POLYMERISED DISPERSIONS AS SOIL CONDITIONERS -THEIR EFFECTS AND FEASIBLE APPLICATIONS

RICHARD TIMOTHY BISHOP

\$60 \$9

STUDIES ON

POLYMERISED DISPERSIONS AS SOIL CONDITIONERS

Geode THEIR EFFECTS AND FEASIBLE APPLICATIONS .

BY

REPART RICHARD TIMOTHY BISHOP

Submitted in partial fulfilment of the requirements for the degree of Doctor of Philosophy in Agriculture in the Department of Soil Science and Agrometerology, University of Natal, Pietermaritzburg.

20 \$ Pretermaniskurg: Univ. or Natel, 1978.

1978 THANK

2

DECLARATION

The thesis is the result of the author's own original work and contains to the best of his knowledge no other work accepted for any other degree or diploma in any University nor any material which has been previously published, except where due reference is made in the text of the thesis.

R.J. Bishop.

R.T. BISHOP

			-1-	Page
	C 0	NTE	NTS	
	ACK	OWLED	DEMENTS	×111
	ABST	RACT		xiv
	INTE		TION	1
CHAPTER I	POLY	MERS	IN LIQUIDS	3
		TNTO		
	8.	DEEL	INTTION OF POLYMERISED DISPERSIONS	í.
	C.	MANI	FACTURING TECHNIQUE	5
	D.	ING	REDIENTS	5
		1	Monomers	6
		2	Dienereinn madium	A
		3	Stabilisers	a
		38.	Emulaifiers	a
		3b.	Colloids	9
		4.	Initiators	10
	E.	MECH	HANISMS OF POLYMERISATION	10
		1.	Relatively insoluble monomers	11
		2.	Slightly soluble monomers	12
		3.	Monomers of intermediate solubility	13
CHAPTER TT	EXT	TING	COMMERCIAL ARRITCATIONS OF POLYMERS	
CHAPTER 11	TOS	SOILS	BURENCIAL PETEIDATIONS OF THE THENS	14
	Α.	CIVI	L ENGINEERING APPLICATIONS	14
		1.	Wind erosion control	14
		2.	Water erosion control on embankments	16
		3.	Load bearing slabs	17
	в.	AGRI	CULTURAL APPLICATIONS	18
		1.	Improving soil aggregation	18
		2.	Moisture conservation	21
		3.	Increasing soil temperature	22
		4.	Preventing soil crusting	23
		5.	Wind and water erosion	23
2		ь.	Controlled release of fertiliser	24
	с.	CONC	CLUSIONS AND SUMMARY	25

CHAPTER III	ABIL	ITIES OF POLYMER DISPERSIONS TO BOND SAND	26
	- A.	INTRODUCTION .	26
	8.	BONDING ABILITIES OF DIFFERENT TYPES OF COMMERCIAL DISPERSIONS	26
		1. Materials 2. Experimental procedure 3. Results and discussion	26 28 30
	C.	THE INFLUENCE OF INGREDIENTS IN DIFFERENT TYPES OF DISPERSIONS ON BOND STRENGTHS	31
	D.	THE INFLUENCE OF PHYSICAL PROPERTIES OF DIFFERENT DISPERSION TYPES ON BOND STRENGTHS	31
100 11		1. Surface tension 1a. Materials and procedure 1b. Results and discussion 2. Particle size	32 32 34 36
	ε.	THE EFFECT OF MINOR VARIATIONS IN A GUM STABILIZED PVAC HOMOPOLYMER DISPERSION ON SAND BONDING	36
		1. Materials and procedure 2. Results and discussion	36 38
	F.	RELATIONSHIP BETWEEN LOW VISCOSITY BATCHES AND HIGH BONDING ABILITY OF THE PVAC HOMOPOLYMER DISPERSION	38
		1. Materials and procedure 2. Results and discussion	40 41
	G.	SUGGESTED MECHANISMS OF SAND BONDING WITH DIFFERENT POLYMER DISPERSION TYPES	42
	н.	CONCLUSIONS	45
CHAPTER IV	WATE	R HOLDOUT STUDIES ON POLYMER DISPERSION	47
	Α.	INTRODUCTION	47
	8.	WETTING PROPERTIES IMPARTED TO BONDED SAND BY DIFFERENT POLYMER DISPERSIONS	47
		1. Materials 2. Experimental procedure 3. Results and discussion	47 47
	с.	CHANGES IN WATER UPTAKE WITH TIME BY SAND BOUND WITH DIFFERENT POLYMER DISPERSIONS	49
		1. Materials 2. Experimental procedure 3. Results and discussion	49 49 50

	D.	POLYMER DISPERSION PROPERTIES WHICH INDUCE WATER REPELLENCY IN SAND	53
	ε.	SUGGESTED MECHANISM RESPONSIBLE FOR CREATING THE HYDROPHOBIC EFFECT	55
		1. Materials and procedure 2. Results and discussion	56 56
	F.	LOWEST EFFECTIVE POLYMER LEVELS IMPARTING WATER REPELLENCY TO SAND	58
		1. Materials and procedure 2. Results and discussion	58 58
	G.	CONCLUSIONS	61
58 () / () / () / ()			
CHAPTER V	WIND	EROSION CONTROL	63
	Α.	EXISTING CONTROL MEASURES	63
		1. Fences	63
		2. Chemicals	64
		 Bulky surface spreads 	64
	8.	SELECTING TYPE AND LEVEL OF DISPERSION TO FORM THICK SAND LAYERS USING SURFACE	
		APPLICATIONS	69
		1. Materials	69
		 Experimental procedure Results and discussion 	69 70
	с.	DETERMINING MINIMUM POLYMER CONCENTRATION NECESSARY TO FORM RAINDROP RESISTANT SAND AGGREGATES	71
		1 Union the commental DUAs becausiumes	
		 As the commercial PVAC homopolymer Materials and procedure Results and discussion 	73 73
		2. Comparison between the PVAc - Gum A	
		dispersion and new development grades	74
		28. Materials	74
		2c. Results and discussion	76
	D.	QUALITY OF DILUTION WATER	77
	ε.	METHODS OF APPLICATION IN THE FIELD	78
		1 Batch sustans	70
		2. Continuous systems	79
		2a. Metering polymer in at the pump	79
		2b. Metering polymer in at exit of hose	84
	F.	AN OBSERVATIONAL FIELD TRIAL TO ASSESS THE RESISTANCE OF AGGREGATES TO WIND BLOWN SAND	84
		1. Materials	86
		2. Experimental procedure	86

	G.	PRAC	TICAL FIELD APPLICATIONS	89
		1.	Site No. 1 - Richards Bay	90
		18.	Venetation by seeding	90
		1b.	Vegetation by planting saplings	94
		2.	Site No. 2 - Durban Bay	94
		3.	Site No. 3 - Mulzenberg marina	07
		1.	Site No. 4 - Flandshasi	101
		5.	Summary and discussion	103
CHAPTER VI	WATE	R ERO	SION CONTROL ON STEEP SLOPES -	400
	UBSE	RVAIL	UNAL TRIALS	106
	Α.	SAND	Y, PERVIOUS SUBSTRATES	107
	в.	SLOP	ES WITH SOME PERMEABILITY	111
	с.	IMPE	RVIDUS SUBSTRATES	113
	D.	SUMM	ARY AND DISCUSSION	115
CHAPTER VII	LOAD	BEAR	ING SLABS ON SAND	119
	А.	EXIS	TING PRODUCTS USED	119
	8.	PERF	ORMANCE COMPARISONS BETWEEN THE HOMOPOLYMER AND CEMENT	121
		1.	Soil strength	121
		1a.	Materials	122
		16.	Experimental procedure	122
		10.	Results and discussion	123
		2.	Shrinkage	124
		3.	Flexibility	125
		4.	Drying time	126
		5.	Resistance to water	126
	с.	IMPR	OVING THE WATER RESISTANCE OF SAND ED WITH POLYMER	127
		1	Preventing water penetration by blending	
			polymer dispersions	127
		2.	Blending water resistant materials into	40.1
		0	the PVAc homopolymer	129
		22.	Materials .	129
		26.	Experimental procedure	129
		20.	Results and discussion	130
		3.	Water resistant monomers in locating type dispersions	131
	D.	OPTI COPO	MISING THE PERFORMANCE OF A LOCATING	
		1.	Reducing the level of stabilizer	133
		18.	Materials	133
		1b.	Experimental procedure	134
		10.	Results and discussion	134

-iv-

E. PRACTICAL DESERVATIONAL TRIALS

1.	A complete road on a sandy soil	138
1a.	Materials	138
1b.	Experimental procedure	138
10.	Results and discussion	142
	and the second of the second s	2.000

- 2. A sub-base for roads on marine sand 142
- F. GENERAL CONCLUSIONS

CHAPTER VIII MOISTURE CONSERVATION

Α.	DEFL	ECTING WATER INTO THE ROOT ZONE	146
	1.	Influence of soil type on water	
		repellency	147
	1a.	Materials	147
	10.	Experimental procedure	147
	10.	Results and discussion	147
	2.	Field trial with sugar cane	148
	2a.	Materials	148
	2b.	Experimental procedure	149
	Zc.	Results and discussion	149
8.	REDL	CING EVAPORATION BY SURFACE TREATMENTS	152
	1.	Influence of soil type	153
	1a.	Materials	153
	1b.	Experimental procedure	153
	10.	Results and discussion	153
	2.	The effect of reduced evaporation on	
		soil temperatures	155
	2a.	Materials	155
	25.	Experimental procedure	155
	20.	Results and discussion	156
	3.	The effect of polymer dispersion type	
		on evaporation rate	157
	38.	Materials	157
	3b.	Experimental procedure	158
	3c.	Results and discussion	158
	4.	Pot experiments to test plant	
		responses	160
-	48.	Materials	161
	40.	Experimental procedure	161
	40.	Results and discussion	161
c.	FIEL	D TRIALS WITH SUGAR CANE	
	1.	The positioning of hydrophobic barriers	163
	1a.	Materials	163
	1b.	Experimental procedure	163
	10.	Results and discussion	166

CHAPTER IX

	2.	The reproducibility of the earlier tillering effect at different sites	172
	2a.	Materials .	172
	26.	Experimental procedure	172
	2c.	Results and discussion	173
	3.	Reducing the volume of carrier water	176
	3a.	Materials	176
	30.	Experimental procedure	1/6
	30.	Results and discussion	1//
	4.	Scaling up to practical applications	179
	48.	Materials	102
	40. 4c.	Results	182
	5.	Treatment of ration crops	185
	58.	Materials	185
	5b.	Experimental procedure	185
	5c.	Results and discussion	186
	6.	General discussion and conclusions	189
USI PHO ADD	NG POL BIC EF	YMER DISPERSIONS WHICH IMPART THE HYDRO- FECT TO IMPROVE THE EFFICIENCY OF SOIL	191
Α.	SUGO	GESTED SYSTEMS FOR CONTROLLING FERTILIZER	192
в.	WET PART	BLENDS OF FERTILIZER, POLYMER AND ICULATE MATERIALS	193
	1.	Influence of copolymer blends and	
		fertilizer levels on water uptakes of	2000
		sand	195
	ia.	Materials	195
	10.	Experimental procedure	195
	10.	Results and discussion	196
	2.	Fertilizer losses from solutions with	
	-	and without copolymer dispersion	198
	28.	Materials	198
	20.	Cxperimental procedure	198
	20.	Results and discussion	199
	3.	Effect of fertilizer concentrations	204
-	7-	on leaching patterns	201
	36.	Function to an and the second	201
	3c.	Results and discussion	202
	4	Field trials with maize	205
	40	Materials for 1976 - 1977 sendon	207
	46.	Experimental procedure	207
	40	Results and discussion for 1976 _ 1977	EU/
		Season	208
	4d.	Materials for 1977 - 1978 sesson	208
	40	Experimental procedure	208
	41.	Results and discussion for 1977 - 1978	
	South		2 10

	(1) Grain yields (11) Nitrogen uptekes	21
5.	Highly concentrated systems to match	
	plant requirements	21
58.	Materials	21
5b.	Experimental procedure	21
5c.	Results and discussion	21
HEDE	TCIDE INVESTIGATIONS	22
HERE		
1.	Maize	22
18.	Materials	22
1b.	Experimental procedure	22
10.	Results and discussion	22
2.	Sugar cane	22
28.	Materials	22
2b.	Experimental procedure	22
20.	Regults and discussion	22
	HEBUITS BID DISCUSSION	
GENE	RAL DISCUSSION AND CONCLUSIONS	22
SOLI	D CONTROLLED RELEASE FERTILIZER	
1.	Dry blends using inorganic hydro-	
	phobic particles	22
18.	Leaching rates of N fertilizers	22
	(i) Materials	22
	(11) Experimental procedure	22
	(111) Results and discussion	22
2.	Blenda usino organic hydrophobic	
	perticles	23
28.	The effectiveness of loose, dry	
~ ~ ~	blends in reducing leaching losses	23
	(1)	
	(1) Materials	23
	(11) Experimental procedure	23
	(111) Results and discussion	23
25.	The effectiveness of wet apprecated	
2.000	briquettes in reducing leaching losses	23
	(1) Materials	23
	(11) Experimental procedure	23
	(111) Results and discussion	23
	Bot elept wields from different N	
2.	containing fortilizers	
7.	Mataniala	23
28.		23
30.	Experimental procedure	23
JC.	Results and discussion	24
4.	Field experiments with maize	24
5.	Summary and discussion	24
		Aug.
GENE	RAL SUMMARY AND CONCLUSIONS	25

CHAPTER X

A. SIGNIFICANCE OF POLYMER DISPERSION COMPOSITIONS

25

-vii-

с.

D.

ε.

8. GRADING OF FEASIBLE APPLICATIONS

1.	Conservation of moisture, fertilizers	262
-	and herbicides in agricultural solis	232
2.	Solid controlled release fertilizers	252
3.	Load bearing applications	255
4.	Control of water erosion on	
	embankments	257
5.	Control of wind erosion in confined	
	aress	257
6.	Control of wind erosion over extensive	
- 21	87682	258

n	C	0	C 1	6.11	n. '	τ.	Υ.
H.	-		E 1	N.	12.	1	х.

1	PHYSICAL PROPERTIES OF THE 10 COMMERCIAL DISPERSIONS USED	259
2	PHYSICAL PROPERTIES OF EXPERIMENTAL DISPERSIONS POLYMERISED	260
3	METHODS OF PHYSICAL ANALYSIS OF DISPERSIONS	261
	A. SURFACE TENSION B. AVERAGE PARTICLE SIZE C. pH D. GRIT LEVEL E. VISCOSITY F. TOTAL SOLIDS	261 262 262 263 263
4	ASSESSMENT OF PVAC HOMOPOLYMER DISTRIBUTION DOWN SAND PROFILE AFTER SURFACE APPLICATION	264
	A. INTRODUCTION B. MATERIALS AND PROCEDURE C. RESULTS AND DISCUSSION	264 264 265
5	THE EFFECT OF PH AND SALT CONCENTRATIONS ON STRENGTH OF POLYMER-BOUND SAND BRIQUETTES	266
	A. MATERIALS AND PROCEDURE B. RESULTS AND DISCUSSION	266 266
	1. pH 2. Salt concentrations	266 267
6.	A CRUDE TEST TO ASSESS RESISTANCE OF SAND BRIQUETTES TO SAND BLASTING	269
	A. INTRODUCTION B. MATERIALS AND PROCEDURE C. RESULTS AND DISCUSSION	269 269 269
7	LOCATION OF SITES WHERE SAND STABILIZING DESERVATIONAL EXPERIMENTS WERE CONDUCTED	271
8	LAYOUT OF PLOTS AT THE SAND STABILIZATION DESERVATIONAL TRIAL AT MUIZENBURG	272

-ix-

APPENDIX

9	ATTEMPTS TO OBTAIN AN AIR DRYING FOAM MULCH	273
	A. LIQUID FOAMING COMPOUND	273
	1. Introduction	273
	2. Materials and procedure	273
	8. MECHANICAL FDAMING MACHINES	274
10	APPARATUS USED FOR DETERMINING RELATIVE HARDNESS OF POLYMER FILMS	277
11	THE AFFECTS OF VARIOUS ADDITIVES TO POLYMER DISPERSIONS ON THE SUBSEQUENT TENSILE STRENGTHS OF SAND BRIQUETTES	278
	A. MATERIALS AND PROCEDURE B. RESULTS	278 278
12	THE AFFECTS OF BITUMEN ADDITIONS TO POLYMER DISPERSIONS ON THE SUBSEQUENT TENSILE STRENGTHS OF SAND BRIDUETTES	281
	or only strageries	
	A. MATERIALS AND PROCEDURE 8. RESULTS	281 261
	a Bituman Jawal	284
	2. pH effect	281
	3. Different dispersions	282
	4. Different production batches of PVAc	282
	5. Bitumen in solvent	283
	 Destabilization of bitumen in liquid blend 	283
	7. Destabilization of bitumen in sand	283
13	THE AFFECTS OF WATER LEVEL ON TENSILE STRENGTHS OF SUBSEQUENT POLYMER BOUND SAND BRIQUETTES	284
	A. INTRODUCTION	284
	8. MATERIALS AND PROCEDURE	284
	C. RESULTS AND DISCUSSION	284
14	PHYSICAL PROPERTIES OF DAXAD STABILIZED STYRENE- ACRYLIC COPOLYMER	286
15 .	EFFECT OF DIFFERENT COALESCING SOLVENTS ON THE UNCONFINED COMPRESSIVE STRENGTHS OF SAND CORES BOUND WITH DAXAD STABILIZED STYRENE_ACRYLIC	
	COPOLYMER	287
	A. INTRODUCTION	287
	8. MATERIALS AND PROCEDURE	287
	C. RESULTS AND DISCUSSION	288
16	SUGAR CANE RANDOMISED BLOCK EXPERIMENT WITH	200
	PATTERENT POISTORE GOUSERVING TREATMENTS	290
	1. Field layout and plot sizes	290
	2. Statistical analysis	290

APPENDIX

	2a.	Analysis of variance of final yield	
		results in tons/cane/hectare	291
	2b.	Analysis of variance of stalk	
		populations x 103/hectare at	
		harvest	292
	2c.	Analysis of variance of stick	
		lengths (in cm) at harvest	293
MEA	N DAIL	Y SCREEN TEMPERATURES AT DOOD HOURS.	
REL	ATIVE	HUMIDITY, SUNSHINE HOURS PER DAY, RUN	
OF	WIND A	ND RAINFALL FOR 1 JUNE 1976 TO 31 MAY	
197	7 AT M	OUNT EDGECOMBE	294
12			
FIE	LD LAY	OUT AND INCREASES IN SHOOT POPULATIONS	
OF	RATOON	CANE RECEIVING A SPRAY OF DILUTE CO-	
POL	VMER D	TSPERSTON	295
1.04			
	1	Site treated in mid Winter	295
	2	Site treated in early Summer	296
	G.	Site created in early Summer	2.20
1.03		DI ANT CANE TOTAL WHERE CODDI VMED	
DIG		PLANT GANE TRIAL WHERE GUPOLTHER	200
015	PERAIU	IN WAS APPLIED BY TRALIDR	2.90
		1	200
	7.	Layout of trial	290
	2.	Statistical enalysis	299
LIN	VEAR RE	LATIONSHIPS BETWEEN LEVEL OF CUPULYMEN	-
APP	LIED A	ND REDUCED EVAPORATION OF SOIL WATER	302
	20.000		-
	1.	Introduction	302
	2.	Materials and procedure	302
	28.	Increasing volumes of the same con-	
		centration	302
	2b.	Increasing concentrations at the	
		same volumes applied	303
	2c.	Increasing emounts of hydrophobic	
	2	sand	303
	3.	Results and discussion	303
DET	AILS D	F EXPERIMENT TO TEST THE EFFECT OF	
DIF	FERENT	CONCENTRATIONS OF A STYRENE-2EHA CO-	
POL	YMER D	ISPERSION ON EARLY TILLERING OF SUGAR	
CAN	IE		306
			500
	1.	Levout of trial	306
	2	Statistical analysis	307
DET	ALLS	F PLOT DESTEN, SOTI DESCRIPTION AND	
STA	TISTIC	AL ANALYSTS OF A MATZE TRIAL DESTONED	
TO	GIVE G	REATER VIELD THROUGH CONSERVATION OF	
MOT	STURF	AND/DR FERTILIZER	3 40
HUI	U. U.L	HILF DR FERTLETER	210
	4	1976 - 1977 -	7.40
		lawout of talal	310
	18.	Layour of Frier	310
	10.	Description of soil	311
	10.	Rainfalls for 1976 - 1977 and 1977 -	
		1978 seasons	312

×-

-xi-

APPENDIX

	1d. 1e.	Leaf N % Statisti	end total yield results cel enelysis	3 13 3 13
		(1)	Leaf N %	314
		(11)	Total plant vield	314
		(111)	Indicated absolute N uptake	314
	2.	1977 - 1	978 season	3 15
	28.	Layout of	r trial	315
	20.	Statisti	cel energers	210
		(1)	Grain yield	316
		(11)	Cob counts	3 76
		(111)	Lear N %	310
		(10)	Plent weights minus cobs and	511
			orain	317
		(v1)	Total plant yields	317
FIE	D TRI	AL INVEST	IGATING THE EFFECT OF COPOLYMER	
DIS	PERSIC	IN SPRAYS	ON THE CONSERVATION OF	
MOIS	STURE,	FERTILIZ	ER AND HERBICIDE	318
Α.	INTE	DOUCTION		318
в.	MATE	RIALS AND	PROCEDURE	3 18
с.	RESL	LTS		319
LAB	DRATOR	Y APPARATI	US USED FOR COMPRESSING DRY ETTES	322
THE	EFFEC	T OF LEVE	L OF PVAC HOMOPOLYMER ON	
WAT	ER UPT	AKE OF SA	ND BRIQUETTES	323
THE INF	INFLU	ENCE OF P	OLYMER BLENDS ON THE , FERTILIZER RELEASE RATES	
AND	EVAPO	RATION RAT	TES OF SANDS MODIFIED WITH	
1 1 1 1				325
THE				325
A.	INTR	ODUCTION		325
A. B.	INTR	ODUCTION LTRATION	RATES	325 325 325
A. B.	INTE INFI 1.	ODUCTION LTRATION Material	RATES	325 325 325 325
A. B.	INTE INFI 1. 2.	ODUCTION LTRATION Material Results	RATES s and procedure and discussion	325 325 325 325 325
A. B.	INTE INFI 1. 2. FERT	DDUCTION LTRATION Material Results ILIZER REP	RATES s and procedure and discussion LEASE RATES	325 325 325 325 325 326 327
A. B.	INTE INFI 1. 2. FERT 1.	ODUCTION LTRATION Material Results ILIZER REI Material	RATES s and procedure and discussion LEASE RATES s and procedure	325 325 325 325 325 326 327 327
A. B.	INTE INFI 1. 2. FERT 1. 2.	ODUCTION LTRATION Material Results ILIZER REI Material Results	RATES s and procedure and discussion LEASE RATES s and procedure and discussion	325 325 325 325 326 327 327 327
A. B. C.	INTE INFI 1. 2. FERT 1. 2. EVAP	ODUCTION LTRATION Material Results ILIZER REI Material Results ORATION RA	RATES s and procedure and discussion LEASE RATES s and procedure and discussion	325 325 325 325 326 327 327 327 327 328 325
A. B. C.	INTE INFI 1. 2. FERT 1. 2. EVAP 1.	ODUCTION LTRATION Material Results ILIZER REI Material ORATION RA	RATES s and procedure and discussion LEASE RATES s and procedure and discussion ATES s and procedure	325 325 325 325 326 327 327 327 327 327 325 325

APPENDIX

28

8. INSECTICIDES	332
 Materials and procedure Results and discussion 	332 333
THE COMBINED EFFECTS OF A COPOLYMER DISPERSION MULCH AND A CHEMICAL RIPENER ON SUGAR CONTENTS OF CANE	334
A. MATERIALS AND PROCEDURE B. RESULTS AND DISCUSSION	334 335
	770

REFERENCES

ACKNOWLEDGEMENTS

The author wishes to express his gratitude to Messre Revertex (S.A.) (Pty.) Limited who supplied the facilities and materials to enable this work to be done. Special credit should be given to Mr C.E. Simpson - Marketing Director - who supported the project from its earliest stages and to other staff members for their assistance in field and laboratory work.

He also thanks his supervisor, Professor M.E. Summer, then Head of the Soil Science Department, University of Natal, who made this Thesis possible by allowing the work to be done on a part time basis and also for his advice and help in the preparation of this manuscript.

Thanks are also due to Dr G.D. Thompson, Director of the S.A.S.A. Experiment Station for allowing his staff and Association's property to be used in assisting with various aspects of the work.

Thanks also to the following for co-operating in field trials: Mr C. Semelink of the C.S.I.R. Roads Research Division, Mr P. Bullock of the Glendale Sugar Company, Mr P. Landrau of C.G. Smith (Pty) Limited, Mr S. Rau of Huletts Sugar Company, Mr J. Groves of the Vegetation Unit, Chamber of Mines, and Dr M. Farina of the Department of Agricultural Technical Services.

Gratitude is also expressed to the numerous others who assisted in one way or another and for the guidance that was undoubtedly received.

Finally the author would like to thank his wife for her active support and his family for all the inconvenience and neglect they so patiently endured during the duration of this project.

ABSTRACT

THE AIM OF THIS PROJECT WAS TO ELUCIDATE AND FIND PRACTICAL APPLICATIONS OF THOSE PROPERTIES IMPARTED TO SOILS BY DIFFERENT SPECIES OF THAT GROUP OF "POLYMERS" DESCRIBED AS POLYMER DISPER-SIONS.

Preliminary laboratory tests were conducted to investigate the aggregating and water repellency effects on sand of a number of variations of different polymer dispersions, namely, polyvinyl acetate (PVAc) homopolymers, vinyl acetate - acrylic copolymers, vinyl acetate - vinylester of versatic acid (VeoVa) copolymers, styrene - acrylic copolymers and styrene - butadiene copolymer dispersions.

These tests indicated that the type and level of stabilizer used during the polymerisation reaction controlled the ability of the dispersion to form strong sand aggregates. Sand briquettes aggregated with PVAc homopolymer dispersions had excellent cohesive strengths, but poor abilities to hold out water. In contrast, all the copolymers produced weak aggregates but had exceptional abilities to prevent water penetration. The ability to repel water was concluded to be a function of the high degree of water insolubility of some polymers and their ability to cost the sand grains.

Applications considered for those polymer dispersions capable of strongly bonding sand were, firstly, the prevention of wind and water erosion, and secondly, as load bearing bases. Promising long term control of wind erosion was observed at several sites when the layer of sand previously consolidated by a polymer dispersion was mechanically ruptured to form in situ clods. On the steep slopes of gold mine dumps the normally highly erodable material was stabilized against water erosion by a surface spray and this permitted the establishment of Initially, load bearing applications could not be considered as sand consolidated by commercially available dispersions lost all its strength after submersion in water. However, a different combination of stabilizer and monomers produced a dispersion which gave sand cores having unconfined compressive strengths of 0.3 megapascals, at 0.5% polymer on marine sand after four days submersion. The improved performance justified consideration for road building applications and the techniques used subsequently to construct a sub-base layer on marine sand and an all-weather road on a sandy - loam are described in the thesis.

