50e-002
6.00e-002
7.50e-002
9.00e-002
1.05e-001
1.20e-001
1.35e-001
1.50e-001
1.65e-001
1.80e-001
1.95e-001
2.10e-001
2.25e-001
2.40e-001
2.55e-001
2.70e-001
2.85e-001
3.00e-001
Critical SRF: 1.8
20 20 20 20 20 20 20
-290
-295
-300
-305
-310
1830
1835
1840
1845
1850
1855
1860
1865
Project
MSEW Design
Analysis Description
Design 39
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 39.fez
INTERPRET 8.005

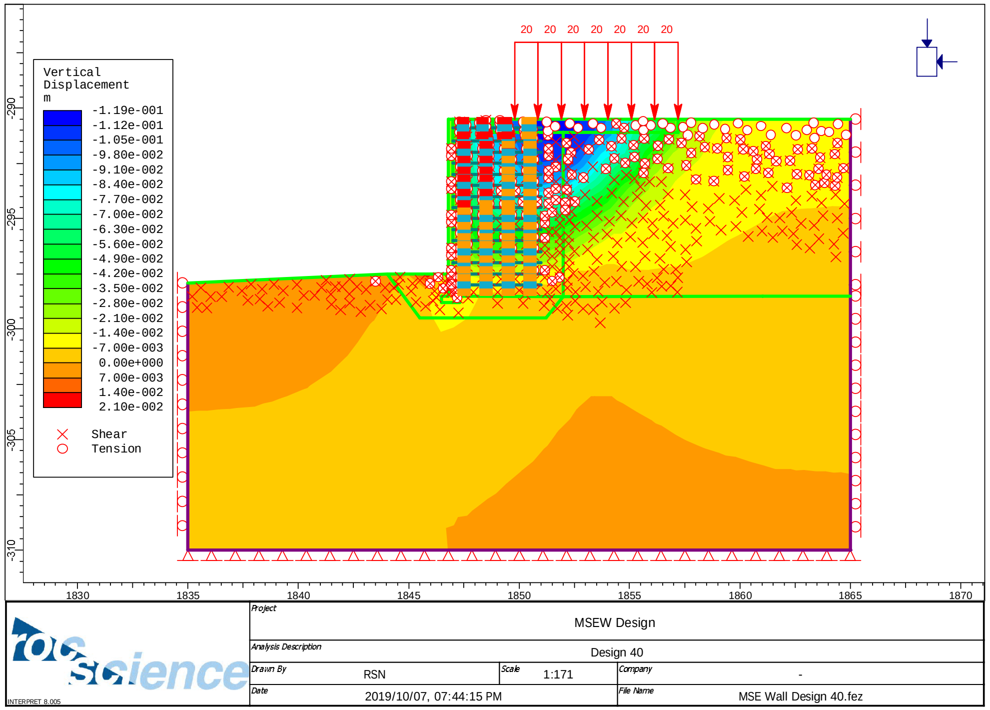


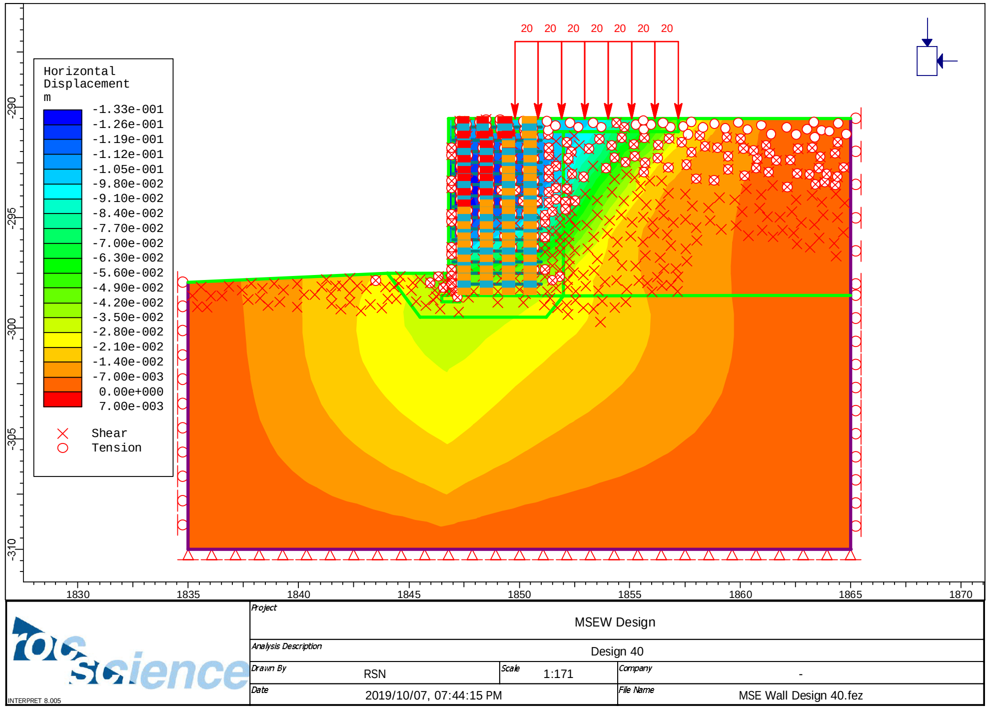
Total Displacement
m
0.00e+000
7.00e-003
1.40e-002
2.10e-002
2.80e-002
3.50e-002
4.20e-002
4.90e-002
5.60e-002
6.30e-002
7.00e-002
7.70e-002
8.40e-002
9.10e-002
9.80e-002
1.05e-001
1.12e-001
1.19e-001
1.26e-001
1.33e-001
1.40e-001
Shear
Tension
20 20 20 20 20 20 20
-290
-295
-300
-305
-310
1830
1835
1840
1845
1850
1855
1860
1865
Project
MSEW Design
Analysis Description
Design 39
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 39.fez
INTERPRET 8.005

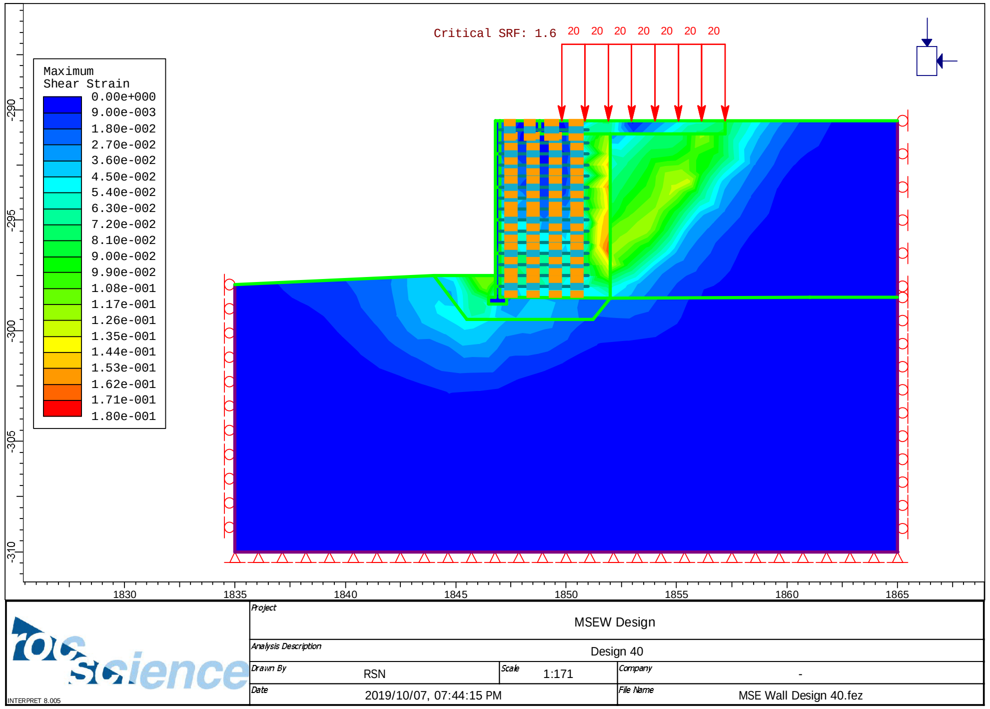

Sigma Z
kPa
0.00
15.00
30.00
45.00
60.00
75.00
90.00
105.00
120.00
135.00
150.00
165.00
180.00
195.00
210.00
225.00
240.00
255.00
270.00
285.00
300.00
Shear
Tension
20 20 20 20 20 20 20
Project
MSEW Design
Analysis Description
Design 40
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 40.fez
INTERPRET 8.005

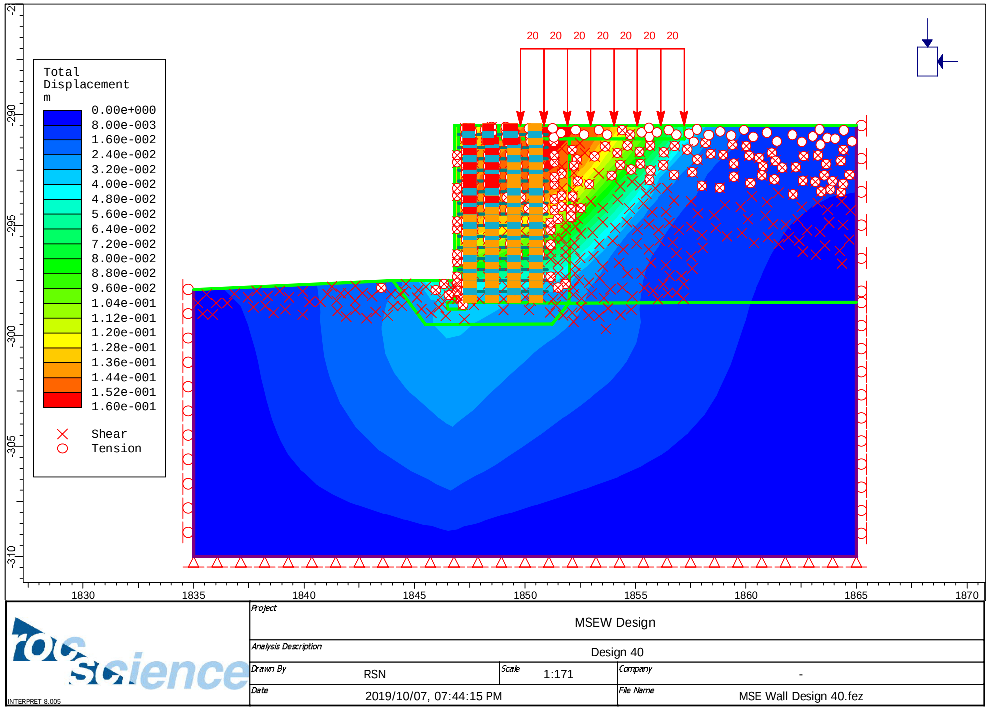

Maximum
Shear Strain
0.00e+000
1.50e-003
3.00e-003
4.50e-003
6.00e-003
7.50e-003
9.00e-003
1.05e-002
1.20e-002
1.35e-002
1.50e-002
1.65e-002
1.80e-002
1.95e-002
2.10e-002
2.25e-002
2.40e-002
2.55e-002
2.70e-002
2.85e-002
3.00e-002
Shear
Tension
20 20 20 20 20 20 20
Project
MSEW Design
Analysis Description
Design 40
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 40.fez
INTERPRET 8.005

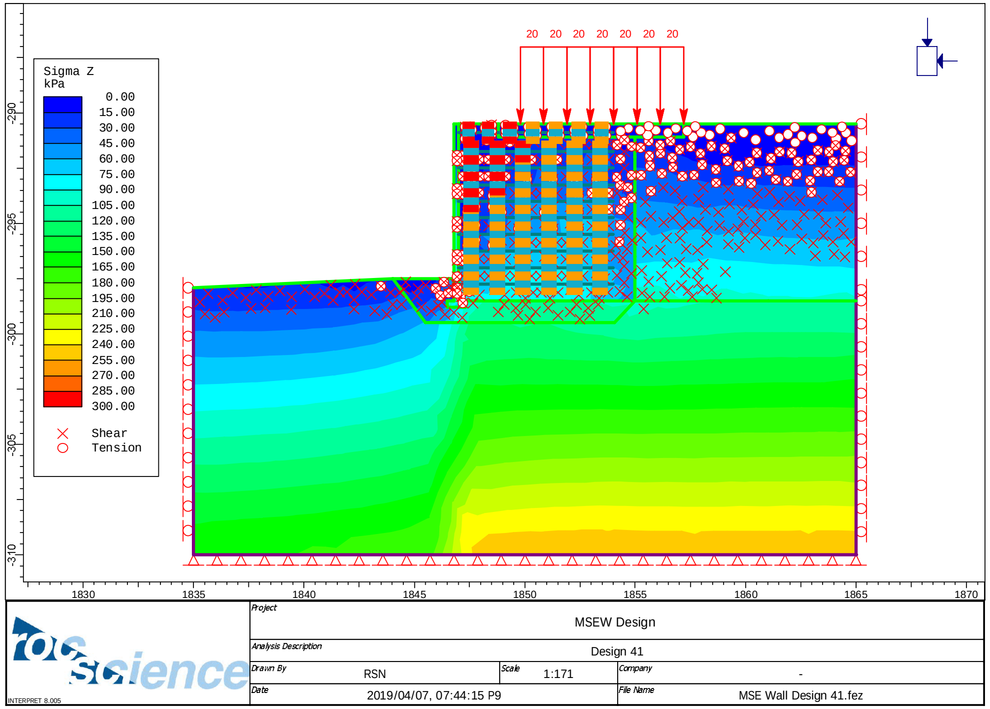

Mean Stress
kPa
0.00
15.00
30.00
45.00
60.00
75.00
90.00
105.00
120.00
135.00
150.00
165.00
180.00
195.00
210.00
225.00
240.00
255.00
270.00
285.00
300.00
Shear
Tension
20 20 20 20 20 20 20
Project
MSEW Design
Analysis Description
Design 40
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 40.fez
INTERPRET 8.005

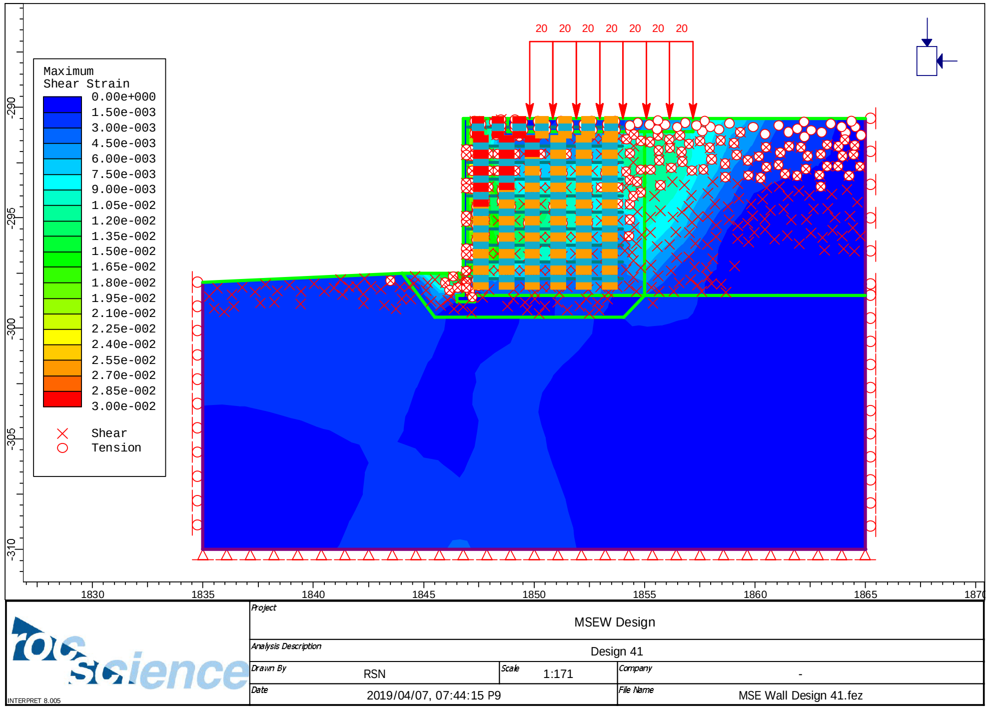

Vertical
Displacement
m
-1.19e-001
-1.12e-001
-1.05e-001
-9.80e-002
-9.10e-002
-8.40e-002
-7.70e-002
-7.00e-002
-6.30e-002
-5.60e-002
-4.90e-002
-4.20e-002
-3.50e-002
-2.80e-002
-2.10e-002
-1.40e-002
-7.00e-003
0.00e+000
7.00e-003
1.40e-002
2.10e-002
Shear
Tension
20 20 20 20 20 20 20
Project
MSEW Design
Analysis Description
Design 40
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 40.fez
INTERPRET 8.005

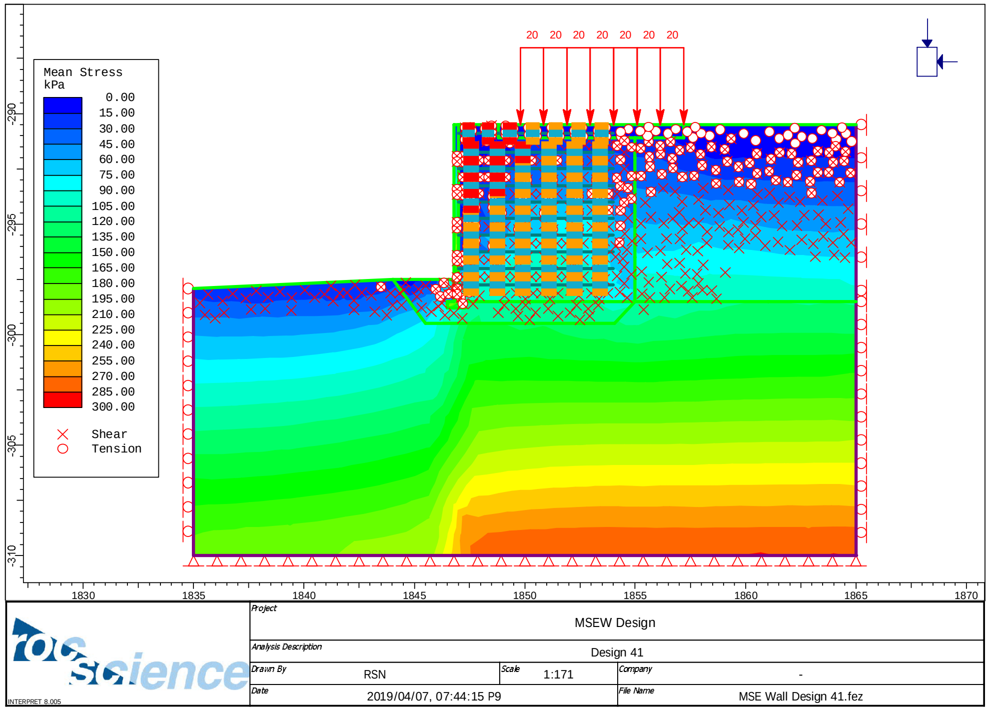

Horizontal Displacement m
-1.33e-001
-1.26e-001
-1.19e-001
-1.12e-001
-1.05e-001
-9.80e-002
-9.10e-002
-8.40e-002
-7.70e-002
-7.00e-002
-6.30e-002
-5.60e-002
-4.90e-002
-4.20e-002
-3.50e-002
-2.80e-002
-2.10e-002
-1.40e-002
-7.00e-003
0.00e+000
7.00e-003
Shear
Tension
20 20 20 20 20 20 20
-290
-295
-300
-305
-310
1830
1835
1840
1845
1850
1855
1860
1865
1870
Project
MSEW Design
Analysis Description
Design 40
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 40.fez
INTERPRET 8.005

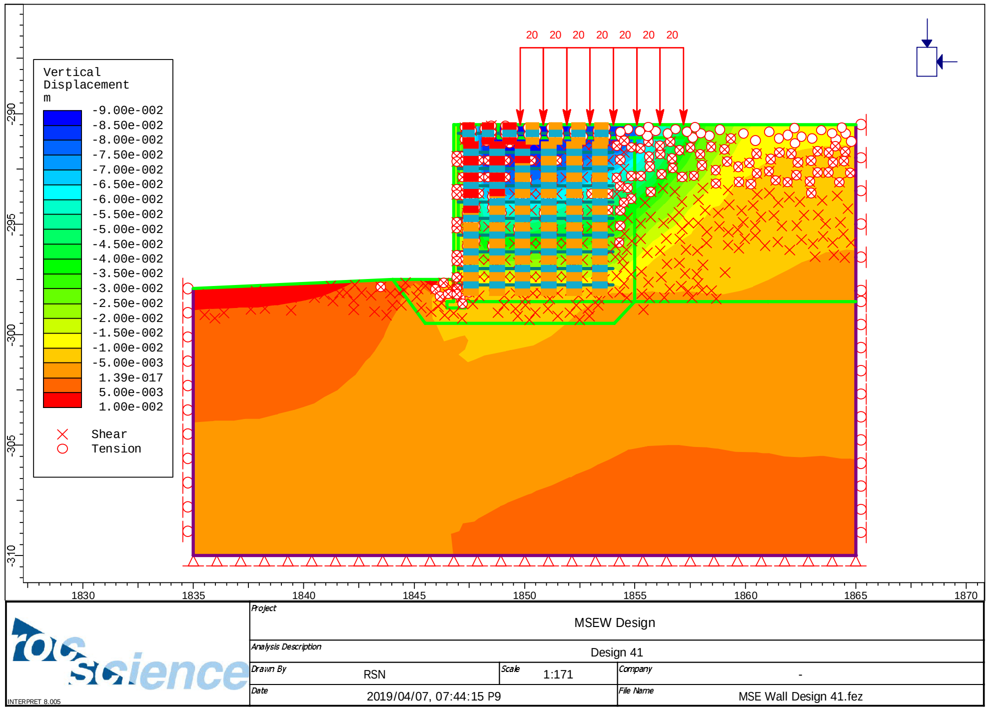

Maximum Shear Strain
0.00e+000
9.00e-003
1.80e-002
2.70e-002
3.60e-002
4.50e-002
5.40e-002
6.30e-002
7.20e-002
8.10e-002
9.00e-002
9.90e-002
1.08e-001
1.17e-001
1.26e-001
1.35e-001
1.44e-001
1.53e-001
1.62e-001
1.71e-001
1.80e-001
Critical SRF: 1.6
20 20 20 20 20 20 20
-290
-295
-300
-305
-310
1830
1835
1840
1845
1850
1855
1860
1865
Project
MSEW Design
Analysis Description
Design 40
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 40.fez
INTERPRET 8.005

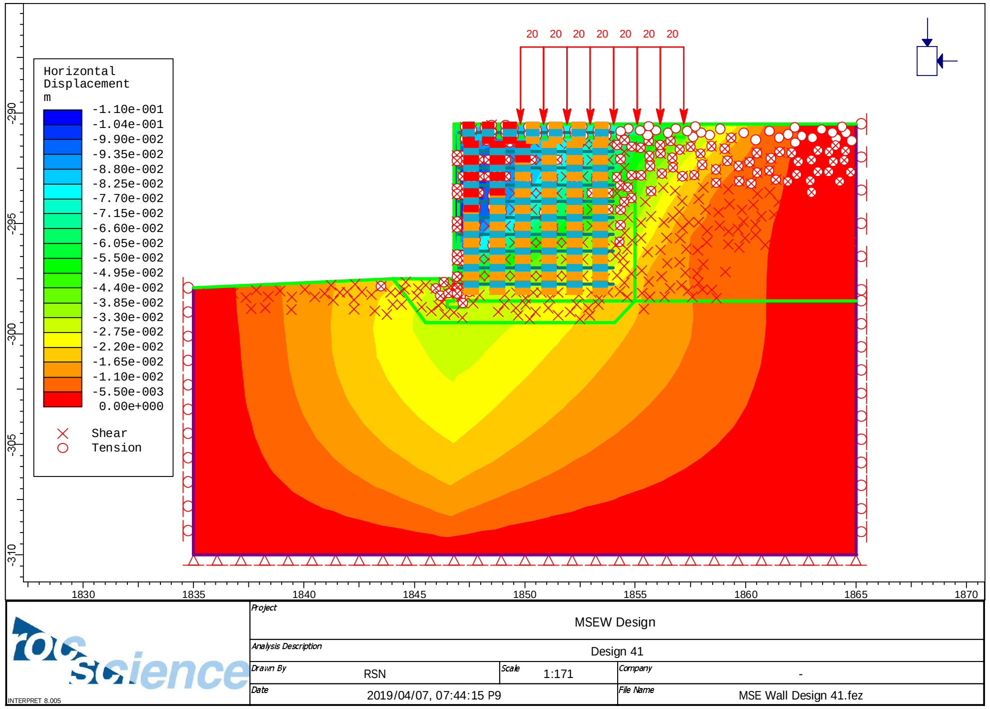

Total Displacement m
0.00e+000
8.00e-003
1.60e-002
2.40e-002
3.20e-002
4.00e-002
4.80e-002
5.60e-002
6.40e-002
7.20e-002
8.00e-002
8.80e-002
9.60e-002
1.04e-001
1.12e-001
1.20e-001
1.28e-001
1.36e-001
1.44e-001
1.52e-001
1.60e-001
Shear
Tension
20 20 20 20 20 20 20
-290
-295
-300
-305
-310
1830
1835
1840
1845
1850
1855
1860
1865
1870
Project
MSEW Design
Analysis Description
Design 40
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 40.fez
INTERPRET 8.005

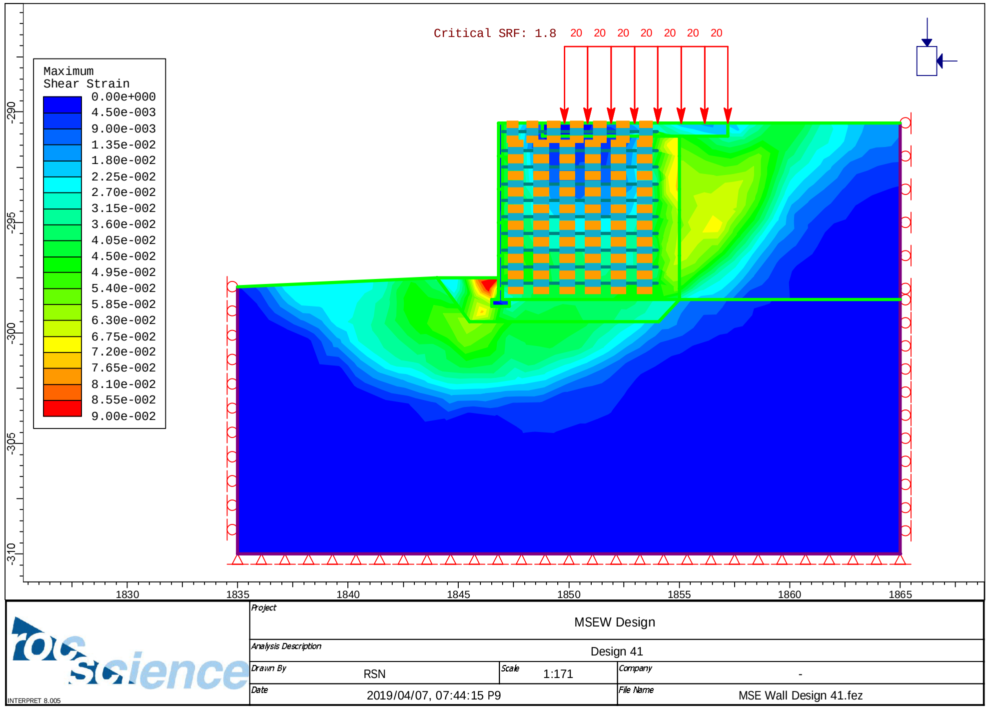

Sigma Z
kPa
0.00
15.00
30.00
45.00
60.00
75.00
90.00
105.00
120.00
135.00
150.00
165.00
180.00
195.00
210.00
225.00
240.00
255.00
270.00
285.00
300.00
Shear
Tension
20 20 20 20 20 20 20
-290
-295
-300
-305
-310
1830
1835
1840
1845
1850
1855
1860
1865
1870
Project
MSEW Design
Analysis Description
Design 41
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/04/07, 07:44:15 P9
File Name
MSE Wall Design 41.fez
INTERPRET 8.005

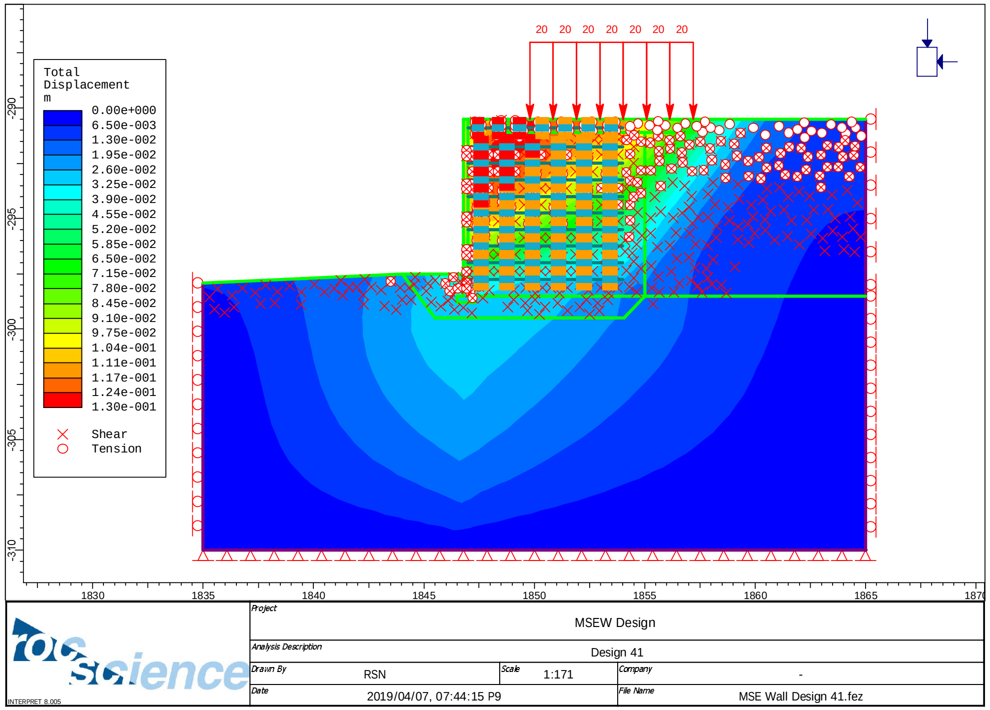

Maximum
Shear Strain
0.00e+000
1.50e-003
3.00e-003
4.50e-003
6.00e-003
7.50e-003
9.00e-003
1.05e-002
1.20e-002
1.35e-002
1.50e-002
1.65e-002
1.80e-002
1.95e-002
2.10e-002
2.25e-002
2.40e-002
2.55e-002
2.70e-002
2.85e-002
3.00e-002
Shear
Tension
20 20 20 20 20 20 20
-290
-295
-300
-305
-310
1830
1835
1840
1845
1850
1855
1860
1865
Project
MSEW Design
Analysis Description
Design 41
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/04/07, 07:44:15 P9
File Name
MSE Wall Design 41.fez
INTERPRET 8.005

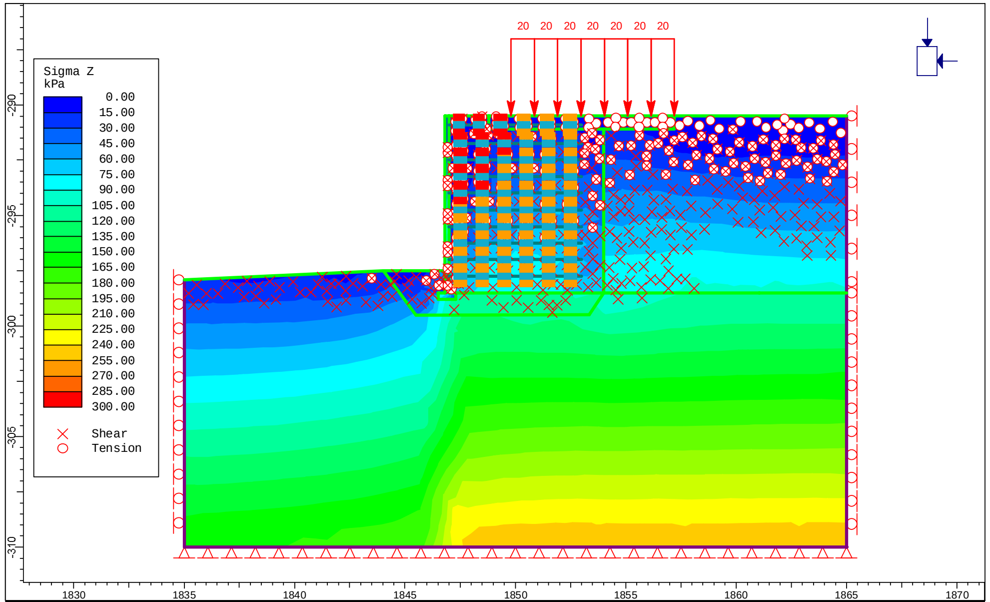

Mean Stress
kPa
0.00
15.00
30.00
45.00
60.00
75.00
90.00
105.00
120.00
135.00
150.00
165.00
180.00
195.00
210.00
225.00
240.00
255.00
270.00
285.00
300.00
Shear
Tension
20 20 20 20 20 20 20
-290
-295
-300
-305
-310
1830
1835
1840
1845
1850
1855
1860
1865
1870
Project
MSEW Design
Analysis Description
Design 41
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/04/07, 07:44:15 P9
File Name
MSE Wall Design 41.fez
INTERPRET 8.005


Vertical
Displacement
m
-9.00e-002
-8.50e-002
-8.00e-002
-7.50e-002
-7.00e-002
-6.50e-002
-6.00e-002
-5.50e-002
-5.00e-002
-4.50e-002
-4.00e-002
-3.50e-002
-3.00e-002
-2.50e-002
-2.00e-002
-1.50e-002
-1.00e-002
-5.00e-003
1.39e-017
5.00e-003
1.00e-002
Shear
Tension
20 20 20 20 20 20 20
-290
-295
-300
-305
-310
1830
1835
1840
1845
1850
1855
1860
1865
1870
Project
MSEW Design
Analysis Description
Design 41
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/04/07, 07:44:15 P9
File Name
MSE Wall Design 41.fez
INTERPRET 8.005


Horizontal Displacement m
-1.10e-001
-1.04e-001
-9.90e-002
-9.35e-002
-8.80e-002
-8.25e-002
-7.70e-002
-7.15e-002
-6.60e-002
-6.05e-002
-5.50e-002
-4.95e-002
-4.40e-002
-3.85e-002
-3.30e-002
-2.75e-002
-2.20e-002
-1.65e-002
-1.10e-002
-5.50e-003
0.00e+000
Shear
Tension
20 20 20 20 20 20 20
1830 1835 1840 1845 1850 1855 1860 1865 1870
-290 -295 -300 -305 -310
Project
MSEW Design
Analysis Description
Design 41
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/04/07, 07:44:15 P9
File Name
MSE Wall Design 41.fez
INTERPRET 8.005

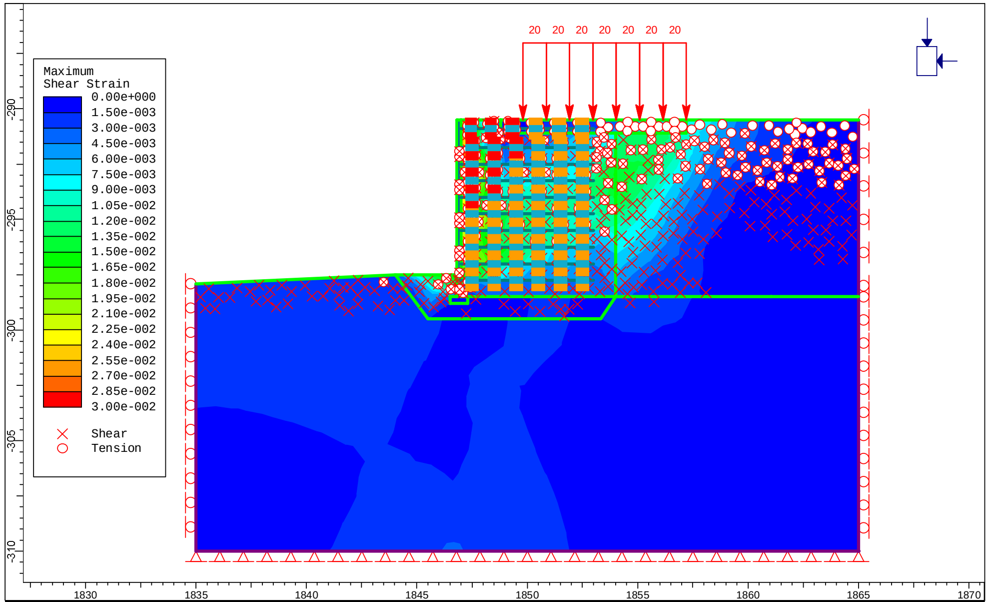

Maximum Shear Strain
0.00e+000
4.50e-003
9.00e-003
1.35e-002
1.80e-002
2.25e-002
2.70e-002
3.15e-002
3.60e-002
4.05e-002
4.50e-002
4.95e-002
5.40e-002
5.85e-002
6.30e-002
6.75e-002
7.20e-002
7.65e-002
8.10e-002
8.55e-002
9.00e-002
Critical SRF: 1.8
20 20 20 20 20 20 20
1830 1835 1840 1845 1850 1855 1860 1865
-290 -295 -300 -305 -310
Project
MSEW Design
Analysis Description
Design 41
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/04/07, 07:44:15 P9
File Name
MSE Wall Design 41.fez
INTERPRET 8.005


Total Displacement m
0.00e+000
6.50e-003
1.30e-002
1.95e-002
2.60e-002
3.25e-002
3.90e-002
4.55e-002
5.20e-002
5.85e-002
6.50e-002
7.15e-002
7.80e-002
8.45e-002
9.10e-002
9.75e-002
1.04e-001
1.11e-001
1.17e-001
1.24e-001
1.30e-001
Shear
Tension
20 20 20 20 20 20 20
1830 1835 1840 1845 1850 1855 1860 1865 1870
-290 -295 -300 -305 -310
Project
MSEW Design
Analysis Description
Design 41
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/04/07, 07:44:15 P9
File Name
MSE Wall Design 41.fez
INTERPRET 8.005



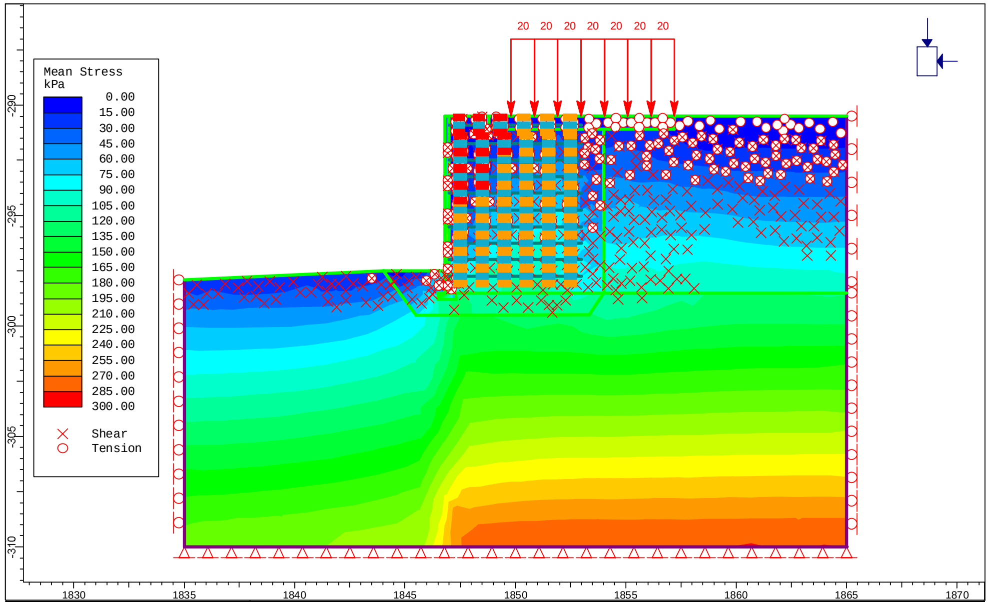
Project	MSEW Design		
Analysis Description	Design 42		
Drawn By RSN	Scale 1:171	Company -	
Date 2019/10/07, 07:44:15 PM		File Name MSE Wall Design 42.fez	

INTERPRET 8.005



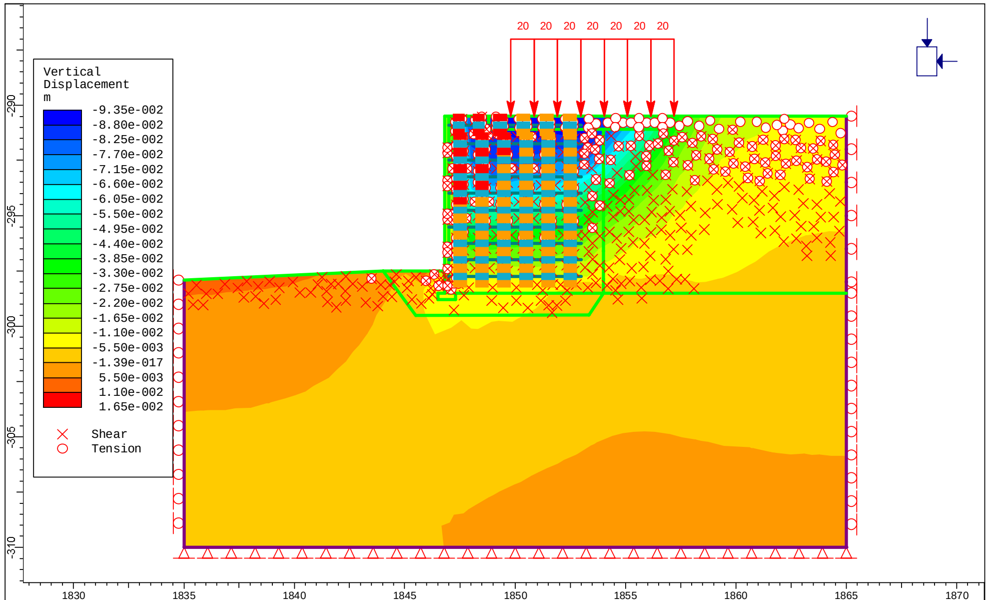
Project	MSEW Design		
Analysis Description	Design 42		
Drawn By RSN	Scale 1:171	Company -	
Date 2019/10/07, 07:44:15 PM		File Name MSE Wall Design 42.fez	

INTERPRET 8.005



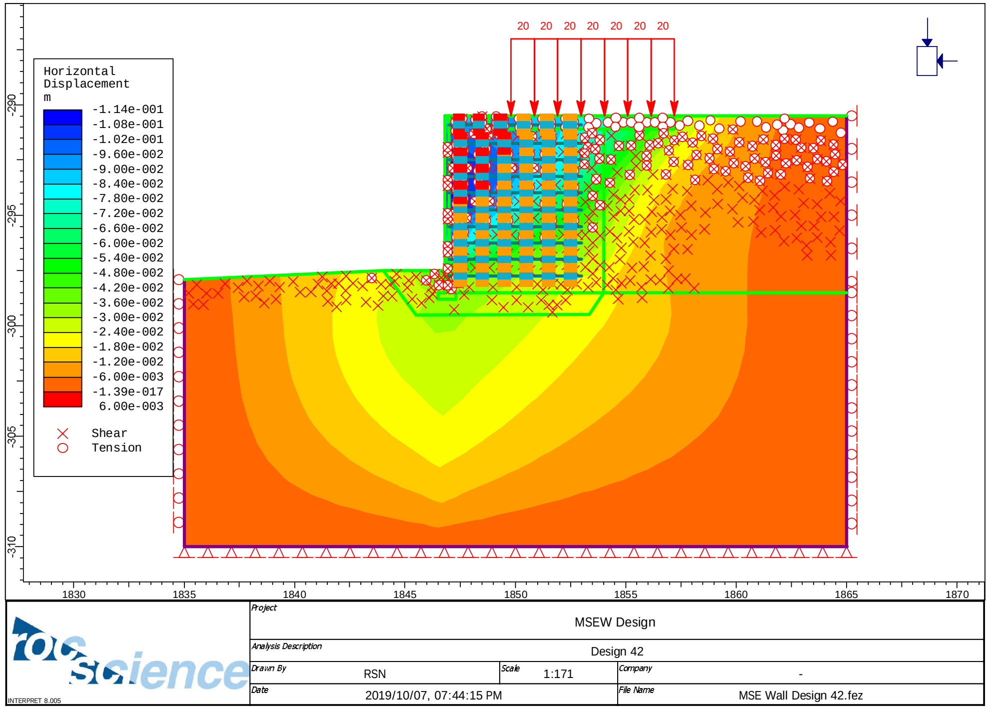
Project	MSEW Design		
Analysis Description	Design 42		
Drawn By RSN	Scale 1:171	Company -	
Date 2019/10/07, 07:44:15 PM		File Name MSE Wall Design 42.fez	

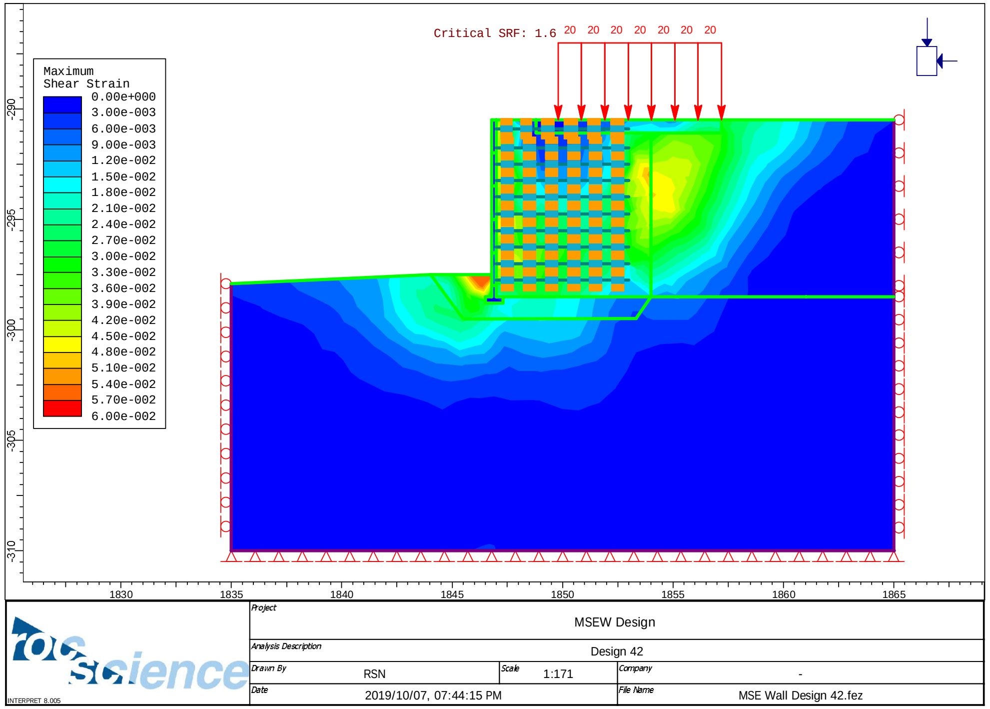
INTERPRET 8.005

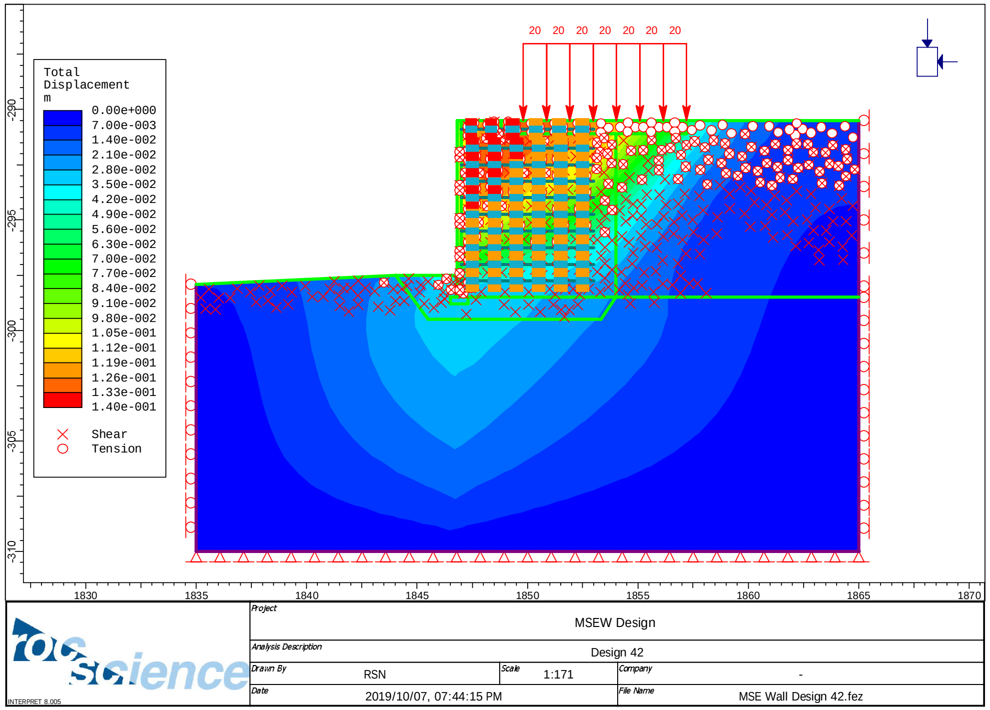


Project	MSEW Design		
Analysis Description	Design 42		
Drawn By RSN	Scale 1:171	Company -	
Date 2019/10/07, 07:44:15 PM		File Name MSE Wall Design 42.fez	

INTERPRET 8.005


20 20 20 20 20 20 20
Horizontal Displacement m
-1.14e-001
-1.08e-001
-1.02e-001
-9.60e-002
-9.00e-002
-8.40e-002
-7.80e-002
-7.20e-002
-6.60e-002
-6.00e-002
-5.40e-002
-4.80e-002
-4.20e-002
-3.60e-002
-3.00e-002
-2.40e-002
-1.80e-002
-1.20e-002
-6.00e-003
-1.39e-017
6.00e-003
Shear
Tension
-290
-295
-300
-305
-310
1830
1835
1840
1845
1850
1855
1860
1865
1870
Project
MSEW Design
Analysis Description
Design 42
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 42.fez
INTERPRET 8.005


Critical SRF: 1.6
20 20 20 20 20 20 20
Maximum Shear Strain
0.00e+000
3.00e-003
6.00e-003
9.00e-003
1.20e-002
1.50e-002
1.80e-002
2.10e-002
2.40e-002
2.70e-002
3.00e-002
3.30e-002
3.60e-002
3.90e-002
4.20e-002
4.50e-002
4.80e-002
5.10e-002
5.40e-002
5.70e-002
6.00e-002
-290
-295
-300
-305
-310
1830
1835
1840
1845
1850
1855
1860
1865
Project
MSEW Design
Analysis Description
Design 42
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 42.fez
INTERPRET 8.005


20 20 20 20 20 20 20
Total Displacement m
0.00e+000
7.00e-003
1.40e-002
2.10e-002
2.80e-002
3.50e-002
4.20e-002
4.90e-002
5.60e-002
6.30e-002
7.00e-002
7.70e-002
8.40e-002
9.10e-002
9.80e-002
1.05e-001
1.12e-001
1.19e-001
1.26e-001
1.33e-001
1.40e-001
Shear
Tension
-290
-295
-300
-305
-310
1830
1835
1840
1845
1850
1855
1860
1865
1870
Project
MSEW Design
Analysis Description
Design 42
Drawn By
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Scale
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Company
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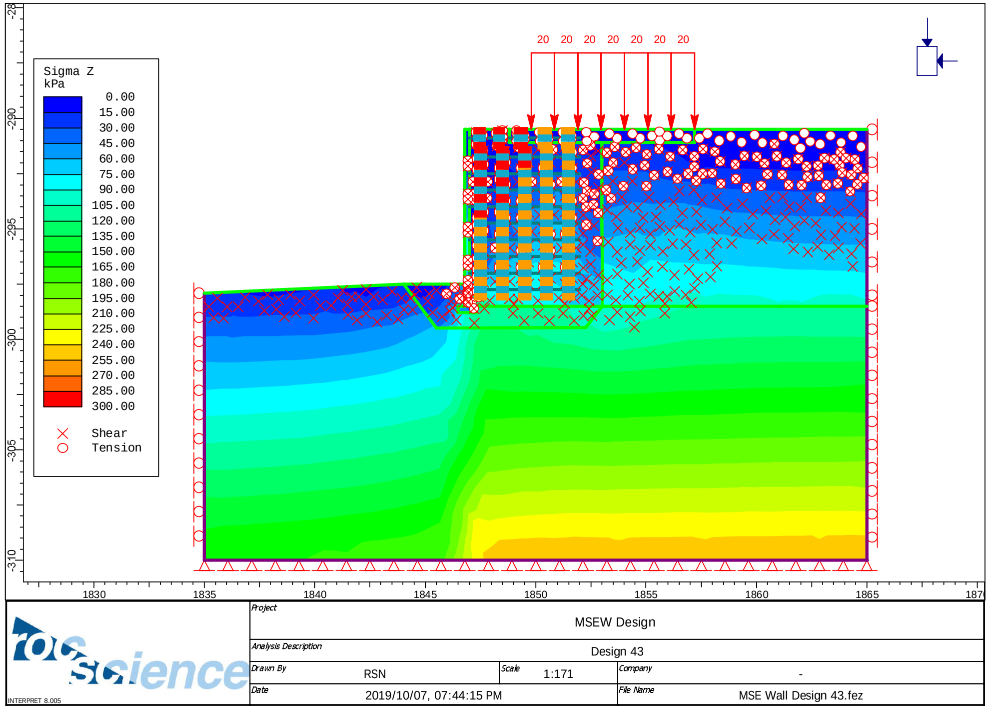
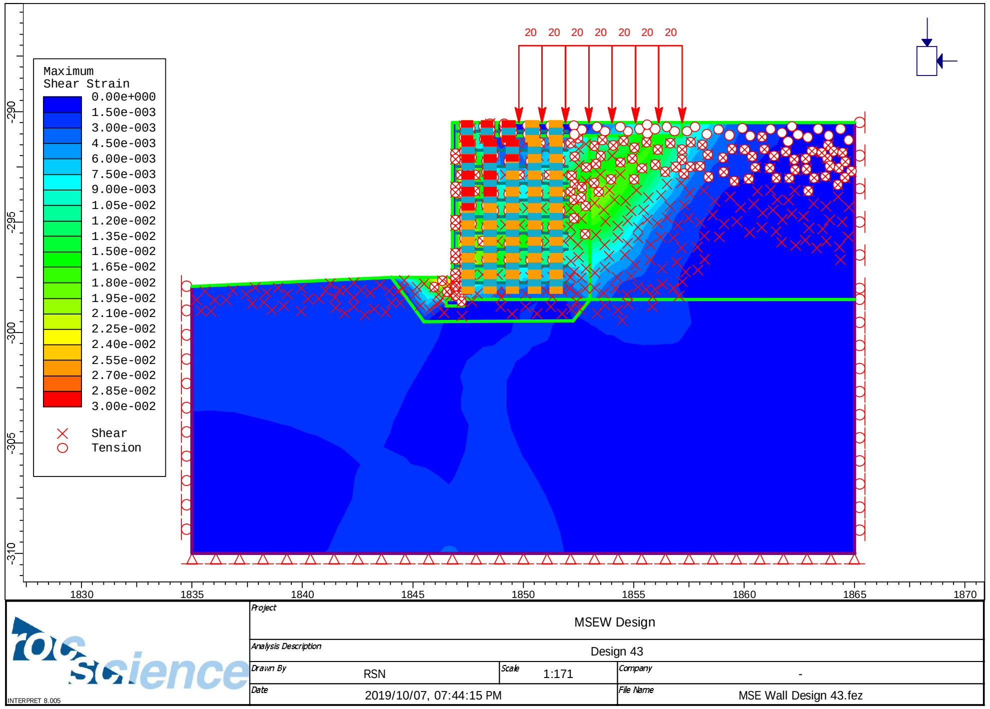
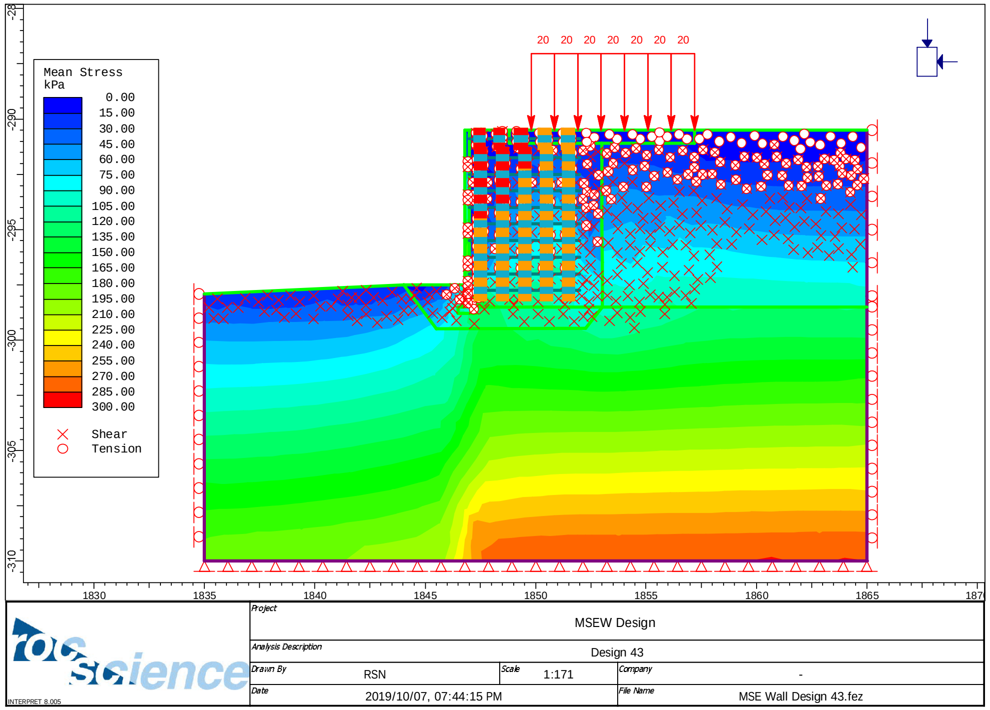
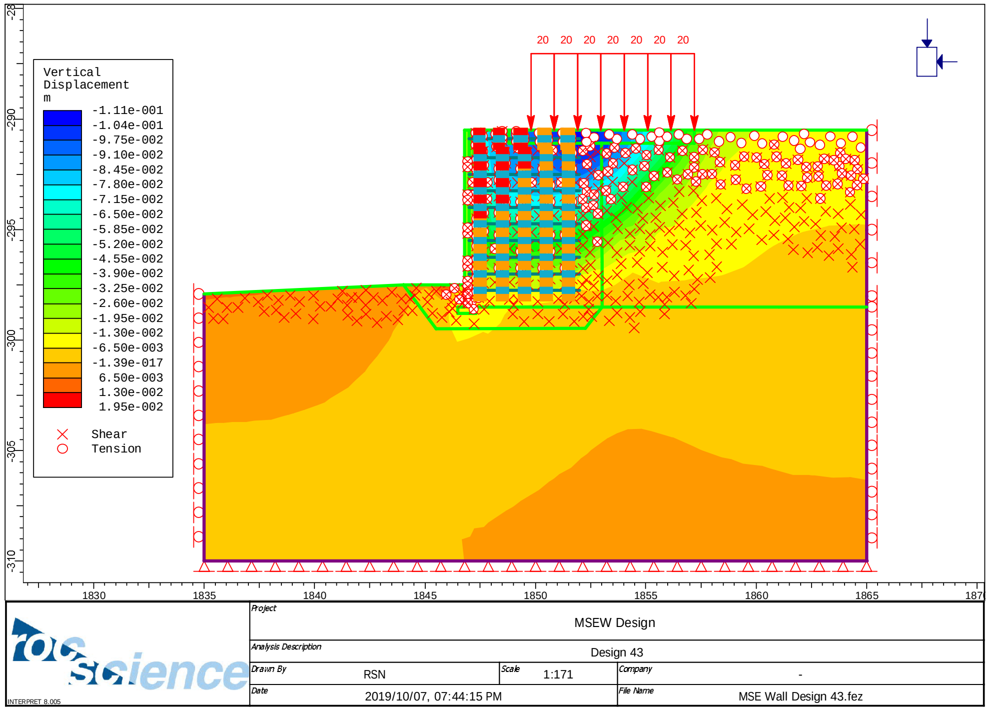
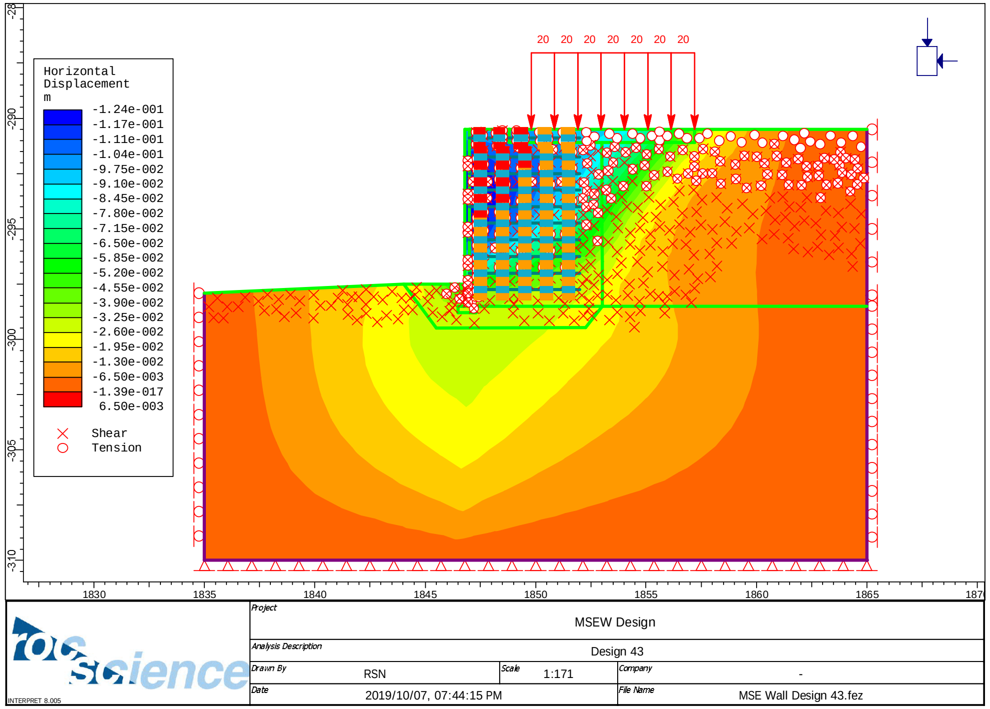
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 42.fez
INTERPRET 8.005

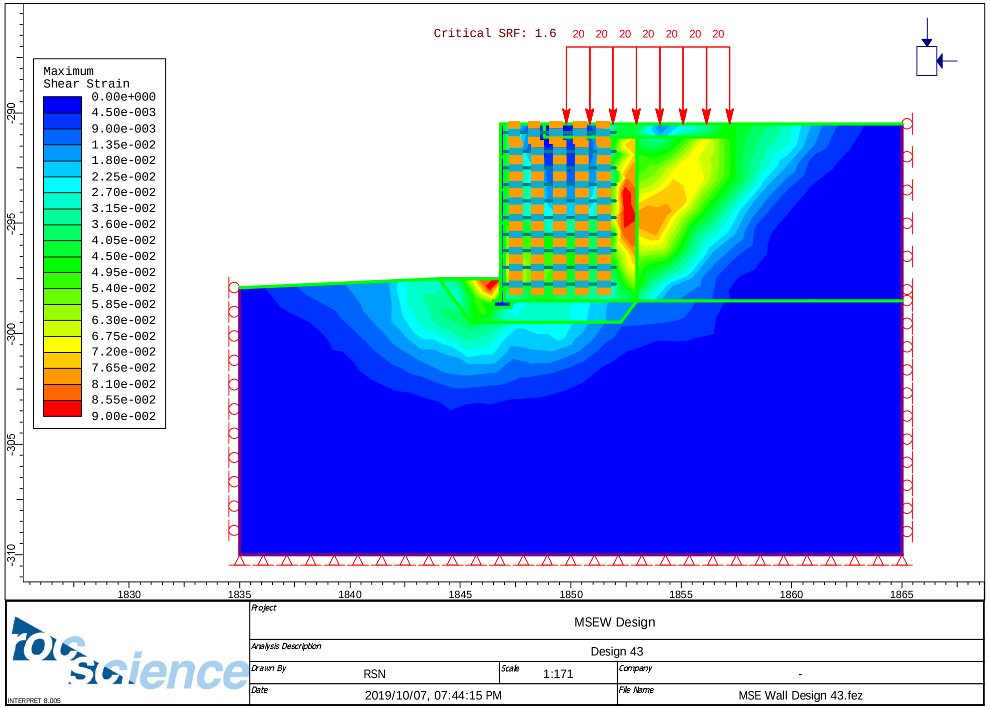

Sigma Z
kPa
0.00
15.00
30.00
45.00
60.00
75.00
90.00
105.00
120.00
135.00
150.00
165.00
180.00
195.00
210.00
225.00
240.00
255.00
270.00
285.00
300.00
Shear
Tension
20 20 20 20 20 20 20
1830 1835 1840 1845 1850 1855 1860 1865
-290 -295 -300 -305 -310
Project
MSEW Design
Analysis Description
Design 43
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 43.fez
INTERPRET 8.005

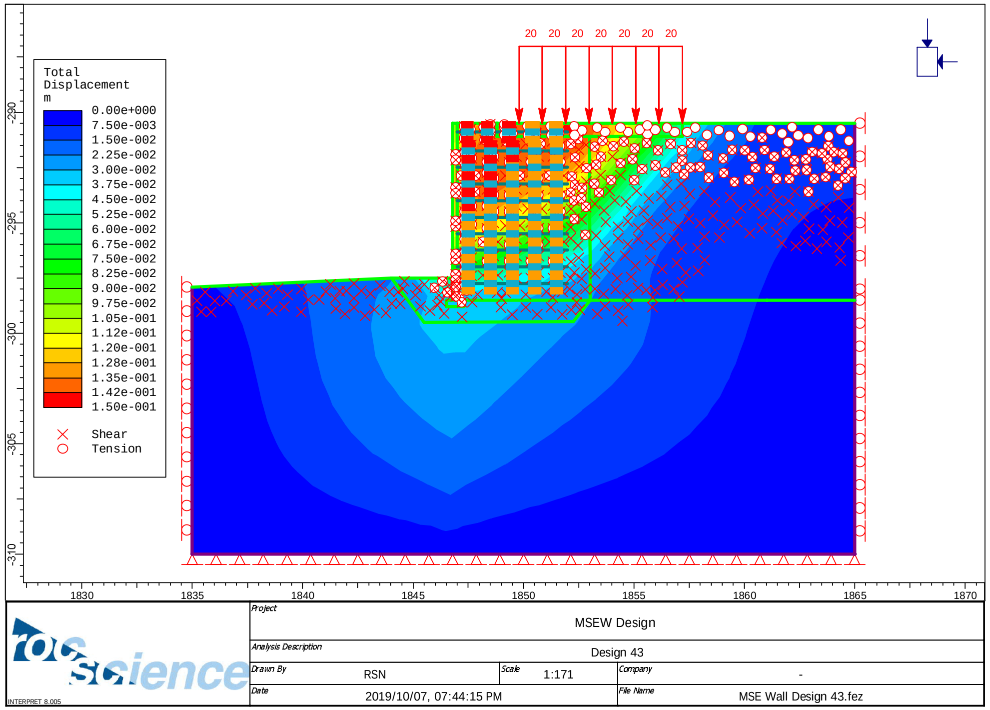

Maximum
Shear Strain
0.00e+000
1.50e-003
3.00e-003
4.50e-003
6.00e-003
7.50e-003
9.00e-003
1.05e-002
1.20e-002
1.35e-002
1.50e-002
1.65e-002
1.80e-002
1.95e-002
2.10e-002
2.25e-002
2.40e-002
2.55e-002
2.70e-002
2.85e-002
3.00e-002
Shear
Tension
20 20 20 20 20 20 20
1830 1835 1840 1845 1850 1855 1860 1865 1870
-290 -295 -300 -305 -310
Project
MSEW Design
Analysis Description
Design 43
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 43.fez
INTERPRET 8.005

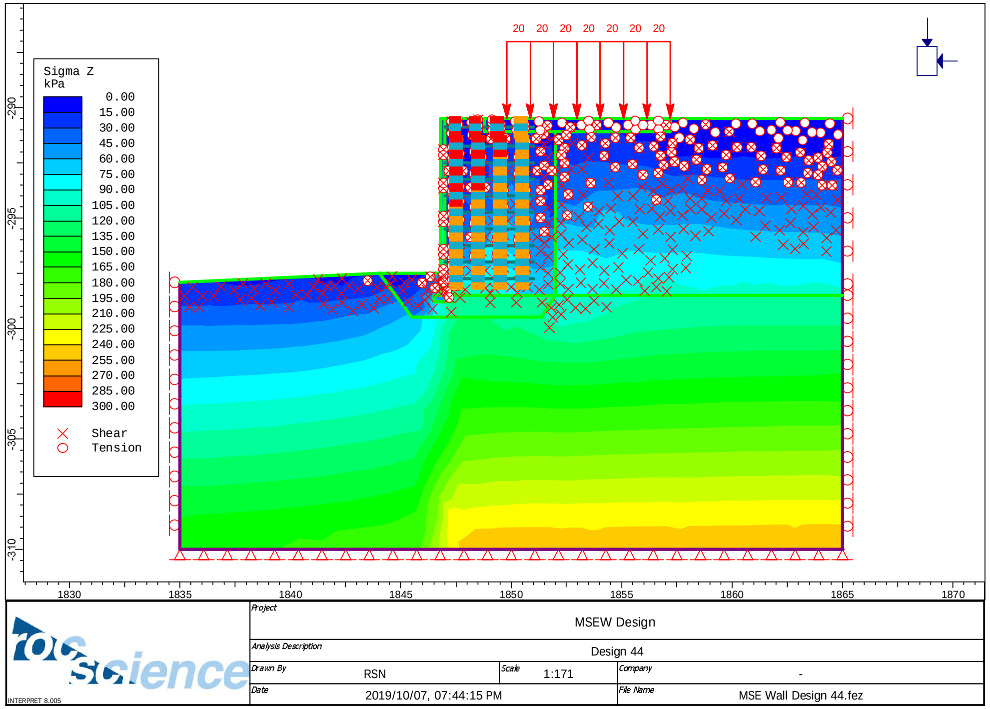

Mean Stress
kPa
0.00
15.00
30.00
45.00
60.00
75.00
90.00
105.00
120.00
135.00
150.00
165.00
180.00
195.00
210.00
225.00
240.00
255.00
270.00
285.00
300.00
Shear
Tension
20 20 20 20 20 20 20
1830 1835 1840 1845 1850 1855 1860 1865
-290 -295 -300 -305 -310
Project
MSEW Design
Analysis Description
Design 43
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 43.fez
INTERPRET 8.005

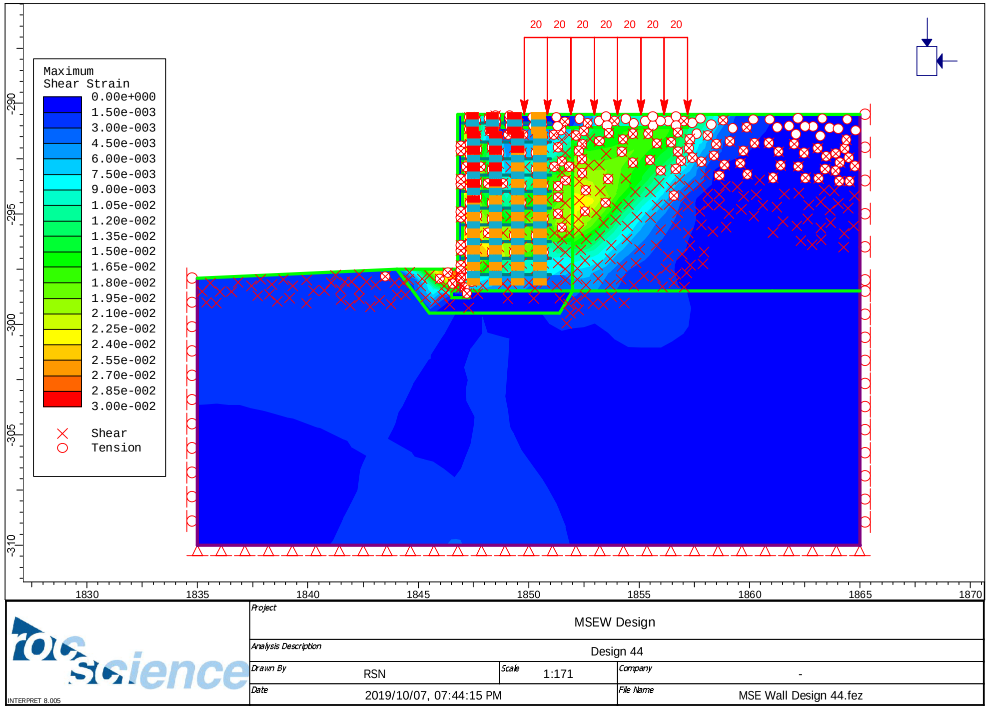

Vertical
Displacement
m
-1.11e-001
-1.04e-001
-9.75e-002
-9.10e-002
-8.45e-002
-7.80e-002
-7.15e-002
-6.50e-002
-5.85e-002
-5.20e-002
-4.55e-002
-3.90e-002
-3.25e-002
-2.60e-002
-1.95e-002
-1.30e-002
-6.50e-003
-1.39e-017
6.50e-003
1.30e-002
1.95e-002
Shear
Tension
20 20 20 20 20 20 20
1830 1835 1840 1845 1850 1855 1860 1865
-290 -295 -300 -305 -310
Project
MSEW Design
Analysis Description
Design 43
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 43.fez
INTERPRET 8.005

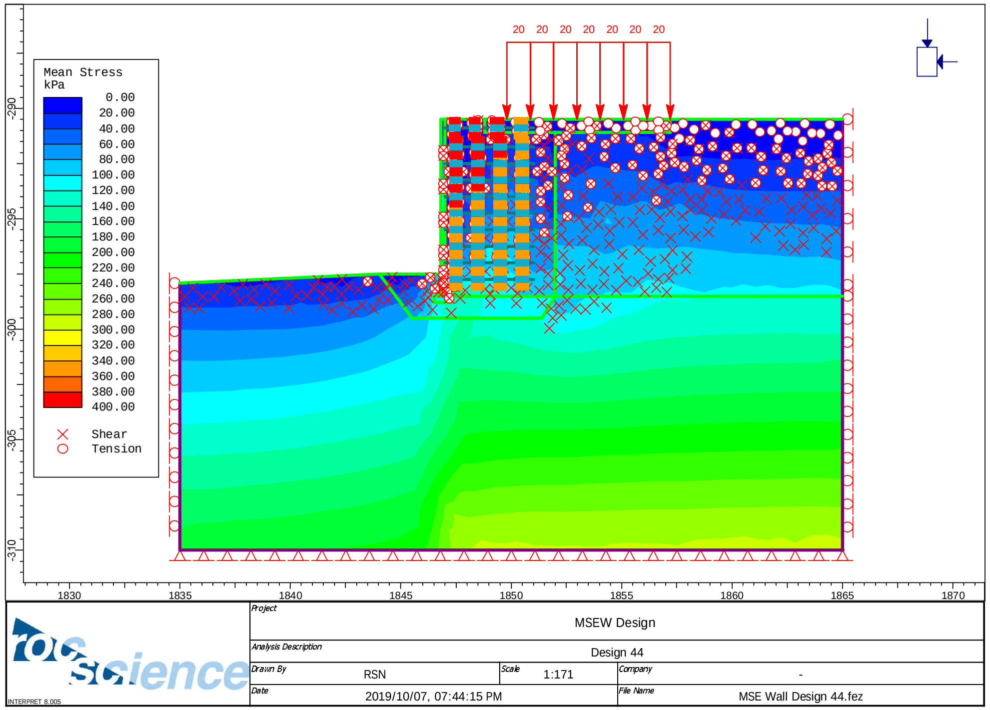

Horizontal Displacement m
-1.24e-001
-1.17e-001
-1.11e-001
-1.04e-001
-9.75e-002
-9.10e-002
-8.45e-002
-7.80e-002
-7.15e-002
-6.50e-002
-5.85e-002
-5.20e-002
-4.55e-002
-3.90e-002
-3.25e-002
-2.60e-002
-1.95e-002
-1.30e-002
-6.50e-003
-1.39e-017
6.50e-003
Shear
Tension
20 20 20 20 20 20 20
-290
-295
-300
-305
-310
1830 1835 1840 1845 1850 1855 1860 1865 1870
Project MSEW Design
Analysis Description Design 43
Drawn By RSN
Scale 1:171
Company -
Date 2019/10/07, 07:44:15 PM
File Name MSE Wall Design 43.fez
INTERPRET 8.005

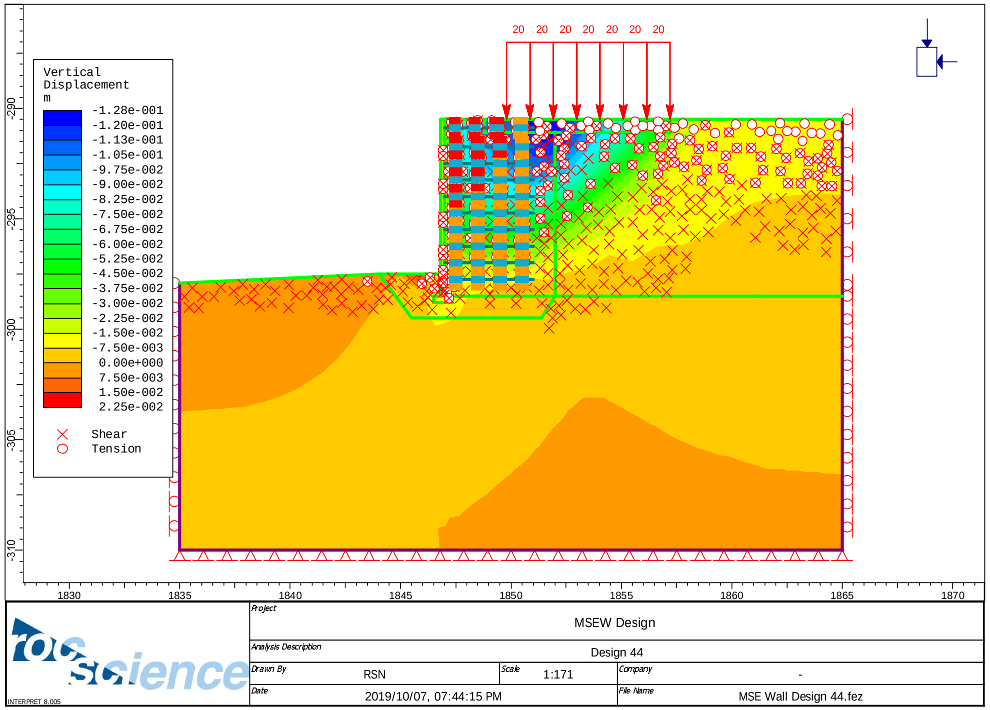

Critical SRF: 1.6
20 20 20 20 20 20 20
Maximum Shear Strain
0.00e+000
4.50e-003
9.00e-003
1.35e-002
1.80e-002
2.25e-002
2.70e-002
3.15e-002
3.60e-002
4.05e-002
4.50e-002
4.95e-002
5.40e-002
5.85e-002
6.30e-002
6.75e-002
7.20e-002
7.65e-002
8.10e-002
8.55e-002
9.00e-002
-290
-295
-300
-305
-310
1830 1835 1840 1845 1850 1855 1860 1865
Project MSEW Design
Analysis Description Design 43
Drawn By RSN
Scale 1:171
Company -
Date 2019/10/07, 07:44:15 PM
File Name MSE Wall Design 43.fez
INTERPRET 8.005