Proposed applications for the water repellency effect were. firstly, to increase efficiency of applied water by deflecting it into the root zone; secondly, to reduce evaporation of soil water and, thirdly, to conserve fertilizers, herbicides, insecticides and other water sensitive soil additives by reducing leaching losses. Laboratory tests showed that sand treated with certain dispersions at 0,019% dry polymer, although remaining free-flowing, not only prevented water percolating into it but also reduced the movement of water vapour by some 50%. As a consequence of this reduced evaporation, surface temperatures of wet soils were shown to be some 3.5 C higher than control soils. The reduced evaporation encouraged the growth of larger plants. In a pot experiment with maize, polymer treated soils yielded 32% more dry matter than did the controls. Field trials showed earlier tillering in sugar cane (39% more at 3 months) over a wide range of soil and climatic conditions, as a result of treatment. An increase in cane yield of 13% and a higher extractable sugar content of 3% gave 16% (or 2,3 tons) more sugar/ha over controls when a surface spray of 33 kg/ha of polymer was applied over the row. Linear relationships between level of copolymer applied and moisture conserved recorded

- XV -

in the laboratory were confirmed, in that a lower polymer treatment produced 6% (or 0,9% tons/ha) more sugar. On soils with higher moisture holding capacities, 10kg/ha of copolymer increased cane yields by approximately 15% or 13 tons/ha. 5kg/ha of copolymer gave earlier tillering (29% at 3 months) but no increase in yield. When 10kg/ha of copolymer mulch were applied onto a heavy alluvium soil at planting, the concentrations of sugar in the cames at hervest were 10% higher where a chemical ripener had been applied, compared to where the ripener alone was used. In a replicated maize trial with 150 kg N/ha, plots receiving a 2 000£/ha spray of 0,5% solids copolymer dispersion over the row at planting yielded 514 kg/ha (or 6,7%) more grain than did the equivalent control plots. The total production of plant matter, although not statistically significant, was 11,3% greater than control.

Laboratory tests showed that materials such as fertilizers and herbicides were released at a more controlled rate when added to the dilute copolymer dispersion before application to the soil. At high N applications leaf samples from a field experiment with maize showed 3, 18 % N where $(NH_4)_2SO_4$ was dissolved in the copolymer dispersion and 2,97% where conventional $(NH_4)_2SO_4$ was applied. The indicated total smount of N recovered by the crop was significantly higher than control (28%). Herbicides, when preblended with dilute copolymer dispersion, were seen to control weeds for as long as 5 months, whereas the herbicides alone were only effective for some 6 weeks.

Similar significant reductions of leaching losses were observed when a dry blend of fertilizer and copolymer treated send or organic material, such as wood flour, was used.

- xvi -

109 kg/ha of urea blended with 120 kg of pretreated wood flour and drilled alongside the planting line yielded 413 kg/ha (or 5,9%) more grain, and the crop recovered 23% more N, than did the control treatments.

INTRODUCTION

The idea of using synthetic or natural polymers as soil conditioners is not new. The possibility of spraying polymers on land to stabilis it against various forms of erosion fired the imagination of the Chemical Industry during the late 1940s and early 1950s when structure stabilisation of agricultural and horticultural soils received much attention. At one time more than 100 different materials were available on the market as "soil conditioners". Typic examples were polymers comprising, or based on, vinyl acetate maleic acid ("Krilium"), hydrolized polyacrylonitrile ("Bondite"), isobutylene maleic acid, methyl methacrylate, polyvinyl alcohol, polyvinyl acetate, asphalt emulsions, natural and synthetic rubber latex polysaccharides and dimethyl octs decyl ammonium chloride ("Arquads".

By the early 1960s most of these products had fallen into disuse and to indicate the decline in interest in synthetic soil conditioner published research papers dropped off from 32 in 1954 to one in 1962. While certain successes were achieved - for example, small amounts of polyvinyl acetate are used for hydroseeding embankments and "Krilium" for soil conditioning - it can be said that no products emerged with worthwhile on-going applications. The main reason for their demise was that the magnitude of their benefit failed to justify their cost.

Despite the previous lack of sustained interest in polymers as soil conditioners, the specific group often referred to as "polymer emulsions", but more correctly "polymer dispersions", were considered worthy of further study. This was because a ten-year association with a chemical company producing polymer dispersions aroused an awareness in the author of the extreme diversity of types, but surprisingly it was found that recorded comparative studies of the specific effects imparted to soils by the different members of this group are scarce. As a result of their immense value in industry, polymer dispersions have reached an advanced stage of technology. The range of their properties is very wide; for example, their dried films can be either so hard or so soft that they can be used in glossy paints or sticky tapes respectively, and it seemed likely that some of these characteristics could be applied profitably to soils.

In 1972 at a "Symposium on the Fundamentals of Soil Conditioners" at Ghent, international interest in research into the use of polymers in agriculture was resurrected and some 23 papers were presented. Two of these papers tried to analyse the reasons for the previous failure of polymers to find commercially useful applications. Gardiner (1972) concluded: "It may be well to concentrate major research and development efforts in areas where the best chance for economic application may be anticipated and to avoid the over extension and over enthusiasm which helped to speed the decline in interest in soil conditioners in the late 1950s".

The objectives of this thesis are in keeping with the above sentiments of Gardiner. The first aim is to make an intensive study to elucidate what effects could be imparted to soils by that specific group of polymers which are polymerised in an aqueous environment. The second objective is to take those dispersions imparting specific effects and to try to determine which of their components were responsible so that the effect could be maximized.

Finally, it was intended to use these optimised dispersions on soils to create beneficial effects of such a magnitude that it would satisfy the very demanding performance / cost requirements of the extensive Agriculture and Civil Engineering Industries.

- 2 -

CHAPTER 1

POLYMERS IN LIQUIDS

A. INTRODUCTION

Polymers in liquid form fall into three categories: those dissolved in solvents, those dissolved in water, and those insoluble in water but existing as minute particles dispersed throughout an aqueous phase. Examples of the soluble types include polyvinyl alcohol (PVA) salts of polyacrylic acid, polyacrylamide (PAM), hydrolyzed polyacrylonitrile and others, while polyvinyl acetate (PVAc) homopolymers, vinyl acetate-acrylate copolymers, styrene-butadiene copolymers, emulsified bitumen, natural rubber latex, etc exist as stable suspensions.

Although some members of the group mentioned last have been extensive used in soil conditioning, the influence of their basic compositions on the properties they impart to soils has been neglected. In a rare publication where the Soil Scientists were actually involved in the polymerisation of the materials they subsequently used, Goor, <u>et al</u> (1976) attributed this poor identification to the easy access to commercial products.

To understand how different polymer dispersions may affect the same soil in very different ways, it is necessary to have knowledge of their basic compositions. A brief summary follows, therefore, to familiarise the reader with the ingredients and mechanisms involved in dispersion polymerisation.

B. DEFINITION OF POLYMERISED DISPERSIONS

The term "polymer emulsion" has been considerably abused in technical literature. Not only has the word "emulsion" deviated from its true meaning of mixtures of liquid in liquid to include solids suspended in liquids, but it also makes no distinction between the methods of manufacture. For example, preformed materials such as bitumens or waxes, which are melted and emulsified by high speed dispersion, as well as products such as polystyrene, where the actual polymerisation takes place in a dominently equeous system, are all referred to as "polymer emulsions".

The group in which polymerisation is actually induced in an aqueous phase is the subject of the present dissertation.

The term "emulsion polymerisation" which is generally used to describe the manufacturing technique is also misleading as there are many extremely important commercial grades which contain no true emulsifiers. To add to the confusion the term "latex" loosely refers to, not only natural or synthetic rubber latex, but also all other monomer containing types.

"Polymerised dispersions" or "polymer dispersions", as used in West Germany, are perhaps technically the most correct terms and will be used from here on to describe those suspensions of synthetic polymers in which the monomers were actually polymerised in a dominantly aqueous medium.

- 4 -

C. MANUFACTURING TECHNIQUE

A polymerised dispersion is formed by reaction in an agitated, jacketed vessel in which a water soluble initiator - for example, an oxidising agent such as hydrogen peroxide - is added to water containing a soluble stabiliser (which may be an emulsifier, colloid, etc.) and stirred rapidly while a polymerisable monomer (containing one or more multiple carbon to carbon bonds) is added. The initiator is decomposed either by heating the mixture or by adding a reducing agent to form a redox system. The free radicles produced then open up the multiple bonds and bring about essentially linear re-arrangements. The polymerisation of the monomer is highly exothermic, but is easy to restrain temperature because of the efficient heat transfer through the aqueous phase. The stabilise in some cases offers sites for polymerisation and also prevents aggregation or sedimentation of the particles during and after manufacture.

D. INGREDIENTS

As indicated, the polymer dispersion system contains at least four basic ingredients:

- 1. Monomers
- Dispersion medium
- 3. Stabiliser
- Initiator

Several other types of substances may be included such as pH buffers, antifoams, bactericides, etc.

- 5 -

1. Monomers

The monomeric phase may be constituted from a very wide range of polymerisable compounds. The present dissertation will, however, be limited to the following:

(a) A mond-ethylenically unsaturated hydrocarbon e.g. styrene



(b) An aliphatic diene e.g. butadiene

$$CH_3 - CH = CH - CH_3$$

(c) Acrylic and methacrylic acid esters of an alcohol having 1 - 18 carbons e.g. butyl acrylate,

> $CH_2 = CH$ C = 0 C = 0 C = 0C = 0

2-ethyl hexyl acrylate,

$$CH_2 = CH$$

 $D = CO - CH_2 - CH - CH_2 - CH_2 - CH_2 - CH_3$
 $\int_{C_2H_5}^{C}$

or methyl metheorylate

$$CH_2 = C$$

 $CH_2 = C$
 $CH_2 = C$
 $CH_3 = C$

(d) Vinyl esters of an alighatic acid having 1 - 18 carbon atoms e.g. vinyl acetate



and vinyl versatate which is a vinyl ester of versatic acid (VeoVa

$$CH_2 = CH - 0 - C - C (CH_3)_2 - C_6H_{13}$$

The following combinations of these monomers were polymerised and used in this study:

- (1) styrene-butadiene carboxylated copolymers (SBR carb.)
- (2) styrene-butadiene uncarboxylated copolymers (SSR uncerb.)

e.g.
$$n \leftarrow CH - CH_2 \rightarrow m \leftarrow CH_2 - CH = CH - CH_2)_n$$

(3) styrene-butyl acrylate copolymers (styrene-BA)

(4) styrene-2 ethyl hexylacrylate copolymers (styrene - 2EHA)

e.g.
$$(-CH_2 - CH_2 -$$

(5) methylmethacrylate - 2EHA copolymer (MMA - 2EHA)

- (6) vinylacetate 2EHA copolymers (VAc 2EHA)
- (7) VAc BA copolymers

e.g.
$$-(-CH_2 - CH_2) - (CH_2 - CH_2) - CH_3$$

 $O = C - OR$

(8) Polyvinylacetate homopolymers (PVAc)

To achieve verious degrees of film hardness in the copolymers, the relative ratios of monomers were varied, while in the case of the homopolymers an external plasticiser, usually dibutyl glycolphthalate (DBGT), was added.

Dispersion medium

This is sometimes referred to as the equeous phase and is the water medium in which the monomer phase will be dispersed. The stabilizers are predispersed in this phase before the monomers are added.

Stabilizers

The types of stabilizers that were selected for initial study are the normally used in commercial dispersions and they can be divided into two main groups: emulsifiers and colloids. Variations within each of these groups on dispersion performance are compared. In later chapters less orthodox types are also investigated.

3a. Emulsifiers

An enormous number of naturally occurring and artificially synthesises emulsifiers are available which characteristically produce micelles at a certain concentration when added to water. They are known collectively by various names such as "emulsifiers", "surfactants", they carry in water which is anionic, cationic or non-ionic (Blackley 1975). It is these surface charges which attract water, thus forming shells around the polymer particles and preventing them from coming together.

Unlike emulsified bitumen, the cationic types find limited application in dispersion polymerisation and receive little attention in this study. The anionic types are subdivided into carboxylates, sulphonates and sulphates while the carboxylate types are further subdivided into fatty acids, rosin acids and others. The nonionic types commonly used are generally polyoxyethylene glycol ethers or esters.

The minimum concentration at which micelles are formed is little affected by the length of the hydrophilic (polyethylene oxide) part of the molecule, but it increases as the number of ethylene oxide units per molecule increases.

3b. Colloids

Although some definitions of colloids imply that they do not go into true solution, the types used for dispersion polymerisation do. These colloidal stabilizers differ from emulsifiers in that they hold and orientate water by stearic, rather than electrostatic, forces. This is possible because of their physical nature having a very high surface area per unit volume.

Such stabilizers used in the present study ranged from complex natural products, for example, gums, to synthetics such as chemically modified hydroxy ethyl celluloses (HEC), polyacrylics, polyvinyl alcohols and their derivatives. The type and concentration of stabilizer, surfactant or colloid is important not only because it often determines whether or not polymerisation can occur, but also because it controls the particle size of the dispersed polymer.

Initiators

Normal conventional redox systems were used, for example, a persulphate ion with a reducing ion such as thiosulphate or bisulphite.

The various other minor ingredients used were the commercially available forms and will not be mentioned unless in some specific circumstance.

E. MECHANISMS OF POLYMERISATION

Although a comprehensive review of the chemistry of dispersion polymerisation will not be presented here, important differences do exist between different systems which control the abilities of the polymers to locate themselves differentially in soils.

Although all the monomers selected for this study are generally considered insoluble in water, some differences do exist. For example, monomers such as styrene and 2-ethyl hexyl acrylate are indeed almost insoluble in water and vinyl acetate, although showing limited miscibility with water, is sufficiently soluble to have a profound effect upon the polymerisation reaction. The solubilities of the monomers in water (as given by the respective suppliers literature) are presented in Table 1. - 11 -

Teble 1

Monomer	Water solubility mass %	
Vinylacetate	1,90	
Methylmethacrylate	1,60	
Butyl acrylate	0,20	
Versatate	0, 10	
Butadiene	0,06	
Styrene	0,03	
2-ethyl hexyl acrylate	0,01	

Solubilities of various monomers at 20 C in water

The differences in solubility dictate in which component of the system the polymerisation reaction occurs.

Relatively insoluble monomers

Secause of the insolubility of monomers such as styrene and 2EHA, polymerisation can only take place at a practical rate if soep micelles are present. Micelles are aggregates of 50 -100 scap molecules which form at a "critical concentration" when surface-active substances are dissolved in water. The individual molecules of these surface-active substances have two distinct reactive regions: one a polar region which has an affinity for water and the other a non-polar region. At the critical micelle concentration the individual molecules orient themselves with the hydrophobic ends clustered within the micelles, and the polar ends in water. The micelles imbibe and solubilize extremely small emounts of monomer which is generally accepted as the principal locus for the initiation of polymer particle nuclei. Another consequence of this dual character within a single molecule results in these molecules being absorbed at interfaces between water and athor mode on that there is a more stable that?

the micelles in which polymerisation has started. As polymer is formed, the micelles swell by the addition of monomer from the aqueous phase and ultimately from the monomer droplets. The driving force into the hydrophobic interior is due to the gain of entropy which accompanies the mixing of two non-polar liquids (Harkins 1950).

Generally by the end of the polymerisation no free micelles exist, as they have been absorbed onto the polymer particles giving them a negative charge. It is these negative shells that ettract water to form the electrostatic double layer which prevents the polymer particles coagulating.

Slightly soluble monomers

Gershberg (1965) found that the order of reaction with respect to the concentration of micelle generator falls significantly as the solubility of the monomer in water increases. As a result, the soap-like generators can be replaced by a protective colloid in the case of the more soluble monomers. The commonly used colloids include natural gums, polyvinyl alcohol and polymethacrylic acid.

With FVAc, for exemple, the crucial initiation of polymerisation in providing the reaction loci for the remainder of the reaction is accepted as occurring in solution in the equeous phase. (Priest 1952). The remainder of the reaction takes place in the swollen polymer droplets which are enveloped in the water soluble colloid, thus discouraging contact with the interiors of the droplets when they collide. Unlike micelles, these stabilisers are not electrolytic, but hold their water by the physical nature of their structure. 3. Monomers of intermediate solubility

The esters of acrylic acid and methacrylic acid tend to be intermediate between the more soluble PVAc and the less soluble styrene. For example, studies by Baxendale <u>et al</u> (1946) confirmed that polymerisation of MAA could occur in aqueous solution but the addition of a surface active agent is accompanied by a considerable increase in both rate and extent of polymerisation. The theory is that, as the polymer molecules grow, they tend to become insoluble and the function of the surface active substance is seen essentially as that of a protective colloid. However, when compared to diene dispersion polymerisation, the systems for acrylates are more selective, requiring the use of synthetic micelle generators rather than soeps from natural sources, and higher temperatures of reaction.

The influence of monomer solubility on the properties which their respective dispersions can impart to marine sand are discussed in the following two chapters.

CHAPTER II

EXISTING COMMERCIAL APPLICATIONS OF POLYMERS TO SOILS

Soil type controls rate of erosion, species and amount of vegetation, and load bearing properties. These few examples indicate the benefits that could result if in situ soils which have undesirable properties could be suitably modified by artificial means. Because of the high bonding efficiencies of polymeric materials e.g. epoxy adhesives, PVAc wood glues, foundry resins and others, it is not surprising that they have been considered in many different aspects for improving soils. Existing applications can be divided into those employed by Civil Engineers and those by Agriculturalists.

A. CIVIL ENGINEERING APPLICATIONS

Because of the high total expenditure on projects being constructed by this sector, the cost limitations on using polymer are not as severe as they are with agriculture. Even so, the beneficial effects induced by polymers must be very obvious and their cost competitive with elternate products.

1. Wind erosion control

The repid encroachment of the world's deserts on useful land and strategic installations by the process of wind erosion has been much publicised. For permanent soil stabilisation the establishment of vegetation is invariably necessary. However, to ensure survival in the critical early stages of seedling development, some form of temporary stabilisation is essential. This may involve the erection of perpendicular fences (Cooke 1972), the covering of the soil surface with imported, bulky materials e.g. reeds, brushwood, topsoil, town refuse (Knottnerus 1976) and other materials, or the application of consolidating chemicals. Armbrust and Dickerson (1971) compared 34 commercially available products as consolidating aids. These included three asphalt emulsions, 8 carboxylated and uncarboxylated styrene butadiene copolymer and polybutadiene dispersions, five plant or animal bi-products, five polymer solutions, three PVAc homopolymer dispersions, five powders, three alkyd resins and two others. The following desirable characteristics were used by these researchers to determine which materials were satisfactory:

- (i) stability of soil aggregates;
- (11) ease of seedling penetration;
- (iii) ease of application; and
- (iv) a cost of less than \$123 per hectare. (USA currency)

The products considered suitable were ammonium lignosulphonate, an emulsified asphalt / rubber blend, an asphalt emulsion, a carboxymethyl cellulose powder, a water-soluble alkyd, a polybutadiene dispersion, a polyvinyl alcohol solution and a carboxylated styrene butadiene dispersion.

Chepil <u>et al</u> (1960, 1963) also compared the suitability of a number of products in combating wind erosion. These included cellulose fibre at 1,1 metric tons per hectare, various gradings of gravel at 45 to 224 tons, emulsified asphalt, styrene butediene and PVAc dispersions at 11,2 tons per hectare as well as ammonium lignin sulphonate, gelatinized starch and various inorganic agents. They concluded that a number of these materials were satisfactory when assessed by criteria similar to those used by Armbrust and Dickerson above. butadiene dispersions in mineral oil as aids in wind erosion control. Success was claimed at application rates as low as 172 kg/ha.

There are very many more such studies indicating that numerous products can be used to prevent wind erosion. Cost seems to remain the biggest single factor preventing large scale commercial applications. Armbrust and Lyles (1976) recommended that future work should be concentration on developing

- (i) methods for applying large volumes rapidly;
- (ii) Films strong enough to withstand raindrop impact and still allow water and plants to penetrate; and
- (iii) films that have no adverse effects on the soil water - sir environment.

Chapter V of this thesis reflects an attempt to meet these objectives.

2. Water erosion control on embankments

Perhaps the widest use of polymers as soil conditioners is in the stabilisation of embankments using the technique of hydroseeding (Moldenhauer and Gabriels 1972). This involves the spraying of seed and fertilizer, sometimes together with a stabilising agent, from a mobile mixing tank. The function of the stabilising agent is, firstly, to control erosion while the plants are becoming established and, secondly, to prevent the seeds being washed to the bottom of the slope. Consolidating agents compared by Moldenhauer and Gabriels (1972) were polyvinyl alcohol, potassium silicate, dimethyloctadecyl ammonium chloride, starch,
cationic bitumen emulsions, styrene butadiene dispersions and polyvinyl alcohol. Except for dimethyloctadecyl ammonium chloride, starch and sodium carboxymethyl cellulose, all remaining chemicals reduced total erosion. PVOH is perhaps the most effective but it suffers from the practical defect in that it takes a long time to dissolve in cold water. De la Pena and Gabriels (1976) also found PVOH, PAM, asphalt emulsion and styrene butadiene dispersion reduced erosion.

Modenhauer <u>et al</u>. (1962, 1964) and Schmidt (1961) compared asphelt suspended in either water or kerosene, straw and polyethylene film. Straw proved to be the most effective but was troublesome to apply. The beneficial effects of straw or a similar fibre mulch cover is undisputed, but if used together with a soil stabiliser and a separate tacking material, the cost is prohibitive. Moldenhauer and Gabriels (1972) concluded that each of the three items would cost from one to several hundred dollars per hectare. Such expense negates the advantages of the technique and in the present recessive economic climate only seed, fertilizer and some sawdust (to assist in even distribution of seed in the tank) is used by most of the South African hydroseeders (Personal communication). Moldenhauer and Gabriels (1972) suggest an ideal material would be one that made the fibre and tacking material unnecessary.

In Chapter VI Section C, attempts are made to meet this ideal with the development of a stable air drying polymer foam.

3. Load bearing slabs

Road builders and construction contractors would welcome a product which at reasonable cost could be incorporated with any

- 17 -

building this is referred to as the sub-base and is the lowest treated layer of the road. Davidson <u>et al.</u> (1960) used lignins, bituminous products, calcium chloride, lime, flyash, Portland cement, molasses, dimethyloctadecylammonium chloride and several chemicals made from tallow as potential road base consolidating materials. Although the dimethyloctadecylammonium chloride gave good results, it does not seem to have been accepted by the road building industry and it is not used at all in Southern Africa. Lime remains by far the most popular product used throughout the world for road sub-base stabilization. However, because it reacts with the alumino silicates present, it cannot be used in sandy soils (clay less than about 5%) (Maude 1977). Gement and bitumen base stabilization is sometimes used in such soils but the former is susceptible to cracking while the latter is difficult to handle.

An investigation into the possibility of using polymer disperaions as the consolidating agents for sub-bases in sands or sandy soils is discussed in Chapter VII.

8. AGRICULTURAL APPLICATIONS

Improving soil aggregation

Aggregation of individual soil particles into clods is often desirable to increase aeration and water infiltration. This is particularly important in sodic soils, soils prone to compaction and those of high clay content. The list of products tested in this application is formidable and according to Schamp (1975) hundreds have been patented. Excellent reviews of the literature have been written by De Boodt (1972), Gardiner (1972) and Schamp (1975).

- 18 -

Chemicals tested can be divided into natural or modified naturally-occurring polymers, and those produced synthetically.

Examples of the modified natural products are polysaccharides (English Patent No. 1033186 - 1966; Japanese Patent No. 10965 -1972; German Patent No. 963690 - 1957 and Swiss Patent No. 335895 - 1959) and lignins (Grebennikov <u>et al</u>. 1975; Vasyliev 1975, Flaig <u>et al</u>. 1975).

The synthetic types can be divided into water soluble polymers, emulsified polymers and polymerised dispersions. By far the largest group tested are the solution types and typical examples are polyacrylamide (PAM) (Schamp and Huylebroeck 1972; El-Gala <u>et al</u> 1975), polyvinyl alcohol (PVOH) (Williams <u>et al</u> 1966; Greenland 1972), vinyl acetate maleic acid (VAMA) (Allison 1956; Strickling 1957; Doyl and Hamlyn 1960), hydrolysed polyacrylonitrile (HPAN) (Duley 1956; Jones and Martin 1957; Mortensen 1957), polyacrylic acid (Homrighausen 1958; Warketin and Miller 1958; Kita and Kawaguchi 1961), isobutylene maleic acid (IBMA) (Jones et al. 1957) and others.

Bitumen emulsions are typical examples of emulsified polymers that have been used for soil consolidation (Pla 1972; Gabriels and De Boodt 1976).

Polymerised dispersions used in this application include polyvinyl acetate homopolymers (Mausbach and Schrader 1976), vinylacetate - maleic acid copolymers (Martin and Jones 1954) and styrene butadiene copolymers (Gabriels 1975).

Several workers (Schamp and Huylebroeck - 1972; Webber - 1972; Pugh <u>et al</u>, 1960) tried to rank the bonding efficiencies of some of these products. Schamp and Huylebroeck (1972) for example

- 19 -

found that solution polymers such as PVOH, PAM, sodium polyacrylete and others imparted no aggregation below a certain molecular weight (10 000 - 40 000) and that bonding strengths increased with molecular weight (even up to 1 000 000). Chemical structure of the polymer was shown to be important, with PVOH being better than PAM - confirming the positive influence of higher molecular weight. Polymer dispersions, mainly homopolymers and copolymers of vinyl acetate and butadiene, gave much poorer results than the better solutions of PVOH. However, no details of the composition nor of the attempt to optimise the performance of these dispersions was mentioned. Such considerations for a number of polymer dispersions are described in the next chapter. Polymer dispersions have an advantage over solutions in that they resist resolubilizing in water. To overcome this deficiency the solutions should be insolubilized in the soil by mechanisms such as complexing, cross linking or absorption on to clay particles. Examples of such are the blending of lignosulphonate with chromium ions (Masakki Akahane et al. 1964), adding glyoxal to PAM (Labofina 1973, and Hartman and Verplancke 1976), and using sodium polyacrylate which is rendered insoluble when absorbed on to clay (Schamp and Huylebroeck 1972). Emulsified bitumen at 1,5% on soil mass basis (De Boodt 1972), sulphate lignin at 0,2% (Grebennikov et al. 1975) and VAMA, HPAN and IBMA as low as 0,01% (Gardener 1972) also effectively achieved aggregation.

No one product seems to have emerged technically superior as a conditioner of soils to depth. In fact, despite there being no lack of suitable materials, Schamp (1975) questions the paucity of commercial application. Gardiner (1972) points out that high cost makes the best soil conditioners completely impractical and quotes that in the late 1950s VAMA was about \$4,40/kg and at tupical conditioners for only the

- 20 -

surface 2cm would be in excess of \$500/ha. It would seem, therefore, that the treatment of agricultural soils to any depth is unfeasible, and it was decided that only the beneficial effects offered to crops by light surface applications of polymer dispersions would be investigated further in this thesis.

Moisture conservation

Attempts at conserving soil moisture using polymers include the use of surface barriers such as polyethylene sheet (Millard 1974 and Rau and Millard 1975) and additions of emulsified bitumen (Lenvain and De Boodt, 1975), dimethyl octa decvl ammonium chloride (DDAC) (Bowers and Hanks, 1961), polyacrylamide (Gabriels et al. 1976), petroleum (Kowsar et al. 1969), fatty alcohols and nonionic surfactants (Law, 1964), hexadecanol (Olsen et al. 1964) and others. There can be no doubt that in areas of erratic or limited rainfall the effective conservation of soil moisture through reduced evaporation can have dramatic effects on crop yields. For example, Rau and Millard (1975) recorded 25 + 3,9 tons more sugar cane/ha where a 30cm wide strip of clear polyethylene sheet was secured over the planted material. Lenvain and De Boodt (1975) recorded a significant increase in yield (30%) of Vetiveria zizanoides (L) Stapf where 2,5%/m² of a hydrophobic bitumenous emulsion containing some 150g of bitumen, was worked into the top 3cm of soil. Kenchev et al. (1976) obtained a 42% increase in dry weight of maize plants (7 - 8th leaf) in pot experiments where alkylammonium chloride was applied at a rate of 0,025% on soil mass basis. Sub-surface barriers to conserve water has received less attention than surface treatments, largely because of the difficulty and cost of application. However, substantial benefits can be obtained. Summer and Gilfillan (1971) reported a

cotton as lint and 24% more lucerne when a 60% asphalt emulsion was sited at a depth of 60cm. The cost of treatment at that time was estimated at R400 - 450/ha and the expected life of the berriers 15 - 20 years. Other workers report similar beneficial results with similar techniques (Erickson <u>st sl</u>. 1968 and Hensen and Erickson 1969).

Applications such as the above are of interest in that the benefits of treatment are assessed quantitatively and not merely visually. The subject of moisture conservation therefore receives much attention in this dissertation and the ability of different polymer dispersions to induce greater sugar cane and maize grain yields is reported on in Chapter VIII.

Increasing soil temperature

Like inadequate moisture, low temperatures seriously limit crop growth in many areas throughout the world. Even in the subtropical climate of the coastal belt in South Africa, sugar cane growth was recorded at 9,7cm per week in summer air temperatures of 23 C, where in winter at 14 C it was 0,7cm per week (Bishop 1964). It is accepted that soil temperatures can be raised by the use of black or dark coloured surface sprays such as bitumen or petroleum bi-products. The securing of a strip of clear polyethylene film over germinating shoots significantly increased soil temperature and yield (Rau and Millard, 1975; Kerchev et al. 1976). Increasing raw material costs made the profitability of this technique dubious for extensive agriculture and it has now been largely discontinued. Rau and Millard (1975) concluded: "For ease of application and cost economy, a liquid mulch applied as a spray would be ideal. To date, no test products have shown promise."

The results presented in Chapter VIII of this dissertation indicate that perhaps a polymerised dispersion could fill this need.

Preventing soil crusting

Many soils have a tendency to crust on the surface after rain, thus impeding the emergence of seedlings. Allison and Moore (1956) found vinyl acetate maleic acid (VAMA), hydrolysed polyacrylonitrile (HPAN) and other chemicals, when worked into the surface soil, reduced crusting. Timm <u>et al</u>: (1971) used gypsum in place of polymers to minimise the development of soil crusts over potatoes. De Vleeschauwer and Gabriels (1976) found that a surface spray of 20g PAM/m² on the sowing lines of sugar beet gave 23% greater seedling emergence than control.

This specific application is not considered further in the present project but it is likely that a light surface spray of polymer dispersion will have a similar effect to the PAM.

Wind and water erosion

Moldenhauer and Gabriels (1972) concluded that the control of water erosion on agricultural soil must cost less than \$10 per hectare, must have a low stabilizer-to-solvent ratio to reduce material handling costs, and must be effective for at least two months. None of the consolidating agents mentioned previously under Civil Engineering applications would satisfy this cost requirement. Change in field management is the more usual remedy of combating erosion. For example, a grass mulch completely eliminated water erosion in banana plantations on the Ivory Coast (Roose 1976). Knottnerus (1976) reports that inter-row planting of winter wheat some two months before sowing sugar beets, potatoes and maize effectively reduced agriculture can afford.

The application of polymer dispersions specifically to reduce erosion in agricultural soils is not considered feasible. However, in Chapter VIII, where surface sprays were applied to achieve moisture, fertilizer and herbicide conservation, baneficial effects which would reduce soil erosion were noted.

- 24 -

Controlled release of fertilizer

A large amount of work has been done with polymers to sttempt to control the release of nutrients from fertilizers. Martakis (1977) has comprehensively reviewed polymers in slow release nitrogen applications and it would seem that the polymers fall into three categories:

- those where the N form is polymerised into a linear molecule e.g. urea formaldehyde (UF) (Einhorn and Hamburger 1908), monomethyleneures (MMA) and dimethylolures (DMU) (Clark et al. 1948 and 1951) and others;
- (ii) those where the inert polymer coats the fertilizer
 material e.g. vinylidene chloride, a ureaform resin, a
 polyacryl ester, a vinyl chloride (Jung 1960),
 polyethylene (Dahnke <u>et al</u>. 1963) and others; and
- (iii) Those where the fertilizer is mixed with soil and then an aggregating polymer added so that the fertilizer is capetured between the soil particles e.g. bitumen emulsion (De Boodt 1976).

It would seem none of the above controlled release products have had a serious impact on the international fertilizer market. This again seems to be a cost problem. Only category (iii) above, where the polymer interacts with the soil, is researched in this fertilizers, which are both effective and economical, using polymer dispersions.

C. CONCLUSIONS AND SUMMARY

While several different polymer dispersions e.g. polyvinylacetate homopolymers, vinyl acetate - maleate and styrene butadiene copolymers, have been considered, along with numerous other chemicals in the above applications, no project seems to have compared their relative efficiencies as a specific group. Furthermore, no attempts were recorded to improve their efficiencies by formulation modifications. This will be attempted in the next Chapter.

Assuming even more efficient polymer dispersions are developed, it does not follow that they will find commercial application. The impression gained after surveying the literature is one of frustration regarding commercial recognition. Although the researchers have tirelessly pursued their subject, encouraged undoubtedly by the polymer industry, no application seems to have emerged as universally acceptable. Several papers give reasons for failure in the past and encouragement for the future. However, in a number of applications which appeared interesting, naturally occurring products are still preferred e.g. hydroseeding, using straw mulch; wind erosion control, using brushwood; and road construction, importing topsoil. For acceptance of any new product in a sceptical world it must be either technically far superior to existing systems and/or far cheaper. For this reason, this thesis considers, firstly, variations in techniques as well as products and, secondly, systems imparting several obvious benefits, so that the magnitude of the combined gain may be undisputed.

- 25 -

CHAPTER III

ABILITIES OF POLYMER DISPERSIONS TO BOND SAND

A. INTRODUCTION

A number of commercially evailable polymer dispersions from Revertex (S.A.)(Pty.) Limited and The Synthetic Latex Company (Pty.) Limited were selected in order to assess their ability to aggregate sand. These companies were singled out for several reasons. First, together they produce the widest range of polymer dispersion types in South Africa, including all those listed in Chapter I, section D.1. Second, the author was employed in a technical capacity by both companies and therefore had an insight into the manufacture and composition of their products. Third, the facilities of the Research and Development laboratories of Revertex (S.A.)(Pty.) Limited were made evailable to the author for the present project.

As an initial investigation the abilities of low concentrations of different polymer dispersion types to impart specific properties to marine sand was investigated.

8. EONDING ABILITIES OF DIFFERENT TYPES OF COMMERCIAL DISPERSION

As indicated in Chapter II, the bonding together of single particles of soil or sand into agglomerates is often desirable.

1. Materials

The dispersions chosen included four different homopolymers, plasticised with 6% dibutylphthalate on total solids basis, and copolymers with the following monomers: VAc-2EHA, VAc-BA, VAc-VeoVa, MMA-2EHA, MMA-BA, Styrene-2EHA, SBR (Carb.) and SBR (uncarb.). The physical properties are given in Appendix 1.

The send used in this experiment was material dredged from Durban Bay at the site of the new pier. The physical properties and analysis of this material are given in Table 2.

Table 2

Physical properties of sand from Ourban Bay

Property	Value and units
pH (in water)	7,60
Moisture content, volume basis*	38,6%
Bulk density*	1,62g/cm ³
Porosity.	38,9%
Clay content	0%
Silt content	0%
Sand content (% retained on sieve)	49.11
2mm	2%
ាភាព	196
710 Jum	756
600 mu	7%
عبر 250	28%
>212 µm	26%
< 212 jum	4 796

· Data from G.E. Martakis (1977)

In an effort to reduce any effects due to particle size distribution,only those particles smaller than 710 µm but larger than 250 µm were used for laboratory tests. It is also noted that no cley is present.

- 27 -

2. Experimental Procedure

Tensile, rather than compression, measurements were used to measure the efficiency of different polymers to bond sand. In addition to being considered a more relevant measure of cohesion, the results can also be obtained sooner because of the faster drying of the smaller test samples. Unconfined compressive strength (UCS) measurements are more pertinent in load bearing applications, e.g. building and road construction. This parameter is therefore used in Chapter VII where such applications are considered.

- 28 -

To have any chance of being economically feasible, especially in agricultural type applications, the dispersions would have to be effective at very low concentrations. Therefore after accurately determining the polymer contents of each dispersion they were diluted down on a mass basis to % of their original content of about 50%. (In polymer dispersion technology the polymer level is taken as the total solids content - see Appendix 3). Polymer - sand briquettes were formed by mixing the graded sand (180g) with the dilute dispersions (34g), then pouring this into stainless steel moulds (5cm x 3,5cm x 0,95 cm), smoothing off, and drying for 17 hours at 55 C.

The modulus of rupture was assessed as a tensile measurement using the Richards Rupture Tester (Richards 1953). This instrument measures the force necessary to break the prepared polymer - sand briquette when it is balanced on two knife edges and a force is brought to bear by a parallel third knife edge on the top surface and midway between the two bottom knife edges. This force is increased by pouring water into a container on the balance until the briquette breaks. The mess of water is then determined. Plate 1 shows a briquette under test. The modulus of rupture is calculated from the following equation (Richards 1953):

$$S = \frac{3 FL}{2 b d^2}$$
 (dyne/cm²)

where

S = modulus of rupture

F = breaking force in dynes

L = distance between two lower supports

b = breadth of send briquette

d = thickness of sand briquette

1 millibar (mb = 10^6 dyne/cm²)



<u>Plate 1</u>: The Richards Rupture Tester used for measuring the tensile strengths of sand-polymer aggregates. Note briquette mould in the foreground. 3. Results and discussion

The modulus of rupture values for graded sand cemented with the different dispersions are presented in Table 3. The briquettes have a 0,19% polymer content on a dry sand basis.

Table 3

The abilities of various polymer dispersions to bond sand (Means of 5 determinations)

Polymer type	Stabilizer type	Briquette modulus of rupture (millibars)
PVAc	Natural gum A	3236
PVAc	Natural gum B	4070
PVAc	PVDH	1496
PVAc	PVDH + HEC	1365
PVAL - ZEHA	HEC + non-ionic surfactant	469
PVAc - VeoVa	HEC + non-ionic surfactant	526
Styrene-2EHA	Anionic surfactant	D
MMA - ZEHA	Polyacrylic acid + anionic surfactant	D
SBR (carb.)	anionic surfactant	D
SBR (uncerb.)	anionic surfactant	D
Co-efficient of Variation %		11,9
Least Significant	16	204
DITTEIENCE	1	277
	4.	

First, there is wide variation in the bonding powers of the different dispersions (Table 3); second, both monomers end stabilizers seem important; and third, surfactants in copolymers inhibit the bonding effect. From these results it cannot be concluded which variable has the dominant influence since no surfactant stabilized PVAc homopolymers, or gum or PVDH

- 30 -

stabilized copolymers were included. No such commercial dispersions were available and a laboratory programme using onelitre reactors to produce them was drawn up.

C. THE INFLUENCE OF INGREDIENTS IN DIFFERENT TYPES OF DISPERSIONS ON BOND STRENGTHS

All attempts to produce a copolymer stabilized dispersion solely with natural gum were futile. However, an MMA-2EHA copolymer stabilized with natural gum plus mineral oil, and two PVAc homopolymers stabilized - in one case with a surfactant and in the other with a hydroxyethylcellulose, were successfully produced. The physical properties of these dispersions are given in Appendix 2. After plasticising the homopolymers with 6% dibutylphthalate, the same tensile test procedure as before was used.

The strengths imparted to sand by these dispersions were 1860, 0 and 1060 millibars respectively. These poor results indicate that the mechanism of bonding is not so simple as to be controlled by the presence of one ingredient only. Rather, it seems that the bonding ability is the result of an interaction between several ingredients combining to produce a desirable characteristic. By measuring various physical properties of polymer dispersions and relating these to the bond strengths they could induce, it was hoped that the desirable characteristics would be recognised.

D. THE INFLUENCE OF PHYSICAL PROPERTIES OF DIFFERENT DISPERSION TYPES ON BOND STRENGTHS

The ability of some and not other polymer dispersions to give good bonding indicates that a steric mechanism may be responsible. Micr scopic examinations at 100 times magnification of bonded soils confirmed the presence of polymer bonds at the points of contact of th sand particles. Plate 2 illustrates this effect. The influence of surface tension and sizes of polymer particles in the different dispersions on the strengths of sand bonded by them was investigated.

Eurface tension

where

Rigole and De Bisschop (1972) working with emulsified bitumen suggested that the surface tension of the emulsion dictates the ability to form wedges between soil particles and that the geometrical characteristics of such wedges between the liquid and surrounding vapour (air plus vapour) atmosphere obey the law of Laplace.

Δ	Pm		$\frac{1}{R_1} - \frac{1}{R_2}$
Δ	Pm	=	capillary pressure gradient
	Ylv	=	surface tension of the liquid
			relative to vapour
	R1	=	greatest length across air space
	RZ		radius of curvature of spherical
			particles

Using an electron microscope they reported the formation of polymer wedges at the points of sand particle contect and postulated that "stable emulsions" form such wedges, whereas dissolved and "unstable emulsions" tend to cover the sand particles entirely. This statement tends to be in conflict with the results shown in Table 3 where surfactants, which are often added to increase the stability of dispersions, seemed to reduce the bonding ability. To try and confirm this detrimental effect the PVAc - Natural gum B dispersion giving good bonding in Table 3 was selected.



<u>Plate 2</u>: 100 times magnification of sand grains scraped from a PVAc homopolymer bound briquette clearly showing the location of the dry polymer.

31

Materials and procedure

B.

99g and 95g samples of the concentrated dispersion were taken and 1g and 5g aliquots of water respectively stirred into them. Another two samples were prepared in the same way except that a concentrated nonionic surfactant replaced the water additions. The surface tension of these four dispersions was measured with a du Nouy tensiometer. The method of surface tension measurement as well as other subsequently mentioned physical analyses of the dispersions are presented in Appendix 3.

All four samples were then diluted down to 75 solids and send briquettes prepared as before.

Results and discussion

The modulus of rupture and surface tension results are presented in Table 4.

Table 4

The effect of reducing surface tension on the bonding ability at 0,19% dry PVAc polymer on a dry sand basis (Means of 5 determinations)

A Addition to Boy and do	Briquette	Polymer dispersion	
homopolymer before dilution to 1% solids	Modulus of rupture (millibars)	Surface tension dyne/om	
1% Water	2 6 15	48	
1% Nonionic surfactant	1 913	40	
5% Water	2 249	48	
5% Monionic surfactant	590 -	37	
C.V. (%)	8,0	19414	
LSD 5%	13		
1%	18 .		

The addition of surfactant drematically reduced both surface tension and the ability to bond send. In polymer dispersion technology the surfactant addition makes the system "mora stable" and the poorer bonding it induces is in direct conflict with the conclusions of Rigole and De Bisschop (1972), when working with emulsified bitumen.

This example indicates the need to be specific in terminology as the word "emulsion" is often used indiscriminately to describe emulsified bitumens or polymerised dispersions. In fact, neither of these products are emulsions and only under questioning did Rigole and De Biaschop (1972) state that their work was limited to emulsified bitumen.

It is noted from Tables 4 and 5 that despite the reduction in modulus of rupture, the PVAc homopolymer at a surface tension value of 37 dyne/cm gives a stronger bond that some dispersions with considerably higher surface tensions. For example, in Table 5,where the surface tensions, average particle sizes and pH values of the dispersion are presented, the MMA-2EHA surfactant stabilized copolymer has a surface tension of 50 dyne/cm but produced a briquette with no strength. While,generally, aggregating ability is positively correlated with both surface tension and particle size, exceptions for both properties are noted.

While it would be desirable to investigate the bonding abilities of dispersions with variable surface tensions and particle sizes, all commercially available dispersions studied showed a strong positive correlation between particle size and surface tension. However, a dispersion which had a very high surface tension (68 dyne/cm) and small avarage particle size (0,23 µm) produced on a laboratory reactor, did not cause substantial bonding (modulus of rupture = 532 mb). It does not seem, therefore, that the bonding ability of polymer dispersions is controlled by their surface tensions.

- 36 -

2. Farticle Size

In the only reference found where researchers polymerized their own dispersions, Goor et al. (1975) concluded that the particle size was very important in determining the ability of the PVAc homopolymers to bond sand. However, exceptions occurred where small particle size dispersions (0,5 and 0,06 µm) gave good bonds and these were attributed to the "chemical nature of the polymer". These conclusions seem to be supported by the results in Table 5 where dispersions having an average particle size in excess of 1 µm produce considerably stronger send briquettes than do those made up of smaller particles. However, the relationship is not linear as the emulsion with the largest sized particles does not produce the strongest briquettes. All efforts to produce dispersions on monomers other than PVAc with average particle sizes over 1 µm failed. This is considered to be due to the effect of the higher solubility of the VAc monomer discussed in Chapter 1 and confirms a dependance of the final properties of the system on its components. The only way comparisons can be made is to consider the effects of variations within dispersions of the same, rather than different, types.

E. THE EFFECT OF MINOR VARIATIONS IN A GUM STABILIZED FVAc HOMOPOLYMER DISPERSION ON SAND BONDING

Materials and procedure

A number of different production batches from two factories of the same PVAc - Natural gum A homopolymer grade previously used

Table 5

The physical properties of various polymer dispersions and the bond strengths imparted to sand at a level of 0,19% dry polymer on a dry sand basis (Means of 5 determinations)

2222		Briquette	Polymer Dispersion			
Polymer type	Stabiliser	Modulus of rupture (millibars)	Surface tension dynes/cm	Average particle size (um)	рH	
PVAc	Gum A	3 236	. 52	1,24	4,8	
PVAc .	Gum 8	4 070	52	1,22	4,9	
PVAc	PVOH	1 496	50	1,80	5,1	
PVAc	PVDH + HEC	1 365	46	1,80	5,0	
VAC-2EHA	HEC + surfactant	469	44	0,80	5,1	
VAc-VeoVa	HEC + surfactant	526	44	0,64	5,1	
Styrene-2EHA (+ starch)	Surfactant	D	35	0,57	9,0	
MMA-2EHA (+ starch)	Polyacrylic acid + surfactant	D	50	0,53	8,8	
SBR (carbox) (+ starch)	Surfactant	D	49	0,27	8,9	
C.V. (%)		11,9	5,4			
LSD 5%		20	4		S2	
1%	1	27	5			

37

- 38 -

were enalysed for surface tension, average particle size, pH, grit (%), viscosity and ex reactor solids. These batches were used to form send briquettes as before. The correlations between the modulus of rupture results of these briquettes and the individual physical properties of the dispersions ex reactor were calculated. These are presented in Table 6.

2. Results and discussion

While there is a positive correlation between sand bonding ability and surface tension, it fails to be statistically significant. The relationship with particle size is even weaker and is, in fact, slightly negative. Rather surprisingly, the feature of these results is the highly significant negative correlation between ex reactor viscosity and strength of sand bond. Because of the excessive dilution before mixing with sand, it is unlikely that low viscosity as such is important for good bonding, but rather that a covarient factor is.

F. RELATIONSHIP BETWEEN LOW VISCOSITY BATCHES AND HIGH BONDING ABILITY OF THE PVAC HOMOPOLYMER DISPERSION

It is well known in polymer dispersion technology that for a given formulation the smaller the polymer particles, the higher the viscosity of the dispersion. This is due to the larger surface area consuming more of the aqueous phase stabilizer. However, from the correlation co-efficients presented in Table 6, it does not seem that these lower viscosities are the result of larger particles. Some other factor is responsible for the lower viscosity and, because this also seems to induce stronger bonds, it is important that it be isolated.

Apart from the effect of larger particle sizes, another way in

Table 6

Correlations between the individual properties of different batches of the PVAc homopolymer dispersions and their abilities to bond sand (Means of 5 determinations)

Production Batch No.	Briquettes	Polyme	r dis	persion	properties	before d	diluti	
	Modulus of rupture (millibars)	Average particle size of polymer (µm)	рН	Grit %	Viscosity Met Cup 4 at 20°C cps	Surface tension dyne/cm	Orig sol %	
Factory 1								
1	2 442	1,39	4,4	0,031	148	47	56	
8	3 002	1,26	4,6	0,024	208	48	57	
32	2 737	1, 14	4,0	0, 147	2 16	49	56	
44	2 991	1,42	4,2	0,102	2 16	46	57	
82	2 920	1,54	4,4	0,055	189	47	56	
141	2 686	1,80	4,4	0,062	202	49	56	
162	2 523	0,90	4,3	0, 142	445	50	56	
702	2 544	1, 18	4,5	0,004	162	47	55	
798	3 655	1,20	4,3	0,063	135	50	55	
711	3 164	1,48	4,3	0,017	135	.52	55	
Factory 2		- e ¹⁶			10	1. 1		
49	3 276	1.38	4.9	0.006	162	45	55	
53	2 656	1,68	5,8	0.019	229	46	55	
106	2 707	1,65	5,5	0,012	256	44	56	
334	2 259	1,42	4,7	0,043	297	46	56	
347	2 523	1,48	4,8	0,008	216	43	53	
357	2 951	1,54	4,7	0,034	243	42	56	
Correlation Coefficient	5	-0, 13	-0, 18	-0,04	-0,49**	0,25	-0	

viscosity could have come about was the aggregation of groups of polymer particles. It is postulated therefore, that a mild or partial aggregation of particles occurred to produce the results shown in Table 6. In contrast to the commonly occurring complete aggregation and destabilization of dispersions, this form would be readily reversible. This could explain why no aggregates were detected in the particle size determinations where dilution and ultrasonic vibration preceed the test.

The reason for normal destabilization is that the amounts of stabilizers or emulsifiers are insufficient to keep the individual particles apart. Lower gum or PVOH levels would also tend to induce this partial aggregation. The fairly strong positive correlation between surface tension and bond strengths in Table 6 tends to confirm that there was less free stabilizer in the aqueous phase of the lower viscosity, stronger bonding batches than in the higher viscosity, weaker bonding ones. Variations in the level of stabilizer in the batches of PVAc dispersion that were tested could have been due to weighing errors, differences in batches of gum or different degrees of stabilizer breakdown during the polymerization.

1. Materials and procedure

In order to measure the effect of different levels of stabilizer in forming bonds in sand, a series of polymerizations was carried out in which the proportions of gum to polymer were systematically varied. The same effect was achieved in another test by taking samples at different times from the reactor. In this latter technique polymer content was continuously increasing so that viscosity measurements are no

- 40 -

longer comparable. As before, these dispersions were diluted down to 1% solids and used to make and test sand briquettes.

- 41 -

Results and discussion

The relationships between bond strengths, gum level and particle size are presented in Table 7.

		Briquette	Polymer dispersion			
Polymer batch No.	Natural gum level per 100 polymer (parts by mass)	Modulus of rupture (millibars)	Surface tension (dyne/cm)	Average particle size (µm)		
1	4,8	2 869	52 at 55% solids	1,34		
2	4,2	2 584	53 at 54% solids	0,98		
3	3,5	4 558	50 at 55% solids	1,80		
4	3,3	4 864 -	41 at 45% solids	0,71		
	.2,9	4 976	41 at 51% solids	1,08		
	2,6	5 250	43 at 56% solids	1,38		
	2,4	5 678	48 at 60% solids	1,80		
5	2,2	Dispersion destabilized completely				

Table 7

The results show a dramatic linear increase in the sand bonding ability of the dispersions as the level of stabilizer is reduced from 4,2 to 2,4 parts. Furthermore, from 3,3 down to 2,4 parts of gum,the surface tensions and particle sizes of the dispersions also increase linearly with bond strengths. However, as was observed with the different commercial batches of the PVAc dispersion in Table 6, the bonding ability is not related to these variables at the high levels of gum (4,8 and 4,2 parts). It is suggested,therefore,that stabilizer must be slightly deficient before the linear relationship between bonding ability, surface tension and particle size is definite. Secause unstable dispersion systems cause the greatest problems in commercial operations, all commercial products and recommended recipes tend to overstabilize. This would explain why, although previously reported results have indicated relationships between bond strengths, surface tensions and sizes of polymer particles, exceptions prevented definite conclusions being drawn (Table 5; Rigole and De Bisschop (1972) and Goor et al. 1975). However, from the results presented in Table 7 it can be fairly definitely stated that in certain polymer dispersion systems those batches having the lowest possible levels of stabilizer will produce dispersions with the highest surface tension, particle size and ability to bond sand. The specific nature of not only the stabilizer but also the complete system, must be emphasized, as numerous attempts to produce the partial instability effect in the surfactant stabilized copolymer dispersions failed. Either a stable or completely coagulated product resulted.

G. SUGGESTED MECHANISMS OF SAND BONDING WITH DIFFERENT POLYMER DISPERSION TYPES

From results presented in this Chapter the particle size relationships between the dispersion and sand appear to control the bond strengths. It is not only the size of the individual polymer particles, but their tendency to form associations while still in suspension, that is important. Schamp <u>et al</u>. (1976) tried to bring the relative particle sizes into perspective and warned about confusing molecular dimensions with microscopic dimensions. They quote typical particle size dimensions as $0,1 \,\mu\text{m}$ for polymer molecules, 1 to 10 μm for clay particles and 1 to 1 000 μm for silica particles. They estimate therefore that only the smallest clay particles (order of magnitude 0, 1 $\times 0,1 \times 0,01 \,\mu\text{m}^3$) are bound by one polymer chain and that in a meniscus between particles thousands to millions of columns molecules will contribute to make an adhesive bond. However, it is obvious from Table 5 that in this study the polymer particles may be as large as 1,80 µm, or 180 times larger than their "typical" quoted figure. This,together with the suggested partial association of numerous particles while still in suspension, means that the relative size of polymer agglomerates to sand grains is considerably greater than that suggested by Schamp <u>et al</u>.

Figure 1 is an attempt to illustrate graphically the following theory to explain the differences in bonding abilities of the various dispersion types.

Those dispersions which made weak sand briquettes are characterised as having relatively small, well stabilized polymer particles, e.g. surfactant stabilized styrene-2EHA copolymer. It is suggested that in the liquid-filled pore spaces very few polymer particles will come together because of the strong repellency in the well stabilized system. Some will be absorbed on to the sand particle surfaces to form a coating. (Evidence of this coating is given in Chapter VII). The majority of particles, however, will move with the receding water up to the sand surface. Evidence of this migration is given in the next Chapter where, at lower concentrations, these dispersions fail to form briquettes and result in loose, single grained sand particles overlaid by a thin polymer rich sheet (Table 11 page 58).