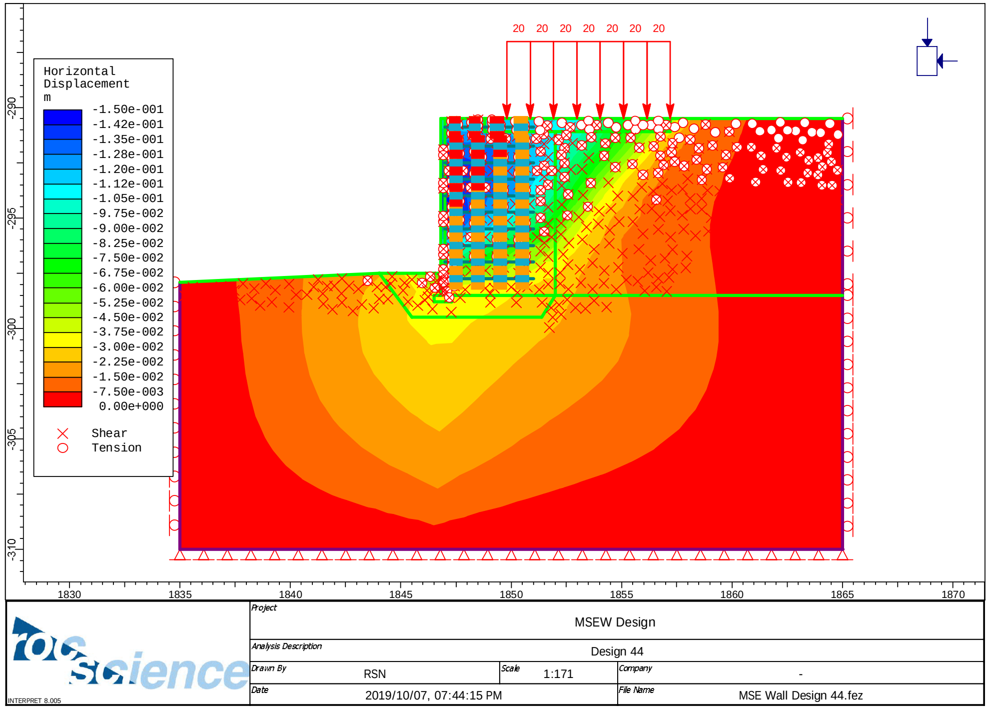

Total Displacement m
0.00e+000
7.50e-003
1.50e-002
2.25e-002
3.00e-002
3.75e-002
4.50e-002
5.25e-002
6.00e-002
6.75e-002
7.50e-002
8.25e-002
9.00e-002
9.75e-002
1.05e-001
1.12e-001
1.20e-001
1.28e-001
1.35e-001
1.42e-001
1.50e-001
Shear
Tension
20 20 20 20 20 20 20
-290
-295
-300
-305
-310
1830 1835 1840 1845 1850 1855 1860 1865 1870
Project MSEW Design
Analysis Description Design 43
Drawn By RSN
Scale 1:171
Company -
Date 2019/10/07, 07:44:15 PM
File Name MSE Wall Design 43.fez
INTERPRET 8.005

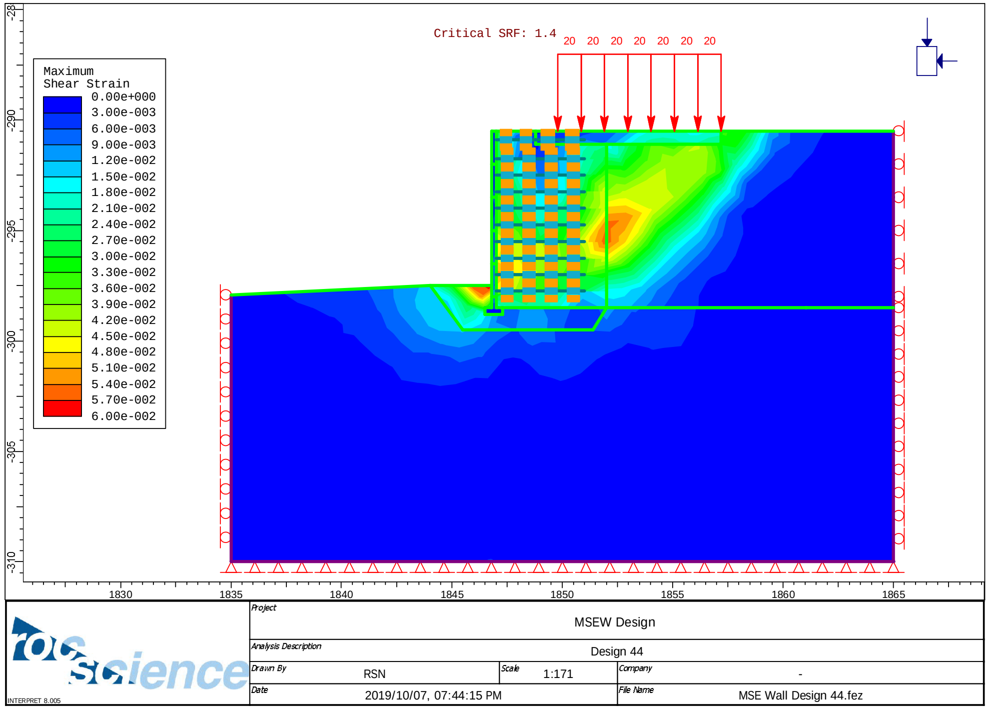

Sigma Z
kPa
0.00
15.00
30.00
45.00
60.00
75.00
90.00
105.00
120.00
135.00
150.00
165.00
180.00
195.00
210.00
225.00
240.00
255.00
270.00
285.00
300.00
Shear
Tension
20 20 20 20 20 20 20
1830 1835 1840 1845 1850 1855 1860 1865 1870
Project
MSEW Design
Analysis Description
Design 44
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 44.fez
INTERPRET 8.005

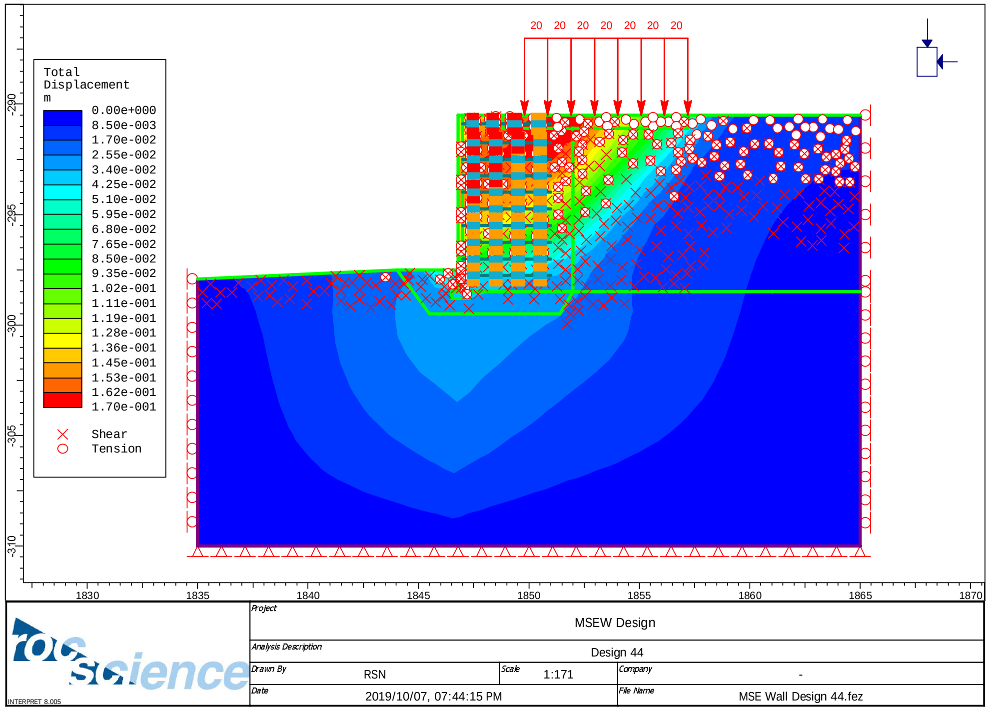

Maximum
Shear Strain
0.00e+000
1.50e-003
3.00e-003
4.50e-003
6.00e-003
7.50e-003
9.00e-003
1.05e-002
1.20e-002
1.35e-002
1.50e-002
1.65e-002
1.80e-002
1.95e-002
2.10e-002
2.25e-002
2.40e-002
2.55e-002
2.70e-002
2.85e-002
3.00e-002
Shear
Tension
20 20 20 20 20 20 20
1830 1835 1840 1845 1850 1855 1860 1865 1870
Project
MSEW Design
Analysis Description
Design 44
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 44.fez
INTERPRET 8.005

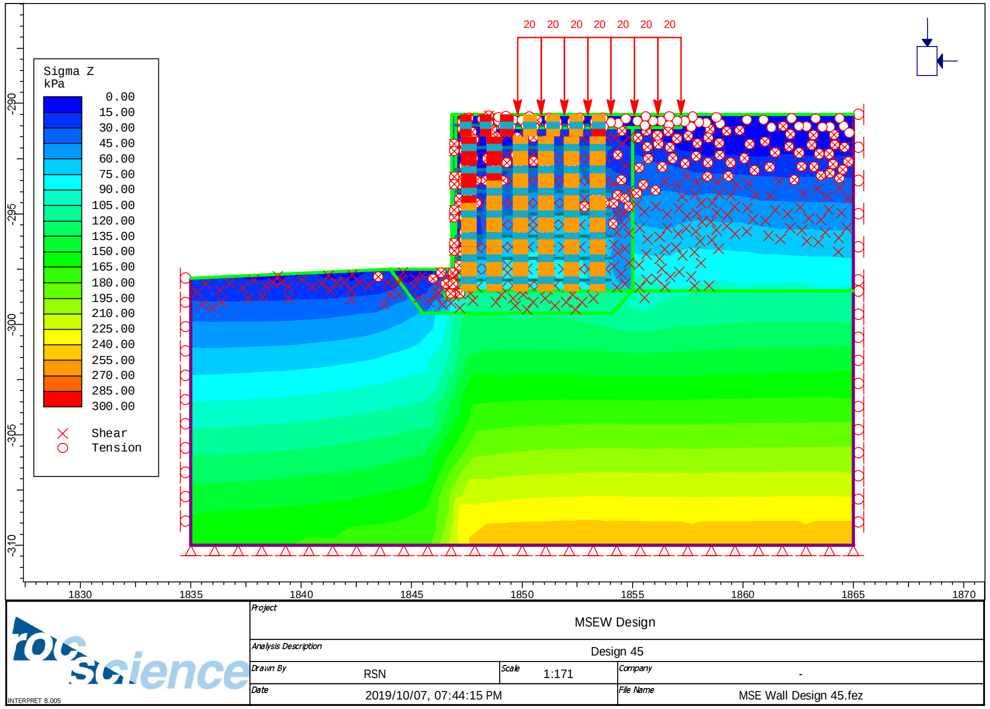

Mean Stress
kPa
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
160.00
180.00
200.00
220.00
240.00
260.00
280.00
300.00
320.00
340.00
360.00
380.00
400.00
Shear
Tension
20 20 20 20 20 20 20
1830 1835 1840 1845 1850 1855 1860 1865 1870
Project
MSEW Design
Analysis Description
Design 44
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 44.fez
INTERPRET 8.005

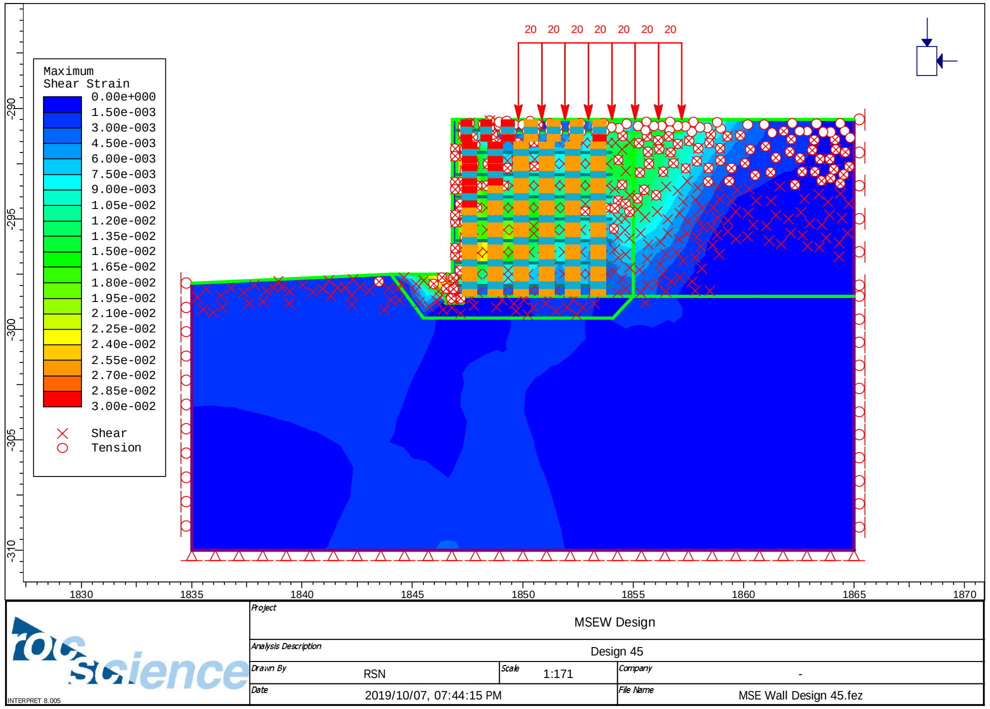

Vertical
Displacement
m
-1.28e-001
-1.20e-001
-1.13e-001
-1.05e-001
-9.75e-002
-9.00e-002
-8.25e-002
-7.50e-002
-6.75e-002
-6.00e-002
-5.25e-002
-4.50e-002
-3.75e-002
-3.00e-002
-2.25e-002
-1.50e-002
-7.50e-003
0.00e+000
7.50e-003
1.50e-002
2.25e-002
Shear
Tension
20 20 20 20 20 20 20
1830 1835 1840 1845 1850 1855 1860 1865 1870
Project
MSEW Design
Analysis Description
Design 44
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 44.fez
INTERPRET 8.005

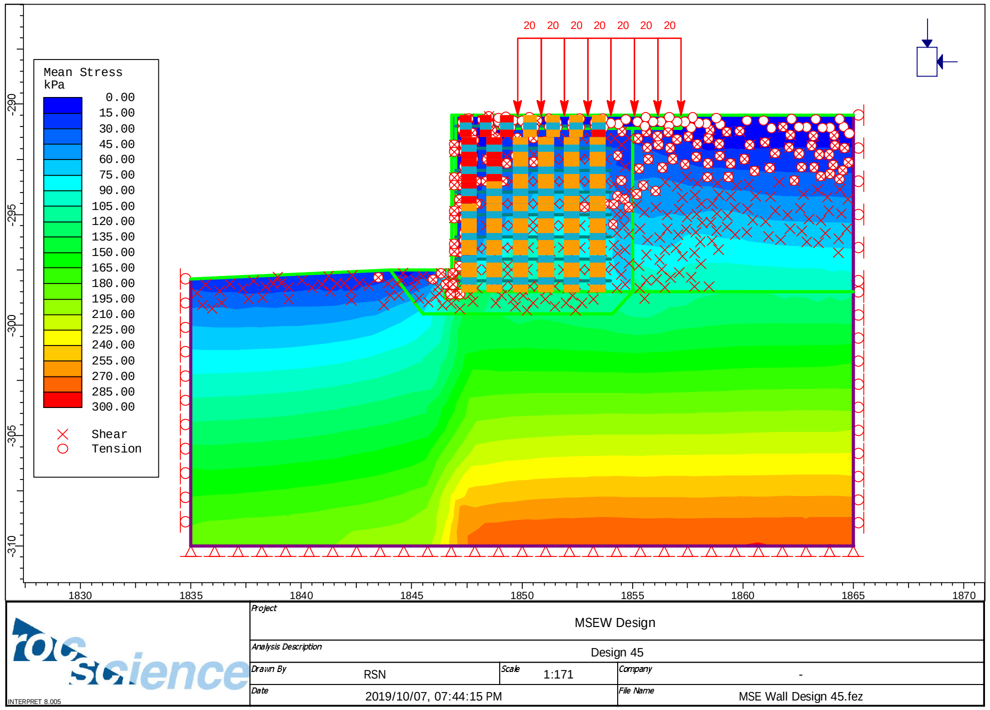

Horizontal
Displacement
m
-1.50e-001
-1.42e-001
-1.35e-001
-1.28e-001
-1.20e-001
-1.12e-001
-1.05e-001
-9.75e-002
-9.00e-002
-8.25e-002
-7.50e-002
-6.75e-002
-6.00e-002
-5.25e-002
-4.50e-002
-3.75e-002
-3.00e-002
-2.25e-002
-1.50e-002
-7.50e-003
0.00e+000
Shear
Tension
20 20 20 20 20 20 20
Project
MSEW Design
Analysis Description
Design 44
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 44.fez
INTERPRET 8.005

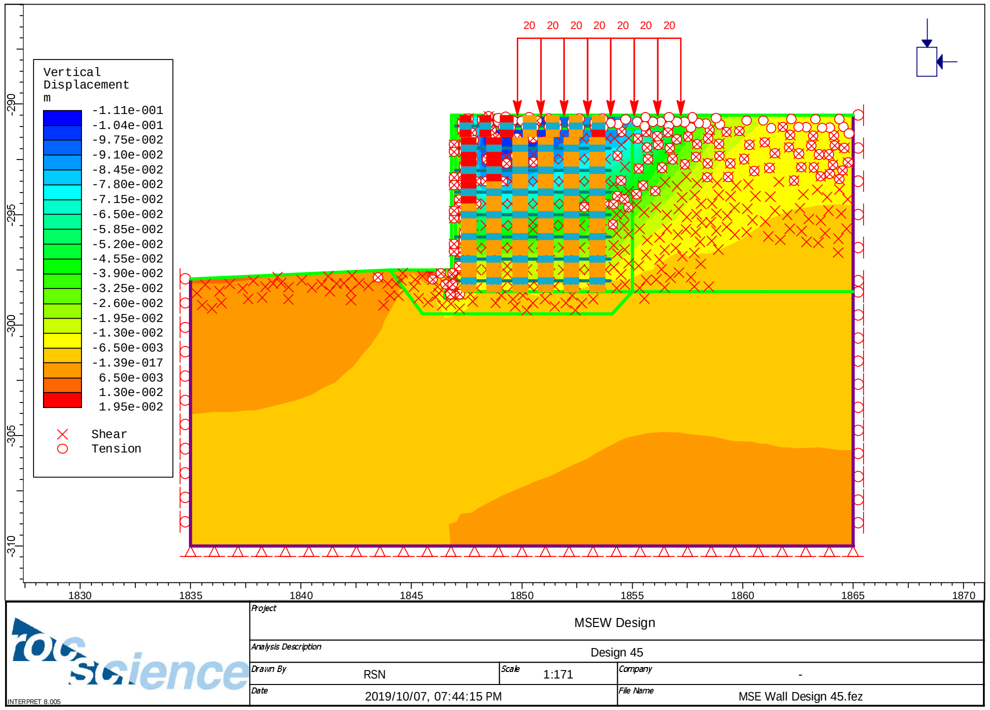

Critical SRF: 1.4
Maximum
Shear Strain
0.00e+000
3.00e-003
6.00e-003
9.00e-003
1.20e-002
1.50e-002
1.80e-002
2.10e-002
2.40e-002
2.70e-002
3.00e-002
3.30e-002
3.60e-002
3.90e-002
4.20e-002
4.50e-002
4.80e-002
5.10e-002
5.40e-002
5.70e-002
6.00e-002
20 20 20 20 20 20 20
Project
MSEW Design
Analysis Description
Design 44
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 44.fez
INTERPRET 8.005

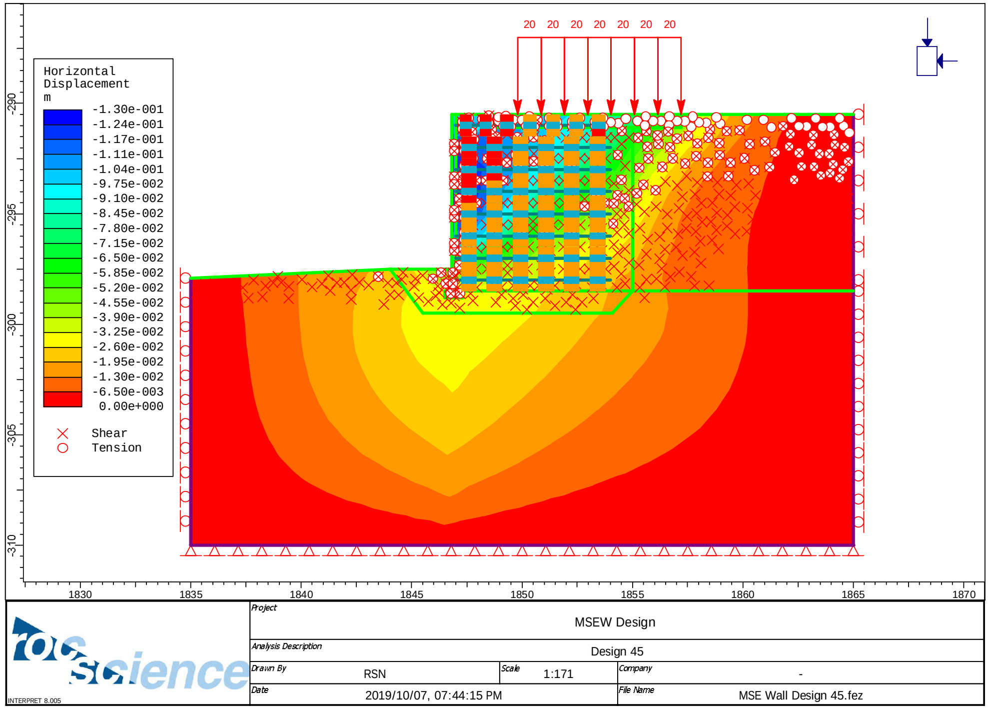

Total
Displacement
m
0.00e+000
8.50e-003
1.70e-002
2.55e-002
3.40e-002
4.25e-002
5.10e-002
5.95e-002
6.80e-002
7.65e-002
8.50e-002
9.35e-002
1.02e-001
1.11e-001
1.19e-001
1.28e-001
1.36e-001
1.45e-001
1.53e-001
1.62e-001
1.70e-001
Shear
Tension
20 20 20 20 20 20 20
Project
MSEW Design
Analysis Description
Design 44
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 44.fez
INTERPRET 8.005

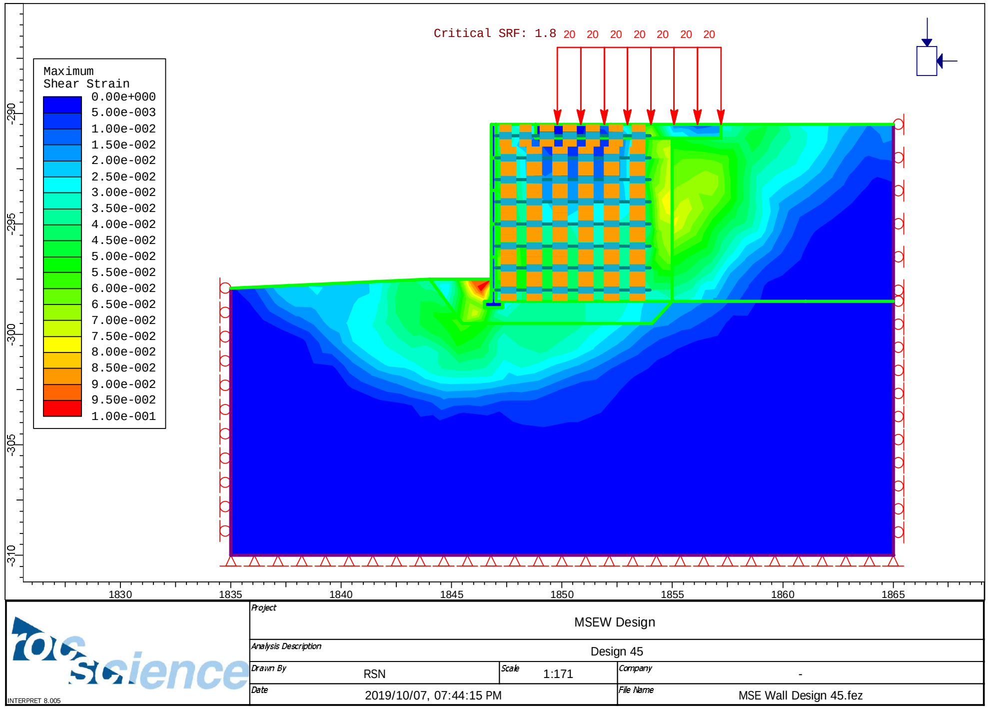

Sigma Z
kPa
0.00
15.00
30.00
45.00
60.00
75.00
90.00
105.00
120.00
135.00
150.00
165.00
180.00
195.00
210.00
225.00
240.00
255.00
270.00
285.00
300.00
Shear
Tension
Project MSEW Design
Analysis Description Design 45
Drawn By RSN
Scale 1:171
Company -
Date 2019/10/07, 07:44:15 PM
File Name MSE Wall Design 45.fez

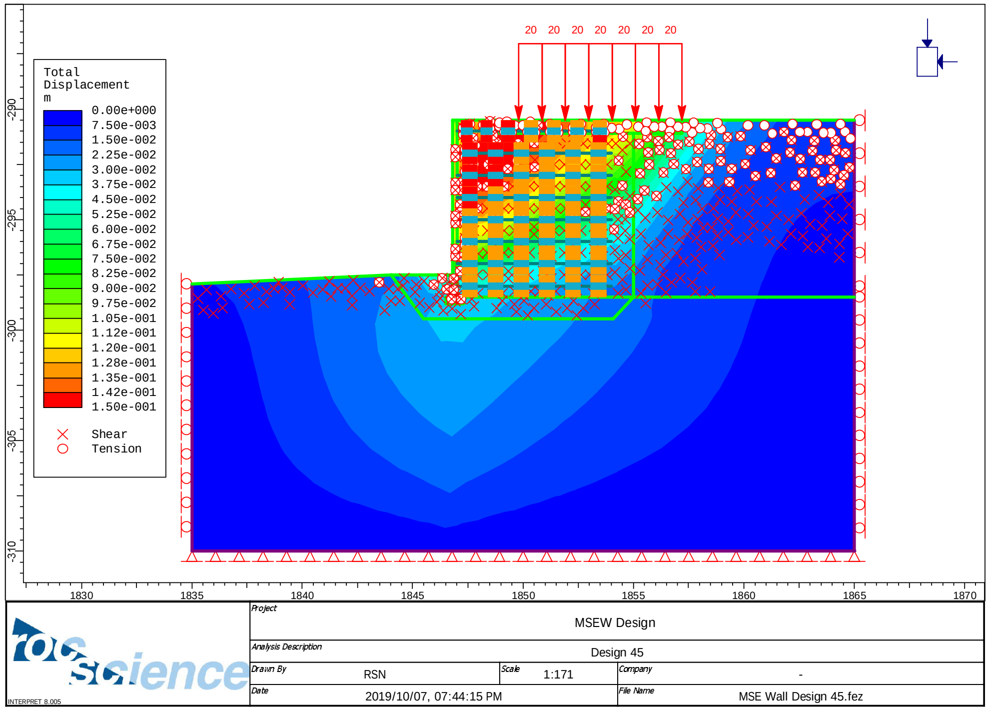

Maximum
Shear Strain
0.00e+000
1.50e-003
3.00e-003
4.50e-003
6.00e-003
7.50e-003
9.00e-003
1.05e-002
1.20e-002
1.35e-002
1.50e-002
1.65e-002
1.80e-002
1.95e-002
2.10e-002
2.25e-002
2.40e-002
2.55e-002
2.70e-002
2.85e-002
3.00e-002
Shear
Tension
Project MSEW Design
Analysis Description Design 45
Drawn By RSN
Scale 1:171
Company -
Date 2019/10/07, 07:44:15 PM
File Name MSE Wall Design 45.fez

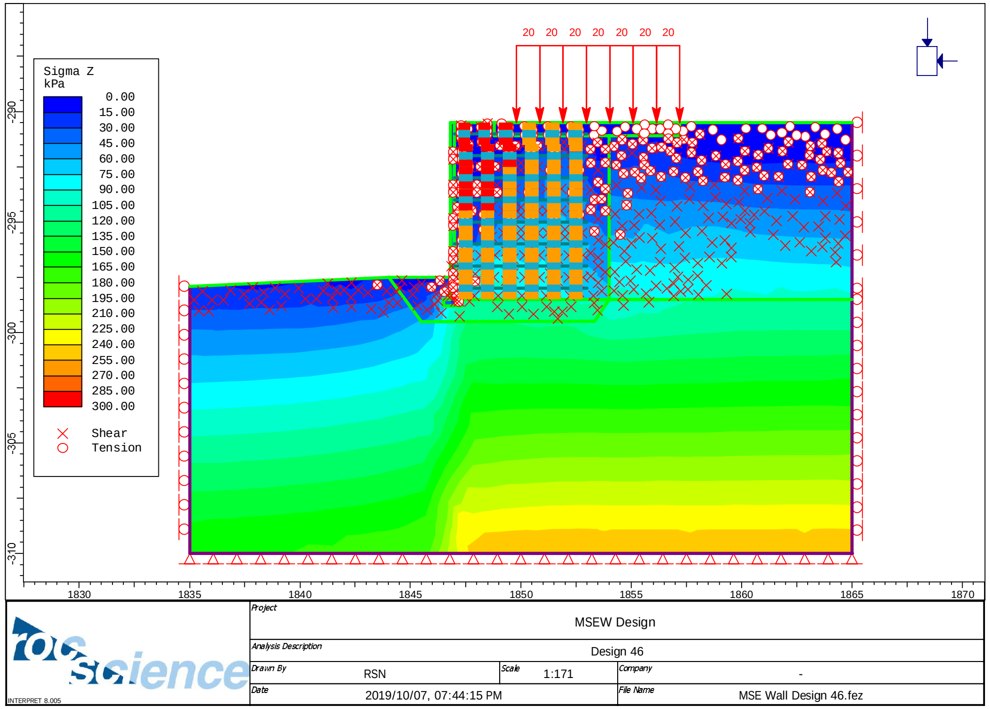

Mean Stress
kPa
0.00
15.00
30.00
45.00
60.00
75.00
90.00
105.00
120.00
135.00
150.00
165.00
180.00
195.00
210.00
225.00
240.00
255.00
270.00
285.00
300.00
Shear
Tension
Project MSEW Design
Analysis Description Design 45
Drawn By RSN
Scale 1:171
Company -
Date 2019/10/07, 07:44:15 PM
File Name MSE Wall Design 45.fez

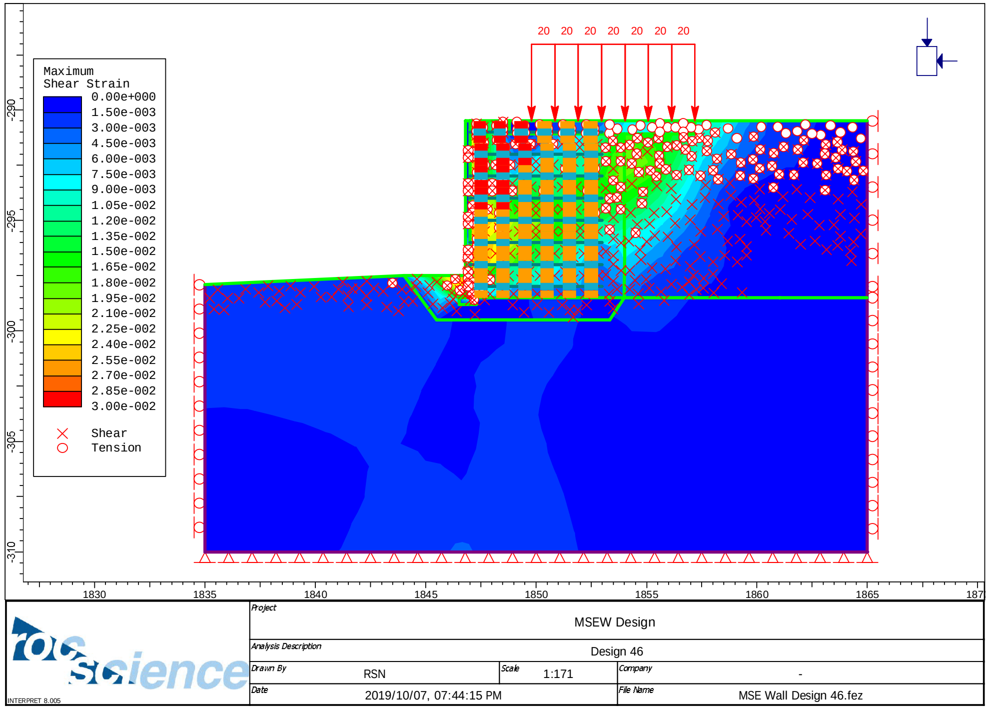

Vertical
Displacement
m
-1.11e-001
-1.04e-001
-9.75e-002
-9.10e-002
-8.45e-002
-7.80e-002
-7.15e-002
-6.50e-002
-5.85e-002
-5.20e-002
-4.55e-002
-3.90e-002
-3.25e-002
-2.60e-002
-1.95e-002
-1.30e-002
-6.50e-003
-1.39e-017
6.50e-003
1.30e-002
1.95e-002
Shear
Tension
Project MSEW Design
Analysis Description Design 45
Drawn By RSN
Scale 1:171
Company -
Date 2019/10/07, 07:44:15 PM
File Name MSE Wall Design 45.fez

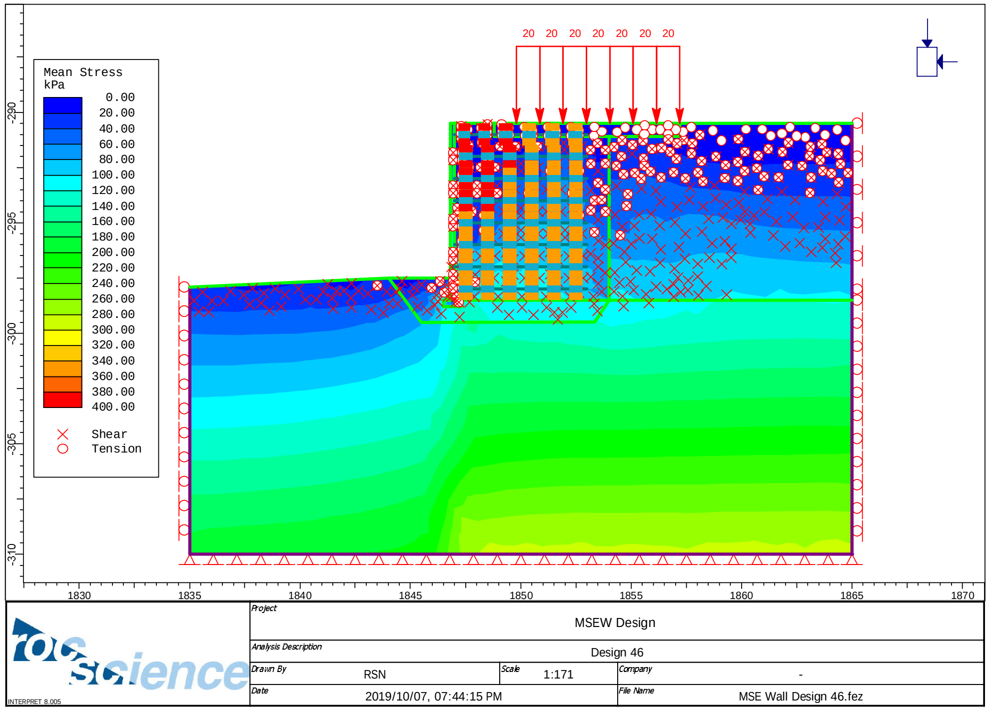

Horizontal Displacement m
-1.30e-001
-1.24e-001
-1.17e-001
-1.11e-001
-1.04e-001
-9.75e-002
-9.10e-002
-8.45e-002
-7.80e-002
-7.15e-002
-6.50e-002
-5.85e-002
-5.20e-002
-4.55e-002
-3.90e-002
-3.25e-002
-2.60e-002
-1.95e-002
-1.30e-002
-6.50e-003
0.00e+000
Shear
Tension
20 20 20 20 20 20 20
-290
-295
-300
-305
-310
1830
1835
1840
1845
1850
1855
1860
1865
1870
roc science
INTERPRET 8.005
Project
MSEW Design
Analysis Description
Design 45
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 45.fez

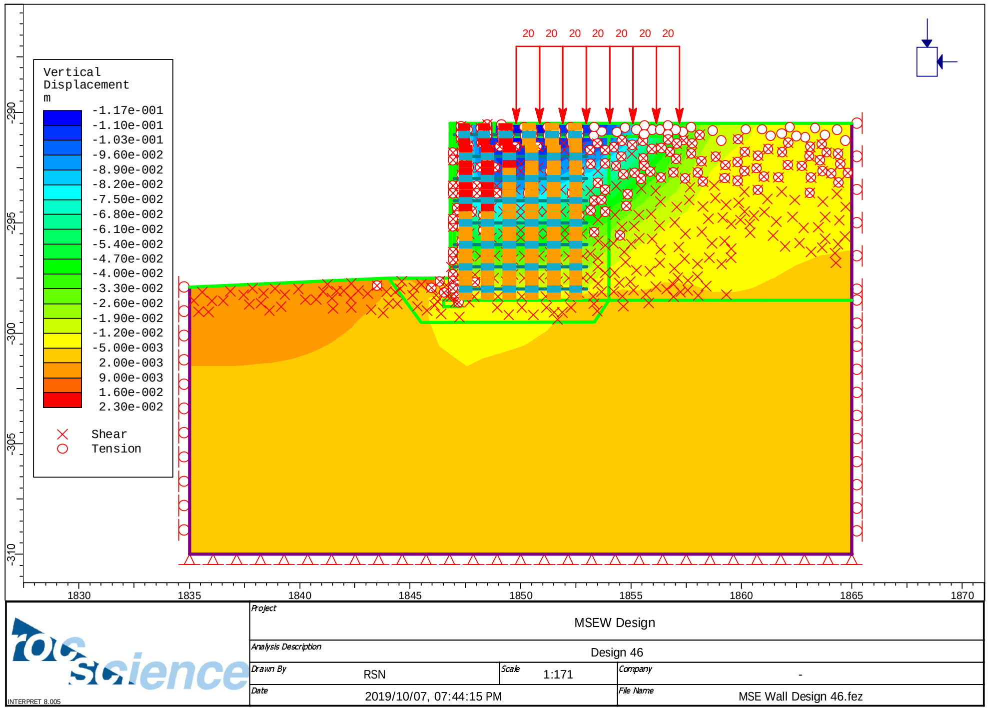

Critical SRF: 1.8
20 20 20 20 20 20 20
Maximum Shear Strain
0.00e+000
5.00e-003
1.00e-002
1.50e-002
2.00e-002
2.50e-002
3.00e-002
3.50e-002
4.00e-002
4.50e-002
5.00e-002
5.50e-002
6.00e-002
6.50e-002
7.00e-002
7.50e-002
8.00e-002
8.50e-002
9.00e-002
9.50e-002
1.00e-001
-290
-295
-300
-305
-310
1830
1835
1840
1845
1850
1855
1860
1865
roc science
INTERPRET 8.005
Project
MSEW Design
Analysis Description
Design 45
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 45.fez

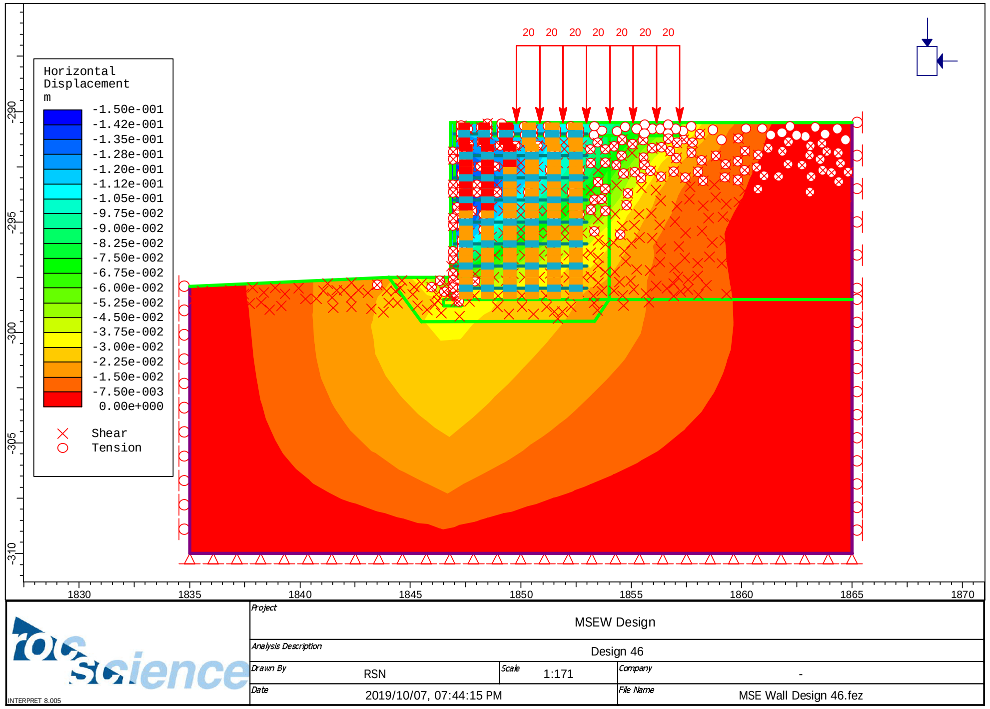

Total Displacement m
0.00e+000
7.50e-003
1.50e-002
2.25e-002
3.00e-002
3.75e-002
4.50e-002
5.25e-002
6.00e-002
6.75e-002
7.50e-002
8.25e-002
9.00e-002
9.75e-002
1.05e-001
1.12e-001
1.20e-001
1.28e-001
1.35e-001
1.42e-001
1.50e-001
Shear
Tension
20 20 20 20 20 20 20
-290
-295
-300
-305
-310
1830
1835
1840
1845
1850
1855
1860
1865
1870
roc science
INTERPRET 8.005
Project
MSEW Design
Analysis Description
Design 45
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 45.fez

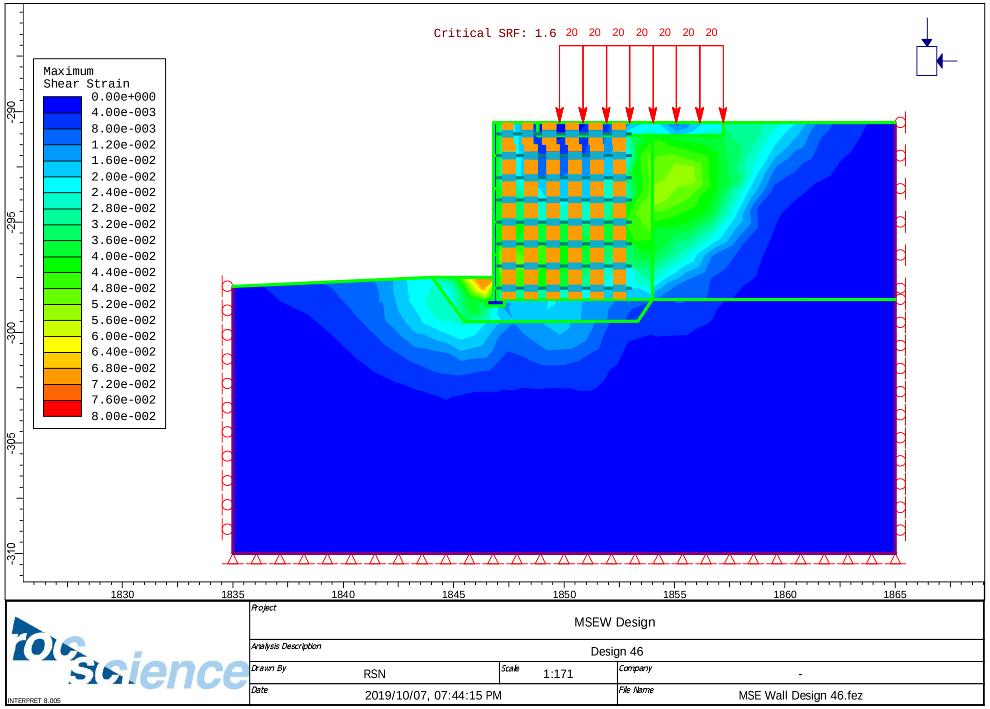

Sigma Z
kPa
0.00
15.00
30.00
45.00
60.00
75.00
90.00
105.00
120.00
135.00
150.00
165.00
180.00
195.00
210.00
225.00
240.00
255.00
270.00
285.00
300.00
Shear
Tension
20 20 20 20 20 20 20
Project
MSEW Design
Analysis Description
Design 46
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 46.fez
INTERPRET 8.005

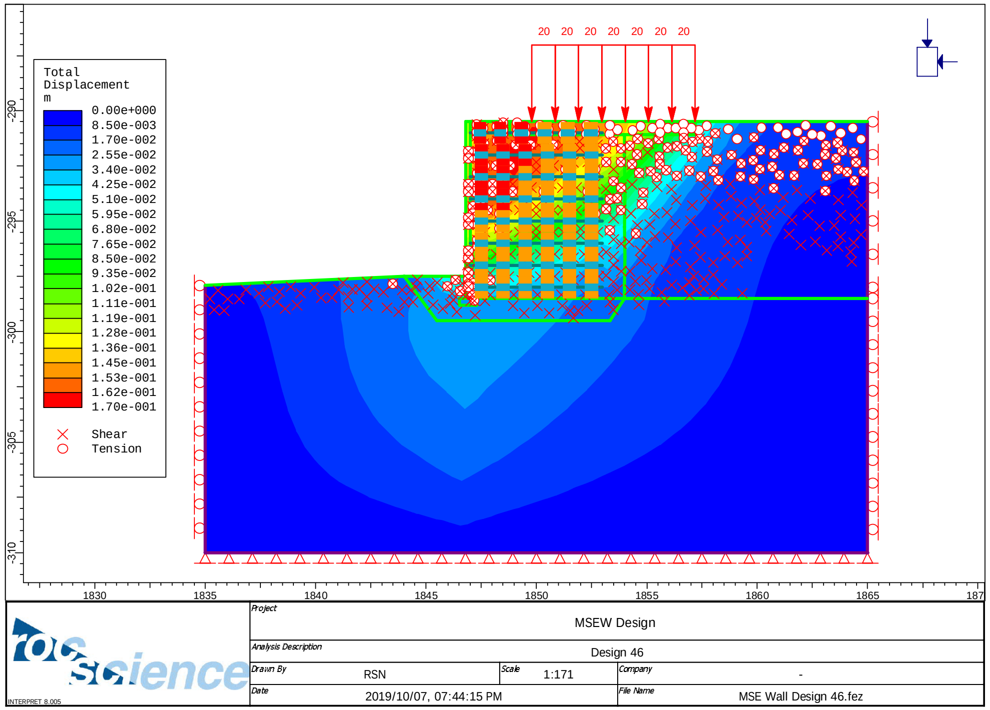

Maximum
Shear Strain
0.00e+000
1.50e-003
3.00e-003
4.50e-003
6.00e-003
7.50e-003
9.00e-003
1.05e-002
1.20e-002
1.35e-002
1.50e-002
1.65e-002
1.80e-002
1.95e-002
2.10e-002
2.25e-002
2.40e-002
2.55e-002
2.70e-002
2.85e-002
3.00e-002
Shear
Tension
20 20 20 20 20 20 20
Project
MSEW Design
Analysis Description
Design 46
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 46.fez
INTERPRET 8.005

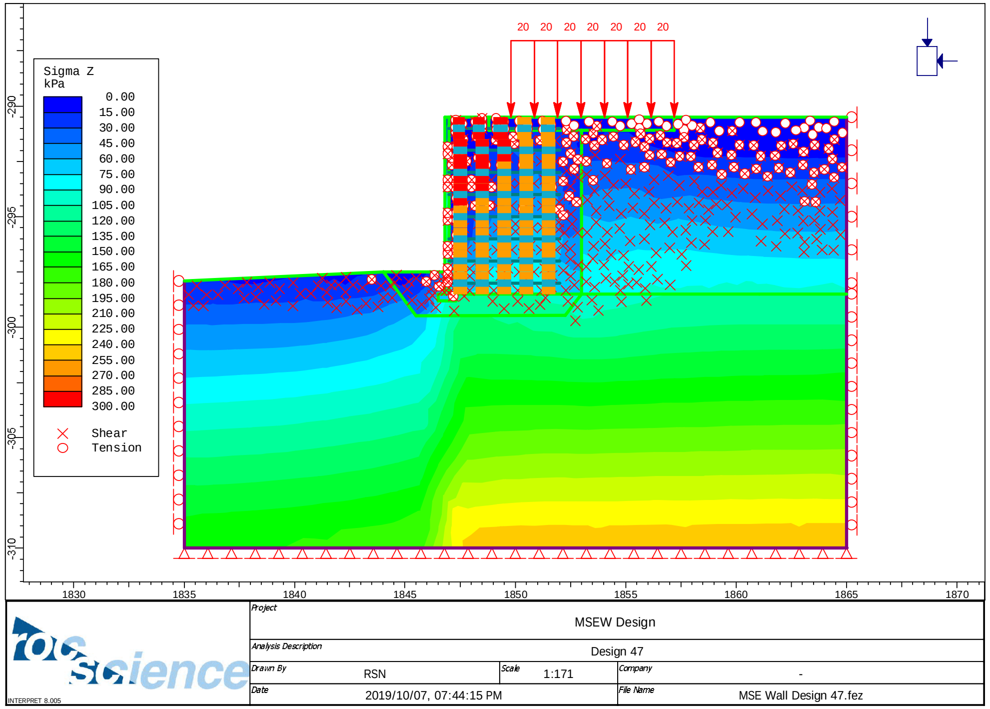

Mean Stress
kPa
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
160.00
180.00
200.00
220.00
240.00
260.00
280.00
300.00
320.00
340.00
360.00
380.00
400.00
Shear
Tension
20 20 20 20 20 20 20
Project
MSEW Design
Analysis Description
Design 46
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 46.fez
INTERPRET 8.005

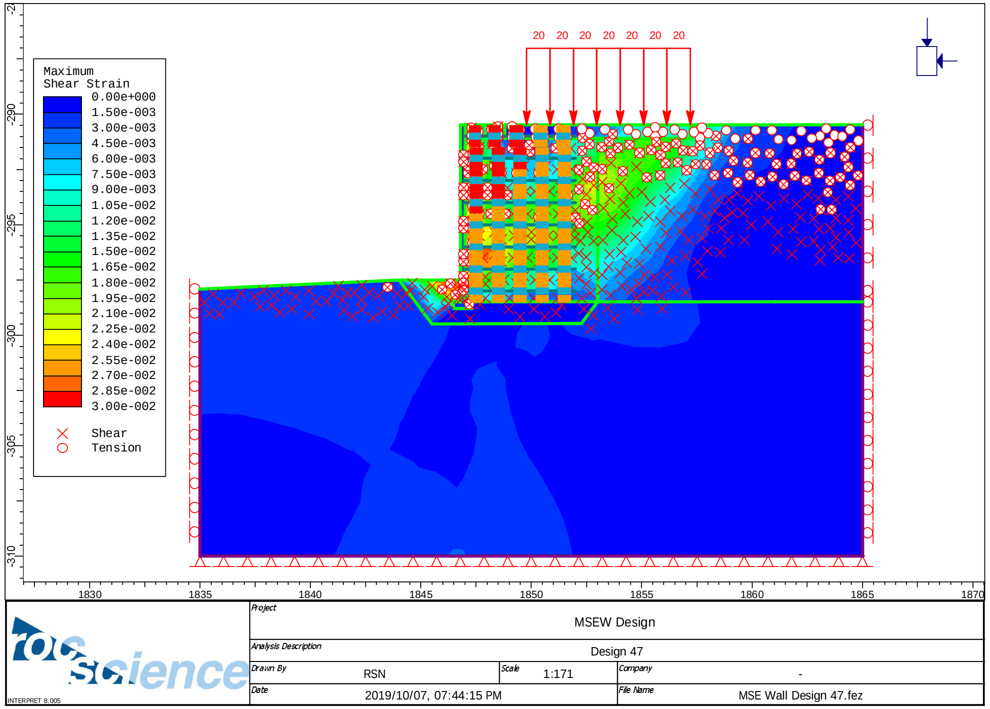

Vertical
Displacement
m
-1.17e-001
-1.10e-001
-1.03e-001
-9.60e-002
-8.90e-002
-8.20e-002
-7.50e-002
-6.80e-002
-6.10e-002
-5.40e-002
-4.70e-002
-4.00e-002
-3.30e-002
-2.60e-002
-1.90e-002
-1.20e-002
-5.00e-003
2.00e-003
9.00e-003
1.60e-002
2.30e-002
Shear
Tension
20 20 20 20 20 20 20
Project
MSEW Design
Analysis Description
Design 46
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 46.fez
INTERPRET 8.005

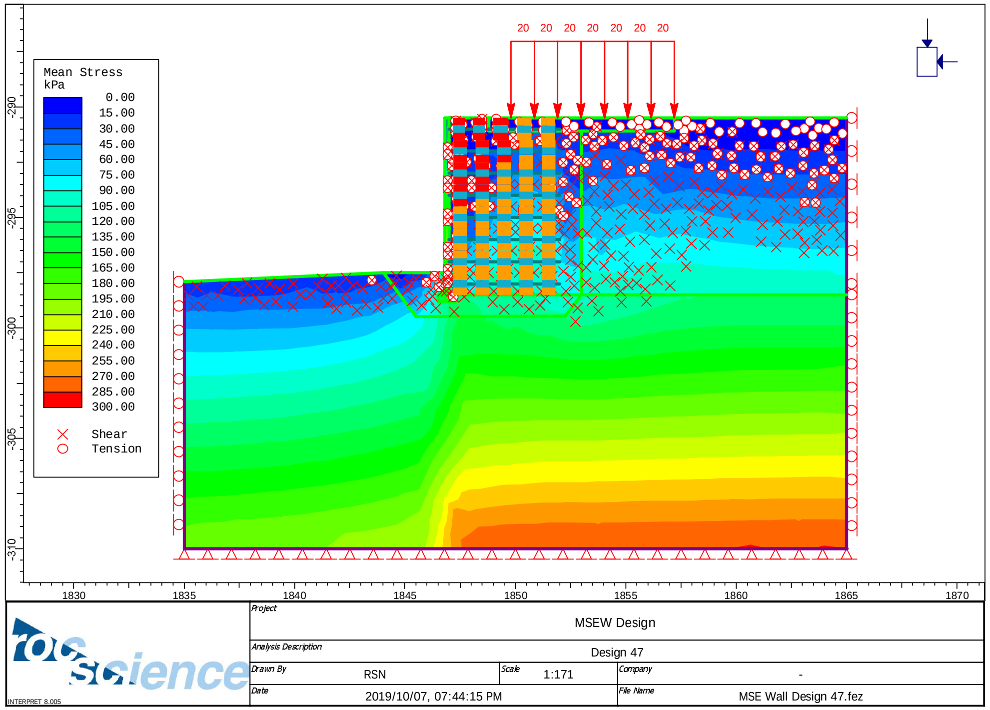

20 20 20 20 20 20 20
Horizontal Displacement m
-1.50e-001
-1.42e-001
-1.35e-001
-1.28e-001
-1.20e-001
-1.12e-001
-1.05e-001
-9.75e-002
-9.00e-002
-8.25e-002
-7.50e-002
-6.75e-002
-6.00e-002
-5.25e-002
-4.50e-002
-3.75e-002
-3.00e-002
-2.25e-002
-1.50e-002
-7.50e-003
0.00e+000
Shear
Tension
-290
-295
-300
-305
-310
1830
1835
1840
1845
1850
1855
1860
1865
1870
Project
MSEW Design
Analysis Description
Design 46
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 46.fez
INTERPRET 8.005

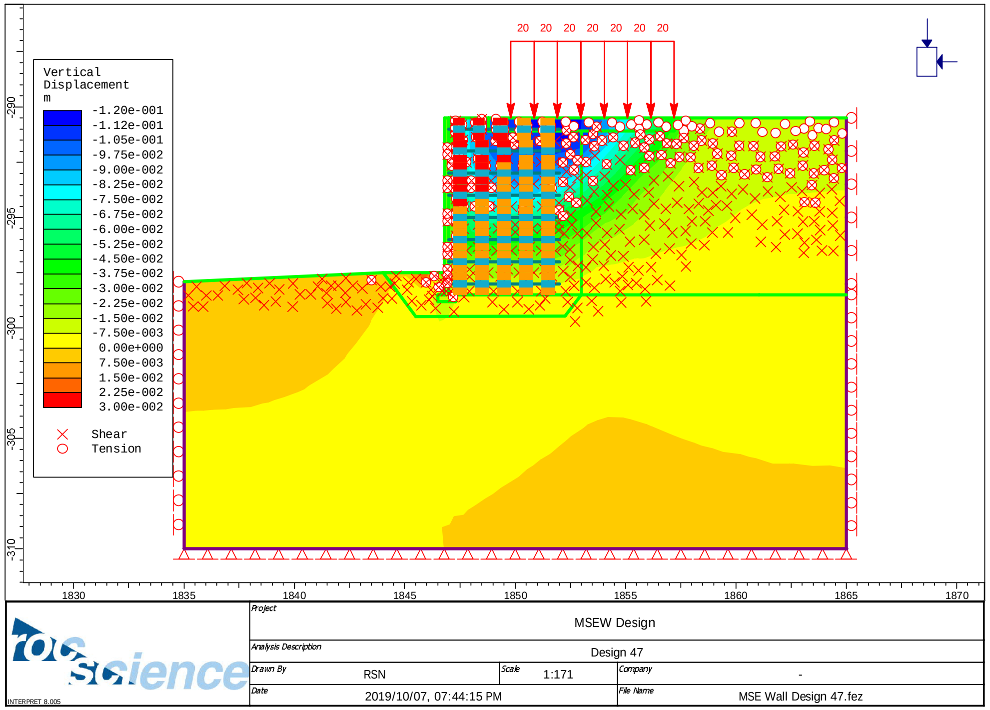

Critical SRF: 1.6 20 20 20 20 20 20 20
Maximum Shear Strain
0.00e+000
4.00e-003
8.00e-003
1.20e-002
1.60e-002
2.00e-002
2.40e-002
2.80e-002
3.20e-002
3.60e-002
4.00e-002
4.40e-002
4.80e-002
5.20e-002
5.60e-002
6.00e-002
6.40e-002
6.80e-002
7.20e-002
7.60e-002
8.00e-002
-290
-295
-300
-305
-310
1830
1835
1840
1845
1850
1855
1860
1865
Project
MSEW Design
Analysis Description
Design 46
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 46.fez
INTERPRET 8.005

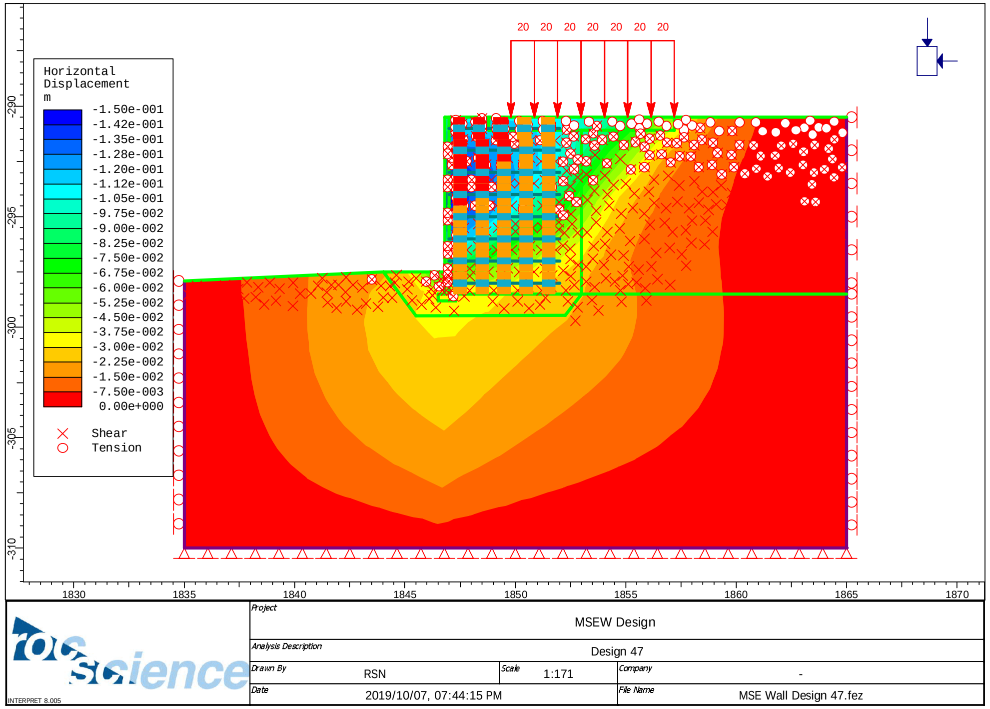

20 20 20 20 20 20 20
Total Displacement m
0.00e+000
8.50e-003
1.70e-002
2.55e-002
3.40e-002
4.25e-002
5.10e-002
5.95e-002
6.80e-002
7.65e-002
8.50e-002
9.35e-002
1.02e-001
1.11e-001
1.19e-001
1.28e-001
1.36e-001
1.45e-001
1.53e-001
1.62e-001
1.70e-001
Shear
Tension
-290
-295
-300
-305
-310
1830
1835
1840
1845
1850
1855
1860
1865
187
Project
MSEW Design
Analysis Description
Design 46
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 46.fez
INTERPRET 8.005

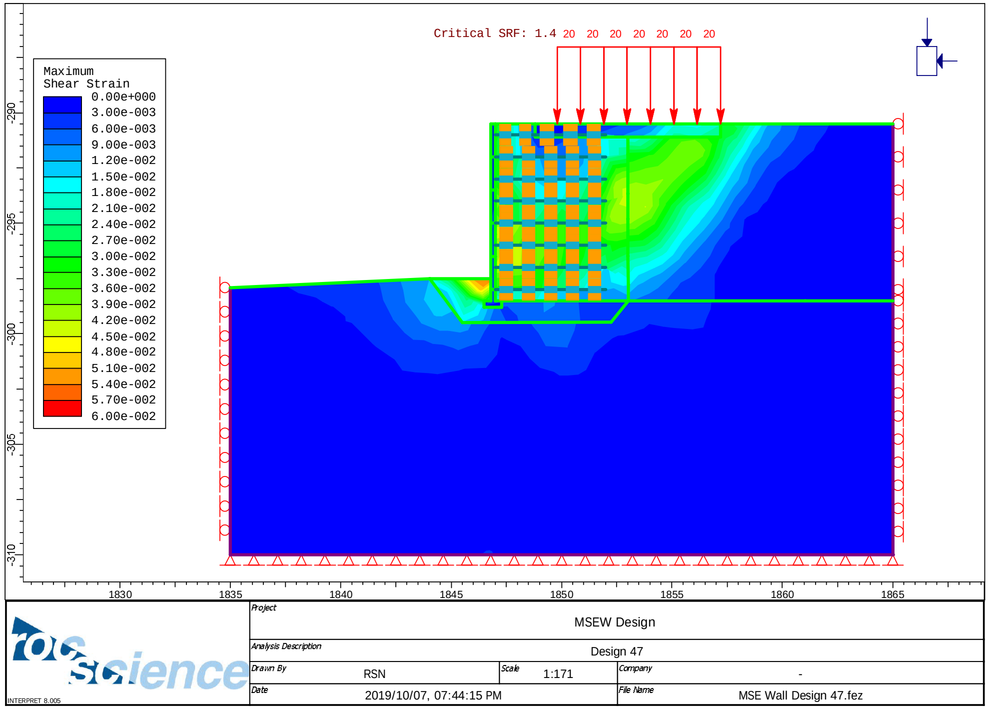

Sigma Z
kPa
0.00
15.00
30.00
45.00
60.00
75.00
90.00
105.00
120.00
135.00
150.00
165.00
180.00
195.00
210.00
225.00
240.00
255.00
270.00
285.00
300.00
Shear
Tension
20 20 20 20 20 20 20
Project
MSEW Design
Analysis Description
Design 47
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 47.fez

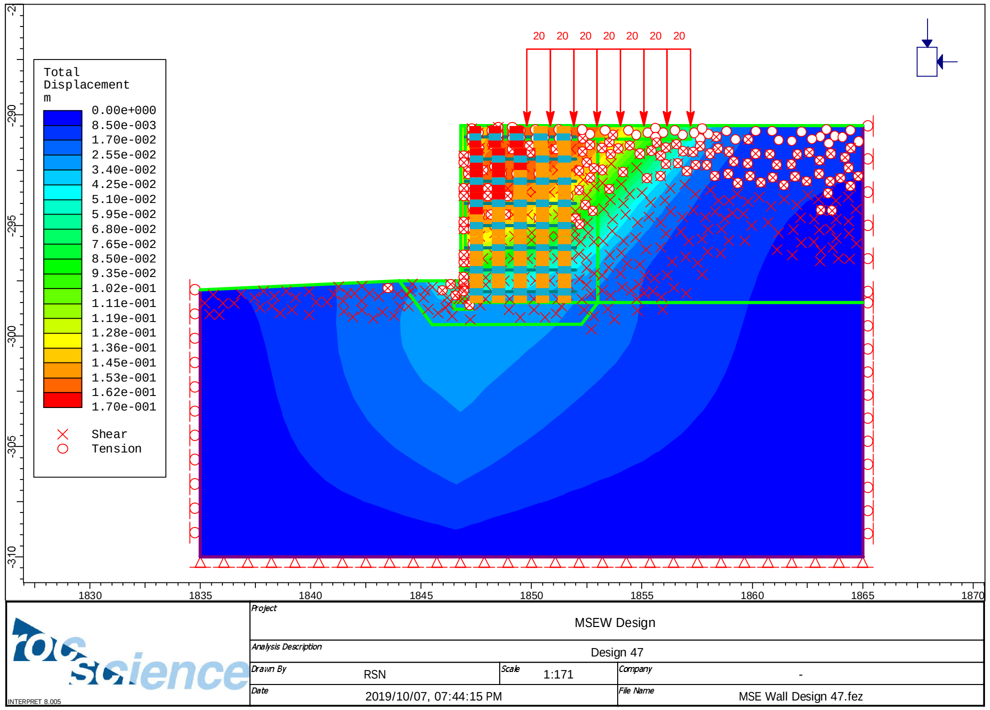

Maximum
Shear Strain
0.00e+000
1.50e-003
3.00e-003
4.50e-003
6.00e-003
7.50e-003
9.00e-003
1.05e-002
1.20e-002
1.35e-002
1.50e-002
1.65e-002
1.80e-002
1.95e-002
2.10e-002
2.25e-002
2.40e-002
2.55e-002
2.70e-002
2.85e-002
3.00e-002
Shear
Tension
20 20 20 20 20 20 20
Project
MSEW Design
Analysis Description
Design 47
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 47.fez

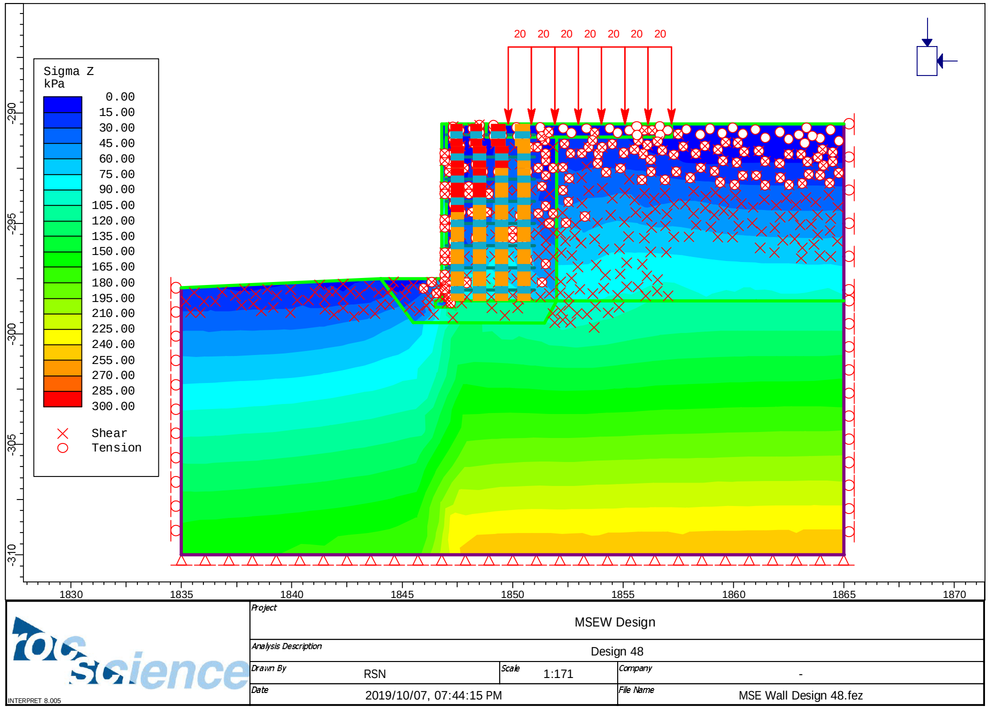

Mean Stress
kPa
0.00
15.00
30.00
45.00
60.00
75.00
90.00
105.00
120.00
135.00
150.00
165.00
180.00
195.00
210.00
225.00
240.00
255.00
270.00
285.00
300.00
Shear
Tension
20 20 20 20 20 20 20
Project
MSEW Design
Analysis Description
Design 47
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 47.fez

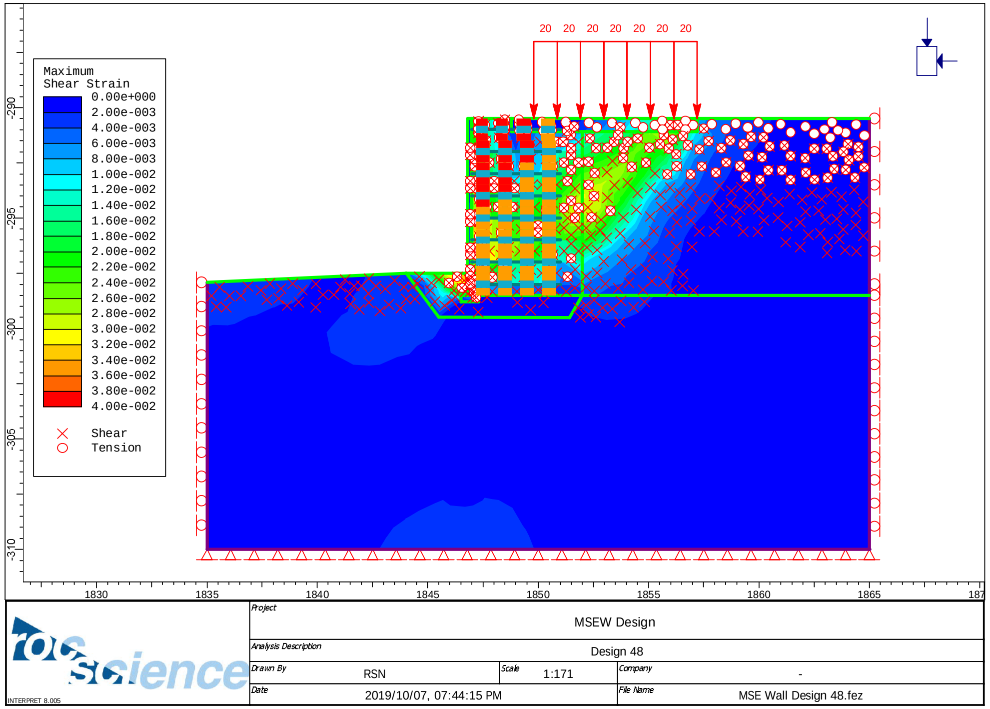

Vertical
Displacement
m
-1.20e-001
-1.12e-001
-1.05e-001
-9.75e-002
-9.00e-002
-8.25e-002
-7.50e-002
-6.75e-002
-6.00e-002
-5.25e-002
-4.50e-002
-3.75e-002
-3.00e-002
-2.25e-002
-1.50e-002
-7.50e-003
0.00e+000
7.50e-003
1.50e-002
2.25e-002
3.00e-002
Shear
Tension
20 20 20 20 20 20 20
Project
MSEW Design
Analysis Description
Design 47
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 47.fez

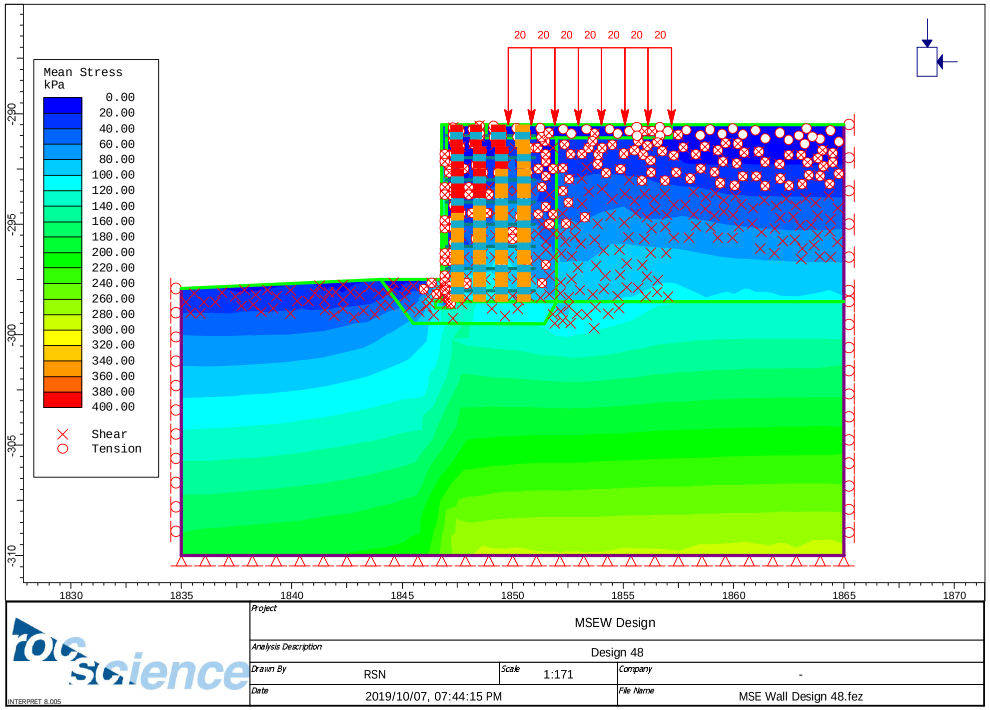

Horizontal Displacement m
-1.50e-001
-1.42e-001
-1.35e-001
-1.28e-001
-1.20e-001
-1.12e-001
-1.05e-001
-9.75e-002
-9.00e-002
-8.25e-002
-7.50e-002
-6.75e-002
-6.00e-002
-5.25e-002
-4.50e-002
-3.75e-002
-3.00e-002
-2.25e-002
-1.50e-002
-7.50e-003
0.00e+000
Shear
Tension
20 20 20 20 20 20 20
Project
MSEW Design
Analysis Description
Design 47
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 47.fez
INTERPRET 8.005

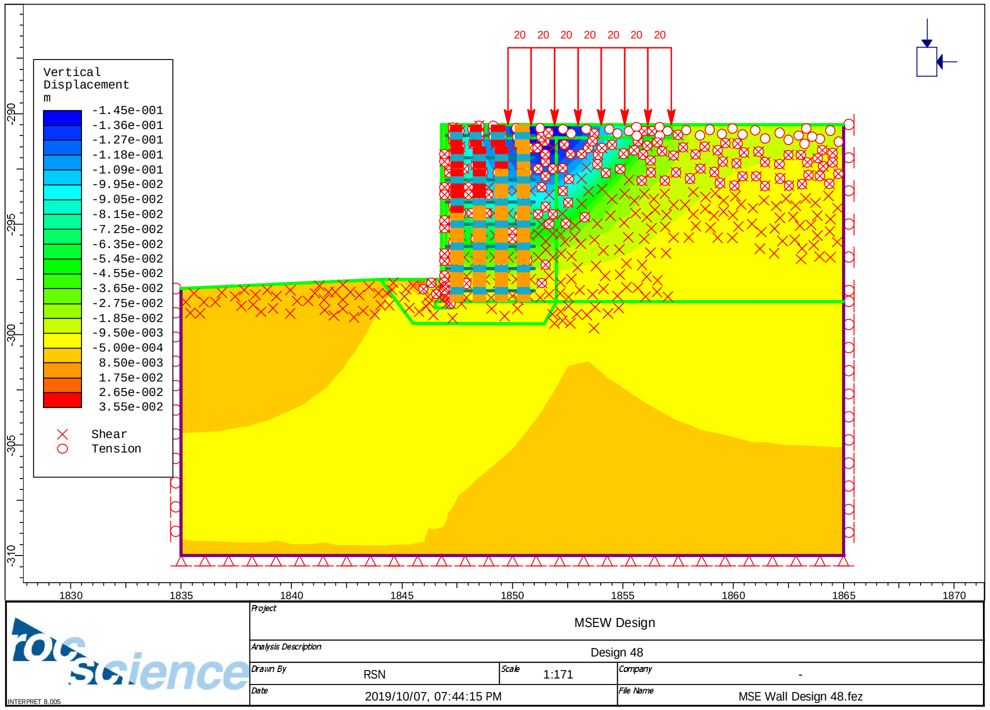

Critical SRF: 1.4
Maximum Shear Strain
0.00e+000
3.00e-003
6.00e-003
9.00e-003
1.20e-002
1.50e-002
1.80e-002
2.10e-002
2.40e-002
2.70e-002
3.00e-002
3.30e-002
3.60e-002
3.90e-002
4.20e-002
4.50e-002
4.80e-002
5.10e-002
5.40e-002
5.70e-002
6.00e-002
20 20 20 20 20 20 20
Project
MSEW Design
Analysis Description
Design 47
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 47.fez
INTERPRET 8.005

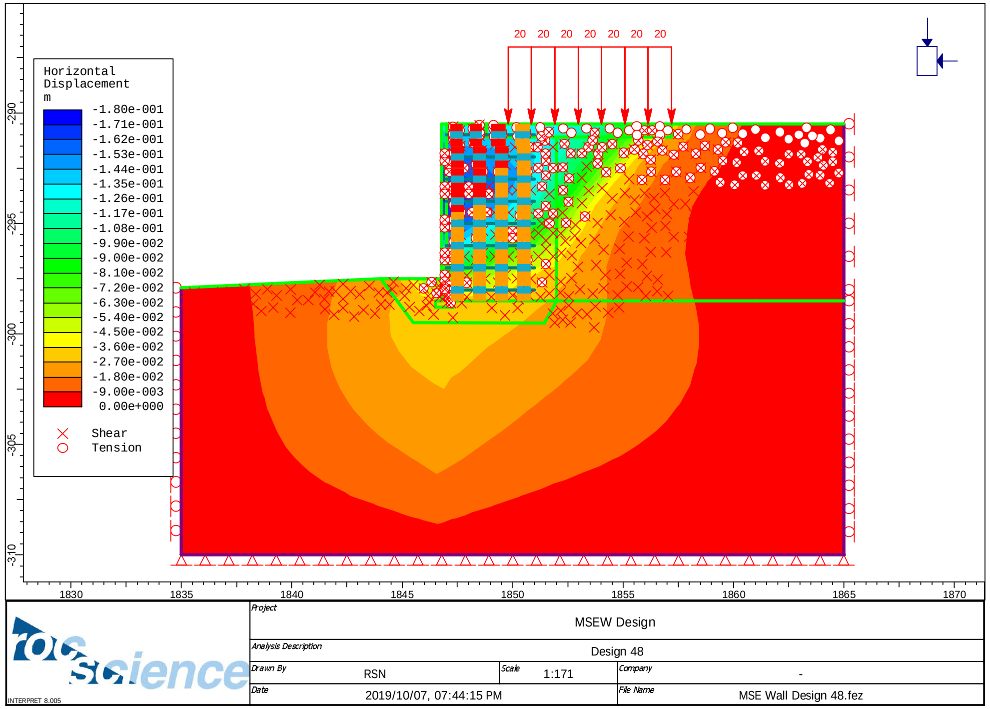

Total Displacement m
0.00e+000
8.50e-003
1.70e-002
2.55e-002
3.40e-002
4.25e-002
5.10e-002
5.95e-002
6.80e-002
7.65e-002
8.50e-002
9.35e-002
1.02e-001
1.11e-001
1.19e-001
1.28e-001
1.36e-001
1.45e-001
1.53e-001
1.62e-001
1.70e-001
Shear
Tension
20 20 20 20 20 20 20
Project
MSEW Design
Analysis Description
Design 47
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 47.fez
INTERPRET 8.005