In contrast to the copolymers, the particles of a gum stabilized PVAc dispersion are initially some five times larger and, instead of strongly repelling each other, they tend to aggregate. The extent of this aggregation probably increases with polymer concentration. In sand it is possible that polymer



Figure 1

Diagramatic representation of suggested mechanisms to explain bonding abilities of differently stabilized polymer dispersions in send

particle aggregation starts as soon as the water begins to be lost into fine cracks in the sand grains, into absorbant materials in the sand and by evaporation. Because of the effinity of the polymer particles for each other only a small proportion are probably left on the surfaces of the sand grains. As the polymer rich associations are drawn back with the receding water they would progressively get bigger until, at a considerably enlarged volume compared to that of the individual particles, they would lodge at the points of sand contact. Here they will coalesce and dry to form bonds. With reduced levels of stabilizer the association will be more efficient and, since even less polymer will coat the overall sand grains or escape through to the surface, the bonds at the points of sand grain contact will be even larger. It is this selective placement mechanism that is considered the key for good bonding of some polymer dispersions at such low Concentrations. This theory suggests that any charge on the sand plays a minor role and that it is the interacting forces between polymer dispersion particles which is all important. This is in complete contrast with bitumen, where the mechanism of bonding is an . interaction between sand grains and the emulsified material.

H. CONCLUSION

It would seem that in previously recorded assessments of polymer dispersions as soil bonding materials, inefficient products were used. For example, in Table 7 the best commercially available product gave bond strengths of only 50% of those obtained from the same dispersion when half the stabilizer was used. This improved bonding efficiency will significantly reduce costs and might now make certain previously unacceptable applications acceptable. The economic feasibilities of such

- 45 -

systems in various sand stabilization applications are discussed in Chapters V, VI and VII.

The reduced stability of the new dispersions results in separation of the phases on standing. However, laboratory tests showed that mild agitation readily redisperses the polymer particles and this does not seem to be a practical problem.

Future research will undoubtedly produce dispersion systems with even more effective polymer locating mechanisms. Perhaps indications of potentially good systems are those which, with minimum stabilizer present, produce particles of large size, and dispersions with high surface tension values.

CHAPTER IV

WATER HOLDOUT STUDIES ON POLYMER DISPERSION TREATED SANDS

A. INTRODUCTION

In most potential applications dry strength of bonded sand or soil must be accompanied by a reasonable resistance to solubilizing or softening in water, e.g. erosion control and road construction. The implications of water sensitivity in these applications are reported on in Chapters V, VI and VII, but a water repellency effect observed during preliminary studies is worthy of note here. In a series of modulus of rupture tests in which the briquettes had soaked in water for four hours, water penetrated some but not others. It was decided to investigate which dispersions imparted the water repellency effect.

B. WETTING PROPERTIES IMPARTED TO BONDED SAND BY DIFFERENT POLYMER DISPERSIONS

1. Materials

The same nine commercially available polymer dispersions described in Chapter III and the same gradings of sand were again used.

Experimental Procedure

As before, the dispersions were diluted down to exactly 1% solids and 34g of these mixed with 180g of graded sand. This mixture was used to fill stainless steel moulds (50 x 35 x 10mm),

17 hours. For those dispersions incapable of forming briquettes, low additions of soluble dextrine or starch into the wet mix overcame the problem. When dry, the sand briquettes were removed from their moulds and allowed to cool. They were then weighed and submerged under a 25mm head of water for 17 hours. After draining off the superficial water the briquettes were reweighed. The water uptake was determined by the differences in mass and expressed as a percentage of the dry briquette mass.

3. Results and discussion

The mean water uptake results over five replications are presented in Table 8.

Table 8

Water uptake of sand-polymer briquettes after being submerged in water for 17 hours. The briquettes have a 0,19% dry polymer content on a dry sand basis (Means of 5 determinations)

		Briquette
Polymer type	Stabilizer system	Water uptake %
PVAc	Natural gum A	28,0
PVAc	Natural gum 8	28,4
PVAc	PVDH	30,1
PVAc	PVOH + HEC	25,5
PVAc-2EHA	HEC + Nonionic surfactant	13,1
PVAc-VeoVa	HEC + Nonionic surfactant	11,4
Styrene-2EHA + Dextrine	Anionic surfactant	7,8
MMA-2EHA + Dextrine	Polyacrylic acid + Anionic surfactant	10,6
SBR carbox. + Dextrine	Anionic surfactant	16,8
SBR uncarbox. + Dextrine		16,2
Coefficient of variation	%	7,1
LSD	5%	1,5
	1%	2.0

- 48 -

The considerable differences in the water holdout properties of sand bonded by different dispersions is noted. The PVAc homopolymer bound briquettes were wet through whereas, with the other dispersions, the briquettes were dry inside. The inverse relationships between bonding abilities and water holdout of various dispersions is recognised and is discussed more fully in Section D.

C. CHANGES IN WATER UPTAKE WITH TIME OF SAND BOUND WITH DIFFERENT POLYMER DISPERSIONS

To investigate the permanence of the observed water holdout effect in larger samples the following experiment was carried out.

1. Faterials

The same graded sand (< 710 µm but> 250 µm) as before was used. Four representative dispersions were selected; gum A stabilized PVAc homopolymer, the PVOH stabilized PVAc homopolymer and the PVAc-VeoVa and Styrene-2EHA copolymers. 0,2% dry soluble starch on dry sand basis was incorporated with the Styrene-2EHA dispersion to achieve aggregation.

Experimental procedure

The different dispersions were diluted to 1% polymer solids and 190g of these mixed in with 1 kg of dry sand. The mixtures were poured into plastic containers 75mm x 60mm in diameter and then lightly compacted. The samples were dried at 55 C for seven days. Small perforations were made with a pin at regular intervals in the plastic moulds to permit the entry of water. The dry send cores were weighed and then placed in 52 containers. Water was added until a head of 30cm was obtained. As a control, a plastic cup filled with loose sand was used. Every 24 hours the plastic containers were carefully removed from the water, drained to remove surface water and reweighed. Four replications of each treatment were included and the water uptake over a period of 30 days is presented in Table 9 and, diagramatically, in Figure 2.

3. Results and discussion

The assertation from the results in Table 8 that the different amounts of water absorbed by send cores depends on the polymer dispersion type bonding them, is confirmed here. The PVAc homopolymers tend to take up water fairly quickly while the VA-VeoVa and Styrene-2EHA copolymers, even after 30 days, have only 57% and 34% water content respectively, compared to that of the control. The sand cylinder containing the Styrene-2EHA copolymer dispersion is particularly significant as water uptake levels off at 7,3% from day 16 onwards. When broken open on the 30th day this core was dry inside. The fall off in weights of the control sample was due to loose sand being lost with the repeated immersion and removal from the water.

Table 9

Water uptakes with time of various sand-polymer mixtures, with D, 19% dry polymer on a dry sand basis (Means of 4 determinations)

Days submersion	Polymer dispersion					
	Control	PVAc homo (PVOH)	PVAc homo (gum)	VA-VeoVa (HEC)	Sty-2EHA:Dex (Surfectent)	
	% Water uptake	% Water upteke	% Water uptske	% Water uptake	% Water uptake	
1	21,2	19,2	10, 1	2,2	1,4	
2	20,8	19,3	14,0	3,0	2,6	
3	20,9	19,7	14,9	3,7	2,6	
4	20,7	19,9	15,3	4,1	3,3	
7	20,5	20,1	16,5	5,6	4,5	
8	20,2	20,2	16,7	6,1	4,9	
9	19,9	20,2	16,9	6,5	5,3	
10	19,7	20,3	17,0	6,8	5,5	
15	19,3	20,4	17,7	8,5	7,0	
16	18,9	20,5	17,7	9,6	7.3	
17	18,5	20,5	17,6	9,7	7,3	
18	18,3	20,6	18,8	9,8	7.4	
21	18,1	20,5	17,8	10,1	7,5	
22	17,7	20,5	17,7	10,2	7,4	
23	17,6	20,5	17,8	10,3	7,4	
24	17,5	20,6	18,9	11,0	7.1	
25	17,2	20,4	18,6	11,2	7,1	
28	17.1	20,4	18,7	11,8	7.4	
29	16,8	20,6	18,1	11,7	7,3	
30	16,8	20,5	17,8	12,0	7,3	
C.V.(%)	5,0	2,8	11, 1	9,4	7,9	
LSD 5%	0,9	1,0	1,5	0,6	0,4	
1%	1,0	1,4	2,0	0,8	0,5	


D. POLYMER DISPERSION PROPERTIES WHICH INDUCE WATER REPELLENCY IN SAND

Soils with hydrophobic properties have been noted before. Savage (1976), Hartmann and Verplancke (1975), Verplancke, et al. (1975), Lenvain and De Boodt (1975), Ildefonsopla (1976) and Fink and Frasier (1976) refer to soils exhibiting water repellent properties. These authors show that such soils may occur naturally, the phenomenon being induced by lignins, heat, soil fauna etc, or they can be artificially created by treating with emulsified bitumens, paraffin waxes or insoluble soeps, heavy fuel oils, or solutions of sodium methyl siliconate, polyvinyl alcohol or polyacrylamide. However, it would appear that polymer dispersions have not been previously reported as being capable of imparting this effect. An investigation to explore this water repellency effect and why it is induced only by some dispersions, was therefore instigated.

It was at first thought that the polymer bonds of the more soluble monomers, e.g. VAc containing types, may let water permeate through them while those of the more water insoluble types, e.g. the acrylics, could effectively resist it. However, addition of a surfactant to the water in which non-wetting send briquettes were submerged, permitted rapid water entry with the release of a stream of air bubbles. This observation, together with the fact that above a certain head of water, penetration also occurred in surfactant free systems, indicated that the holdout is due to surface tension.

The indicated inverse relationship between the bonding and water repelling abilities in sand (see Figure 3) of any particular polymer dispersion suggests that two opposing

- 53 -





To elucidate whether the hydrophobic effect is induced by the monomers or stabilizers, natural gum-oil stabilized copolymer dispersions were made and their abilities to impart water repellency to sand tested. In all cases they showed good water repellency and very low tensile strengths. In contrast, surfactant stabilized PVAc homopolymers imparted poor water repellency and poor tensile strengths. To ensure that the PVAc - Gum A homopolymer was costing the sand grains completely, the dispersion was mixed with methanol so that a proportion of the polymer went into true solution. This was removed by phase separation, mixed with sand, dried and tested for water repellency. No hydrophobic effect was evident.

These results, coupled with the conclusions of the previous Chapter, indicate strongly that while the stabilizer system controls the placement of the polymer in the sand, it is the monomer type that induces the hydrophobic effect.

E. EUGGESTED MECHANISM RESPONSIBLE FOR CREATING THE HYDROPHOBIC EFFECT

Because only the copolymers induced the hydrophobic effect, it was considered possible that their dual composition might cause them to orientate and give a hydrophilic and, which attaches to the sand grain and a hydrophobic and, which is exposed outwards.

A polystyrene homopolymer in xylene was therefore prepared and used to saturate send. This sytem induced a strong hydrophobic effect which tends to eliminate a polarising mechanism. In contrast, a dried film of PVAc homopolymer dissolved in xylene did not show appreciable water repellency. These results again tend to confirm that the type of monomer is all important in im-

- 55 -

The most obvious difference between styrene and vinyl acetate monomers is their relative solubility (Table 1 page 10). In order to test the relative resistances of the polymerized films to hydrolysis the following accelerated test was conducted.

1. Materials and procedure

Wet films of the various polymer dispersions were drawn down on gless and dried at 50 C for 4 hours. They were then soaked in water and floated off the glass and redried.

Hydrolysis is described as the chemical reaction in which water acts upon another substance to form one or more entirely new substances. Since it is the elements of water, H- and -OH, which take place in the reaction, the rate of decomposition can be accelerated by using acids or aqueous alkalis. Pieces, 4cm x 6cm, of the different polymer films were therefore accurately weighed and immersed in a 2% caustic solution at 25 C. After 48 hours the films were removed, washed with distilled water, dried at 50 C for 2 hours and after cooling, reweighed.

Results and discussion

The percentage loss in weights of the polymer films were as follows.

Table 10

- 57 -

Percentage loss in weight of polymer films after being submerged in 2% NaOH solution for 48 hours (Means of duplicate determinations)

	% Loss in weight
PVAc - Gum A	Complete film disintegration
PVAc - Gum B	Complete film disintegration
PVAc - PVOH	Complete film disintegration
PVAC - PVOH + HEC	Complete film disintegration
VAC - 2EHA	11,88
VAc - VeoVa	2,52
Styrene - 2EHA	0, 13
MMA - ZEHA	0,45
SBR (Carbox.)	0,28

As is noted from Table 10 the PVAc homopolymers have very poor film resistance in conditions strongly favouring hydrolysis, but when incorporated in a copolymer with a less soluble monomer the performance is dramatically improved. These results, coupled with the observed best resistance of the copolymer comprised of the two least soluble monomers, that is the styrene and 2-EHA (Table 8 page 48), seem strong evidence that the ability of polymer dispersions to impart water repellency to sand is a function of the ability of their films to resist attack by water.

F. LOWEST EFFECTIVE POLYMER LEVELS IMPARTING WATER REPELLENCY TO SAND

If a microscopic coating of water insoluble polymer around the sand grains imparts water repellency, then it was considered possible that much lower levels than the 0,19% dry polymer on dry sand basis used to date may achieve the same effect. An investigation was therefore undertaken to assess the appearance

1. Materials and procedure

The preparations of samples were as before, in that the polymer dispersions were diluted down to the desired solids content and then 190g of these intimately mixed with 1 kg of graded sand. The sand was dried at 55 C overnight. When the cohesive strength was inadequate to form briquettes, the hydrophobic effect was assessed by creating a depression in the treated sand and then pipetting in 100g of water to give a head of approximately 2,5 cm. The hydrophobic effect was taken as positive if the water remained for longer than 24 hours in the depression (see Plate 3). The results of the various concentrations of three selected dispersions are given in Table 11.

- 58 -

2. Results and discussion

Table 11

Effects of decreasing concentrations of certain polymer dispersions on the appearance and water repelling abilities of treated sand

Polymer type	Polymer on dry sand basis %	Solids of added disper sion	Sand appearance after drying	Wate holdo qualit
VAc-VeoVa	0, 190	1,0	Brittle skin over hard sand	Positi
	0, 095	0,5	Thinner skin easily eroded below	Positi
	0, 0 19	0,1	No skin - loose sand	Positi
Styrene acrylic- dextrine (40:60)	0, 190 0, 095 0, 019	1,0 0,5 0,1	Tough skin over loose sand Tough skin over loose sand Thin skin over loose sand	Positi Positi Positi
Styrene-	0, 190	1,0	Tough skin easily eroded below	Positi
2EHA	0, 095	0,5	Thinner skin easily eroded	Positi



Plate 3: The water holdout achieved in free-flowing marine sand by 0,019% dry polymer treatment

.

From Table 11 it is clear that even at concentrations as low as 0,019% dry polymer on dry sand basis, the hydrophobic effect is still pronounced. An extended series of different dispersions were then tested at even lower concentrations to determine, firstly, the most efficient product and, secondly, the lowest level of its effectiveness.

Table 12

The ability of different polymer dispersions to impart water repellency when added at 0,019% and 0,009% dry polymer on dry sand basis

		Duration of water holdout			
Polymer		Dry polymer on sand (%)			
Туре	Average particle size jum	0,019%	0,009%		
SBR (uncarbox.)	0,2	30 seconds	Nil		
PVAc homopolymer	1,1	70 seconds	Nil		
VAC-2EHA	0,7	11 minutes	Nil		
SER carboxylated	0,2	5 hours	Nil ···		
VAc-VeoVa	0,8	24 hours	Nil .		
MMA-2EHA	0,3	24 hours	30 minutes		
BA-ZEHA	0,5	24 hours	Nil '		
Styrene-2EHA	0,2	24 hours	24 hours		

Of all the dispersions tested at 0,009% dry polymer on dry sand, only two imparted water repellency for more than 30 minutes and only one exceeded 24 hours. In fact, water was still in the depression after 7 days and was apparently only lost through evaporation. However, at a 0,000% dry addition level to sand this dispersion also lost its effectiveness. This dispersion and the MMA-2EHA copolymer giving a 30 minute water holdout at 0,009% polymer, are characterised by having less than 0,5% film small particle sizes (less than 0,4 µm). From straightforward surface area considerations it seems that, if a polymer dispersion exhibits the ability to impart water repellency then the smaller its particle size, the more efficient will the costing of the sand grains be.

Tests showed that the effect can be achieved by drying out the wet polymer treated soil at ambient temperatures. Complete drying, however, is essential.

G. CONCLUSIONS

The most significant aspect of the observed very strong hydrophobic effect imparted to sand is the very low level of polymer dispersion necessary to induce it. This high degree of efficiency plus the fact that the only other elements necessary to achieve the effect are the dilution water, in situ sand and conditions favouring drying, means the whole operation is very economical. For example, a metric ton of sand can be made water repellent for approximately 15 (S.A.) cents.

Since extremely low cost is an essential requirement in any extensive soil conditioning programme, it was worth investigating to what beneficial uses this water repellency effect could be put. Potential applications considered included moisture, fertilizer and herbicide conservation and these are discussed later in Chapters VIII and IX, where polymer dispersions which induce weak bonding but a strong hydrophobic effect, were used. It was found that, although the tensile strengths were down some 10% when 80 parts of a marginally stabilized PVAc homopolymer were blended with 20 parts of a surfactant stabilized copolymer, the consolidated sand had excellent non-wetting properties. Since load-bearing slabs must not lose strength when submerged in water, the suitability of polymer dispersion blends in road building was investigated. This is reported on in Chapter VII.

Finally, those dispersions imparting no hydrophobic effect but with maximum sand bonding properties were used in applications considered to be pertinent. Those considered in this dissertation are wind and water erosion control, and the techniques used and results obtained are described in Chapters V and VI respectively.

CHAPTER V

WIND EROSION CONTROL

From 1972 to about 1976 a number of large scale Civil Engineering projects were under construction in South Africa where the movement of sand by wind was severely hampering progress. These included the new herbour at Richards Bay, the new No. 2 Pier at Durban harbour, the development of the Marina Da Gama at Muizenberg and the Sishen to Saldanha railway line. These capital intensive projects involved several local and international construction companies with experience in the problems of moving sand. The sites therefore afforded an excellent opportunity to study not only the methods favoured for sand consolidation, but also to test out the effectiveness and likelihood of commercial acceptability of using polymer dispersions.

- 63 -

A. EXISTING CONTROL MEASURES

At each of the above sites tests using different materials were organised by the contractors to assess their effectiveness in preventing the movement of sand by wind. These included the use of:

1. Fences

The erection of upright fences made of boards, plastic nets (see Plate 4) reeds (see Plate 5) (Cooke, 1972) and stacked brushwood (see Plate 6). While reasonably effective in the short term, these became completely covered by sand after a few months, as is indicated in Plate 5. Such systems do not seem to lend themselves to large flat exposed areas, but seem more successful on slopes such as with dune reclamation and mine dumps (see Plate 5).

- 54 -

2. Chemicals

Chemicals sprayed to form thin films on the send included bitumen products, PVAc dispersions, petroleum oils (see Plate 7) and cold styrene-butadiene copolymer and oil blends.

These products suffered from the disadvantage that the thin films are easily ruptured. Once this occurred the wind removed the exposed loose sand and undermined the surrounding film.

Bulky surface spreads

The following products were imported and spread out on the sand: ash, topsoil, reeds (see Plate 8), brushwood (see Plate 9) and even town refuse. The materials in this group were undoubtedly the most successful and one or other of them was eventually used to solve the sand movement problems at all five sites mentioned.

In attempting to analyse why these last mentioned products were technically successful, it was concluded that their bulk and durability ensured that they remained in aitu for many years thus permitting natural vegetation to become established. It was felt that if a chemical stabilizer was to be truly successful it should be used in such a way that it would simulate these effects. The object of the following



Plate 4: Fences of plastic mash to reduce sand movement by wind



Plate 5: Closely spaced fences of reads to reduce sand movement on a mine dump



- 66 -

Plate 5: Brushwood barriers strategically placed to reduce wind blown sand entering waterwaya



Plate 7: A thin layer of petroleum by-product being sprayed on marine sand to prevent wind erosion



Plate 8: Reeds spread out on reclaimed send to maintain levels



Plate 9: Spreed brushwood forming en effective sand stabilizer a bulky, durable surface layer which would permit natural seeding of the area.

B. EELECTING TYPE AND LEVEL OF DISPERSION TO FORM THICK SAND LAYERS USING SURFACE APPLICATIONS

For in situ and consolidating processes a surface treatment is preferable to the mechanical incorporation of the bonding medium into the sand. The non-migrating characteristics of certain polymer dispersions when mixed into send, (Chepter III), suggests that they may consolidate send to depth after having been poured on to the surface. This possibility was investigated.

1. Materials

The PVAc - Gum A homopolymer dispersion and the carboxylated SBR were selected as representing non-migrating and migrating types. The same graded (>250 μm but <710 μm) sand as before was used.

2. Experimental procedure

Four x 100ml glass measuring cylinders were filled up to the 100ml graduation with loose sand. Each dispersion was diluted with water to Exactly % solids contents and then 25ml aliquots of each were dripped on to the sand surface of the two cylinders. It was noted that the sand was maistened down to the 58ml graduation. The cylinders were left in a constant temperature - humidity room at 25 C and 50% R.H. for 24 hours. The surface crusts which formed in this time were removed by carefully tilting the cylinders to the horizontal and prizing noted and the cylinders replaced in the constant temperature humidity room. After two further 24 hour intervals the volumes of the newly dried bonded sand were removed and recorded.

- 70 -

3. Results and discussion

The bonded sand layers of the two different types of dispersion were very different in appearance. The PVAc homopolymer produced a thick hard aggregate of sand whereas the carboxylated SBR formed a thin, flexible, "rubbery" layer. The volumes of sand bonded on the three consecutive days are presented in Table 13.

Table 13

Volume of sand aggregated when 25ml of different dispersions at 1% concentration were dripped on to 5,3 sq cm of sand (Means of duplicate determinations)

STORE STORE	Polymer dispersion type		
	PVAc homopolymer	SBR (carbox.) copolymer	
Initial volume of sand moistened	58 ml	58 ml	
Crust volumes after 24 hours	17 ml	4 ml	
Crust volumes after 48 hours	14 ml	4 ml	
Crust volumes after 72 hours	nil	nil	
Volume of bonded sand to volume of liquid pene- tration	54%	14%	

The above results confirm that the diluted PVAc homopolymers are capable of forming thick consolidated surface layers when watered on to the sand surface, whereas the surfactant stabilized copolymers cannot. An actual field test applying the two dispersions at 1% solids from a watering can on to the sand surface confirmed these different effects. At 10 litres per square metre the carboxylated styrene-butadiene copolymer treated sand dried to a thin (± 6mm) rubbery slab (see Plate 10), whereas the PVAc homopolymer gave a hard, thick (± 75mm) crust of sand (see Plate 19).

It is also noted from Table 13 that consolidation did not occur to the full depth of liquid penetration. This may be due, firstly, to some of the PVAc homopolymer particles migrating back to the surface on drying or, secondly, to the polymer being filtered out by the sand as the liquid moves down. An experiment described in Appendix 4 to assess the distribution of polymer after drying indicated that no filtering out of polymer was occurring,but there is evidence of polymer migration back to the surface. While indicating that caution is necessary when predicting dry crust thickness from wet penetration,this does not seem to be a practical problem.

C. DETERMINING MINIMUM POLYMER CONCENTRATION NECESSARY TO FORM RAINDROP RESISTANT SAND AGGREGATES

1. Using the commercial PVAc homopolymer

It is obviously necessary to ensure that the synthetic sand aggregates are resistant to raindrop impact. To assess the minimum required polymer level the following experiment was

- 71 -



Plate 10: The thin rubbery send layer formed after applying 10 litres/m2 of a surfectent stabilized styremebutadiene copolymer dispersion at 7% solids

1a. Materials and procedure

The PVAc - Gum A dispersion was diluted to verious concentrations and these blended with graded sand to form briquettes in the Richards Rupture test moulds. Five briquettes were prepared at each concentration, dried for 17 hours at 55 C, and, after removal from their moulds, were weighed and placed on a wire mesh frame. The frame was placed outside and a thunderstorm in which 95 mm of rain fell in three hours provided a severe test of the stability of the bonded sand. The remains of the briquettes were redried and weighed again in order to measure the loss of sand incurred. The results are presented in Table 15.

- 73 -

1b. Results and discussion

Table 15

Effect of a reinstorm on the stability of sand briquettes bonded with reducing levels of the PVAc homopolymer (Means of five determinations)

Solids content of the PVAc dispersion (%)	Polymer content in send (% dry weight)	% of briquette left after severe rainstorm
1,50	0,28	96,7
1,35	0,26	91,6
1,20	0,23	94,8
1,05	0,20	91,3
0,90	0,17	88,0
0,75	0,14	96,4
0,60	0,11	0
0,45	0,09	. 0
C.V. (%)		5,2
L60 5%		6,1

- 74 -

sand basis survived the reinstorm, at the 0,1% level they disinte-grated completely. Because it is edvisable, in practice, to introduce some margin of sefety, a level of 0,20% is suggested as the minimum required to ansure stability against reindrop impact.

 Comparison between the PVAc - Gum A dispersion and new development grades

From the results presented in Chapters III and IV, surface application of the newly developed dispersions should produce stronger, more water resistant sand aggregates than the commercially available ones. It was decided therefore to compare the raindrop resistance of sand briquettes bonded with

- (1) the standard PVAc homopolymer dispersion;
- (ii) modified versions of the above using lower levels of stabilizer, and
- (iii) blends of dispersions imparting strong bonds and hydrophobic properties.

2a. Materials

The PVAc homopolymer dispersion was selected together with dispersions polymerized with 50% and 35% of the standard gum stabilizer level. In addition, blands of the PVAc dispersion and the surfactant stabilized styrene-2EHA copolymer were included in the ratios 66:33 and 75:25 on a dry polymer basis. These five dispersions were diluted to exactly % solids content. The graded send (> 250 µm < 750 µm) was again used. 2b. Experimental procedure

Plastic cups 8,0 cm x 7,6 cm in diameter (surface area 45,4 sq cm) were filled with 200g of sand. They were divided into five groups with four cups in each. To each of the four cups 66ml of the particular dispersion at 1% solids content was dripped on to the surface. This was repeated for the five different dispersions. The cups were then dried at 55 C. The aggregated material was removed, superficial loose sand brushed off, and the aggregated sand weighed. These aggregates were then placed on wire mesh trays and exposed to the environment for 6 weeks, during which time several periods of heavy rain were experienced. The briquettes were then dried off at 55 C and reweighed. The percentage losses in weight due to water erosion are given in Table 16.

75 -

2c. Results and discussion

Table 16

10

Loss in weight of sand briquettes bonded with different polymer dispersions after exterior exposure for 6 weeks (Means of 4 determinations)

Polymer dispersion type		Original weight of sand aggregate (g)	% loss in send aggregate weigh after exposure	
1.	PVAc homopolymer (100% gum stabilizer)	273,7 = 0,24% polymer on send basis	19,7	
2.	PVAc homopolymer (50% gum stabilizer)	260,7** = 0,25% polymer on sand basis	17,3**	
3.	PVAc homopolymer (35% gum stabilizer)	254,4** = D,26% polymer on sand basis	16,7**	
4.	75 parts of PVAc with 25 parts of surfactant stabilized styrene-2EHA copolymer	289,6** = 0,23% polymer on sand basis	14,2**	
5.	As in 4. but ratio 66:33	272,3 = 0,24% polymer on sand basis	15,6**	
C.V	. (%)	3,2	8,0	
LSD	5%	8,9	1.4	
	1%	12,3	2,0	

.. Statistically significant at the 16 level

It is interesting to note that the modifications to the PVAc dispersion have significantly improved its ability to produce better rain resistant sand aggregates, although the lower levels of gum stabilizer also reduce the thickness of the consolidated layer. However, the 25% addition of styrene-2EHA copolymer dispersion to the PVAc homopolymer not only significantly increases the weight of sand aggregated, but also gives aggregates with the highest resistance to erosion by rain. The blend with 33% styrene-2EHA copolymer appears extreme and results indicate that perhaps levels below 25% are optimum.