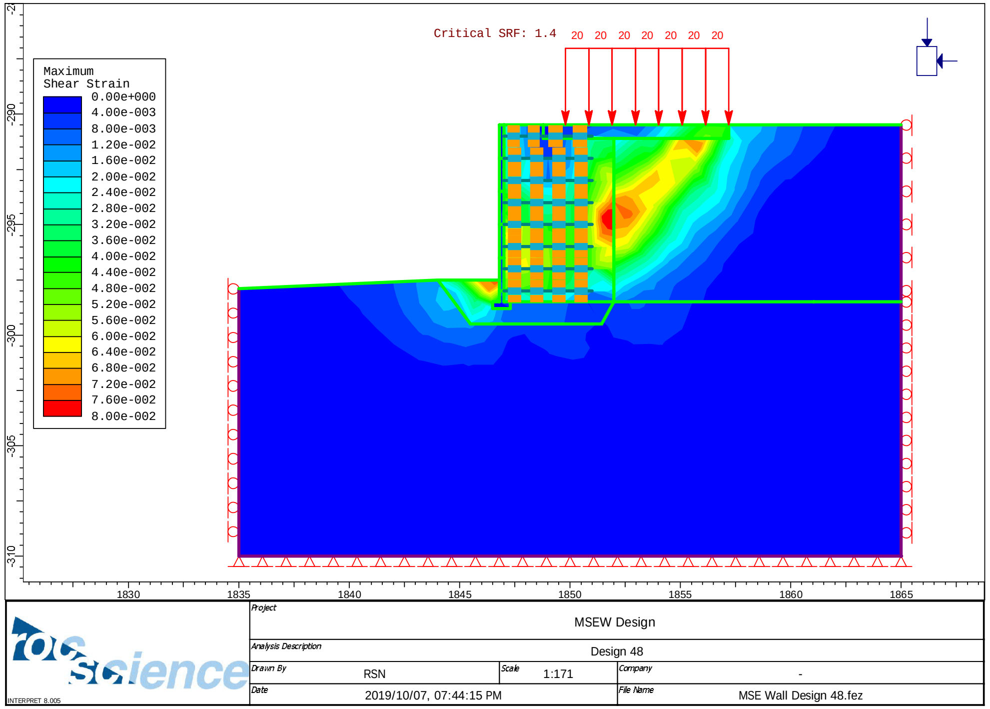

Sigma Z
kPa
0.00
15.00
30.00
45.00
60.00
75.00
90.00
105.00
120.00
135.00
150.00
165.00
180.00
195.00
210.00
225.00
240.00
255.00
270.00
285.00
300.00
Shear
Tension
20 20 20 20 20 20 20
Project
MSEW Design
Analysis Description
Design 48
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 48.fez
INTERPRET 8.005

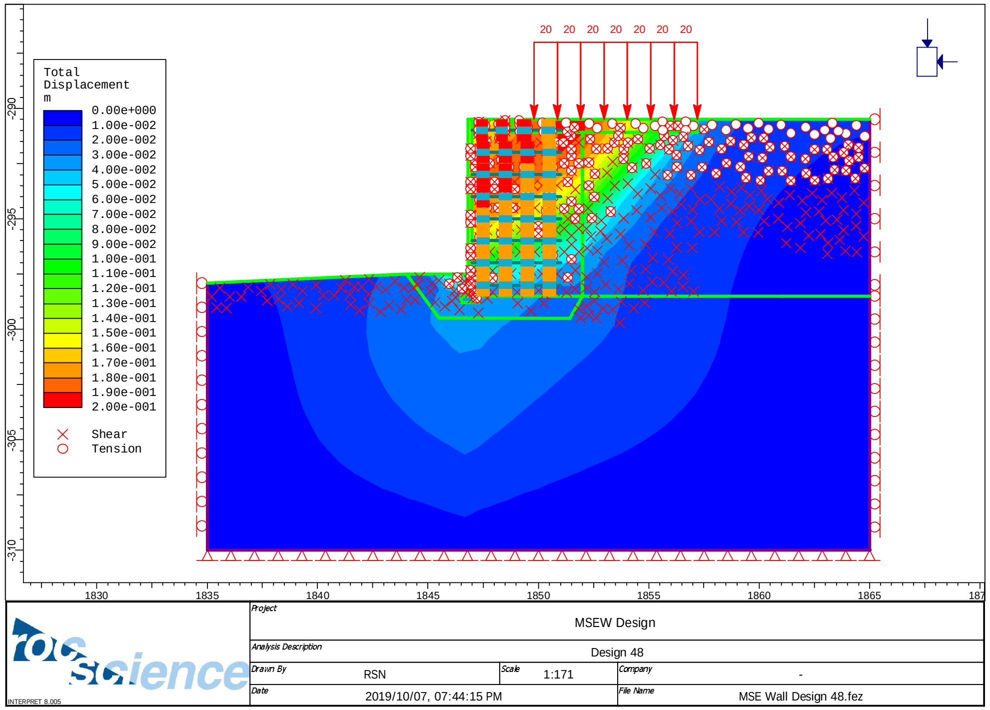

Maximum
Shear Strain
0.00e+000
2.00e-003
4.00e-003
6.00e-003
8.00e-003
1.00e-002
1.20e-002
1.40e-002
1.60e-002
1.80e-002
2.00e-002
2.20e-002
2.40e-002
2.60e-002
2.80e-002
3.00e-002
3.20e-002
3.40e-002
3.60e-002
3.80e-002
4.00e-002
Shear
Tension
20 20 20 20 20 20 20
Project
MSEW Design
Analysis Description
Design 48
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 48.fez
INTERPRET 8.005

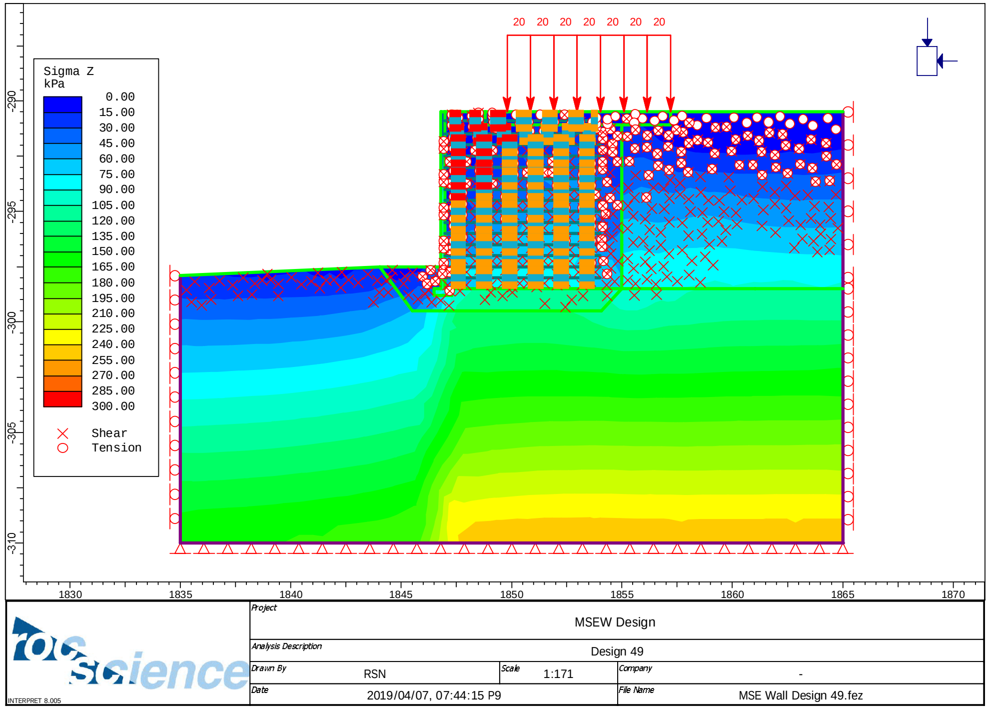

Mean Stress
kPa
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
160.00
180.00
200.00
220.00
240.00
260.00
280.00
300.00
320.00
340.00
360.00
380.00
400.00
Shear
Tension
20 20 20 20 20 20 20
Project
MSEW Design
Analysis Description
Design 48
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 48.fez
INTERPRET 8.005

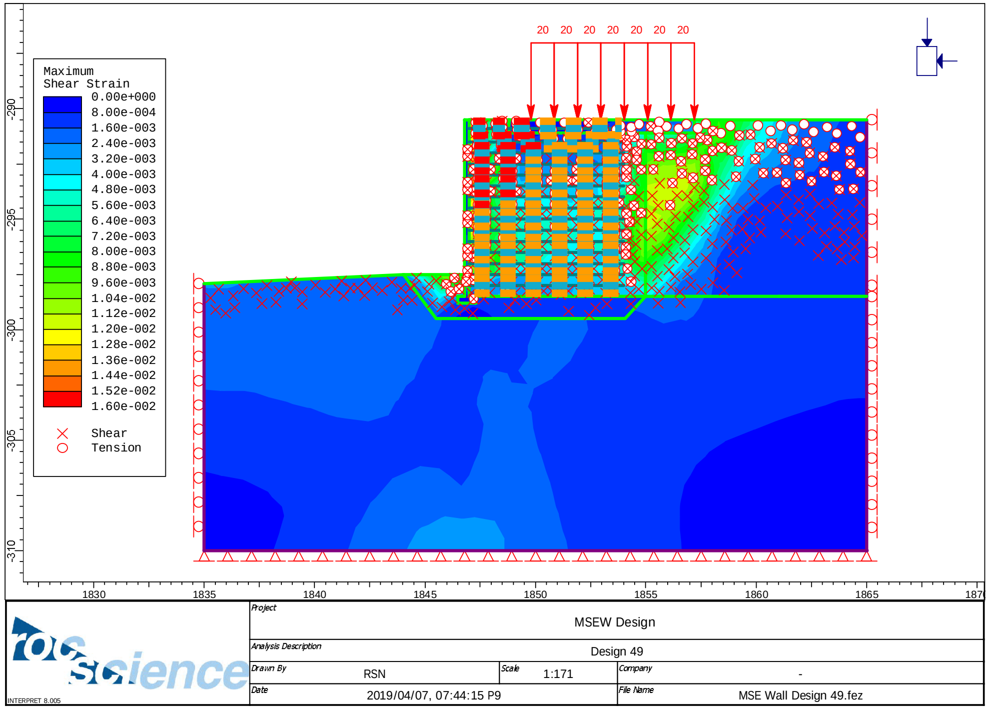

Vertical
Displacement
m
-1.45e-001
-1.36e-001
-1.27e-001
-1.18e-001
-1.09e-001
-9.95e-002
-9.05e-002
-8.15e-002
-7.25e-002
-6.35e-002
-5.45e-002
-4.55e-002
-3.65e-002
-2.75e-002
-1.85e-002
-9.50e-003
-5.00e-004
8.50e-003
1.75e-002
2.65e-002
3.55e-002
Shear
Tension
20 20 20 20 20 20 20
Project
MSEW Design
Analysis Description
Design 48
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 48.fez
INTERPRET 8.005

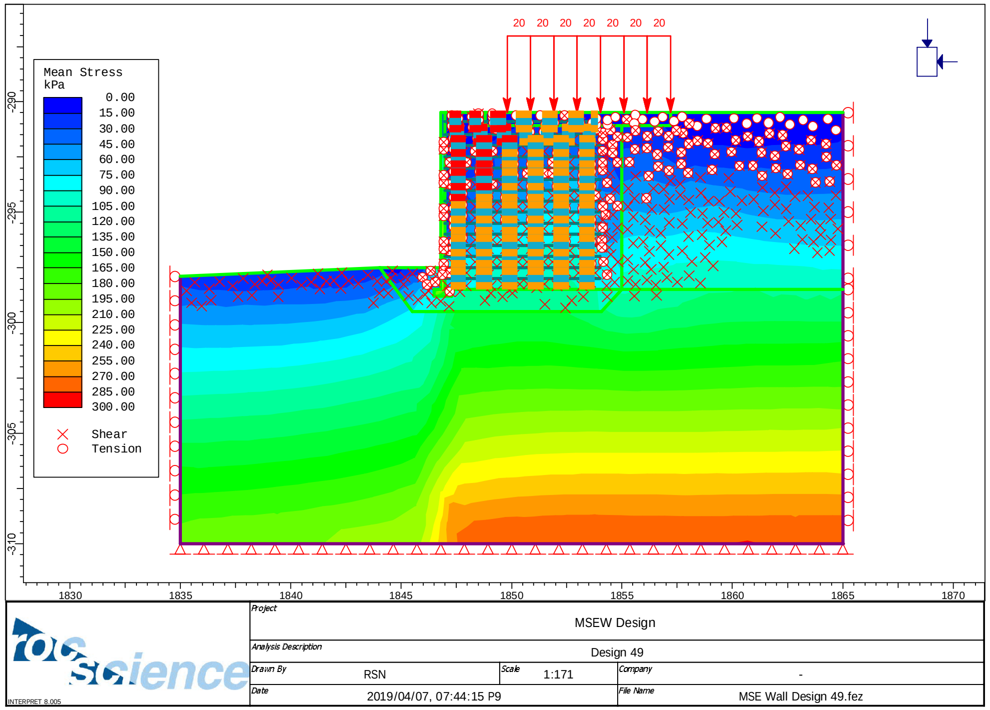

Horizontal Displacement m
-1.80e-001
-1.71e-001
-1.62e-001
-1.53e-001
-1.44e-001
-1.35e-001
-1.26e-001
-1.17e-001
-1.08e-001
-9.90e-002
-9.00e-002
-8.10e-002
-7.20e-002
-6.30e-002
-5.40e-002
-4.50e-002
-3.60e-002
-2.70e-002
-1.80e-002
-9.00e-003
0.00e+000
Shear
Tension
20 20 20 20 20 20 20
-290
-295
-300
-305
-310
1830 1835 1840 1845 1850 1855 1860 1865 1870
Project MSEW Design
Analysis Description Design 48
Drawn By RSN
Scale 1:171
Company -
Date 2019/10/07, 07:44:15 PM
File Name MSE Wall Design 48.fez
INTERPRET 8.005

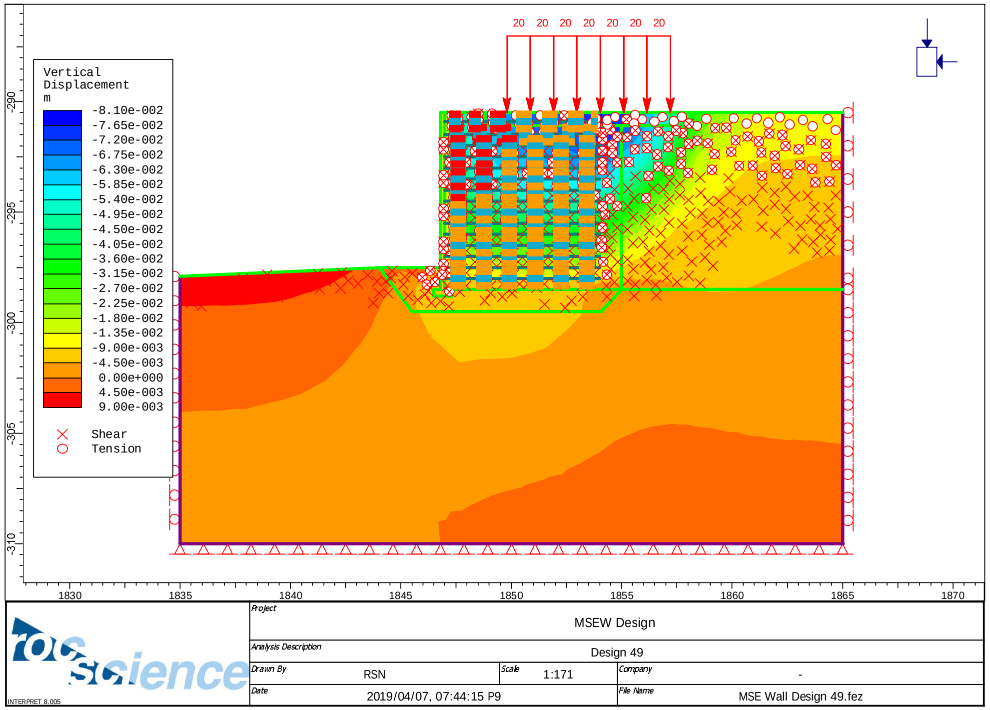

Maximum Shear Strain
0.00e+000
4.00e-003
8.00e-003
1.20e-002
1.60e-002
2.00e-002
2.40e-002
2.80e-002
3.20e-002
3.60e-002
4.00e-002
4.40e-002
4.80e-002
5.20e-002
5.60e-002
6.00e-002
6.40e-002
6.80e-002
7.20e-002
7.60e-002
8.00e-002
Critical SRF: 1.4
20 20 20 20 20 20 20 20
-290
-295
-300
-305
-310
1830 1835 1840 1845 1850 1855 1860 1865
Project MSEW Design
Analysis Description Design 48
Drawn By RSN
Scale 1:171
Company -
Date 2019/10/07, 07:44:15 PM
File Name MSE Wall Design 48.fez
INTERPRET 8.005

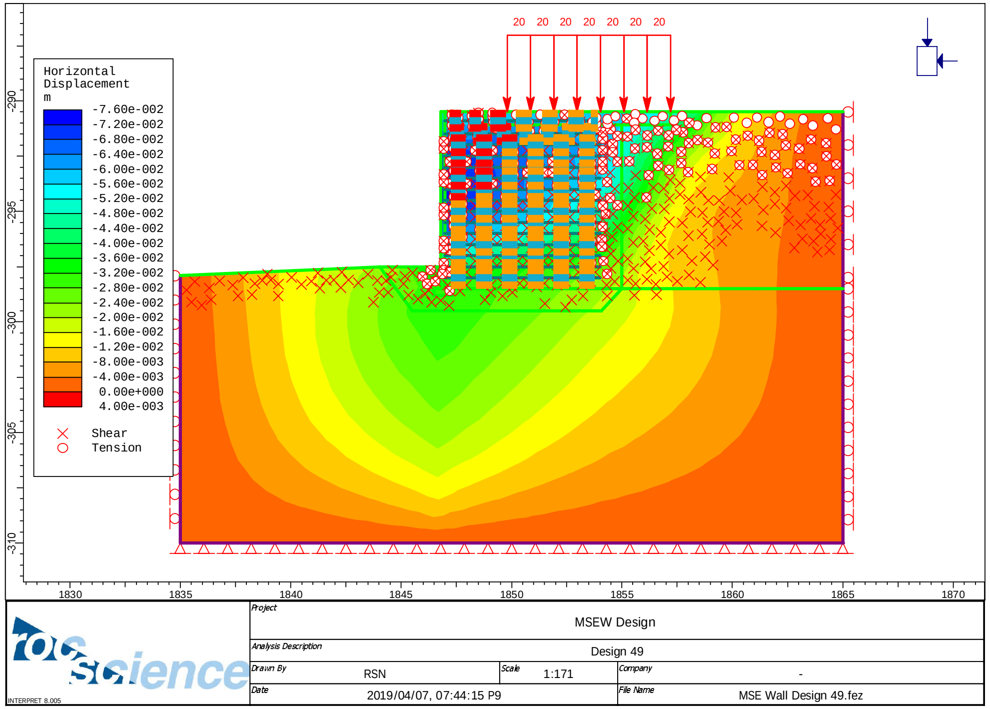

Total Displacement m
0.00e+000
1.00e-002
2.00e-002
3.00e-002
4.00e-002
5.00e-002
6.00e-002
7.00e-002
8.00e-002
9.00e-002
1.00e-001
1.10e-001
1.20e-001
1.30e-001
1.40e-001
1.50e-001
1.60e-001
1.70e-001
1.80e-001
1.90e-001
2.00e-001
Shear
Tension
20 20 20 20 20 20 20
-290
-295
-300
-305
-310
1830 1835 1840 1845 1850 1855 1860 1865
Project MSEW Design
Analysis Description Design 48
Drawn By RSN
Scale 1:171
Company -
Date 2019/10/07, 07:44:15 PM
File Name MSE Wall Design 48.fez
INTERPRET 8.005

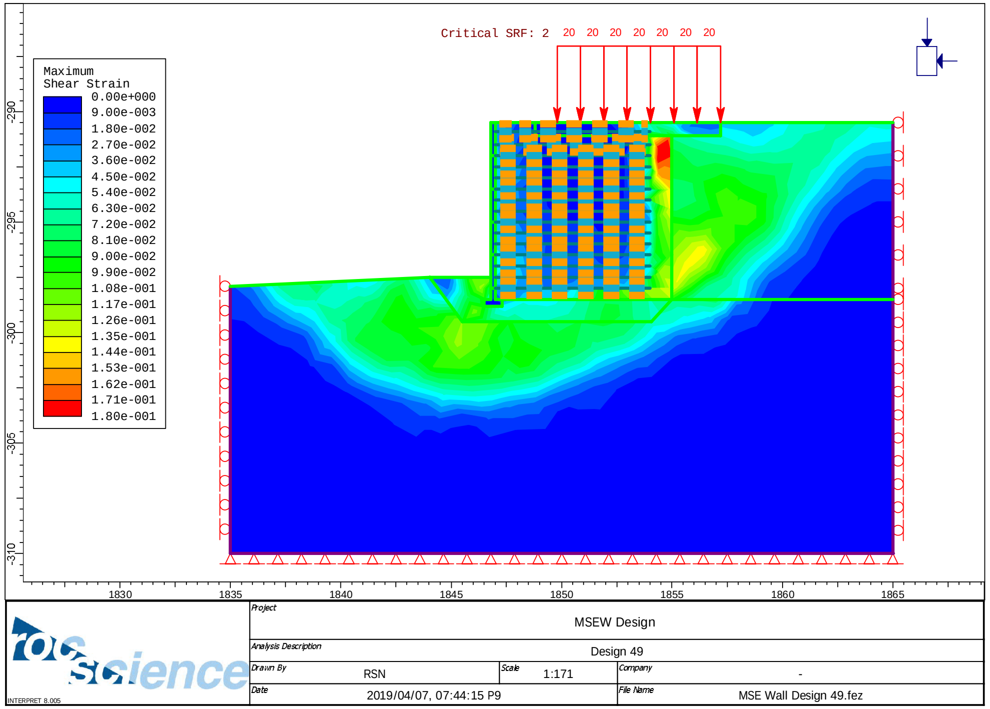

Sigma Z
kPa
0.00
15.00
30.00
45.00
60.00
75.00
90.00
105.00
120.00
135.00
150.00
165.00
180.00
195.00
210.00
225.00
240.00
255.00
270.00
285.00
300.00
Shear
Tension
20 20 20 20 20 20 20
-290
-295
-300
-305
-310
1830 1835 1840 1845 1850 1855 1860 1865 1870
rocscience
Project
MSEW Design
Analysis Description
Design 49
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/04/07, 07:44:15 P9
File Name
MSE Wall Design 49.fez
INTERPRET 8.005

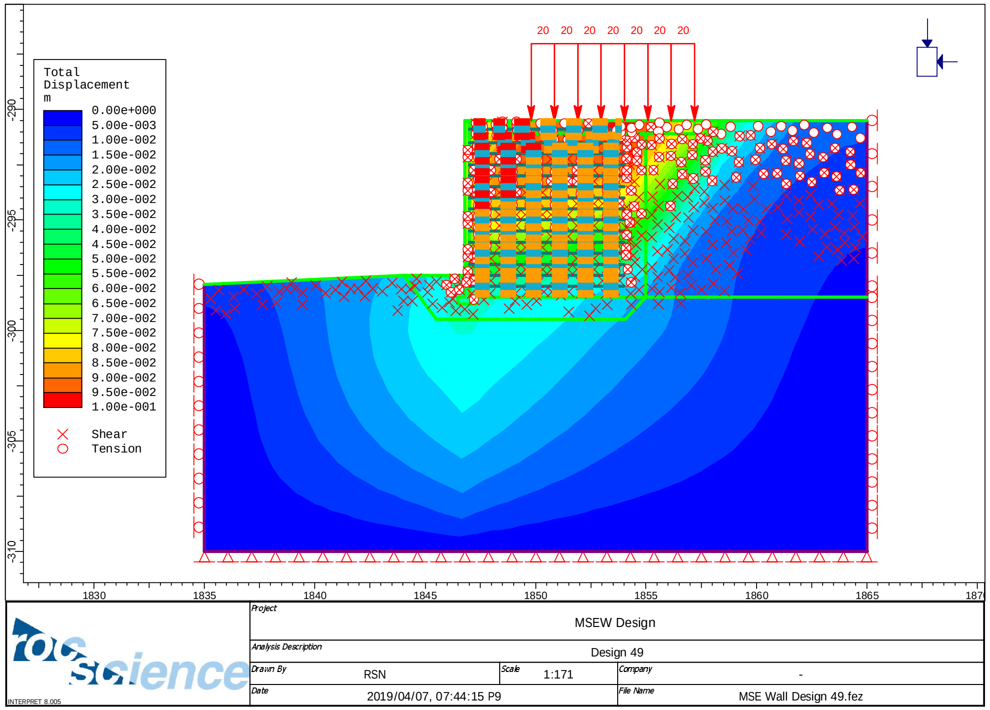

Maximum
Shear Strain
0.00e+000
8.00e-004
1.60e-003
2.40e-003
3.20e-003
4.00e-003
4.80e-003
5.60e-003
6.40e-003
7.20e-003
8.00e-003
8.80e-003
9.60e-003
1.04e-002
1.12e-002
1.20e-002
1.28e-002
1.36e-002
1.44e-002
1.52e-002
1.60e-002
Shear
Tension
20 20 20 20 20 20 20
-290
-295
-300
-305
-310
1830 1835 1840 1845 1850 1855 1860 1865
rocscience
Project
MSEW Design
Analysis Description
Design 49
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/04/07, 07:44:15 P9
File Name
MSE Wall Design 49.fez
INTERPRET 8.005


Mean Stress
kPa
0.00
15.00
30.00
45.00
60.00
75.00
90.00
105.00
120.00
135.00
150.00
165.00
180.00
195.00
210.00
225.00
240.00
255.00
270.00
285.00
300.00
Shear
Tension
20 20 20 20 20 20 20
-290
-295
-300
-305
-310
1830 1835 1840 1845 1850 1855 1860 1865 1870
rocscience
Project
MSEW Design
Analysis Description
Design 49
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/04/07, 07:44:15 P9
File Name
MSE Wall Design 49.fez
INTERPRET 8.005


Vertical
Displacement
m
-8.10e-002
-7.65e-002
-7.20e-002
-6.75e-002
-6.30e-002
-5.85e-002
-5.40e-002
-4.95e-002
-4.50e-002
-4.05e-002
-3.60e-002
-3.15e-002
-2.70e-002
-2.25e-002
-1.80e-002
-1.35e-002
-9.00e-003
-4.50e-003
0.00e+000
4.50e-003
9.00e-003
Shear
Tension
20 20 20 20 20 20 20
-290
-295
-300
-305
-310
1830 1835 1840 1845 1850 1855 1860 1865 1870
rocscience
Project
MSEW Design
Analysis Description
Design 49
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/04/07, 07:44:15 P9
File Name
MSE Wall Design 49.fez
INTERPRET 8.005


Horizontal Displacement m
-7.60e-002
-7.20e-002
-6.80e-002
-6.40e-002
-6.00e-002
-5.60e-002
-5.20e-002
-4.80e-002
-4.40e-002
-4.00e-002
-3.60e-002
-3.20e-002
-2.80e-002
-2.40e-002
-2.00e-002
-1.60e-002
-1.20e-002
-8.00e-003
-4.00e-003
0.00e+000
4.00e-003
Shear
Tension
20 20 20 20 20 20 20
Project
MSEW Design
Analysis Description
Design 49
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/04/07, 07:44:15 P9
File Name
MSE Wall Design 49.fez
INTERPRET 8.005


Maximum Shear Strain
0.00e+000
9.00e-003
1.80e-002
2.70e-002
3.60e-002
4.50e-002
5.40e-002
6.30e-002
7.20e-002
8.10e-002
9.00e-002
9.90e-002
1.08e-001
1.17e-001
1.26e-001
1.35e-001
1.44e-001
1.53e-001
1.62e-001
1.71e-001
1.80e-001
Critical SRF: 2
20 20 20 20 20 20 20
Project
MSEW Design
Analysis Description
Design 49
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/04/07, 07:44:15 P9
File Name
MSE Wall Design 49.fez
INTERPRET 8.005


Total Displacement m
0.00e+000
5.00e-003
1.00e-002
1.50e-002
2.00e-002
2.50e-002
3.00e-002
3.50e-002
4.00e-002
4.50e-002
5.00e-002
5.50e-002
6.00e-002
6.50e-002
7.00e-002
7.50e-002
8.00e-002
8.50e-002
9.00e-002
9.50e-002
1.00e-001
Shear
Tension
20 20 20 20 20 20 20
Project
MSEW Design
Analysis Description
Design 49
Drawn By
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Scale
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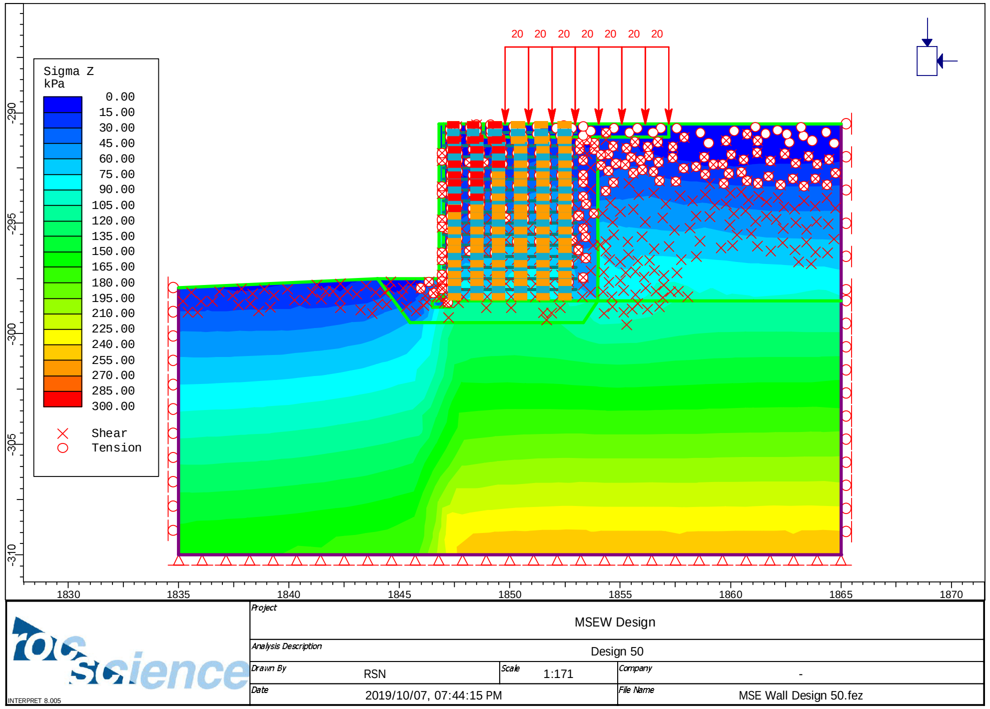
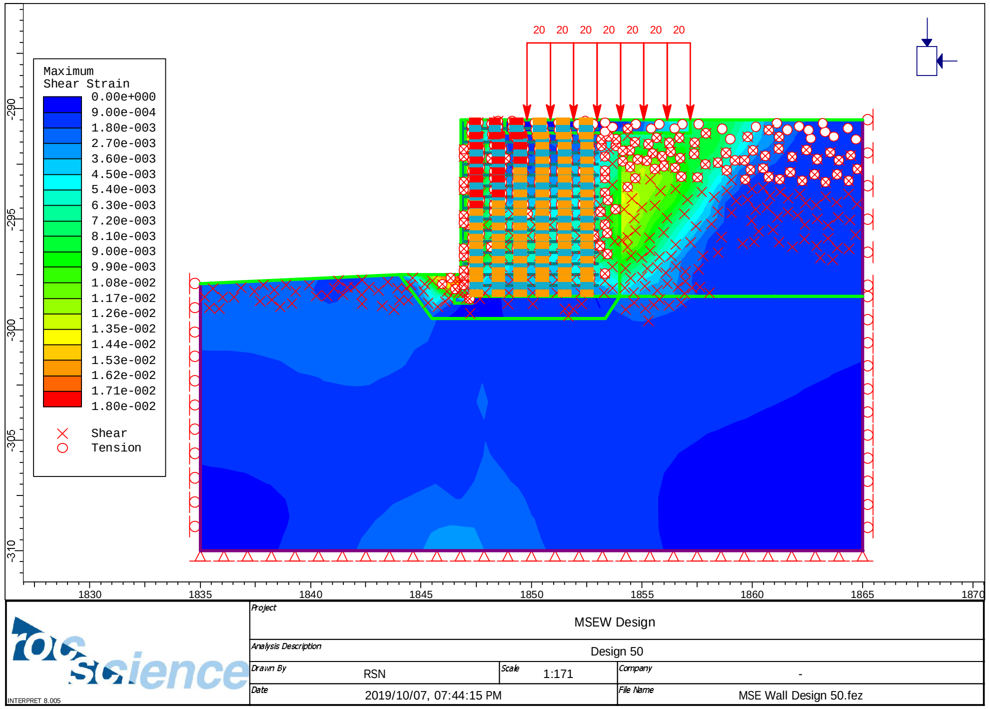
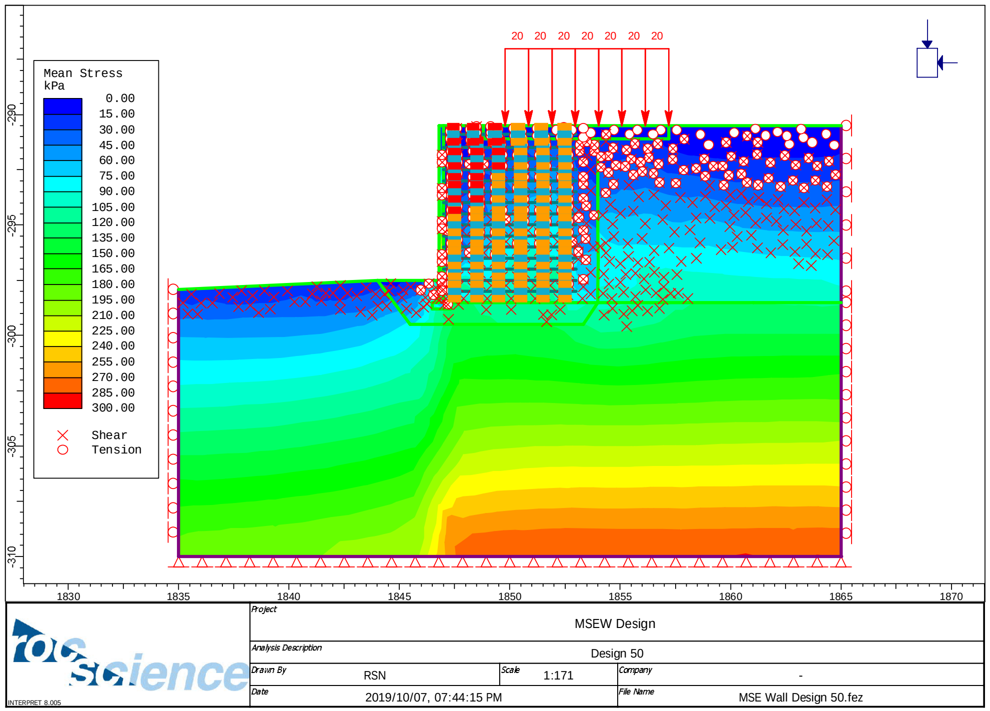
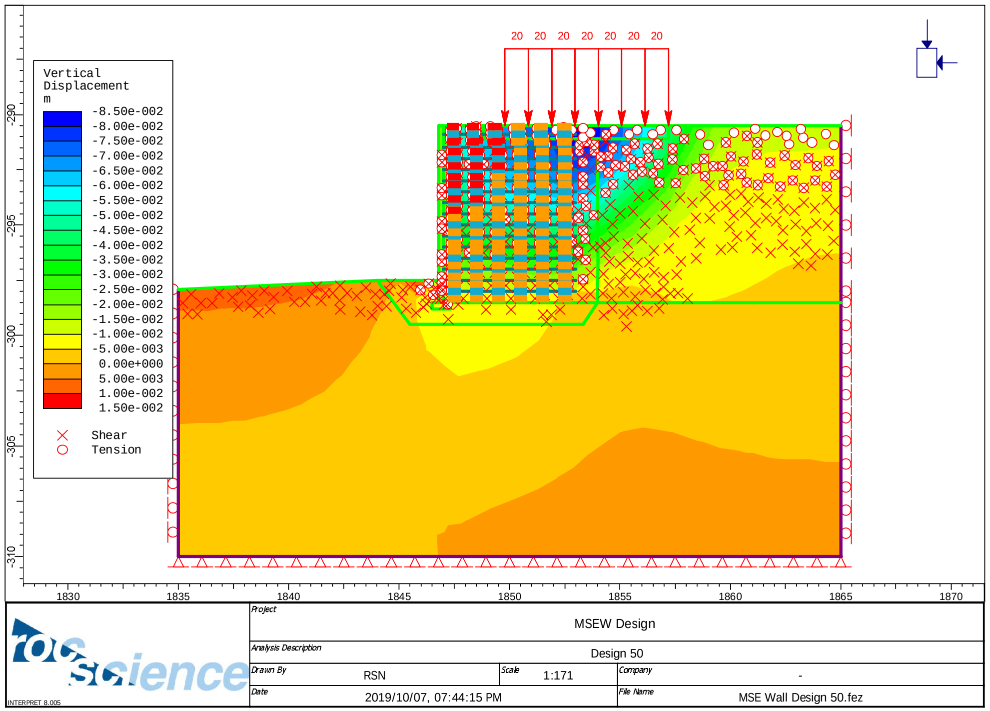
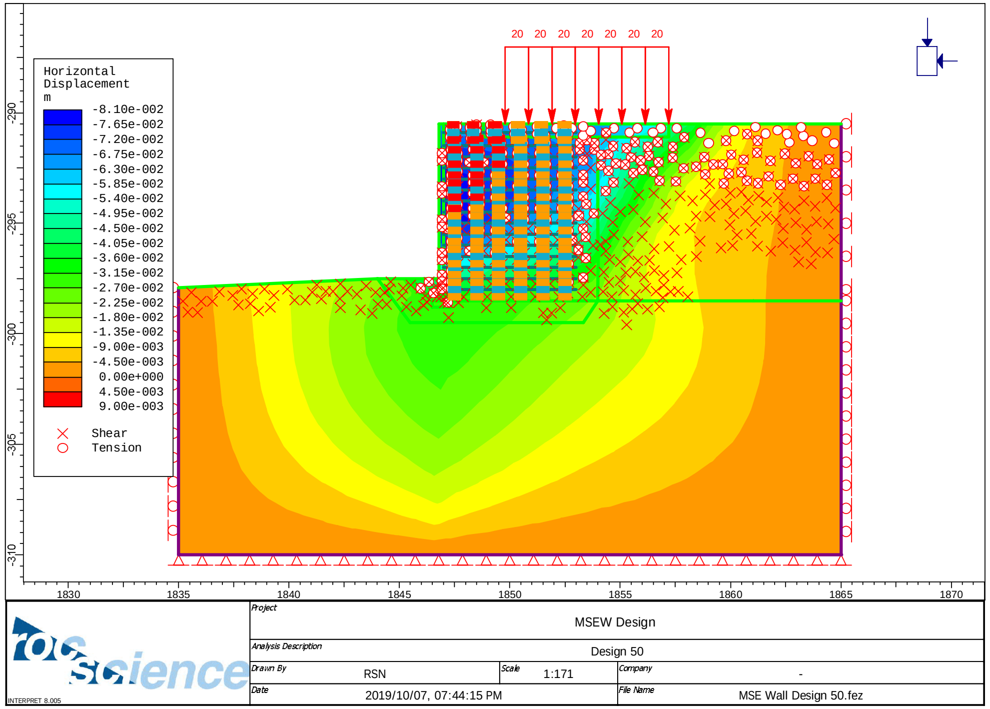
Company
-
Date
2019/04/07, 07:44:15 P9
File Name
MSE Wall Design 49.fez
INTERPRET 8.005

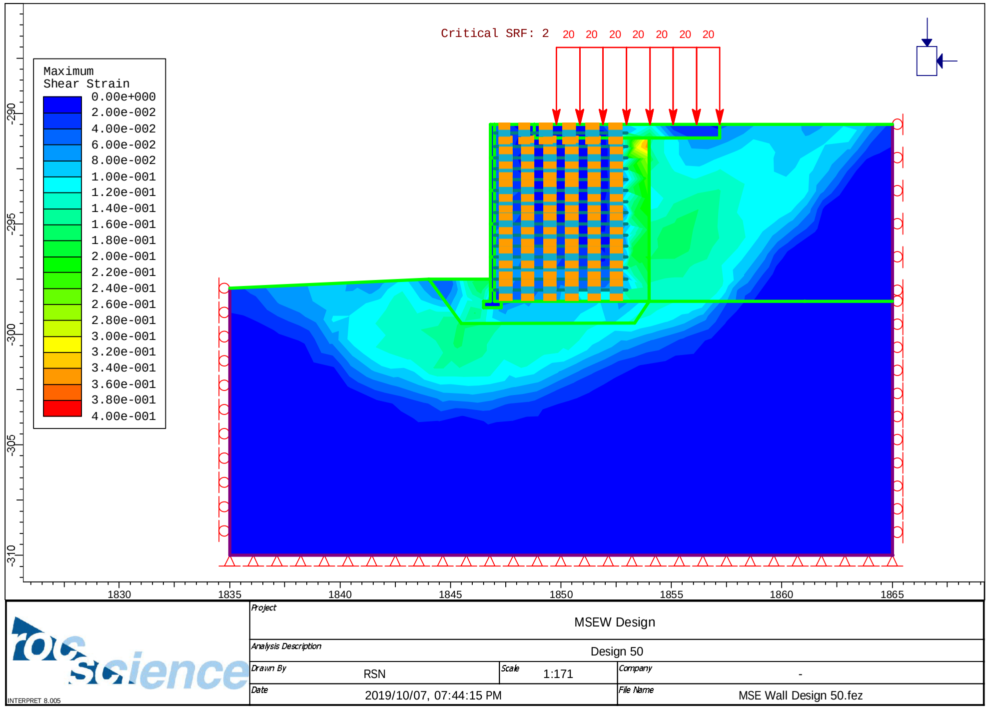

Sigma Z
kPa
0.00
15.00
30.00
45.00
60.00
75.00
90.00
105.00
120.00
135.00
150.00
165.00
180.00
195.00
210.00
225.00
240.00
255.00
270.00
285.00
300.00
Shear
Tension
Project
MSEW Design
Analysis Description
Design 50
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 50.fez
INTERPRET 8.005

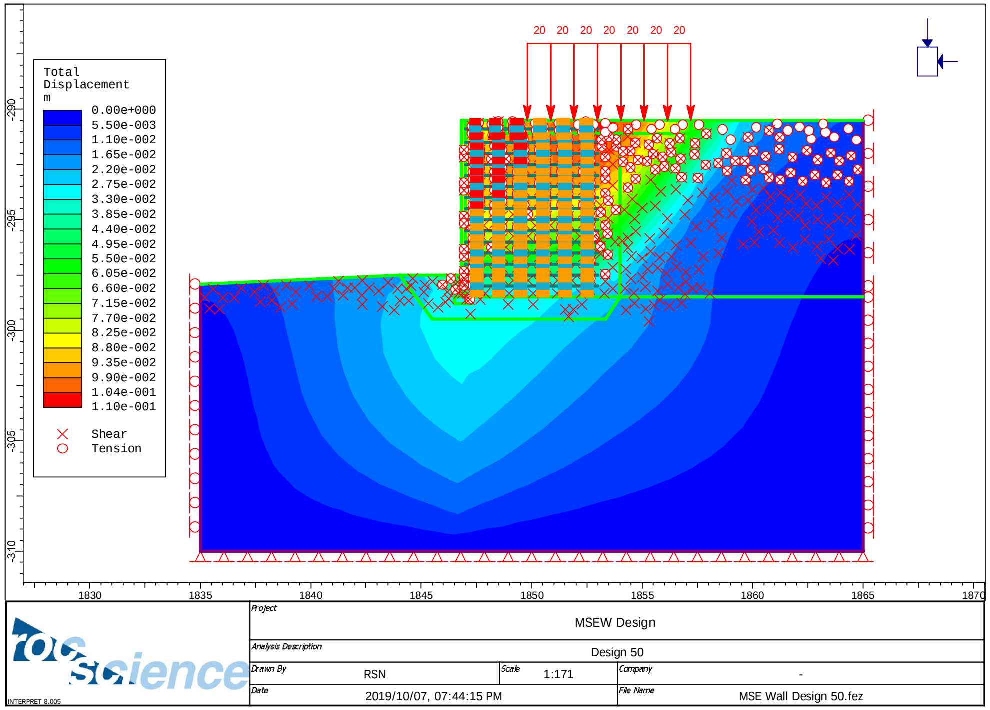

Maximum
Shear Strain
0.00e+000
9.00e-004
1.80e-003
2.70e-003
3.60e-003
4.50e-003
5.40e-003
6.30e-003
7.20e-003
8.10e-003
9.00e-003
9.90e-003
1.08e-002
1.17e-002
1.26e-002
1.35e-002
1.44e-002
1.53e-002
1.62e-002
1.71e-002
1.80e-002
Shear
Tension
Project
MSEW Design
Analysis Description
Design 50
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 50.fez
INTERPRET 8.005

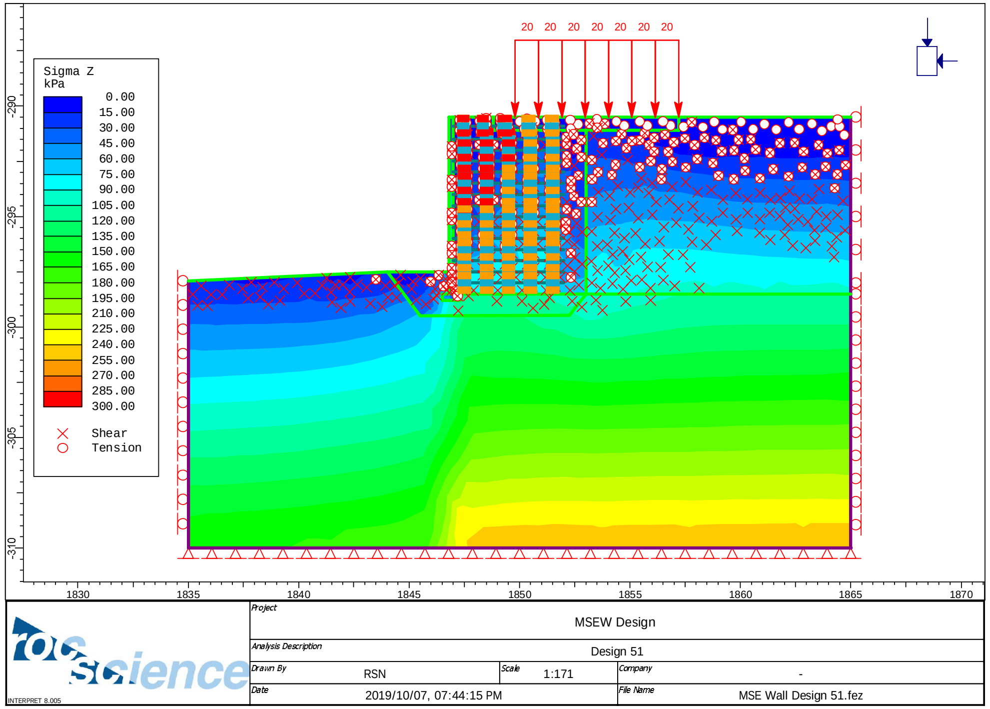

Mean Stress
kPa
0.00
15.00
30.00
45.00
60.00
75.00
90.00
105.00
120.00
135.00
150.00
165.00
180.00
195.00
210.00
225.00
240.00
255.00
270.00
285.00
300.00
Shear
Tension
Project
MSEW Design
Analysis Description
Design 50
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 50.fez
INTERPRET 8.005

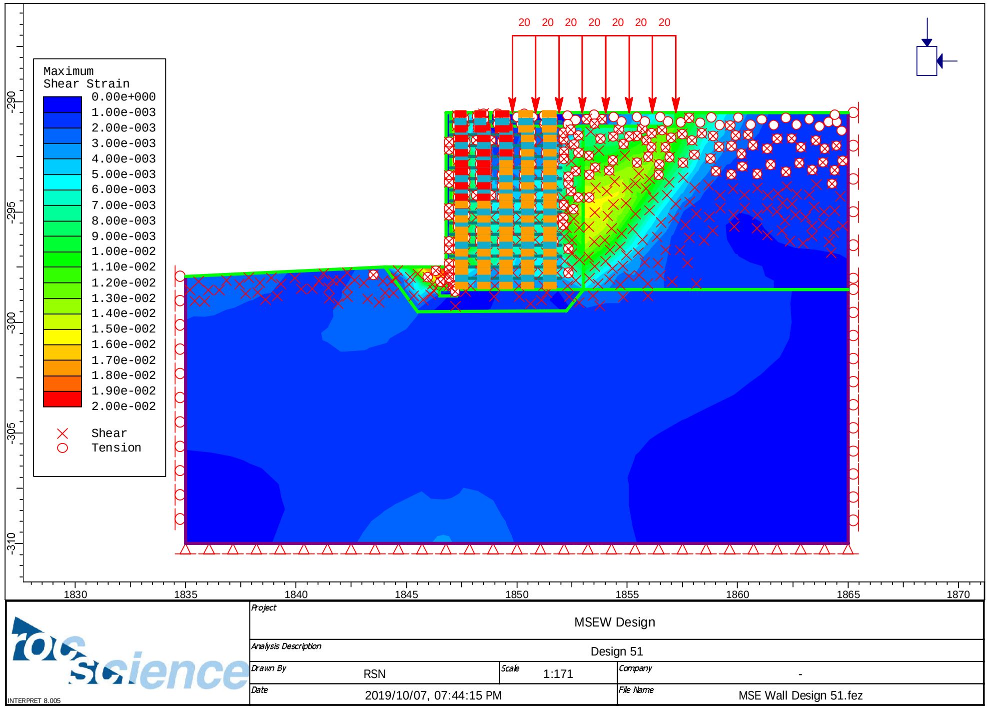

Vertical
Displacement
m
-8.50e-002
-8.00e-002
-7.50e-002
-7.00e-002
-6.50e-002
-6.00e-002
-5.50e-002
-5.00e-002
-4.50e-002
-4.00e-002
-3.50e-002
-3.00e-002
-2.50e-002
-2.00e-002
-1.50e-002
-1.00e-002
-5.00e-003
0.00e+000
5.00e-003
1.00e-002
1.50e-002
Shear
Tension
Project
MSEW Design
Analysis Description
Design 50
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 50.fez
INTERPRET 8.005

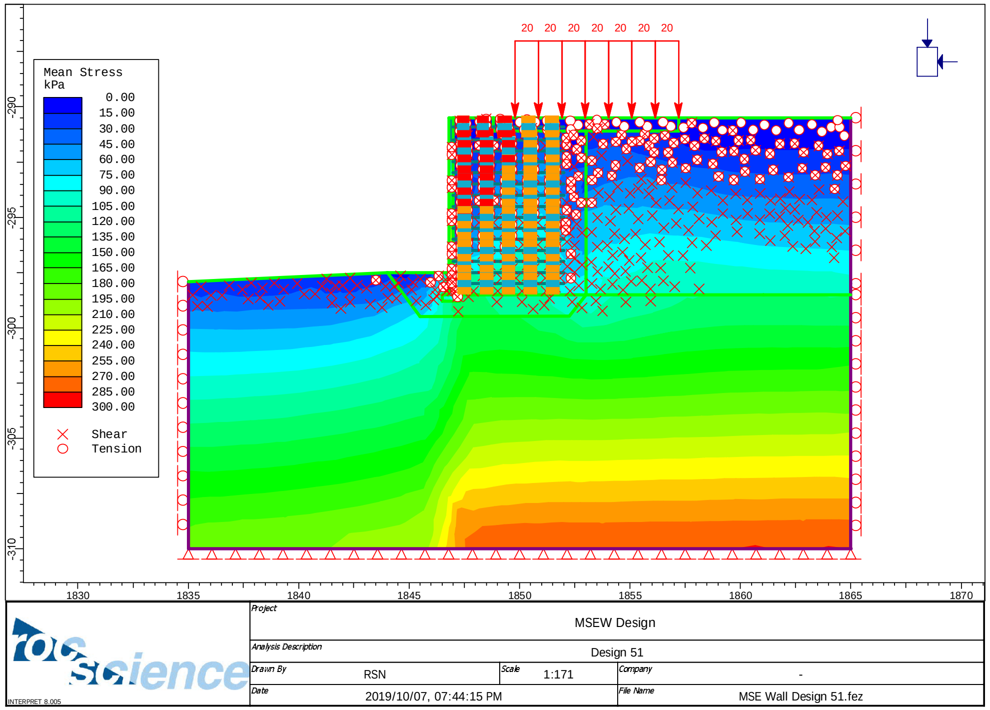

20 20 20 20 20 20 20
Horizontal Displacement m
-8.10e-002
-7.65e-002
-7.20e-002
-6.75e-002
-6.30e-002
-5.85e-002
-5.40e-002
-4.95e-002
-4.50e-002
-4.05e-002
-3.60e-002
-3.15e-002
-2.70e-002
-2.25e-002
-1.80e-002
-1.35e-002
-9.00e-003
-4.50e-003
0.00e+000
4.50e-003
9.00e-003
Shear
Tension
-290
-295
-300
-305
-310
1830
1835
1840
1845
1850
1855
1860
1865
1870
Project
MSEW Design
Analysis Description
Design 50
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 50.fez
INTERPRET 8.005

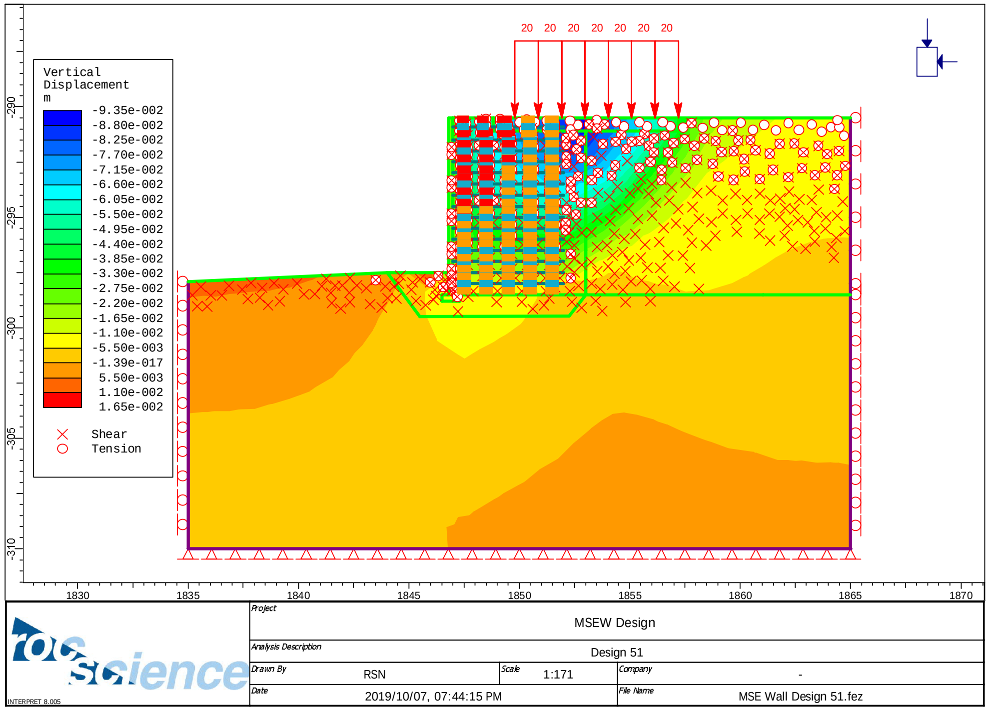

Critical SRF: 2
20 20 20 20 20 20 20
Maximum Shear Strain
0.00e+000
2.00e-002
4.00e-002
6.00e-002
8.00e-002
1.00e-001
1.20e-001
1.40e-001
1.60e-001
1.80e-001
2.00e-001
2.20e-001
2.40e-001
2.60e-001
2.80e-001
3.00e-001
3.20e-001
3.40e-001
3.60e-001
3.80e-001
4.00e-001
-290
-295
-300
-305
-310
1830
1835
1840
1845
1850
1855
1860
1865
Project
MSEW Design
Analysis Description
Design 50
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 50.fez
INTERPRET 8.005

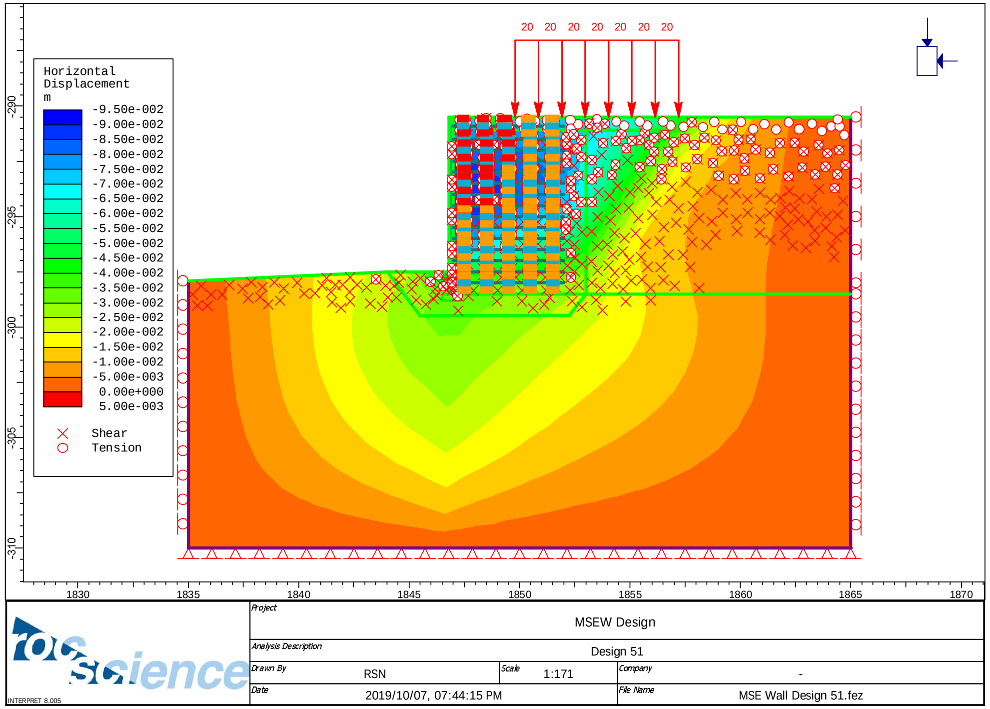

20 20 20 20 20 20 20
Total Displacement m
0.00e+000
5.50e-003
1.10e-002
1.65e-002
2.20e-002
2.75e-002
3.30e-002
3.85e-002
4.40e-002
4.95e-002
5.50e-002
6.05e-002
6.60e-002
7.15e-002
7.70e-002
8.25e-002
8.80e-002
9.35e-002
9.90e-002
1.04e-001
1.10e-001
Shear
Tension
-290
-295
-300
-305
-310
1830
1835
1840
1845
1850
1855
1860
1865
1870
Project
MSEW Design
Analysis Description
Design 50
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 50.fez
INTERPRET 8.005


20 20 20 20 20 20 20
Sigma Z
kPa
0.00
15.00
30.00
45.00
60.00
75.00
90.00
105.00
120.00
135.00
150.00
165.00
180.00
195.00
210.00
225.00
240.00
255.00
270.00
285.00
300.00
Shear
Tension
-290
-295
-300
-305
-310
1830 1835 1840 1845 1850 1855 1860 1865 1870
Project
MSEW Design
Analysis Description
Design 51
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 51.fez
INTERPRET 8.005

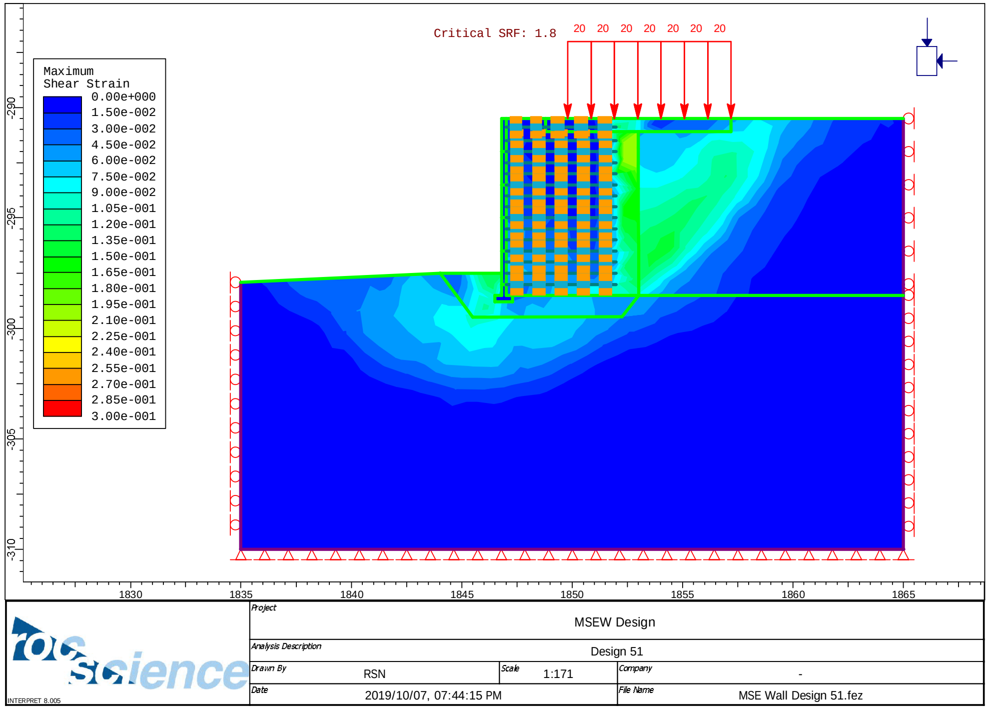

20 20 20 20 20 20 20
Maximum
Shear Strain
0.00e+000
1.00e-003
2.00e-003
3.00e-003
4.00e-003
5.00e-003
6.00e-003
7.00e-003
8.00e-003
9.00e-003
1.00e-002
1.10e-002
1.20e-002
1.30e-002
1.40e-002
1.50e-002
1.60e-002
1.70e-002
1.80e-002
1.90e-002
2.00e-002
Shear
Tension
-290
-295
-300
-305
-310
1830 1835 1840 1845 1850 1855 1860 1865 1870
Project
MSEW Design
Analysis Description
Design 51
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 51.fez
INTERPRET 8.005


20 20 20 20 20 20 20
Mean Stress
kPa
0.00
15.00
30.00
45.00
60.00
75.00
90.00
105.00
120.00
135.00
150.00
165.00
180.00
195.00
210.00
225.00
240.00
255.00
270.00
285.00
300.00
Shear
Tension
-290
-295
-300
-305
-310
1830 1835 1840 1845 1850 1855 1860 1865 1870
Project
MSEW Design
Analysis Description
Design 51
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 51.fez
INTERPRET 8.005

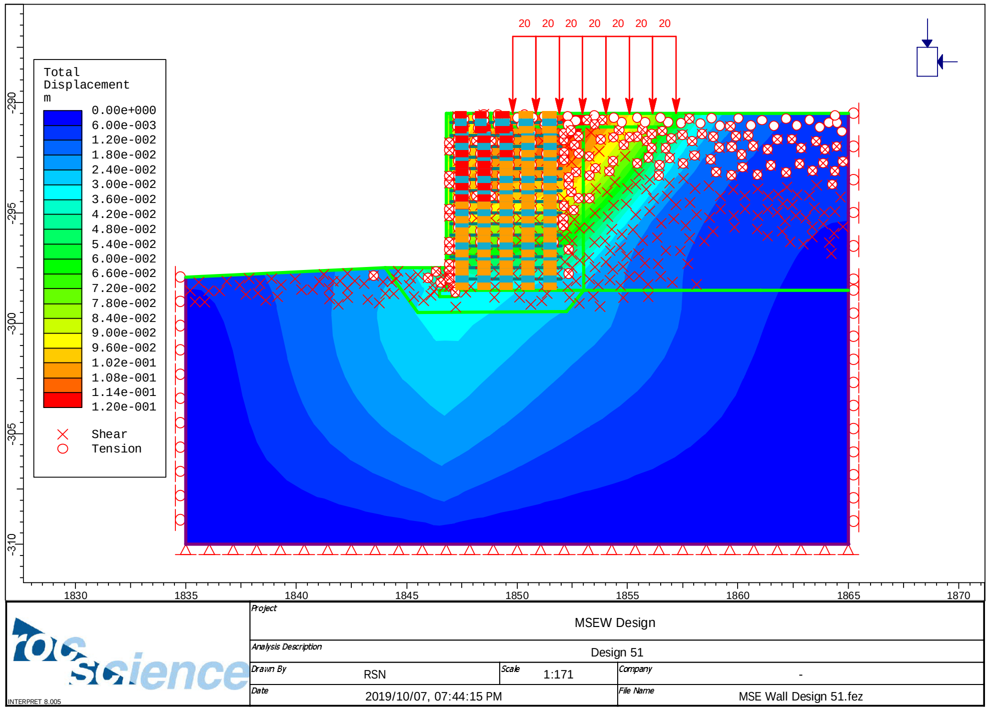

20 20 20 20 20 20 20
Vertical
Displacement
m
-9.35e-002
-8.80e-002
-8.25e-002
-7.70e-002
-7.15e-002
-6.60e-002
-6.05e-002
-5.50e-002
-4.95e-002
-4.40e-002
-3.85e-002
-3.30e-002
-2.75e-002
-2.20e-002
-1.65e-002
-1.10e-002
-5.50e-003
-1.39e-017
5.50e-003
1.10e-002
1.65e-002
Shear
Tension
-290
-295
-300
-305
-310
1830 1835 1840 1845 1850 1855 1860 1865 1870
Project
MSEW Design
Analysis Description
Design 51
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 51.fez
INTERPRET 8.005



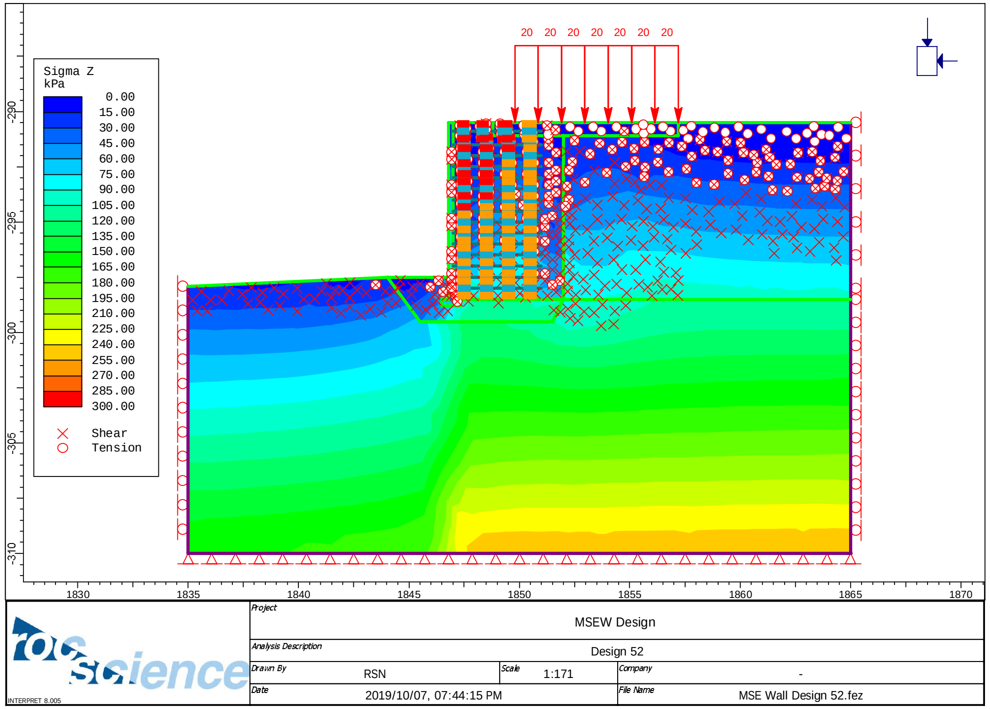
Horizontal Displacement m
-9.50e-002
-9.00e-002
-8.50e-002
-8.00e-002
-7.50e-002
-7.00e-002
-6.50e-002
-6.00e-002
-5.50e-002
-5.00e-002
-4.50e-002
-4.00e-002
-3.50e-002
-3.00e-002
-2.50e-002
-2.00e-002
-1.50e-002
-1.00e-002
-5.00e-003
0.00e+000
5.00e-003
Shear
Tension
20 20 20 20 20 20 20
Project
MSEW Design
Analysis Description
Design 51
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 51.fez
INTERPRET 8.005

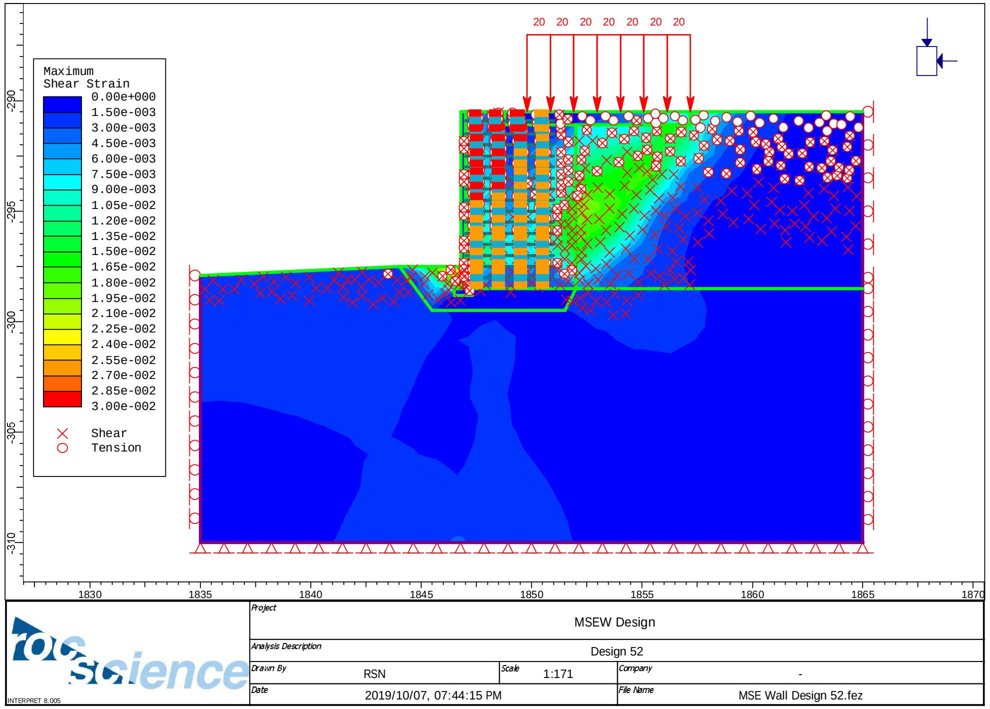


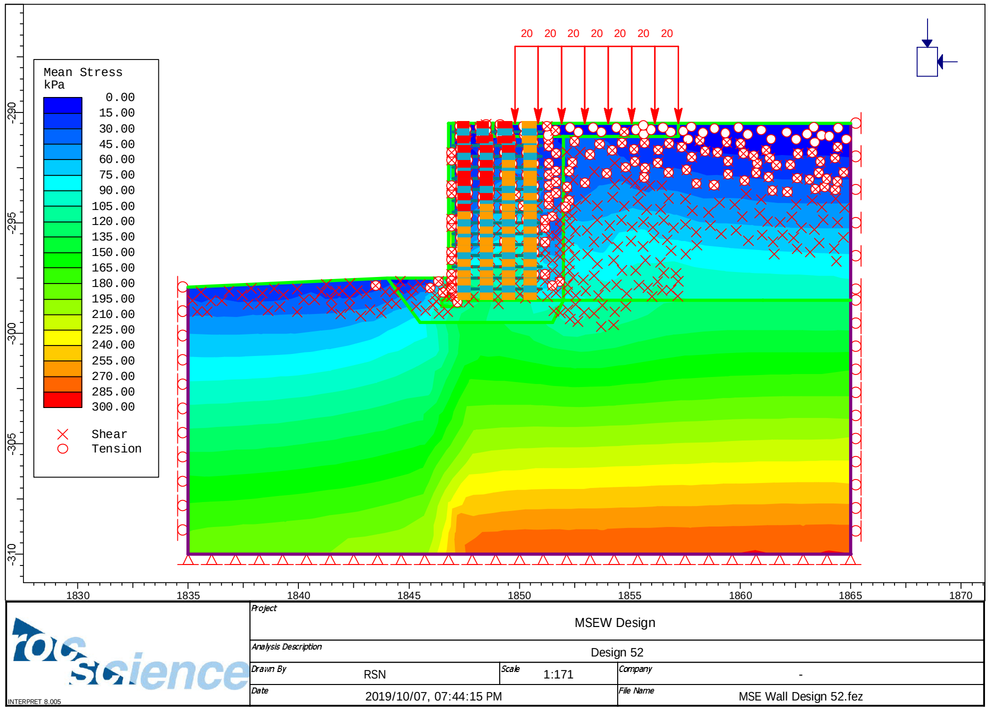
Maximum Shear Strain
0.00e+000
1.50e-002
3.00e-002
4.50e-002
6.00e-002
7.50e-002
9.00e-002
1.05e-001
1.20e-001
1.35e-001
1.50e-001
1.65e-001
1.80e-001
1.95e-001
2.10e-001
2.25e-001
2.40e-001
2.55e-001
2.70e-001
2.85e-001
3.00e-001
Critical SRF: 1.8
20 20 20 20 20 20 20
Project
MSEW Design
Analysis Description
Design 51
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 51.fez
INTERPRET 8.005

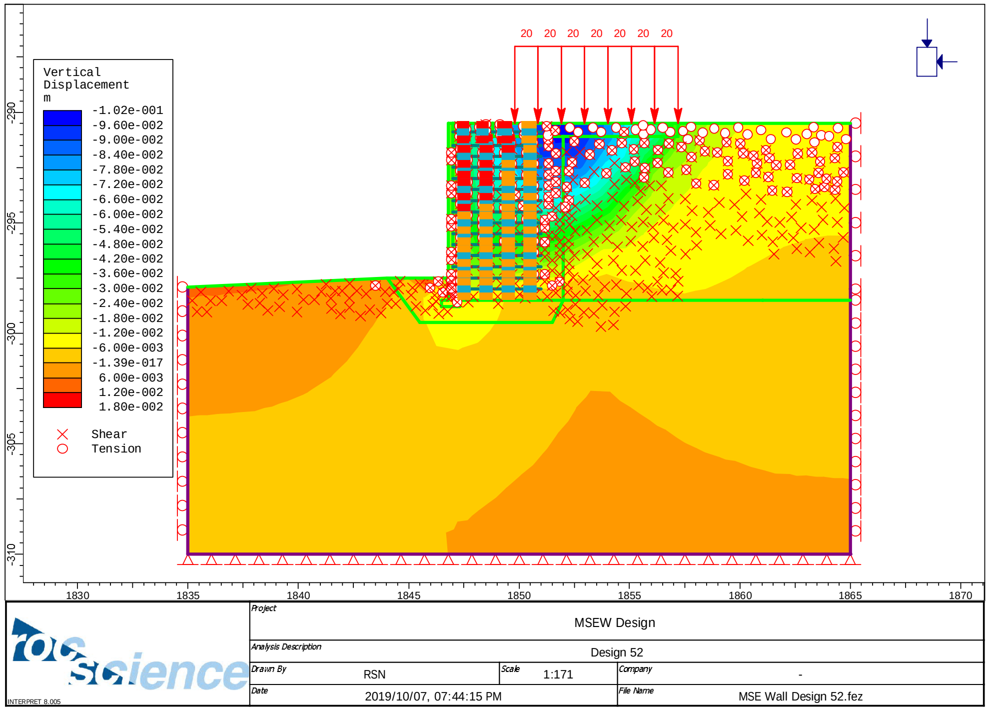


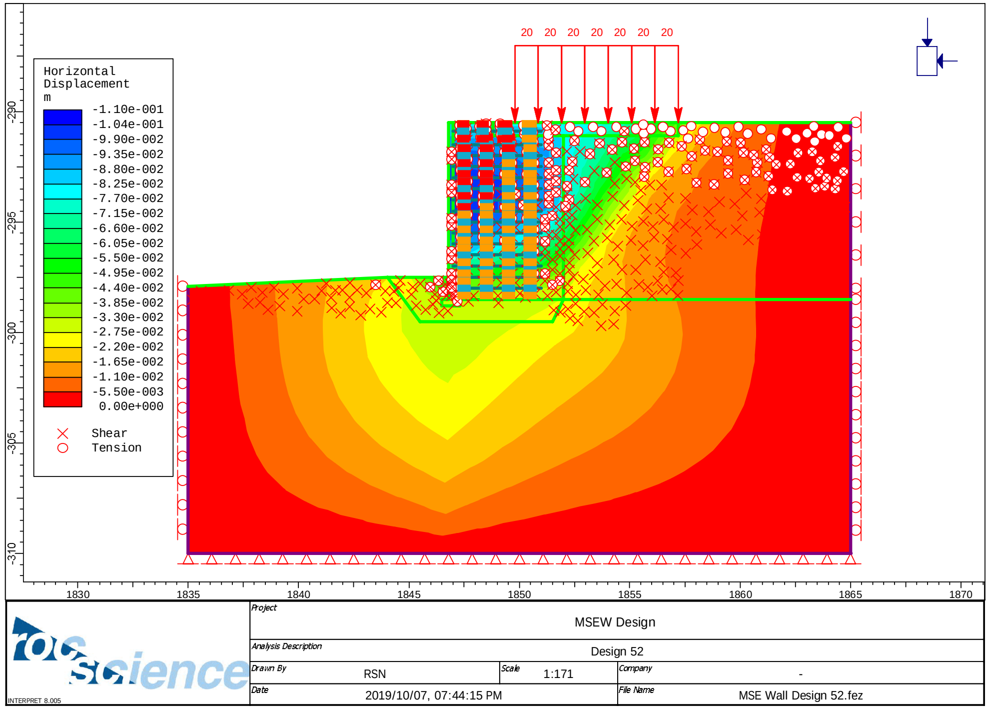
Total Displacement m
0.00e+000
6.00e-003
1.20e-002
1.80e-002
2.40e-002
3.00e-002
3.60e-002
4.20e-002
4.80e-002
5.40e-002
6.00e-002
6.60e-002
7.20e-002
7.80e-002
8.40e-002
9.00e-002
9.60e-002
1.02e-001
1.08e-001
1.14e-001
1.20e-001
Shear
Tension
20 20 20 20 20 20 20
Project
MSEW Design
Analysis Description
Design 51
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 51.fez
INTERPRET 8.005

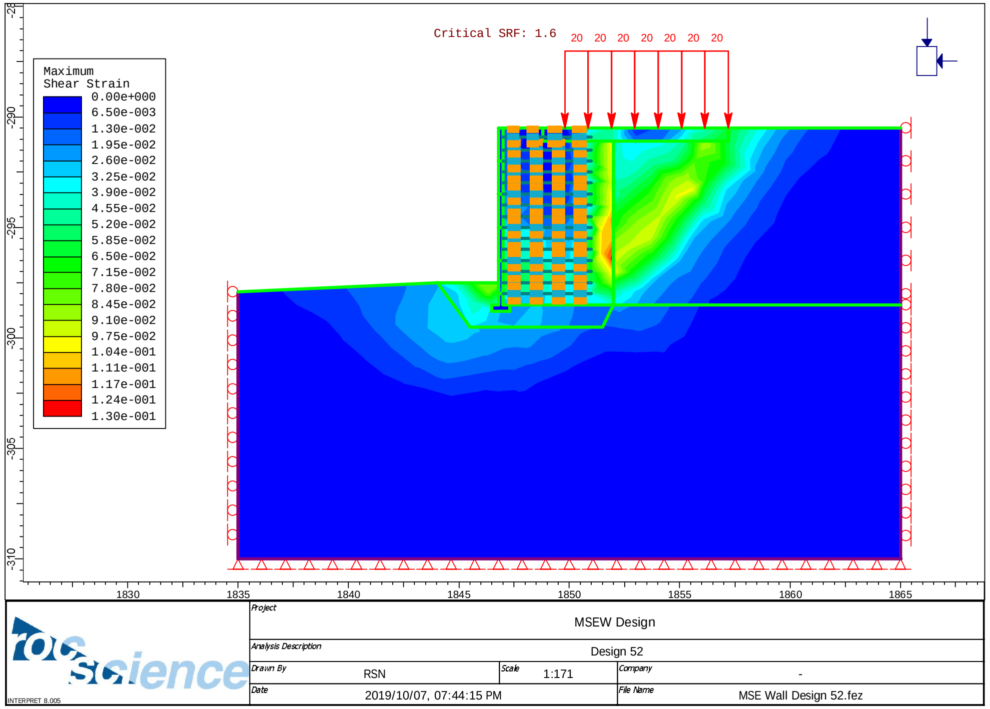

20 20 20 20 20 20 20
Sigma Z
kPa
0.00
15.00
30.00
45.00
60.00
75.00
90.00
105.00
120.00
135.00
150.00
165.00
180.00
195.00
210.00
225.00
240.00
255.00
270.00
285.00
300.00
Shear
Tension
1830 1835 1840 1845 1850 1855 1860 1865 1870
-290 -295 -300 -305 -310
Project
MSEW Design
Analysis Description
Design 52
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 52.fez
INTERPRET 8.005

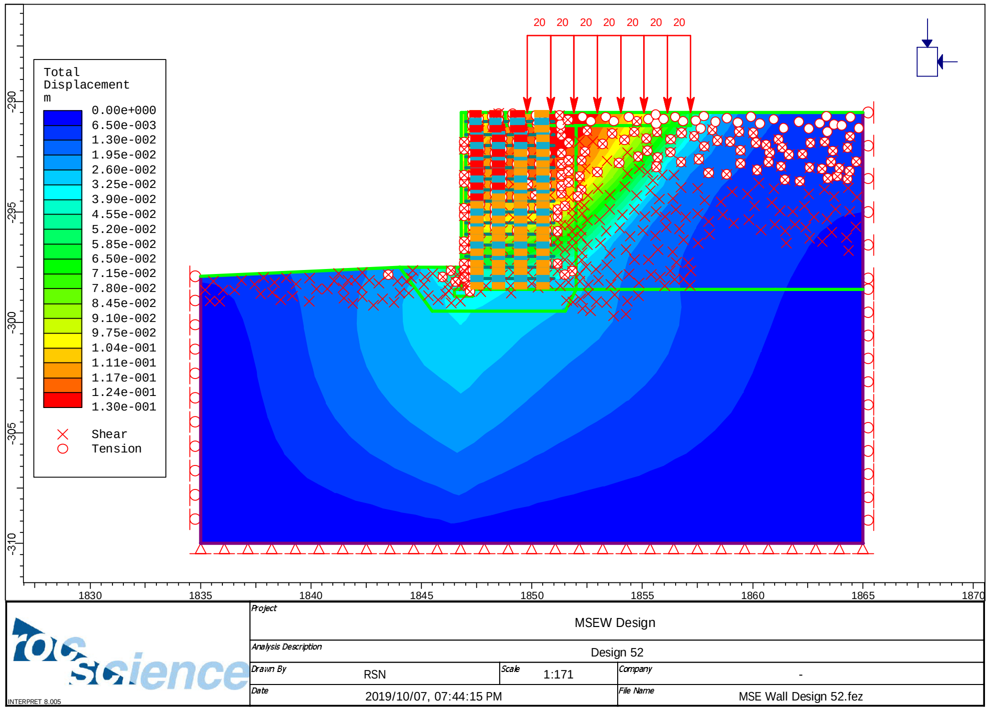

20 20 20 20 20 20 20
Maximum
Shear Strain
0.00e+000
1.50e-003
3.00e-003
4.50e-003
6.00e-003
7.50e-003
9.00e-003
1.05e-002
1.20e-002
1.35e-002
1.50e-002
1.65e-002
1.80e-002
1.95e-002
2.10e-002
2.25e-002
2.40e-002
2.55e-002
2.70e-002
2.85e-002
3.00e-002
Shear
Tension
1830 1835 1840 1845 1850 1855 1860 1865 1870
-290 -295 -300 -305 -310
Project
MSEW Design
Analysis Description
Design 52
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 52.fez
INTERPRET 8.005

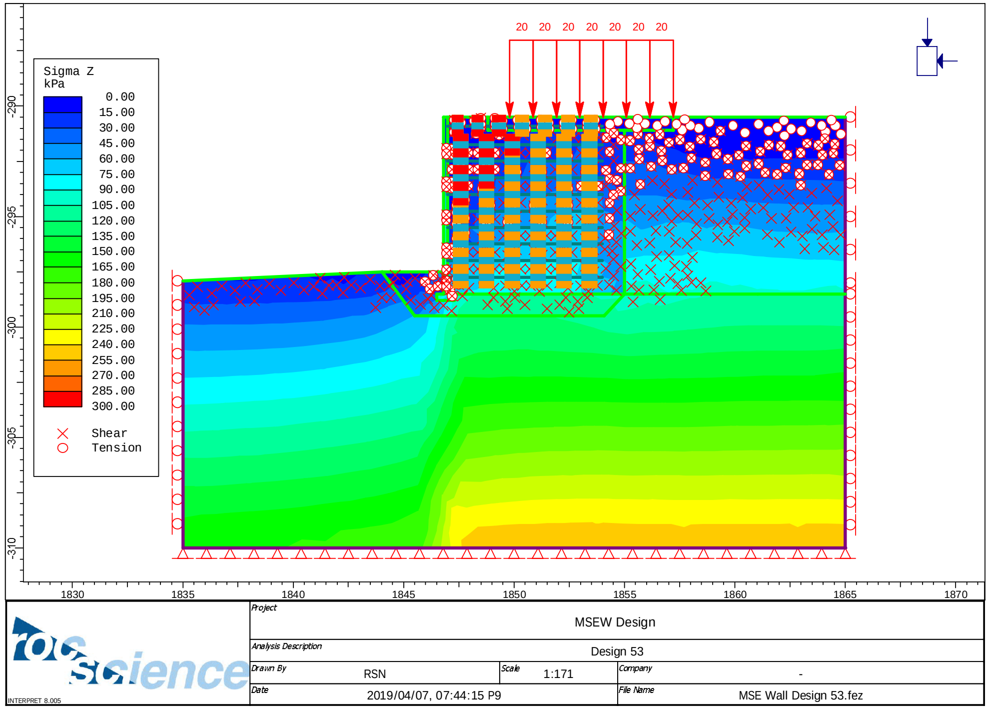

20 20 20 20 20 20 20
Mean Stress
kPa
0.00
15.00
30.00
45.00
60.00
75.00
90.00
105.00
120.00
135.00
150.00
165.00
180.00
195.00
210.00
225.00
240.00
255.00
270.00
285.00
300.00
Shear
Tension
1830 1835 1840 1845 1850 1855 1860 1865 1870
-290 -295 -300 -305 -310
Project
MSEW Design
Analysis Description
Design 52
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 52.fez
INTERPRET 8.005

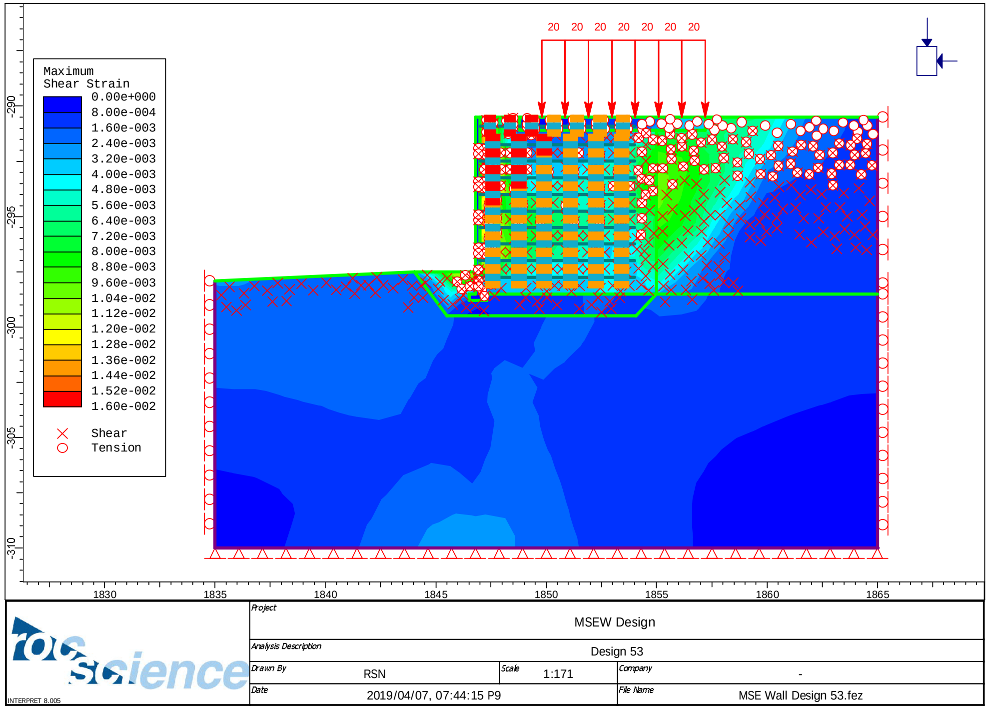

20 20 20 20 20 20 20
Vertical
Displacement
m
-1.02e-001
-9.60e-002
-9.00e-002
-8.40e-002
-7.80e-002
-7.20e-002
-6.60e-002
-6.00e-002
-5.40e-002
-4.80e-002
-4.20e-002
-3.60e-002
-3.00e-002
-2.40e-002
-1.80e-002
-1.20e-002
-6.00e-003
-1.39e-017
6.00e-003
1.20e-002
1.80e-002
Shear
Tension
1830 1835 1840 1845 1850 1855 1860 1865 1870
-290 -295 -300 -305 -310
Project
MSEW Design
Analysis Description
Design 52
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 52.fez
INTERPRET 8.005

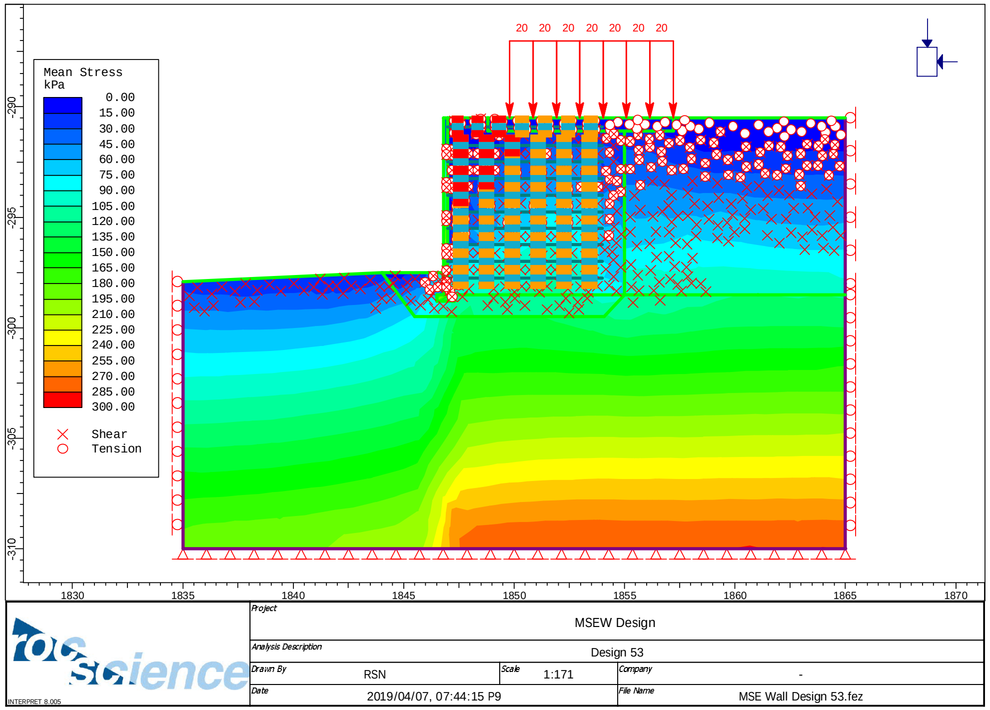

Horizontal Displacement m
-1.10e-001
-1.04e-001
-9.90e-002
-9.35e-002
-8.80e-002
-8.25e-002
-7.70e-002
-7.15e-002
-6.60e-002
-6.05e-002
-5.50e-002
-4.95e-002
-4.40e-002
-3.85e-002
-3.30e-002
-2.75e-002
-2.20e-002
-1.65e-002
-1.10e-002
-5.50e-003
0.00e+000
Shear
Tension
20 20 20 20 20 20 20
1830 1835 1840 1845 1850 1855 1860 1865 1870
-290 -295 -300 -305 -310
Project MSEW Design
Analysis Description Design 52
Drawn By RSN
Scale 1:171
Company -
Date 2019/10/07, 07:44:15 PM
File Name MSE Wall Design 52.fez
INTERPRET 8.005

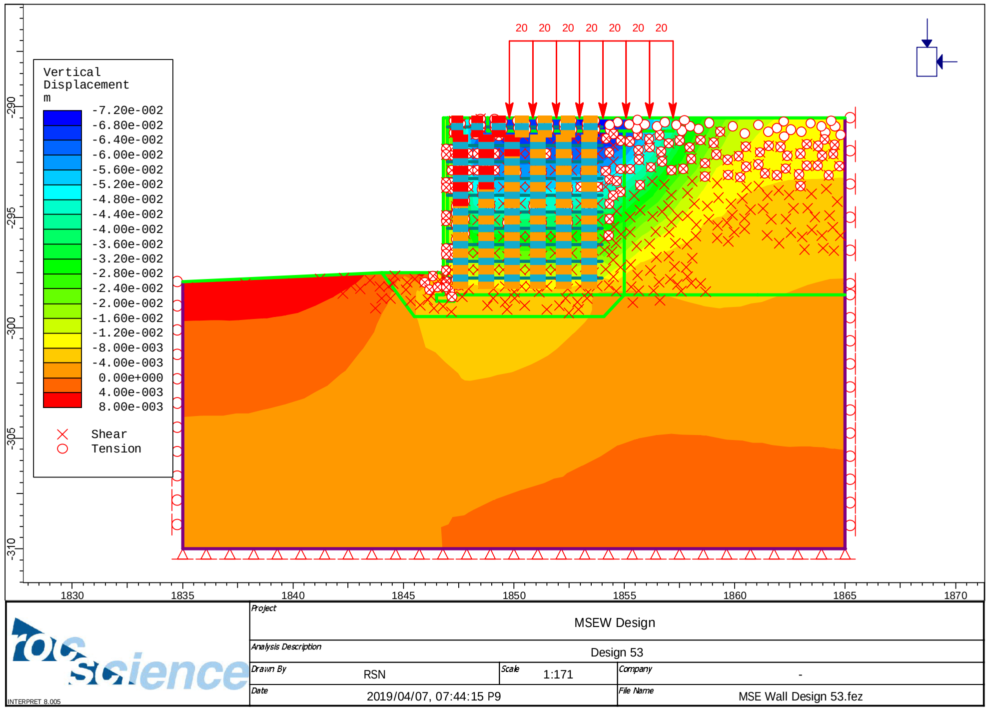

Maximum Shear Strain
0.00e+000
6.50e-003
1.30e-002
1.95e-002
2.60e-002
3.25e-002
3.90e-002
4.55e-002
5.20e-002
5.85e-002
6.50e-002
7.15e-002
7.80e-002
8.45e-002
9.10e-002
9.75e-002
1.04e-001
1.11e-001
1.17e-001
1.24e-001
1.30e-001
Critical SRF: 1.6
20 20 20 20 20 20 20
1830 1835 1840 1845 1850 1855 1860 1865
-290 -295 -300 -305 -310
Project MSEW Design
Analysis Description Design 52
Drawn By RSN
Scale 1:171
Company -
Date 2019/10/07, 07:44:15 PM
File Name MSE Wall Design 52.fez
INTERPRET 8.005

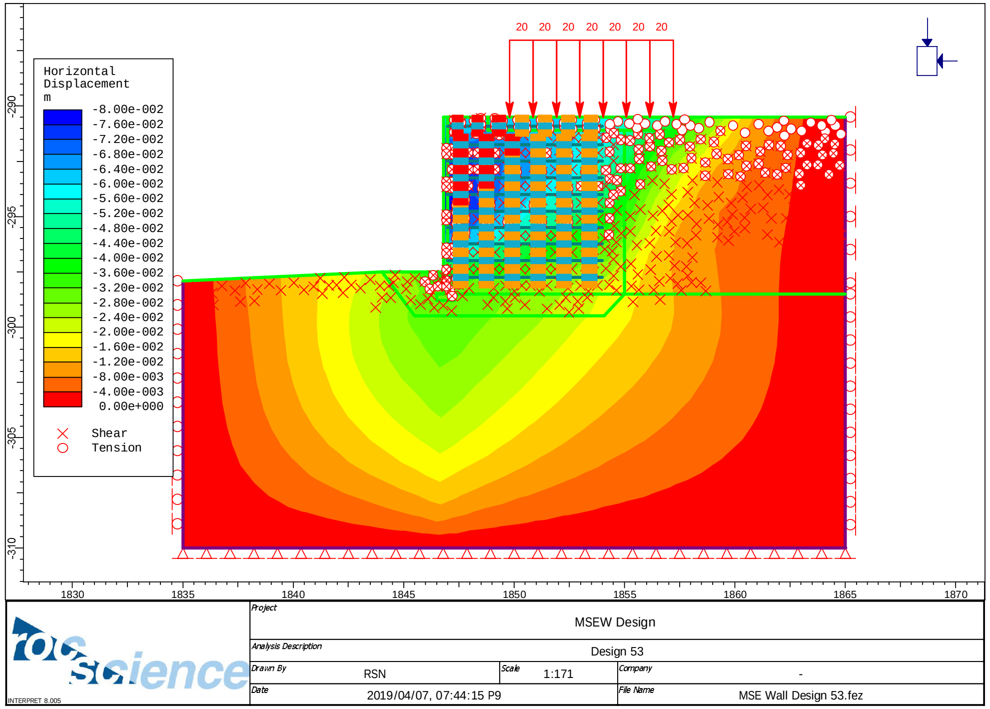

Total Displacement m
0.00e+000
6.50e-003
1.30e-002
1.95e-002
2.60e-002
3.25e-002
3.90e-002
4.55e-002
5.20e-002
5.85e-002
6.50e-002
7.15e-002
7.80e-002
8.45e-002
9.10e-002
9.75e-002
1.04e-001
1.11e-001
1.17e-001
1.24e-001
1.30e-001
Shear
Tension
20 20 20 20 20 20 20
1830 1835 1840 1845 1850 1855 1860 1865 1870
-290 -295 -300 -305 -310
Project MSEW Design
Analysis Description Design 52
Drawn By RSN
Scale 1:171
Company -
Date 2019/10/07, 07:44:15 PM
File Name MSE Wall Design 52.fez
INTERPRET 8.005


Sigma Z
kPa
0.00
15.00
30.00
45.00
60.00
75.00
90.00
105.00
120.00
135.00
150.00
165.00
180.00
195.00
210.00
225.00
240.00
255.00
270.00
285.00
300.00
Shear
Tension
20 20 20 20 20 20 20
-290
-295
-300
-305
-310
1830 1835 1840 1845 1850 1855 1860 1865 1870
Project MSEW Design
Analysis Description Design 53
Drawn By RSN
Scale 1:171
Company -
Date 2019/04/07, 07:44:15 P9
File Name MSE Wall Design 53.fez
INTERPRET 8.005

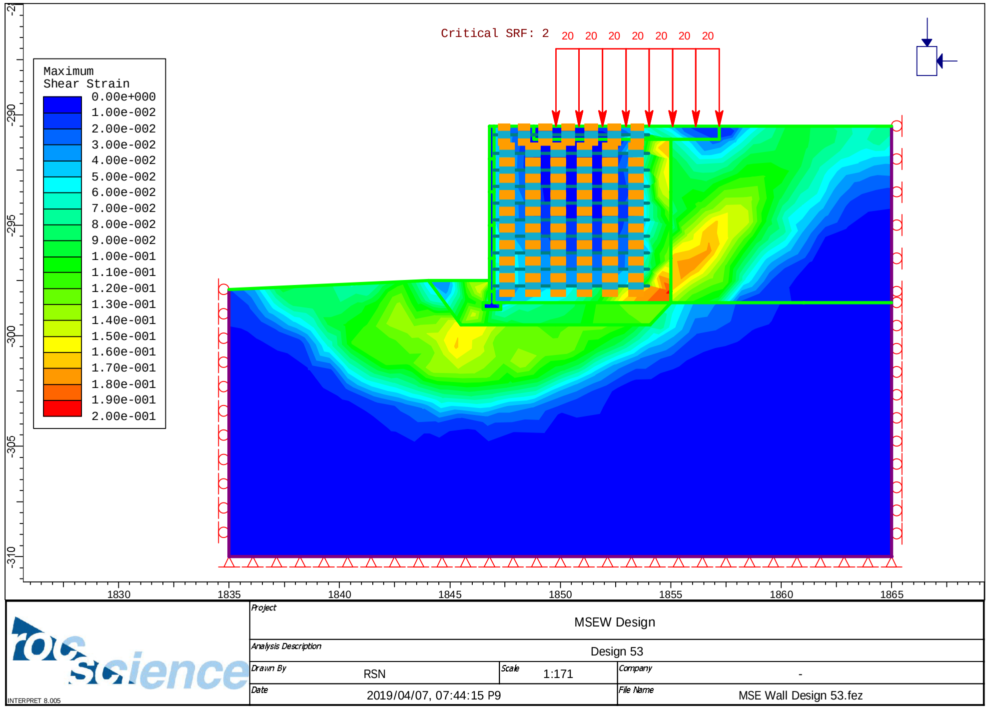

Maximum
Shear Strain
0.00e+000
8.00e-004
1.60e-003
2.40e-003
3.20e-003
4.00e-003
4.80e-003
5.60e-003
6.40e-003
7.20e-003
8.00e-003
8.80e-003
9.60e-003
1.04e-002
1.12e-002
1.20e-002
1.28e-002
1.36e-002
1.44e-002
1.52e-002
1.60e-002
Shear
Tension
20 20 20 20 20 20 20
-290
-295
-300
-305
-310
1830 1835 1840 1845 1850 1855 1860 1865
Project MSEW Design
Analysis Description Design 53
Drawn By RSN
Scale 1:171
Company -
Date 2019/04/07, 07:44:15 P9
File Name MSE Wall Design 53.fez
INTERPRET 8.005


Mean Stress
kPa
0.00
15.00
30.00
45.00
60.00
75.00
90.00
105.00
120.00
135.00
150.00
165.00
180.00
195.00
210.00
225.00
240.00
255.00
270.00
285.00
300.00
Shear
Tension
20 20 20 20 20 20 20
-290
-295
-300
-305
-310
1830 1835 1840 1845 1850 1855 1860 1865 1870
Project MSEW Design
Analysis Description Design 53
Drawn By RSN
Scale 1:171
Company -
Date 2019/04/07, 07:44:15 P9
File Name MSE Wall Design 53.fez
INTERPRET 8.005

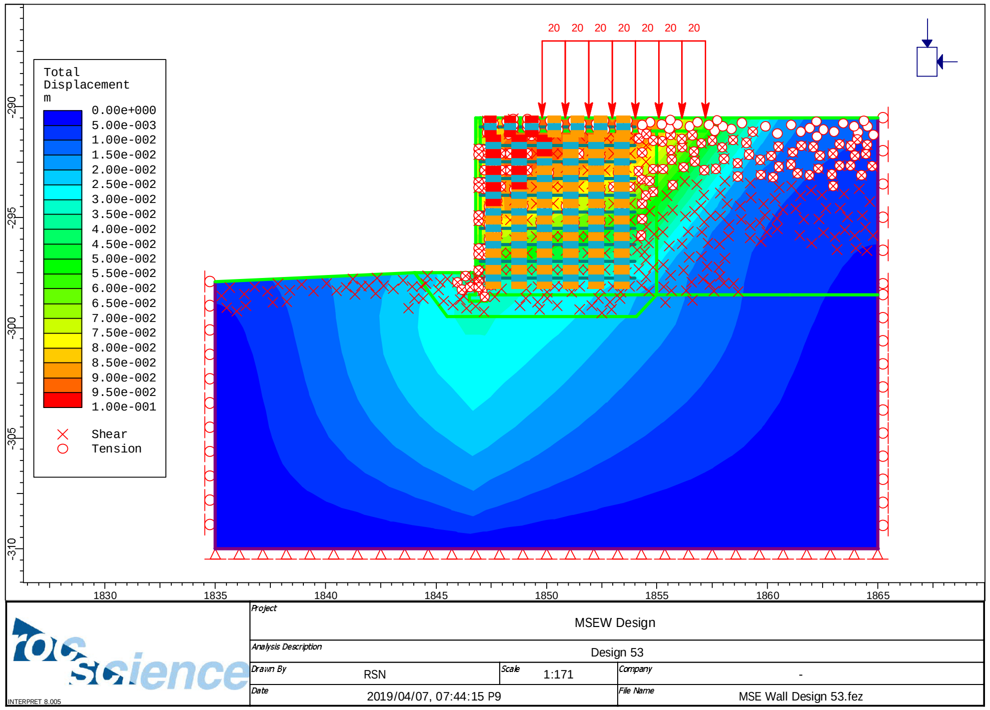

Vertical
Displacement
m
-7.20e-002
-6.80e-002
-6.40e-002
-6.00e-002
-5.60e-002
-5.20e-002
-4.80e-002
-4.40e-002
-4.00e-002
-3.60e-002
-3.20e-002
-2.80e-002
-2.40e-002
-2.00e-002
-1.60e-002
-1.20e-002
-8.00e-003
-4.00e-003
0.00e+000
4.00e-003
8.00e-003
Shear
Tension
20 20 20 20 20 20 20
-290
-295
-300
-305
-310
1830 1835 1840 1845 1850 1855 1860 1865 1870
Project MSEW Design
Analysis Description Design 53
Drawn By RSN
Scale 1:171
Company -
Date 2019/04/07, 07:44:15 P9
File Name MSE Wall Design 53.fez
INTERPRET 8.005



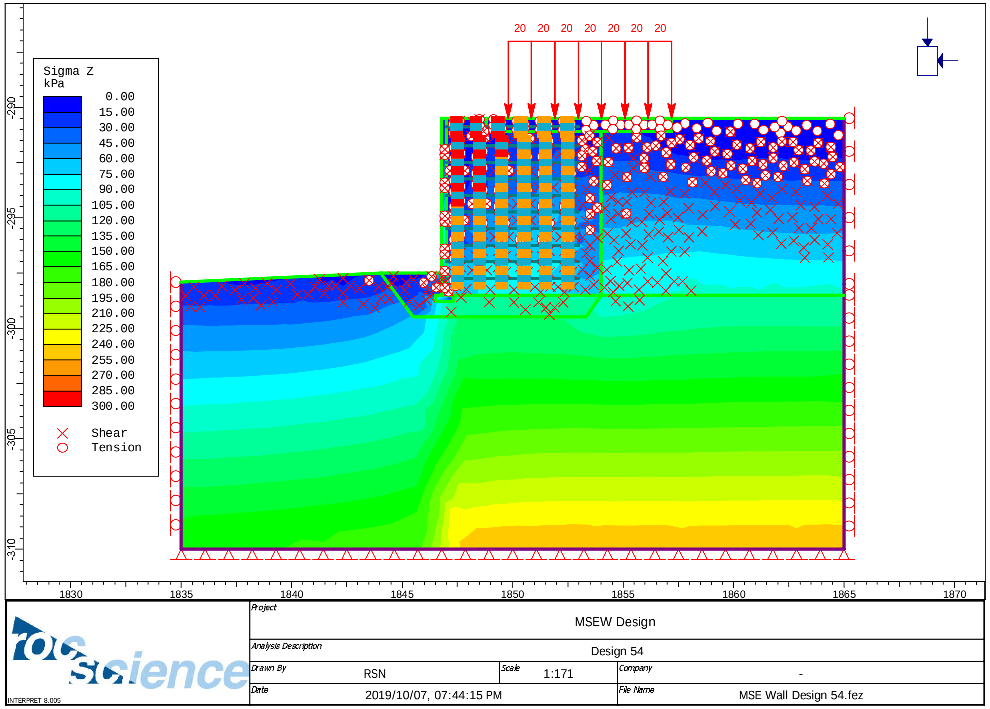
20 20 20 20 20 20 20
Horizontal Displacement m
-8.00e-002
-7.60e-002
-7.20e-002
-6.80e-002
-6.40e-002
-6.00e-002
-5.60e-002
-5.20e-002
-4.80e-002
-4.40e-002
-4.00e-002
-3.60e-002
-3.20e-002
-2.80e-002
-2.40e-002
-2.00e-002
-1.60e-002
-1.20e-002
-8.00e-003
-4.00e-003
0.00e+000
Shear
Tension
1830 1835 1840 1845 1850 1855 1860 1865 1870
-290 -295 -300 -305 -310
Project MSEW Design
Analysis Description Design 53
Drawn By RSN
Scale 1:171
Company -
Date 2019/04/07, 07:44:15 P9
File Name MSE Wall Design 53.fez
INTERPRET 8.005

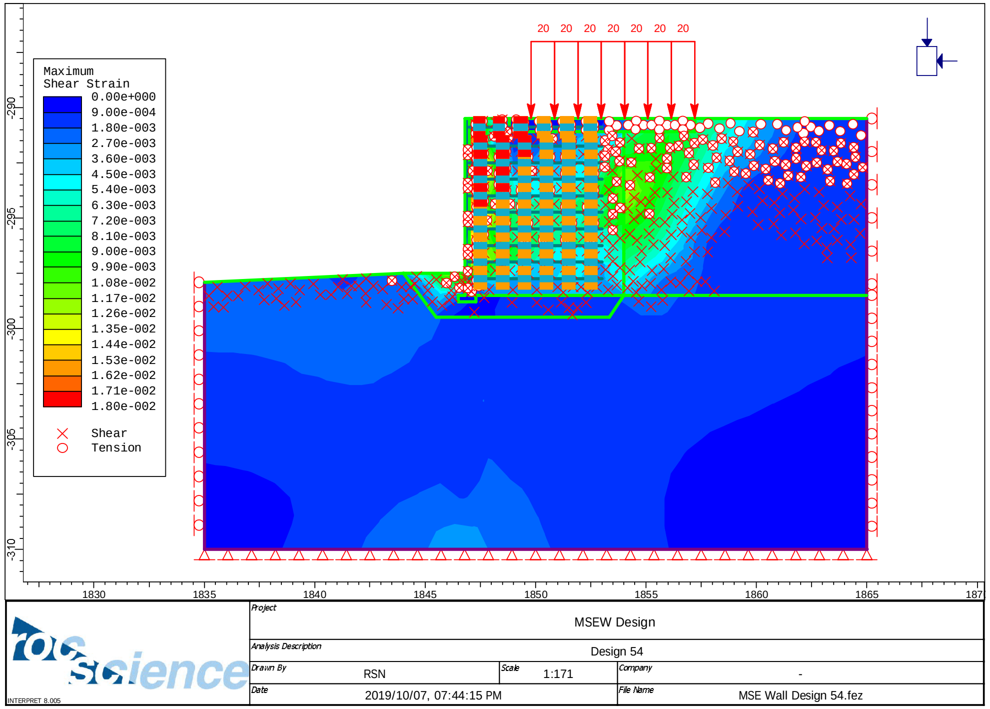


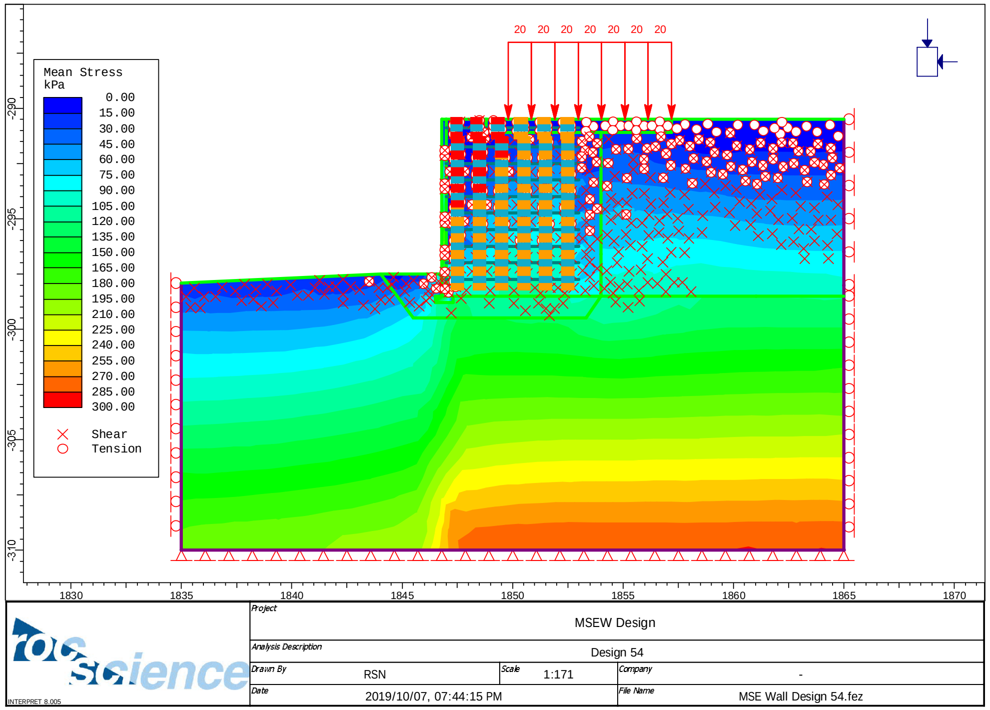
Critical SRF: 2
20 20 20 20 20 20 20
Maximum Shear Strain
0.00e+000
1.00e-002
2.00e-002
3.00e-002
4.00e-002
5.00e-002
6.00e-002
7.00e-002
8.00e-002
9.00e-002
1.00e-001
1.10e-001
1.20e-001
1.30e-001
1.40e-001
1.50e-001
1.60e-001
1.70e-001
1.80e-001
1.90e-001
2.00e-001
1830 1835 1840 1845 1850 1855 1860 1865
-290 -295 -300 -305 -310
Project MSEW Design
Analysis Description Design 53
Drawn By RSN
Scale 1:171
Company -
Date 2019/04/07, 07:44:15 P9
File Name MSE Wall Design 53.fez
INTERPRET 8.005

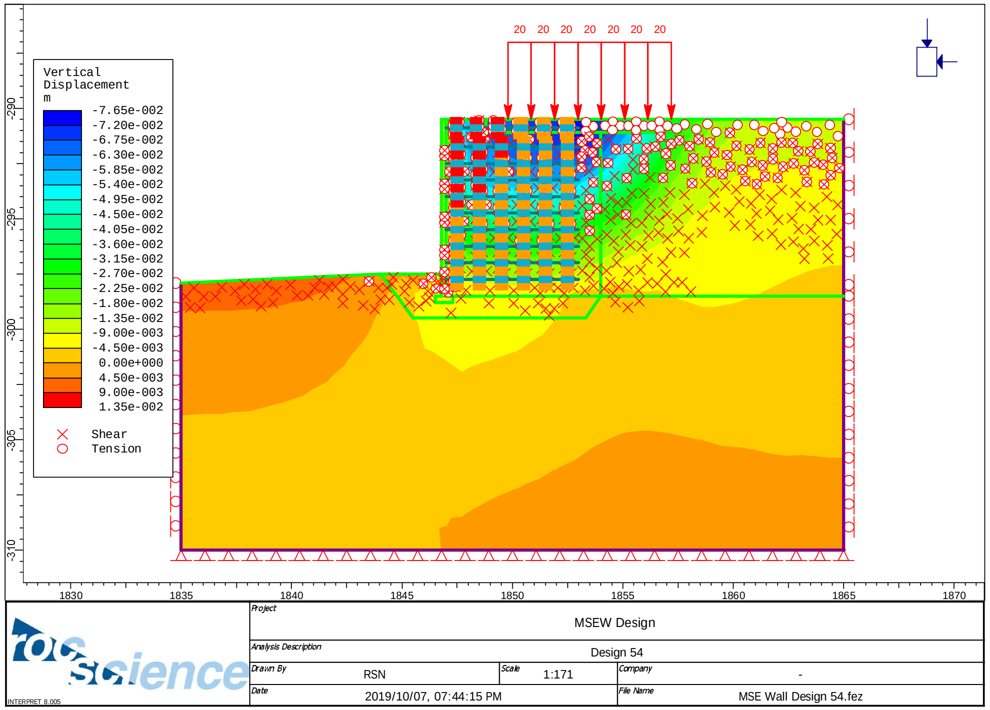


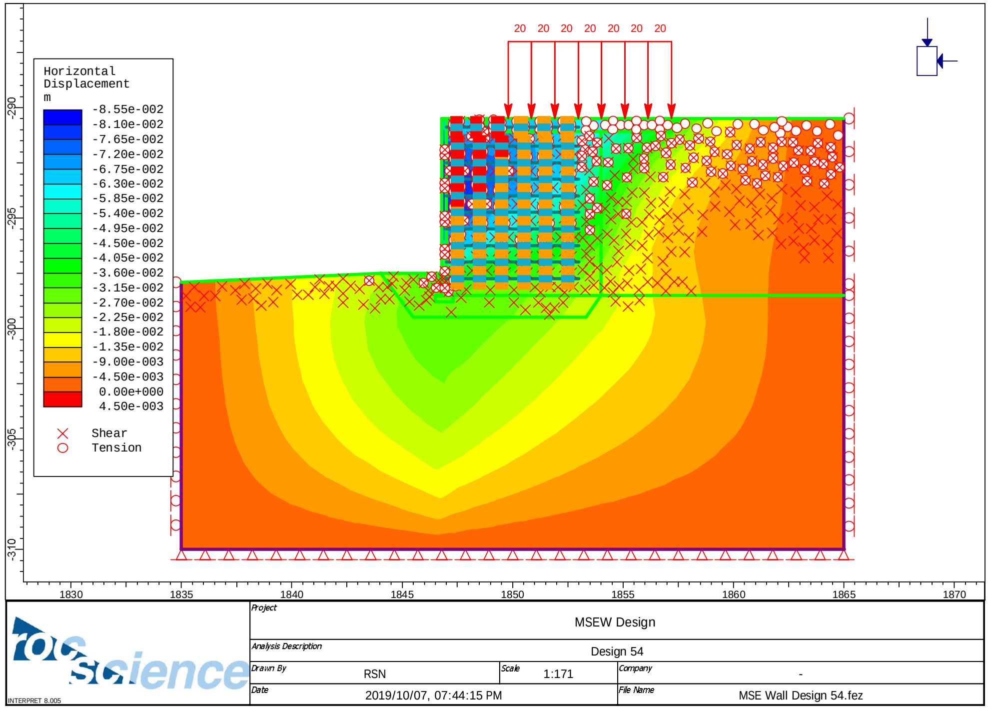
20 20 20 20 20 20 20
Total Displacement m
0.00e+000
5.00e-003
1.00e-002
1.50e-002
2.00e-002
2.50e-002
3.00e-002
3.50e-002
4.00e-002
4.50e-002
5.00e-002
5.50e-002
6.00e-002
6.50e-002
7.00e-002
7.50e-002
8.00e-002
8.50e-002
9.00e-002
9.50e-002
1.00e-001
Shear
Tension
1830 1835 1840 1845 1850 1855 1860 1865
-290 -295 -300 -305 -310
Project MSEW Design
Analysis Description Design 53
Drawn By RSN
Scale 1:171
Company -
Date 2019/04/07, 07:44:15 P9
File Name MSE Wall Design 53.fez
INTERPRET 8.005

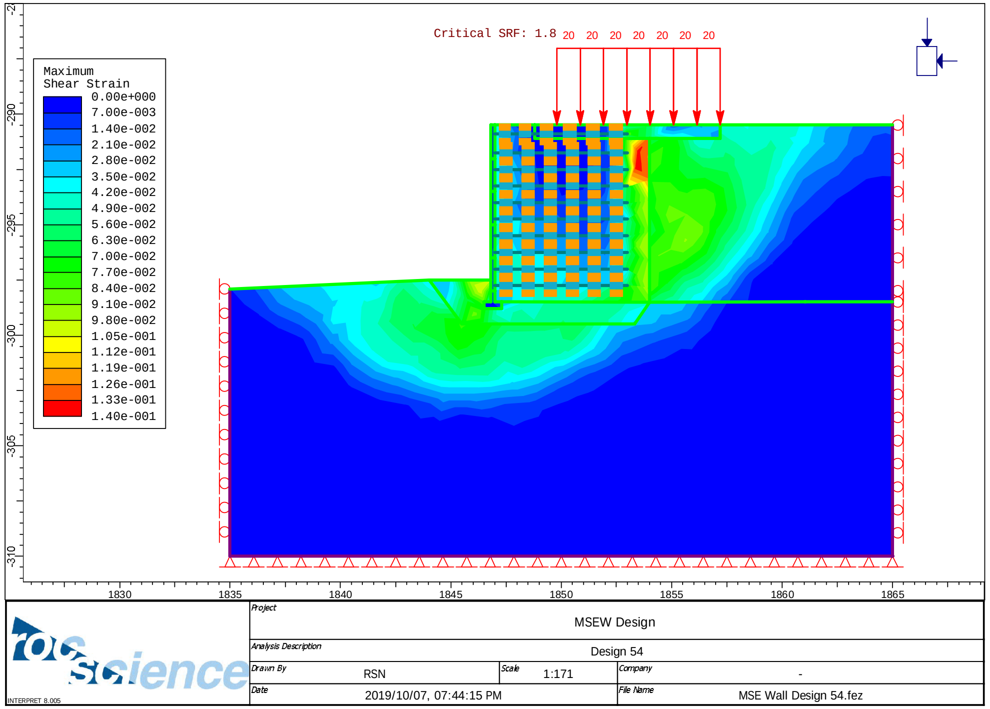

Sigma Z
kPa
0.00
15.00
30.00
45.00
60.00
75.00
90.00
105.00
120.00
135.00
150.00
165.00
180.00
195.00
210.00
225.00
240.00
255.00
270.00
285.00
300.00
Shear
Tension
20 20 20 20 20 20 20
1830 1835 1840 1845 1850 1855 1860 1865 1870
-290 -295 -300 -305 -310
Project
MSEW Design
Analysis Description
Design 54
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 54.fez
INTERPRET 8.005

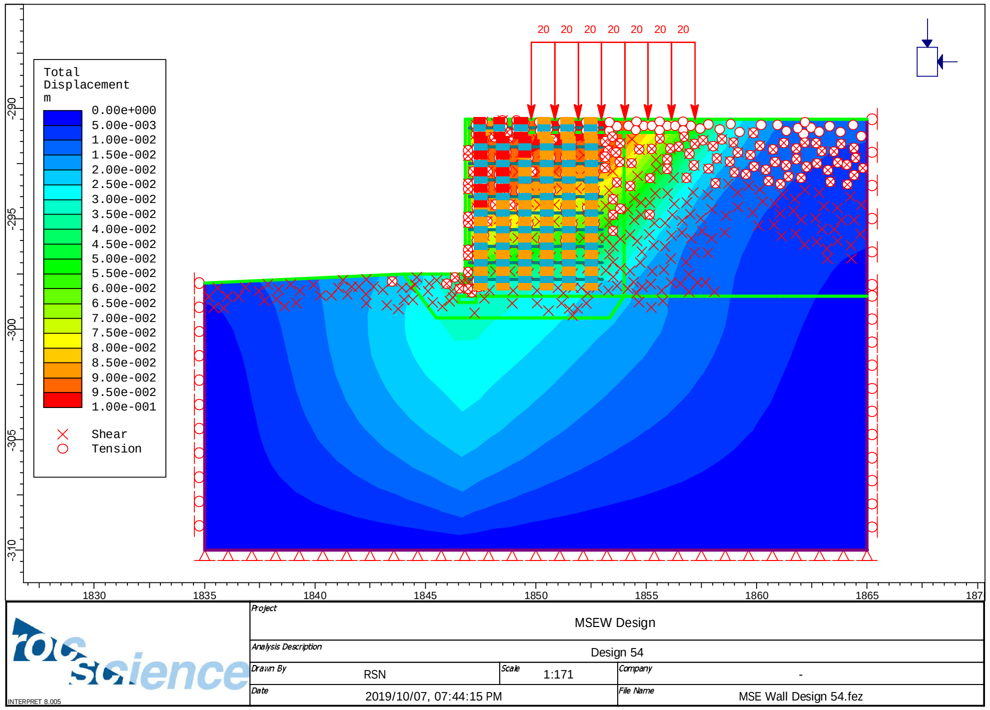

Maximum
Shear Strain
0.00e+000
9.00e-004
1.80e-003
2.70e-003
3.60e-003
4.50e-003
5.40e-003
6.30e-003
7.20e-003
8.10e-003
9.00e-003
9.90e-003
1.08e-002
1.17e-002
1.26e-002
1.35e-002
1.44e-002
1.53e-002
1.62e-002
1.71e-002
1.80e-002
Shear
Tension
20 20 20 20 20 20 20
1830 1835 1840 1845 1850 1855 1860 1865 187
-290 -295 -300 -305 -310
Project
MSEW Design
Analysis Description
Design 54
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 54.fez
INTERPRET 8.005

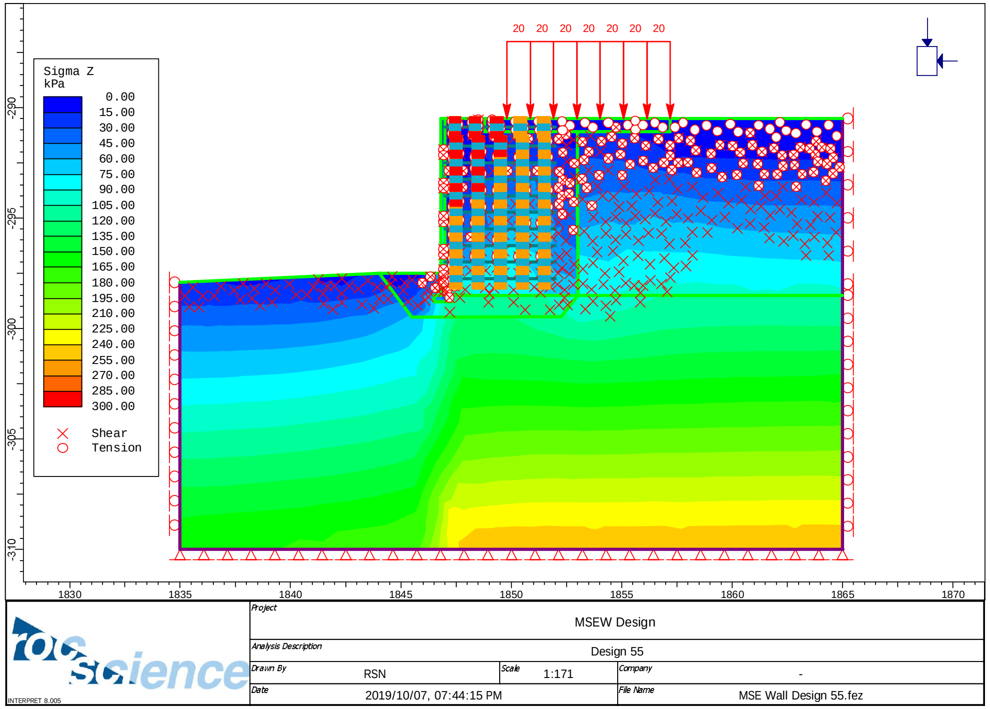

Mean Stress
kPa
0.00
15.00
30.00
45.00
60.00
75.00
90.00
105.00
120.00
135.00
150.00
165.00
180.00
195.00
210.00
225.00
240.00
255.00
270.00
285.00
300.00
Shear
Tension
20 20 20 20 20 20 20
1830 1835 1840 1845 1850 1855 1860 1865 1870
-290 -295 -300 -305 -310
Project
MSEW Design
Analysis Description
Design 54
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 54.fez
INTERPRET 8.005

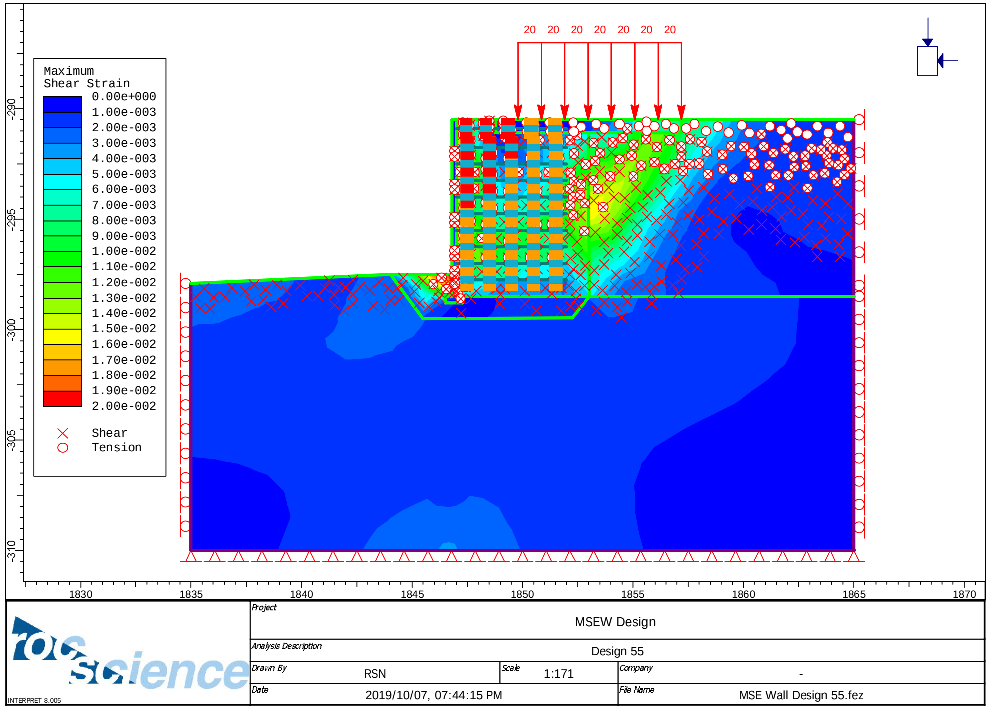

Vertical
Displacement
m
-7.65e-002
-7.20e-002
-6.75e-002
-6.30e-002
-5.85e-002
-5.40e-002
-4.95e-002
-4.50e-002
-4.05e-002
-3.60e-002
-3.15e-002
-2.70e-002
-2.25e-002
-1.80e-002
-1.35e-002
-9.00e-003
-4.50e-003
0.00e+000
4.50e-003
9.00e-003
1.35e-002
Shear
Tension
20 20 20 20 20 20 20
1830 1835 1840 1845 1850 1855 1860 1865 1870
-290 -295 -300 -305 -310
Project
MSEW Design
Analysis Description
Design 54
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 54.fez
INTERPRET 8.005

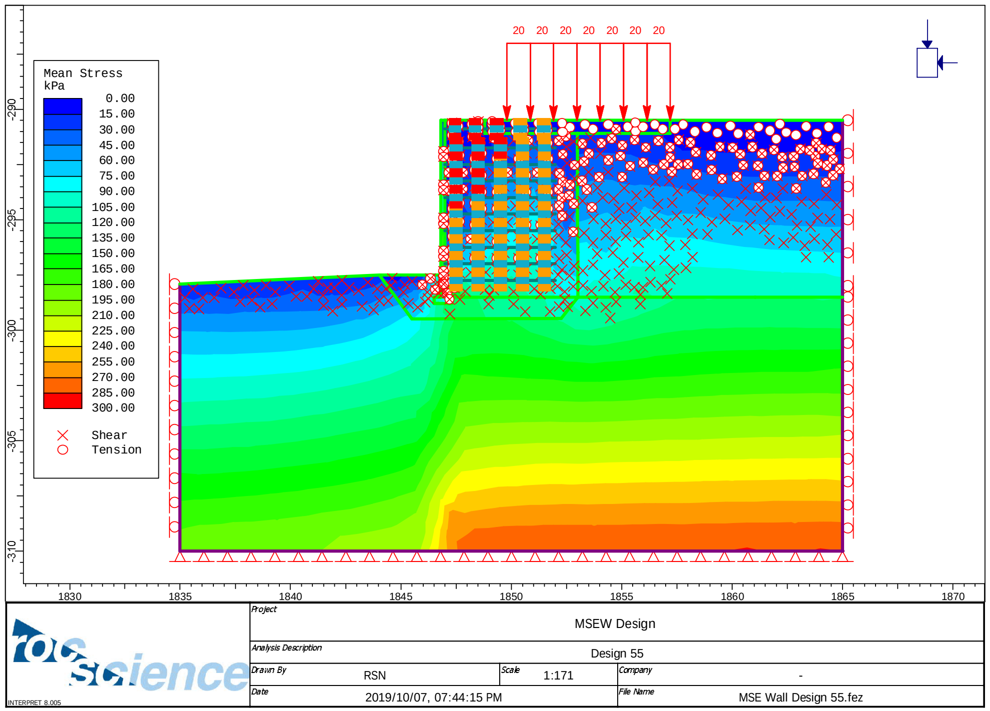

Horizontal Displacement m
-8.55e-002
-8.10e-002
-7.65e-002
-7.20e-002
-6.75e-002
-6.30e-002
-5.85e-002
-5.40e-002
-4.95e-002
-4.50e-002
-4.05e-002
-3.60e-002
-3.15e-002
-2.70e-002
-2.25e-002
-1.80e-002
-1.35e-002
-9.00e-003
-4.50e-003
0.00e+000
4.50e-003
Shear
Tension
20 20 20 20 20 20 20
1830 1835 1840 1845 1850 1855 1860 1865 1870
-290 -295 -300 -305 -310
Project MSEW Design
Analysis Description Design 54
Drawn By RSN
Scale 1:171
Company -
Date 2019/10/07, 07:44:15 PM
File Name MSE Wall Design 54.fez
INTERPRET 8.005

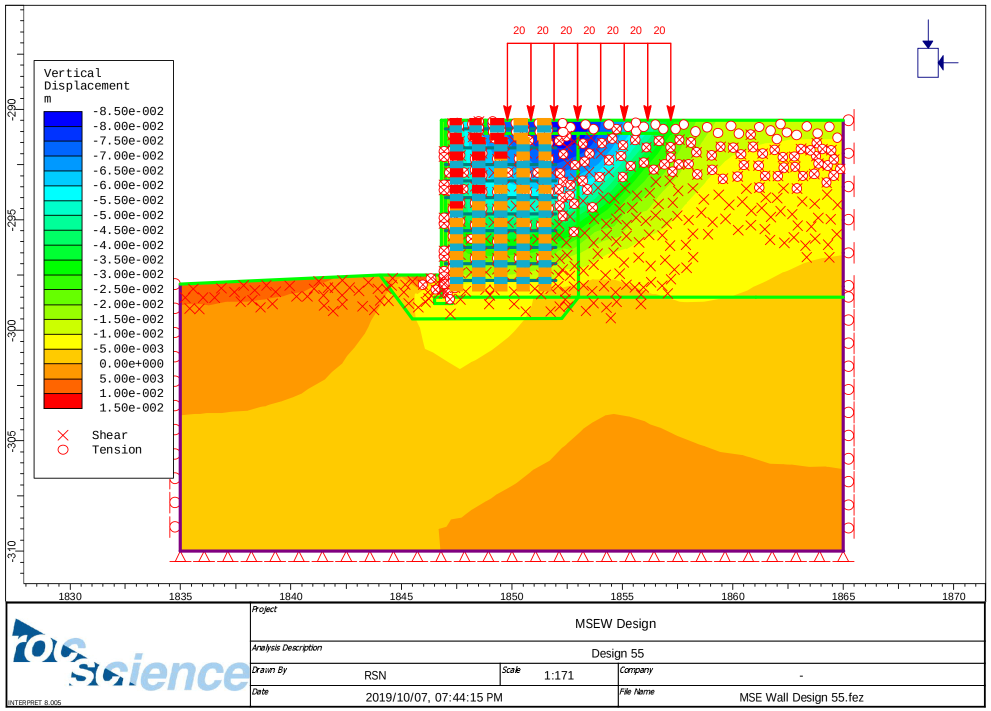

Critical SRF: 1.8
Maximum Shear Strain
0.00e+000
7.00e-003
1.40e-002
2.10e-002
2.80e-002
3.50e-002
4.20e-002
4.90e-002
5.60e-002
6.30e-002
7.00e-002
7.70e-002
8.40e-002
9.10e-002
9.80e-002
1.05e-001
1.12e-001
1.19e-001
1.26e-001
1.33e-001
1.40e-001
20 20 20 20 20 20 20
1830 1835 1840 1845 1850 1855 1860 1865
-290 -295 -300 -305 -310
Project MSEW Design
Analysis Description Design 54
Drawn By RSN
Scale 1:171
Company -
Date 2019/10/07, 07:44:15 PM
File Name MSE Wall Design 54.fez
INTERPRET 8.005

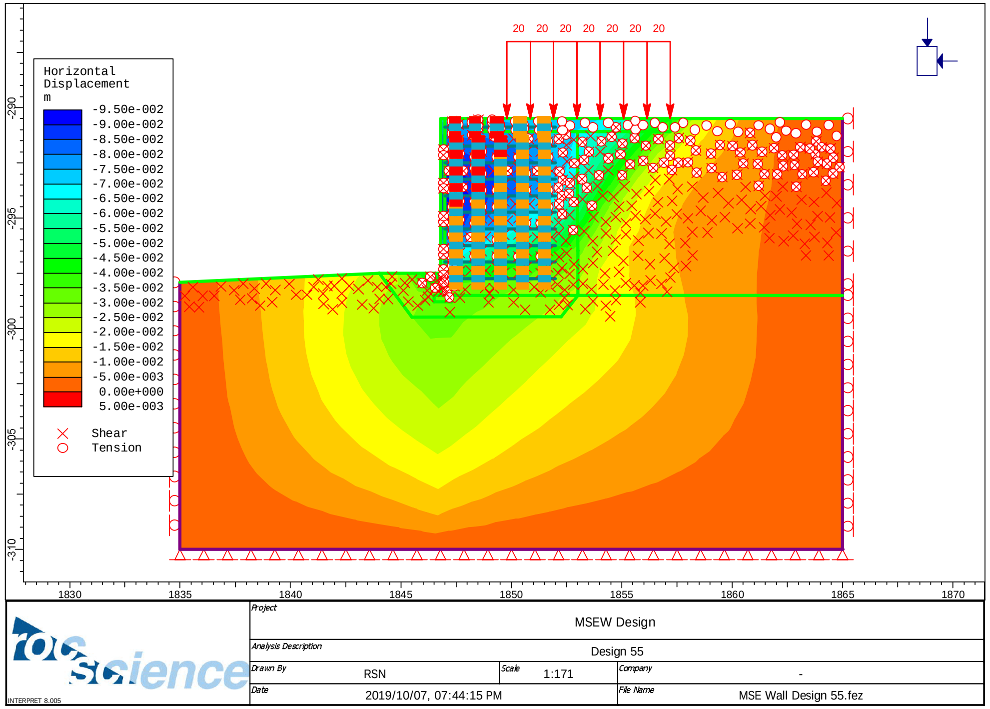

Total Displacement m
0.00e+000
5.00e-003
1.00e-002
1.50e-002
2.00e-002
2.50e-002
3.00e-002
3.50e-002
4.00e-002
4.50e-002
5.00e-002
5.50e-002
6.00e-002
6.50e-002
7.00e-002
7.50e-002
8.00e-002
8.50e-002
9.00e-002
9.50e-002
1.00e-001
Shear
Tension
20 20 20 20 20 20 20
1830 1835 1840 1845 1850 1855 1860 1865
-290 -295 -300 -305 -310
Project MSEW Design
Analysis Description Design 54
Drawn By RSN
Scale 1:171
Company -
Date 2019/10/07, 07:44:15 PM
File Name MSE Wall Design 54.fez
INTERPRET 8.005


Sigma Z
kPa
Shear
Tension
Project
MSEW Design
Analysis Description
Design 55
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 55.fez

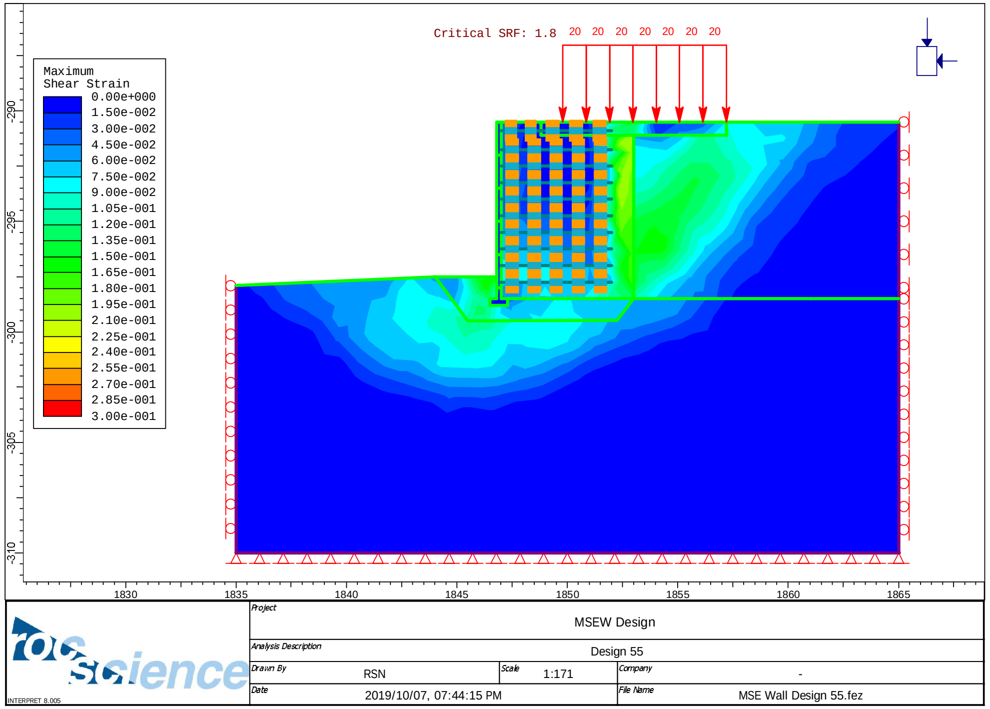

Maximum
Shear Strain
Shear
Tension
Project
MSEW Design
Analysis Description
Design 55
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 55.fez


Mean Stress
kPa
Shear
Tension
Project
MSEW Design
Analysis Description
Design 55
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 55.fez

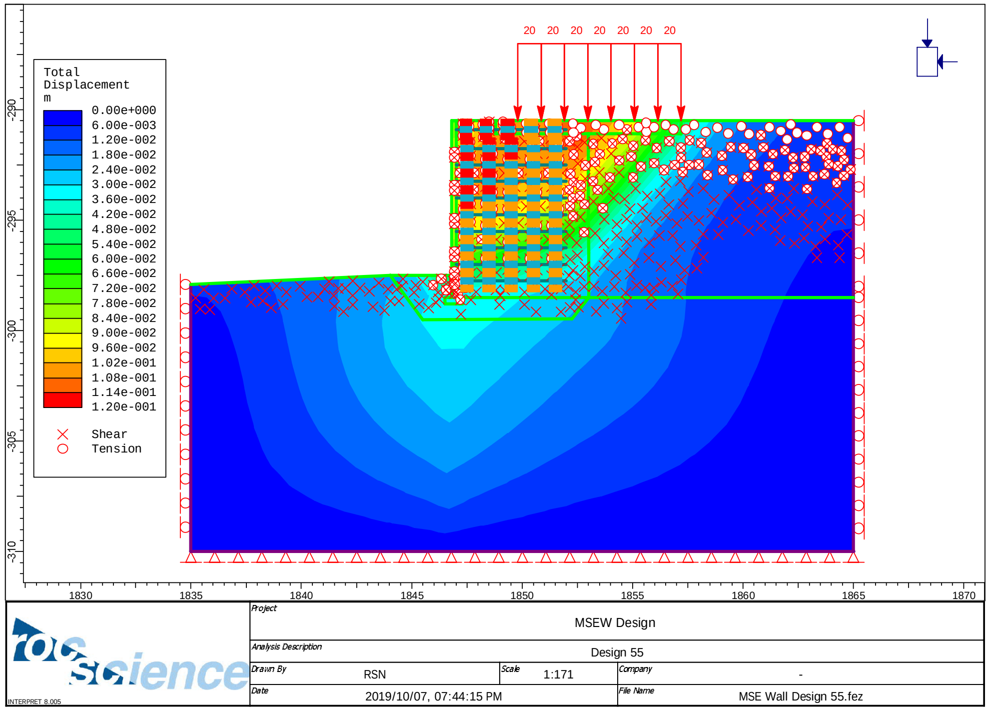

Vertical
Displacement
m
Shear
Tension
Project
MSEW Design
Analysis Description
Design 55
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 55.fez



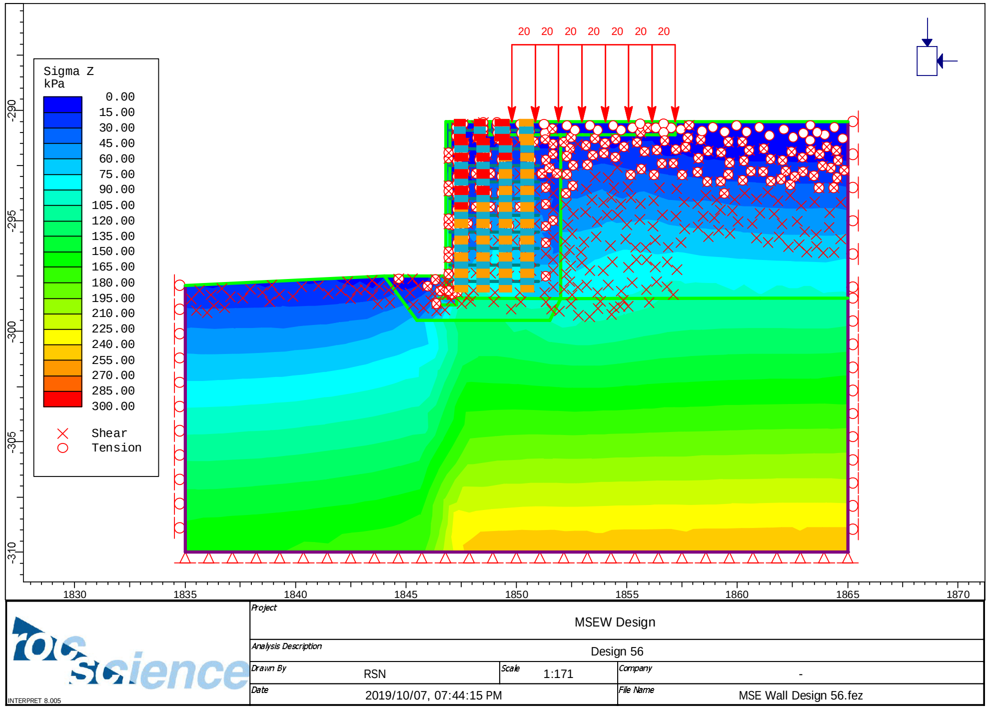
20 20 20 20 20 20 20
Horizontal Displacement m
-9.50e-002
-9.00e-002
-8.50e-002
-8.00e-002
-7.50e-002
-7.00e-002
-6.50e-002
-6.00e-002
-5.50e-002
-5.00e-002
-4.50e-002
-4.00e-002
-3.50e-002
-3.00e-002
-2.50e-002
-2.00e-002
-1.50e-002
-1.00e-002
-5.00e-003
0.00e+000
5.00e-003
Shear
Tension
-290
-295
-300
-305
-310
1830
1835
1840
1845
1850
1855
1860
1865
1870
Project
MSEW Design
Analysis Description
Design 55
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 55.fez
INTERPRET 8.005

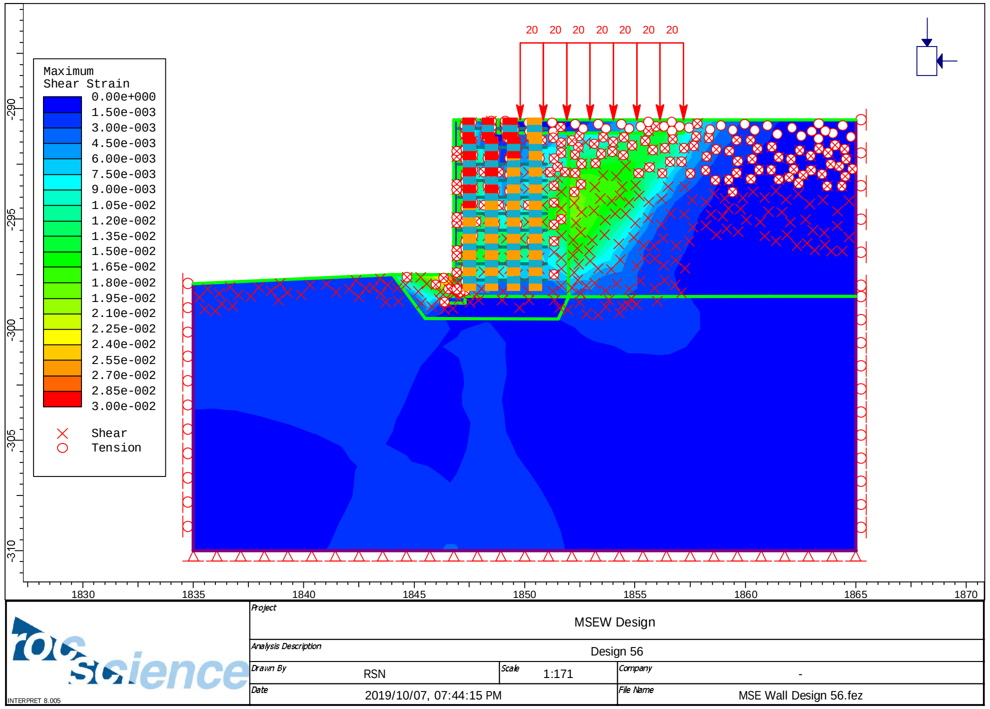


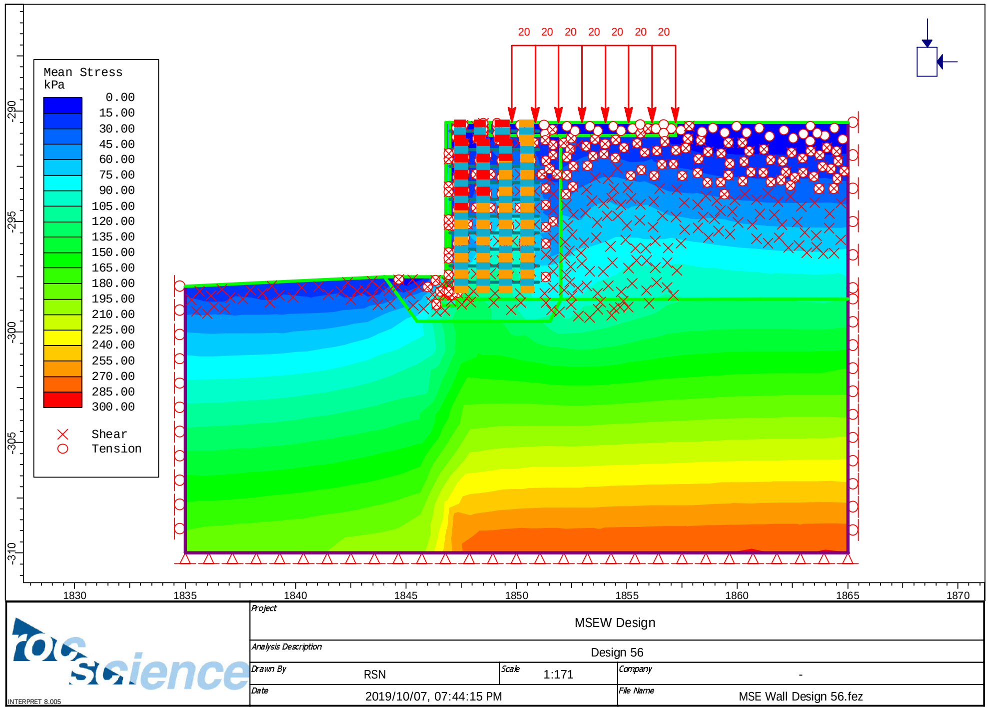
Critical SRF: 1.8
20 20 20 20 20 20 20
Maximum Shear Strain
0.00e+000
1.50e-002
3.00e-002
4.50e-002
6.00e-002
7.50e-002
9.00e-002
1.05e-001
1.20e-001
1.35e-001
1.50e-001
1.65e-001
1.80e-001
1.95e-001
2.10e-001
2.25e-001
2.40e-001
2.55e-001
2.70e-001
2.85e-001
3.00e-001
-290
-295
-300
-305
-310
1830
1835
1840
1845
1850
1855
1860
1865
Project
MSEW Design
Analysis Description
Design 55
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 55.fez
INTERPRET 8.005

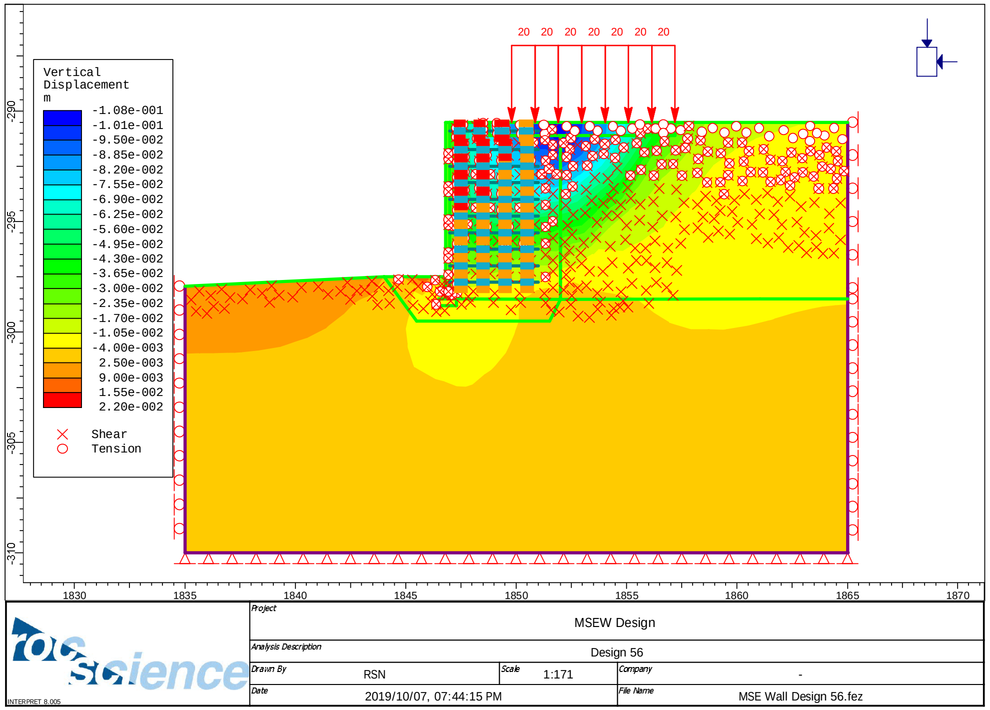


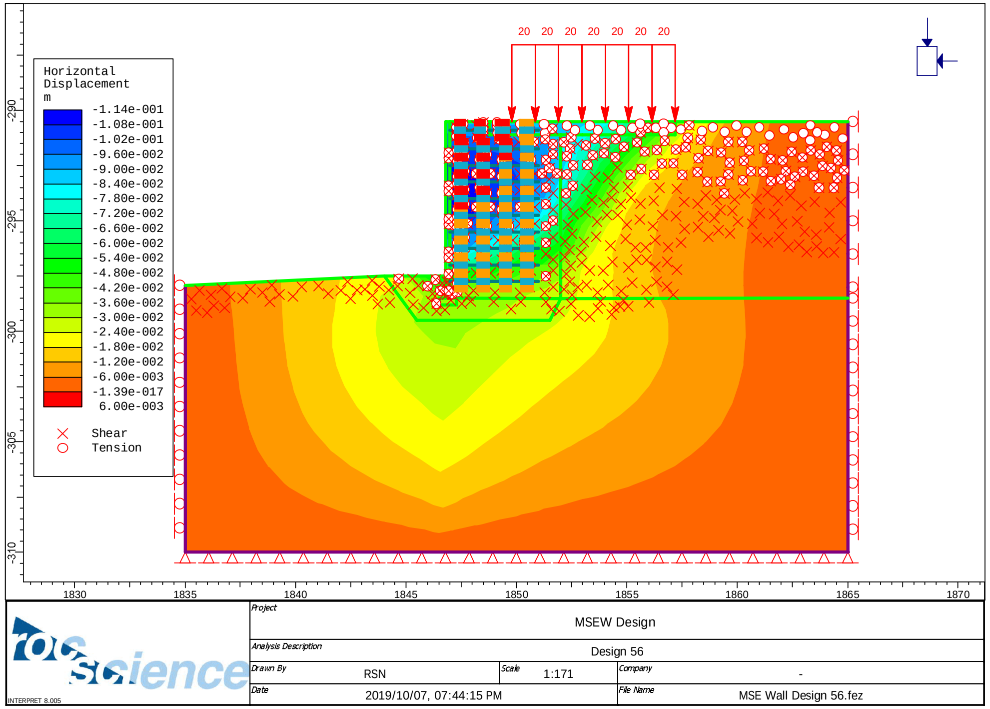
20 20 20 20 20 20 20
Total Displacement m
0.00e+000
6.00e-003
1.20e-002
1.80e-002
2.40e-002
3.00e-002
3.60e-002
4.20e-002
4.80e-002
5.40e-002
6.00e-002
6.60e-002
7.20e-002
7.80e-002
8.40e-002
9.00e-002
9.60e-002
1.02e-001
1.08e-001
1.14e-001
1.20e-001
Shear
Tension
-290
-295
-300
-305
-310
1830
1835
1840
1845
1850
1855
1860
1865
1870
Project
MSEW Design
Analysis Description
Design 55
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 55.fez
INTERPRET 8.005