- 77 -

In a separate exercise, blends of the polymer dispersions with various hot water soluble maize attaches and dextrines were assessed. Although under dry conditions higher bond strengths were obtained, there was no improvement in raindrop resistance. The increased cost of its inclusion therefore does not seem justified. This, coupled with its vulnerability to microbial attack, its tendency to gel in the drum under cold conditions and problems with it penetrating fine sand, precluded its inclusion in later practical application studies.

D. QUALITY OF DILUTION WATER

Although the PVAc - Gum A homopolymer produces the desired bulky surface, it will require large amounts of carrier water to do so. Because the four construction sites mentioned earlier were all adjacent to the sea or lagoons, the use of this water would greatly facilitate the operation. Initial tests showed that while the PVAc homopolymers were stable in sea water, most of the surfactant stabilized types coagulated. However, by adding extra nonionic surfactant to the carboxylated SBR it could be made stable. The bonding ability of the PVAc homopolymer was unaffected by changes in pH above about 4,0. Appendix 5 details these test results together with the effects of sodium chloride, calcium chloride and ferric chloride concentrations on the tensile strengths imparted by the PVAc homopolymer dispersion. Perhaps, as expected, the trivalent followed by the divalent ions have the greatest detrimental effect on the bonding ability of the polymer. However, the modulus of musture value is still 4000 sillibres at a said

chloride concentration of 2,87% and it can be considered feasible to use sea water.

The only problem observed subsequently when using sea water for dilution in field trials was that it apparently took longer to dry out than if fresh water was used. The rate of drying out of send briquettes bound with the PVAc homopolymer diluted with fresh and Indian Ocean water are compared in Table 17.

Table 17

Drying rates of PVAc and briquettes prepared with fresh and sea water (Means of duplicate determinations)

	Days of	f drying	out under	embient a	conditions
	1	2	3	4	5
	% loss of added water (corrected for salt content)				
Fresh water Sea water	44,9	78,2	93,5 95,1	94,5	96,6

As can be seen, the use of sea water does have a slight retarding effect on the rate of drying in the early stages but, perhaps more important, is the actual uptake of water on day 6 when humidity was high. If a choice is available, the use of fresh water would be preferable.

E. METHODS OF APPLICATION IN THE FIELD

In any sand consolidation process it is desirable that the whole area be treated as fast as possible as wind blown sand from the untreated area not only has a severe abrasive action on the areas already consolidated, but also many tons of sand can be dumped on to the treated areas in one brief cals Armbrust and Lyles (1976) recognised the importance of developing methods of applying large volumes of stabilizing agent rapidly.

1. Batch systems

Although this mode of application is the most reliable, it is also the slowest and most laborious. Typically, a measured amount of the polymer dispersion is added to a mobile tank of known volume. The dilution water is then poured in and the tank transported to the test site where the contents are distributed evenly over a demarcated area. Distribution can be either from a long hose connected to the tanker which is parked on an access road (see Plate 11), or directly on to the sand if vehicles can move over it. In the latter method of application it was found that a bar distributor (see Plate 12) gave a far more reliable result than did the use of a dish spray (see Plate 13). When the tanker is empty it must be returned to the water source. More time can be taken up by travelling and refilling than actually treating the sand.

Continuous systems

By siting a pump at the water source and using very long pipes to reach the treatment area, travelling and refilling times could be eliminated. Some means of blending the dispersion into the carrier water is obviously necessary.

a. Metering polymer in at the pump

If the polymer dispersion can be included at the water source, then only one access road and off-loading point for the poly-



Plate 11: A hydroseeder with a pressurised tank and long hose will permit send treatment if access roads are evailable



Plate 12:

A tanker being drawn by a vehicle copeble of being driven over sand. The bar applicator gives accurate and even application



Plate -13: An unsuitable dish distributor which gives uneven and inaccurate coverage

more eccurate control over the metering operation than at the end of the pipe, where the terrain could be very inhospitable. A pilot system was therefore developed and the pump modified for metering in polymer dispersion. The unit is illustrated in Plate 14 and consists of:

- 62 -

a 6,5 h.p. petrol-driven engine, a centrifugal pump delivering up to 150 litres/minute, a 25 litre graduated polymer dispersion holding tank, and 1 000 metres of 3,7 cm diameter flexible hose (see Plate 15).

Drice the water delivery of the pump is calibrated, the rate at which the concentrated dispersion should be drawn into it to give the correct solids is calculated. This is then measured by having pegs at levels equivalent to one litre volumes down the inside of the 25% polymer dispersion container. The rate of fall in level of the dispersion can then be related to the volume entering the pump. This is controlled by a valve to give the desired solids concentration. The action of the centrifugal pump ensures mixing of the two ingredients.

To eliminate fluctuations in the concentration of the polymer, the ideal is to have a mixing tank feeding into a larger holding tank from which the pump is supplied. The above pilot plant is theoretically capable of treating ten hectares per day, but obviously a larger pump and several distribution points would increase the rate appreciably. The use of a mobile overhead spray irrigation system in place of several hand operated hoses would also facilitate the operation.



Plate 14: A centrifuged pump adapted to draw polymer dispersion at a controlled rate from the header tank and mix it with pumped water



Plate 15:

Spraying send with dilute polymer dispersion which is being metered into see water at the delivery pump

One disadvantage found in practice was that when the SBR copolymer went through the centrifugal pump it was coagulated by the mechanical shear. This resulted in the pump seizing and the hose being rendered useless. The following system can be used to introduce the polymer into the water after the pump, thus overcoming the problem with shear.

b. Metering polymer in at exit of hose

If a pressurised water supply is already available it is more convenient to introduce the polymer into the dilution water via a venturi at the end of the hose. A number of commercial venturi systems which deliver a constant ratio of concentrate into the dilution water are available and range in size from small to large (see Plate 16). While the larger types generally have a feed rate control, the smaller ones do not. In the latter case it is usually necessary to predilute the polymer dispersion to give the correct solids content reaching the send.

F. AN DESERVATIONAL FIELD TRIAL TO ASSESS THE RESISTANCE OF AGGREGATES TO WIND BLOWN SAND

Probably the most necessary requirement of a send stabilizing material is its ability to render the consolidated surface resistant to abrasion by windborne sand. It is remarkable that this is so often neglected by laboratory researchers when essessing binders (see Page 16). Although a simple laboratory test was devised to simulate the sand blasting effect (see Appendix 6), it was felt that a small scale observotional field test was essential.

- B4 -



1. Materials

The test site chosen was on, and just over, the brow of a north facing slope at the No. 2 Pier site, Durban harbour. The site and surrounding 150 hectares consisted of loose dredged marine sand. The test ran from May to September 1973 when conditions were dry with strong winds from either the south or north and the treated plots were subjected to severe sand blasting.

Unfortunately, none of the more efficient development grades were included as the laboratory and field tests were running concurrently. However, the concentrations of the PVAc - Gum A homopolymer plasticised with 6% dibutylglycolphthalate and the carboxylated SBR used in this trial were kept well above the considered critical level.

Experimental procedure

Six plots, each 15 x 15 metres, were pegged out on the sand. The relevant polymer dispersions were measured into the tank of a hydroseeder and then water added to give the desired polymer concentrations. The concentrations used and the rates per hectare of the diluted material applied under pressure from the hose on to the sand, are given below:

Plot 1:	The plasticised PVAc homopolymer at 3%	
	solids at 150 0002/ha.	

- Plot 2: The same polymer as in Plot 1 at 3% solids but reduced to 75 0001/ha.
- Plot 3: The same polymer as in Plot 1 at 1,5% solids at 150 0001/ha.
- Plot 4: The carboxylated SBR at 3% solids and 150 0001/ha.

- 86 -

Plot 5:	The same polymer as in Plot 4 at 3%
	solids but reduced to 75 0001/ha.
Plot 6:	The same polymer as in Plot 4 but at
	1 5% enlids and 150 0001/he.

The plots were allowed to dry for 14 days and then half of each was broken up with a hoe to present a roughened surface. The nature of the sand crusts formed with each treatment at this stage and the general appearance of the plots after the 5 month exposure period were recorded.

Results and discussion

- Plot 1: The unplasticised PVAc dispersion imparted a rigid consolidated layer of sand some 10cm thick (see Plate 20). The continuous crust was badly eroded in a few weeks by wind blown sand (see Plate 17), whereas the clods were still in reasonable condition at the end of the trial. It was noted that loose sand filled in around the clods. The clods presumably protect the sand from being blown away and it, in turn, protects the clods from abrasion (see Plats 21 and 22).
- Plot 2: Results were very similar to those in Plot 1 except that the crust was about 5cm thick.
- Plot 3: This plot was indistinguishable from Plot 1 and indicates that a solids content of 1,5% is satisfactory, provided the crust is broken up into clods.
- Plot 4: The carboxylated SBR formed a thin slab (approximately 2cm) which was depressed with pressure. The continuous and ruptured areas showed good resistance to abrasion (see Plate 10 on page 72).



- 88. -

Pista 17:

The unclodded polymer aggregated sand is quickly eroded if subjected to severe sand bloating
Plot 5: The lower rate per square metre of SBR at 3% solids gave a similar result to that in Plot 4. In contrast to the result in Plot 4, however, the continuous layer here was severely eroded by wind.

As a continuous film,only the carboxylated SBR at 3% solids content offered some resistance to erosion by wind blown sand. For the other treatments, the broken surface resisted erosion and consequently held levels more effectively. The PVAc dispersion at 1,5% solids and 151/m² gave the bulkiest crust.

In the following large scale field observations the clodded effect using the plasticised PVAc forms the main treatment, but other dispersions are sometimes included for comparison. The method of application used depended on conditions at the site.

G. PRACTICAL FIELD APPLICATIONS

The location of the four construction sites at which field trials were laid down are given in the map in Appendix 7. At all these sites the final objective was to obtain permanent stabilization of loose, clay-free sand through the establishment of vegetation. Because only complete auccess would be acceptable in practice, degrees of difference in results were considered irrelevant. Results of the effects of initial treatments and the state of the plots several months later are therefore presented in photographic rather than quantitative measurement form.

- 89 -

1. Site No. 1 - Richards Bay

a. Vegetation by seeding

Approximately 2 000 hectares of dredged and levelled marine sand had to be permanently stabilized. The area has an annual reinfell of over 1 000mm, hot summers with sporadic high winds from the north or south and a typical four-month winter drought.

- 90 -

In December 1972, an area of approximately 1 000 square metres which was bordered on the north side by mangrove trees and on the south by a wide expanse of loose sand, was sprayed with 7 500% of the plasticised PVAc - Gum A homopolymer containing 1,2% solids. The dilution was carried out in a hydroseeder tank and then sprayed on to the sand so that ponding occurred (see Plate 18).

Within ten days the expected hard, load-bearing, cohesive layer some 5cm thick had formed. This was physically broken up into clods (see Plate 19), fertilized with an N-P-K mixture and seeded with a variety of grasses (see Plate 20). Plate 20 also shows how the clods prevented the seeds being blown away and afforded shade to them.

The stand of grass, mainly <u>Eragrostis curvula</u> after some 12 weeks is shown in Plate 21. It also illustrates how loose sand filled in around and buried the clods. The state of the trial in August 1974, at the end of the dry winter, is shown in Plate 22. While the grass was suffering from drought, the durability of the synthetic aggregates and their ability to hold sand levels is very clear.



Breaking up the dry consolidated layer of aggregated sand into clods



The resulting stand of grass with the clods having been covered in by a thin layer of loose sand. Note seed formation Plate 21:



<u>Plate 22</u>: The relative levels of send some 8 months after consolidation and clodding showing how the surrounding loose send has been blown out b. Vegetation by planting saplings

A larger area (1 hectare) bounded by loose sand on three sides and a lagoon to the east, was treated in December 1974 in a co-operative trial with the Department of Parks and Gardens, Richards Bay Town Board. The metering pump was used (see Plate 23) and 7,5 litres per square metre of liquid containing the PVAc homopolymer at 1,2% solids, % Urea and 1% KCl were applied. It should be recorded that the application took place on wet sand and was followed immediately by heavy rain.

- 94 -

The excellent crust was broken up into clods two weeks later (see Plate 24) and a selection of indigenous shrubs e.g. Brachylaene discolour, Carissa grandifolia and others, dune creepers e.g. <u>Sceevola thunbergii</u> and trees e.g. <u>Equiseti folia</u> were planted in the rockery-like environment (see Plate 25).

The condition of the plot in December 1975 is shown in Plate 26. Once again the ability of the synthetic clods to hold sand was illustrated, as was the need for selection of adapted plants. Most saplings had been stripped of their leaves and had little chance of survival, but the superior condition of the legume creeper, <u>Scaevola thunbergii</u>, when compared to the other plants, would seem to indicate the need for a regular supply of nitrogen. Attempts to develop a system which controls fertilizer release are discussed in Chapter IX.

Eite No. 2 - Durben Bay

The situation at the new No. 2 Pier site at Durban Bay was similar to that of Richards Bay and the site where the pre-



- 95 -

Plate 23:

The modified pump being sited to draw salt water from the lagoon and bland it with polymer dispersion



Plate 24: The polymer consolidated sand being broken up into clods some 2 weeks after spraying



Plate 25: A variety of plants being planted in the synthetically clodded marine sand. Note distributed seeds of the indigenous legume



Plate 26:

The condition of the test site some 10 months after treatment showing the poor performance of most shrubs and trees. Only the synthetically seeded legume was thriving

- 96 -

egain for further investigation. A very exposed area of some 150 hectares of reclaimed marine sand required stabilization egainst strong winds. Here winter drought conditions with an ennual rainfall of some 900mm and frequent strong winds, especially from the north and south, prevail.

- 97 -

Application was by hydroseeder during May and June 1973 and, in total, about 10 hectares were stabilized. Once again excellent consolidation to depth was obtained (see Plate 27) but the establishment of vegetation failed, largely because the surrounding loose sand (note background of Plate 27) engulfed the developing seedlings. Only on some of the high spots did stands of <u>Eregrostis curvuls</u> and <u>Colombus sorgum</u> survive (see Plate 28). This trial illustrated the need for repid and complete stabilization of entire problem areas.

3. Site No. 3 - Muizenberg marina development

Muizenberg, which is adjacent to Cape Town, differs from the former two sites in that a Mediterranean climate prevails, with a winter rainfall of about 500mm per annum and an eightmonth summer drought. It is subjected to exceptionally high winds - in excess of 11 knots for 48% of the year and in excess of 7 knots for 26% of the year. The Marina was comprised of fingers of loose sand surrounded by water. This sand was continually being blown into the waterways,which silted up.

A co-operative trial was put down with the resident horticulturelists. A site bounded by water on three sides was selected and along the fourth side, where a roadway traversed the site, a 1,5 metre high PVC mesh netting fence was erected to prevent



```
Plate 27:
```

Mechanically breaking up the artificially consolidated marine and



Plate 28:

A good stand of tracrostis curvuls and Columbus sorpum on the top of an artificially clodded bank

the entry of sand from without (see Plate 29). In October 1974 the plasticised PVAc homopolymer and the carboxylated SBR copolymer dispersions were applied at 7,51/m² and 1,2% solids contents. The concentrated SBR required 0,3% additional nonionic surfactant to prevent it destabilizing in the saline lagoon water. Each plot was approximately 1 000 square metres and the following treatments were applied. (Layout details are given in Appendix 8.)

Windward side:

- Plot A: The PVAc consolidated crust (3cm thick) formed after two days drying and was broken up into rows some 25cm wide and 2 metres apart across the slight slope. A mixture of grass seeds was sown into these rows.
- Plot B: The SBR was sprayed over the area. The resulting crust was left intact and was not planted.
- Plot C: Prior to planting, furrows some 50cm deep by 50cm wide were ploughed at 3 metre centres across the slight slope. A variety of plants e.g. <u>Gazania</u> <u>uniflora</u>, <u>Mesembryanthemum edule</u> and others, and saplings e.g. <u>Equiseti folia</u>, were planted along and in the ridges of the furrows and then oversprayed with the PVAc homopolymer at 7,5%/m² (see Plate 30).

Plot D: As in Plot A, but the crust was left intact and not planted.

- 99 -



Plate 29: A general view of the Muizenberg test site showing the protective most and the PVC fence



Plate 30: Overspraying planted vegetation with the PVAc homopolymer at 1,2% solids

Leeward side:

Plot E: A variety of seedlings was planted and overspraved with the SBR at 7,51/m².

Inspection of the site in May 1975 showed:

- (i) All polymer treatments had held sand levels well. The continuous crusts showed signs of wear despite the protection of the 30 metre wide most.
- (11) The furrows in Plot C were completely filled with loose mand, which had smothered the plants. In contrast, the <u>Mesembryanthemum edule</u>, a succulent creeper, planted on the ridges was thriving, despite having received virtually no rain during the eight hot summer months (see Plate 31).
- (iii) The fact that plants in Plate E, including <u>Gazania</u> <u>uniflors</u>, also had not only survived the severe summer drought, but were actually flowering, indicated that the SBR consolidated layer was conserving moisture. This aspect is studied in detail later in Chapter VIII.

(iv) None of the plants grown from seed survived, indicating that cuttings or transplants have a greater chance of becoming established.

4. Eite No. 4 - Elandsbasi

At Elandsbaai (annual rainfall approximately 250mm), on the Cape West Coast, the Sishen to Saldanha railway line passes through a "desert" some 20 000 hectares in extent. The problem of loose sand filling the stone ballast on which the railway tracks

- 101 -



Plate 31: A succulent creeper growing well in the ertificially consolidated marine sand. Note the depth of consolidation indicated by the removed clod were laid and the general build up of sand on the line was the cause of much concern. A site on this coast was chosen for an observational trial. A water hole was dug just above the high tide mark and the metering pump previously described, used again. The PVAc homopolymer at 1,2% solids was sprayed on to an area of steep undulating dunes. Excellent consolidation to depths of up to 200mm was obtained (see Plate 32), where application was excessive. Conditions were extremely arid, thus permitting drying out to this depth. The area was broken up into clods using picks and no vegetation was introduced. It was hoped that the indigenous vegetation would reseed itself in the stabilized area. However, after 24 months no vegetation was present despite the outcrops of synthetic bonded sand (see Plate 33) still being very obvious. Again, this is probably due to the abrasive and smothering actions of the surrounding loose sand.

5. Summary and discussion

Although at all four sites the PVAc homopolymer successfully created a bulky, durable surface layer of clods, the vegetation established was sparse. Only <u>Scaevola thunberaii</u> at Richards Bay and <u>Mesembryanthemum edule</u> at Muizenberg successfully established themselves. Resident engineers at all 4 sites considered the results inferior to those which can be achieved by more conventional techniques. For instance, good stands of gress were established at some of the sites where soil was applied as a topdressing (100mm layer). These observations indicate that it is not sufficient for the polymer-bound sand clods to merely hold levels, but they must also improve the moisture and fertilizing properties. Such conservation of



Plate 32: Excellent aggregation to some 200nm depth was achieved in the arid conditions



Plate 33: The "rocky" outcrops of artificially clodded marine sand are obvious, even after being subjected to severe sand blasting moisture and fertilizer in sand was achieved by the application of copolymer dispersions capable of imparting the water repellency effect, and this is discussed in Chapters VII and VIII. Future sand stabilization studies should, therefore, consider blends of the PVAc homopolymer, a copolymer dispersion and a soluble fertilizer. Appendix 26 (page 325) shows that the rates of water infiltration into, and its loss from, sands can be accurately controlled by varying the ratios of these 3 components. Agglomerates formed in this way will limit the penetration of water through them, thus reducing the leaching losses of fertilizers contained therein (see page 199). Also, by drying out quickly, the agglomerates will form a mulch which will reduce evaporation losses (see page 154). Alternatively, this blend of 3 components can be applied at a greatly reduced concentration so that, although no consolidation occurs, the water repellent effect is still generated. Removal of this loose layer by wind can be prevented by any one of the techniques described in Sections A1 and A2 of this Chapter. The cost of this complete treatment should be well below that of imported soil.

In its present form the PVAc alone may find application in:

- less extensive areas, where the whole site can be quickly treated in order to prevent sand abrasion,
- areas where subsequent vegetation is not required,
- (111) remote areas where no topsoil, brushwood or similar materials are available.

The relative merits of using polymer dispersions to combat wind erosion compared with other potential applications are discussed in Chapter X.

- 105 -

WATER EROSION CONTROL ON STEEP SLOPES - DESERVATIONAL TRIALS

106 -

Moldenhauer and Gabriels (1972) outlined some methods used for the permanent stabilization of steep banks. In almost all cases the stabilizing material is sprayed on to the slope together with seed and fertilizer in an abundance of carrier water. The object of the stabilizer is to bind the seed to the soil and to hold moisture until the seedling becomes rooted.

Despite the formidable list of chemical binding agents that have been used in this application (see page 17), none of the commercial hydroseeders in South Africa use any of these by choice (personal communication). They generally spray only seed and fertilizer or, at best, some wood pulp is included to help distribute the seed in the mixing tank. Obviously it is more economical to re-treat problem areas than to elways include binder. Specifications very occasionally call for the use of a PVAc dispersion but here, too, the authorities are questioning the benefits and, although some 400 tons were specified in 1974, this had dropped to less than 100 tons in 1977. Because the benefits of a binder are often not very obvious, the use of stabilizers is likely to decrease. It is the object of this Chapter to investigate, with visually assessed field trials, some obvious benefits by changes in application technique rather than type of binder. As with the last Chapter, the only criteria for ongoing commercial

applications is that the new system be completely successful at costs less than those of existing procedures. Effects created and final results obtained are, therefore, illustrated as photographs and not as quantitative measurements.

It is unlikely that one embankment stabilizing system will work effectively for all conditions and soil type is considered an important variable.

A. SANDY, PERVIOUS SUBSTRATES

The steep-sided dumps of the Witwatersrand gold mines presented test sites for observational experiments. Two types of dumps exist - the older sand dumps and a far greater proportion of very fine particle size slime dumps. The established method to prevent sand movement by wind is to erect reed paddocks. This is a laborious process and some 3,75 kilometres of fences are used to protect one hectare of sand (Cooke, 1972). Mist spray irrigation is set up, firstly to gently leach out detrimental acid and secondly to establish vegetation during the cold, dry winter months when there is little rain to cause erosion. This is obviously a very expensive practice. It was felt that an effective surface binder might eliminate the need for reed fences and reduce the need for artificial leaching, as use could be made of the natural summer rainfall. Because the PVAc homopolymer imparts good aggregation without preventing infiltration of water, it was considered to be ideal for this application.

In February 1974, areas of a very steep (gradient 27°) send dump on Norse mine were sprayed with the plasticised PVAc dispersion. However, instead of using the more conventional hydroseeding rate of 21/m² of a 4% solids material, 7,51/m² of a 1,4% solids concentration was sprayed, to give a thick load-bearing slab. A large commercial venturi (rate adjustable) at the exit end of the hose (see Plate 34) was used to apply the material. As the areas were to be subsequently seeded, 5% limestone ammonium nitrate and 5% potassium chloride were dissolved in the concentrated PVAc dispersion.

- 105 -

As expected, a strong, thick crust (see Plate 35) resulted on drying. To establish vegetation, half of the treated areas were physically broken up into clods and seeded with a variety of grasses.

Inspection of the plots in February 1975, after exceptionally heavy October rains, showed no signs of erosion of either the clods or the continuous crusts. There had been some slippage of the clods (Plate 36) and it is suggested that rather than completely breaking the surface on steep clopes, contour cuts or random holes in the solid slab would be more suitable. This approach would also increase effective rainfall and ensure more efficient leaching in the growth areas as a greater volume of water would be channelled into them. To date (mid 1978) there has been no marked deterioration in either the consolidated slabs or clods and in the seeded area vegetation has established.

The thick durable crust is undeniably the result of the application of a polymer dispersion and the system lends itself to the quick stabilization of newly shaped slopes which can then



Plate 34:

Venturi being used to draw up dispersion at the exit end of water hose. Note next container of dispersion being brought into position



```
Plate 35:
```

The unbroken polymer aggregated sand efficiently resisted water erosion on steep slopes for several

- 110



Plate 35: Slippage of artificially created clode . occurs on steep slopes with heavy rain

be left intect for several years without fear of erosion. As and when conditions are favourable, planting in contours along the slope can be carried out.

8. SLOPES WITH SOME PERMEABILITY

The material of the slimes dumps has particles ranging in size from 1 µm to 250 µm with 50% by mass between 20 µm and 50 µm, restricted permeability and is highly susceptible to erosion by water. Newly shaped slopes are very hard and strewn with equally hard clods (see Plate 37). It was decided to attempt to stabilize the clods and slopes by impregnating them with relatively high volumes of low polymer content sprays. The unevenness of the surface, if stable, would ensure that any distributed seeds would lodge on the steep gradients and not be washed down to the bottom. In August 1974 a newly shaped slimes dump at Blaukrans with an easterly aspect, was divided into 3 x 200 square metre strips. The Management of the Vegetation Unit of the Chamber of Mines was reluctant to leave a control strip as the erosion would be excessive and only necessitate reshaping at a later stage. All three areas were therefore sprayed (using the commercial venturi) with approximately 7,51/m2 of the PVAc homopolymer at 1,4% and 0,76% solids and the styrene-2EHA copolymer at 0,22% polymer content (see Plate 37). On drying, all three treatments resulted in surfaces which were visually indistinguishable from untreated surfaces and the thick crusts obtained on the absorbant sand dumps were absent. Despite this, one half of each plot was then mulched with dry grass, fertilized and seeded in customary manner. The other half of each plot was left bare. The polymer treated areas did not receive the normal mist spray irrigation but had to rely on the natural



Plate 37: Treating a clodded surface with a 1,2% solids polymer dispersion. Dilution of the concentrate was via a commercial venturi

reins, which sterted in September. All three surfaces survived the torrential rains which fell in that October and eight months later showed very little erosion (see Plate 38). The seeded areas were now well grassed and also showed little sign of erosion (see Plate 38). A year after spraying the remaining bare halves of these plots were seeded, and they are now indistinguishable from the surrounding irrigated areas which were treated in the normal way by the Vegetation Unit (see Plate 39).

112 -

The mein features of these apparently successful results are, firstly, the very low polymer concentrations at which they were achieved and, secondly, that the type of dispersion seems irrelevant. It may be that success was due to using relatively high volumes of low binder content dispersion and, because the substrate was similar to many highly erodable agricultural soils, the technique may be usefully applied in land reclamation work.

C. IMPERVIOUS SUBSTRATES

Many high clay soils present a smooth impervious surface when sloped. The treatments described previously in sections A and B, using high volumes of liquid, are considered unsuitable as run-off will be excessive.

For slopes of this type a fixed mulch seems to give the most successful results. Moldenhauer and Gabriels (1972) describe hydroseeding in the U.S.A., where straw or other fibre is first mechanically blown on to embankments and then over-sprayed with a "tacking material", seed and fertilizer. These researchers



Plate 38: The unseeded areas on the left show only alight water erosion, while the seeded areas achieved excellent vegetative cover without artificial watering



Plate 39: The polymer treated areas vegetated only with natural rainfall are now indistinguishable from the rest of the irrigated slopes

- 134 -

fibre and tacking material unnecessary".

It was considered that an air-drying polymer foam created in situ might be such a "material". Advantages over the conventional mulching systems would include reduced transport costs of the bulky mulch, a greater bond between mulch and soil, a reduction of fire hazards, the need for a single rather than a double operation and, by the inclusion of a green pigment, a more mesthetically acceptable appearance in the short term.

- 115 -

Although a mechanically foamed material containing seed, fertilizer and polymer was successfully applied on to an embankment (see Plate 40), it failed to hold its structure on drying out. While this could be achieved fairly easily with the use of a high solids content material (approximately 70%) at the commercially acceptable level of about 4% polymer, this proved to be very difficult to obtain in practice. The best compound formulated and the types of mechanical foamers tested to ensure the seeds were not damaged are presented in Appendix 9. Such foam would preferably be applied from the top of the embankment, as tests showed that it flowed down leaving behind an inte-grated layer,about 5mm thick,of foam, seed and fertilizer.

D. SUMMARY AND DISCUSSION

Although thin layers of different chemicals used to temporarily stabilize steep slopes have received much attention, none seem to be used generally. A major reason for this is that the benefits are not sufficiently obvious and newly treated slopes which cannot be distinguished will continue to be regarded



Plate 40: 2% polymer-containing foam being applied to a smooth embankment

with contempt. In embenkment stabilization, the repid creation of a thick load-bearing slab might find wider acceptance. Treatment in the early stages of the project could prevent wind and water borne soil being dumped on to the construction site until final stabilization through vegetation can be achieved. Another advantage of such thick slabs is that they can support reasonable load without being ruptured. This will permit access across the slopes without creating areas which are vulnerable to erosion. Continuous slabs may also find application in industry. Examples would include the reduction of air polution and reduced losses of powders from storage dumps. By including a proportion of a copolymer, such dumps would shed water and remain relatively dry inside.

- 717 +

In other specific problem areas polymer binders may be useful. For example, on a highly erodible substrate the application of relatively large volumes of dilute polymer dispersion were obviously beneficial. Because success was achieved with both the PVAc homopolymer and styrene-acrylic dispersions, it would seem most binders will be effective. However, the additional benefits of moisture and fertilizer conservation (reported on in Chapters VII and VIII) obtained with the copolymer dispersions indicate that future research should concentrete on these types. Similarly the implications of these benefits on the results obtained with conventional hydroseeding should be investigated.

The use of a foamed air-stable mulch offers obvious advantages over conventional hydroseeding in that it will give the seed some protection against dehydration, UV light and birds. However, a stable air-drying foam could not be successfully applied in this programme of work. The potential advantages offered by such a system suggests that research should be continued on it. The need for greater viscosity and solids at low cost may be met by the introduction of products such as sawdust or wood pulp. Because the moisture and fertilizer conserving effects can also be imparted to such organic materials, (see Chapter IX, Section 2) a copolymer dispersion should be used as binder.

CHAPTER VII

LOAD BEARING SLABS ON SAND

Throughout the field trials described in the previous chapters the ability of the thick crusts imparted by the PVAc homopolymer dispersions to support load without rupturing was always impressive. The feasibility of polymer dispersions being used in applications requiring this property was therefore investigated.

A. EXISTING PRODUCTS USED

The modern road is made up of three principal components: (1) the subgrade or road foundation, (2) the base or main structural element of the road and (3) the wearing surface (Glanville, 1954). The subgrade layers utilize the in situ soil and, relative to the layers nearer the surface, have lower load bearing and resistance-to-abrasion properties. However, if the composition of the soil is inadequate as a foundation, special treatments must be followed. These may be either physical or chemical.

The physical treatment involves the incorporation of the correct size and percentage of grains which are lacking in the weak soil. The chemical treatment involves the use of cementing materials, such as lime, Portland cement, bituminous materials and, to a lesser extent products, such as calcium and sodium chloride, calcium acrylate, sulphite lignin and mixtures of aniline, furfural and bitumen (Lambe, 1951). man. In the road building industry "lime" refers specifically to calcium hydroxide. Proportions ranging from 3% to 8% by mass are intimately mixed into the soil before it is compacted.

In 1971 some 100 million square yards of base per annum were consolidated in this way. This data is quoted by Krebs and Walker (1971) who also state that because lime depends for its action on pozzelanic materials in the soil, it gives pour remults where the clay content is less than about 12%.

Portland cement can be used to stabilize sandy soils. Here 8% to 10% cement on dry sand mass is intimately mixed in and compacted to give a base which hardens progressively as the cement hydrates. However, cracks frequently develop in the hardened material and Clare (1954) states that opinions differ as to the seriousness of these on the final performance of the road. Another potential defect of cement stabilized subgrade is that it is very brittle and Sargious (1975) states that such bases perform well only as long as they are not overstressed.

In recent years, bitumens, consisting of cut back asphalts, emulsified asphalts or tars, have often been used to produce subgrades. According to Oglesby (1975) the percentage of binder, by mass, ranges from 4% to 10% for asphalt cements, cutbacks and tars, and from 5% to 10% for emulsified asphalte. To form suitable bases with bitumen, the sand must be relatively clean and stable; that is, the surface properties and grain shape must be such that they will resist displacement under load. Krebs and Walker (1975) state that for successful bitumen stabilization, the soil should not contain more than 12% "fines", the organic matter content and level of soluble salts should be

- 120-

low and the pH should not be high.

In South Africa very little use is made of materials other then the above to stabilize road subgrade (Maude, personal communique). The most common means of obtaining a lasting subbase is to import suitable soil and then use lime to consolidate it. A need therefore exists in the road building industry for a product which can be added to any sands or sandy soils to give suitable load bearing slabs. The possibility of e polymer dispersion satisfying this need was investigated.

B. PERFORMANCE COMPARISONS BETWEEN THE PVAC HOMOPOLYMER AND CEMENT

To assess whether polymer dispersions could even remotely be considered in road base applications, some of the more important properties required of them are considered below. With polymer dispersions some 35 times more expensive than cement on a dry weight basis, the dispersions would have to be considerably more efficient to be competitive. The ability of the bonded soil to support heavy loads without rupturing is the most important requirement of a road foundation.

1. Soil strength

Methods of measuring soil strength have been divided by Maclean (1948) into two broad classes:

- (1) Shear strength tests:
 - (a) Unconfined compression strength (UCS) test.
 - (b) Shear box test.

(c) Triaxial compression test.

(2) Bearing strength tests:

(a) Plate - bearing test.

(b) California bearing ratio (CBR) test.

Of the above, the unconfined compressive strength and the California bearing ratio tests are most generally used in the road construction industry. The unconfined compression test, developed by Cooling and Golder (1940) was preferred in the present project, as it is the more convenient and rapid method of measuring the strength of polymer bound sand cores.

1a. Materials

In this initial test the unplasticised PVAc homopolymer was compared with Portlend Cement. Graded (> 250 µm < 750 µm) marine sand, devoid of clay, was used. Aluminium tubing of 44mm internal diameter was accurately cut into 88mm lengths. These sections were then cut through lengthwise to function as split moulds. Two metal hose clamps were used to hold the halves together.

1b. Experimental procedure

Different weights of the 56% solids PVAc dispersion were made up to 70g with water and mixed by hand with 1 000g of sand to give 0.5%, 1.0%, 2.0%, 4.0% and 5.0% dry polymer on dry sand basis. These mixtures were used to fill the hollow moulds, with constant manual compaction. The filled moulds were then left standing upright under infra red heater bars with the temperature on the sand surface being 65C. After 17 hours the moulds were split open and the unconfined sand cores dried for 24 hours in an oven at 55C.

- 122-

The cement bonded cores were made by dry blending the cement with 1 000g of sand before mixing in 190g of water. The mixtures were compacted in the moulds in the same way as the samples containing the PVAc had been, and then left in a constant temperature/humidity room at 25C and 50% R.H. After

24 hours the moulds were removed and the unrestricted cores left in the room for a further 7 days before testing.

The sand cores were then subjected to tests on a Houndsfield Model W tensiometer. This instrument consists of a metal framework in which the sand specimen is compressed by a helical spring. The load is applied at 15mm per minute by an electrically driven screw. The cores were placed lengthwise in the relevant clamp and presented an area of 15,2cm² to the applied load. The point of shear was clearly indicated on the visual readout. The shear strength is equal to half the unconfined compression strength of the sand core (Maclean, 1948). This force was converted to kilopascals (kPa) using the following equation:

1c. Results and discussion

The UCS results for the sand cores bound with different amounts of the PVAc homopolymer and cement are presented in Table 18.

- 123-

Table 18

Unconfined compressive strengths in kilopascals of marine sand bonded with increasing levels of cement and PVAc homopolymer dispersion (Means of 4 replicates)

	Level of bonding material on dry sand basis									Is
	0,5%		1,0%		2,0%		4,0%		5,0%	
- 19	Ce- ment	PVAc	Ce- ment	PVAc	Ce- ment	PVAc	Ce- ment	PVAc	Ce- ment	PVAc
UCS (kPa)	nil	980	nil	1630	70	2770	780	3260	880	3770
	C.V. (%) = 11.8 LSD 5% = 659; 1% = 880									

At the concentrations used in Table 18 the PVAc dispersion is definitely more effective at aggregating sand than is cement. This, presumably, is due to the locating mechanism of the PVAc dispersion described in Chapter III. The minimum requirement for soil strength of sub-base as stated in the Natel Roads Department Specifications (1970) is 1 D40 kPe. The PVAc dispersion exceeds this level at 1.0% polymer on dry sand basis, but for cement the UCS is inadequate even at 5.0%. Only at 8% cement content (a concentration at which severe shrinkage cracks result) were strengths of this order achieved. These results indicate that although the PVAc homopolymer may still be less economical than cement, polymer dispersions are worthy of further study as, firstly, it should be possible to formulate systems that are more efficient than the PVAc homopolymer, and secondly, polymers may have certain technical advantages.

2. Shrinkage

The same materials and concentrations as used in sub-section 1 were used to fill shrinkape moulds (250mm x 25mm x 25mm). At

- 124-
all the concentration levels of the PVAc dispersion listed in Table 18 the shrinkage on drying out was nil. In fact, the aggregated sand adhered to the sides of the steel moulds and at the higher polymer levels the briquettes could not be removed. In contrast, the sand aggregated with cement fell out of the moulds when inverted and shrinkages of up to 16 were recorded.

Flexibility

The ideal road base should be able to support load and yet have some flexibility. The method guoted in the Natal Roads Department Specifications (1970) to assess flexibility of subgrade is the Marshall flow test. This is a measure of the amount of distortion under pressure that unconfined soil cores (100 x 50mm diameter) can undergo before they rupture. The force is exerted perpendicularly to the length of the core. Good quality bitumen is considered to have ideal flexibility. with Marshall flow values of 2 - 6mm (van Darlen, 1975). In contrast, cement treated base has a value of zero. The flexibility of a polymer film laid down from a dispersion is usually expressed as the minimum film forming temperature (mft) needed for the particles to coalesce. Details of the test procedure for such measurements are given in Appendix 10. The mft values of the PVAc homopolymer dispersion with increasing levels of plasticiser, and the Marshall flow values on soil cores made from them, (van Darlen, 1975), are presented in Table 19.

-125-

Table 19

Minimum film forming temperatures of plasticised PVAc homopolymer dispersions and the Marshall flow results of sand cores formed from them (2% dry polymer on dry sand)

Level of dibutylglycolphthalate on total solids of dispersion basis	0%	5%	10%	15%	20%
mft values (C)	18	13	8	6	3
Marshall flow (mm)	2,7	3,2	5,6	7,5	10,0

Even without external plasticisers the PVAc homopolymer is apparently sufficiently flexible for use in road base but above 10% DBGP it would seem to be too flexible.

Drying rate

Because the mechanism of aggregation of the polymer dispersions is physical and is dependent on the drying out of the system, the rate of bond development is much slower than is the case with the hydration of cement or the destabilisation of cationic emulsified bitumens when they contact the soil. This is a disadvantage that will have to be accommodated as no practical solution is obvious. Mays of minimising the problem would include the limitation of application to areas where rapid drying is possible, the use of the minimum amount of liquid and the use of stronger, thinner slabs.

5. Resistance to water

Load bearing bases are required to resist loss of strength after prolonged soaking in water. The performance of cement bonded

- 126-

aggregates generally increases slightly after soaking. In contrast, the unconfined compressive strengths of sand bonded with the PVAc dispersion fall to only about 5% of the original level after 17 hours soaking in water, e.g. from 1 281 to 60 kilopescals.

Briquettes allowed to dry out after soaking had strengths comparable to unsoaked samples (see Table 20). This indicates that the polymer does not dissolve but rather softens in wet conditions. If this defect could be overcome the polymer dispersion might be a useful product for road base, and perhaps other load bearing applications. A programme was therefore undertaken to improve the water sensitivity of sand bonded with polymers added as dispersions.

C. IMPROVING THE WATER RESISTANCE DF SAND BONDED WITH POLYMER

Three different approaches were considered in an effort to reduce the sensitivity of polymer-bound sand to water. These were, firstly, to prevent water penetration by blending in a dispersion which imparts a hydrophobic effect; secondly, to blend into the dispersion some other material that would cost or interact with the polymer; and thirdly, to find a locating type dispersion comprised of water resistant monomers.

 Preventing water penetration by blending polymer dispersions

It was felt that sand bonded with an 80:20 blend of the PVAc homopolymer and a hydrophobic inducing MMA-2EHA copolymer would have better strengths after soaking, because water would be prevented from percolating into it. (See page 61). Cores were made as before using the graded marine sand with the PVAc dispersion alone, and with an 80:20 blend of the PVAc homopolymer and the copolymer acrylic dispersion respectively. The levels of polymer used were 0,5% dry polymer on a dry sand basis.

Table 20

Unconfined compressive strengths of marine send bonded with the PVAc homopolymer and an 80:20 blend of the PVAc with an MMA-2EHA copolymer before and after submerging in water for 17 hours (Means of 2 replicates)

Polymer	Condition of	Unconfined compressive strengths of send cores (kPa)					
	centre	Before soak	After soak	After redrying			
PVAc homopolymer	wet through	1 281	60	1 243			
80:20 PVAc: MMA-ZEHA	dry	1 066	0	1 128			
	C.V. (%) =	17,1	LSD 5%	= 297; = 415			

Although the sand cores made with the polymer blends remained comparatively dry inside, their strengths still fell off dramatically after soaking in water. It would seem therefore that the PVAc film is so sensitive to moisture that even a humid atmosphere seriously softens it. The regaining of strength on redrying indicates that a softening rather than a breaking of the polymer bonds occurs. Various chemicals were added to the PVAc homopolymer dispersion in the hope that they might interact with or coat the bonds formed. Chemicals known to increase the water resistance of polymers and those used in general water proofing applications were considered. These included coalescing agents, emulsified wax, silicones, sodium silicate, stearates and emulsified and soluble bitumen. The results obtained by these additives are presented in Appendix 11. Only bitumen in solvent applied to a preformed sand-PVAc core made practical improvements to the performance under wet conditions. This was investigated further.

2a. Materials

The graded marine sand and PVAc homopolymer as previously described, were used again. Commercially available solid bitumen was selected for use with industrial petroleum ether and "paint thinners" (white spirits). These two solvents were chosen because, being largely aliphatic, they dissolve bitumen but do not meterially soften the PVAc film.

2b. Experimental procedure

Sand cores were prepared as before, using the PVAc homopolymer at 0,5% dry polymer on a dry sand basis. 60g of solid bitumen shavings were added to 200g of petroleum ether. The mixture was stirred vigorously for 2 hours until a noticeable proportion of the bitumen had dissolved. Four sand cores were individually weighed and then the dissolved bitumen³ dripped on to them.

-129-

Penetration into the cores was immediate and when they were obviously saturated they were set aside to dry for 2 days at 250 and 50% R.H. They were reweighed and the increase between this and the original measurement was taken as the amount of bitumen present. The same procedure was repeated for the bitumen in white spirits. As controls, 4 cores were not impregnated with bitumen while another 4 were made up using no PVAc dispersions but only the solution of bitumen in white spirits. When all cores were dry, 2 from each series were immersed in water for 17 hours. Immediately after removal from the water these and the unsoaked cores were subjected to unconfined compressive strength measurements.

2c. Results and discussion

It was noted on inspection of the ruptured cores that while the bitumen in the white spirits treatment was evenly distributed throughout the sand, the central core of the petroleum ether treatments contained none. The unconfined compressive strength results are presented in Table 21.

Although treatment 3 offers a real improvement in wet performance, the cost of solvent in practical applications would be excessive. Attempts to get dilute aqueous bitumen emulsion to penetrate the cores were only successful after extra surfactants were added. This treatment, however, made the bonds even more sensitive to water and the sand cores disintegrated when submerged.

Aqueous bitumen emulsions blended with the PVAc homopolymer before mixing with sand also had a detrimental effect, pre-

-130-

Table 21

The effect of impregnating PVAc homopolymer-bound sand cores with bitumen in solvent on unconfined compressive strengths (Means of duplicate replicates)

		Unconf strengt	ined compressive hs of sand cores (kPa)
		Dry	After 17 hours submersion
1.	PVAc dispersion at 0,5% dry polymer on sand	1 180	54
2.	As above, but cores post saturated with bitumen in petroleum ether. 3,6% bitumen on sand	1 432	498
3.	As in 2 above but using white spirits in place of petroleum ether	1 341	883
4.	Bitumen in white spirits. 3,6% bitumen on sand	٥	a

3. Water resistant monomers in locating

type dispersions

The results reported so far are disappointing. Although there are some marginal improvements in the strengths of sand cores after submersion, these are of no real importance. From the previous conclusions reached it would seem that, if a polymer dispersion is to succeed in imparting water resistance to sand appregates, then:

 (a) it must locate polymer at the points of grain contact, and

-131-

(b) it must be comprised of monomers which are much less water sensitive than vinyl acetate.

Attempts to get the surfactant type copolymer dispersion comprised of two water resistant monomers e.g. styrene and 2EHP, to locate in sand by using very dry mixtures proved fruitless. These results are presented in Appendix 13 and indiceted that while good bonding is obtained by the PVAc homopolymer over a wide range of water additions, the surfactant stabilized copolymers always produce weak send briguettes.

After monitoring the polymerisation performance of several stabilizers in copolymer dispersions, one system was eventually found which gave strong sand cores. This system was unique in that it imparted both good bonding and a strong hydrophobic effect from one polymerisation. The stabilizer used was a lower alkyl napthalene sulphonic acid salt ("Dexad" 15) manufactured by W.R. Grace & Company, Cambridge. Massachusetts, USA, 02140, who describe its mechanism of dispersion stabilization as being partially stearic and partially electrostatic. This description tends to support the observation in Chapter III that the stearic stabilizers, e.g. natural gum and PVOH, produce systems capable of locating polymer at the points of sand contact, while the electrostatic types, e.g. ionic surfactants, with the right monomers, cost the whole sand grain to produce the hydrophobic effect. The physical properties of a dispersion using this stabilizer with styrene and BA as monomers at a ratio of 55:45 are given in Appendix 14. The relative dry and post submersion unconfined compression strengths of this dispersion and of the PVAc homopolymer are presented in Table 22. The same sand, level of polymer at 0,5% on a dry weight basis and test procedure as

-133-

Table 22

Unconfined compressive strengths of sand cores bound with different polymers before and after submersion in water (Means of 2 replicates)

	Unco	onfined compresentation (kP	essive a)
	Dry	Period of s 4 hours	ubmersion 4 days
PVAc homopolymer	1 393	74	40
PVAc: MMA-2EHA blend (80:20)	1 106	62	D
Styrene-BA copolymer (Daxad stabilized)	1 484	451	226

Although the sand cores bound with the Daxed stabilized copolymer also fall off dramatically after soaking, the improvement over the PVAc seemed sufficient justification to pursue this evenue.

D. OPTIMISING THE PERFORMANCE OF A

LOCATING COPOLYMER SYSTEM

In Chapter IV it was seen that the bond strengths imparted by the natural gum stabilized PVAc homopolymer were increased substantially by reducing the level of stabilizer present during polymerisation. It was possible that the same im-

Reducing the level of stabilizer

1a. Materials

a condumer of sturene and 2FH2 at a matte of 55.45 use

polymerised with 8,2g of Daxed 15 (as received) per 100g of total monomer. The polymerisation was then repeated but with only 83%, 73%, 67%, 50%, 25% and 10% of the stabilizer present. The same graded marine sand as before was used.

1b. Experimental procedure

The minor variations in solids contents of these dispersions were determined (120C for 3 hours). Water was then added to each dispersion in sufficient quantities to give a final weight of 70g, containing a constant 5g of polymer. This 70g of liquid was then mixed by hand into 1 000g of sand and compressed into the unconfined compressive strength moulds as before. It was noted that the system containing 10% of stabilizer coagulated on mixing with the sand. The moulds were dried under the IR lamps overnight and then the unsupported cores dried in an oven at 55C for 48 hours. Two cores from each series were soaked in water for 4 hours and then all cores were subjected to the unconfined compressive strength test.

1c. Results and discussion

The unconfined compressive strengths of dry cores and cores after submersions for 4 hours were as follows:

3

Table 23

- 135-

The effect of different levels of a lower alkyl napthelene sulphonic acid salt stabilizer on the ability of a styrene-2EHA copolymer dispersion to bond sand (Means of 2 determinations)

	Uncon	fined	compre	esive	streng	ths (k	Pa)		
14.	Level of stabilizer present during polymersiation								
C. S. Company	100%	8375	73%	67%	50%	25%	10%		
Tested dry	1346	1206	1328	1431	1516	1097	258		
Tested after 4 hours submersion	442	497	554	664	545	5 16	65		

There is no significant increase in the bonding strength imparted by the dispersion as the level of stabilizer decreases. This result questions the theory put forward in Chapter IV that the ability of low levels of a polymer dispersion to bond sand is due to partial, controlled applomeration of the particles. However, the high surface tension (56 dynes/cm) of the copolymer dispersion containing the highest level of Daxad compared to a value of 52 dyne/cm for the PVAc homopolymer, indicates that it may be a less effective stabilizer than the ratural gum. Perhaps even at this highest Daxed level a proportion of the polymer particles are aggregating due to the stearic forces, but further applomeration is prevented by the electrostatic influences present. Another significant espect is that. although the Daxad stabilized dispersion has a low average particle size of 0,3 µm, the test results indicate that there is a very wide distribution of sizes. The presence of a few large particles would also assist in blocking the exits from pore spaces, thereby cousing a build-up of polymer at these

points. Inspection of the particles with an electron microscope should confirm the presence and size of any very large particles.

2. Varying the hardness of the film

By increasing the level of styrene relative to 2EMA in a copolymer, the resulting films will become more brittle. Because the flexibility of the polymer bunds between sand grains is likely to effect their load bearing properties, a number of dispersions using 8,2g of Daxed per 100 dry polymer were prepared in which the ratios of styrene to 2EMA were varied. These dispersions were used in the normal way to form sand cores and unconfined compressive strength measurements were conducted on them.

Table 24

The effect of hardness of polymers in Daxad stabilized dispersions on the unconfined compressive strengths of sand cores bound by them. Polymer levels at 0,5% dry polymer on a dry sand basis (Means of 2 determinations)

Monomer ratios Styrene:2EHA		mft C	Unconfined compressive strengths (kPa)				
			Dry	4 hours submerged			
47	: 53	7	387	161			
49	: 51	17	581	290			
55	: 45	23	1355	451			
65	: 35	34	1572	506			
75	: 25	40	1274	431			
PVAc	homopolymer	18	1128	> 97			

-135-

It is interesting to note that as the styrene content is reduced from 55 parts to 49 parts there is a dramatic decreate in the ability of the treated sand cores to support load. A styrene level of 65 parts appears optimum and. presumably, et 75 parts the file is too hard and cannot be properly integrated, even in the oven at 55C. Thus, although in practice a hard film is desirable (notwithstanding the Marshall flow requirements) because of the better load bearing properties it imperts to sund, it cannot be so hard that it fails to form a film at ambient temperatures. A compromise whereby the particles are temporarily softened during the drying period is possible by the addition of a coalescing solvent. The evaporation rate of such a solvent should be slightly slower then that of water, so that it is not lost before the film dries out; but equally it should not remain too long, thus giving weak wand appregates. An investigation into the properties of several coalescing agents in the styrene-2EHA copplymer are described in Appendix 15. Oxitol acetate seems a suitable solvent as it evaporates 10% more slowly than water and at 8 parts by weight (as received) with 100 parts dry polymer it reduces the mft of the 55 parts styrene copolymer from 230 to 80. The unconfined compressive strengths of sand cores treated with this material at 0,5% polymer on dry sand basis were 1237 kPa after 21 days at embient temperature, whereas cores containing some other slower evaporating solvents only reached 735 kPs.

Because the laboratory results were sufficiently encouraging a trial section of road was laid down.

- 137-

E. PRACTICAL DESERVATIONAL TRIALS

1. A complete road on a sandy soil

In July 1977 a test road was put down in conjunction with the Roads Research Division of the South African Council for Scientific and Industrial Research (C.S.I.R.) at their test site in Pretoria. The requirements for this trial were slightly different to the application first envisaged as it was for a complete road and not just the base. However, another trial specifically for a base layer on marine sand is referred to in subsection 2.

1a. Materials

۰.

A 40 x 10 x 0,5 metre trench was rotovated in red "Kalahari sand". The clay content of this soil was 1%. The styrene-2EHA copolymer at monomer ratios of 55:45 and a Daxed level of 8,2% on dry polymer basis was the dispersion selected. No coalescing solvent was added as the high mft (23C) of this polymer dispersion had not yet been appreciated.

1b. Experimental procedure

The optimum moisture content for compaction of the soil was determined by the C.S.I.R. laboratories and the required amount of water was applied to the soil from a tanker borne spray bar. Three passes with a rotovator were made to thoroughly mix in the water. The whole area was then compacted with a heavy roller.

The following day the length of the test strip was divided into

- 138-

4 x 10m sections. The while area was rotovated to a depth of 2,5cm to reduce run off of the subsequently applied polymer. 720 kg of the 50% solids content polymer dispersion were poured into the tanker and a further 720 kg of water was added. The tanker was then driven backwards and forwards for a short time with the recirculation pump operating to ensure good mixing. Half the material was evenly applied over the 400m test area from the spray bar of the tanker (see Plate 41). This was then rotovated into the soil accurately to depths of 2,5cm, 5,0cm, 7,5cm and 10cm respectively for the 4 x 10m lengths demarkated (see Plate 42). The second half of the diluted polymer was next applied and rotovated in as before. A third rotovation was carried out to the same differential depths as the previous two.

Thus 3,5 kg/m² of the diluted dispersion containing 1,8 kg dry polymer were applied over the whole 400 m² area. Assuming 1 cubic metre of soil weighs 1 800 kg, then the 2,5cm deep mixture contains 2% of dry polymer on dry sand basis, the 5,0cm depth 1,0%, the 7,5cm depth 0,67% and 10cm depth 0,5% dry polymer. The soil in the 2,5cm and 5,0cm treatments was obviously wet but in the 10cm treatment it was only slightly damp.

It was possible to compact the entire area with a rubber wheeled roller (see Plate 43) immediately, but the 2,5cm area was considered too wet to permit the use of a heavy steelwheeled version (see Plate 44). The test area was therefore left overnight and the next day compacted successfully with the heavy roller. Finally, a grader was used to smooth the whole area.