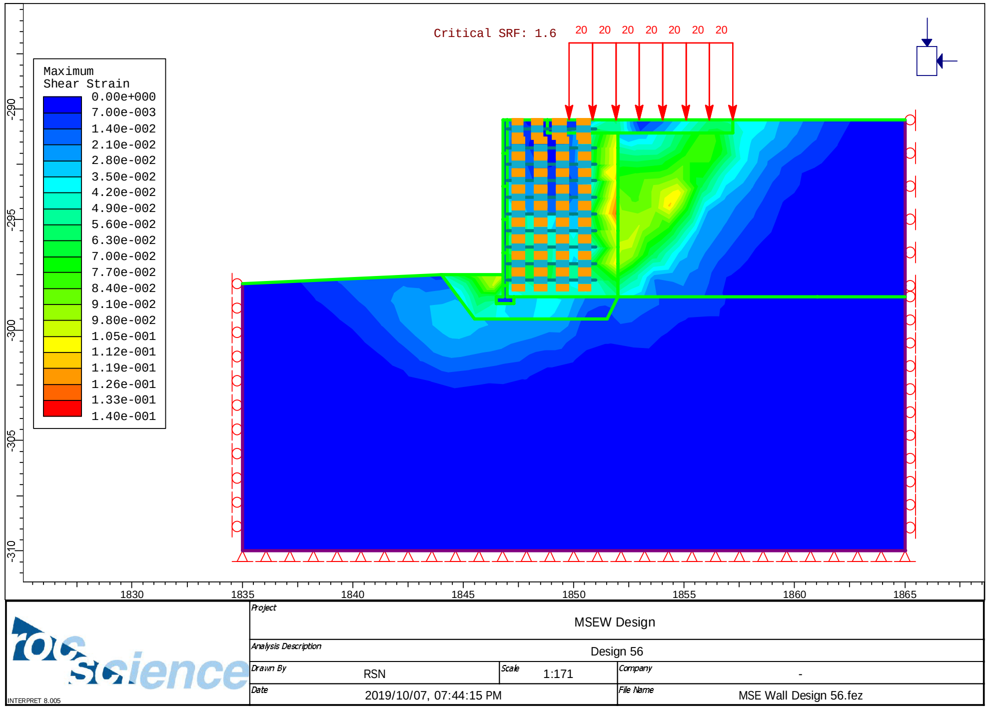

20 20 20 20 20 20 20
Sigma Z
kPa
0.00
15.00
30.00
45.00
60.00
75.00
90.00
105.00
120.00
135.00
150.00
165.00
180.00
195.00
210.00
225.00
240.00
255.00
270.00
285.00
300.00
Shear
Tension
-290
-295
-300
-305
-310
1830 1835 1840 1845 1850 1855 1860 1865 1870
Project
MSEW Design
Analysis Description
Design 56
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 56.fez
INTERPRET 8.005

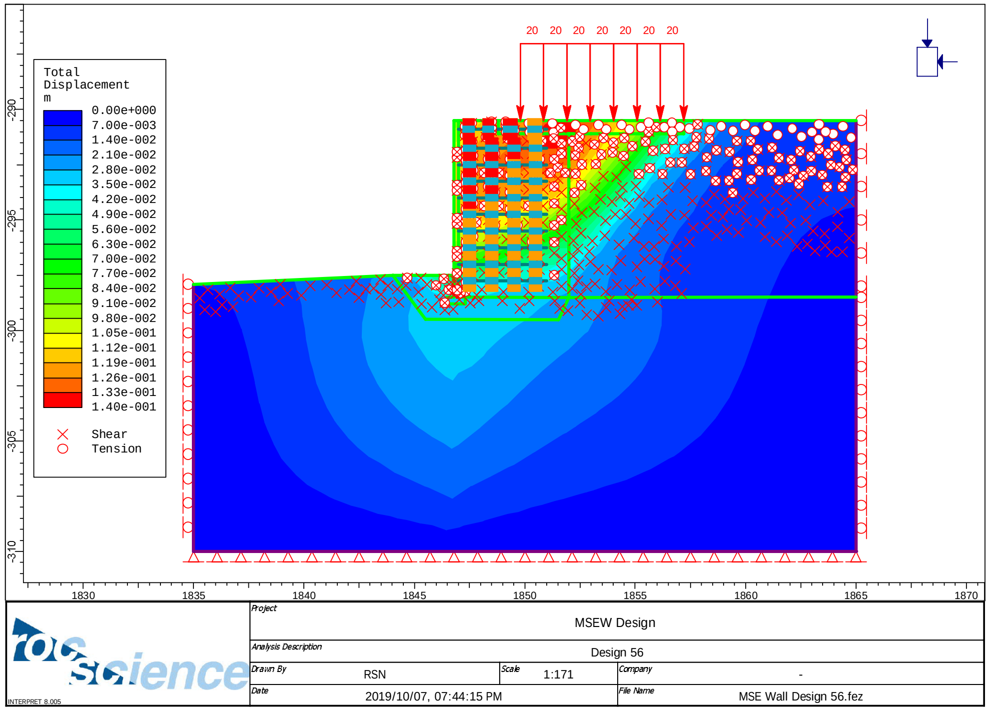

20 20 20 20 20 20 20
Maximum
Shear Strain
0.00e+000
1.50e-003
3.00e-003
4.50e-003
6.00e-003
7.50e-003
9.00e-003
1.05e-002
1.20e-002
1.35e-002
1.50e-002
1.65e-002
1.80e-002
1.95e-002
2.10e-002
2.25e-002
2.40e-002
2.55e-002
2.70e-002
2.85e-002
3.00e-002
Shear
Tension
-290
-295
-300
-305
-310
1830 1835 1840 1845 1850 1855 1860 1865 1870
Project
MSEW Design
Analysis Description
Design 56
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 56.fez
INTERPRET 8.005

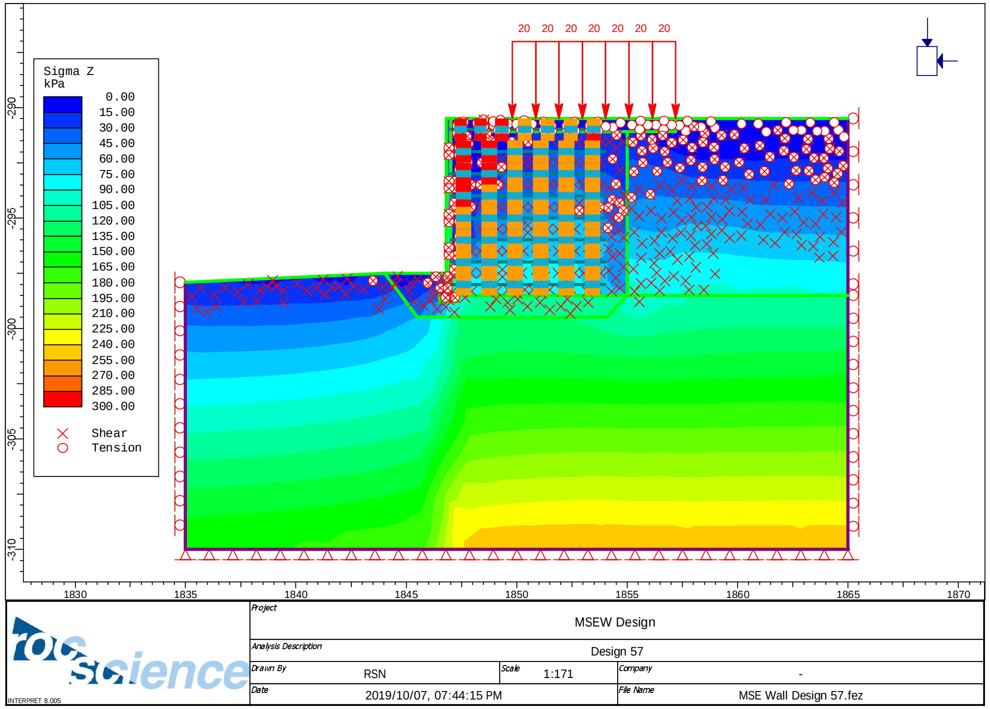

20 20 20 20 20 20 20
Mean Stress
kPa
0.00
15.00
30.00
45.00
60.00
75.00
90.00
105.00
120.00
135.00
150.00
165.00
180.00
195.00
210.00
225.00
240.00
255.00
270.00
285.00
300.00
Shear
Tension
-290
-295
-300
-305
-310
1830 1835 1840 1845 1850 1855 1860 1865 1870
Project
MSEW Design
Analysis Description
Design 56
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 56.fez
INTERPRET 8.005


20 20 20 20 20 20 20
Vertical
Displacement
m
-1.08e-001
-1.01e-001
-9.50e-002
-8.85e-002
-8.20e-002
-7.55e-002
-6.90e-002
-6.25e-002
-5.60e-002
-4.95e-002
-4.30e-002
-3.65e-002
-3.00e-002
-2.35e-002
-1.70e-002
-1.05e-002
-4.00e-003
2.50e-003
9.00e-003
1.55e-002
2.20e-002
Shear
Tension
-290
-295
-300
-305
-310
1830 1835 1840 1845 1850 1855 1860 1865 1870
Project
MSEW Design
Analysis Description
Design 56
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 56.fez
INTERPRET 8.005


Horizontal Displacement
m
-1.14e-001
-1.08e-001
-1.02e-001
-9.60e-002
-9.00e-002
-8.40e-002
-7.80e-002
-7.20e-002
-6.60e-002
-6.00e-002
-5.40e-002
-4.80e-002
-4.20e-002
-3.60e-002
-3.00e-002
-2.40e-002
-1.80e-002
-1.20e-002
-6.00e-003
-1.39e-017
6.00e-003
Shear
Tension
20 20 20 20 20 20 20
1830 1835 1840 1845 1850 1855 1860 1865 1870
-290 -295 -300 -305 -310
Project
MSEW Design
Analysis Description
Design 56
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 56.fez
INTERPRET 8.005


Maximum Shear Strain
0.00e+000
7.00e-003
1.40e-002
2.10e-002
2.80e-002
3.50e-002
4.20e-002
4.90e-002
5.60e-002
6.30e-002
7.00e-002
7.70e-002
8.40e-002
9.10e-002
9.80e-002
1.05e-001
1.12e-001
1.19e-001
1.26e-001
1.33e-001
1.40e-001
Critical SRF: 1.6
20 20 20 20 20 20 20
1830 1835 1840 1845 1850 1855 1860 1865
-290 -295 -300 -305 -310
Project
MSEW Design
Analysis Description
Design 56
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 56.fez
INTERPRET 8.005


Total Displacement
m
0.00e+000
7.00e-003
1.40e-002
2.10e-002
2.80e-002
3.50e-002
4.20e-002
4.90e-002
5.60e-002
6.30e-002
7.00e-002
7.70e-002
8.40e-002
9.10e-002
9.80e-002
1.05e-001
1.12e-001
1.19e-001
1.26e-001
1.33e-001
1.40e-001
Shear
Tension
20 20 20 20 20 20 20
1830 1835 1840 1845 1850 1855 1860 1865 1870
-290 -295 -300 -305 -310
Project
MSEW Design
Analysis Description
Design 56
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 56.fez
INTERPRET 8.005



Sigma Z
kPa
0.00
15.00
30.00
45.00
60.00
75.00
90.00
105.00
120.00
135.00
150.00
165.00
180.00
195.00
210.00
225.00
240.00
255.00
270.00
285.00
300.00
Shear
Tension
20 20 20 20 20 20 20
-290
-295
-300
-305
-310
1830 1835 1840 1845 1850 1855 1860 1865 1870
Project
MSEW Design
Analysis Description
Design 57
Drawn By
RSN
Scale
1:171
Company
-
Date
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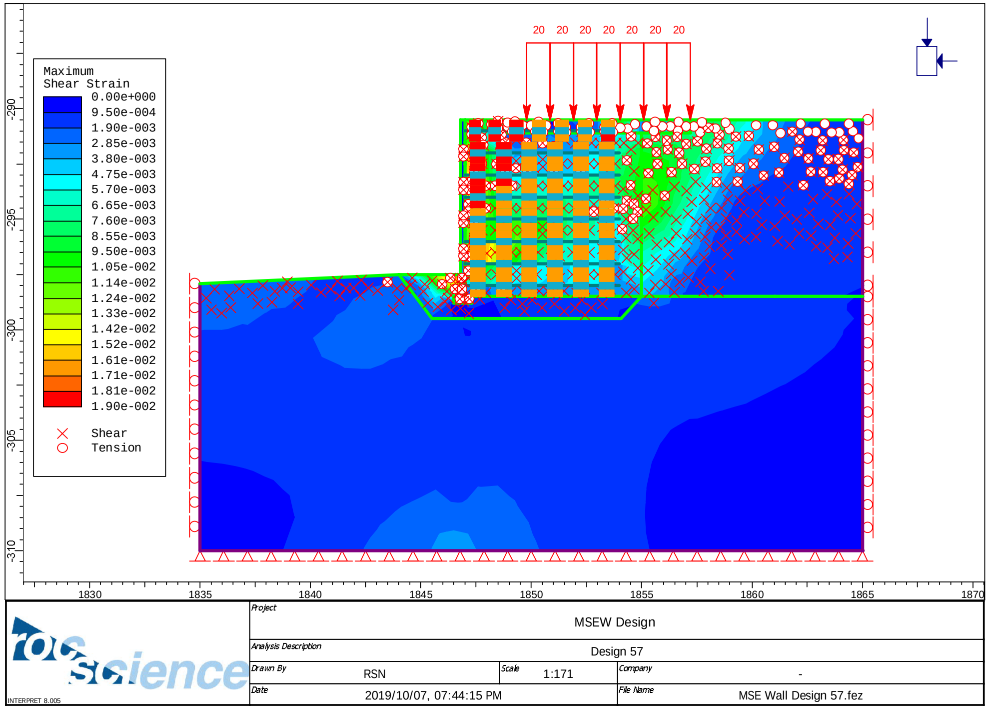
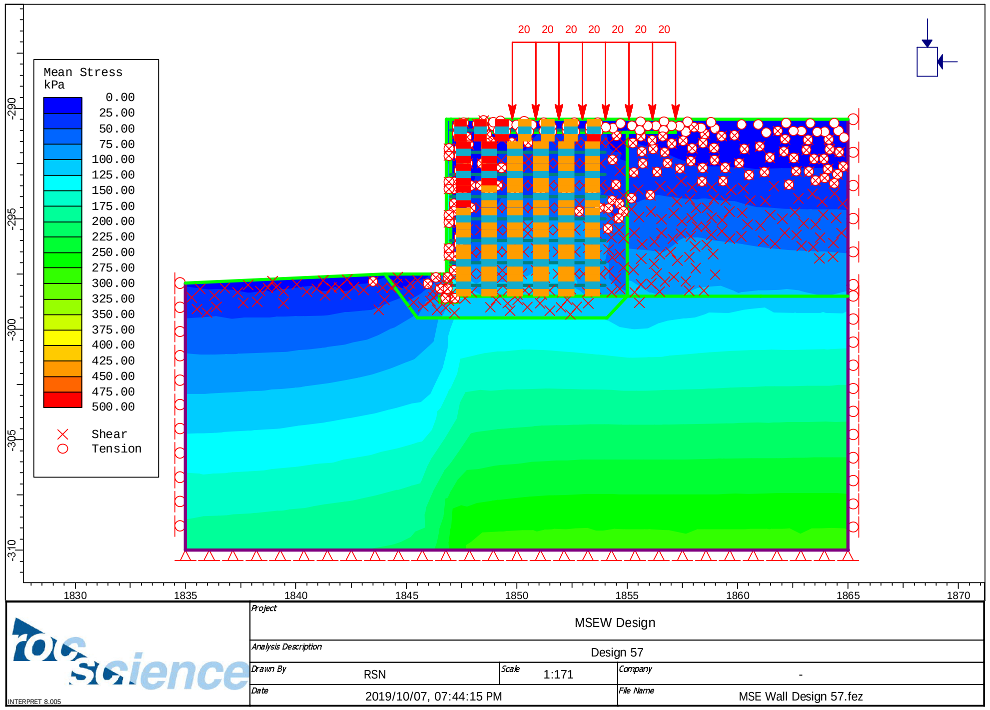
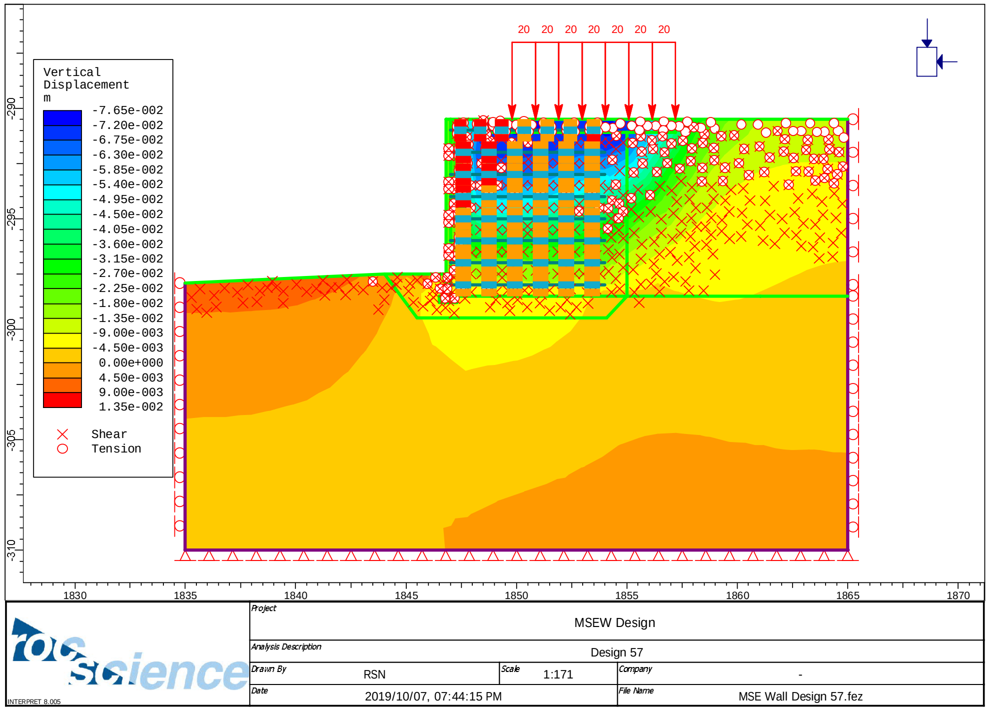
File Name
MSE Wall Design 57.fez
INTERPRET 8.005



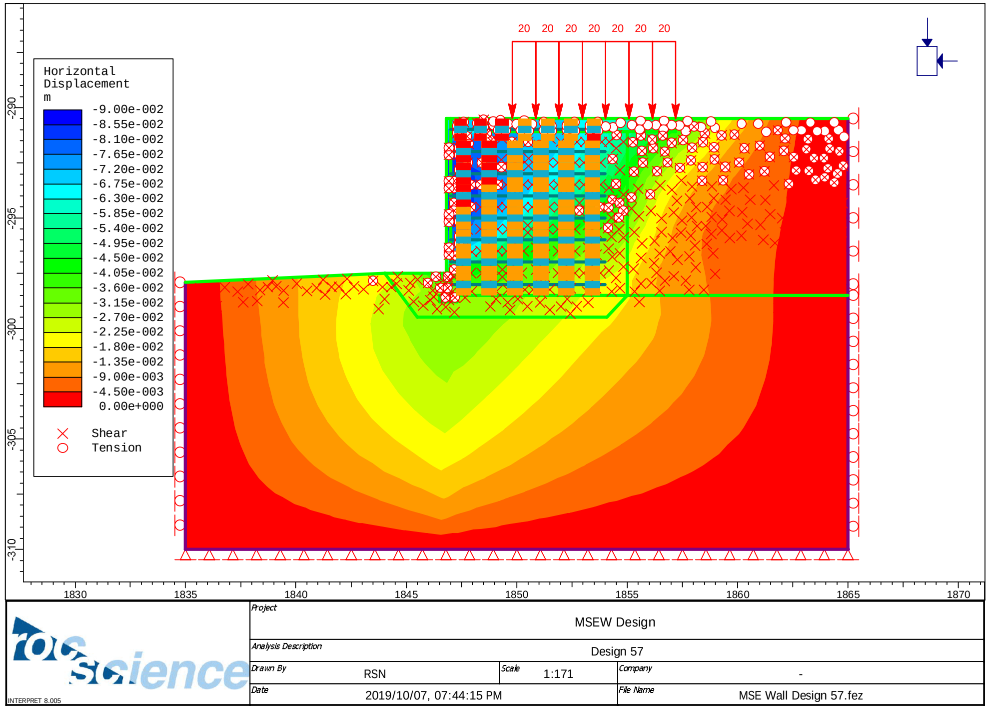
Maximum
Shear Strain
0.00e+000
9.50e-004
1.90e-003
2.85e-003
3.80e-003
4.75e-003
5.70e-003
6.65e-003
7.60e-003
8.55e-003
9.50e-003
1.05e-002
1.14e-002
1.24e-002
1.33e-002
1.42e-002
1.52e-002
1.61e-002
1.71e-002
1.81e-002
1.90e-002
Shear
Tension
20 20 20 20 20 20 20
-290
-295
-300
-305
-310
1830 1835 1840 1845 1850 1855 1860 1865 1870
Project
MSEW Design
Analysis Description
Design 57
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 57.fez
INTERPRET 8.005

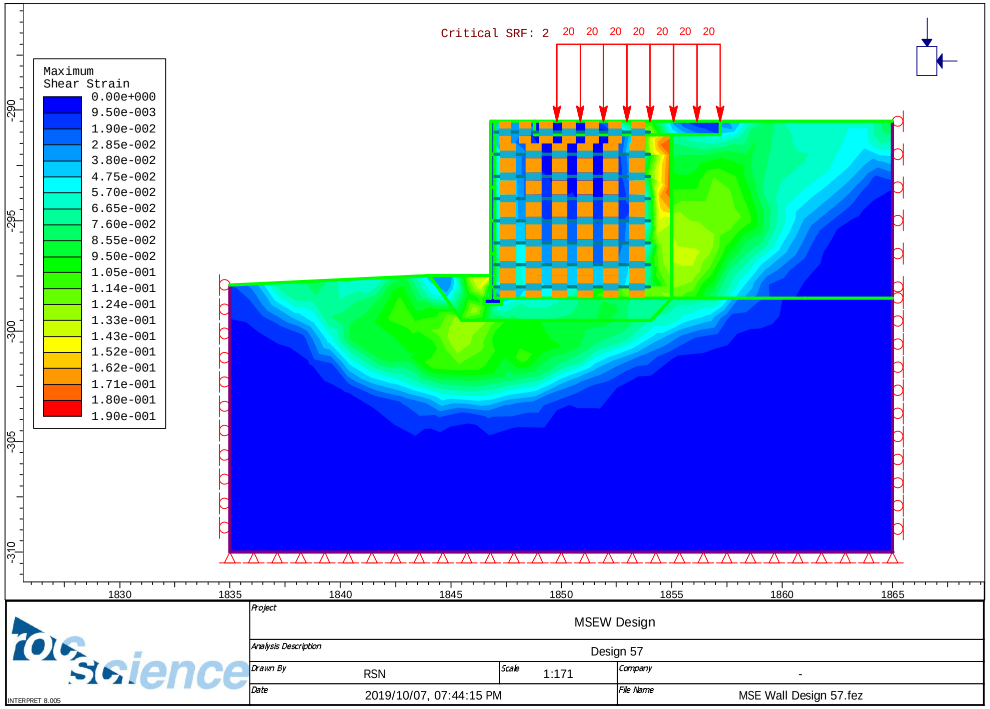


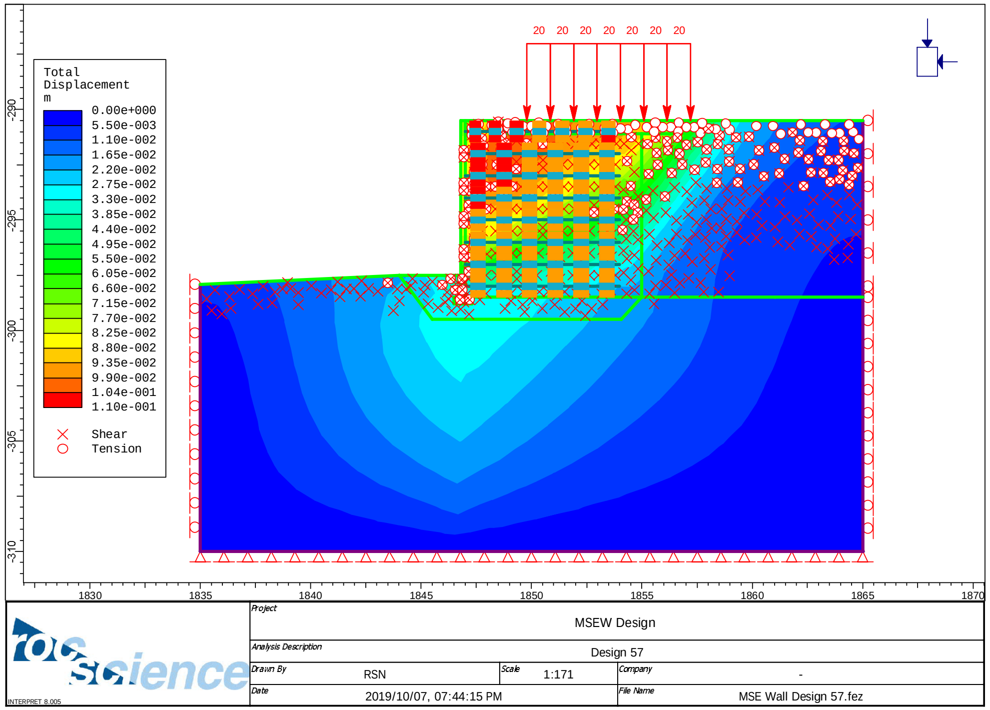
Mean Stress
kPa
0.00
25.00
50.00
75.00
100.00
125.00
150.00
175.00
200.00
225.00
250.00
275.00
300.00
325.00
350.00
375.00
400.00
425.00
450.00
475.00
500.00
Shear
Tension
20 20 20 20 20 20 20
-290
-295
-300
-305
-310
1830 1835 1840 1845 1850 1855 1860 1865 1870
Project
MSEW Design
Analysis Description
Design 57
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 57.fez
INTERPRET 8.005

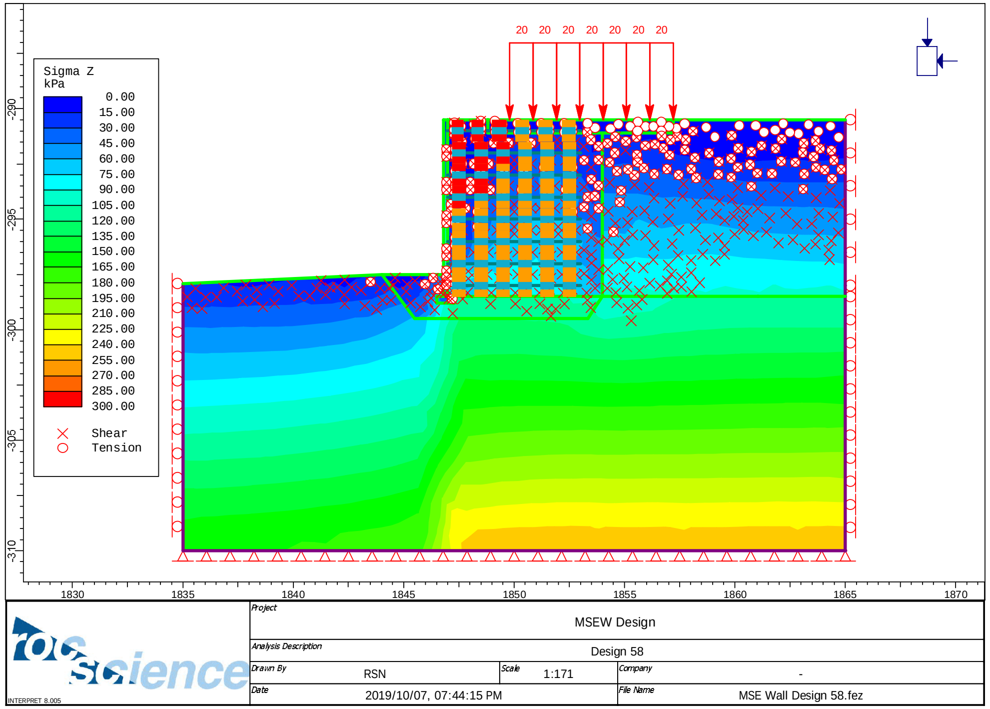


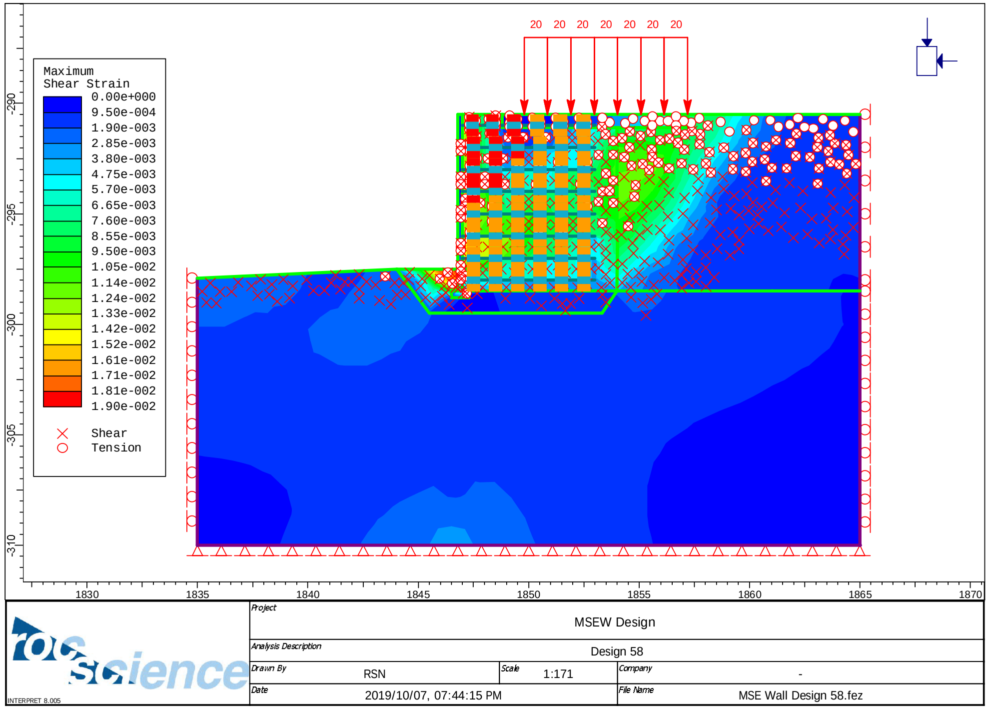
Vertical
Displacement
m
-7.65e-002
-7.20e-002
-6.75e-002
-6.30e-002
-5.85e-002
-5.40e-002
-4.95e-002
-4.50e-002
-4.05e-002
-3.60e-002
-3.15e-002
-2.70e-002
-2.25e-002
-1.80e-002
-1.35e-002
-9.00e-003
-4.50e-003
0.00e+000
4.50e-003
9.00e-003
1.35e-002
Shear
Tension
20 20 20 20 20 20 20
-290
-295
-300
-305
-310
1830 1835 1840 1845 1850 1855 1860 1865 1870
Project
MSEW Design
Analysis Description
Design 57
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 57.fez
INTERPRET 8.005

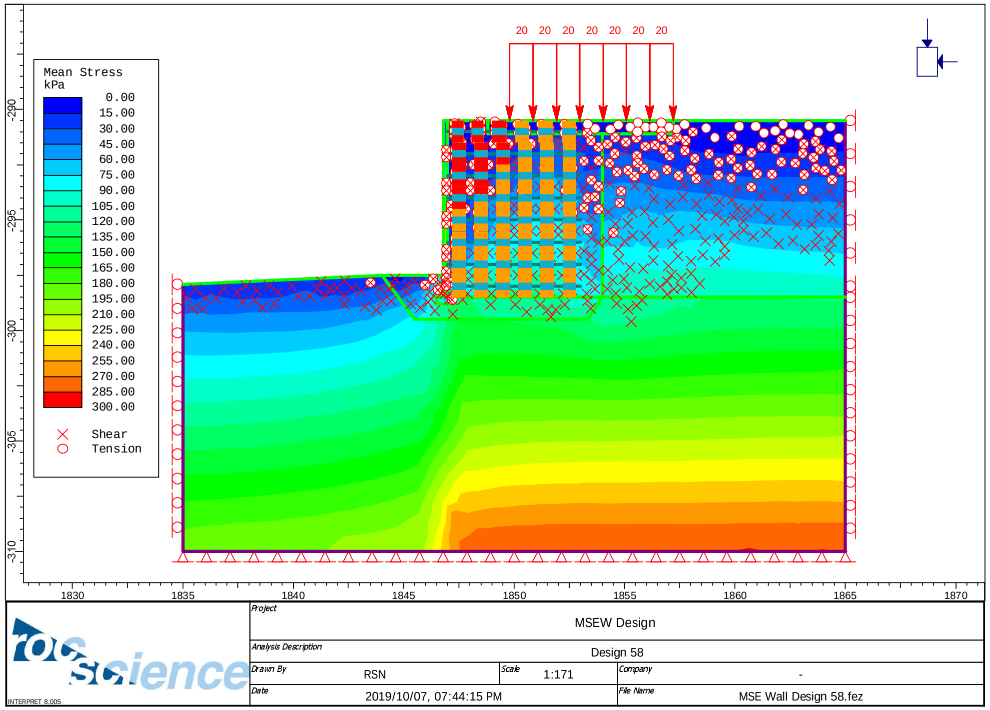

Horizontal Displacement
m
-9.00e-002
-8.55e-002
-8.10e-002
-7.65e-002
-7.20e-002
-6.75e-002
-6.30e-002
-5.85e-002
-5.40e-002
-4.95e-002
-4.50e-002
-4.05e-002
-3.60e-002
-3.15e-002
-2.70e-002
-2.25e-002
-1.80e-002
-1.35e-002
-9.00e-003
-4.50e-003
0.00e+000
Shear
Tension
20 20 20 20 20 20 20
1830 1835 1840 1845 1850 1855 1860 1865 1870
-290 -295 -300 -305 -310
Project
MSEW Design
Analysis Description
Design 57
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 57.fez
INTERPRET 8.005

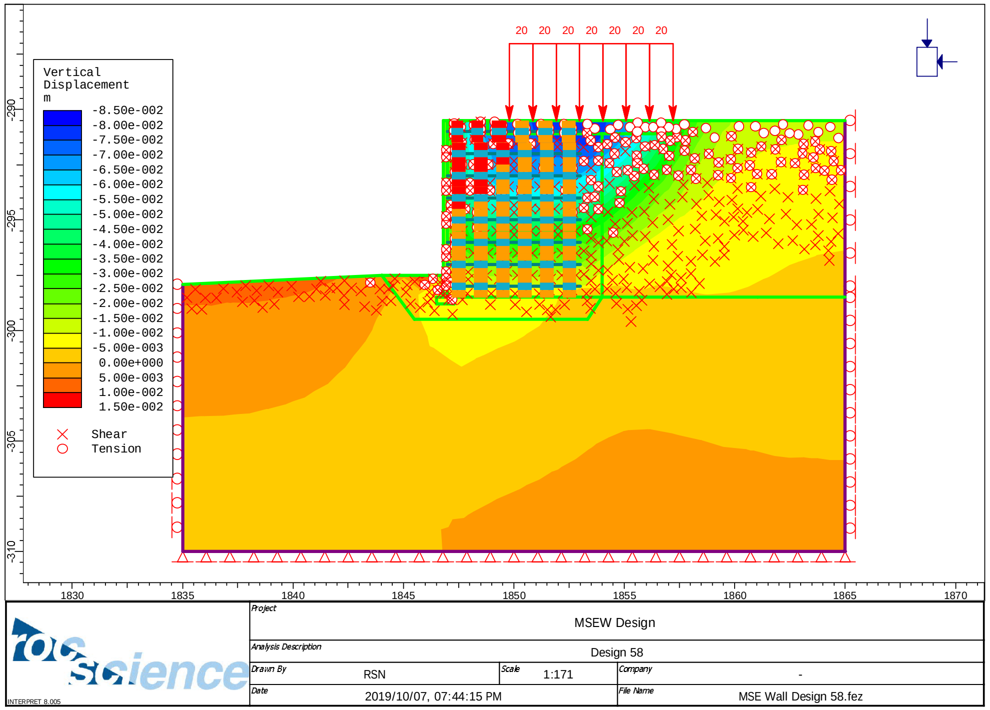

Critical SRF: 2
Maximum Shear Strain
0.00e+000
9.50e-003
1.90e-002
2.85e-002
3.80e-002
4.75e-002
5.70e-002
6.65e-002
7.60e-002
8.55e-002
9.50e-002
1.05e-001
1.14e-001
1.24e-001
1.33e-001
1.43e-001
1.52e-001
1.62e-001
1.71e-001
1.80e-001
1.90e-001
20 20 20 20 20 20 20
1830 1835 1840 1845 1850 1855 1860 1865
-290 -295 -300 -305 -310
Project
MSEW Design
Analysis Description
Design 57
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 57.fez
INTERPRET 8.005

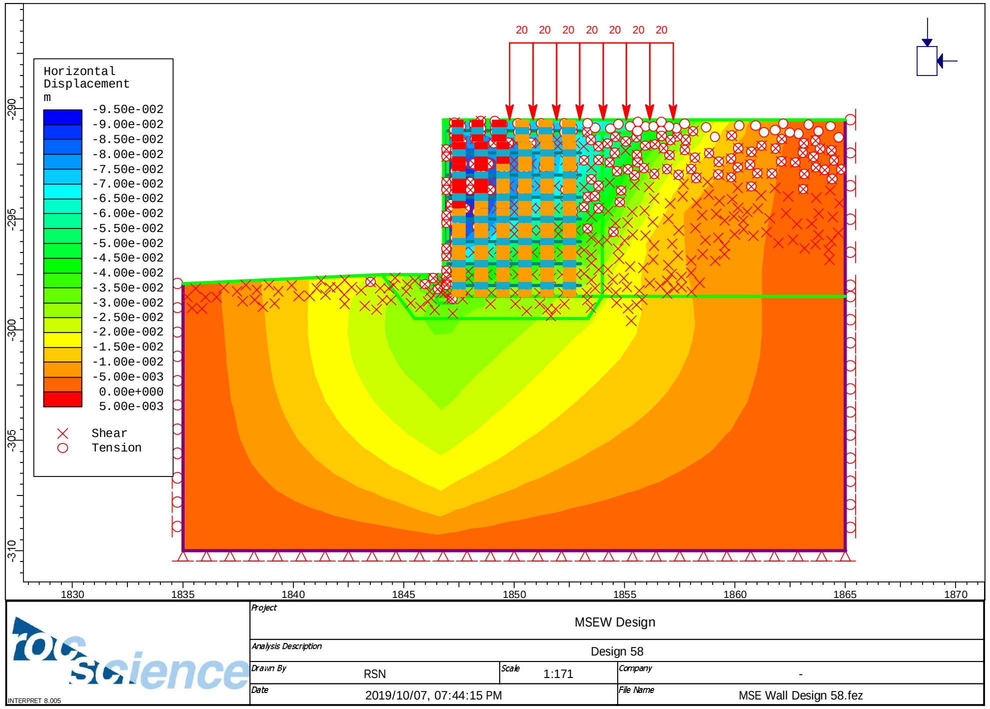

Total Displacement
m
0.00e+000
5.50e-003
1.10e-002
1.65e-002
2.20e-002
2.75e-002
3.30e-002
3.85e-002
4.40e-002
4.95e-002
5.50e-002
6.05e-002
6.60e-002
7.15e-002
7.70e-002
8.25e-002
8.80e-002
9.35e-002
9.90e-002
1.04e-001
1.10e-001
Shear
Tension
20 20 20 20 20 20 20
1830 1835 1840 1845 1850 1855 1860 1865 1870
-290 -295 -300 -305 -310
Project
MSEW Design
Analysis Description
Design 57
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 57.fez
INTERPRET 8.005

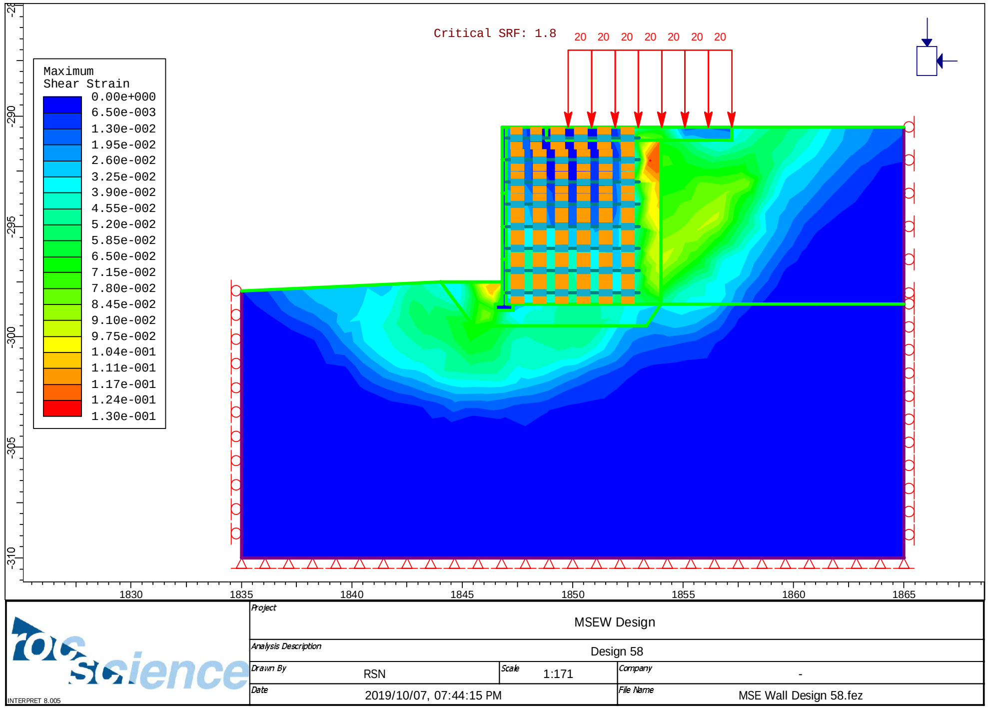

Sigma Z
kPa
0.00
15.00
30.00
45.00
60.00
75.00
90.00
105.00
120.00
135.00
150.00
165.00
180.00
195.00
210.00
225.00
240.00
255.00
270.00
285.00
300.00
Shear
Tension
20 20 20 20 20 20 20
-290
-295
-300
-305
-310
1830
1835
1840
1845
1850
1855
1860
1865
1870
rocscience
INTERPRET 8.005
Project
MSEW Design
Analysis Description
Design 58
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 58.fez

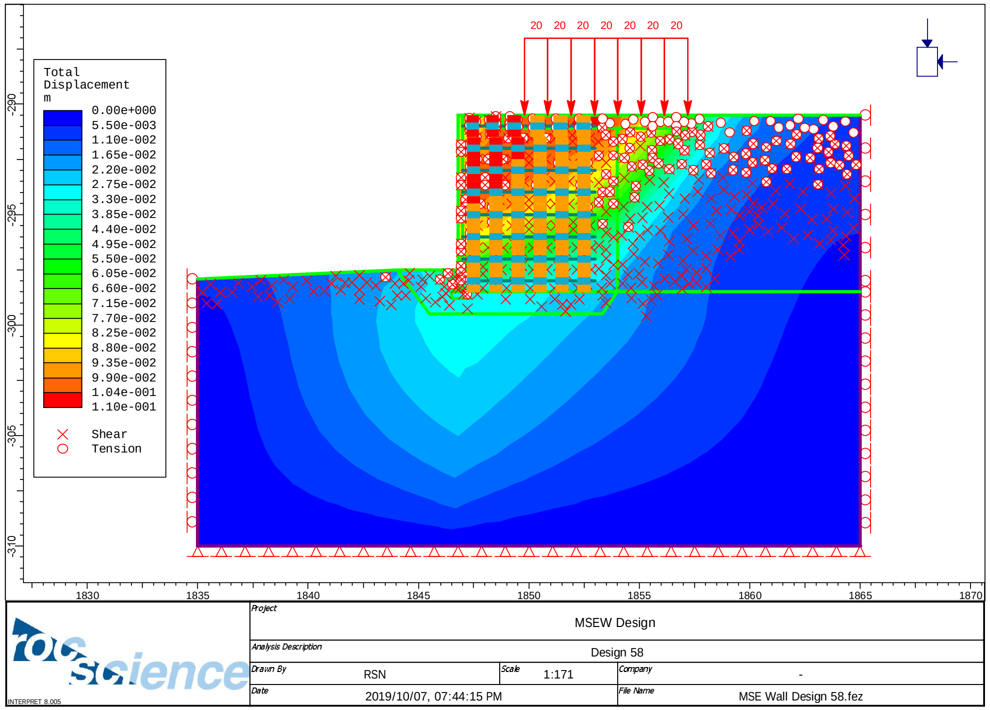

Maximum
Shear Strain
0.00e+000
9.50e-004
1.90e-003
2.85e-003
3.80e-003
4.75e-003
5.70e-003
6.65e-003
7.60e-003
8.55e-003
9.50e-003
1.05e-002
1.14e-002
1.24e-002
1.33e-002
1.42e-002
1.52e-002
1.61e-002
1.71e-002
1.81e-002
1.90e-002
Shear
Tension
20 20 20 20 20 20 20
-290
-295
-300
-305
-310
1830
1835
1840
1845
1850
1855
1860
1865
1870
rocscience
INTERPRET 8.005
Project
MSEW Design
Analysis Description
Design 58
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 58.fez

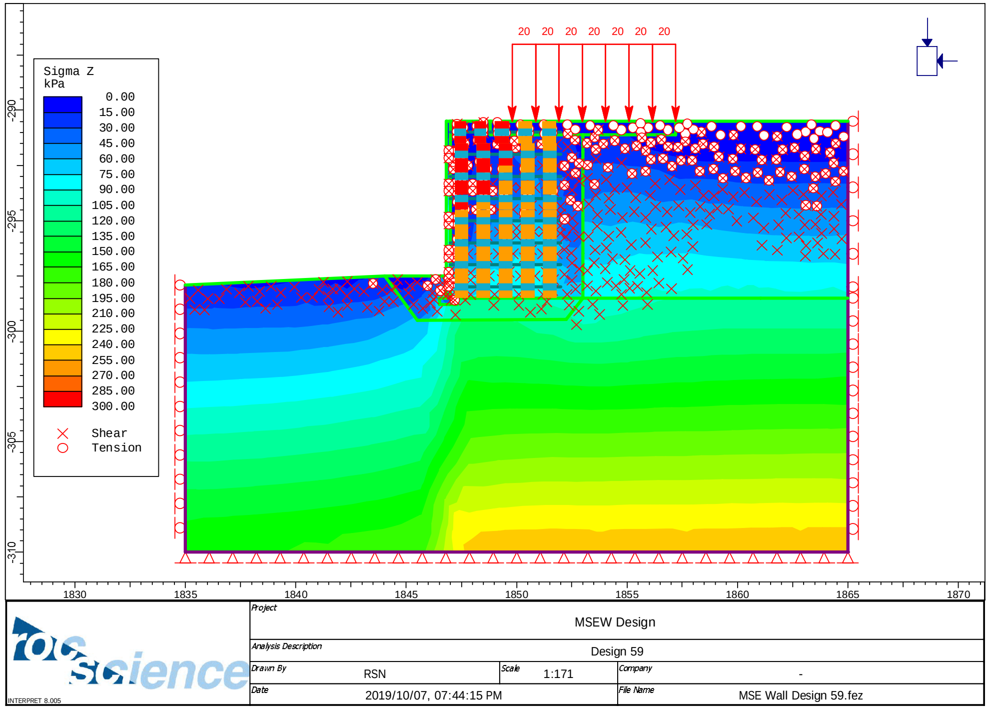

Mean Stress
kPa
0.00
15.00
30.00
45.00
60.00
75.00
90.00
105.00
120.00
135.00
150.00
165.00
180.00
195.00
210.00
225.00
240.00
255.00
270.00
285.00
300.00
Shear
Tension
20 20 20 20 20 20 20
-290
-295
-300
-305
-310
1830
1835
1840
1845
1850
1855
1860
1865
1870
rocscience
INTERPRET 8.005
Project
MSEW Design
Analysis Description
Design 58
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 58.fez

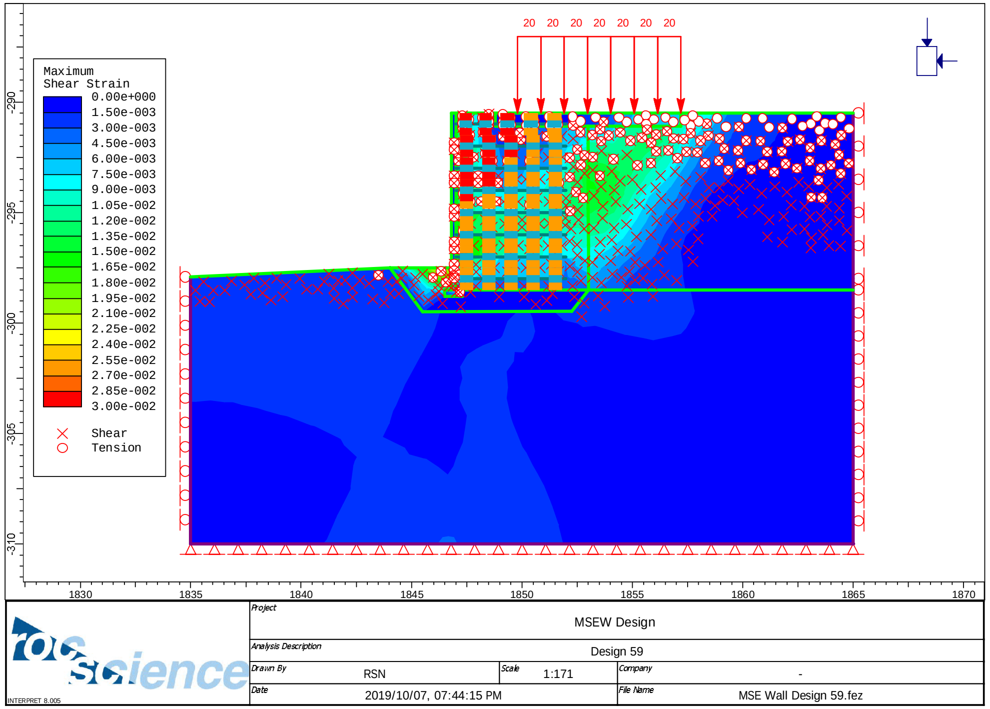

Vertical
Displacement
m
-8.50e-002
-8.00e-002
-7.50e-002
-7.00e-002
-6.50e-002
-6.00e-002
-5.50e-002
-5.00e-002
-4.50e-002
-4.00e-002
-3.50e-002
-3.00e-002
-2.50e-002
-2.00e-002
-1.50e-002
-1.00e-002
-5.00e-003
0.00e+000
5.00e-003
1.00e-002
1.50e-002
Shear
Tension
20 20 20 20 20 20 20
-290
-295
-300
-305
-310
1830
1835
1840
1845
1850
1855
1860
1865
1870
rocscience
INTERPRET 8.005
Project
MSEW Design
Analysis Description
Design 58
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 58.fez

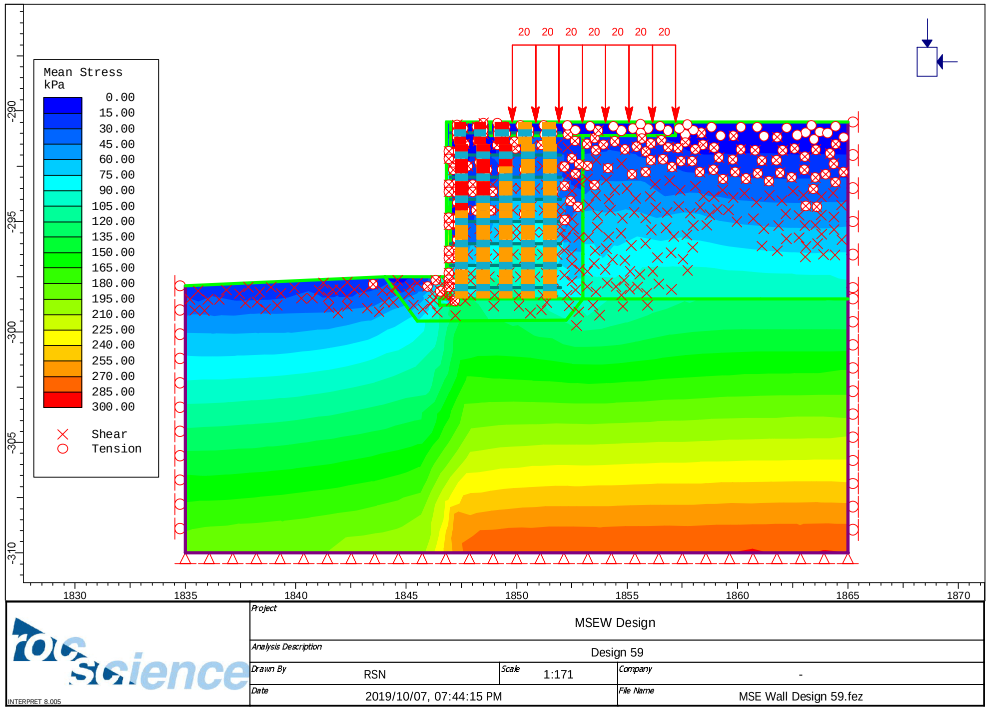

Horizontal Displacement m
-9.50e-002
-9.00e-002
-8.50e-002
-8.00e-002
-7.50e-002
-7.00e-002
-6.50e-002
-6.00e-002
-5.50e-002
-5.00e-002
-4.50e-002
-4.00e-002
-3.50e-002
-3.00e-002
-2.50e-002
-2.00e-002
-1.50e-002
-1.00e-002
-5.00e-003
0.00e+000
5.00e-003
Shear
Tension
20 20 20 20 20 20 20
Project MSEW Design
Analysis Description Design 58
Drawn By RSN
Scale 1:171
Company -
Date 2019/10/07, 07:44:15 PM
File Name MSE Wall Design 58.fez
INTERPRET 8.005

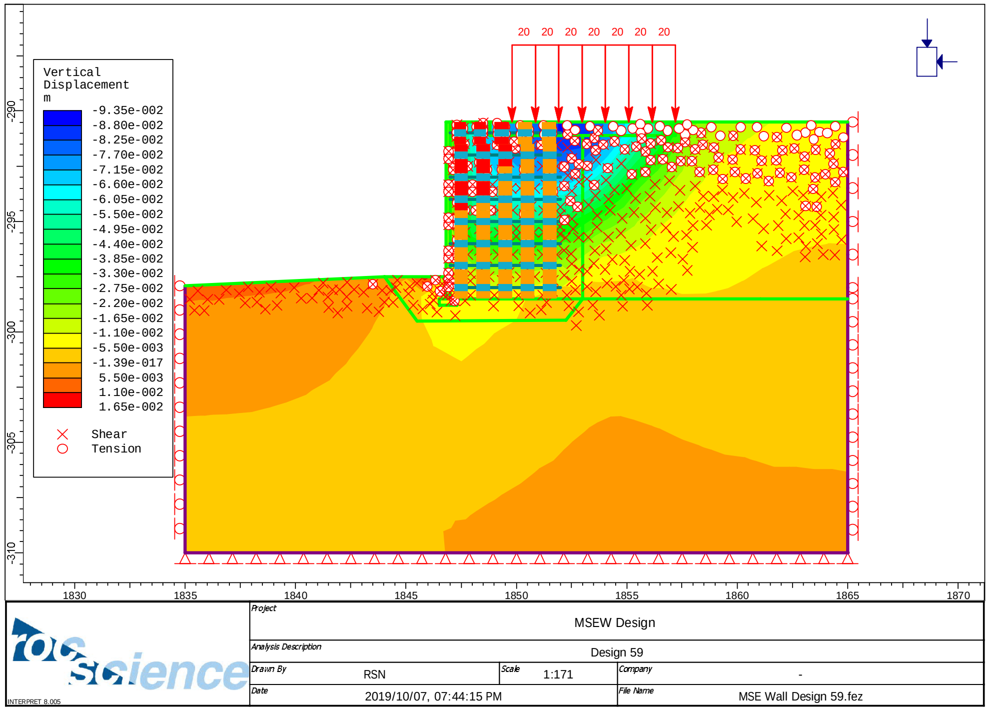

Maximum Shear Strain
0.00e+000
6.50e-003
1.30e-002
1.95e-002
2.60e-002
3.25e-002
3.90e-002
4.55e-002
5.20e-002
5.85e-002
6.50e-002
7.15e-002
7.80e-002
8.45e-002
9.10e-002
9.75e-002
1.04e-001
1.11e-001
1.17e-001
1.24e-001
1.30e-001
Critical SRF: 1.8
20 20 20 20 20 20 20
Project MSEW Design
Analysis Description Design 58
Drawn By RSN
Scale 1:171
Company -
Date 2019/10/07, 07:44:15 PM
File Name MSE Wall Design 58.fez
INTERPRET 8.005

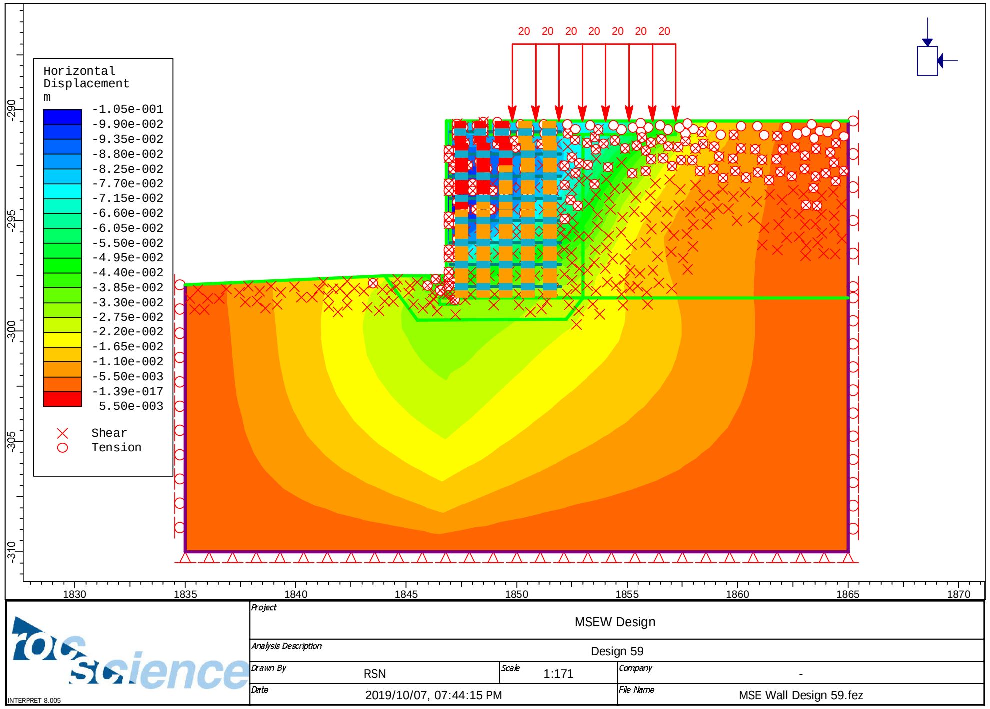

Total Displacement m
0.00e+000
5.50e-003
1.10e-002
1.65e-002
2.20e-002
2.75e-002
3.30e-002
3.85e-002
4.40e-002
4.95e-002
5.50e-002
6.05e-002
6.60e-002
7.15e-002
7.70e-002
8.25e-002
8.80e-002
9.35e-002
9.90e-002
1.04e-001
1.10e-001
Shear
Tension
20 20 20 20 20 20 20
Project MSEW Design
Analysis Description Design 58
Drawn By RSN
Scale 1:171
Company -
Date 2019/10/07, 07:44:15 PM
File Name MSE Wall Design 58.fez
INTERPRET 8.005

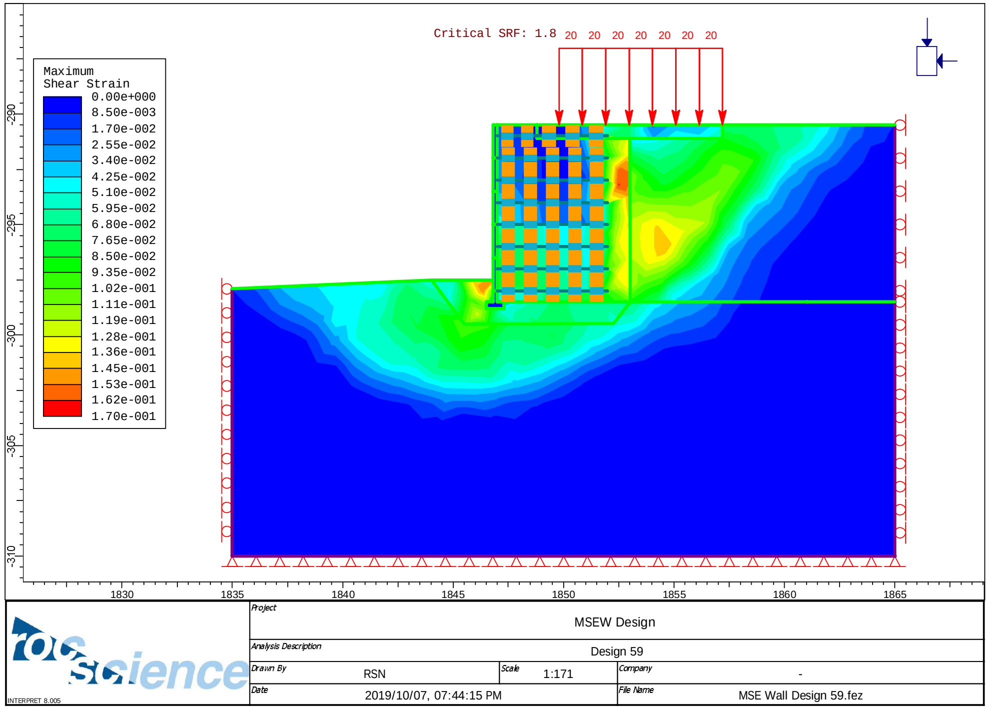

Sigma Z
kPa
0.00
15.00
30.00
45.00
60.00
75.00
90.00
105.00
120.00
135.00
150.00
165.00
180.00
195.00
210.00
225.00
240.00
255.00
270.00
285.00
300.00
Shear
Tension
20 20 20 20 20 20 20
Project
MSEW Design
Analysis Description
Design 59
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 59.fez
INTERPRET 8.005

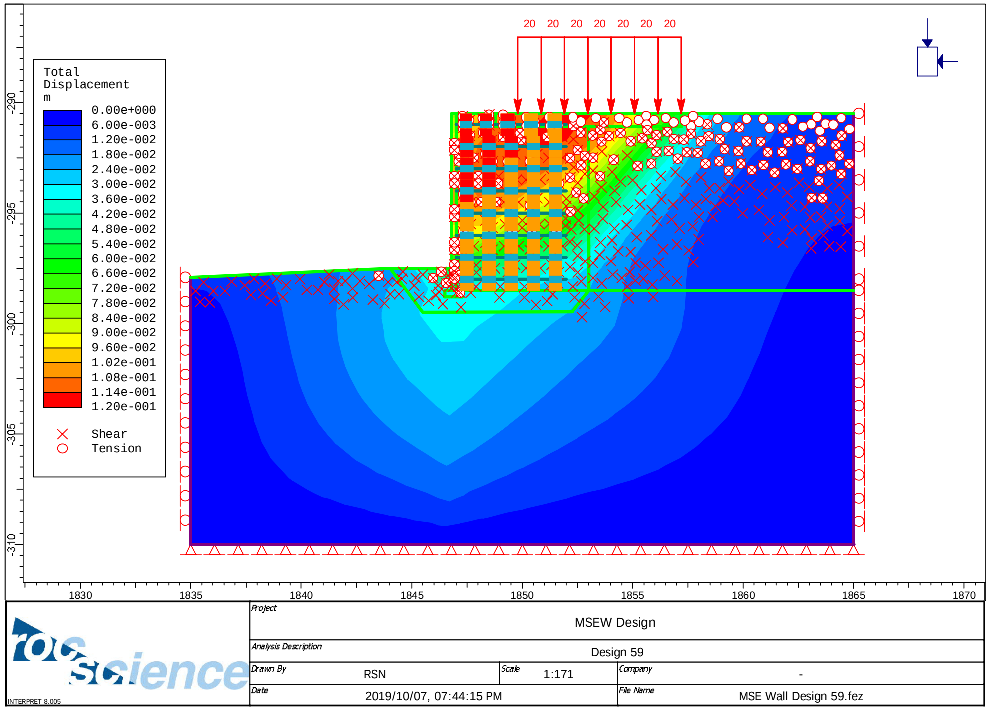

Maximum
Shear Strain
0.00e+000
1.50e-003
3.00e-003
4.50e-003
6.00e-003
7.50e-003
9.00e-003
1.05e-002
1.20e-002
1.35e-002
1.50e-002
1.65e-002
1.80e-002
1.95e-002
2.10e-002
2.25e-002
2.40e-002
2.55e-002
2.70e-002
2.85e-002
3.00e-002
Shear
Tension
20 20 20 20 20 20 20
Project
MSEW Design
Analysis Description
Design 59
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 59.fez
INTERPRET 8.005

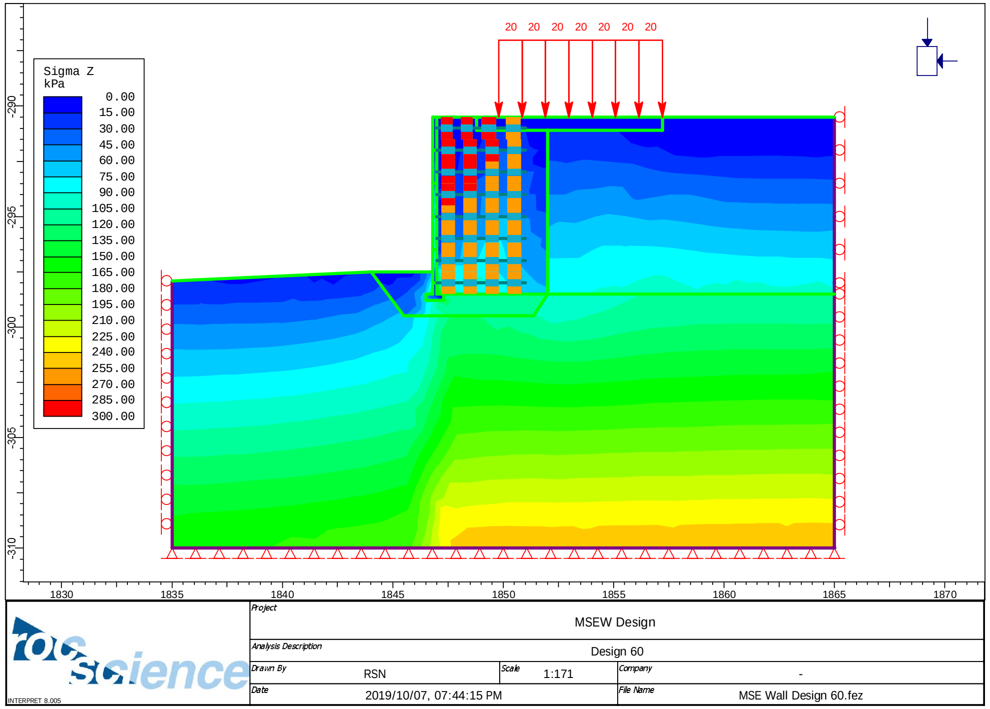

Mean Stress
kPa
0.00
15.00
30.00
45.00
60.00
75.00
90.00
105.00
120.00
135.00
150.00
165.00
180.00
195.00
210.00
225.00
240.00
255.00
270.00
285.00
300.00
Shear
Tension
20 20 20 20 20 20 20
Project
MSEW Design
Analysis Description
Design 59
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 59.fez
INTERPRET 8.005

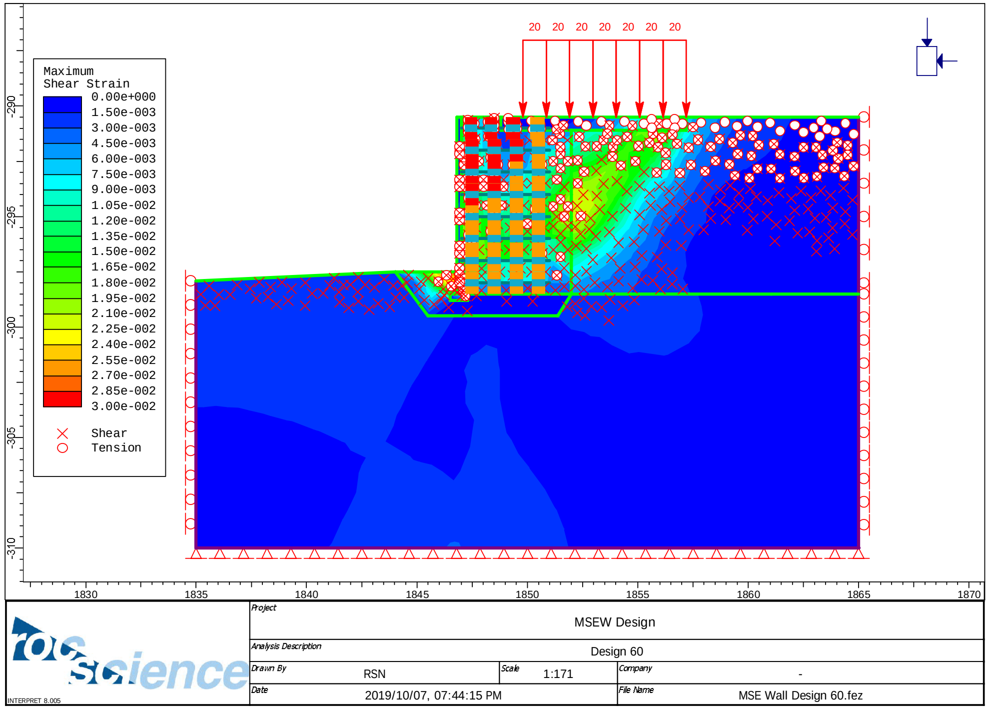

Vertical
Displacement
m
-9.35e-002
-8.80e-002
-8.25e-002
-7.70e-002
-7.15e-002
-6.60e-002
-6.05e-002
-5.50e-002
-4.95e-002
-4.40e-002
-3.85e-002
-3.30e-002
-2.75e-002
-2.20e-002
-1.65e-002
-1.10e-002
-5.50e-003
-1.39e-017
5.50e-003
1.10e-002
1.65e-002
Shear
Tension
20 20 20 20 20 20 20
Project
MSEW Design
Analysis Description
Design 59
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 59.fez
INTERPRET 8.005

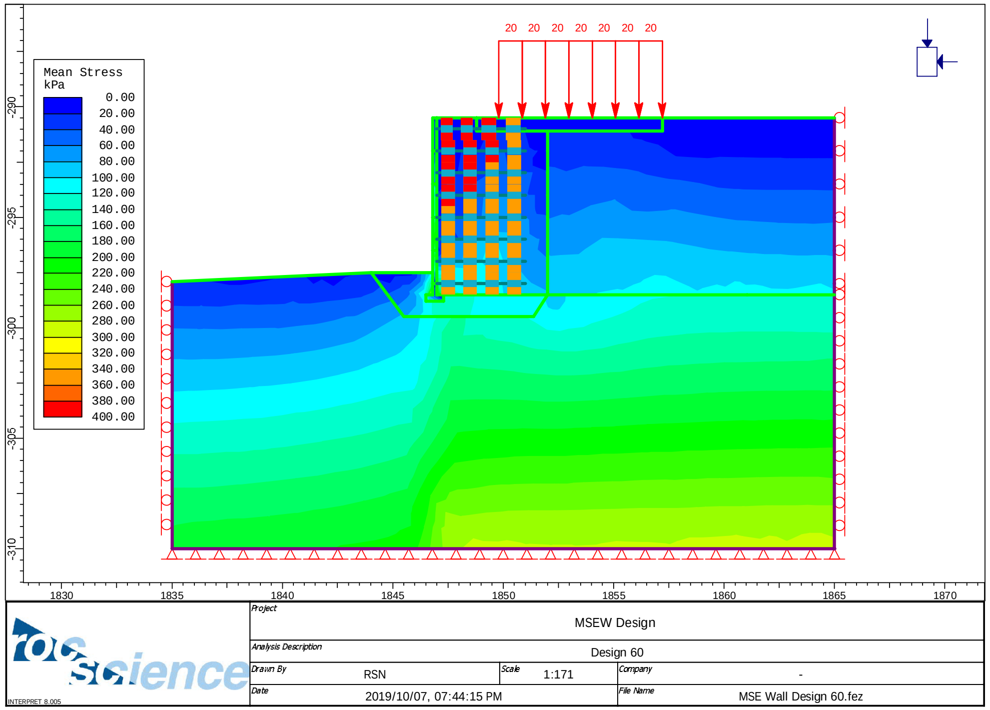

20 20 20 20 20 20 20
Horizontal Displacement m
-1.05e-001
-9.90e-002
-9.35e-002
-8.80e-002
-8.25e-002
-7.70e-002
-7.15e-002
-6.60e-002
-6.05e-002
-5.50e-002
-4.95e-002
-4.40e-002
-3.85e-002
-3.30e-002
-2.75e-002
-2.20e-002
-1.65e-002
-1.10e-002
-5.50e-003
-1.39e-017
5.50e-003
Shear
Tension
-290
-295
-300
-305
-310
1830 1835 1840 1845 1850 1855 1860 1865 1870
Project
MSEW Design
Analysis Description
Design 59
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 59.fez
INTERPRET 8.005

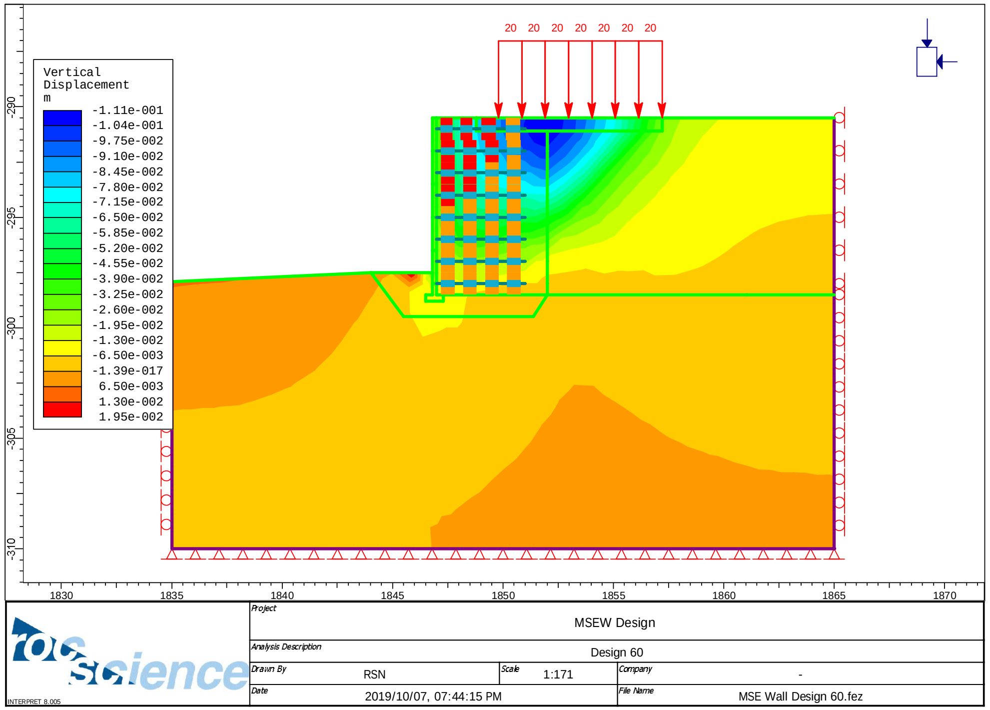

Critical SRF: 1.8
20 20 20 20 20 20 20
Maximum Shear Strain
0.00e+000
8.50e-003
1.70e-002
2.55e-002
3.40e-002
4.25e-002
5.10e-002
5.95e-002
6.80e-002
7.65e-002
8.50e-002
9.35e-002
1.02e-001
1.11e-001
1.19e-001
1.28e-001
1.36e-001
1.45e-001
1.53e-001
1.62e-001
1.70e-001
-290
-295
-300
-305
-310
1830 1835 1840 1845 1850 1855 1860 1865
Project
MSEW Design
Analysis Description
Design 59
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 59.fez
INTERPRET 8.005

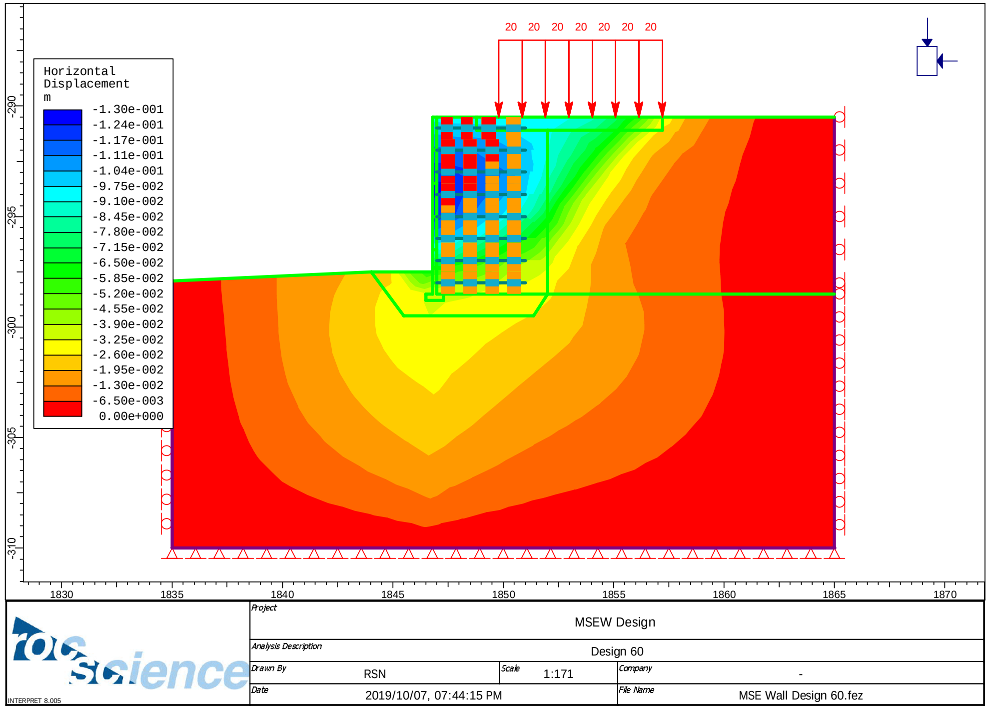

20 20 20 20 20 20 20
Total Displacement m
0.00e+000
6.00e-003
1.20e-002
1.80e-002
2.40e-002
3.00e-002
3.60e-002
4.20e-002
4.80e-002
5.40e-002
6.00e-002
6.60e-002
7.20e-002
7.80e-002
8.40e-002
9.00e-002
9.60e-002
1.02e-001
1.08e-001
1.14e-001
1.20e-001
Shear
Tension
-290
-295
-300
-305
-310
1830 1835 1840 1845 1850 1855 1860 1865 1870
Project
MSEW Design
Analysis Description
Design 59
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 59.fez
INTERPRET 8.005