-139-



Plete 41: The diluted copolymer dispersion being applied on to the soil



<u>Plate 42</u>: A machine rotovating the copolymer dispersion into the soil accurately to the predetermined depths

1



Plate 43: Initial light compaction immediately after rotovation of the polymer dispersion into the soil



Plate 44:

The heavy roller used for final compaction when the treated sand was sufficiently dry Results and discussion

Two weeks after treatment the surfaces had dried to hard aggregated soils indicating that coalescence of the polymer had been achieved (see Plate 45). The 2,5cm deep treatment showed a shrinkage creck in one area due, presumably, to too much liquid being applied per unit mass of soil. The other 3 treatments showed no such crecks. Light trafficking of the whole area at this stage had no detrimental effects. The surface abrasion resistance of the 2,5cm and 5,0cm deep treatments was obviously better in a subjective test than the two deeper treatments. In later heavy trafficking tests all treated areas performed well, with the 5cm treatment showing up the best.

It is obviously premature to conclude whether the above type of treatments will perform satisfactorily in practice. However, the results are sufficiently encouraging to consider sections being laid down as actual all weather earth roads.

A sub-base on marine sand

The opportunity of putting down a practical road base trial with the Cape Town Municipality arose at Mitchells Plein in the Western Cape. The in situ material was a white sand devoid of clay. The importation and laying down of a 10cm thick layer of crushed stone was the technique currently being used to form a stable base.

In March 1978 the patch of an intended road was excavated and levelled. The same polymer dispersion as described in subsection 1 above was used. It was dilited to 18% solids and

- 142-



Plate 46: Polymer dispersion being applied to form a sub-base on marine sand. Note the depth of excevation below surface level 10 1/m² was rotovated into the pand to a depth of 10cm. The area was compacted and graded as described in the previous triml. Plate 46 shows the copolymer being applied.

Three weeks after treatment the base had still not dried out sufficiently to give the desired load bearing properties. Because the construction programme could not be delayed, the area had to be ploughed out and replaced by crushed stone. In retrospect a very dry mixture should have been used, as uneven polymer distribution can be overcome more easily than slow drying of the sand.

GENERAL CONCLUSIONS

The slow drying rates of soils bound with polymer dispersion seems to be the main factor that will prevent them from finding general load bearing applications. The more arid and remote the areas of construction, the more likely is the system to find appeal.

In areas of normal evaporation rates it would seem that on soils containing some clay there is a greater chance of successful applications than on sands. This is because the cohesive nature of such soils, when compacted, can temporarily support load until the dispersion dries out. Perhaps the polymer dispersions will fill the need in the road building industry for a satisfactory bunding material to operate in soils of between 5% and 42% clay. On true sand it seems basic changes in the systems used to build roads will have to be made if polymer dispersions are to find application. For example, instead of the road being suck into the sund (see Plate 46), a built up system such as is used on railway lines would facilitate drying. In most areas the incentive to make such changes does not seem to exist at this stage.

The other defect of the system is that of the bound sand softening in water, but it appears to be possible to overcome this within the scope of technology. This may require a two part operation such as post impregnation of sand aggregates with bitumen. Apart from road base applications, it seems feasible that soil bound with polymer dispersion could also be used for building purposes in brick or slab form. Providing the material is able to maintain high load bearing properties under all conditions, it could be of considerable interest for use in low cost housing projects. Again, the more remote the building site is from the factories manufacturing conventional building units, the more appealing the polymer bound soil bricks will become.

- 145-

CHAPTER VIII

MOISTURE CONSERVATION

The extremely low cost of imparting the water repellency phenomenon to send as described in Chapter IV, warranted an investigation to find possible applications in agriculture. Recognising that the mechanism of repellency is one of surface tension, the possible benefits to be gained by creating barriers to deflect water, rather than absolutely contain it, were considered.

A. DEFLECTING WATER INTO THE ROOT ZONE

Correct siting of water repellent burriers would ensure that water falling outside the reach of seeds and plant roots could be deflected towards them, thereby increasing effective rainfall. For example, seeds could be planted in the lowest points of furrows or flat dish shaped depressions lined with pre-treated send. The desired effect is clearly demonstrated as, if a drop of water is placed on the rim of the lined depression, it quickly trevels to the bottom of the depression. Without a lining, the drop is immediately absorbed into the surrounding soil and is lost to the seed. As the polymer at these concentrations has no aggregating effect, the lined depressions would need to be filled with ordinary send.

Instead of importing treated sand, it would be easier to treat the soil in situ. Therefore the possibility of making soils, as distinct from sand, water repellent was investigated. If water repellency is to be a useful characteristic, it must be possible to generate it in soil as well as in sand.

ta. Materials

A surfactant stabilized styrene-2EMA copolymer was used with a marine sand, a Clansthal series sand and a heavy black alluvium soil containing 0%, 1% and 40% clay, respectively.

1b. Experimental procedure

The polymer dispersion was diluted with water to 0,2% solids and sufficient of this used to slurry each soil. These were then dried at 55C and gently crushed to remove aggregation. Depressions were made in the soils and 5ml aliquots of water were added.

1c. Results and discussion

While the marine sand showed the expected resistance to penetration by water, the Clansthal sand showed excellent initial water repellency but this was only effective for approximately 15 minutes. The heavy black soil showed no sign of water repellency. However, after increasing the concentration of the slurry medium to 1,0% solids followed by drying and crushing, the black soil then showed water repellency tendencies, but also for only approximately 15 minutes. Concentrations of polymer at 2,0% and 5,0% were then tried, with no improvement over the 4,0% level. It was concluded that while the water repellency effect can be imparted to all soils, the ability to give absolute water holdout is limited to sands devoid of clay. One possibility of this observation is that the clay fractions absorb water and swell, thus disturbing the packing and allowing the water to gradually channel through. Another possibility is that because of the relatively higher surface area exposed in the clay containing soils (due to smaller and less regular shaped particles) it is more difficult for the polymer to coat all grains completely.

2. Field trial with sugar cane

To essess whether water deflected into the planting rows of sugar cane setts would have any beneficial effects on germination, an experiment was conducted on a Clansthal series sand at Mount Edgecombe in July 1975.

2a. Materials

The Clansthal sand had the following composition; clay content 8%, pH in water 8,8, exchangeable K 49ppm, Ca 4150ppm, Mg 45ppm, Na 9ppm and an acid (0,02N H₂SO₄) soluble P content of 94 ppm.

The surfactant stabilized styrene-2EHA copolymer dispersion was used. To obtain water repellant marine sand this

- 11.8-

polymer dispersion was diluted 1 000 times with water before mixing with sand in the ratio of 100 parts sand to 19 parts diluted dispersion on a most basis. This was then spread in a layer approximately 5mm thick and allowed to air dry. After 3 days, when the sand exhibited the water repellency effect, it was transported to the field test site.

2b. Procedure

Four replications of four treatments, each comprising 48m of came row, were laid down. One treatment (a) was a control and the others were:

- (b) furrows sprayed with 5 000 litres per hectare of the styrene-CLHA emulsion containing 0,4% solids, two weeks prior to planting;
- (c) furrows sprayed with 5 000 litres per hectare of the styrene-20HA emulsion containing 0,4% solids, immediately before planting;
- (d) furrows lined with a finm layer of pre-treated marine send.

Treatment (d) is illustrated in Plate 47. Stalk counts, height measurements and yields were carried out both in the plant and the first ration crops.

2c. Results and discussion

The results of this trial are shown in Table 25. The data from a single line trial can only be interpreted tentatively.



A shallow furrow lined with water repellent sand onto which some control soil and then sugar cane setts are placed before covering in Plate 47:

Toble 26

Shopt counts, height measurements and final cane yield of sugar cone in an experiment designed to increase plant evallable

maisture (Planted on 17.7.75). 4 Replications of single line.

			d. 10		Plant crop	1.5.76	0- 10-		
7- 6	Mean sh	oot counts	× 10 ³ per h	ectare	Cane yit d		Mean stal	k heights	in am
In turrow treatments	11/9/75	11/11/75	17/12/75	25/2/76	Harvest 19/9/75 tons/ha	11/11/75	17/12/75	25/2/75	Sticks at Harvest 19/9/76
A. Normal planting % of Control	22 100%	45 100%	153 100%	137 100%	60,2 100%	140 100%	189 100%	586 100%	1 450 100%
8. C.4% solids dispersion and air dried for 2 weeks % of Control	30* 137%	59* 12 <i>3%</i>	194 127%	202 147%	75.2* 125%	16 1•• 115%	232•• 12 <i>3%</i>	682** 116%	1 738 120%
C. 0.4% solids dispersion and planted immediately % of Control	26 118%	66** 138%	204 134%	17 1 125%	71,5 119%	147 105%	2 15 * * 1 14%	703	1 602 11 1%
D. Pretreated marine sand % of Control	33** 149%	59** 123%	192 125%	172 126%	69,7 116%	159• 114%	22 1** 117%	664• 113%	1 65 1 115%
C.V. (%) LSD 5%	25,4 7 10	11,6 7 10	30, 1 59 82	34,2 62 85	17,4 14,6 20,2	8,3 13 18	7,9 16 22	11,4 75 103	15,0 .71 515
					First Ratoon			6.	
	7/10/76	14/12/76	7/2/77		Harvested 8/12/77 Mean of † duplicate results	14/12/76	7/2/77		Harvest 19/9/76
					1.2.1.1		1000		13 APR

			8.115		duplicate results	- 2557/12-	N. BO		
A. % of Control	82 100%	258 100%	182 100%		56,7 100%	249 100%	845 100%		1 650 100%
9. % of Control	115** 140%	308** 119%	203 112%	104	70,3 124%	277	900 107%		1 65 1 100%
C. % of Control	104 ° 12.7%	300• 116%	2 15 119%		61,4 108%	269 108%	942 • • 1 12%		1 788 108%
D. % of Control	103* 125%	300• 116%	204 112%		60,3 106%	277	923 109%	·	1 682 102%
C.V. (%) LSD 5%	17,4 19 25	10,6 32 44	22,3 48 66		13,9 28,1 40,9	10,5 29 40	5,6 53 73		10,1 394 573

Statistically significant at the 5% level
Statistically significant at the 1% level
To eliminate edge effects only the 2 innermost replications of each treatment were harvested

hut the early short and height measurements are considered to be meaningful because at that stage the edge effects must have been minimal. From the time of the earliest short counts the polymer dispersion treated plots showed marked increases in numbers over the control plots. Not only were there more shorts, but they were also consistently taller and, elthough only one treatment gave a statistically significant higher yield at the 5% level, the results indicate that all treatment could be commercially remunerative. For example, the 15 tons/he extra care achieved is worth approximately 190 rand for a polymer dispersion cost of about 40 rand. Furthermore, the improvement in plant crop performance made by the polymer dispersion seems to carry through to the first retoon.

5. REDUCING EVAPORATION BY SURFACE TREATMENTS

The magnitude of the shoot count differences in the above sugar cans experiment seemed more dramatic than could be attributed to the water deflecting effect of the treated soil barriers. The shoot count curves with time are very similar to those reported by Millard (1974) and Rau and Millard (1975) when using clear polyethylene sheet mulch over the sugar cane rows. They also reported early tillering and significant yield increases - as high as 25 ± 3,9 tons cane per hectore. Their conclusions were that the polyethylene sheet mulch prevented moisture loss and increased soil temperature. It was a distinct possibility that the shellow treated barriers may be giving increased shoot counts due to the same effects.

- 152-

Influence of soil type

It was of interest to determine whether or not a layer of water repellent soil had any effect on the movement of water vapour in a soil profile.

1a. Materials

The surfactant stabilized styrene-2EHA copolymer dispersion was again used. An alluvium (41% clay), a Cleveland soil (15% clay), a Clansthal sand (7% clay) and a marine sand (0% clay) were used in this experiment.

1b. Experimental procedure

Six 200g samples of each soil were placed in 280ml plastic containers with surface areas of 42 cm². On the surface of the soil in three out of each set of six pots 10 ml of 1% solids surfactant stabilized styrene-2EHA dispersion was poured, and 10 ml of water was added to the remaining three pots in each set. All cups were then weighed before placing them in a room where the temperature was controlled at 25C and the relative humidity at 50%. The pots were weighed at regular intervals to determine evaporation losses. When constant weight was attained, 30ml of water was added to each pot and the drying procedure was repeated.

1c. Results and discussion

The rates of evaporation of water from the four different soil types are presented in Table 26.

- 153-

Table 26

- 154-

The effects of a surface treatment of 2,38 ℓ/m^2 of a 1,0% solids styrene-2EMA copolymer dispersion on the evaporation rate of soil water (Means of 3 determinations)

				Soil	type				
	A11	uvium	Clev	eland	Clar	sthal	Ma	Marine	
Period @ 25C and 50% RH	Con- trol	Treat- ed	Con- trol	Treat- ed	Con- trol	Treat- ed	Con- trol	Treat- ed	
		Init 10ml	tial dr L of 10	ying out % solids	t (% re s dispe	tention rsion ad	of ided)		
24 hours	61,9	59,6	53,4	51,3	63,4	61,8	63,2	62,8	
48 hours	33,7	33,4	16,8	14,3	35,3	32,2	31,9	35,2	
		Aft. fur	er dryi ther 30	ng at 55 Mil of wi	SC (% r ater ad	etention	n of		
24 hours	53,8	75,8	57,8	88,0	51,0	78,3	52,0	66,7	
48 hours	30,9	73,0	21,0	84,0	22,8	72,5	28,8	57,3	
72 hours	22,B	67,7	14,6	79,3	13,0	66,1	8,6	48,6	
96 hours	17,5	63,0	9,1	74,0	7,5	59,5	4,7	39,6	
168 hours	10,5	52,3	4,2	61,7	2,6	49,7	1,0	23,8	
192 hours	8,7	48,4	2,4	58,0	1,7	41,0	0,4	19,1	
216 hours	6,4	42,8	2,0	52,0	1,4	34,3	0	13,2	
240 hours	5,3	37,8	1,9	46,3	1,6	28,8	D	8,9	
C.V. (%)	7	7,4		11,8	1	12,6	5	9,3	

- The above results show that there were no differences in the rates of evaporation of the original 10g of liquid added to the four soil types. However, even at the first readings, taken 24 hours after the first 30g of water were added, marked reductions in evaporation losses were noted in those soils having received polymer. At 96 hours the percentages of this water remaining in
- the treated and untreated soils were respectively: the

Alluvium, 63% and 18%; the Cleveland series, 74% and 9%; the Clenathel sand, 60% and 8% and the marine sand, 40% and 5%

It was considered very likely that the above measured reduced evaporation rates induced the beneficial effects observed in the sugar care experiment. However, since the similar tillering and greater yield effect induced by clear polyethylene sheet was attributed largely to increases in soil temperature this aspect was gloo investigated.

 The effect of reduced evaporation on soil temperatures

2s. Materials

The styrene-2EHA copolymer dispersion was diluted with water to a solids content of 0,5%. Clansthal sand from the site of the earlier reported field experiment was used.

2b. Experimental procedure

Four 5-litre containers were filled with Clansthal sand and a thermometer was placed in each container so that its bulb was 20nm below the surface of the soil. Surfactant stabilized styrene-2EHA copolymer containing 0,5% solide was dripped on to the surface of the soil in two containers until the soil was just soaked. Equivalent amounts of water were added to the other two containers, and all four were left to dry in the sun. After a week one litre of water was poured on to the soil surface in each container, and temperatures were recorded

- 155-

2c. Results and discussion

The soil temperatures recorded in the two treatments are presented in Table 27.

Table 27

Effect of a surface treatment with a styrene-2CHA copolymer dispersion on wet soil temperatures (Means of 2 determinations)

Date	Time	Controls	Surface polymer treatment
26.10.76	9 a.m. (water added)	23,00	23,0C
26.10.76	3 p.m.	28,0C	31,50**
27.10.76	9 a.m.	21,00	21,50
27.10.76	3 p.m.	28,0C	30,00*
28.10.76	9 a.m.	22,50	23,00
28.10.76	3 p.m.	32,00	34,00*
16.11.76	9 a.m.	30,5C	30,00
15.11.76	3 p.m.	34,00	34,00
c.v. (%) =	3,6; LSD: 5% = 2	,00 1	% = 2,70
· Statis	tically significant at th tically significant at th	e 5% level e 1% level	

Although no significant temperature differences were noted at 9 a.m. each day, at 3 p.m. on 26.10.76 the temperature in the control pots was 28C and in the pots with polymer modified soil on the surface it was 31,5C. When the pots had dried out completely no differences were recorded at either time. The temperature differences arise because the treated soils, which loss less water, are cooled less than the controls, and not because

- 156-

The magnitude of the temperature difference is much less than the 9C advantage reported by Millard (1974) at 4cm depth beneath a clear polyethylene sheet. However, the ability of the polymer dispersion modified soil to "eliminate" the higher temperature effect when surface soil moisture becomes limiting could be an edvantage over polyethylene sheeting.

Secause water follows the line of least resistance the treated surface layer will remain relatively dry compared to the bulk of ordinary soil beneath it. This is readily illustrated if water is applied to a 2cm layer of treated sand overlying ordinary sand in a glass beaker. Only at the sand - glass interface does water percolate through while the treated layer of sand remains dry. Thin layers of hydrophobic soil, as in the above experiment, will likewise be dryer than the surrounding soil and will form a mulch. This mulch is remarkably effective in reducing the evaporation of soil water. Because of this reduced evaporation the plant available moisture contents and surface soil temperatures will be higher relative to control soils. Such conditions are beneficial to seed germination and plant growth. Because theory implies that only those dispersions imparting the water repellency effect to soils will reduce evaporation, a laboratory test was conducted to check this supposition.

The effect of polymer dispersion type on evaporation rate

3a. Materials

The same group of polymer dispersions used in Chapter III and

- 157-

described in Appendix 1 were chosen for study. The ability of these dispersions to impart the water repellency effect to sand is shown in Table 8 on page 48. This table reveals that only the PVAc homopolymers showed very little water repellency compared to the other grades. The Clansthal sand was again used.

3b. Experimental procedure

Twenty-four 200g samples of Clansthal sand were placed in 280ml plastic containers. Gml of the different polymer dispersions at % solids concentrations were poured onto the surface of the soil in 3 sets of pots (Table 28). The pots were dried overnight at 55C and weighed before pouring 30g of water into them. The pots were kept at 25C and 50% RH and weighed daily to determine evaporation losses. The results of these weighings are presented in Table 28.

3c. Results and discussion

All those dispersions which were previously shown to impart the water repellent effect to sand have a retarding effect on the evaporation of water from treated soil. In contrast, the PVAc homopolymer actually increases the rate of water loss. An experiment to assess the water uptakes of sand briquettes bound with increasing quantities of the PVAc homopolymer is reported on in Appendix 25. The results of this experiment show that those briquettes which received the polymer dispersion at a concentration of 1% solids held considerably more water (29%) than did the control sand. This is in complete contrast to the water holdout effect imparted to send by the copolymer dispersion (Table 8 page

Table 28

The effect of surface treatments with different dispersions at 7% solids on the evaporation rates of water from a Clansthal sand (means of 3 determinations)

Period @	Polymer type													
25C and 50% RH	Control	PVAc homo	PVAC- 2EHA	PVAc- VeoVa	Styrene 2EHA	MMA- 2EHA	SBR carb	SBR uncarb	C.V. (%)	LS 5%	10 1%			
	%	retent. 1	ion of 3 nitial p	Oml of w olymer c	ater added	(after liquid)	drying							
24 hours	53,7	37,4	73,6	57,3	70,1	71,5	70,1	68,9	7,7	8,3	11,4			
48 hours	35,8	28,5	66,4	47,B	61,9	64,1	61,1	58,4	8,6	7,8	11.7			
72 hours	22,0	20,9	59,0	37,3	52,7	54,7	52,3	48,3	9,9	7,5	10,2			
95 hours	15,2	15,2	51,9	28,5	45,2	47,0	46,5	38,5	13,7	8,6	11,7			
120 hours	10,1	11,8	45,4	22,4	37,7	39,3	35,9	28,4	15,7	8,0	10,9			
192 hours	4,7	5,7	27,5	9,9	17.7	21,1	15,1	10,5	22,9	6,0	8,1			
215 hours	3,7	4,4	24,1	7.1	12,9	15,8	11, 1	7,8	23,6	4,7	6,3			
240 hours	4,4	3,3	17,0	6,4	10,5	13, 1	9,4	7,4	21,4	3,7	5,1			

159-

colloid stabilizer (See page 9).

This again emphasises the differences in properties imparted to soils by the two broad groups of polymer dispersions. For example, in Experiment 3 above, the dry surface layer of copolymer treated soil present after water application reduced evaporation as it terminated the capillary channels before they reached the atmosphere. In contrast, the homopolymer treated surface soil probably prolonged evaporation as it remained damp longer than the control soil because of the hydrophilic attraction and the uninterrupted supply of capillary water from the underlying soil, functioning like a wick. If this is occurring in practice it is no wonder that the hydroseeders in South Africa have become disillusioned with this type of dispersion. Appendix 26 illustrates how the rates of infiltration into, and evaporation from, sands can be accurately controlled by pre-treating the sand with blends of the two different dispersion types.

- 160-

It is not known why the PVAC-VeoVa copolymer was less efficient than the other copolymers in reducing evaporation (at shown in Table 28).

The styrene-2EMA copolymer is one of the most effective dispersions in reducing eveporation from soils. It was therefore selected for use in a number of pot and field experiments to test plant responses.

4. Pot experiments to test plant responses

To investigate the effect of the observed reduction in evaporation on plant yields a pot experiment with² maize was
Marine sand and the same surfactant stabilized styrene-2EHA copolymer as before were used.

4b. Experimental procedure

Eight x 5 litre plastic buckets were each filled with 8kg of marine sand. A glass tube was placed in the centre of the loose sand. Four maize seeds were planted into each bucket and a fertilizer mixture containing 0,55g N, 0,37g P and 0,19g K was worked into the sand.

Just enough of a 0,2% solids styrene-2EHA copolymer was added to wet the sand on the surface of four of the buckets.

The remaining four buckets were used as controls.

The buckets were put in the sun and when the polymer treated sand was dry exactly two litres of water were added to each bucket via the glass tube. The buckets were sat aside and received no further treatment.

4c. Results and discussion

The plants in the control pots wilted four days before the plants in the polymer treated ones. This was some four weeks after the start of the experiment. When all the plants were obviously dead they were harvested, dried and weighed. The dry matter yields are presented in Table 29.

- 15 1-

Table 29

The effect of a surface treatment of 0,2% solids styrene-2EHA dispersion on the dry matter yield of maize produced from 21 of water.

	Dry	Means			
Treatments					
1. Control	5,4	5,0	7,4	5,6	4,9
2. 0,2% solids styrene- 2EHA dispersion	7,3	8,1	8,7	6,9	7,8*
Percent increase of treat- ment 2 over treatment 1	35%	62%	18%	23%	32%
C.V. (%) = 8,9; LSD	5% =	2,0		1% = 3	2,9
· Statistically significant	t at t	he 5% :	level		

The polymer treatment increased dry matter yield by 32%. The effects of reduced evaporation therefore seem capable of increasing available water and thus plant yields. Replicated field triels were laid down to investigate this phenomenon further.

C. FIELD TRIALS WITH SUGAR CANE

From the results presented above, it would seem that surface treatments might be just as effective in inducing earlier tillering and increased yields in sugar cane as the infurrow treatments were. A field trial comparing an infurrow application with a complete surface cover treatment and an over row only treatment was conducted.

- 162-

1. The positioning of hydrophobic berriers

The major time of planting in the South African Sugar Industry is in the wet summer months between October and March. Frequently this period has to be extended but, as rainfall in the ensuing months is erratic, germination is often poor due to dehydration of the plant material. The effects of different placements of the copolymer dispersion on moisture conservation were compared with the more conventional practice of applying heavy dressings of filter press cake to prevent dehydration. Filter cake is a by-product of the sugar mills and consists largely of water, organic matter, mud and low levels of plant nutrients, especially P.

1a. Materials

The field site was on a Clansthal sand adjacent to the previously reported single line trial at the Central Field Station of the South African Sugar Association. The analysis of the aoil is on page 148. The surfactant stabilized styrene-2EHA copolymer dispersion was again used and the filter cake employed was the normal product from the Natal Estates Mill.

1b. Experimental procedure

Five replications of a randomised block design experiment were laid down in conjunction with the South African Sugar Association in May 1976 following good rains a few days previously. The layout of the plots, fertilizer and soil fumigent (Temik) treatments and the statistical analysis

- 163-

of the results are given in Appendix 16. The soil fumigant was included to ensure that nematodes did not retard the development of the crop.

The six treatments applied were as follows:

- A. Control + Temik.
- 8. 40 tons/ha of filter cake in the planting furrow + Temik.
- C. 40 tons/he of filter cake in the planting furrow without Temik.
- D. 4,4 tons/ha of styrene-2EHA, containing 0,75% solids, sprayed in a band 30cm wide over the cane row and lightly compacted by trampling. Equivalent to 1,9 l/m² over row (see Plate 48).
- E. 3,5 tons/ha of styrene-2EHA, containing 0,75% solids, sprayed over the complete plot without any compaction. Equivalent to 0,35 £/m² (see Plate 49).
- F. 4,4 tons/ha of styrene-2EHA, containing 0,75% solids, sprayed in the furrow before planting, compacted and planted while wet.

The climatic conditions prevailing for the period of the experiment are given in Appendix 17.

All treatments were shellow planted with a view to obtaining increased soil temperature. It was hoped that the moisture conserving treatments would prevent dehydration. No rein fell until mid September, which subjected the planting material and young shoots to extreme dehydration.

- 164-



- 165-

The application of an over-row treatment of 4 400 £ of 0,75% solids copolymer Plate 48: dispersion



3

Plate 49: The application of a complete surface treatment of 3 500 £ of 0,75% solids copolymer dispersion

1c. Results and discussion

The shoot counts, height measurements and final yields at 16 months are recorded in Table 30. Table 31 summarises the sugar concentrations in the stalks and total sugar yields per hectare per annum relative to 100mm of rainfall. The results in Table 30 confirm the earlier tillering and increased yields of the previously reported single line experiment. In fact, Tables 30 and 31 indicate four different beneficial effects with the surface polymer treatments. These and their magnitude relative to the control treatment for the row only and for the overall polymer treatments respectively, were as follows:

- (i) earlier tillering; 22% and 15% more shoots at three months;
- (ii) more sticks at harvest; 5, % or 6 000/hs and 3,5%
 or 4 000/hs;
- (iii) greater cane yields; 12,6% or 12 tons/ha and 4,2% or 4 tons/ha;
- (1v) more estimated recoverable sugar (ERS) % cane; 2,7% and 1,3%.