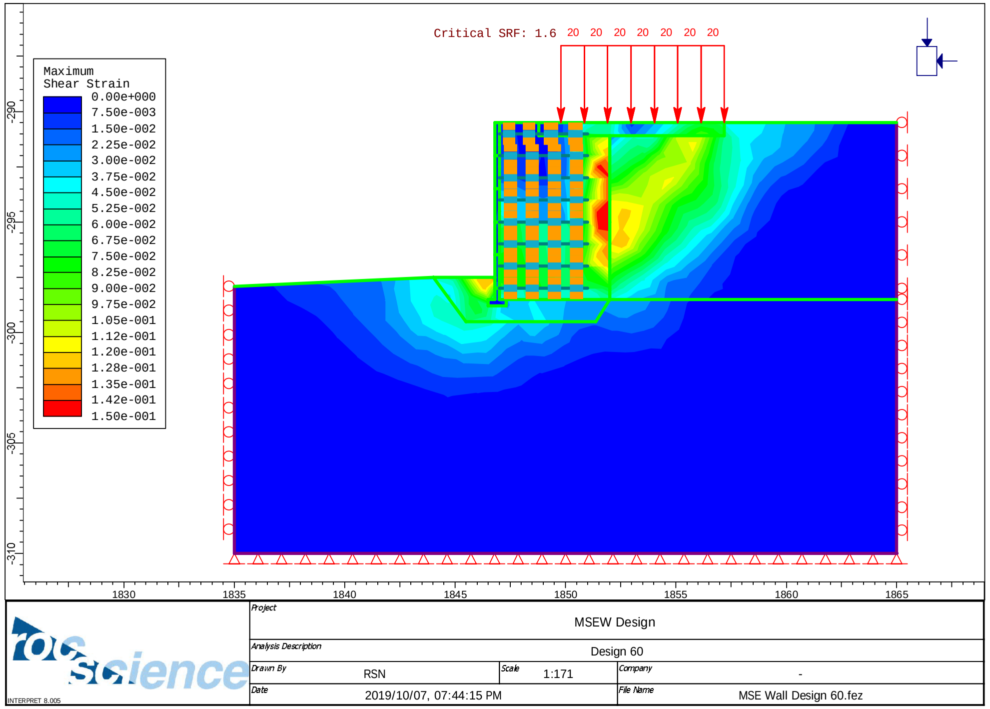

Sigma Z
kPa
0.00
15.00
30.00
45.00
60.00
75.00
90.00
105.00
120.00
135.00
150.00
165.00
180.00
195.00
210.00
225.00
240.00
255.00
270.00
285.00
300.00
20 20 20 20 20 20 20
Project
MSEW Design
Analysis Description
Design 60
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 60.fez
INTERPRET 8.005

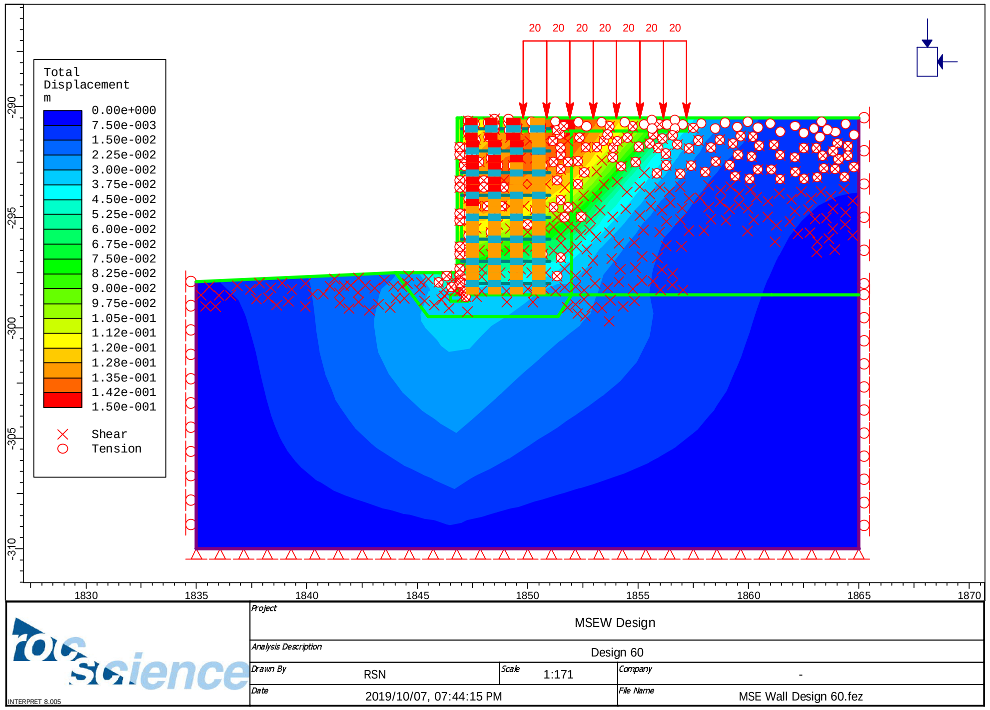

Maximum
Shear Strain
0.00e+000
1.50e-003
3.00e-003
4.50e-003
6.00e-003
7.50e-003
9.00e-003
1.05e-002
1.20e-002
1.35e-002
1.50e-002
1.65e-002
1.80e-002
1.95e-002
2.10e-002
2.25e-002
2.40e-002
2.55e-002
2.70e-002
2.85e-002
3.00e-002
Shear
Tension
20 20 20 20 20 20 20
Project
MSEW Design
Analysis Description
Design 60
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 60.fez
INTERPRET 8.005

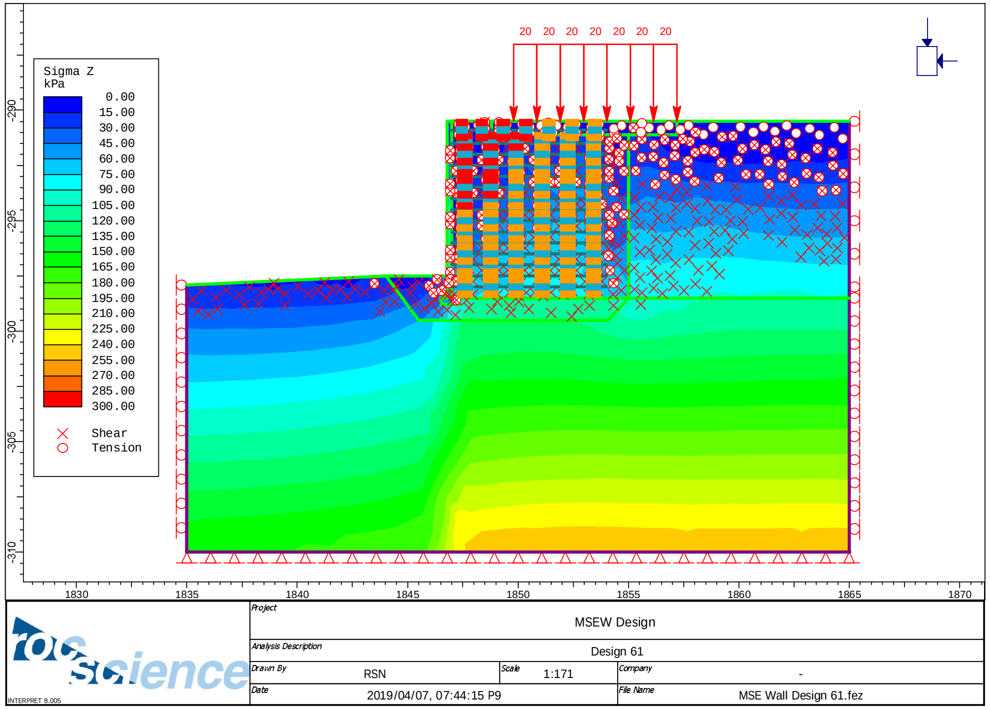

Mean Stress
kPa
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
160.00
180.00
200.00
220.00
240.00
260.00
280.00
300.00
320.00
340.00
360.00
380.00
400.00
20 20 20 20 20 20 20
Project
MSEW Design
Analysis Description
Design 60
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 60.fez
INTERPRET 8.005

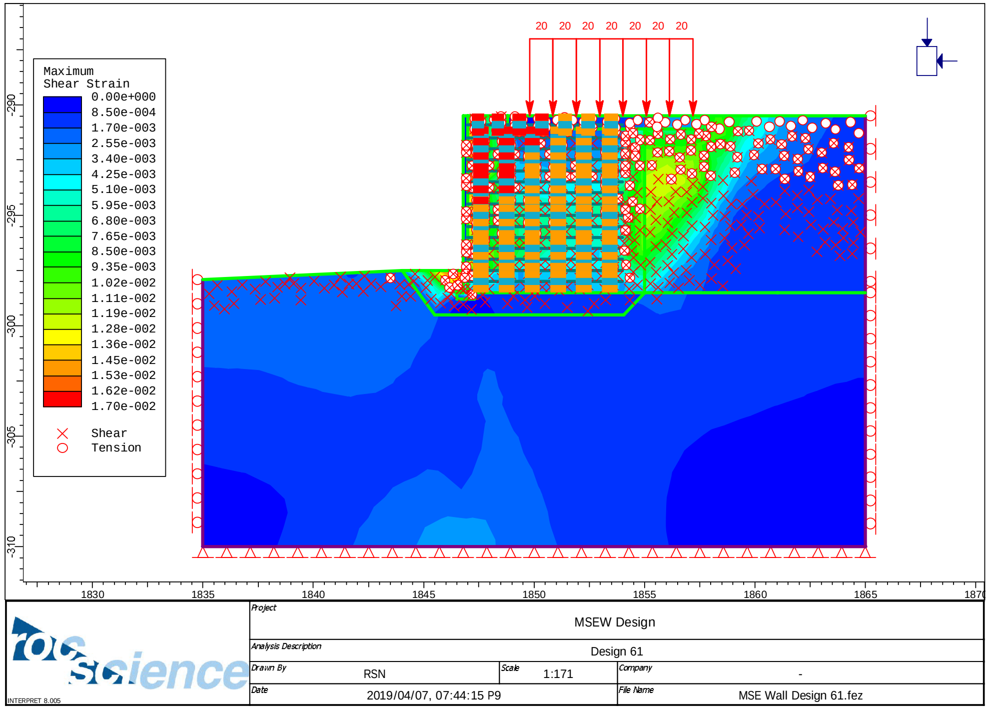

Vertical
Displacement
m
-1.11e-001
-1.04e-001
-9.75e-002
-9.10e-002
-8.45e-002
-7.80e-002
-7.15e-002
-6.50e-002
-5.85e-002
-5.20e-002
-4.55e-002
-3.90e-002
-3.25e-002
-2.60e-002
-1.95e-002
-1.30e-002
-6.50e-003
-1.39e-017
6.50e-003
1.30e-002
1.95e-002
20 20 20 20 20 20 20
Project
MSEW Design
Analysis Description
Design 60
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 60.fez
INTERPRET 8.005

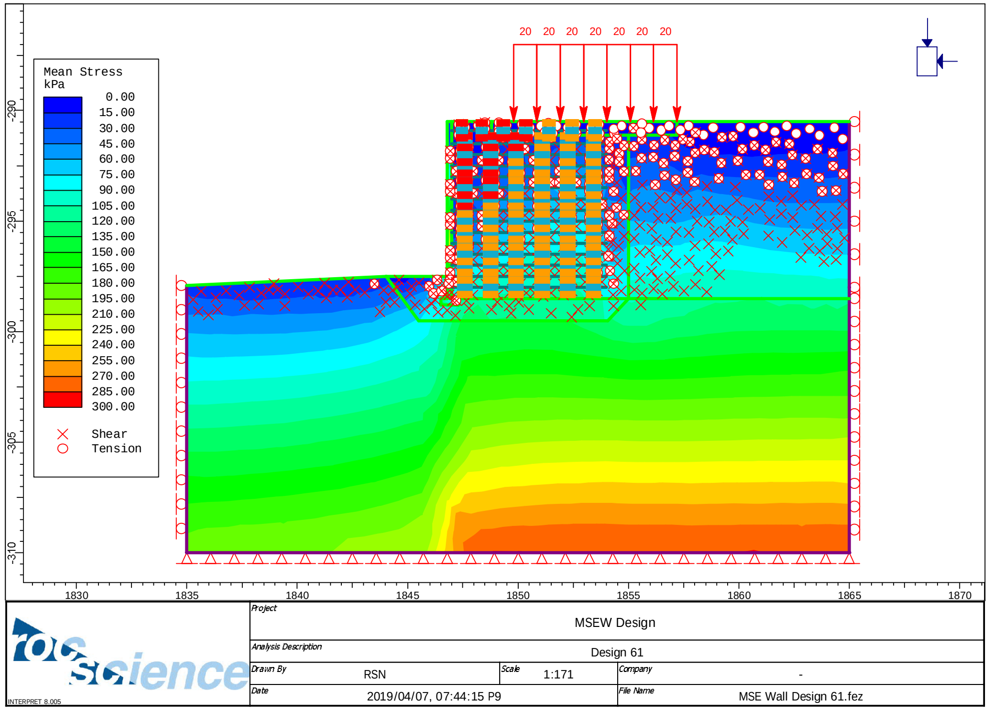

Horizontal Displacement
m
-1.30e-001
-1.24e-001
-1.17e-001
-1.11e-001
-1.04e-001
-9.75e-002
-9.10e-002
-8.45e-002
-7.80e-002
-7.15e-002
-6.50e-002
-5.85e-002
-5.20e-002
-4.55e-002
-3.90e-002
-3.25e-002
-2.60e-002
-1.95e-002
-1.30e-002
-6.50e-003
0.00e+000
20 20 20 20 20 20 20
Project
MSEW Design
Analysis Description
Design 60
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 60.fez
INTERPRET 8.005

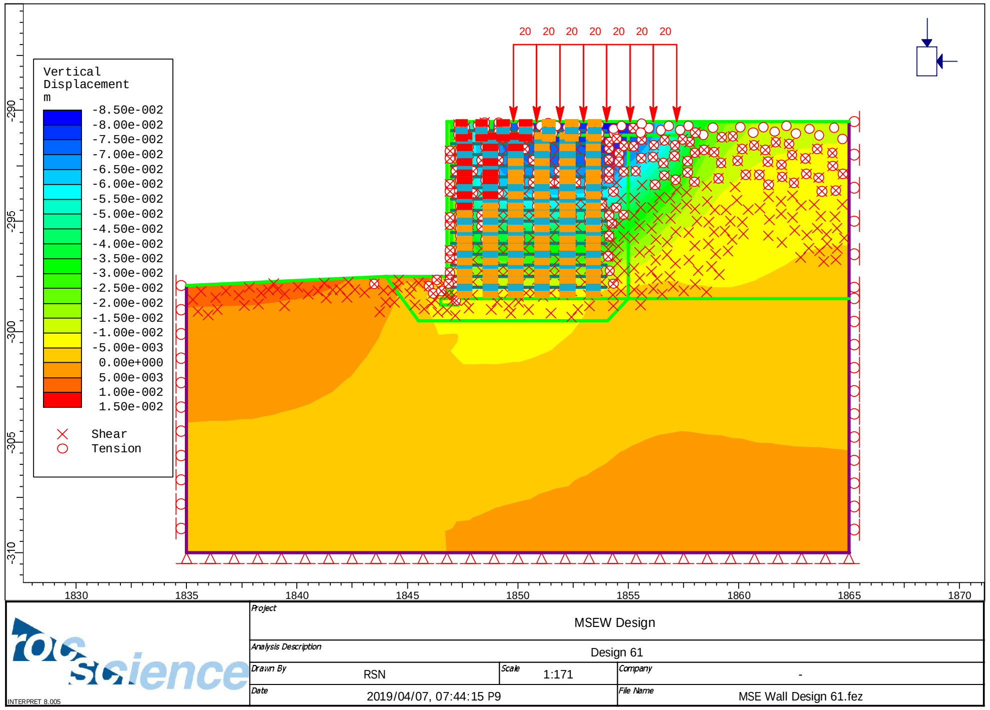

Maximum Shear Strain
0.00e+000
7.50e-003
1.50e-002
2.25e-002
3.00e-002
3.75e-002
4.50e-002
5.25e-002
6.00e-002
6.75e-002
7.50e-002
8.25e-002
9.00e-002
9.75e-002
1.05e-001
1.12e-001
1.20e-001
1.28e-001
1.35e-001
1.42e-001
1.50e-001
Critical SRF: 1.6
20 20 20 20 20 20 20
Project
MSEW Design
Analysis Description
Design 60
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 60.fez
INTERPRET 8.005

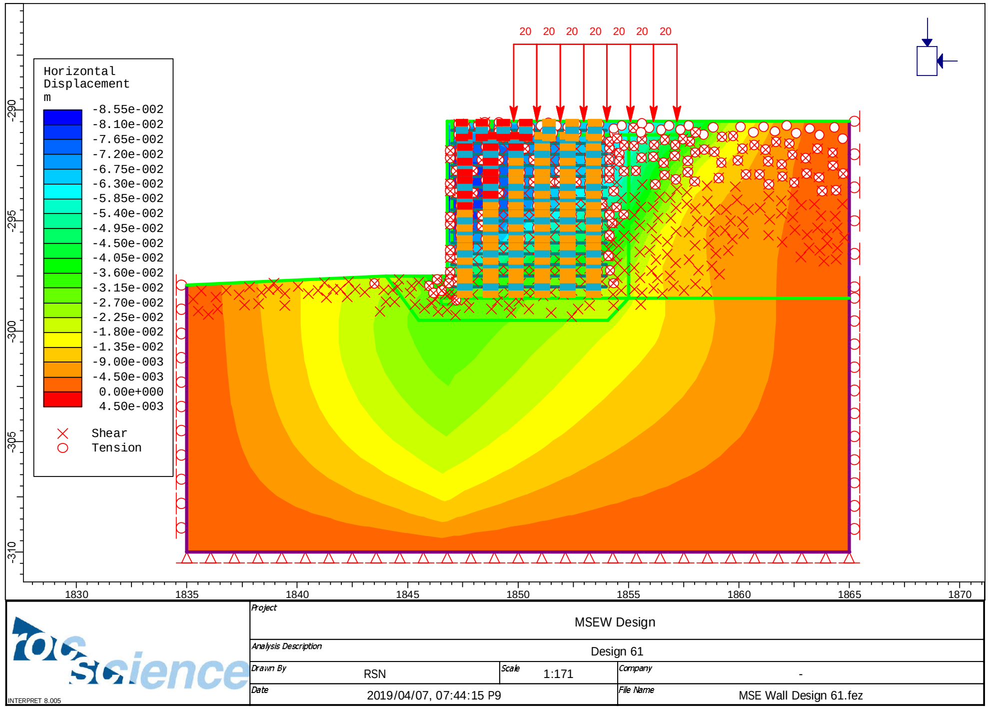

Total Displacement
m
0.00e+000
7.50e-003
1.50e-002
2.25e-002
3.00e-002
3.75e-002
4.50e-002
5.25e-002
6.00e-002
6.75e-002
7.50e-002
8.25e-002
9.00e-002
9.75e-002
1.05e-001
1.12e-001
1.20e-001
1.28e-001
1.35e-001
1.42e-001
1.50e-001
Shear
Tension
20 20 20 20 20 20 20
Project
MSEW Design
Analysis Description
Design 60
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 60.fez
INTERPRET 8.005

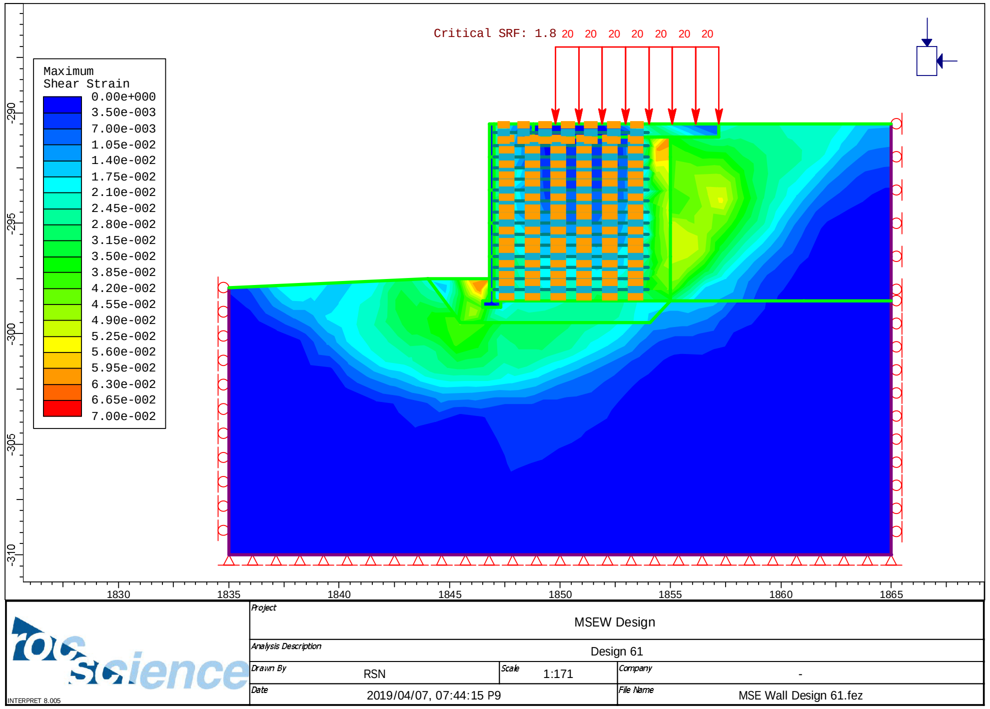

Sigma Z
kPa
0.00
15.00
30.00
45.00
60.00
75.00
90.00
105.00
120.00
135.00
150.00
165.00
180.00
195.00
210.00
225.00
240.00
255.00
270.00
285.00
300.00
Shear
Tension
Project
MSEW Design
Analysis Description
Design 61
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/04/07, 07:44:15 P9
File Name
MSE Wall Design 61.fez
INTERPRET 8.005

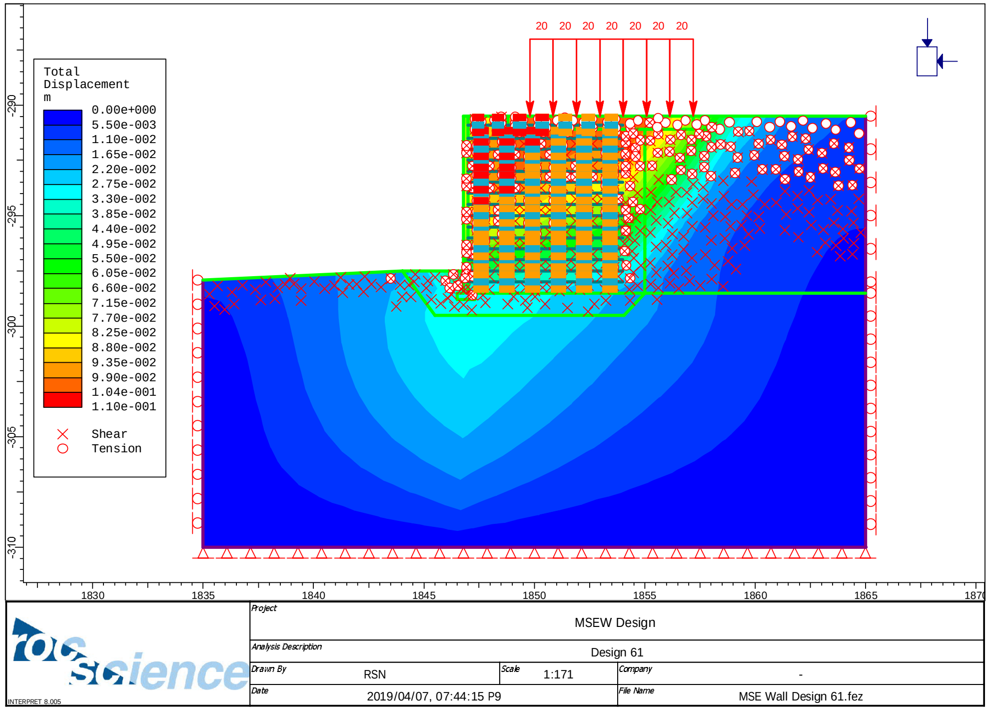

Maximum
Shear Strain
0.00e+000
8.50e-004
1.70e-003
2.55e-003
3.40e-003
4.25e-003
5.10e-003
5.95e-003
6.80e-003
7.65e-003
8.50e-003
9.35e-003
1.02e-002
1.11e-002
1.19e-002
1.28e-002
1.36e-002
1.45e-002
1.53e-002
1.62e-002
1.70e-002
Shear
Tension
Project
MSEW Design
Analysis Description
Design 61
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/04/07, 07:44:15 P9
File Name
MSE Wall Design 61.fez
INTERPRET 8.005

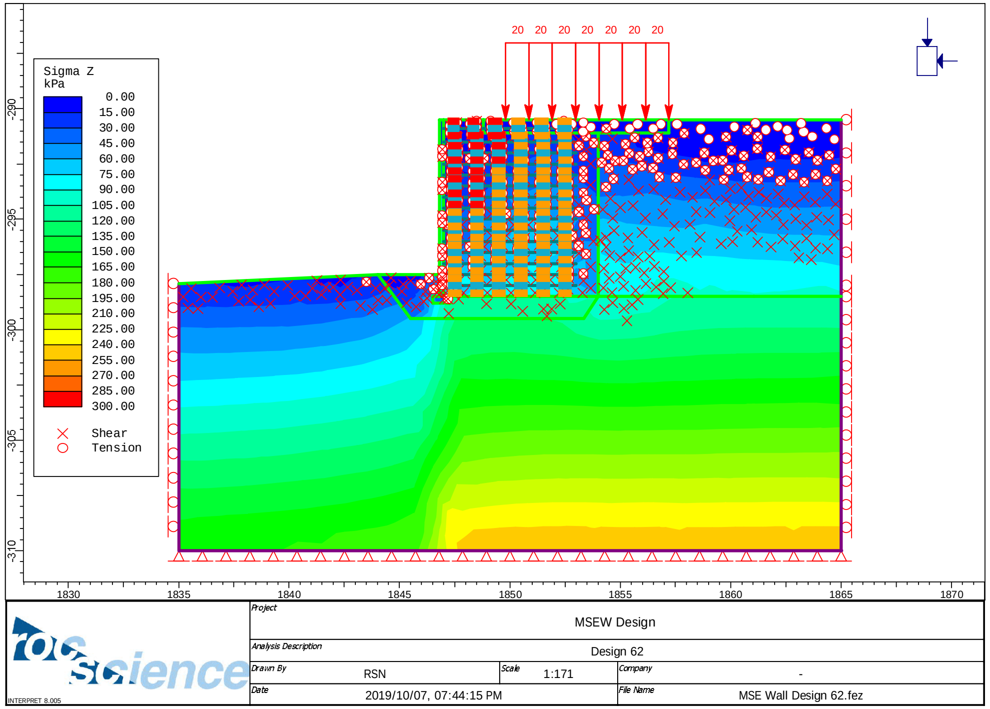

Mean Stress
kPa
0.00
15.00
30.00
45.00
60.00
75.00
90.00
105.00
120.00
135.00
150.00
165.00
180.00
195.00
210.00
225.00
240.00
255.00
270.00
285.00
300.00
Shear
Tension
Project
MSEW Design
Analysis Description
Design 61
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/04/07, 07:44:15 P9
File Name
MSE Wall Design 61.fez
INTERPRET 8.005

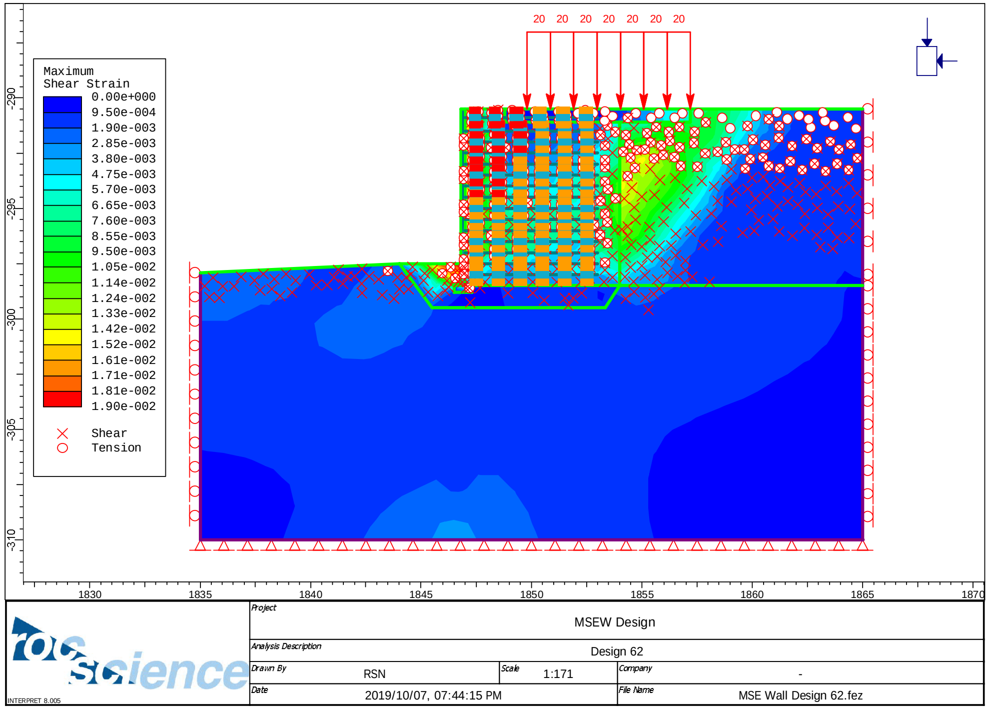

Vertical
Displacement
m
-8.50e-002
-8.00e-002
-7.50e-002
-7.00e-002
-6.50e-002
-6.00e-002
-5.50e-002
-5.00e-002
-4.50e-002
-4.00e-002
-3.50e-002
-3.00e-002
-2.50e-002
-2.00e-002
-1.50e-002
-1.00e-002
-5.00e-003
0.00e+000
5.00e-003
1.00e-002
1.50e-002
Shear
Tension
Project
MSEW Design
Analysis Description
Design 61
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/04/07, 07:44:15 P9
File Name
MSE Wall Design 61.fez
INTERPRET 8.005

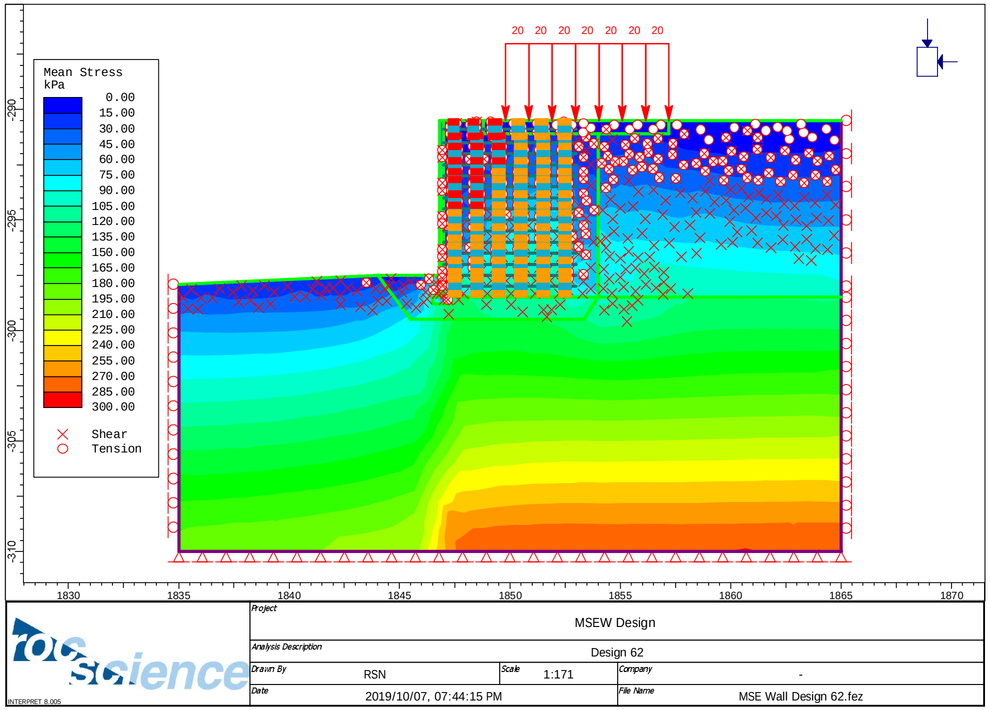

20 20 20 20 20 20 20
Horizontal Displacement m
-8.55e-002
-8.10e-002
-7.65e-002
-7.20e-002
-6.75e-002
-6.30e-002
-5.85e-002
-5.40e-002
-4.95e-002
-4.50e-002
-4.05e-002
-3.60e-002
-3.15e-002
-2.70e-002
-2.25e-002
-1.80e-002
-1.35e-002
-9.00e-003
-4.50e-003
0.00e+000
4.50e-003
Shear
Tension
-290
-295
-300
-305
-310
1830
1835
1840
1845
1850
1855
1860
1865
1870
Project
MSEW Design
Analysis Description
Design 61
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/04/07, 07:44:15 P9
File Name
MSE Wall Design 61.fez
INTERPRET 8.005

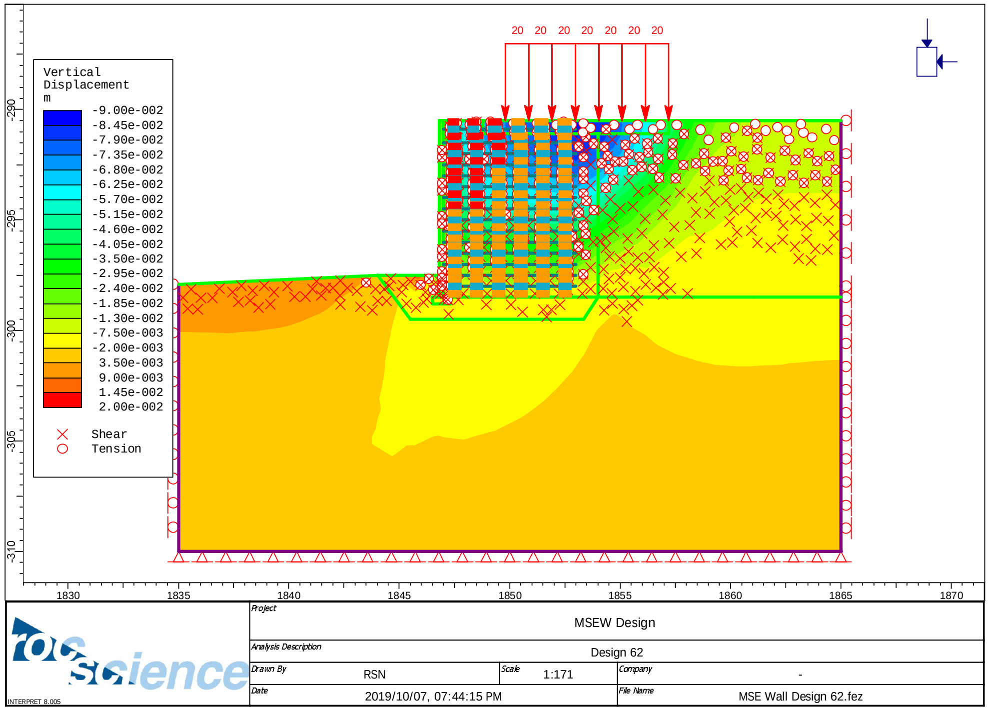

Critical SRF: 1.8
20 20 20 20 20 20 20
Maximum Shear Strain
0.00e+000
3.50e-003
7.00e-003
1.05e-002
1.40e-002
1.75e-002
2.10e-002
2.45e-002
2.80e-002
3.15e-002
3.50e-002
3.85e-002
4.20e-002
4.55e-002
4.90e-002
5.25e-002
5.60e-002
5.95e-002
6.30e-002
6.65e-002
7.00e-002
-290
-295
-300
-305
-310
1830
1835
1840
1845
1850
1855
1860
1865
Project
MSEW Design
Analysis Description
Design 61
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/04/07, 07:44:15 P9
File Name
MSE Wall Design 61.fez
INTERPRET 8.005

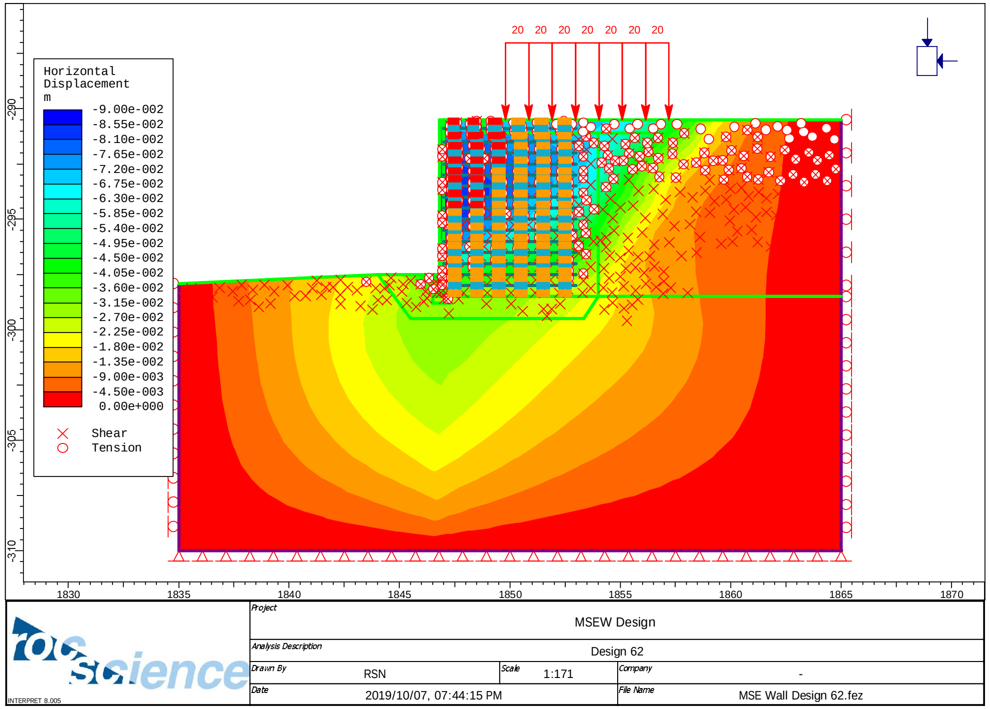

20 20 20 20 20 20 20
Total Displacement m
0.00e+000
5.50e-003
1.10e-002
1.65e-002
2.20e-002
2.75e-002
3.30e-002
3.85e-002
4.40e-002
4.95e-002
5.50e-002
6.05e-002
6.60e-002
7.15e-002
7.70e-002
8.25e-002
8.80e-002
9.35e-002
9.90e-002
1.04e-001
1.10e-001
Shear
Tension
-290
-295
-300
-305
-310
1830
1835
1840
1845
1850
1855
1860
1865
Project
MSEW Design
Analysis Description
Design 61
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/04/07, 07:44:15 P9
File Name
MSE Wall Design 61.fez
INTERPRET 8.005


Sigma Z
kPa
0.00
15.00
30.00
45.00
60.00
75.00
90.00
105.00
120.00
135.00
150.00
165.00
180.00
195.00
210.00
225.00
240.00
255.00
270.00
285.00
300.00
Shear
Tension
20 20 20 20 20 20 20
Project
MSEW Design
Analysis Description
Design 62
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 62.fez

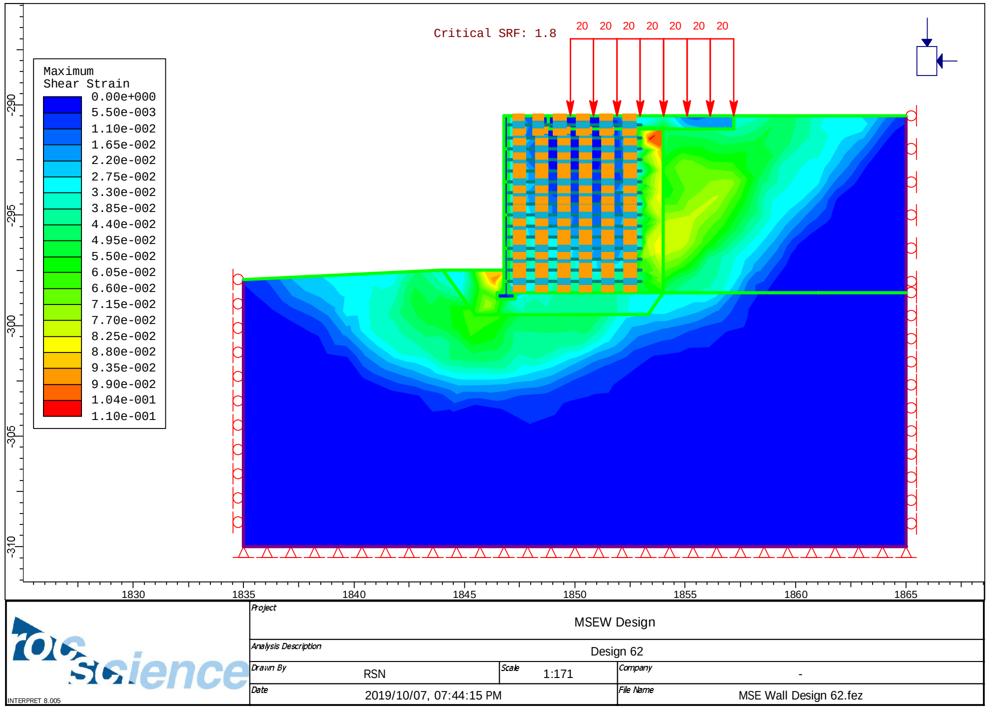

Maximum
Shear Strain
0.00e+000
9.50e-004
1.90e-003
2.85e-003
3.80e-003
4.75e-003
5.70e-003
6.65e-003
7.60e-003
8.55e-003
9.50e-003
1.05e-002
1.14e-002
1.24e-002
1.33e-002
1.42e-002
1.52e-002
1.61e-002
1.71e-002
1.81e-002
1.90e-002
Shear
Tension
20 20 20 20 20 20 20
Project
MSEW Design
Analysis Description
Design 62
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 62.fez


Mean Stress
kPa
0.00
15.00
30.00
45.00
60.00
75.00
90.00
105.00
120.00
135.00
150.00
165.00
180.00
195.00
210.00
225.00
240.00
255.00
270.00
285.00
300.00
Shear
Tension
20 20 20 20 20 20 20
Project
MSEW Design
Analysis Description
Design 62
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 62.fez

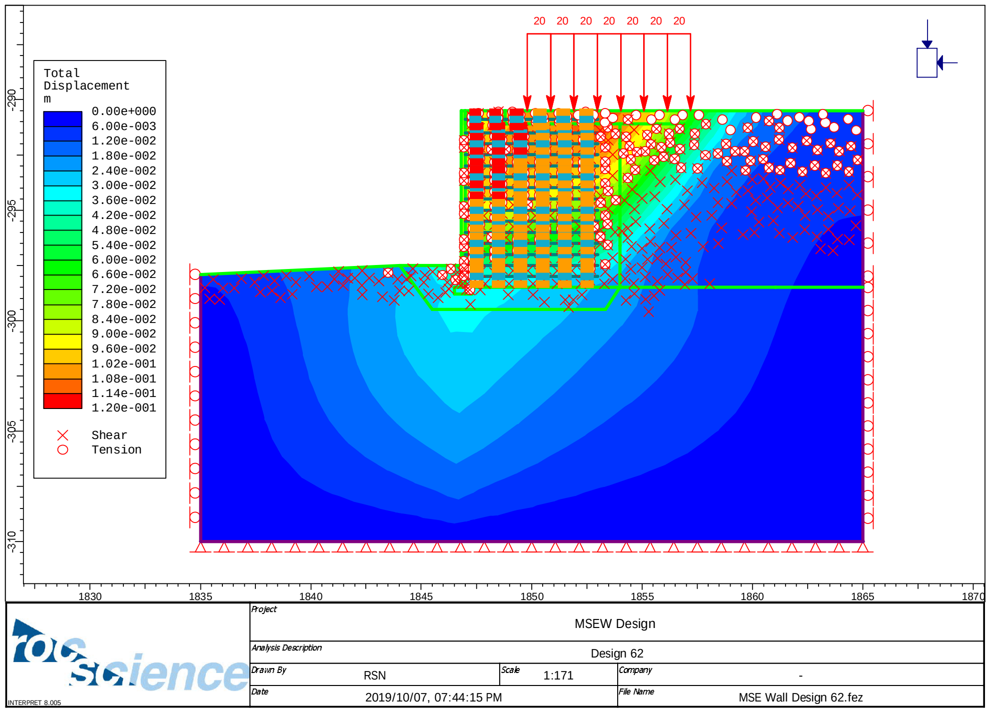

Vertical
Displacement
m
-9.00e-002
-8.45e-002
-7.90e-002
-7.35e-002
-6.80e-002
-6.25e-002
-5.70e-002
-5.15e-002
-4.60e-002
-4.05e-002
-3.50e-002
-2.95e-002
-2.40e-002
-1.85e-002
-1.30e-002
-7.50e-003
-2.00e-003
3.50e-003
9.00e-003
1.45e-002
2.00e-002
Shear
Tension
20 20 20 20 20 20 20
Project
MSEW Design
Analysis Description
Design 62
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 62.fez



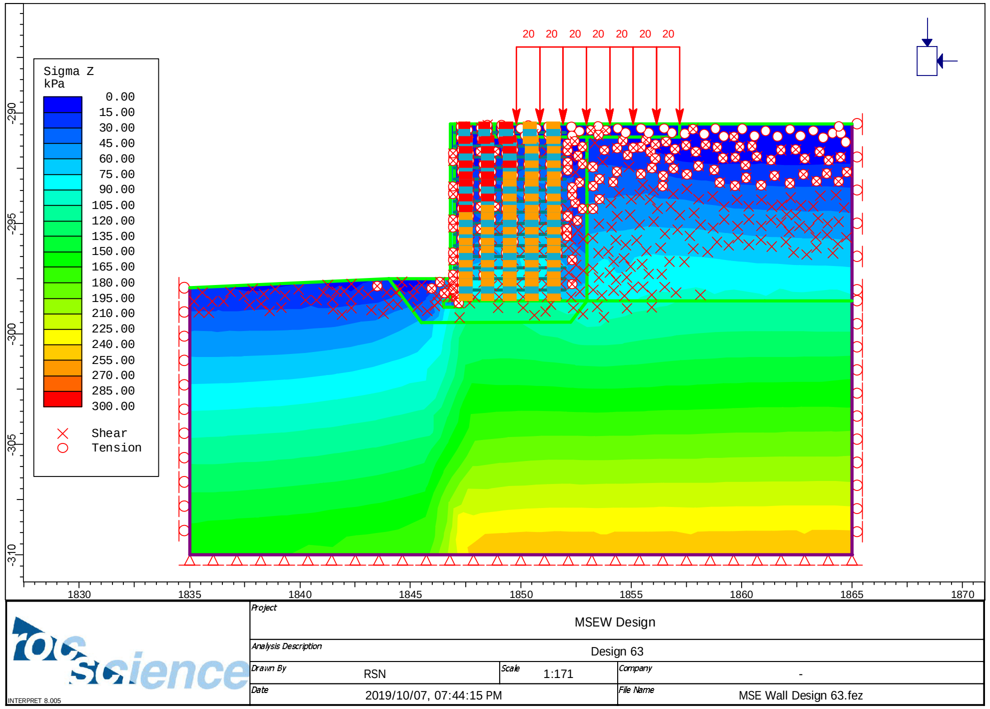
Horizontal Displacement m
-9.00e-002
-8.55e-002
-8.10e-002
-7.65e-002
-7.20e-002
-6.75e-002
-6.30e-002
-5.85e-002
-5.40e-002
-4.95e-002
-4.50e-002
-4.05e-002
-3.60e-002
-3.15e-002
-2.70e-002
-2.25e-002
-1.80e-002
-1.35e-002
-9.00e-003
-4.50e-003
0.00e+000
Shear
Tension
20 20 20 20 20 20 20
Project MSEW Design
Analysis Description Design 62
Drawn By RSN
Scale 1:171
Company -
Date 2019/10/07, 07:44:15 PM
File Name MSE Wall Design 62.fez
INTERPRET 8.005

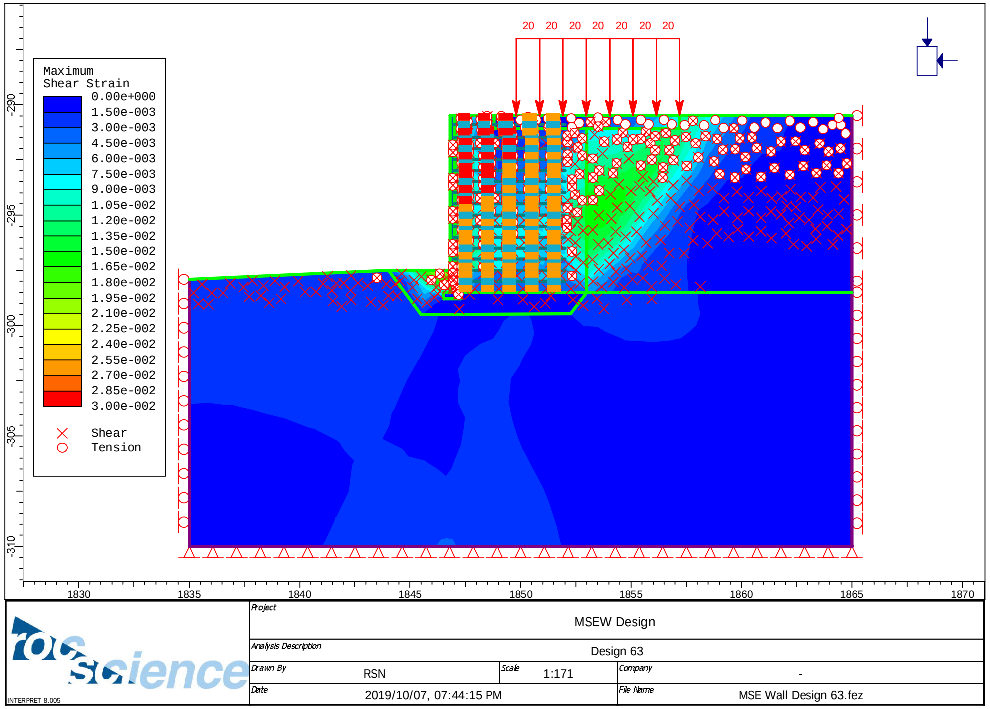


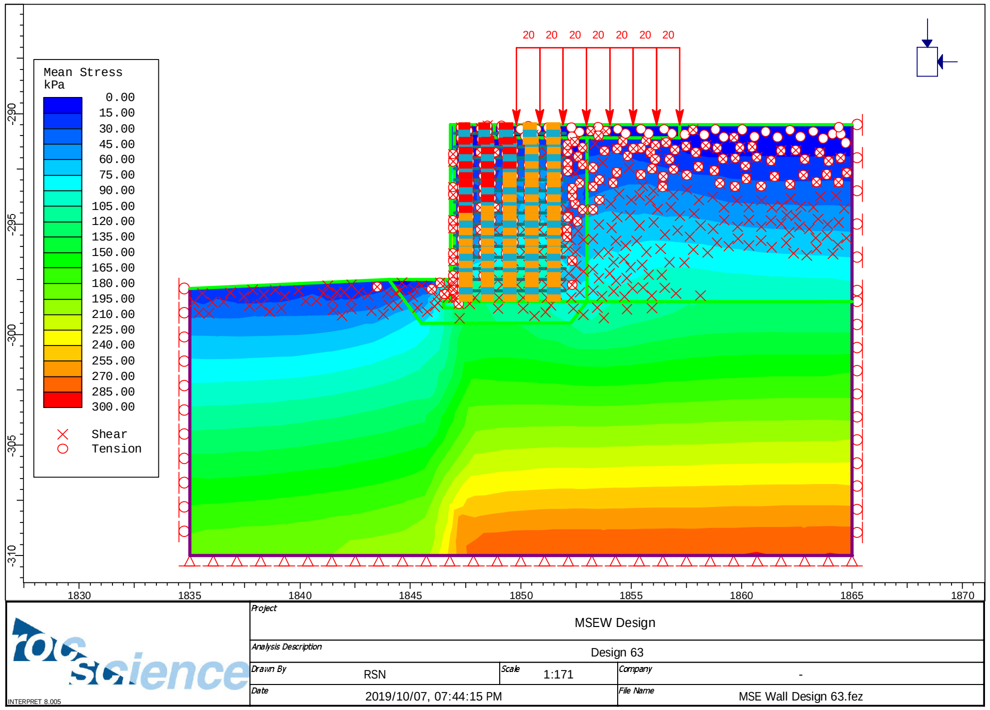
Maximum Shear Strain
0.00e+000
5.50e-003
1.10e-002
1.65e-002
2.20e-002
2.75e-002
3.30e-002
3.85e-002
4.40e-002
4.95e-002
5.50e-002
6.05e-002
6.60e-002
7.15e-002
7.70e-002
8.25e-002
8.80e-002
9.35e-002
9.90e-002
1.04e-001
1.10e-001
Critical SRF: 1.8
20 20 20 20 20 20 20
Project MSEW Design
Analysis Description Design 62
Drawn By RSN
Scale 1:171
Company -
Date 2019/10/07, 07:44:15 PM
File Name MSE Wall Design 62.fez
INTERPRET 8.005

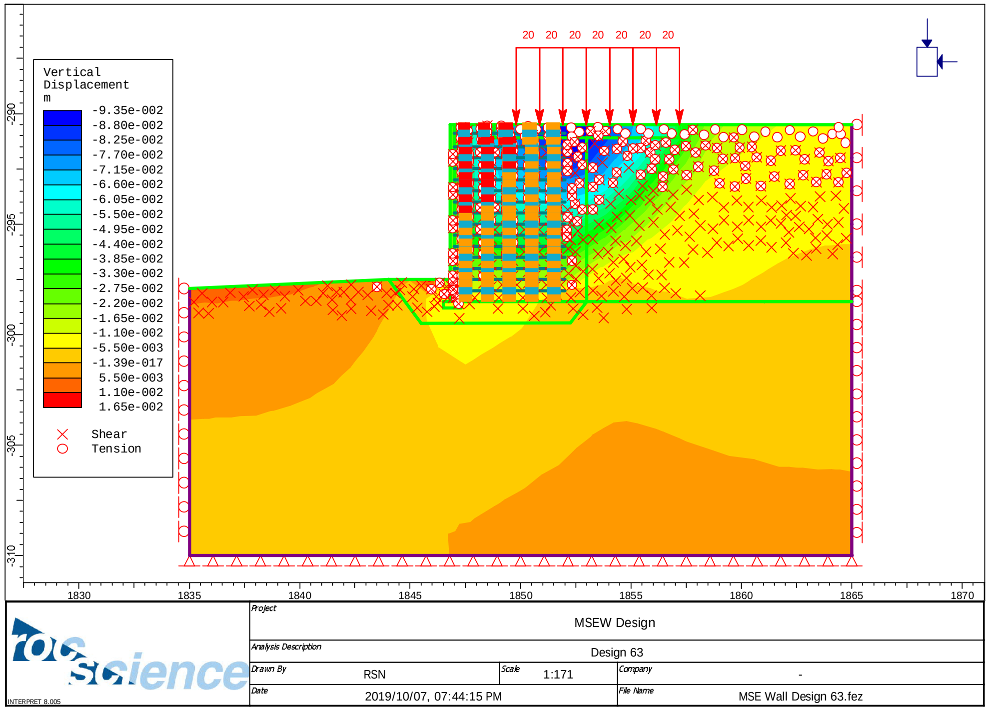


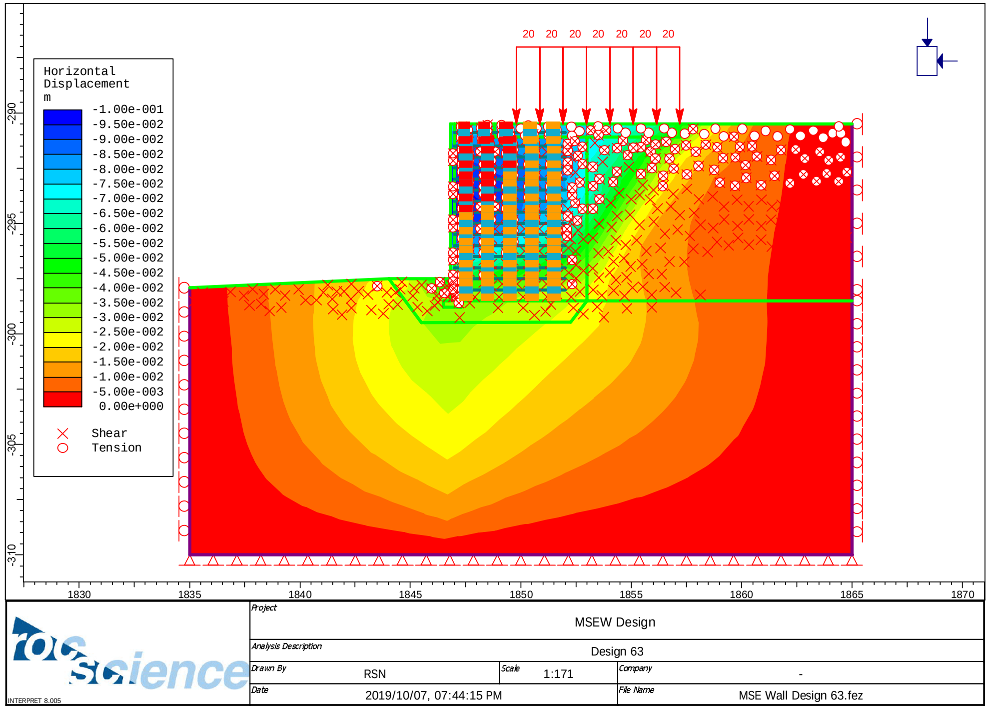
Total Displacement m
0.00e+000
6.00e-003
1.20e-002
1.80e-002
2.40e-002
3.00e-002
3.60e-002
4.20e-002
4.80e-002
5.40e-002
6.00e-002
6.60e-002
7.20e-002
7.80e-002
8.40e-002
9.00e-002
9.60e-002
1.02e-001
1.08e-001
1.14e-001
1.20e-001
Shear
Tension
20 20 20 20 20 20 20
Project MSEW Design
Analysis Description Design 62
Drawn By RSN
Scale 1:171
Company -
Date 2019/10/07, 07:44:15 PM
File Name MSE Wall Design 62.fez
INTERPRET 8.005

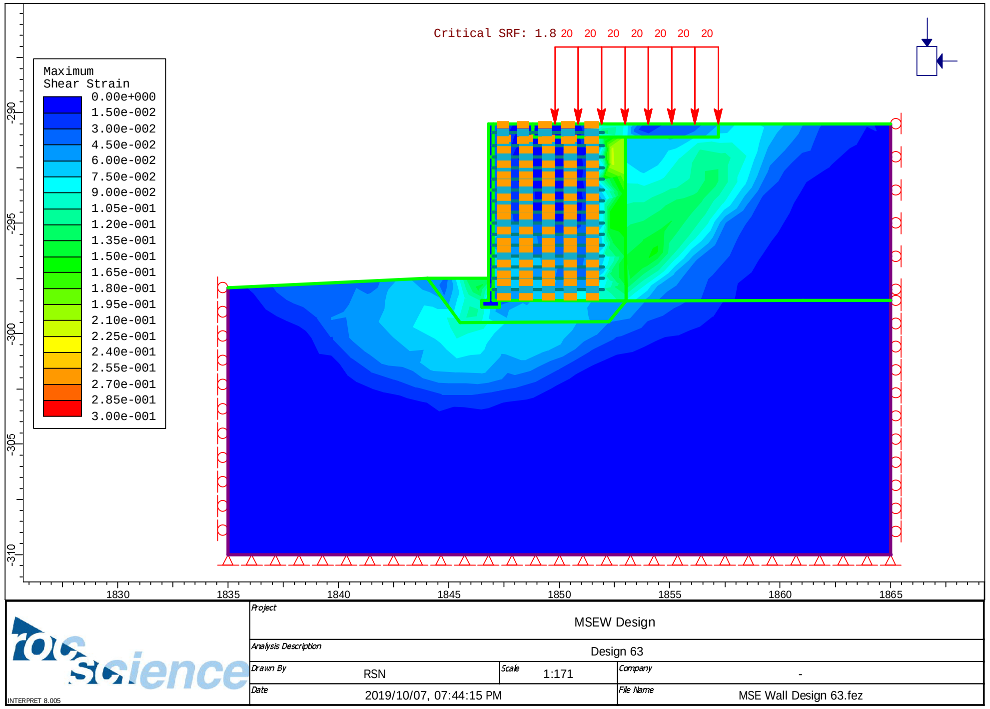

Sigma Z
kPa
0.00
15.00
30.00
45.00
60.00
75.00
90.00
105.00
120.00
135.00
150.00
165.00
180.00
195.00
210.00
225.00
240.00
255.00
270.00
285.00
300.00
Shear
Tension
Project
MSEW Design
Analysis Description
Design 63
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 63.fez
INTERPRET 8.005

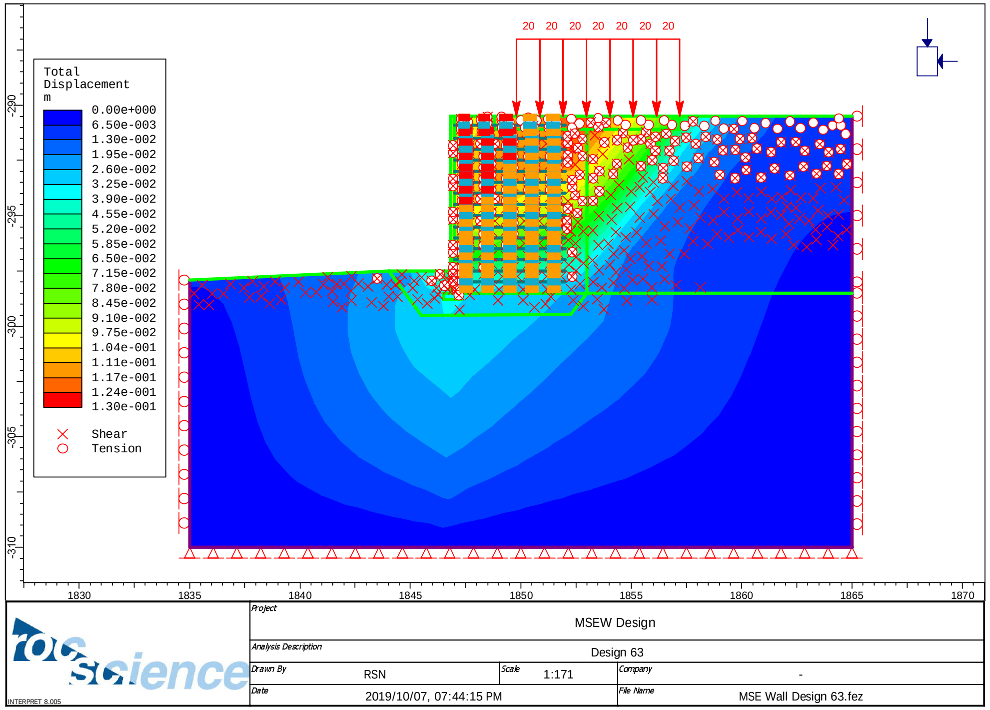

Maximum
Shear Strain
0.00e+000
1.50e-003
3.00e-003
4.50e-003
6.00e-003
7.50e-003
9.00e-003
1.05e-002
1.20e-002
1.35e-002
1.50e-002
1.65e-002
1.80e-002
1.95e-002
2.10e-002
2.25e-002
2.40e-002
2.55e-002
2.70e-002
2.85e-002
3.00e-002
Shear
Tension
Project
MSEW Design
Analysis Description
Design 63
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 63.fez
INTERPRET 8.005

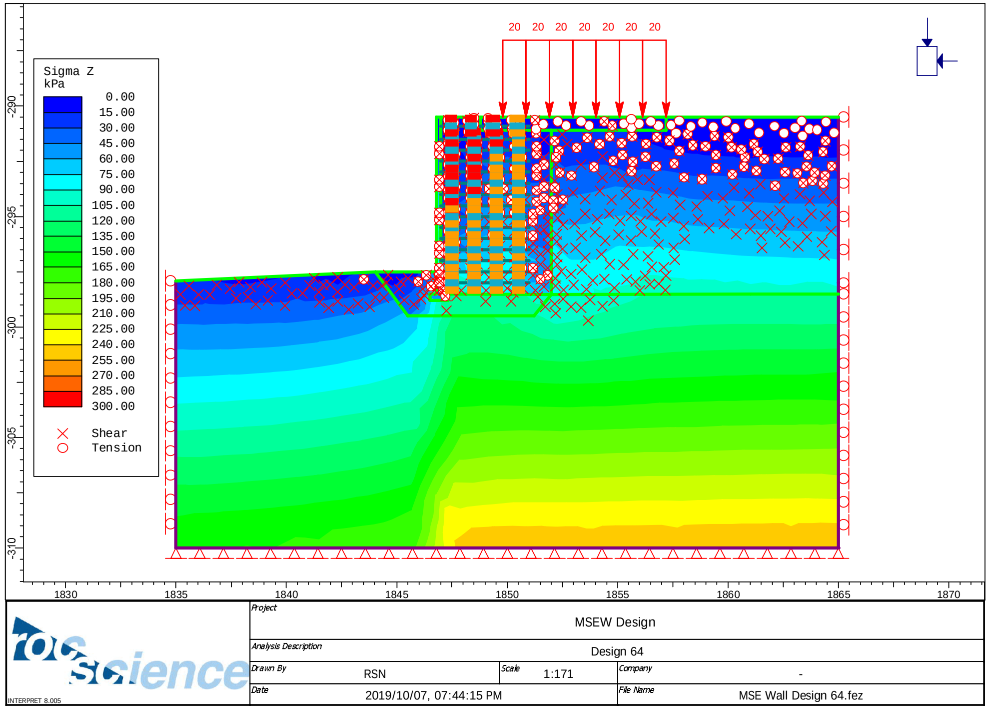

Mean Stress
kPa
0.00
15.00
30.00
45.00
60.00
75.00
90.00
105.00
120.00
135.00
150.00
165.00
180.00
195.00
210.00
225.00
240.00
255.00
270.00
285.00
300.00
Shear
Tension
Project
MSEW Design
Analysis Description
Design 63
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 63.fez
INTERPRET 8.005

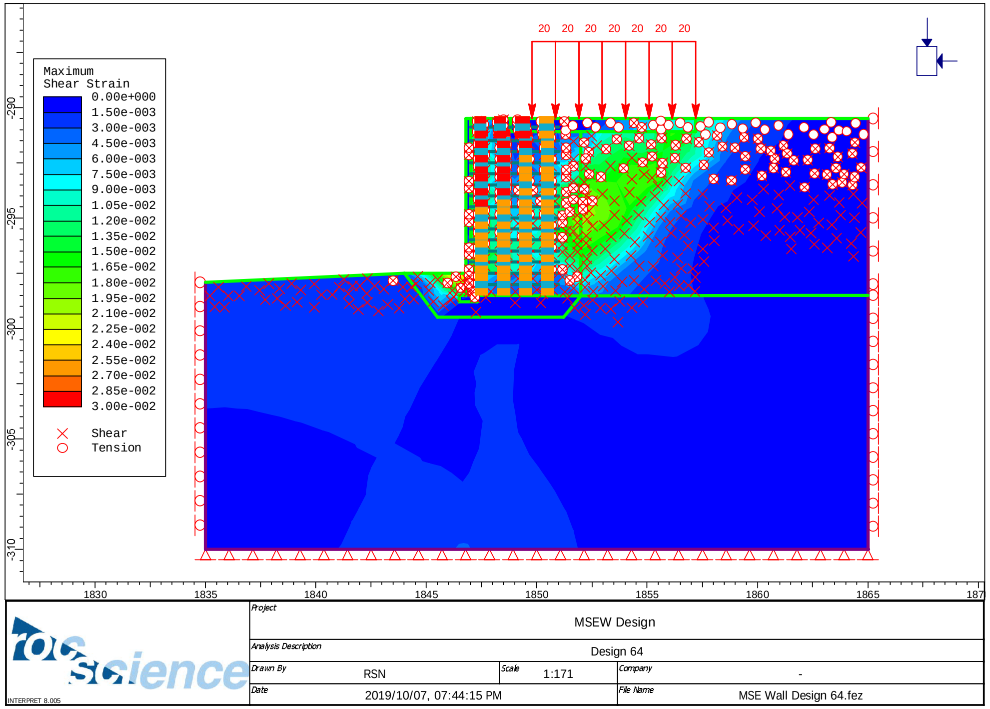

Vertical
Displacement
m
-9.35e-002
-8.80e-002
-8.25e-002
-7.70e-002
-7.15e-002
-6.60e-002
-6.05e-002
-5.50e-002
-4.95e-002
-4.40e-002
-3.85e-002
-3.30e-002
-2.75e-002
-2.20e-002
-1.65e-002
-1.10e-002
-5.50e-003
-1.39e-017
5.50e-003
1.10e-002
1.65e-002
Shear
Tension
Project
MSEW Design
Analysis Description
Design 63
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 63.fez
INTERPRET 8.005

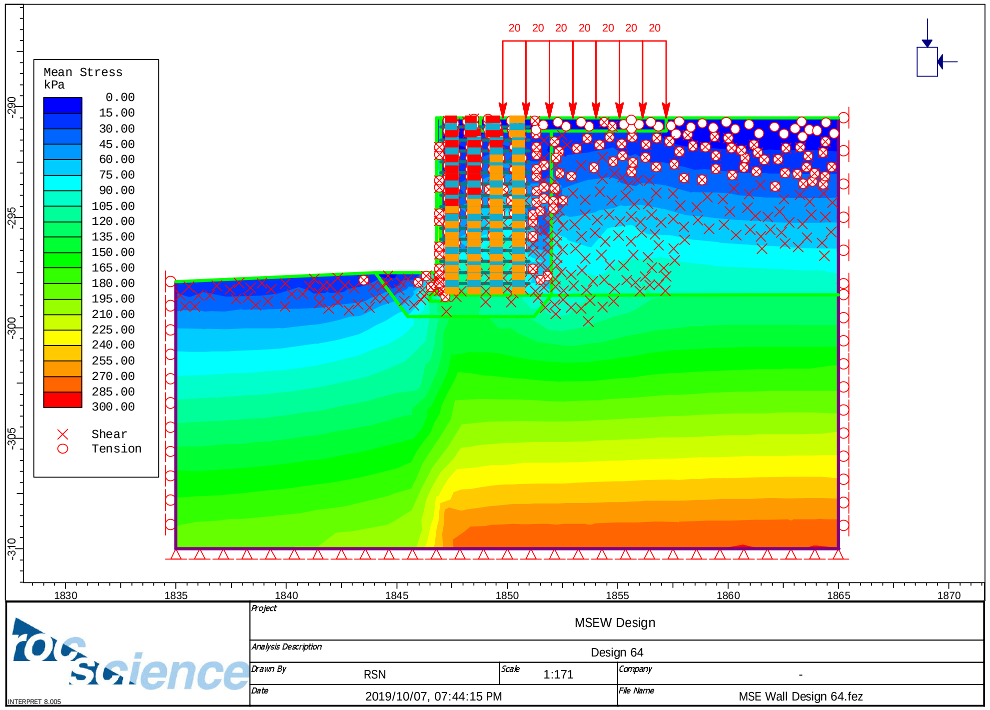

Horizontal Displacement m
-1.00e-001
-9.50e-002
-9.00e-002
-8.50e-002
-8.00e-002
-7.50e-002
-7.00e-002
-6.50e-002
-6.00e-002
-5.50e-002
-5.00e-002
-4.50e-002
-4.00e-002
-3.50e-002
-3.00e-002
-2.50e-002
-2.00e-002
-1.50e-002
-1.00e-002
-5.00e-003
0.00e+000
Shear
Tension
20 20 20 20 20 20 20
Project: MSEW Design
Analysis Description: Design 63
Drawn By: RSN
Scale: 1:171
Company: -
Date: 2019/10/07, 07:44:15 PM
File Name: MSE Wall Design 63.fez
INTERPRET 8.005

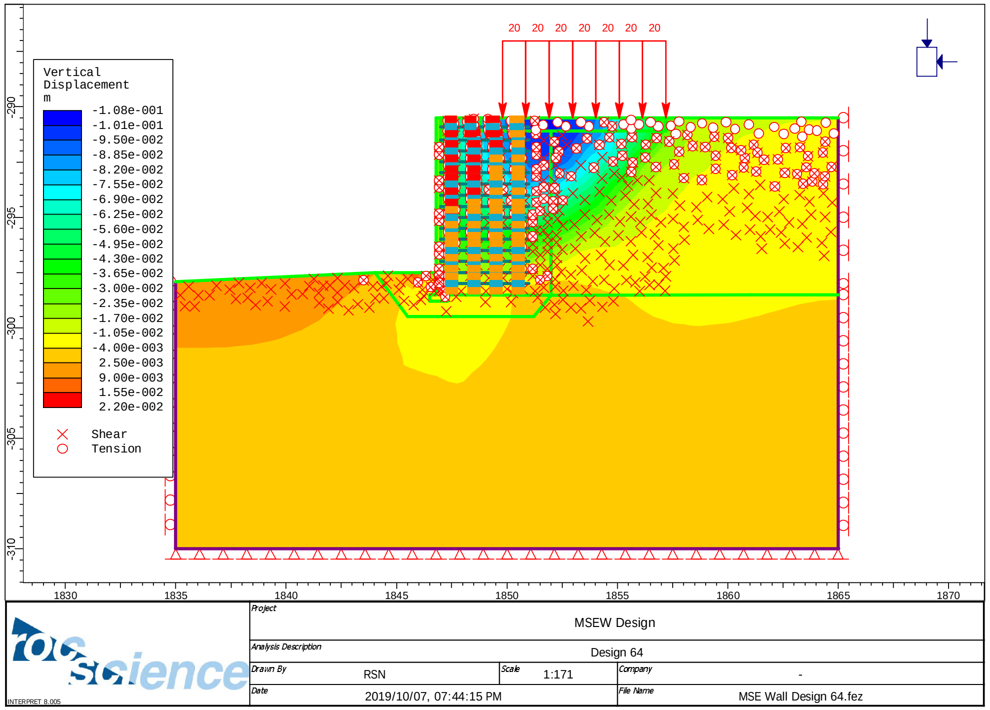

Maximum Shear Strain
0.00e+000
1.50e-002
3.00e-002
4.50e-002
6.00e-002
7.50e-002
9.00e-002
1.05e-001
1.20e-001
1.35e-001
1.50e-001
1.65e-001
1.80e-001
1.95e-001
2.10e-001
2.25e-001
2.40e-001
2.55e-001
2.70e-001
2.85e-001
3.00e-001
Critical SRF: 1.8
20 20 20 20 20 20 20
Project: MSEW Design
Analysis Description: Design 63
Drawn By: RSN
Scale: 1:171
Company: -
Date: 2019/10/07, 07:44:15 PM
File Name: MSE Wall Design 63.fez
INTERPRET 8.005

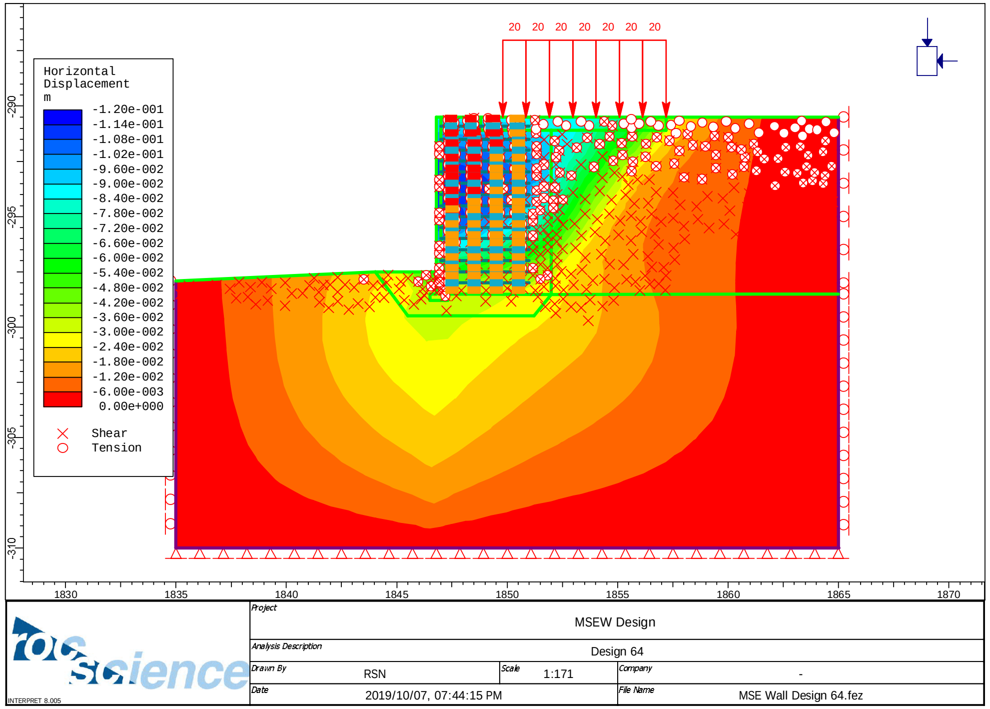

Total Displacement m
0.00e+000
6.50e-003
1.30e-002
1.95e-002
2.60e-002
3.25e-002
3.90e-002
4.55e-002
5.20e-002
5.85e-002
6.50e-002
7.15e-002
7.80e-002
8.45e-002
9.10e-002
9.75e-002
1.04e-001
1.11e-001
1.17e-001
1.24e-001
1.30e-001
Shear
Tension
20 20 20 20 20 20 20
Project: MSEW Design
Analysis Description: Design 63
Drawn By: RSN
Scale: 1:171
Company: -
Date: 2019/10/07, 07:44:15 PM
File Name: MSE Wall Design 63.fez
INTERPRET 8.005

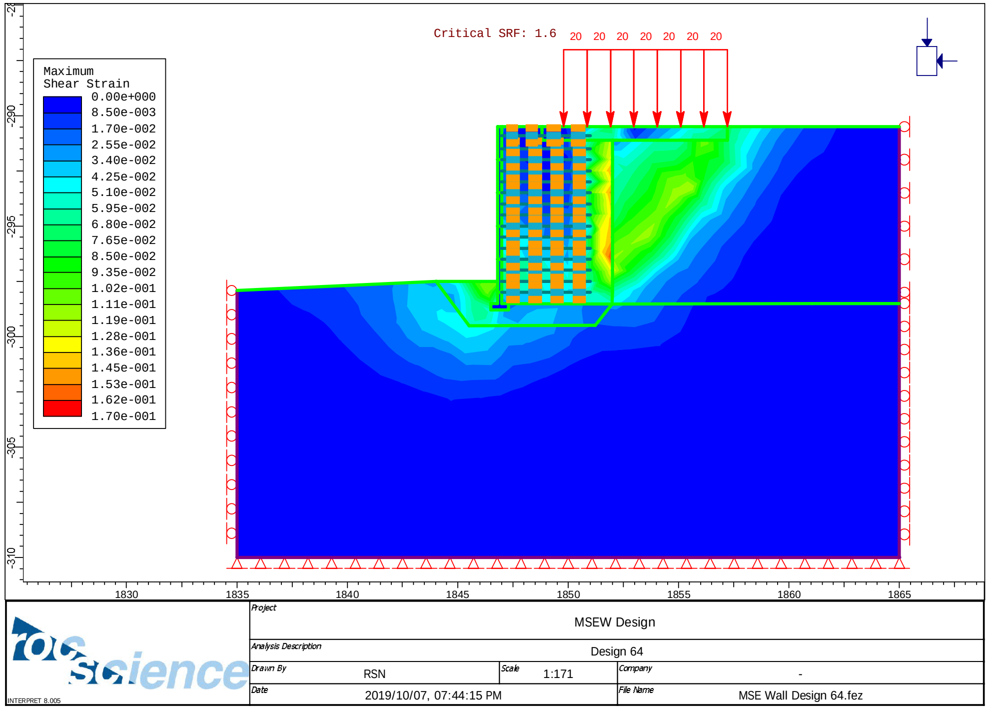

Sigma Z
kPa
0.00
15.00
30.00
45.00
60.00
75.00
90.00
105.00
120.00
135.00
150.00
165.00
180.00
195.00
210.00
225.00
240.00
255.00
270.00
285.00
300.00
Shear
Tension
20 20 20 20 20 20 20
-290
-295
-300
-305
-310
1830 1835 1840 1845 1850 1855 1860 1865 1870
rocscience
Project MSEW Design
Analysis Description Design 64
Drawn By RSN
Scale 1:171
Company -
Date 2019/10/07, 07:44:15 PM
File Name MSE Wall Design 64.fez
INTERPRET 8.005

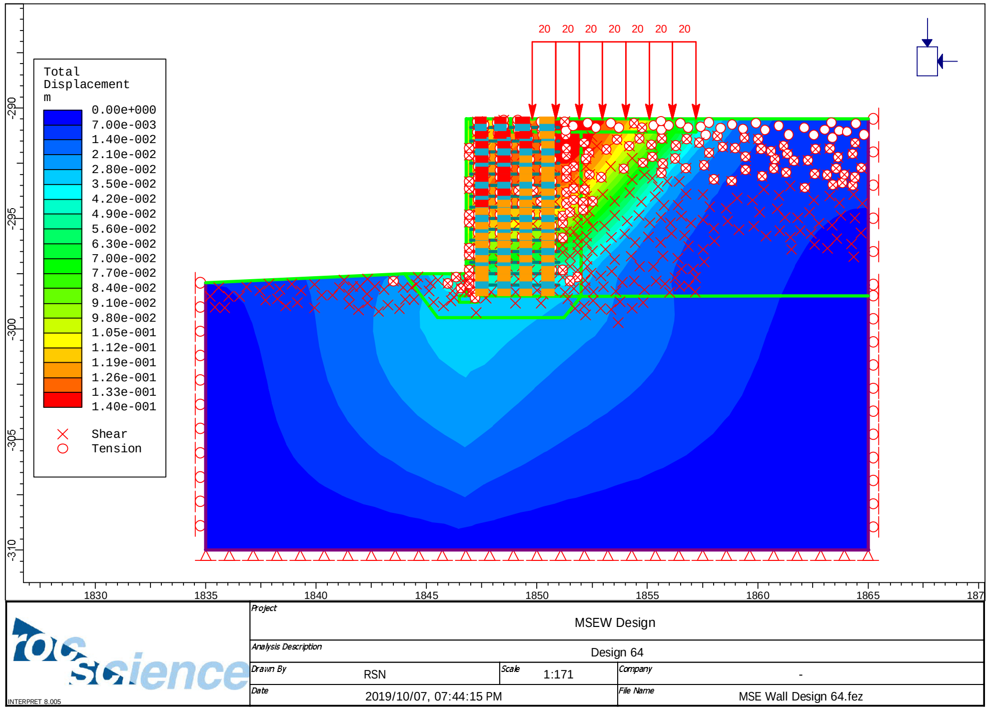

Maximum
Shear Strain
0.00e+000
1.50e-003
3.00e-003
4.50e-003
6.00e-003
7.50e-003
9.00e-003
1.05e-002
1.20e-002
1.35e-002
1.50e-002
1.65e-002
1.80e-002
1.95e-002
2.10e-002
2.25e-002
2.40e-002
2.55e-002
2.70e-002
2.85e-002
3.00e-002
Shear
Tension
20 20 20 20 20 20 20
-290
-295
-300
-305
-310
1830 1835 1840 1845 1850 1855 1860 1865 187
rocscience
Project MSEW Design
Analysis Description Design 64
Drawn By RSN
Scale 1:171
Company -
Date 2019/10/07, 07:44:15 PM
File Name MSE Wall Design 64.fez
INTERPRET 8.005

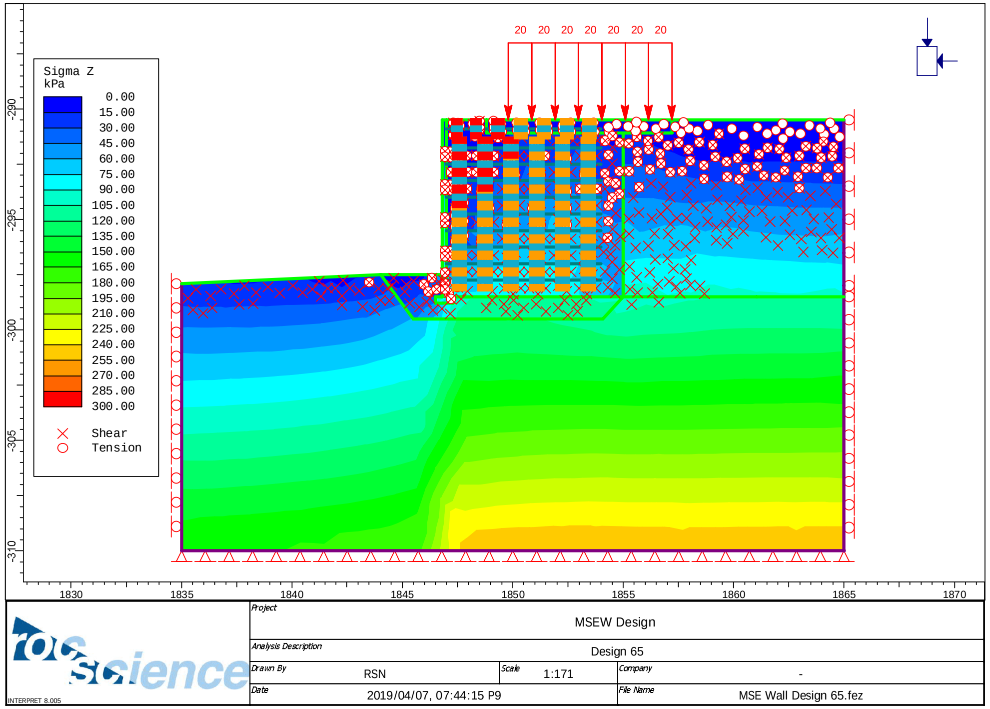

Mean Stress
kPa
0.00
15.00
30.00
45.00
60.00
75.00
90.00
105.00
120.00
135.00
150.00
165.00
180.00
195.00
210.00
225.00
240.00
255.00
270.00
285.00
300.00
Shear
Tension
20 20 20 20 20 20 20
-290
-295
-300
-305
-310
1830 1835 1840 1845 1850 1855 1860 1865 1870
rocscience
Project MSEW Design
Analysis Description Design 64
Drawn By RSN
Scale 1:171
Company -
Date 2019/10/07, 07:44:15 PM
File Name MSE Wall Design 64.fez
INTERPRET 8.005

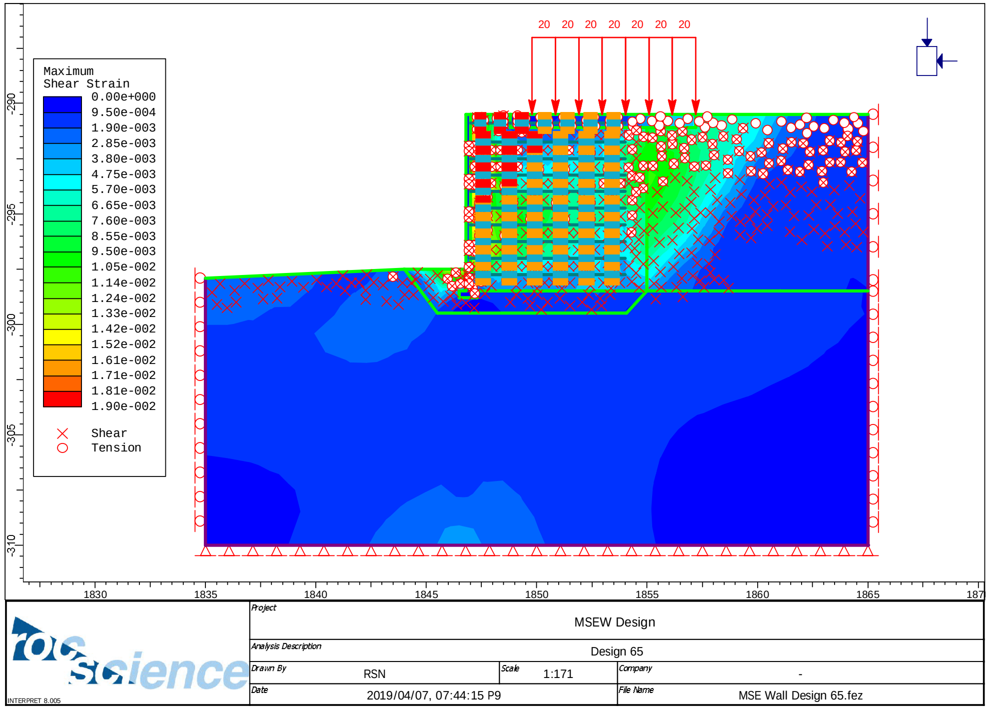

Vertical
Displacement
m
-1.08e-001
-1.01e-001
-9.50e-002
-8.85e-002
-8.20e-002
-7.55e-002
-6.90e-002
-6.25e-002
-5.60e-002
-4.95e-002
-4.30e-002
-3.65e-002
-3.00e-002
-2.35e-002
-1.70e-002
-1.05e-002
-4.00e-003
2.50e-003
9.00e-003
1.55e-002
2.20e-002
Shear
Tension
20 20 20 20 20 20 20
-290
-295
-300
-305
-310
1830 1835 1840 1845 1850 1855 1860 1865 1870
rocscience
Project MSEW Design
Analysis Description Design 64
Drawn By RSN
Scale 1:171
Company -
Date 2019/10/07, 07:44:15 PM
File Name MSE Wall Design 64.fez
INTERPRET 8.005

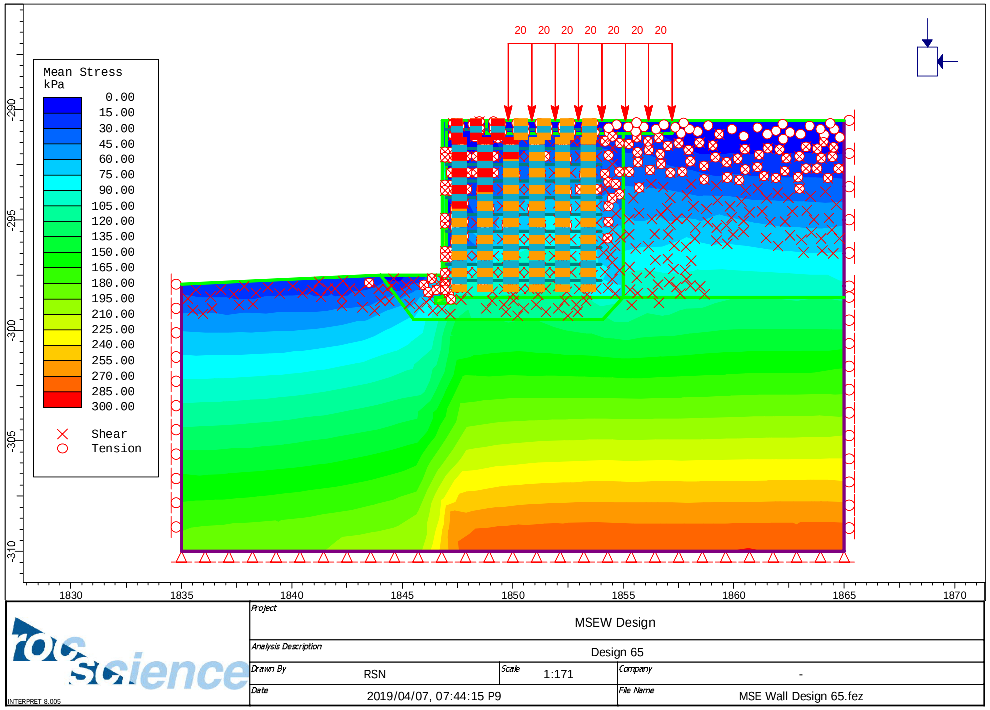

20 20 20 20 20 20 20
Horizontal Displacement
m
-1.20e-001
-1.14e-001
-1.08e-001
-1.02e-001
-9.60e-002
-9.00e-002
-8.40e-002
-7.80e-002
-7.20e-002
-6.60e-002
-6.00e-002
-5.40e-002
-4.80e-002
-4.20e-002
-3.60e-002
-3.00e-002
-2.40e-002
-1.80e-002
-1.20e-002
-6.00e-003
0.00e+000
Shear
Tension
-290
-295
-300
-305
-310
1830
1835
1840
1845
1850
1855
1860
1865
1870
Project
MSEW Design
Analysis Description
Design 64
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 64.fez
INTERPRET 8.005

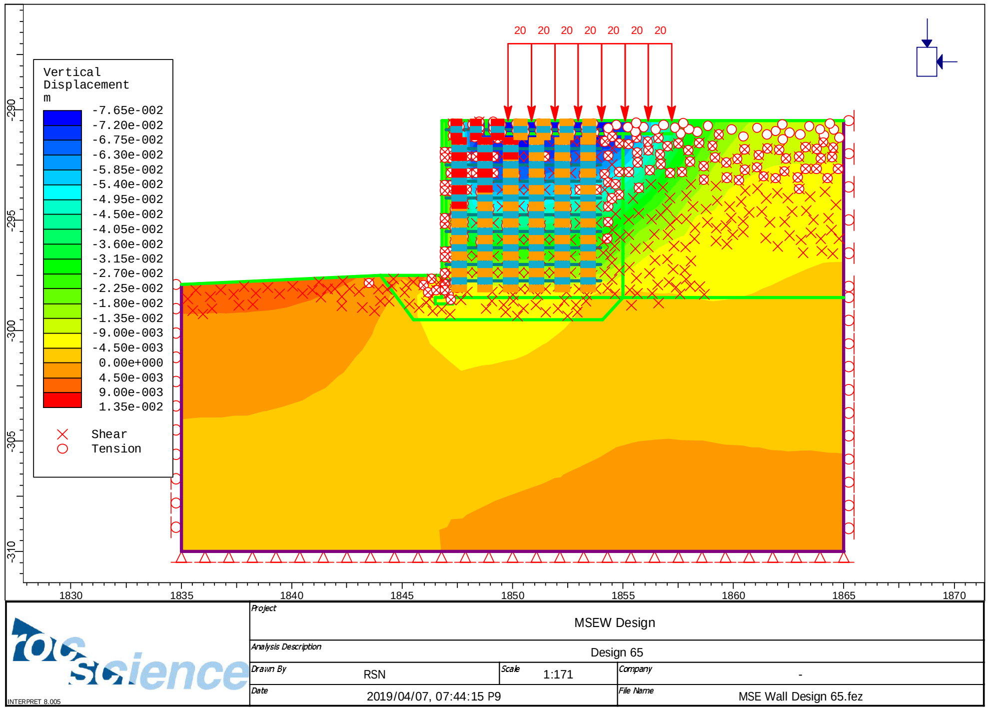

Critical SRF: 1.6
20 20 20 20 20 20 20
Maximum Shear Strain
0.00e+000
8.50e-003
1.70e-002
2.55e-002
3.40e-002
4.25e-002
5.10e-002
5.95e-002
6.80e-002
7.65e-002
8.50e-002
9.35e-002
1.02e-001
1.11e-001
1.19e-001
1.28e-001
1.36e-001
1.45e-001
1.53e-001
1.62e-001
1.70e-001
-290
-295
-300
-305
-310
1830
1835
1840
1845
1850
1855
1860
1865
Project
MSEW Design
Analysis Description
Design 64
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 64.fez
INTERPRET 8.005

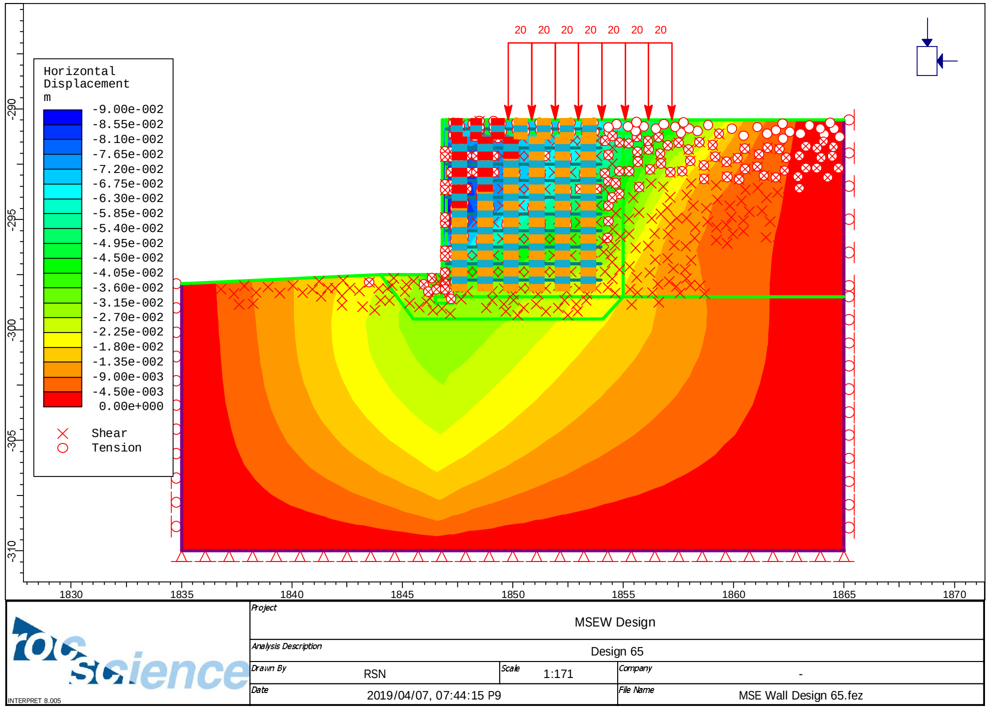

20 20 20 20 20 20 20
Total Displacement
m
0.00e+000
7.00e-003
1.40e-002
2.10e-002
2.80e-002
3.50e-002
4.20e-002
4.90e-002
5.60e-002
6.30e-002
7.00e-002
7.70e-002
8.40e-002
9.10e-002
9.80e-002
1.05e-001
1.12e-001
1.19e-001
1.26e-001
1.33e-001
1.40e-001
Shear
Tension
-290
-295
-300
-305
-310
1830
1835
1840
1845
1850
1855
1860
1865
Project
MSEW Design
Analysis Description
Design 64
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 64.fez
INTERPRET 8.005


Sigma Z
kPa
0.00
15.00
30.00
45.00
60.00
75.00
90.00
105.00
120.00
135.00
150.00
165.00
180.00
195.00
210.00
225.00
240.00
255.00
270.00
285.00
300.00
Shear
Tension
20 20 20 20 20 20 20
1830 1835 1840 1845 1850 1855 1860 1865 1870
-290 -295 -300 -305 -310
Project MSEW Design
Analysis Description Design 65
Drawn By RSN
Scale 1:171
Company -
Date 2019/04/07, 07:44:15 P9
File Name MSE Wall Design 65.fez
INTERPRET 8.005

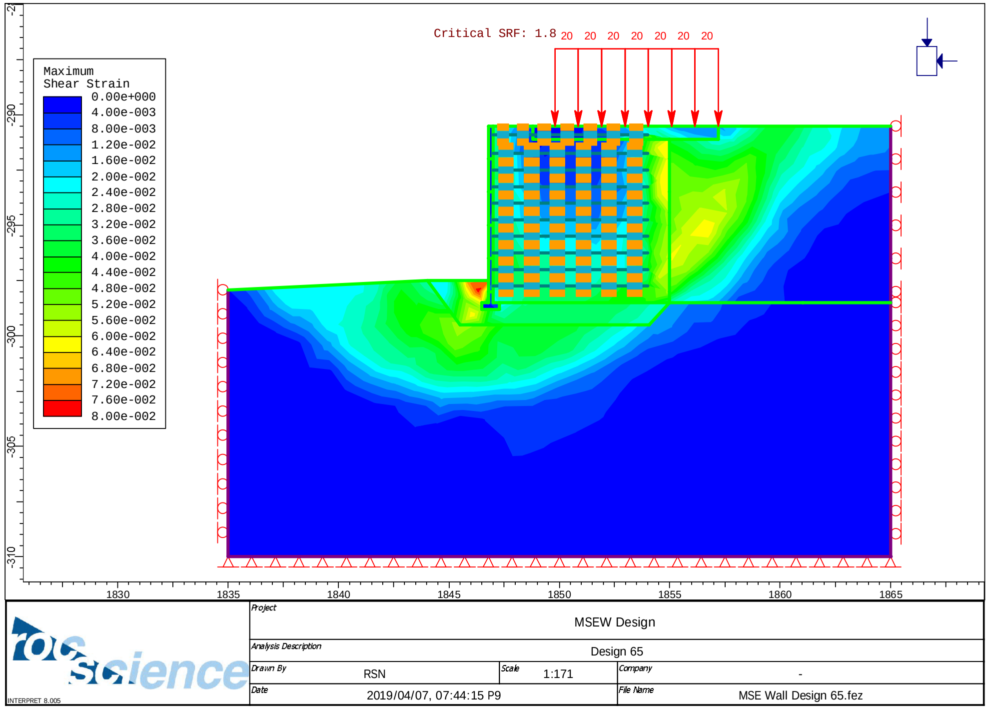

Maximum
Shear Strain
0.00e+000
9.50e-004
1.90e-003
2.85e-003
3.80e-003
4.75e-003
5.70e-003
6.65e-003
7.60e-003
8.55e-003
9.50e-003
1.05e-002
1.14e-002
1.24e-002
1.33e-002
1.42e-002
1.52e-002
1.61e-002
1.71e-002
1.81e-002
1.90e-002
Shear
Tension
20 20 20 20 20 20 20
1830 1835 1840 1845 1850 1855 1860 1865
-290 -295 -300 -305 -310
Project MSEW Design
Analysis Description Design 65
Drawn By RSN
Scale 1:171
Company -
Date 2019/04/07, 07:44:15 P9
File Name MSE Wall Design 65.fez
INTERPRET 8.005


Mean Stress
kPa
0.00
15.00
30.00
45.00
60.00
75.00
90.00
105.00
120.00
135.00
150.00
165.00
180.00
195.00
210.00
225.00
240.00
255.00
270.00
285.00
300.00
Shear
Tension
20 20 20 20 20 20 20
1830 1835 1840 1845 1850 1855 1860 1865 1870
-290 -295 -300 -305 -310
Project MSEW Design
Analysis Description Design 65
Drawn By RSN
Scale 1:171
Company -
Date 2019/04/07, 07:44:15 P9
File Name MSE Wall Design 65.fez
INTERPRET 8.005

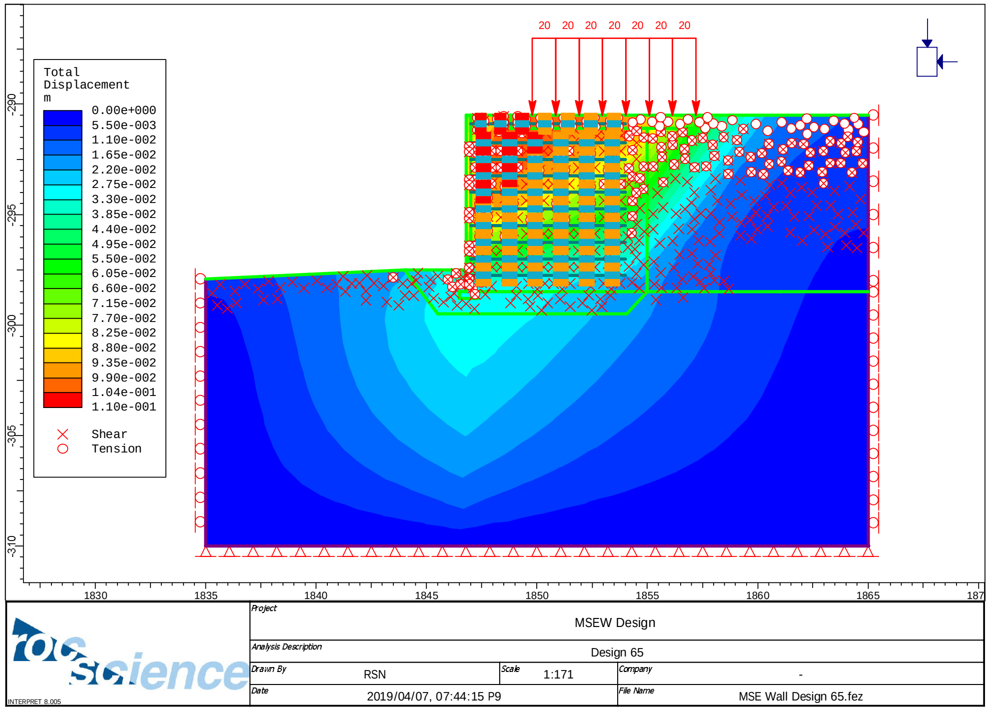

Vertical
Displacement
m
-7.65e-002
-7.20e-002
-6.75e-002
-6.30e-002
-5.85e-002
-5.40e-002
-4.95e-002
-4.50e-002
-4.05e-002
-3.60e-002
-3.15e-002
-2.70e-002
-2.25e-002
-1.80e-002
-1.35e-002
-9.00e-003
-4.50e-003
0.00e+000
4.50e-003
9.00e-003
1.35e-002
Shear
Tension
20 20 20 20 20 20 20
1830 1835 1840 1845 1850 1855 1860 1865 1870
-290 -295 -300 -305 -310
Project MSEW Design
Analysis Description Design 65
Drawn By RSN
Scale 1:171
Company -
Date 2019/04/07, 07:44:15 P9
File Name MSE Wall Design 65.fez
INTERPRET 8.005



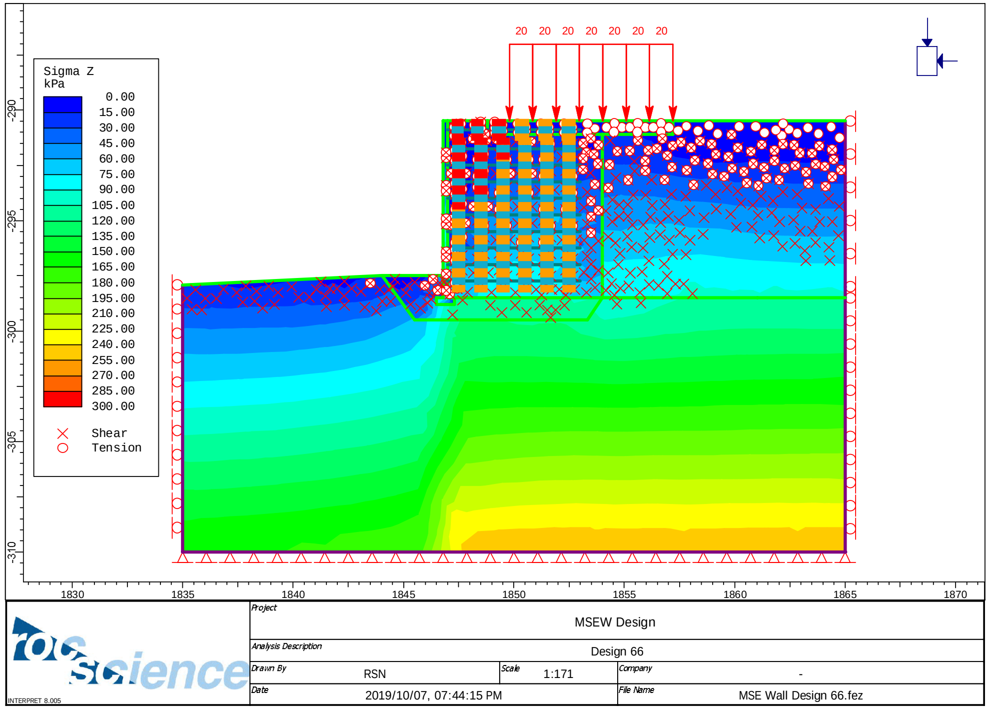
Horizontal Displacement m
-9.00e-002
-8.55e-002
-8.10e-002
-7.65e-002
-7.20e-002
-6.75e-002
-6.30e-002
-5.85e-002
-5.40e-002
-4.95e-002
-4.50e-002
-4.05e-002
-3.60e-002
-3.15e-002
-2.70e-002
-2.25e-002
-1.80e-002
-1.35e-002
-9.00e-003
-4.50e-003
0.00e+000
Shear
Tension
20 20 20 20 20 20 20
1830 1835 1840 1845 1850 1855 1860 1865 1870
-290 -295 -300 -305 -310
Project
MSEW Design
Analysis Description
Design 65
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/04/07, 07:44:15 P9
File Name
MSE Wall Design 65.fez
INTERPRET 8.005

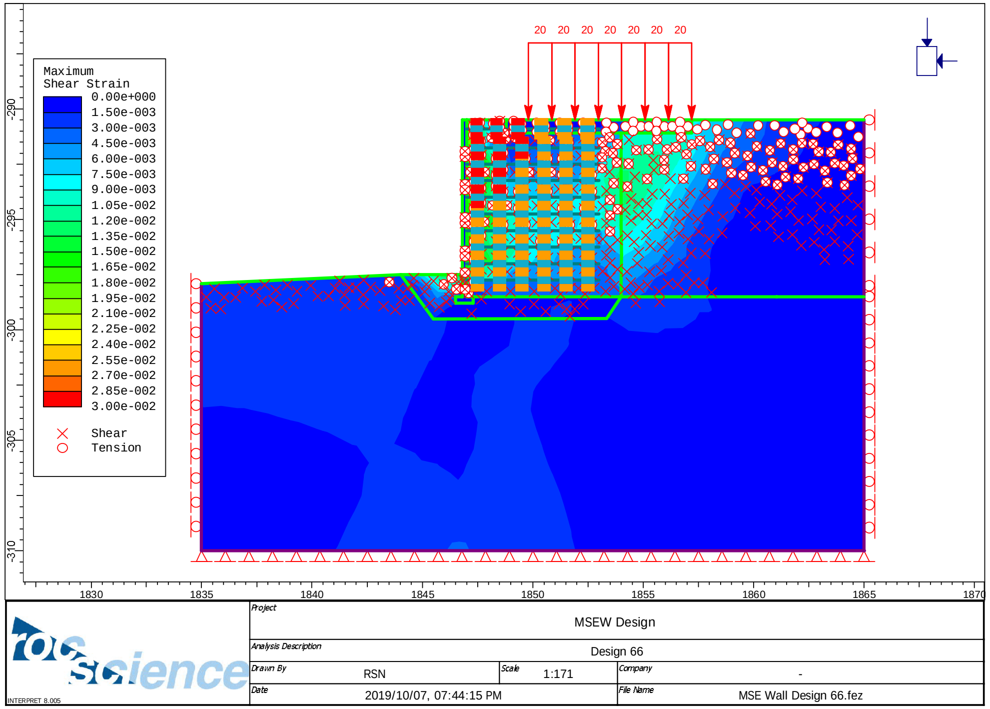


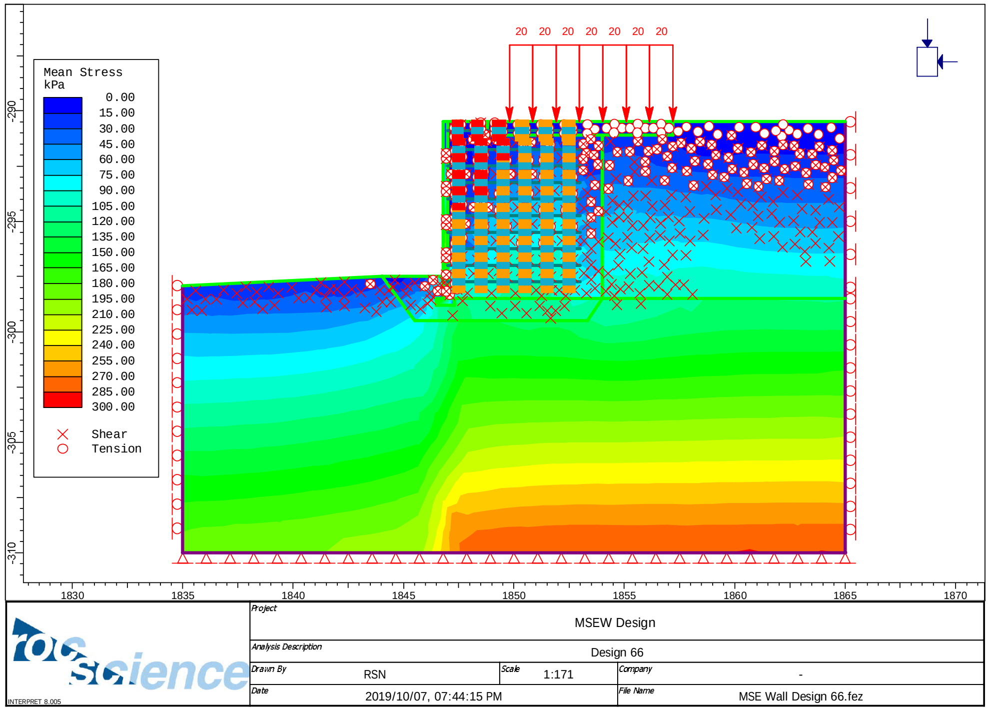
Critical SRF: 1.8
Maximum Shear Strain
0.00e+000
4.00e-003
8.00e-003
1.20e-002
1.60e-002
2.00e-002
2.40e-002
2.80e-002
3.20e-002
3.60e-002
4.00e-002
4.40e-002
4.80e-002
5.20e-002
5.60e-002
6.00e-002
6.40e-002
6.80e-002
7.20e-002
7.60e-002
8.00e-002
20 20 20 20 20 20 20
1830 1835 1840 1845 1850 1855 1860 1865
-290 -295 -300 -305 -310
Project
MSEW Design
Analysis Description
Design 65
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/04/07, 07:44:15 P9
File Name
MSE Wall Design 65.fez
INTERPRET 8.005

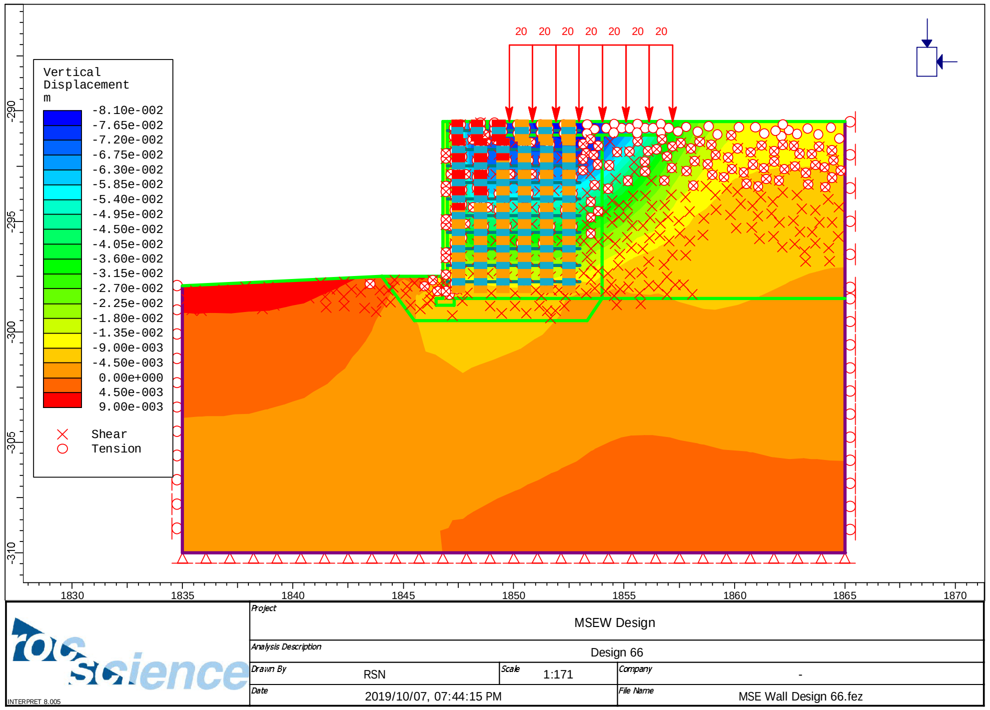


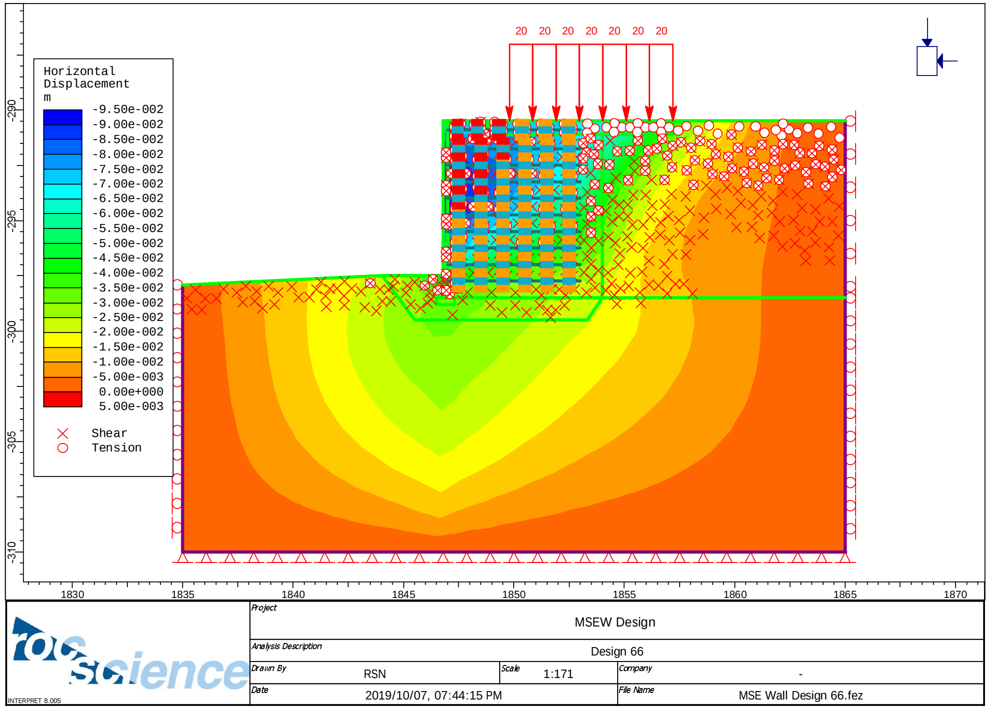
Total Displacement m
0.00e+000
5.50e-003
1.10e-002
1.65e-002
2.20e-002
2.75e-002
3.30e-002
3.85e-002
4.40e-002
4.95e-002
5.50e-002
6.05e-002
6.60e-002
7.15e-002
7.70e-002
8.25e-002
8.80e-002
9.35e-002
9.90e-002
1.04e-001
1.10e-001
Shear
Tension
20 20 20 20 20 20 20
1830 1835 1840 1845 1850 1855 1860 1865
-290 -295 -300 -305 -310
Project
MSEW Design
Analysis Description
Design 65
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/04/07, 07:44:15 P9
File Name
MSE Wall Design 65.fez
INTERPRET 8.005


Sigma Z
kPa
0.00
15.00
30.00
45.00
60.00
75.00
90.00
105.00
120.00
135.00
150.00
165.00
180.00
195.00
210.00
225.00
240.00
255.00
270.00
285.00
300.00
Shear
Tension
20 20 20 20 20 20 20
1830 1835 1840 1845 1850 1855 1860 1865 1870
-290 -295 -300 -305 -310
Project
MSEW Design
Analysis Description
Design 66
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 66.fez
INTERPRET 8.005


Maximum
Shear Strain
0.00e+000
1.50e-003
3.00e-003
4.50e-003
6.00e-003
7.50e-003
9.00e-003
1.05e-002
1.20e-002
1.35e-002
1.50e-002
1.65e-002
1.80e-002
1.95e-002
2.10e-002
2.25e-002
2.40e-002
2.55e-002
2.70e-002
2.85e-002
3.00e-002
Shear
Tension
20 20 20 20 20 20 20
1830 1835 1840 1845 1850 1855 1860 1865 1870
-290 -295 -300 -305 -310
Project
MSEW Design
Analysis Description
Design 66
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 66.fez
INTERPRET 8.005


Mean Stress
kPa
0.00
15.00
30.00
45.00
60.00
75.00
90.00
105.00
120.00
135.00
150.00
165.00
180.00
195.00
210.00
225.00
240.00
255.00
270.00
285.00
300.00
Shear
Tension
20 20 20 20 20 20 20
1830 1835 1840 1845 1850 1855 1860 1865 1870
-290 -295 -300 -305 -310
Project
MSEW Design
Analysis Description
Design 66
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 66.fez
INTERPRET 8.005


Vertical
Displacement
m
-8.10e-002
-7.65e-002
-7.20e-002
-6.75e-002
-6.30e-002
-5.85e-002
-5.40e-002
-4.95e-002
-4.50e-002
-4.05e-002
-3.60e-002
-3.15e-002
-2.70e-002
-2.25e-002
-1.80e-002
-1.35e-002
-9.00e-003
-4.50e-003
0.00e+000
4.50e-003
9.00e-003
Shear
Tension
20 20 20 20 20 20 20
1830 1835 1840 1845 1850 1855 1860 1865 1870
-290 -295 -300 -305 -310
Project
MSEW Design
Analysis Description
Design 66
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 66.fez
INTERPRET 8.005


Horizontal Displacement m
-9.50e-002
-9.00e-002
-8.50e-002
-8.00e-002
-7.50e-002
-7.00e-002
-6.50e-002
-6.00e-002
-5.50e-002
-5.00e-002
-4.50e-002
-4.00e-002
-3.50e-002
-3.00e-002
-2.50e-002
-2.00e-002
-1.50e-002
-1.00e-002
-5.00e-003
0.00e+000
5.00e-003
Shear
Tension
20 20 20 20 20 20 20
Project
MSEW Design
Analysis Description
Design 66
Drawn By
RSN
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1:171
Company
-
Date
2019/10/07, 07:44:15 PM
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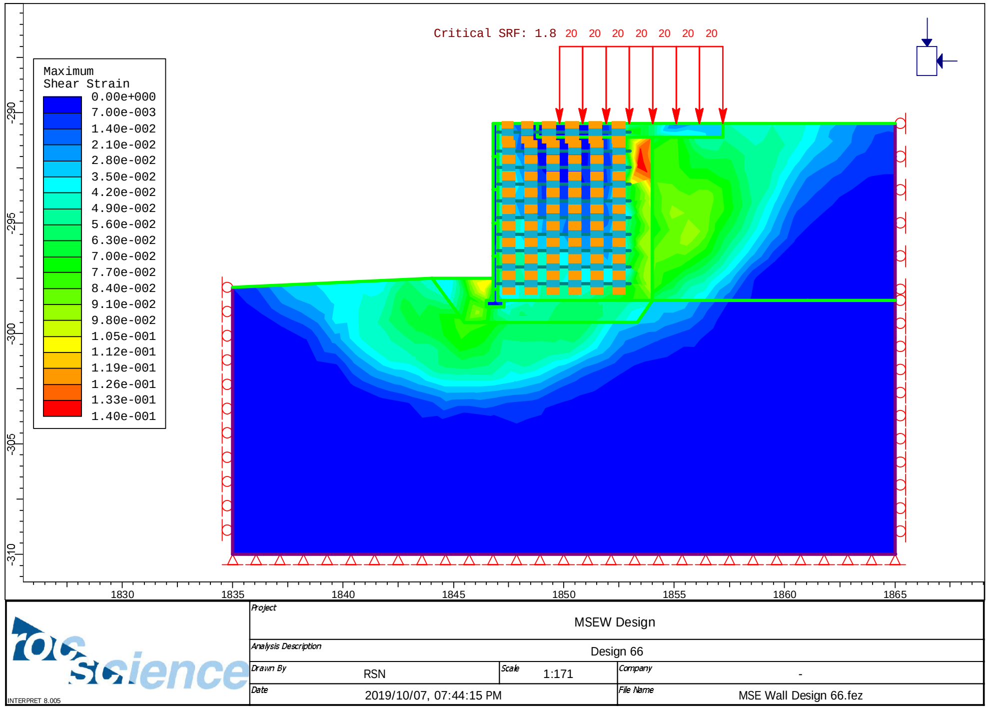
MSE Wall Design 66.fez
INTERPRET 8.005


Maximum Shear Strain
0.00e+000
7.00e-003
1.40e-002
2.10e-002
2.80e-002
3.50e-002
4.20e-002
4.90e-002
5.60e-002
6.30e-002
7.00e-002
7.70e-002
8.40e-002
9.10e-002
9.80e-002
1.05e-001
1.12e-001
1.19e-001
1.26e-001
1.33e-001
1.40e-001
Critical SRF: 1.8
20 20 20 20 20 20 20
Project
MSEW Design
Analysis Description
Design 66
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
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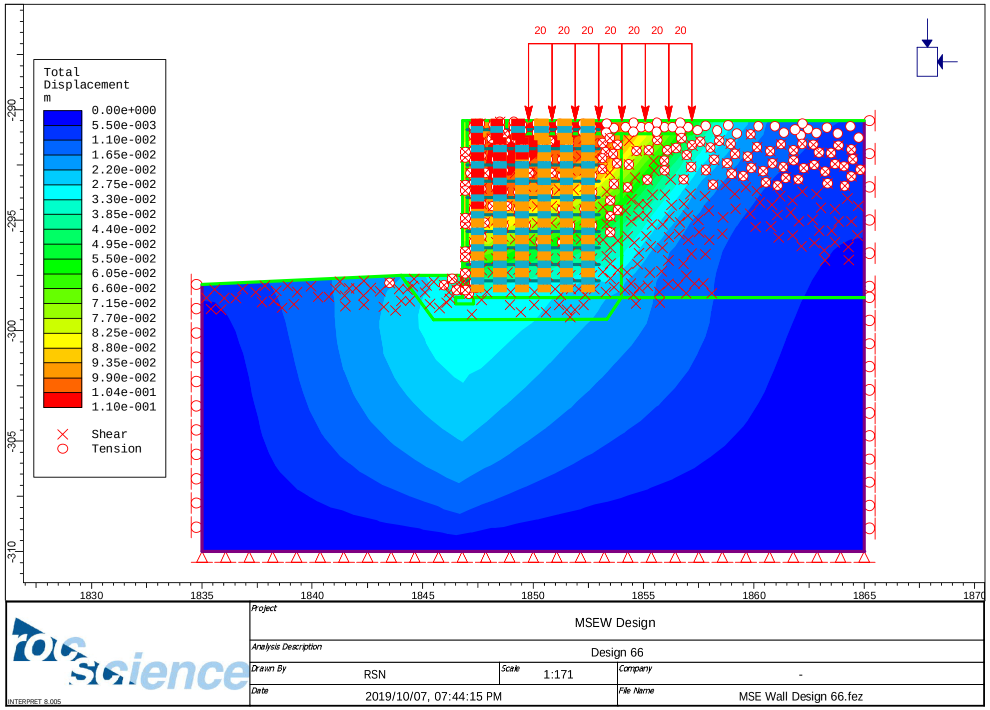
INTERPRET 8.005


Total Displacement m
0.00e+000
5.50e-003
1.10e-002
1.65e-002
2.20e-002
2.75e-002
3.30e-002
3.85e-002
4.40e-002
4.95e-002
5.50e-002
6.05e-002
6.60e-002
7.15e-002
7.70e-002
8.25e-002
8.80e-002
9.35e-002
9.90e-002
1.04e-001
1.10e-001
Shear
Tension
20 20 20 20 20 20 20
Project
MSEW Design
Analysis Description
Design 66
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RSN
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1:171
Company
-
Date
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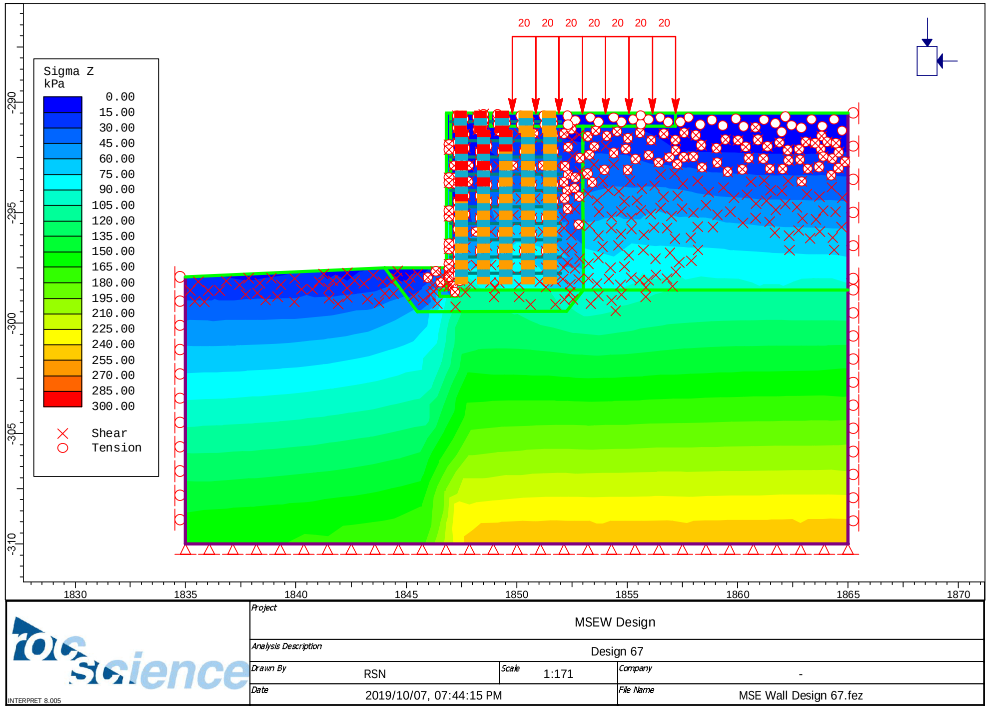
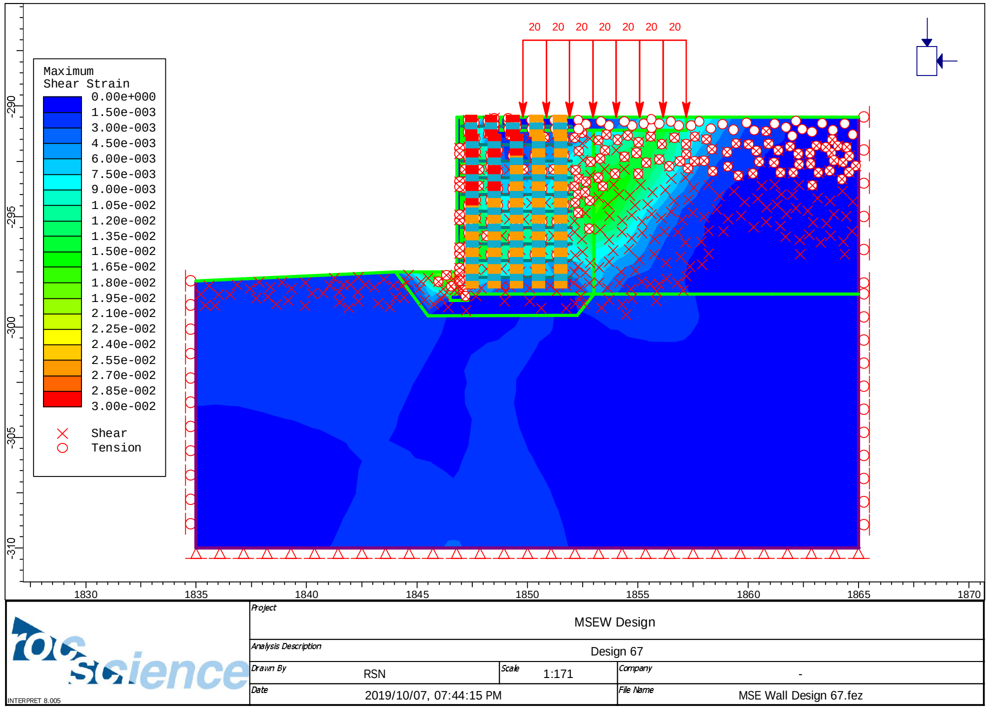
INTERPRET 8.005


Sigma Z
kPa
0.00
15.00
30.00
45.00
60.00
75.00
90.00
105.00
120.00
135.00
150.00
165.00
180.00
195.00
210.00
225.00
240.00
255.00
270.00
285.00
300.00
Shear
Tension
Project
MSEW Design
Analysis Description
Design 67
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 67.fez
INTERPRET 8.005


Maximum
Shear Strain
0.00e+000
1.50e-003
3.00e-003
4.50e-003
6.00e-003
7.50e-003
9.00e-003
1.05e-002
1.20e-002
1.35e-002
1.50e-002
1.65e-002
1.80e-002
1.95e-002
2.10e-002
2.25e-002
2.40e-002
2.55e-002
2.70e-002
2.85e-002
3.00e-002
Shear
Tension
Project
MSEW Design
Analysis Description
Design 67
Drawn By
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Company
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Date
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File Name
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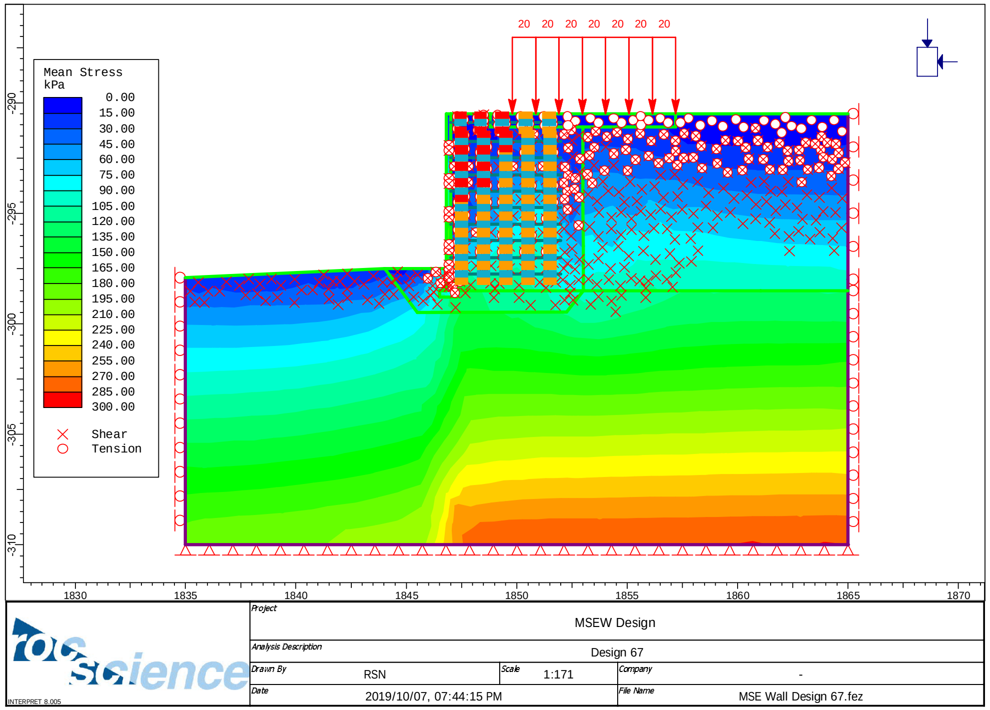
INTERPRET 8.005


Mean Stress
kPa
0.00
15.00
30.00
45.00
60.00
75.00
90.00
105.00
120.00
135.00
150.00
165.00
180.00
195.00
210.00
225.00
240.00
255.00
270.00
285.00
300.00
Shear
Tension
Project
MSEW Design
Analysis Description
Design 67
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Scale
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Company
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Date
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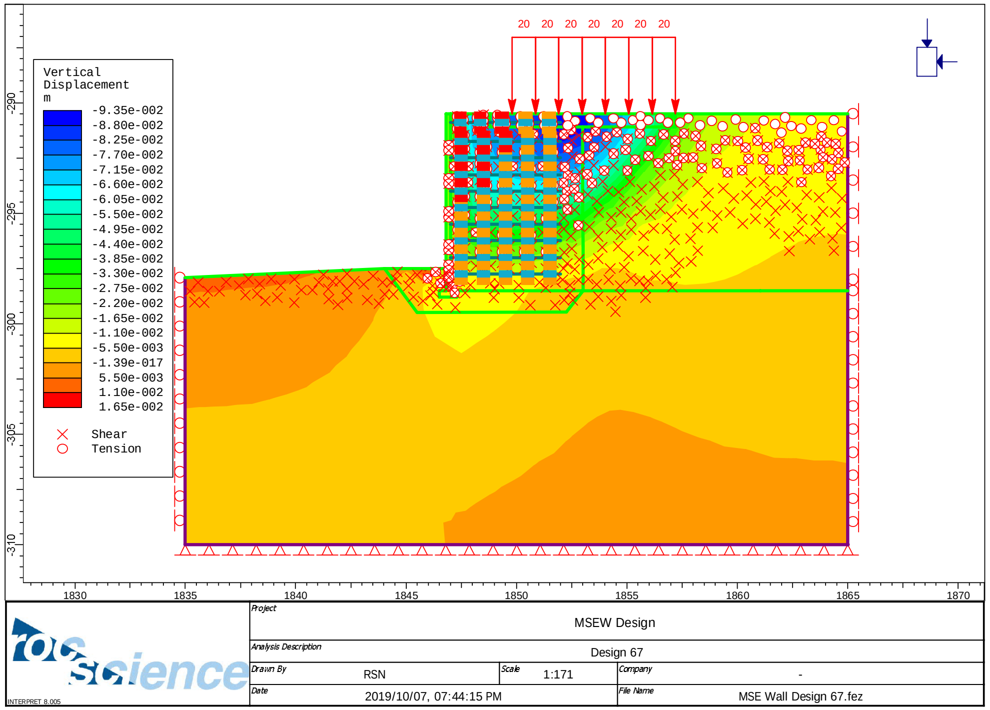
INTERPRET 8.005


Vertical
Displacement
m
-9.35e-002
-8.80e-002
-8.25e-002
-7.70e-002
-7.15e-002
-6.60e-002
-6.05e-002
-5.50e-002
-4.95e-002
-4.40e-002
-3.85e-002
-3.30e-002
-2.75e-002
-2.20e-002
-1.65e-002
-1.10e-002
-5.50e-003
-1.39e-017
5.50e-003
1.10e-002
1.65e-002
Shear
Tension
Project
MSEW Design
Analysis Description
Design 67
Drawn By
RSN
Scale
1:171
Company
-
Date
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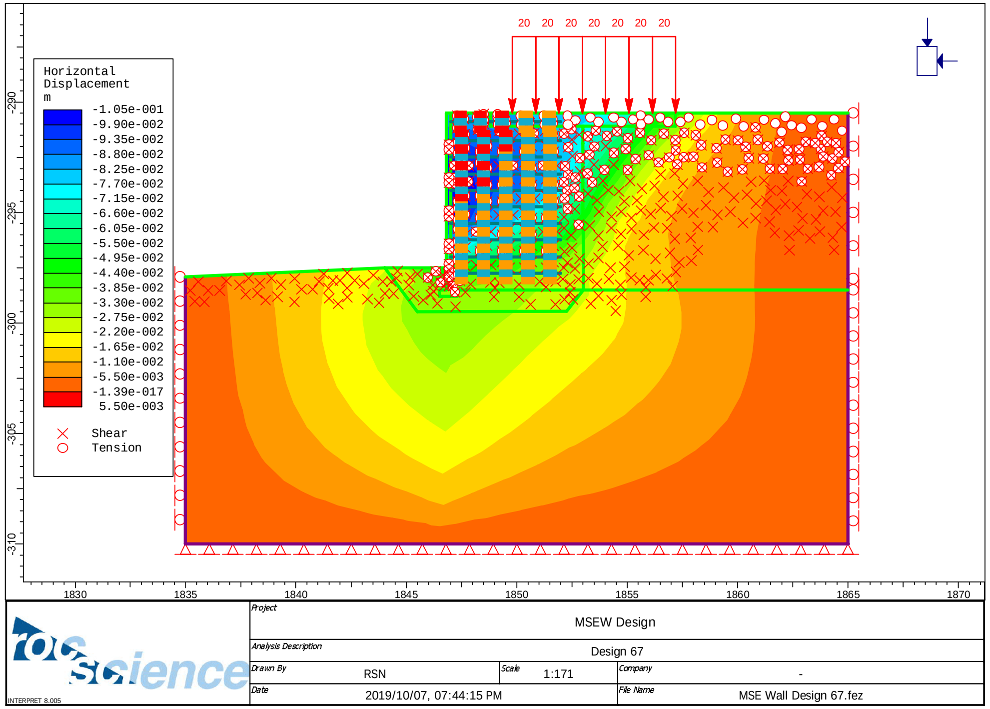
File Name
MSE Wall Design 67.fez
INTERPRET 8.005


20 20 20 20 20 20 20
Horizontal Displacement m
-1.05e-001
-9.90e-002
-9.35e-002
-8.80e-002
-8.25e-002
-7.70e-002
-7.15e-002
-6.60e-002
-6.05e-002
-5.50e-002
-4.95e-002
-4.40e-002
-3.85e-002
-3.30e-002
-2.75e-002
-2.20e-002
-1.65e-002
-1.10e-002
-5.50e-003
-1.39e-017
5.50e-003
Shear
Tension
1830 1835 1840 1845 1850 1855 1860 1865 1870
-290 -295 -300 -305 -310
Project
MSEW Design
Analysis Description
Design 67
Drawn By
RSN
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Company
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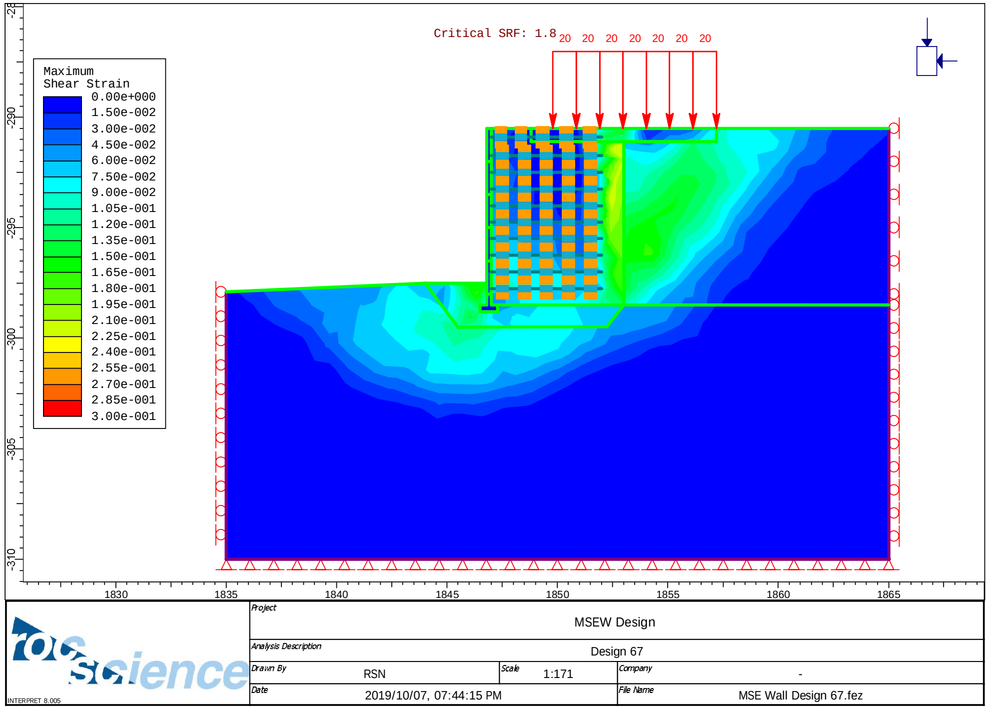
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 67.fez
INTERPRET 8.005


Critical SRF: 1.8
20 20 20 20 20 20 20
Maximum Shear Strain
0.00e+000
1.50e-002
3.00e-002
4.50e-002
6.00e-002
7.50e-002
9.00e-002
1.05e-001
1.20e-001
1.35e-001
1.50e-001
1.65e-001
1.80e-001
1.95e-001
2.10e-001
2.25e-001
2.40e-001
2.55e-001
2.70e-001
2.85e-001
3.00e-001
1830 1835 1840 1845 1850 1855 1860 1865
-290 -295 -300 -305 -310
Project
MSEW Design
Analysis Description
Design 67
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RSN
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Company
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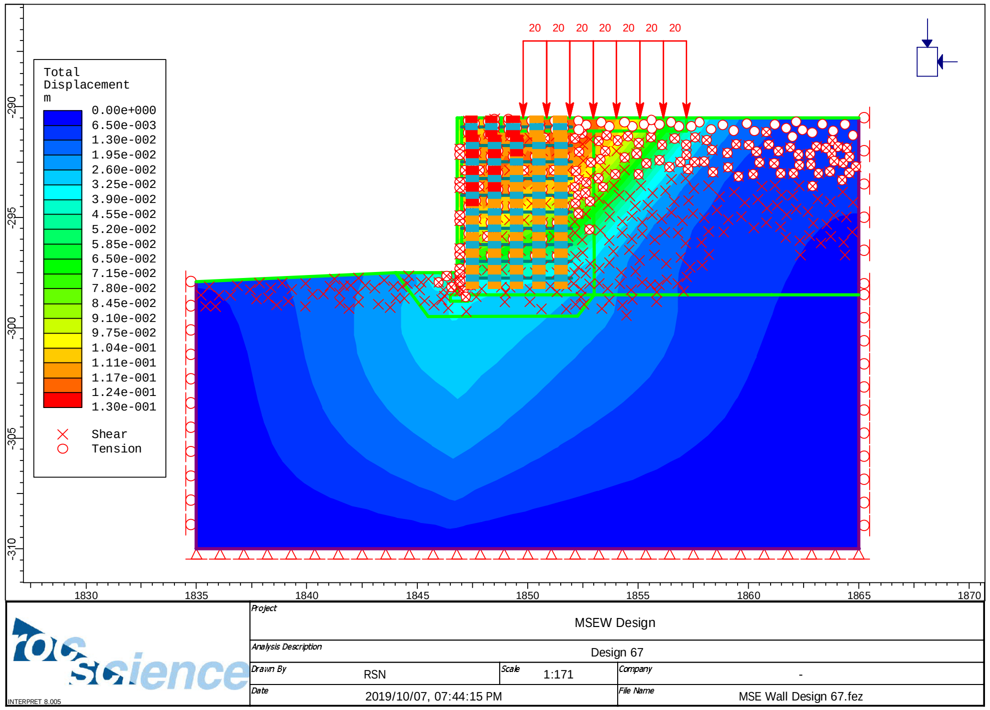
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 67.fez
INTERPRET 8.005


20 20 20 20 20 20 20
Total Displacement m
0.00e+000
6.50e-003
1.30e-002
1.95e-002
2.60e-002
3.25e-002
3.90e-002
4.55e-002
5.20e-002
5.85e-002
6.50e-002
7.15e-002
7.80e-002
8.45e-002
9.10e-002
9.75e-002
1.04e-001
1.11e-001
1.17e-001
1.24e-001
1.30e-001
Shear
Tension
1830 1835 1840 1845 1850 1855 1860 1865 1870
-290 -295 -300 -305 -310
Project
MSEW Design
Analysis Description
Design 67
Drawn By
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Scale
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Company
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Date
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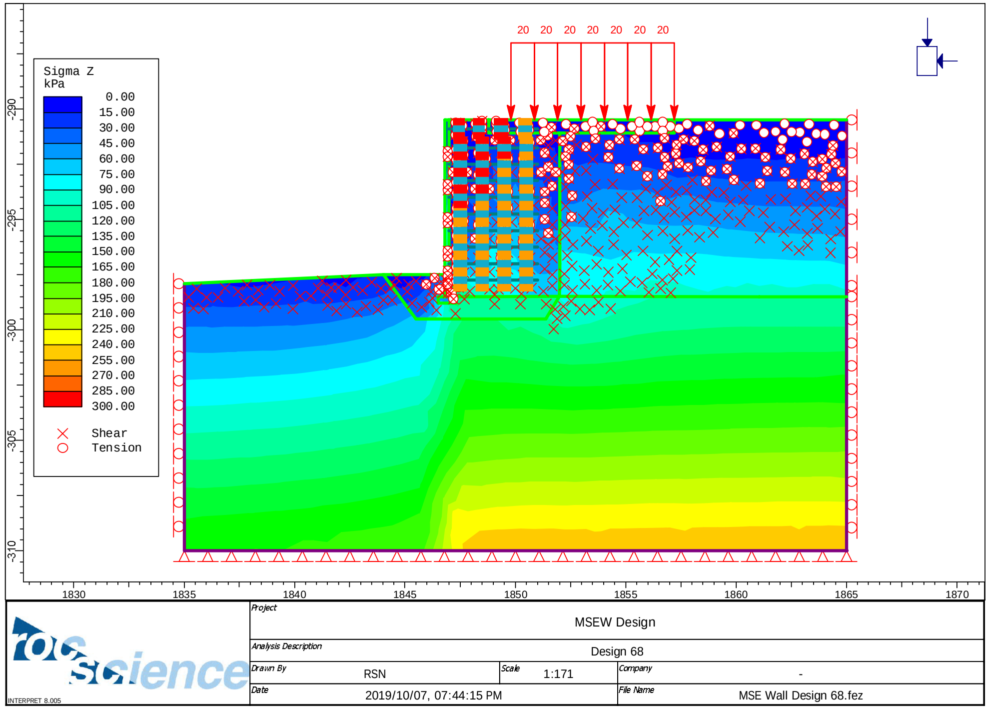
MSE Wall Design 67.fez
INTERPRET 8.005


Sigma Z
kPa
0.00
15.00
30.00
45.00
60.00
75.00
90.00
105.00
120.00
135.00
150.00
165.00
180.00
195.00
210.00
225.00
240.00
255.00
270.00
285.00
300.00
Shear
Tension
20 20 20 20 20 20 20
1830 1835 1840 1845 1850 1855 1860 1865 1870
-290 -295 -300 -305 -310
Project
MSEW Design
Analysis Description
Design 68
Drawn By
RSN
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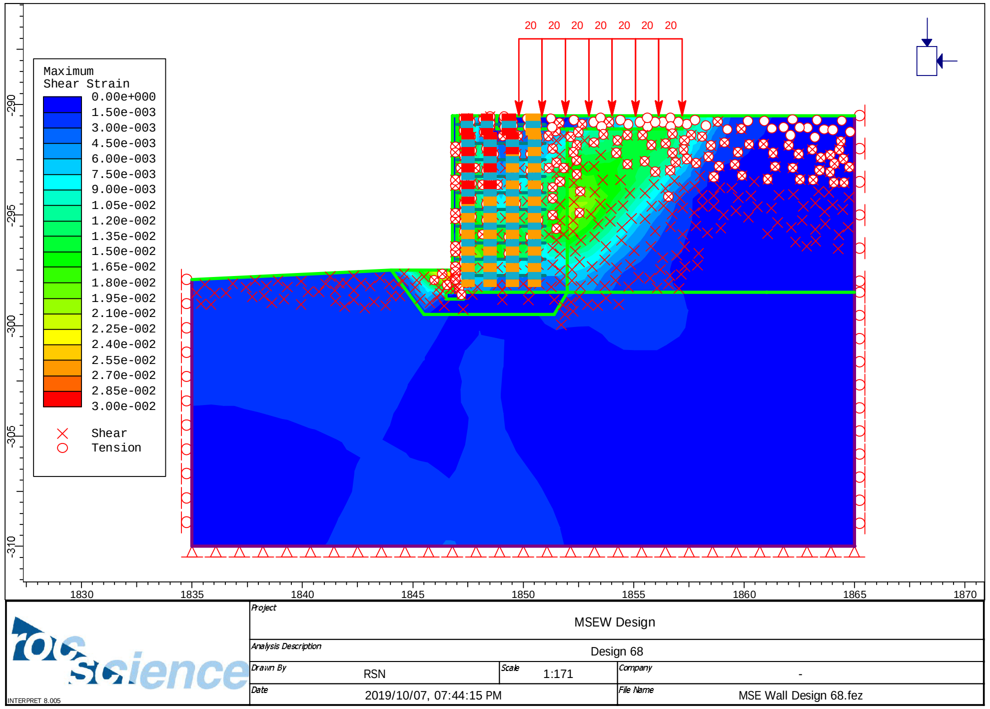
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 68.fez
INTERPRET 8.005


Maximum
Shear Strain
0.00e+000
1.50e-003
3.00e-003
4.50e-003
6.00e-003
7.50e-003
9.00e-003
1.05e-002
1.20e-002
1.35e-002
1.50e-002
1.65e-002
1.80e-002
1.95e-002
2.10e-002
2.25e-002
2.40e-002
2.55e-002
2.70e-002
2.85e-002
3.00e-002
Shear
Tension
20 20 20 20 20 20 20
1830 1835 1840 1845 1850 1855 1860 1865 1870
-290 -295 -300 -305 -310
Project
MSEW Design
Analysis Description
Design 68
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Company
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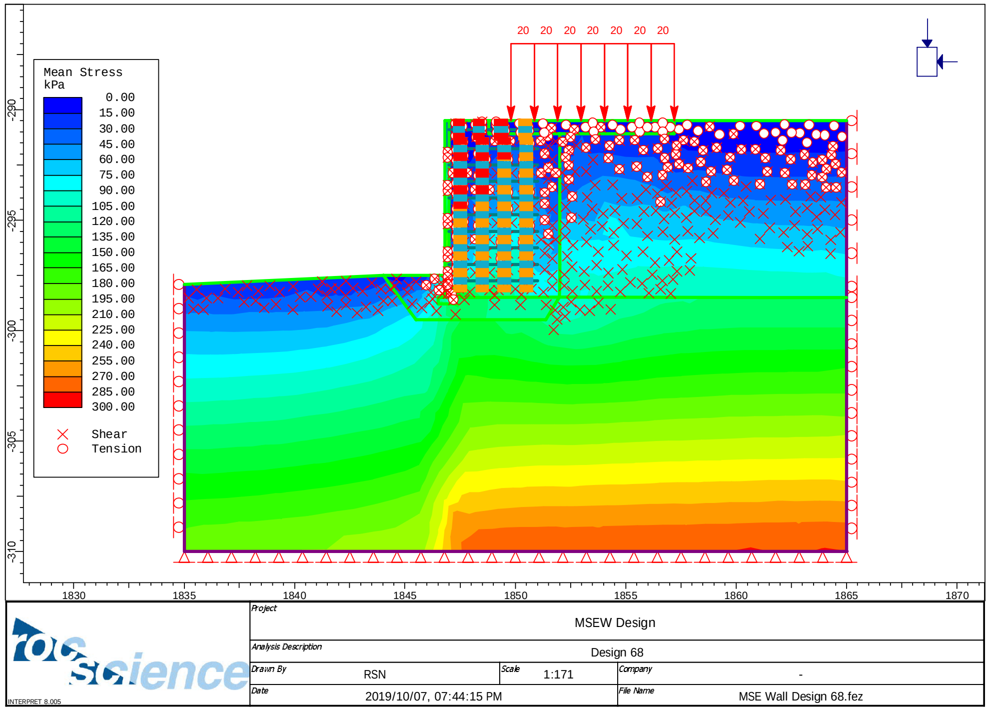
INTERPRET 8.005


Mean Stress
kPa
0.00
15.00
30.00
45.00
60.00
75.00
90.00
105.00
120.00
135.00
150.00
165.00
180.00
195.00
210.00
225.00
240.00
255.00
270.00
285.00
300.00
Shear
Tension
20 20 20 20 20 20 20
1830 1835 1840 1845 1850 1855 1860 1865 1870
-290 -295 -300 -305 -310
Project
MSEW Design
Analysis Description
Design 68
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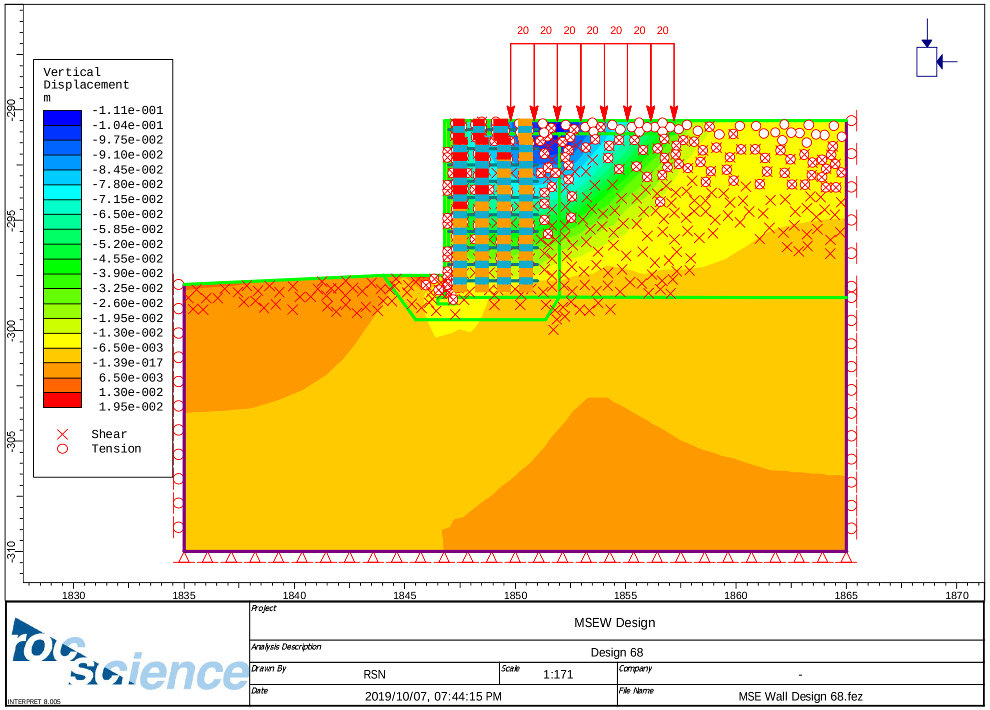
INTERPRET 8.005


Vertical
Displacement
m
-1.11e-001
-1.04e-001
-9.75e-002
-9.10e-002
-8.45e-002
-7.80e-002
-7.15e-002
-6.50e-002
-5.85e-002
-5.20e-002
-4.55e-002
-3.90e-002
-3.25e-002
-2.60e-002
-1.95e-002
-1.30e-002
-6.50e-003
-1.39e-017
6.50e-003
1.30e-002
1.95e-002
Shear
Tension
20 20 20 20 20 20 20
1830 1835 1840 1845 1850 1855 1860 1865 1870
-290 -295 -300 -305 -310
Project
MSEW Design
Analysis Description
Design 68
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Company
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File Name
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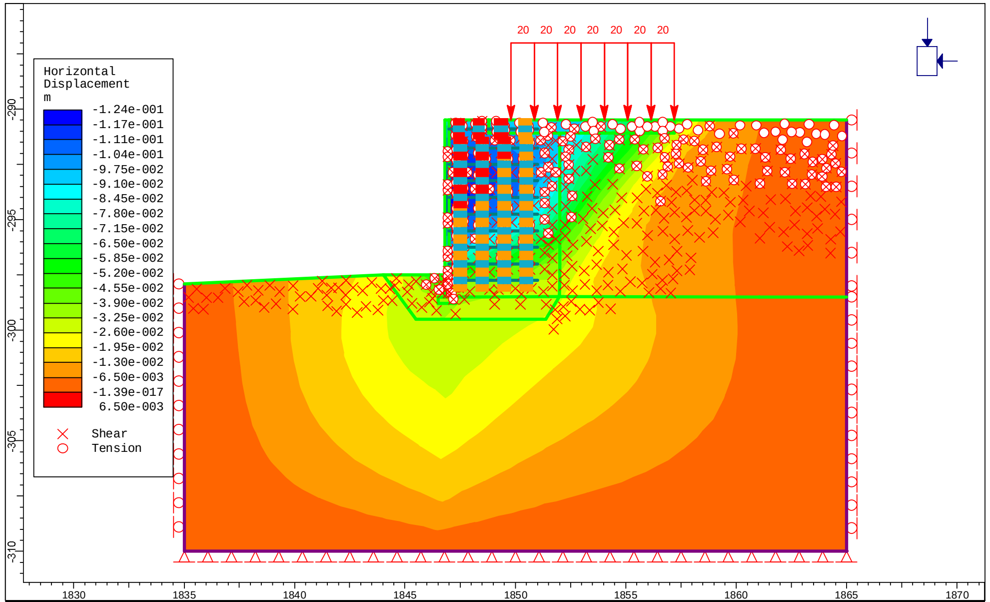
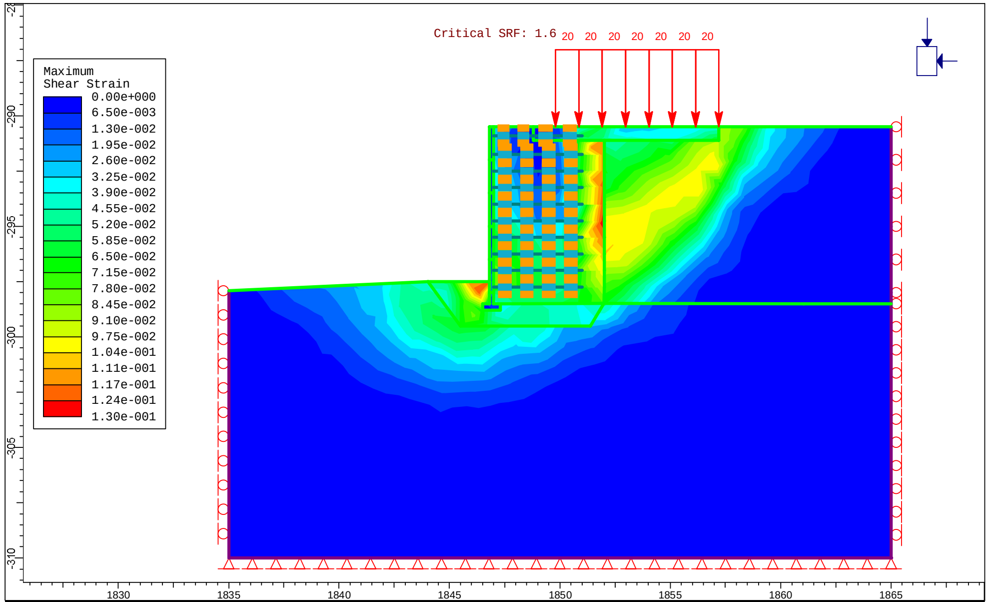
INTERPRET 8.005



Project	MSEW Design		
Analysis Description	Design 68		
Drawn By	RSN	Scale	1:171
Company	-		
Date	2019/10/07, 07:44:15 PM	File Name	MSE Wall Design 68.fez

INTERPRET 8.005



Project	MSEW Design		
Analysis Description	Design 68		
Drawn By	RSN	Scale	1:171
Company	-		
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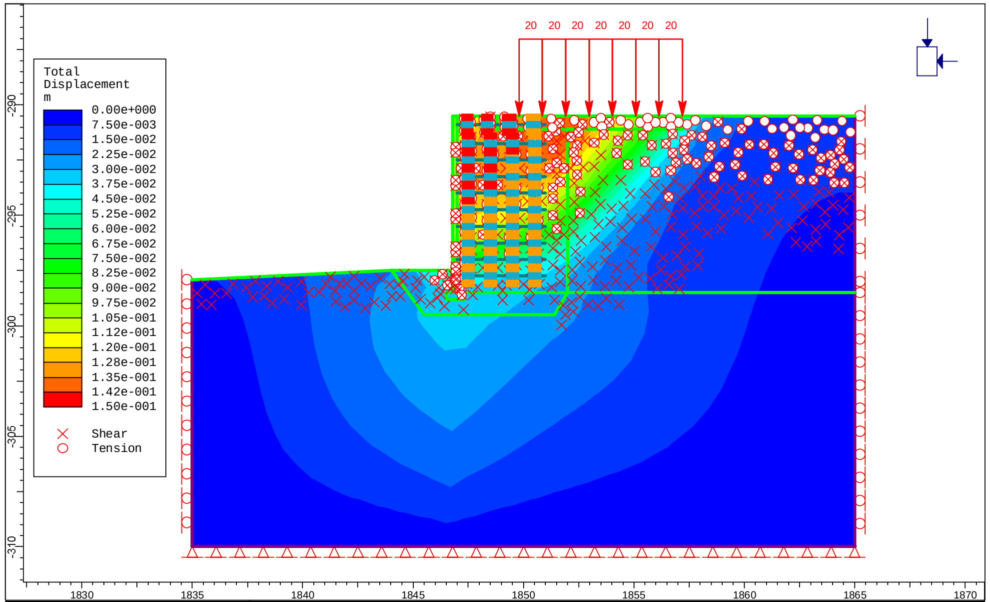
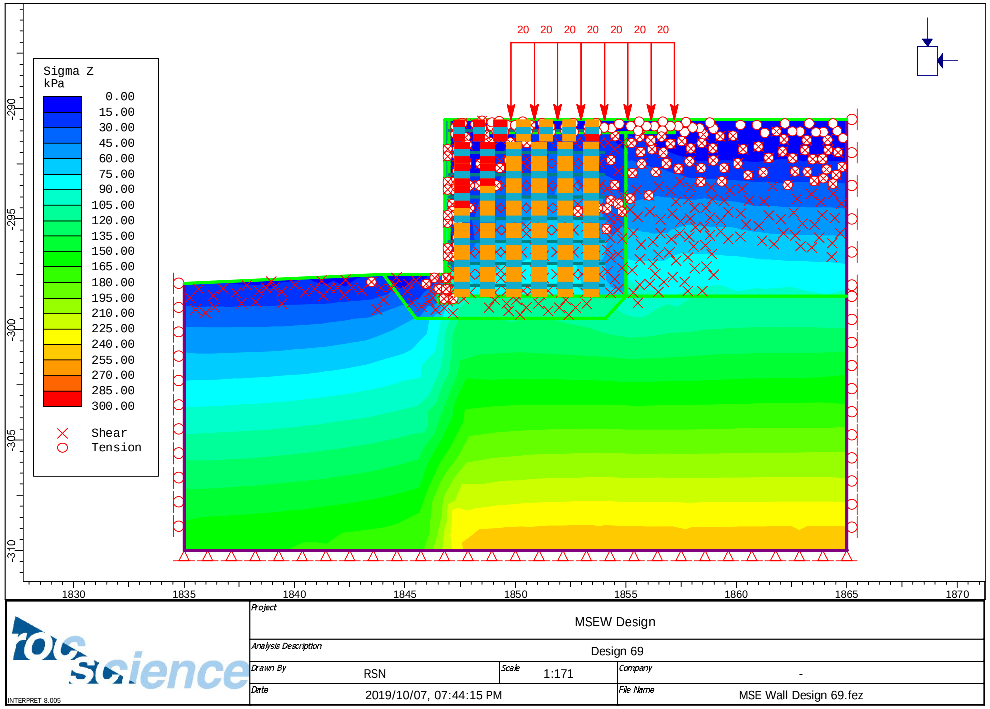
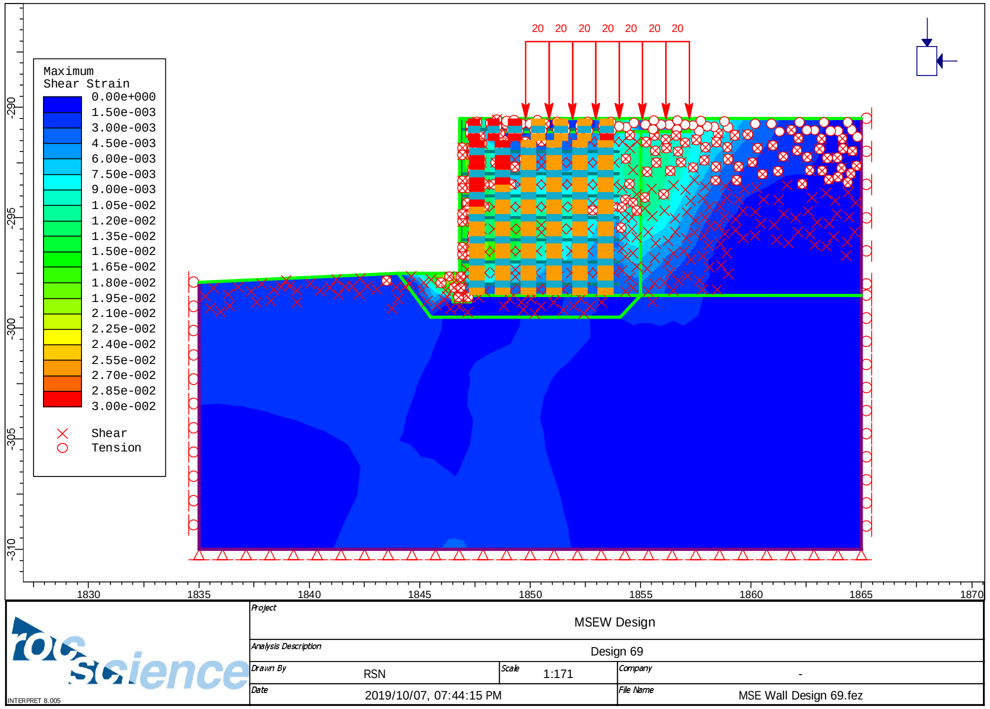
INTERPRET 8.005



Project	MSEW Design		
Analysis Description	Design 68		
Drawn By	RSN	Scale	1:171
Company	-		
Date	2019/10/07, 07:44:15 PM	File Name	MSE Wall Design 68.fez

INTERPRET 8.005


Sigma Z
kPa
0.00
15.00
30.00
45.00
60.00
75.00
90.00
105.00
120.00
135.00
150.00
165.00
180.00
195.00
210.00
225.00
240.00
255.00
270.00
285.00
300.00
Shear
Tension
Project
MSEW Design
Analysis Description
Design 69
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 69.fez
INTERPRET 8.005


Maximum
Shear Strain
0.00e+000
1.50e-003
3.00e-003
4.50e-003
6.00e-003
7.50e-003
9.00e-003
1.05e-002
1.20e-002
1.35e-002
1.50e-002
1.65e-002
1.80e-002
1.95e-002
2.10e-002
2.25e-002
2.40e-002
2.55e-002
2.70e-002
2.85e-002
3.00e-002
Shear
Tension
Project
MSEW Design
Analysis Description
Design 69
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Company
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Date
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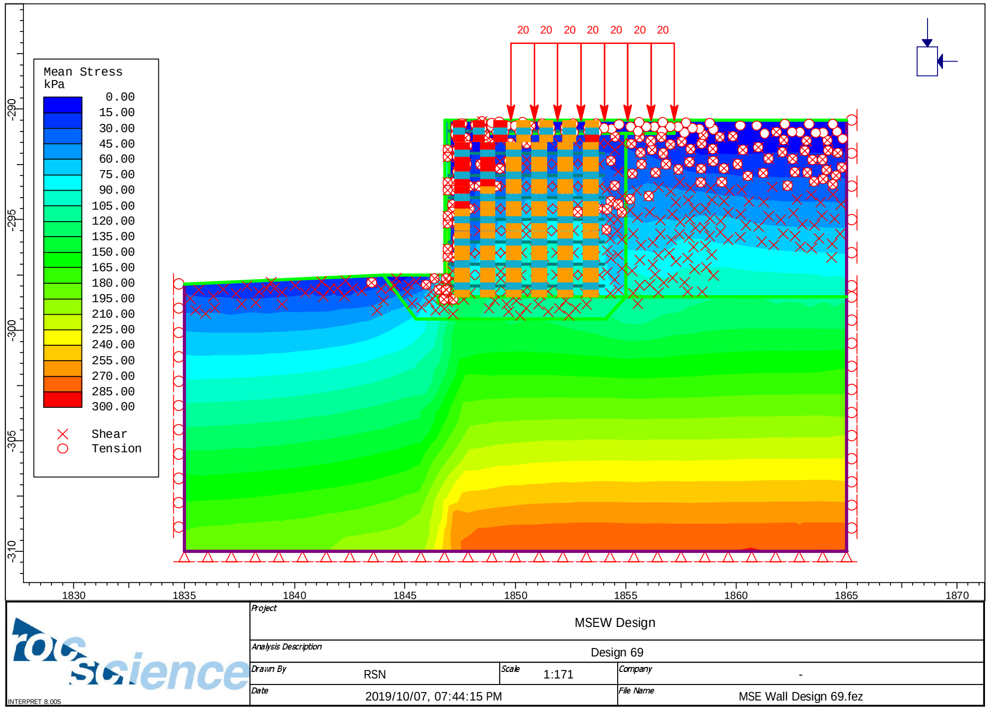
MSE Wall Design 69.fez
INTERPRET 8.005


Mean Stress
kPa
0.00
15.00
30.00
45.00
60.00
75.00
90.00
105.00
120.00
135.00
150.00
165.00
180.00
195.00
210.00
225.00
240.00
255.00
270.00
285.00
300.00
Shear
Tension
Project
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Analysis Description
Design 69
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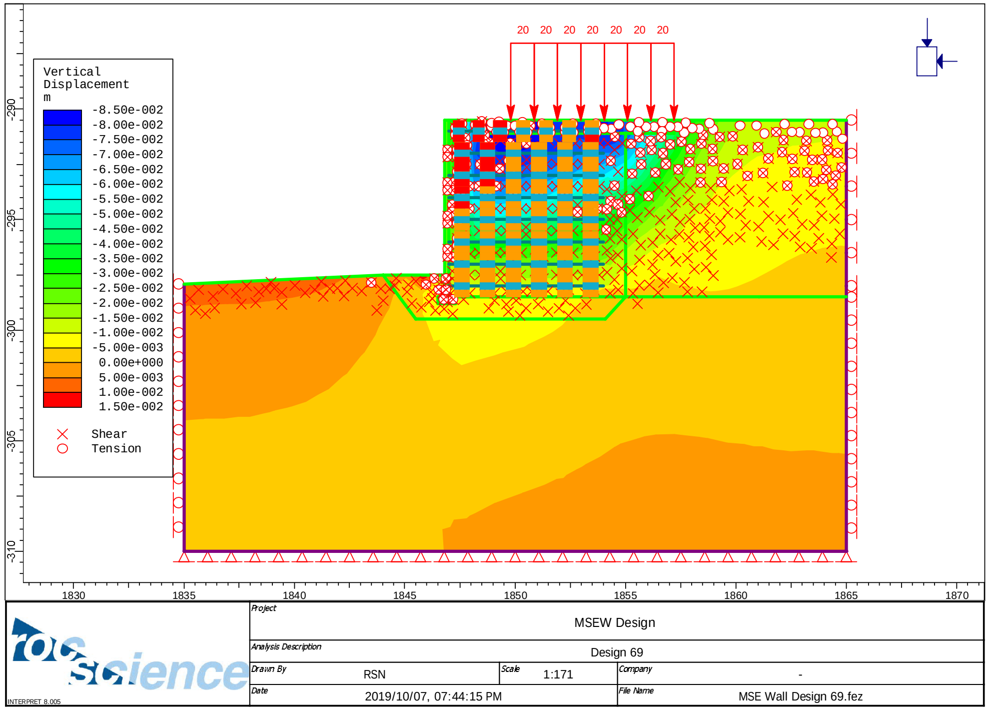
Vertical
Displacement
m
-8.50e-002
-8.00e-002
-7.50e-002
-7.00e-002
-6.50e-002
-6.00e-002
-5.50e-002
-5.00e-002
-4.50e-002
-4.00e-002
-3.50e-002
-3.00e-002
-2.50e-002
-2.00e-002
-1.50e-002
-1.00e-002
-5.00e-003
0.00e+000
5.00e-003
1.00e-002
1.50e-002
Shear
Tension
Project
MSEW Design
Analysis Description
Design 69
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RSN
Scale
1:171
Company
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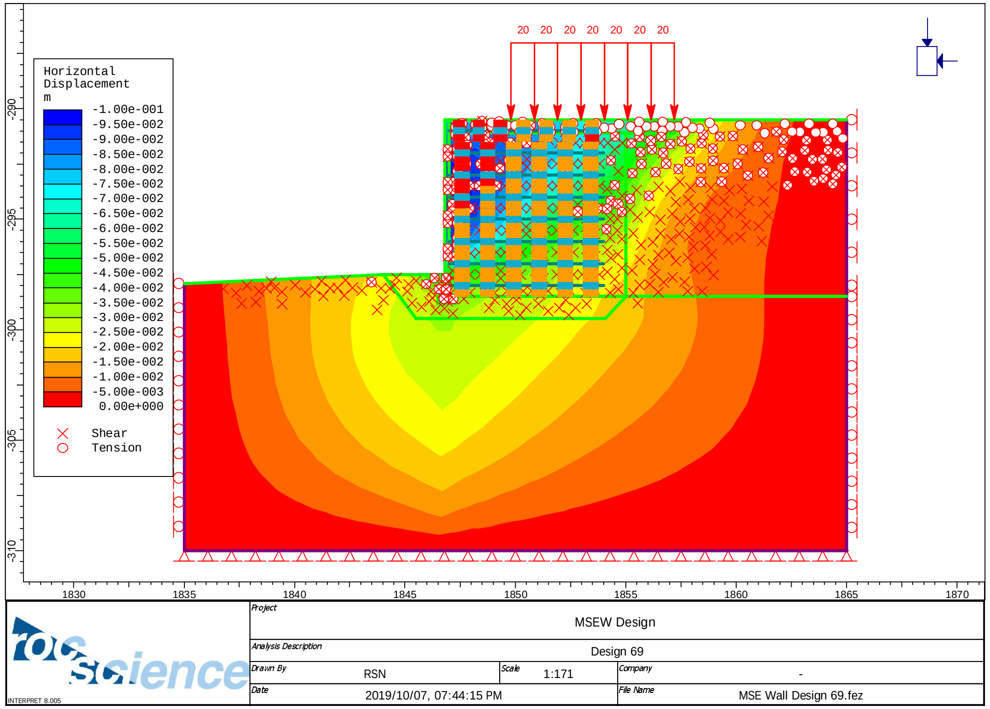
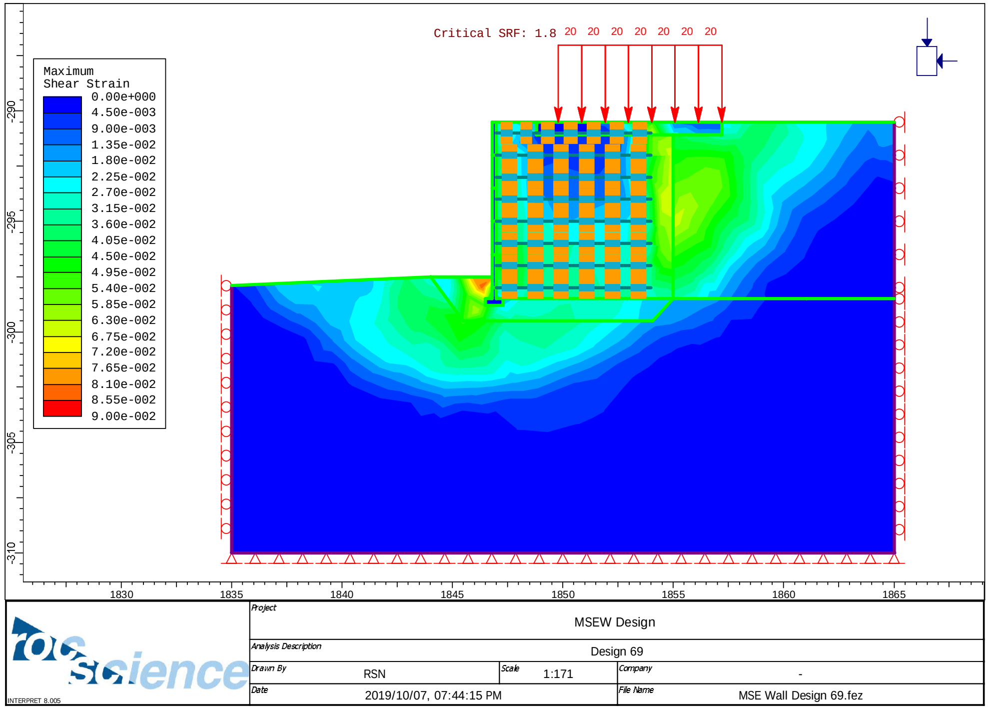
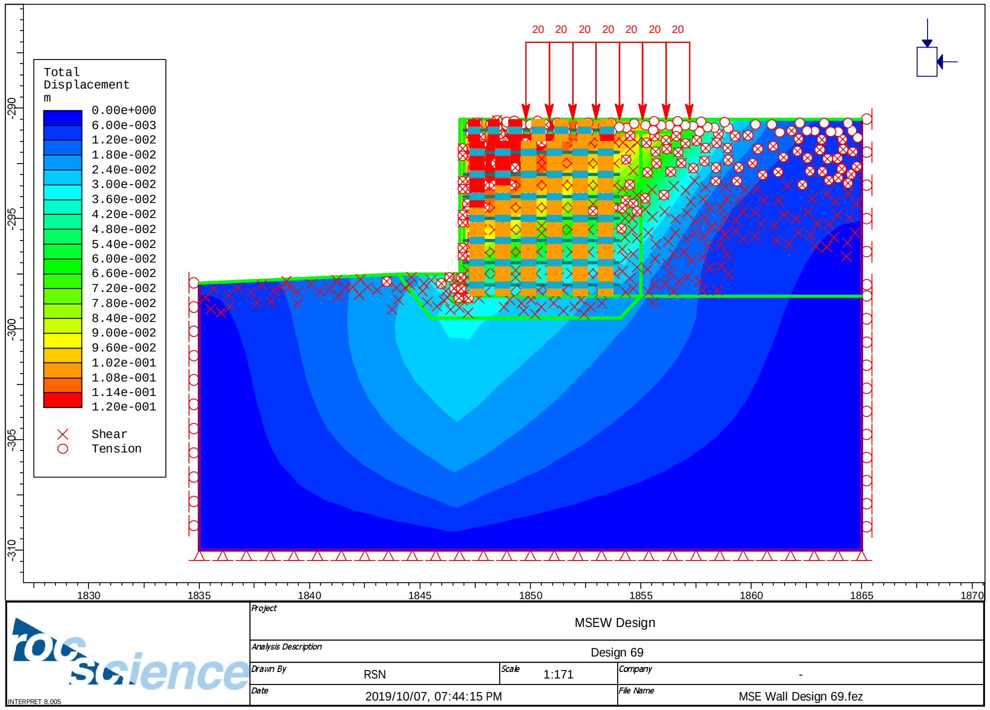
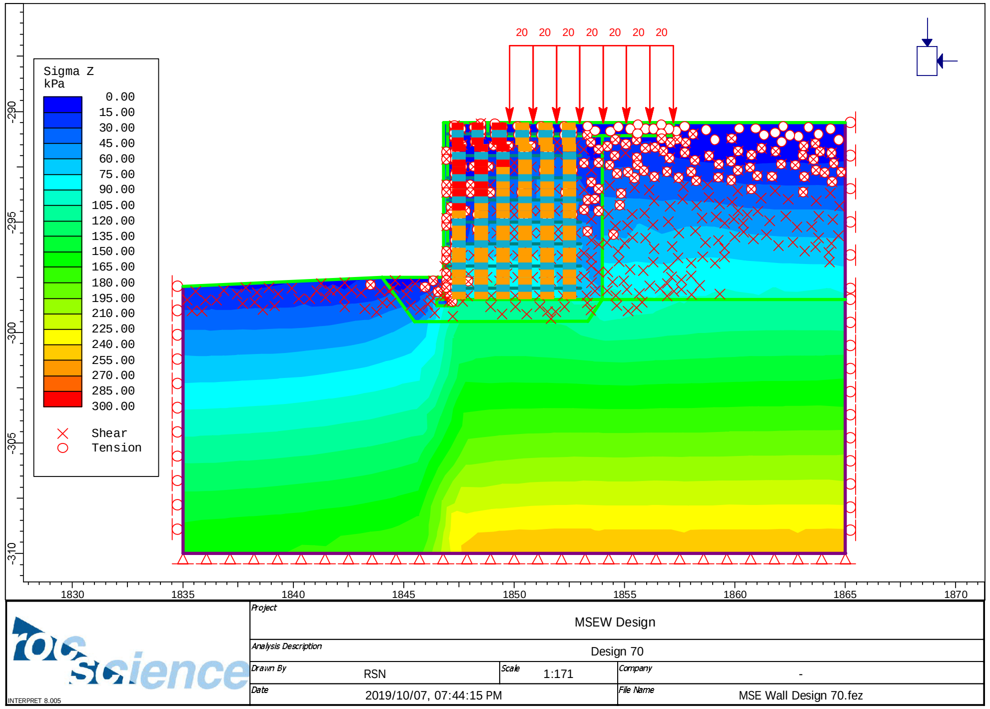
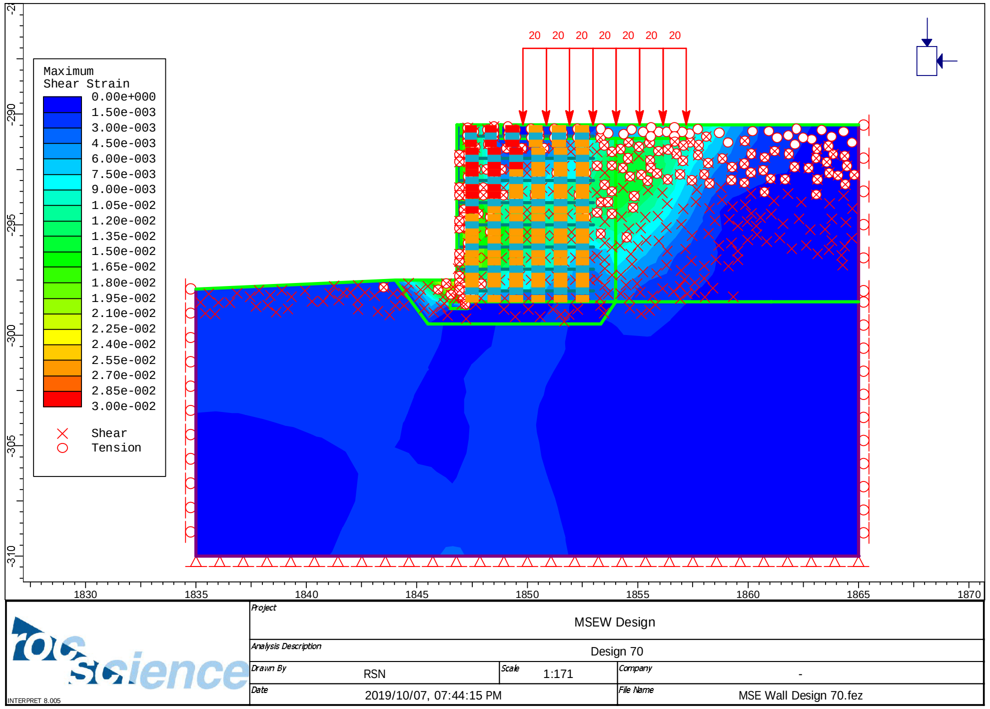
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 69.fez
INTERPRET 8.005

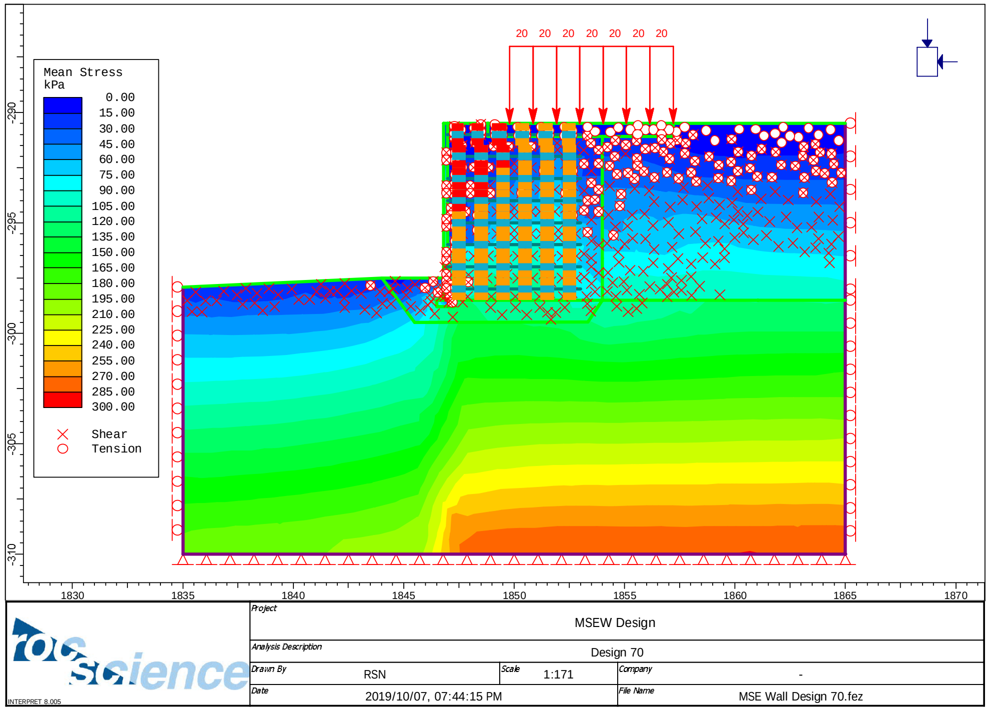

Horizontal Displacement m
-1.00e-001
-9.50e-002
-9.00e-002
-8.50e-002
-8.00e-002
-7.50e-002
-7.00e-002
-6.50e-002
-6.00e-002
-5.50e-002
-5.00e-002
-4.50e-002
-4.00e-002
-3.50e-002
-3.00e-002
-2.50e-002
-2.00e-002
-1.50e-002
-1.00e-002
-5.00e-003
0.00e+000
Shear
Tension
20 20 20 20 20 20 20
Project: MSEW Design
Analysis Description: Design 69
Drawn By: RSN
Scale: 1:171
Company: -
Date: 2019/10/07, 07:44:15 PM
File Name: MSE Wall Design 69.fez
INTERPRET 8.005

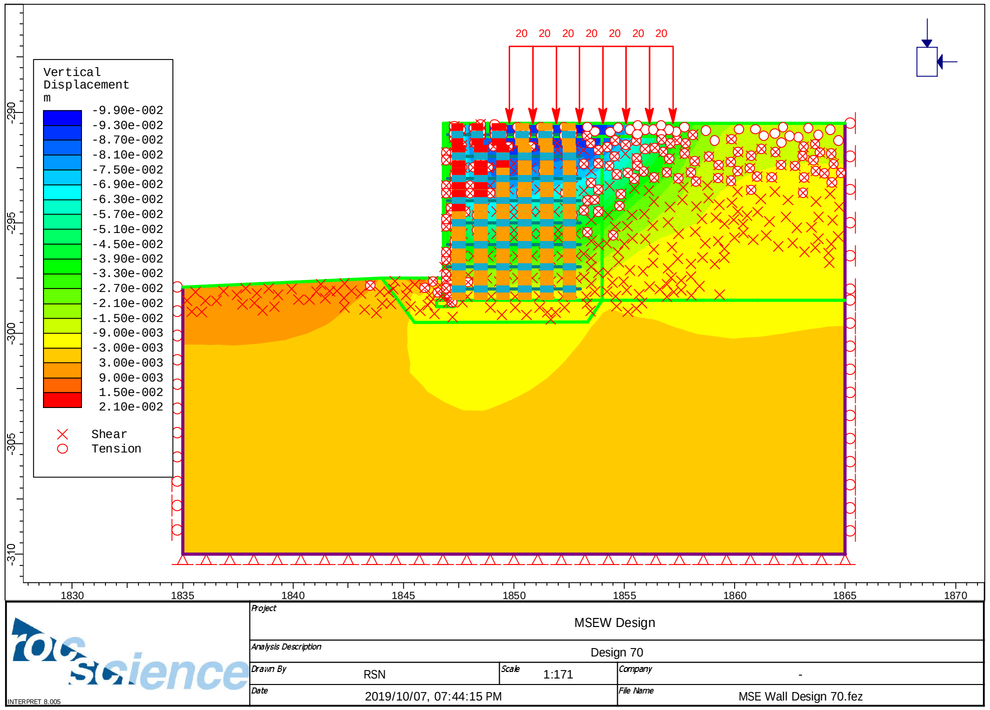

Maximum Shear Strain
0.00e+000
4.50e-003
9.00e-003
1.35e-002
1.80e-002
2.25e-002
2.70e-002
3.15e-002
3.60e-002
4.05e-002
4.50e-002
4.95e-002
5.40e-002
5.85e-002
6.30e-002
6.75e-002
7.20e-002
7.65e-002
8.10e-002
8.55e-002
9.00e-002
Critical SRF: 1.8
20 20 20 20 20 20 20
Project: MSEW Design
Analysis Description: Design 69
Drawn By: RSN
Scale: 1:171
Company: -
Date: 2019/10/07, 07:44:15 PM
File Name: MSE Wall Design 69.fez
INTERPRET 8.005

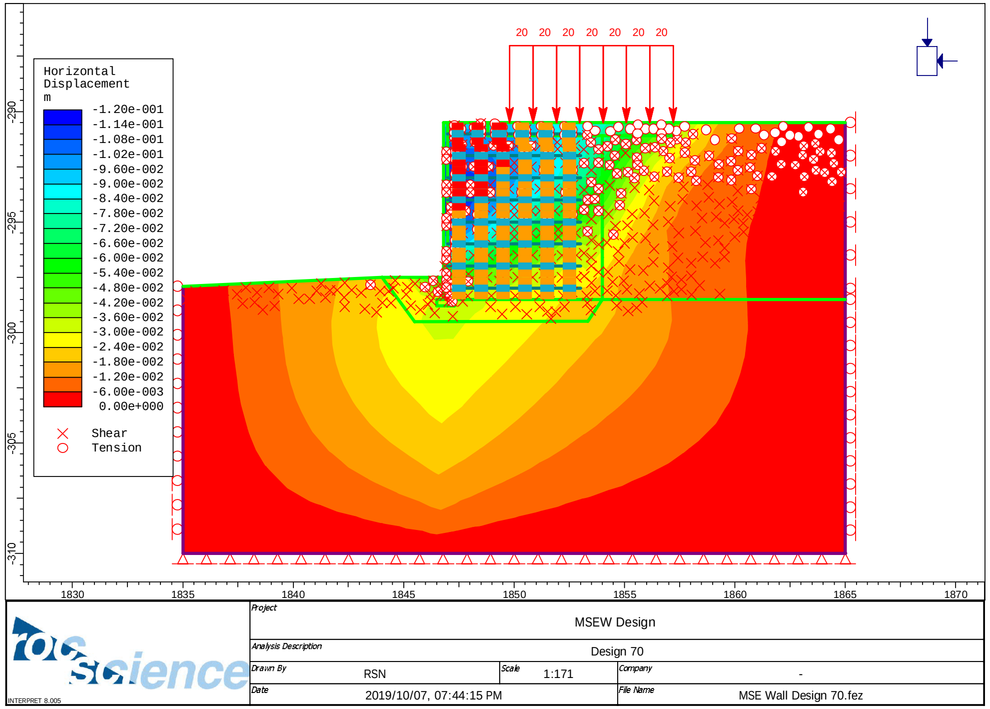

Total Displacement m
0.00e+000
6.00e-003
1.20e-002
1.80e-002
2.40e-002
3.00e-002
3.60e-002
4.20e-002
4.80e-002
5.40e-002
6.00e-002
6.60e-002
7.20e-002
7.80e-002
8.40e-002
9.00e-002
9.60e-002
1.02e-001
1.08e-001
1.14e-001
1.20e-001
Shear
Tension
20 20 20 20 20 20 20
Project: MSEW Design
Analysis Description: Design 69
Drawn By: RSN
Scale: 1:171
Company: -
Date: 2019/10/07, 07:44:15 PM
File Name: MSE Wall Design 69.fez
INTERPRET 8.005

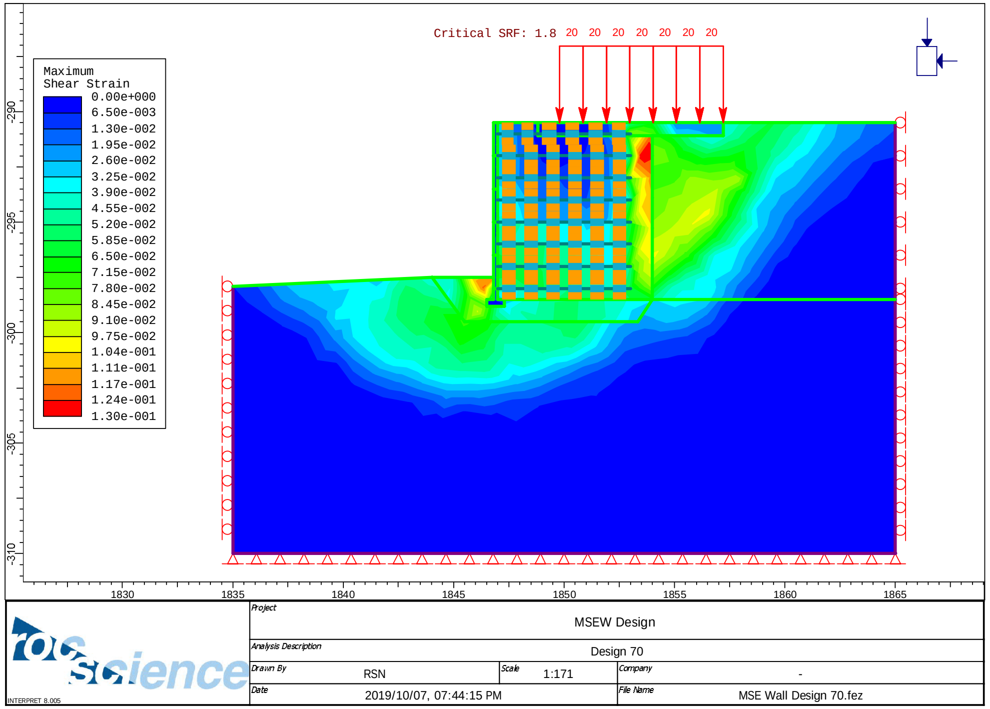

Sigma Z
kPa
0.00
15.00
30.00
45.00
60.00
75.00
90.00
105.00
120.00
135.00
150.00
165.00
180.00
195.00
210.00
225.00
240.00
255.00
270.00
285.00
300.00
Shear
Tension
20 20 20 20 20 20 20
Project
MSEW Design
Analysis Description
Design 70
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 70.fez
INTERPRET 8.005

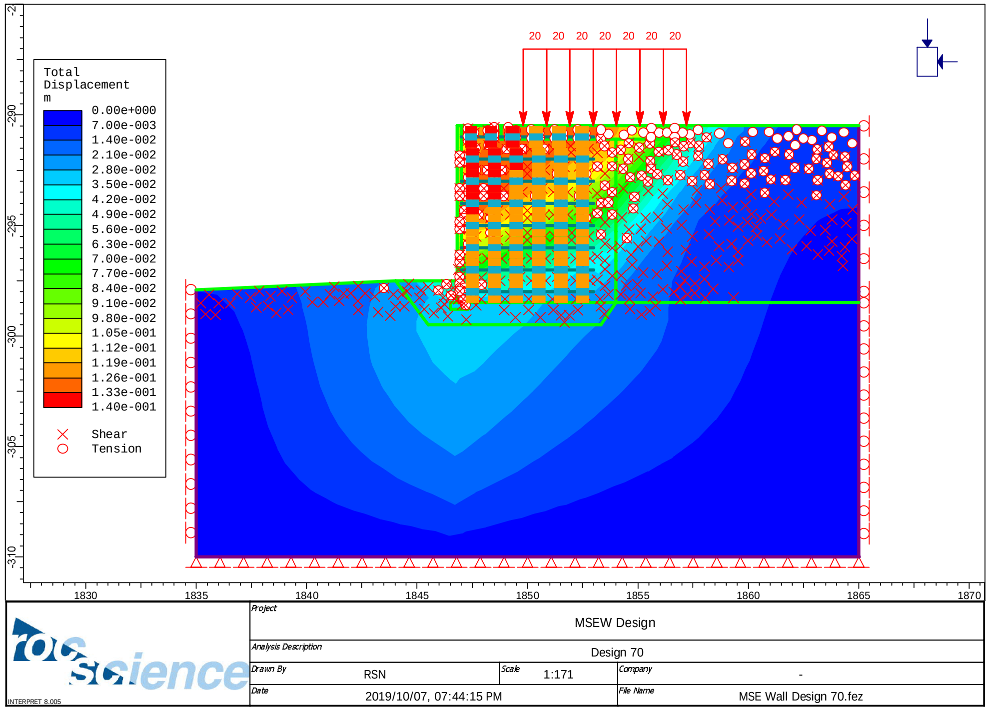

Maximum
Shear Strain
0.00e+000
1.50e-003
3.00e-003
4.50e-003
6.00e-003
7.50e-003
9.00e-003
1.05e-002
1.20e-002
1.35e-002
1.50e-002
1.65e-002
1.80e-002
1.95e-002
2.10e-002
2.25e-002
2.40e-002
2.55e-002
2.70e-002
2.85e-002
3.00e-002
Shear
Tension
20 20 20 20 20 20 20
Project
MSEW Design
Analysis Description
Design 70
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 70.fez
INTERPRET 8.005

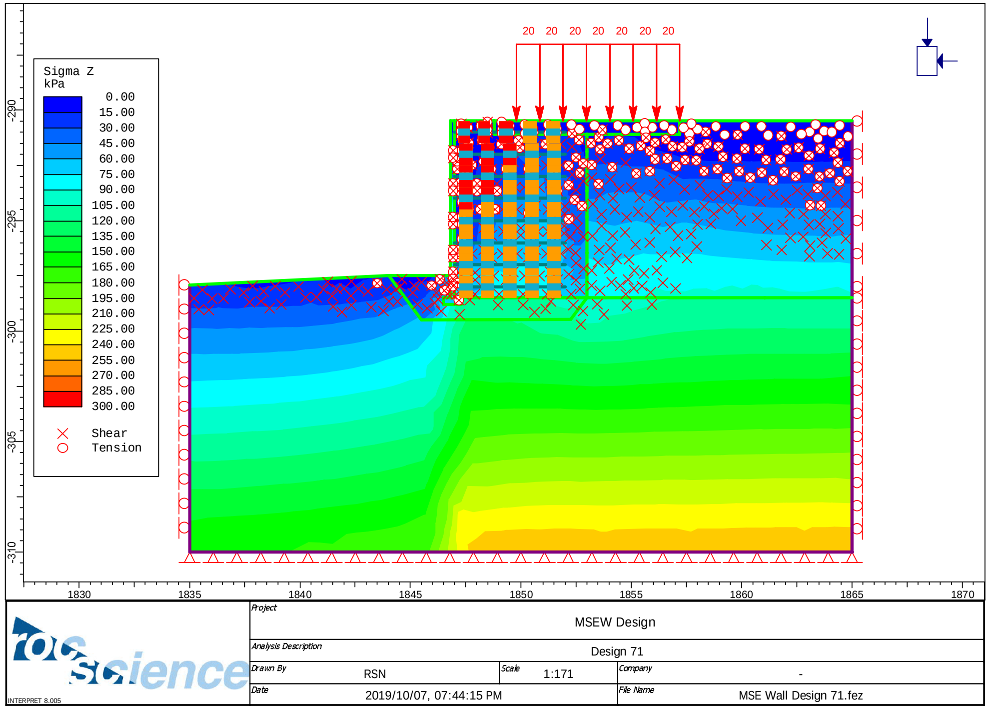

Mean Stress
kPa
0.00
15.00
30.00
45.00
60.00
75.00
90.00
105.00
120.00
135.00
150.00
165.00
180.00
195.00
210.00
225.00
240.00
255.00
270.00
285.00
300.00
Shear
Tension
20 20 20 20 20 20 20
Project
MSEW Design
Analysis Description
Design 70
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 70.fez
INTERPRET 8.005


Vertical
Displacement
m
-9.90e-002
-9.30e-002
-8.70e-002
-8.10e-002
-7.50e-002
-6.90e-002
-6.30e-002
-5.70e-002
-5.10e-002
-4.50e-002
-3.90e-002
-3.30e-002
-2.70e-002
-2.10e-002
-1.50e-002
-9.00e-003
-3.00e-003
3.00e-003
9.00e-003
1.50e-002
2.10e-002
Shear
Tension
20 20 20 20 20 20 20
Project
MSEW Design
Analysis Description
Design 70
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 70.fez
INTERPRET 8.005

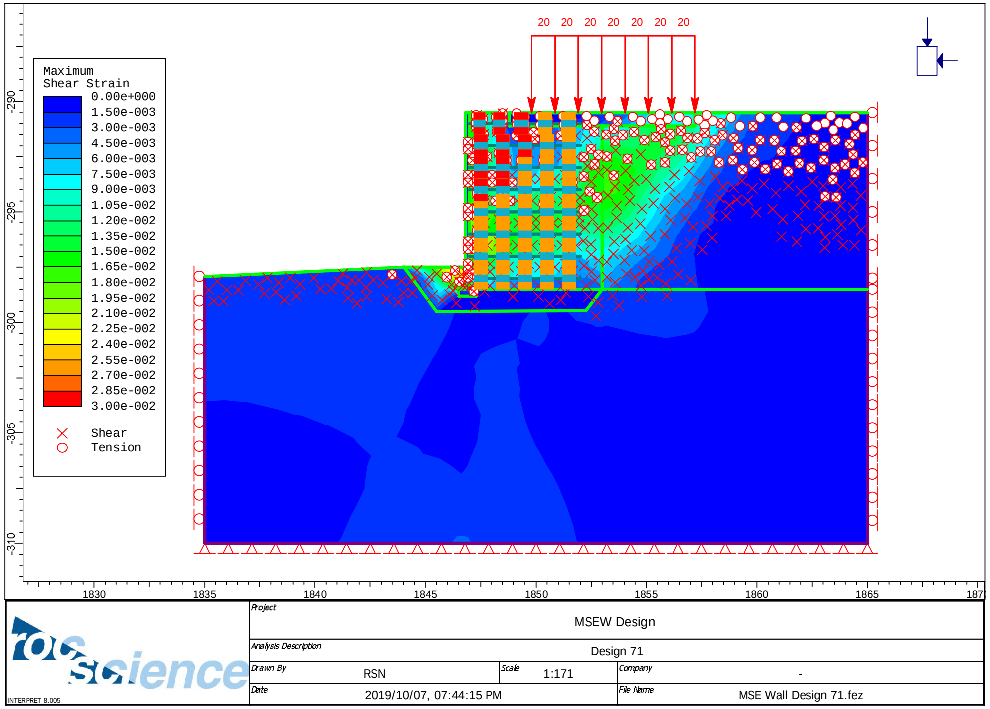

20 20 20 20 20 20 20
Horizontal
Displacement
m
-1.20e-001
-1.14e-001
-1.08e-001
-1.02e-001
-9.60e-002
-9.00e-002
-8.40e-002
-7.80e-002
-7.20e-002
-6.60e-002
-6.00e-002
-5.40e-002
-4.80e-002
-4.20e-002
-3.60e-002
-3.00e-002
-2.40e-002
-1.80e-002
-1.20e-002
-6.00e-003
0.00e+000
Shear
Tension
-290
-295
-300
-305
-310
1830
1835
1840
1845
1850
1855
1860
1865
1870
Project
MSEW Design
Analysis Description
Design 70
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 70.fez
INTERPRET 8.005


Critical SRF: 1.8
20 20 20 20 20 20 20
Maximum
Shear Strain
0.00e+000
6.50e-003
1.30e-002
1.95e-002
2.60e-002
3.25e-002
3.90e-002
4.55e-002
5.20e-002
5.85e-002
6.50e-002
7.15e-002
7.80e-002
8.45e-002
9.10e-002
9.75e-002
1.04e-001
1.11e-001
1.17e-001
1.24e-001
1.30e-001
-290
-295
-300
-305
-310
1830
1835
1840
1845
1850
1855
1860
1865
Project
MSEW Design
Analysis Description
Design 70
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 70.fez
INTERPRET 8.005

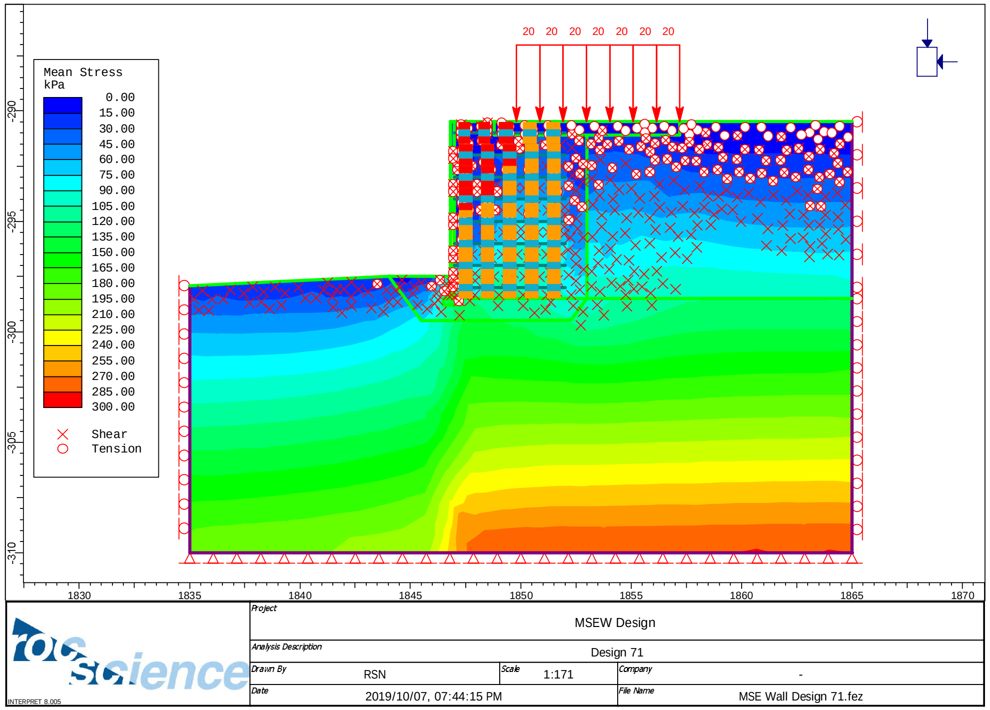

20 20 20 20 20 20 20
Total
Displacement
m
0.00e+000
7.00e-003
1.40e-002
2.10e-002
2.80e-002
3.50e-002
4.20e-002
4.90e-002
5.60e-002
6.30e-002
7.00e-002
7.70e-002
8.40e-002
9.10e-002
9.80e-002
1.05e-001
1.12e-001
1.19e-001
1.26e-001
1.33e-001
1.40e-001
Shear
Tension
-290
-295
-300
-305
-310
1830
1835
1840
1845
1850
1855
1860
1865
1870
Project
MSEW Design
Analysis Description
Design 70
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 70.fez
INTERPRET 8.005



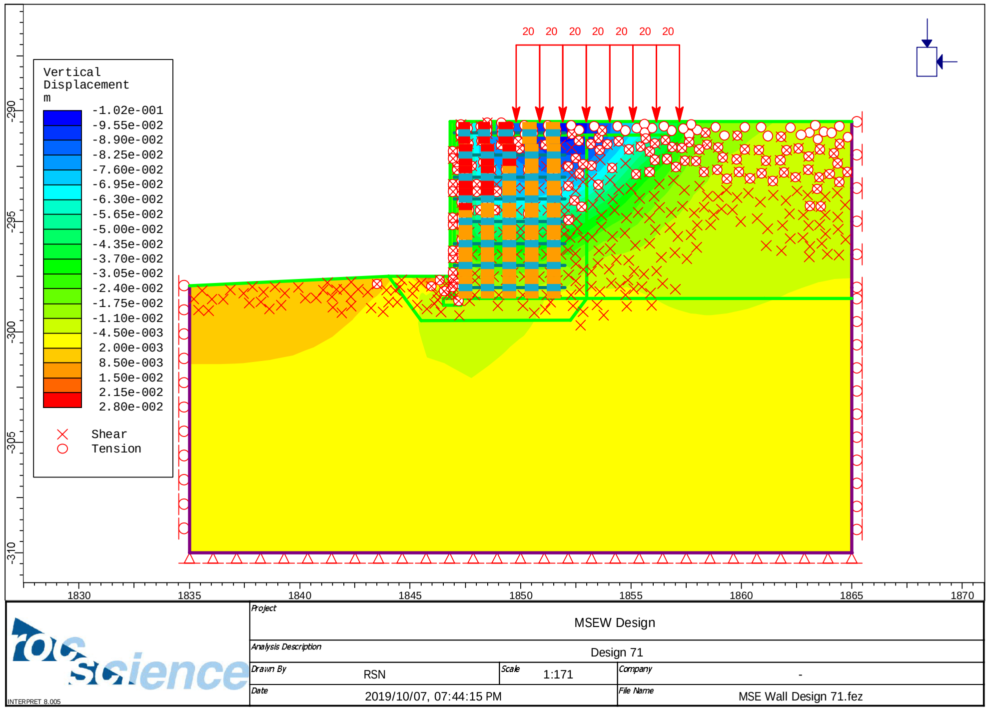
Sigma Z
kPa
0.00
15.00
30.00
45.00
60.00
75.00
90.00
105.00
120.00
135.00
150.00
165.00
180.00
195.00
210.00
225.00
240.00
255.00
270.00
285.00
300.00
Shear
Tension
20 20 20 20 20 20 20
-290
-295
-300
-305
-310
1830 1835 1840 1845 1850 1855 1860 1865 1870
Project
MSEW Design
Analysis Description
Design 71
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 71.fez
INTERPRET 8.005



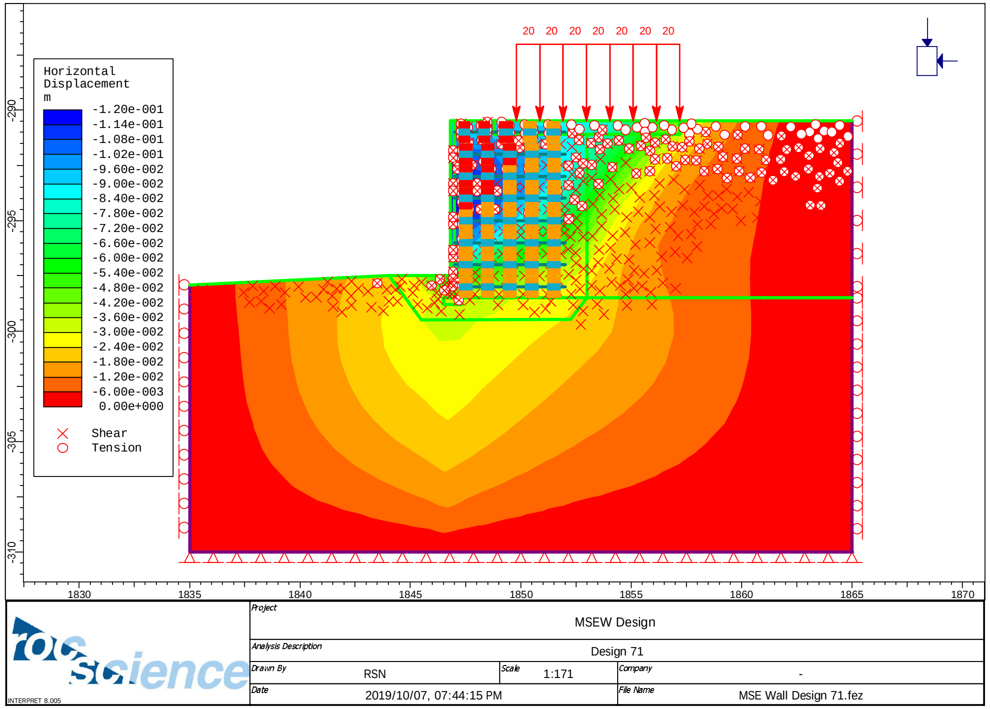
Maximum
Shear Strain
0.00e+000
1.50e-003
3.00e-003
4.50e-003
6.00e-003
7.50e-003
9.00e-003
1.05e-002
1.20e-002
1.35e-002
1.50e-002
1.65e-002
1.80e-002
1.95e-002
2.10e-002
2.25e-002
2.40e-002
2.55e-002
2.70e-002
2.85e-002
3.00e-002
Shear
Tension
20 20 20 20 20 20 20
-290
-295
-300
-305
-310
1830 1835 1840 1845 1850 1855 1860 1865 187
Project
MSEW Design
Analysis Description
Design 71
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 71.fez
INTERPRET 8.005

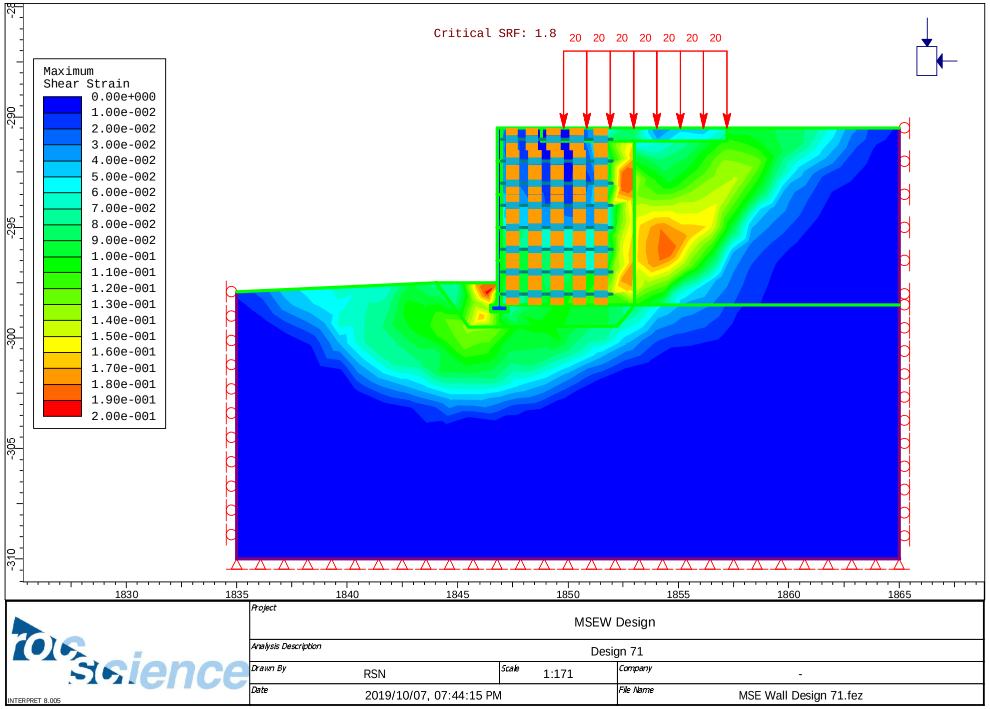


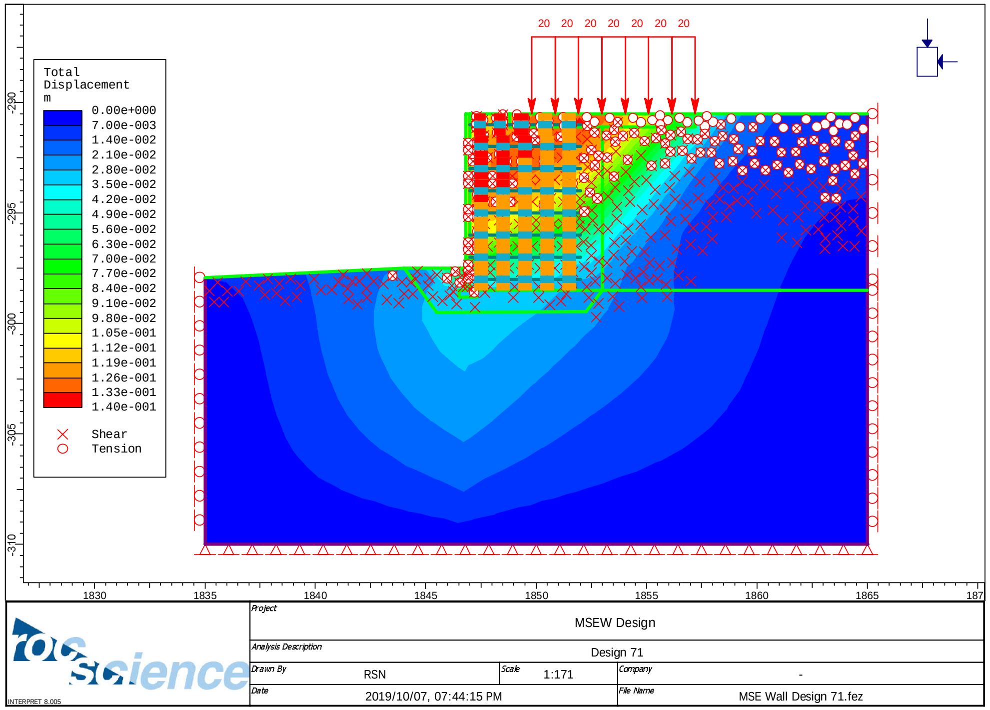
Mean Stress
kPa
0.00
15.00
30.00
45.00
60.00
75.00
90.00
105.00
120.00
135.00
150.00
165.00
180.00
195.00
210.00
225.00
240.00
255.00
270.00
285.00
300.00
Shear
Tension
20 20 20 20 20 20 20
-290
-295
-300
-305
-310
1830 1835 1840 1845 1850 1855 1860 1865 1870
Project
MSEW Design
Analysis Description
Design 71
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 71.fez
INTERPRET 8.005

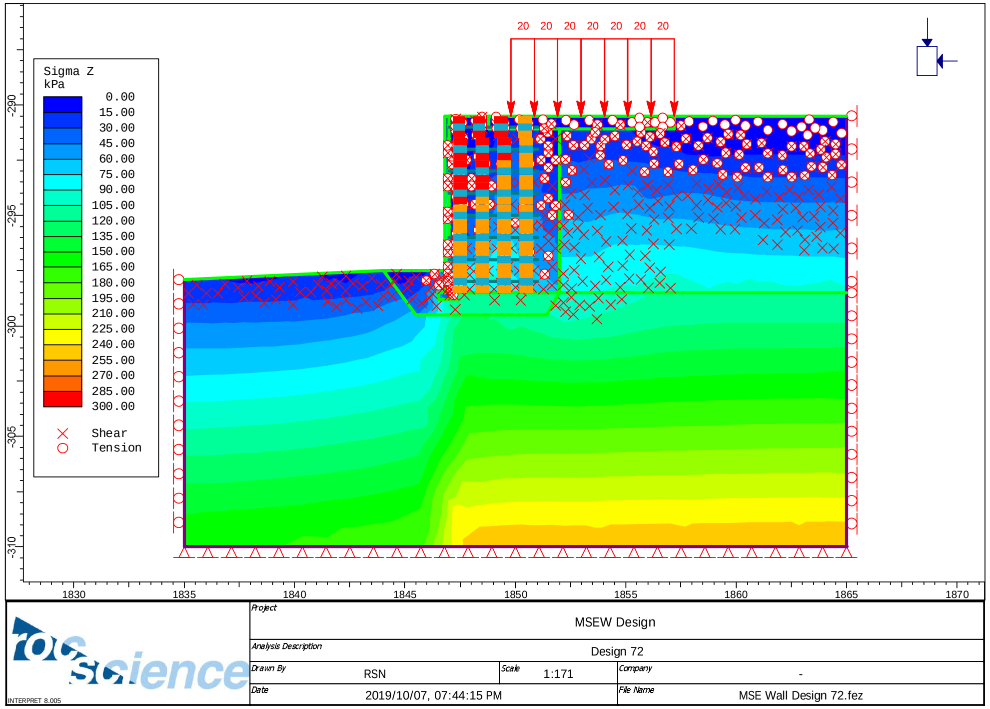


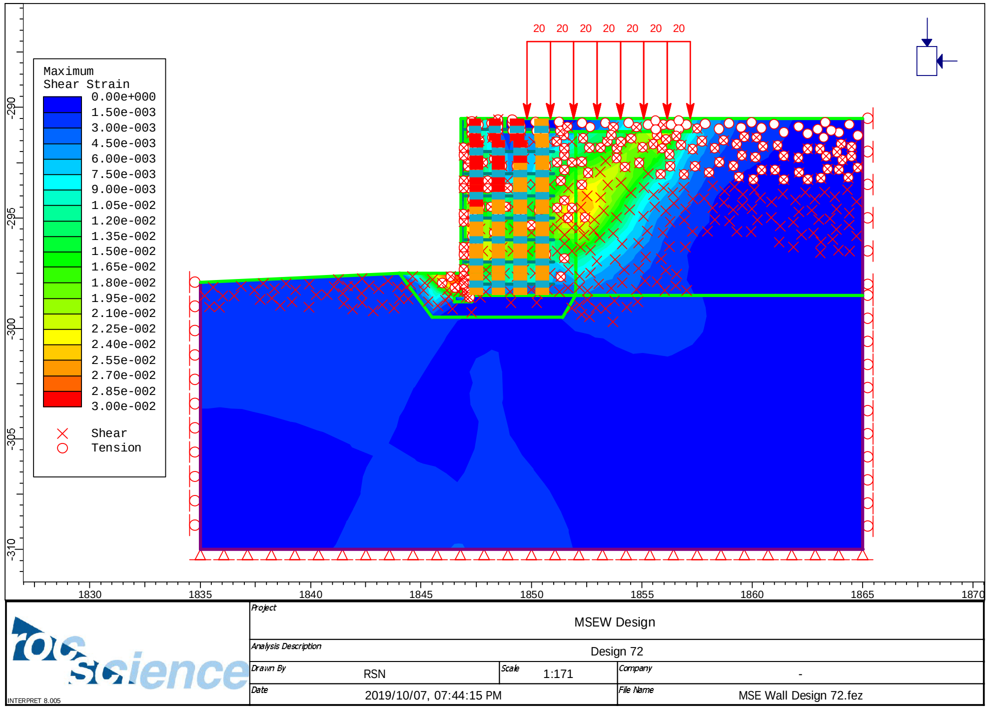
Vertical
Displacement
m
-1.02e-001
-9.55e-002
-8.90e-002
-8.25e-002
-7.60e-002
-6.95e-002
-6.30e-002
-5.65e-002
-5.00e-002
-4.35e-002
-3.70e-002
-3.05e-002
-2.40e-002
-1.75e-002
-1.10e-002
-4.50e-003
2.00e-003
8.50e-003
1.50e-002
2.15e-002
2.80e-002
Shear
Tension
20 20 20 20 20 20 20
-290
-295
-300
-305
-310
1830 1835 1840 1845 1850 1855 1860 1865 1870
Project
MSEW Design
Analysis Description
Design 71
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 71.fez
INTERPRET 8.005

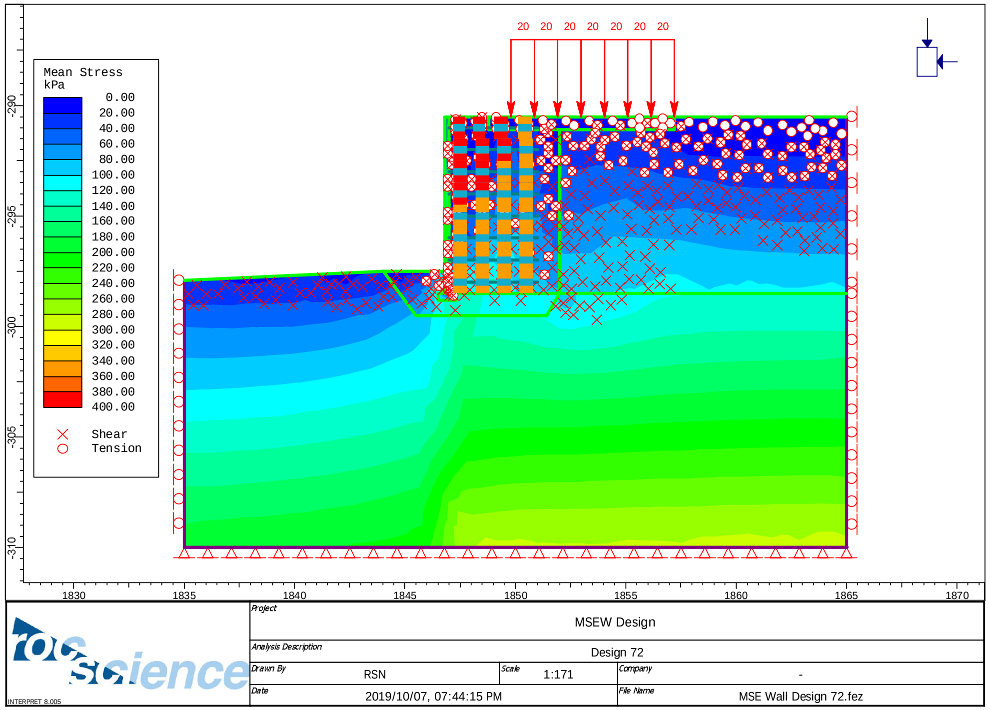

20 20 20 20 20 20 20
Horizontal Displacement m
-1.20e-001
-1.14e-001
-1.08e-001
-1.02e-001
-9.60e-002
-9.00e-002
-8.40e-002
-7.80e-002
-7.20e-002
-6.60e-002
-6.00e-002
-5.40e-002
-4.80e-002
-4.20e-002
-3.60e-002
-3.00e-002
-2.40e-002
-1.80e-002
-1.20e-002
-6.00e-003
0.00e+000
Shear
Tension
-290
-295
-300
-305
-310
1830
1835
1840
1845
1850
1855
1860
1865
1870
Project
MSEW Design
Analysis Description
Design 71
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 71.fez
INTERPRET 8.005

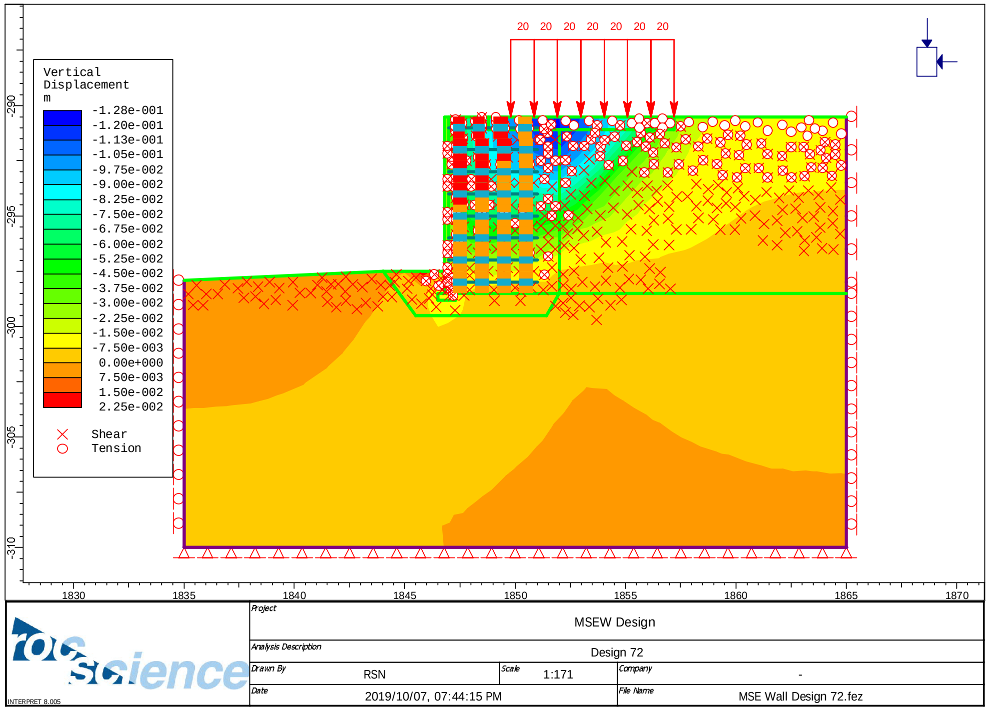

Critical SRF: 1.8
20 20 20 20 20 20 20
Maximum Shear Strain
0.00e+000
1.00e-002
2.00e-002
3.00e-002
4.00e-002
5.00e-002
6.00e-002
7.00e-002
8.00e-002
9.00e-002
1.00e-001
1.10e-001
1.20e-001
1.30e-001
1.40e-001
1.50e-001
1.60e-001
1.70e-001
1.80e-001
1.90e-001
2.00e-001
-290
-295
-300
-305
-310
1830
1835
1840
1845
1850
1855
1860
1865
Project
MSEW Design
Analysis Description
Design 71
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 71.fez
INTERPRET 8.005

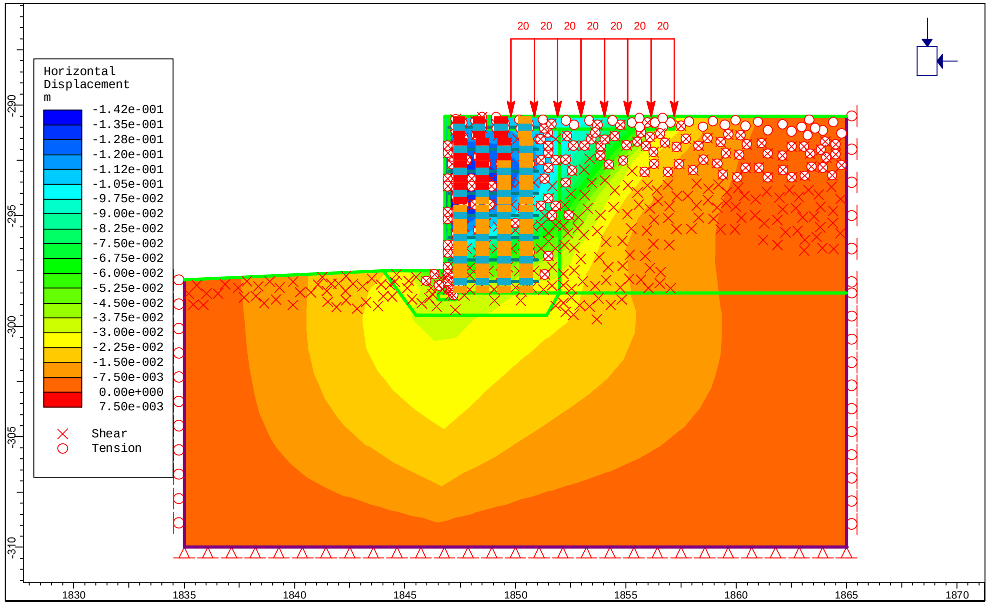

20 20 20 20 20 20 20
Total Displacement m
0.00e+000
7.00e-003
1.40e-002
2.10e-002
2.80e-002
3.50e-002
4.20e-002
4.90e-002
5.60e-002
6.30e-002
7.00e-002
7.70e-002
8.40e-002
9.10e-002
9.80e-002
1.05e-001
1.12e-001
1.19e-001
1.26e-001
1.33e-001
1.40e-001
Shear
Tension
-290
-295
-300
-305
-310
1830
1835
1840
1845
1850
1855
1860
1865
Project
MSEW Design
Analysis Description
Design 71
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 71.fez
INTERPRET 8.005


Sigma Z
kPa
0.00
15.00
30.00
45.00
60.00
75.00
90.00
105.00
120.00
135.00
150.00
165.00
180.00
195.00
210.00
225.00
240.00
255.00
270.00
285.00
300.00
Shear
Tension
20 20 20 20 20 20 20
-290
-295
-300
-305
-310
1830 1835 1840 1845 1850 1855 1860 1865 1870
Project
MSEW Design
Analysis Description
Design 72
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 72.fez
INTERPRET 8.005


Maximum
Shear Strain
0.00e+000
1.50e-003
3.00e-003
4.50e-003
6.00e-003
7.50e-003
9.00e-003
1.05e-002
1.20e-002
1.35e-002
1.50e-002
1.65e-002
1.80e-002
1.95e-002
2.10e-002
2.25e-002
2.40e-002
2.55e-002
2.70e-002
2.85e-002
3.00e-002
Shear
Tension
20 20 20 20 20 20 20
-290
-295
-300
-305
-310
1830 1835 1840 1845 1850 1855 1860 1865 1870
Project
MSEW Design
Analysis Description
Design 72
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 72.fez
INTERPRET 8.005


Mean Stress
kPa
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
160.00
180.00
200.00
220.00
240.00
260.00
280.00
300.00
320.00
340.00
360.00
380.00
400.00
Shear
Tension
20 20 20 20 20 20 20
-290
-295
-300
-305
-310
1830 1835 1840 1845 1850 1855 1860 1865 1870
Project
MSEW Design
Analysis Description
Design 72
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 72.fez
INTERPRET 8.005


Vertical
Displacement
m
-1.28e-001
-1.20e-001
-1.13e-001
-1.05e-001
-9.75e-002
-9.00e-002
-8.25e-002
-7.50e-002
-6.75e-002
-6.00e-002
-5.25e-002
-4.50e-002
-3.75e-002
-3.00e-002
-2.25e-002
-1.50e-002
-7.50e-003
0.00e+000
7.50e-003
1.50e-002
2.25e-002
Shear
Tension
20 20 20 20 20 20 20
-290
-295
-300
-305
-310
1830 1835 1840 1845 1850 1855 1860 1865 1870
Project
MSEW Design
Analysis Description
Design 72
Drawn By
RSN
Scale
1:171
Company
-
Date
2019/10/07, 07:44:15 PM
File Name
MSE Wall Design 72.fez
INTERPRET 8.005



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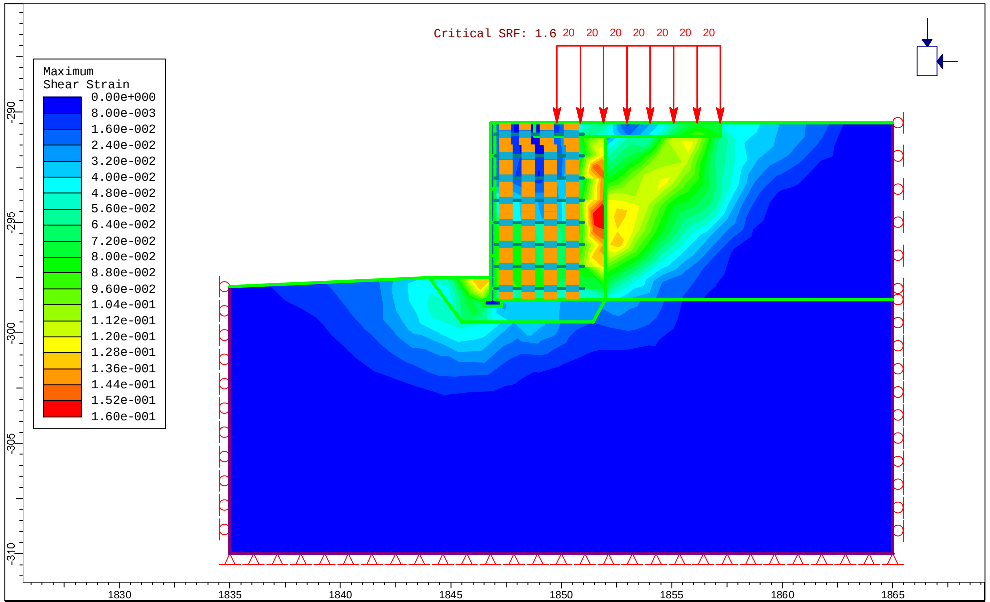

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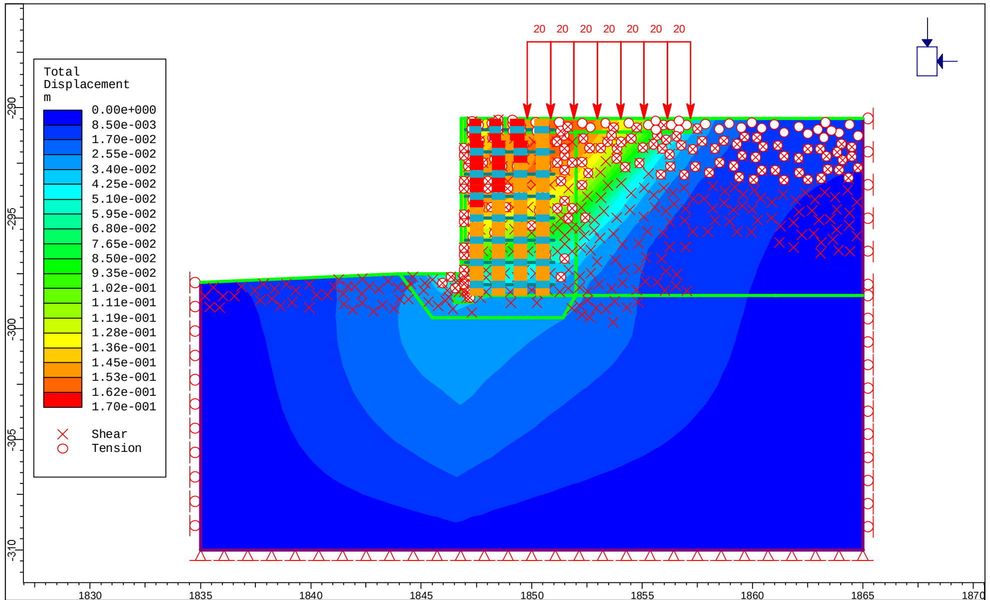

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