Although the last three listed advantages failed individually to be statistically significant, their cumulative effect on additional sugar production (16,2% or 2,3 tons/ha) failed only by 0,1 tons/ha to achieve the 5% level, where applied only over the row. In the overall treatment the extra yield of sugar was less (6,3% or 0,9 tons/ha). The larger responses to the over-row only treatment relative to the overall spray, while not statistically significant, are remarkably consistent. These better responses are due to a greater volume

- 166-

- 167--

Table 30

Mean shoot crunts and reight intocomments with time of shallow planted sugar care with verlous anti-dehydration treatments (Means of 5 replications)

17

14

141

			Shoot counts per hectare \times 10 ³					Hei men	Vield		
Treatmente	1975			1977 At harvest	1976	1977	At Narvest	tona cane per hectare			
		25/B	97/9	7/12	8/12	19/1	14/9/77	6/ 12	19/1	16/9/77	14/9/77
84	Pohitol - Tertk L of Conitol	39 100)	60 100),	94 100).	242	198	5 15 100%	37	89	190 100/	95 103).
8.	Filter cake at 40 tons/ha + Temik 5 of Control	19**	30** 50),	50** 78,	188** 79;:	172 67,	110 95).	33** 83).	84 95%	194 10251	97 102)
с.	Filter cake at 40 tons/ha no Temik 5 of Scrippl	49* • 49)	38** 63,	6 8** 72,	173** 72/,	405 84/2	111 985	35 93),	88 29	179 949-	96. 96
٥.	Surface row only polymer - Temik	37 957.	73	13011 139,	282**	209 104/2	122 105%	41-	97 - 109;	793 102;1	107 1135
ε.	Surfece complete cover polymer - Temik % of Control	44 105).	69* 115%	13 1** 139,2	272	196 99),	120 1045	42**	58 1100	190 100)0	99 104/2
F.	Polymer in four at planting - Temik) of Canton	36 97);	60 100%	103 110/2	2.16 89),	181 91,	144 937	36 969	85 96%	192 101),	95 100;1
ε.ν	• (1) 10 10 10 10 10 10 10 10 10 10 10 10 10	12,8 5	13,4 8 11	14,8 16 22	15,5 35 47	13 P 58	9,8 9 12	9,2 3 4	7,4 6 8	5,8 1% 70	14.2 14.4 19.7

5% level of eignificance
 1% level of significance

Table 31

1000

Estimated recoverable sugar % cane (ERS %), tons ERS per hectare and tons ERS per 100mm of rainfall

in a sugar cane experiment designed to conserve soil moisture (Means of 5 replicates)

- 168-

	Treatments	tc/ha	ERS% cane	ters /hs	tc/he /ennum	ters/hs /ennum	tc/100mm reinfell	ters/ 1DDmm rainfell
А.	Control + Temik % of Control	95 100%	14,9 100%	14,2 100/-	70 100%	10,4 100%	8,74 100,	1,31 100,
в.	Filter cake at 40 tons/ha • Temik % of Control	97 102%	14,9 100)	14,5 102%	71 101%	10,7 103%	8,93 102%	1, 33 102%
с.	Filter cake at 40 tons/ha - Temik % of Control	91 96%	14,6 98%	13,3 94%	67 96%	9,8 94%	8,37 96%	1,22 93%
D.	Surface row only polymer + Temik % of Control	107 113%	15,3 103%	16,5 116%	79 113%	12,1 116%	9,84 113%	1,52 116%
٤.	Surface complete cover polymer + Temik % of Control	99 104%	15,1 101%	15,1 106%	73 104%	11, 1 107,0	9.11 104%	1,39 106%
F.	Polymer in row at planting + Temik % of Control	95 100,0	14,9 100/2	14,2	70 100%	10,4 100,0	8,74 100%	1,31 100%
C.V LSD	. (%) 5%	11,2 14,4 19,7	2,9 0,58 0,79	12,5 2,42 3,30			10 2 S	

8. Fe

the destruction of the treated barrier in the interows by mechanical weeding.

The linear correlations between amounts of copolymer applied and, firstly, moisture conserved (Appendix 20) and, secondly, tons of cane produced (Table 33), are affirmed later. Further evidence of higher sugar concentrations (10,2% more ERS % cane) where a copolymer mulch is applied is given in Appendix 28.

It is difficult to explain why the in furrow treatment, unlike the previous trial at the same site, did not show earlier tillering. The main difference between the treatments here and the wet treatments used in the single line trial was that, firstly, the wet treated soil was compacted and, secondly, the setts were shallow planted. These two operations would have resulted in a hard, impervious layer forming under the setts in the prolonged dry spell which must have restricted the penetration of roots down to moister areas.

The dramatic detrimental effect of the filter cake on tillering is noted. Perhaps this was due to its provision of a localised area of high moisture content early in the experiment. The roots of plants in this treatment therefore may have been restricted and, when the filter cake dried out, they would not have found adequate water to sustain top growth.

Comparing the shoot populations with the age of the crop, this experiment differs from the previous field experiment (page 151) in that it showed little increase in tillering rate in the first three months. However, in the fourth month, September, soon after the first spring rains had

- 169-

fallen, a significant increase in the number of shoots in the row-only treatment occurred. At a later stege this also happened in the complete-cover polymer treatment. In addition to the first light rain falling in September, it is also noted from Appendix 17 that the average soil temperatures increased from 17,6C in August to 20,6C in September. These results are in keeping with the work on sugar cane of Ruker and Edgerton (1931) who showed that below 21C minimum growth occurs. The slight soil temperature enhancing effect of the copolymer dispersion may well have enabled this critical temperature to be exceeded, thereby initiating earlier active growth. In summer the soil temperatures could fall below 21C in wet, sunless conditions. This would explain why the earlier tillering effect is even observed in epring planted cane (Table 33).

The effects of the earlier tillering on shoot populations for the duration of the experiment in Table 30 are presented graphically in Figure 4. It is seen that the increased numbers relative to control reached a maximum of 39% in October. However, as with the polyethylene sheet mulch work of Millard (1974) (on other than sandy soils) the difference had virtually disappeered by January. The extra stalks in the surface polymer treatments at harvest were therefore surprising. This re-appearance of extra stalks may be the result of an inaccurate January count, but it is considered more likely to be an indication that the plants in these plots were enjoying a better moisture status. Such extra moisture may continue to be coming from the hydrophobic layer or from a better root system of the earlier developed plants, or both. Rau and Millard (1975) showed in root excevation

-170-



Stalk populations with time of sugar cane grown with and w put on over row only spray of 0,75% solids styrent-20MA co

- 172-

on other soils.

The reproducibility of the earlier tillering effect at different sites

The spraying of polymer bands over the rows of cane was considered to be the easiest and most economical method of treatment.

2a. Materials

Nine sites were selected throughout the Natel sugar industry. They differed in soil type, cane variety, altitude, climatic conditions and time of planting. Descriptions of these sites are presented in Table 32. The styrene-2EHA copolymer dispersion was egain used.

2b. Experimental procedure

The general procedure followed was to mark out eight plots each consisting of 8 metres x 6 rows of newly planted commercial cane. Four randomly selected plots received 2 000 %/ha of polymer emulsion at 0,5% solids (10kg dry polymer per ha) sprayed in a band 30cm wide over the row. The other four plots were left as controls and shoot counts were taken regularly. It was only possible to obtain yield date at 3 of the 9 sites (See Table 32). The shoot counts at different times at the various sites and the final came yields at 3 of them, are presented in Table 32.

- 172-

(i) Earlier tillering

Although a meaningful statistical assessment is limited by the high veriability and low number of plots, it is noted that at only one of the nine sites did the polymer treatments fail to induce earlier tillering. This was at Site No. 9, and the reason for this is unknown.

Time of application seems to influence the rate of new shoot development. For example, whereas newly planted fields treated in March (Site No's 1 and 2) showed the earlier tillering effect 9 weeks after treatment, the replicated experiment (Table 30) treated in May, only showed the effect after 18 weeks. These results indicate that the flush of extra shoots can only occur if environmental conditions are suitable and the crop has reached a certain stage of development. To achieve maximum yield benefit, therefore, time of treatment is important in order for the crop to make maximum use of the moisture conserving effect. In the South African Euger Industry this optimum time of application would be in spring or summer. This would ensure that the flush of new shoots, and roots (as illustrated by Millard (1974) in root excavation work), has occurred before the erratic rainfalls of autumn and the winter droughts, commence.

5

Table 32

1

-MAP->

Shoot counts of control end styrene-ZEMA copolyter treated plets with time at nine different sites. Mare available final cane yield data are included (Maans of 4 replicates)

Site No.	Location - Description	Dete	No of shoots/ha x 103		Control			L	50
			Control	Sprayed	No/ha x 103	9ó	C.V. (%)	5%	1
1 Seven Willi Flat	Seven Daks Williamson seties - Flat area	Spreyed 24/3/77 Counted 2/6/77 Counted 20/12/77 At hervest 30/10/78	30 239 109	43 273 116	13** 34 7*	46 14 6	5,7 12,8 9,0	4 59 6	E BC
				tone cone/	'ha				1
		Vield results	30,8	104.6	13,8*	15	6,8	11	16
2	Seven Caks Shortlands series - North Slope	Sprayed 24/3/77 Counted 2/6/77 Counted 20/12/77 At harvest	66 169 105	79 2.18 106	13 49 1	20 29 1	17,4 28,1 23,6	22 77 41	29 104 59
				tons cane/	'he				
		Yield results	108,6	105,0	-3,6	-3	27,3	48	70
3 N. In N	Napumulo Inanda series - N:Co 376	Sprayed 1/4/77 Counted 2/6/77 Counted 21/9/77 At harvest	32 62 88	45 85 87	13 26• - 1	40 42 1	17,6 13,3 15,5	14 21 20	19 38 26
			tons cane/ha						
		Vield results	66,7	69,2	2,5	4	25.4	28	38
la .	Braemar Cartref series - Cartref form N:Co 376 East Slope	Sprayed 7/4/77 Counted 21/5/77 Counted 6/7/77 Site ploughed out	17 38	24 51	7 13	41 34	21,3 17,2	9 18	12 24
5	Glendale Glendale series - Shortlands form N:Co 310 North Slope	Sprayed 17/5/77 Counted 2/6/77 Counted 25/9/77 Vandals removed pegs	32 74	45 103	13* 29	41 39	13,2 24,6	11 35	14 52
5	Sezela (Equeffa) Milkwood maries - Cansland form N:Co 376 South	Sprayed 22/8/77 Counted 15/11/77 Counted 20/12/77 Vendels removed pegs	155 236	232 255	77** 19	50 8	20,0 22,2	27 75	36 102
,	Serela (Beneva) Milkwood series - Densland form N 52/219 Flat	Sprayed 22/8/77 Counted 15/11/77 Counted 20/12/77 Field harvested without notification	114 179	154 234	50• 55*	44 31	18,4 10,4	44 45	55
1	Sezela (lfafa) Dundes series - Alluvium N:Co 376 Flat	Sprayed 22/8/77 Counted 15/11/77 Counted 20/12/77 Vendels removed pegs	88 220	109 249	21 29	24 13	20,2 4,3	30 18	42 25
2	Sezela (Equeffa) Milkunod series - Dansland form N:Co 376 South Steep	Sprayed 25/6/77 Counted 15/11/77 Counted 22/2/77 Field harvested without notification	103 206	104 203	1 -5	1 -3	7,7 17,3	16 73	22 98

Statistically significant at the 50 level
 Statistically significant at the 40 level

(ii) Cane yields and final stalk populations

Earlier tillering is not synonymous with increased final stalk populations or greater cane yields at harvest. Although at all three sites harvested, earlier tillering was induced by treatment, only at Site No. 1 did statistically significant increases in stalk populations (17 DDD/ha or 7%) and cane yields (13,8 tons or 15,0%) result. Lack of yield response at the other two sites is attributed primarily to the low concentration (0,5% solids) of copolymer applied and the high variability of the yield data. The low concentration and low total amount of copolymer applied per hectare was used because of the good responses obtained from treatment on Clansthal sands and because Rau and Millard (1975) obtained best responses on high clay content soils (through earlier tillering with polyethylene sheet). However, the detrimental effect of increasing clay content on the ability of low concentrations of copolymer to impart the hydrophobic effect to soils (page 148), was overlooked. The need for the copolymer concentration to exceed 1% solids if both earlier tillering and increased yield are desired, is illustrated in the next sub-section (Table 33).

Secondary factors which may have contributed to the poor yield responses to treatment at Site No's 3 and 2 were the presence of some unidentified growth retarding factor at the former (yields only 67 tons/ha), and severe lodging of the cane at the latter. (Lodging is the falling over of cane due to its inability to support its own weight and is indicative of an over mature crop). Since the initial numerical advantage of copolymer dispersion treatment

- 175-

declines with time, the physiological age of the crop at hervest must influence the degree of yield response.

-176-

3. Reducing the volume of carrier water

The application of dispersions to soils would be much more acceptable in practice if the volume of carrier water could be substantially reduced. Laboratory tests showed (Appendix 20) that the magnitude of reduction in evaporation was directly related to the amount of polymer dispersion applied. These results showed that although a high volume of low concentration polymer gives a more consistent conservation, the same effect can be achieved by using lower volumes at higher concentrations. With the low volumes of liquid it is importent to have efficient spray nozzles. A field experiment to access the effects of using lower volumes of carrier water was therefore laid down.

3a. Materiels

The surfactant stabilized styrene-2EHA copolymer dispersion was again used. The soil was of the Datadale series (35% clay).

3b. Experimental procedure

² randomised block field experiment was marked out on a field of commercial cane at Eston. Details of plot layouts, sizes and statistical analyses of results are given in Appendix 21. Four replications of each of the following treatments were applied on the 14/10/77. All polymer treatments were apray applied in a band 30 cm wide over the row.

- Control no treatment
- 8. 1 500 L/he of the styrene-2EHA disperion at 0,5% salids (7,5 kg/ha dry or 2,5 g/m² over row)
- C. 1 000 L/ha of dispersion at 0,5% solids (5 kg/ha dry or 1,7 g/m² over row)
- D. 1 000 1/he of dispersion at 0,75% solids (7,5 kg/ha dry or 2.5 g/m² over row)
- E. 1 000 L/he of dispersion at 1% solids (10 kg/ha dry or 3.3 g/m² over row)
- F. 500 t/he of dispersion at 12 solids (5 kg/he dry or 1.7 g/m² over row)
- G. 500 1/hs of dispersion at 2% solids (10 kg/hs dry or 3,3 g/m² over row)

Shoot counts were taken regularly and final cane yields on the 8/12/78 were recorded.

3c. Results and discussion

The shoot counts taken 2 and 3 months after treatment, stick counts at harvest and final cane yields are presented in Table 33.

Earlier tillering can be achieved with very low concentrations, and very low total weights (5 kg/ha dry) of the copolymer dispersion. These results illustrate the remarkable efficiency of the copolymer dispersion and, while other chemicals such an herbicides, mematicides and ripeners, for example, may also produce dramatic effects at such low rates, their mechanisms are chemical. In contrast, the increased productivity of the soil by modification with copolymer is considered to be

Table 33

6

The effects of various rates and concentrations of over row polymer dispersion sprays on shoot populations and final came yields (Means of 4 replications)

	Trestmante	Shoot e	munts x 1	Vield (tons cane/ha)	
	1169 calerica	14/12/77	27/1/78	8/12/78	8/ 12/78
А.	Control % of Control	104	144	114	94,6 100
8.	1 500 l/ha at D,5% solids (7,5 kg/ha dry) % of Control	103 99	175**	116 102	97,3 103
с.	1 000 f/ha at 0,5% solids (5,0 kg/ha dry) % of Control	108	178**	110 97	91, 1 96
D.	1 000 t/ha of 0,75% solide (7,5 kg/ha dry) % of Control	103 99	156* 108	119	101.4
ε.	1 000 1/ha at 1,0% solids (10 kg/he dry) % of Control	12 1* 1 16	175**	12 7 111	107,5
F.	500 2/ha at 1,0% solids (5 kg/ha dry) % of Control	112 108	172** 119	123 108	103,4 109
G.	500 f/ha at 2,0% solids (10 kg/ha dry) % of Control	109 105	129	115 102	92,7 98
C.V.	. (%)	15,6	6,8	9,3	7,8
	5%	17	12	15	11,2
	106	24	16	22	15,2

Statistically significant at the 5% level

For the beneficial effects of the modified soil barrier to persist through to harvest, the level of copolymer must be higher (10 kg/hs dry) and the barrier as continuous as possible. For example, only Treatment E in Table 33 resulted in a statistical increase in cane yield over control. Although 10 kg/ha of dry copolymer were also applied in Treatment G, it is believed that the 480 1/ha of carrier water applied with it was inadequate to completely wet the soil surface. At the 7,5 kg/hs copolymer levels the better response of Treatment D over Treatment B, although not statistically significant, is indicative of a more effective coating of soil grains by the higher polymer concentration. The linear correlations between amount of copolymer applied and, firstly, stalk population at harvest and, secondly, cane yield, are illustrated by comparing the results of Treatments C, D and E, where a constant 1 000 1/ha of product was applied. These results are illustrated in Figures 5 and 6. Although the 12,9 ton/ha cane yield increase (worth approximately 160 rand) from the 10 kg/ha copolymer applied (costing approximately 20 rend) is economically very satisfactory, much greater profitability can be expected with higher levels of copolymer. Further field experiments using higher amounts of copolymer with a minimum of 1 000 1/ha of water, applied over the row, will indicate the optimum level.

4. Scaling up to practical applications

The main disadvantage of polymer dispersion application arises from the necessity to handle large volumes of liquid in the field. To investigate the feasibility of full scale applications, a section of field on a Clansthal sand at Umdloti was treated on 30/8/77, using conventional farm implements.

- 179-





4a. Materiels

The surfectant stabilized styrene-2EHA copolymer dispersion was again used. A 400 % herbicide unit was mounted on the back of a tractor and two outlets fitted with 45° angle spray nozzles. A 5 000 % mobile tank containing water was brought to the field to refill the herbicide tank.

187

4b. Experimental procedure

The speed of the tractor (approximately 6 km/hr) and the pressure applied to the spray pump were calibrated to spray 2 500 1/he in a 30 cm wide band over the row. Four litres of the concentrated polymer dispersion (50% solids) were added and the herbicide tank made up to 400 1 with water. A sample drawn from the tank showed that the turbulence during the water addition and movement of the tractor ensured good mixing. Using a driver with one assistant, one hectare could be covered in 90 minutes. (The acceptable results with higher concentrations of copolymer at 1 000 1/ha were not available at the time this experiment was laid down.) Four plots of 34 metre x 8 rows were marked out in a newly planted field. 2 500 1/ha of 100 x diluted copolymer was applied to two alternate plots, with the remaining two plots receiving 2 500 1/ha of water only. Shoot counts ware recorded et intervals and stick populations and yields were noted at harvest.

4c. Results

The shoot counts, and stick populations and weights of came at harvest (9/11/78) from this experiment are presented in

Table 34

417.18

Sugar cane shoot counts, final stalk counts and yields from cane treated at planting with 2 500 litres of water applied from a tractor, with and without a styrene-2EHA copolymer added (Means of 16 lines)

Treatments	Shoot counts x 10 ³ /ha (planted 31/8/77)						
	11/11/ 77	8/ 12/ 77	20/1/ 78	27/2/ 78	9/11/ 78	9/11/ 78	
2 5001 water/ ha over row	33	77	119	120	108	74,0	
2 500% of 0,5% polymer disper- sion over row	39	101**	152**	143**	111	78,4	
1 advantage over control	201	31%	28%	19%	3%	6%	
C.V. (%)	10,6	18,2	5,6	6,5	9,1	7,3	
LSD 5%	7	17	15	13	15	8	
T.	9	23	21	17	21	12	

The new familiar earlier tillering as a result of treatment indicates that the technique of application was satisfactory. The yield increase of 6% over control from 12,5 kg/he of copolymer is in keeping with the 13% and 4% increases obtained previously when 33 and 9 kg/he of copolymer respectively were present in bands 30 cm wide over the row (Table 30). The relationship between increased yields and levels of copolymer applied on this soil series is illustrated in Figure 7. Another interesting aspect of this experiment is that, deepite the late spring planting (31/8/77), when average temperatures certainly were not limiting, the beneficial tillering effects are still very pronounced, with 31% more shorts being present



in mid aummer. This also accurred in the October planted experiment (Table 35) and emphasizes the non-critical nature of the season of application. In contrest, Millard (1974) concluded that polyethylene sheet, which reises temperatures even in dry soils, would probably prove detrimental to germination if applied during the summer months.

5. Treatment of ratoon crops

To date the earlier tillering effect has been limited to plant cane. Since about 90% of cane crops are rations it was important to see if the same beneficial effects could be imparted to them by the copolymer spray.

5s. Meteriels

Two rateons of different eges at Undioti on Clanathal sands were selected. The same Styrene-2EHA copolymer dispersions as before was used.

55. Experimental procedure

One retoon was treated in mid-winter and the other in late Spring. Layouts of the plots and details of the sites are presented in Appendix 18.

Site 1: On 31 June 1977, 25 metre x 16 rows of a six week old third ration were pegged out. Four plots of four lines were demarkated. One pair of elternate plots was randomly selected to receive the treatment of 3 600 *l*/ha of the copolymer dispersion at 0,5% solids (18 kg/ha dry or 6 g/m² over row).

The other two plots, elternating with those treated, were left as controls. Shoat counts were taken immediately after treatment and again at regular intervals to monitor changes in population.

Site 2: On 30 August 1977, 85 metre x 16 rows of a twelve week old second ration drop were sprayed from a tractor-barne herbicide unit. A randomly selected block of eight of the lines received 2 500 t/hs of the 0,5% solids polymer dispersion (12,5 kg/hs or 4 g/m² over row) while the other eight received 2 500 t/hs of water. Shoot counts were taken within days of treatment and again at regular intervals to monitor relative changes. Final yields from the two differently treated blocks, as well as those from the adjacent commercial care, were compared.

Sc. Results and discussion

The shoot counts at Site No's 1 and 2 at various intervals after spraying are presented in Table 35 and Appendix 18 respectively.

It is seen from the above table that the flush of new shoots took place within four weeks of treatment, despite having been sprayed in late June when conditions were very dry. This very repid response indicates that a developed plant system is very consitive to, and can take immediate advantage of, the increased soil humidity. Although the

-126-

Table 35

Shoot counts from retoon cone treated on 31/6/77 with 3 600 litres per hectare row only of a 0,5% solids styrene-2000 copolymer dispersion (Means of A lines)

		No. of	% increase	Actual		LSD	
Date counted	Treatment	shoots x 10 ³ /ha	x 10 ³ /ha date of fr treatment t		C.V. (5)	5%	12
31/6/77	Control Polymer	88 87			39,8		
28/7/77	Control Polymer	102 diff. 129 +27**	15.9 diff. 45.9 +30.0	14 } diff. 40 } +26	15,2	13	18
25/8/77	Control Polymer	98 diff.	11.4 diff. 30.3 +18.9	10] diff. 27 } +17	16,0	11	15
10/11/77	Control Polymer	100 diff. 124 324**	13,6] diff. 39,5] +28,1	12 diff. 35 } +23	12,7	17	15
7/12/77	Control Polymer	126] diff. 183] +57**	43,2] diff. 105,6] +62,4	38 diff. 94 } +56	10,6	22	30

Statistically significant at the 70 level

magnitude of the differences between treated and untreated lines is reduced during the extreme winter drought, it remains statistically significant. With the spring rains the expected flush of new abouts occurred in both treatments, but again it was of greater magnitude in the polymer treated lines. The result is that in the six months after application the rate of new shoot development was 2,5 times faster in the treated lines than in the controls, giving 56×10^3 more shoots per hectare. Unfortunately, the recording of yield date was thwarted by the field being suddenly harvested without notification to the author.

The three month old ratoon at Site No. 2, aprayed in spring after the first rains had fallen, failed to give either accelerated rate of new shoot production or increased yield over control (Appendix 18). The considered reason for this is that the crop had already reached an advanced stage of tillering (80 x 103 per hectare) when treated. Rau and Millard (1975) noted no earlier tillering in 2 out of 3 experiments with polyethylene sheet on rateons. Even at the one positive site the population advantage had disappeared five months after treatment and this was escribed to the faster formation of leaf canopy in ration, as compared to plant, crops. From previous results in this chapter and the result from Site No. 1 above, it seems most likely that substantial amounts of copolymer sprayed over the row immediately after barvest will result in earlier tillering and increased cane yields. Further field trials will be needed to substantiate this claim.

- 192-

6. General discussion and conclusions

-100-

Specific capolymer dispersions have beneficial effects on crops through their remarkable power to reduce evaporation when used in combination with spil. For example, with supar cane 5 ko/ha of dry copolymer sprayed in a band 30 cm wide over newly planted setts significantly increased the rate of early development of the crop. Better developed crops are more able to resist droughts and disease and can also compete more effectively with weeds. The intensity of the moisture conserving effect increases linearly with the amount of copplymer applied and at higher levels the earlier tillering effect is sustained to give increased crop yields. The actual incunts of copolymer applied will depend on the commercial values of the types of crops treated. For example, on an Datadale series soil 10 kg/hs of dry copolymer, worth approximately 20 rand, produced 12,9 tons extra cane, worth approximately 150 rand. Because this yield increase was linearly greater than that obtained from 5 and 7,5 kg/hs of copplymer respectively, it is likely that higher application rates, say 30 kg/ha will give even greater financial returns. The higher concentrations of sugar (30) in the treated cane and the carry-over effect of the higher stalk populations into the ration crops, makes the application of higher levels of copolymer financially attractive.

Factors, other than the rate of copolymer epplication, which affect the magnitude of the yield response are the type of soil, time of application and the age of the crop at harvest. For example, whereas on the Datadels series soil 10 kg/he of copolymer was required to produce 12 tons/ha of extra came, 33 kg/ha were required on a Clensthal send to produce an increase of similar magnitude. It would seem that soils with greater moisture holding capacities give greater yield increases per unit weight of copolymer applied. However, because these spils invariably have higher contents of clay, they have a greater surface area per unit volume. They therefore need more water and more polymer to ensure sufficient costing of soil grains. Although time of year is not critical to the earlier tillering effect, the crop must be at a certain stage of development for it to occur. For this reason, the copolymer should be applied during, or just before, the active growing months (summer or early spring) to achieve maximum benefit. This does not apply to newly harvested rations as their already existant, well developed root systems ensure rapid response to copolymer treatment. As the difference in shoot population between treated and untreated plant cane is reduced with time, cane crops should be harvested at the earliest possible age.

It is likely that crops other than sugar cane will benefit from the effects of reduced evaporation. Experiments with maize are described in the next chapter where the possibilities of the hydrophobic barriers conserving fertilizer and herbicide, as well as water, are considered.

- 195-

USING POLYMER DISPERSIONS WHICH IMPART THE HYDROPHOBIC EFFECT TO IMPROVE THE EFFICIENCY OF SOIL ADDITIVES

It is a known fact that much of the fertilizer applied to wandy soils is leached away and last to plants. This elso happens to a losser extent with herbicides, insecticides and other water sensitive soil additives. Many attempts to produce controlled release fertilizers, particularly nitrogen, have been made and, although some concercial materials are produced, they are all considerably ware expensive than the standard products. A comprehensive review on slow release mitragen fortilizers use made by F. Presas et al (1973). Song of the systems succested to give controlled fertilizer release include the use of fertilizers with relatively insoluble coatings of different thicknesses (Perr, 1964); the addition to the fertilizer of inhibitors which affect specified soil microbial groups (Ferr, 1967) or the use of materials with different depress of susceptibility to microbial sttack (Hauck, 1964); the use of different organic compositions such as aming ecids, which can be taken directly into some plants without first being converted to NO. (Parr, 1967); and the encouragement of the growth of beneficial rhizosphere microflora (Parr and Norman, 1954).

It would seem possible that the ability of the water repellent soils described in Chapter VIII to deflect downward moving water sway from fertilizers, thereby preventing them from being leached sway, could be harnessed as a cheap and practical method of conservation. Studies have been

made by other researchers ((R. France et el (1973)) of various polymar/fertilizer blends but the above application has never been pursued. Anter and de Boodt (4976) investigated soluble fertilizers in systems containing water sensitive polymers. They used solutions of polyacrylamide and polyvioyl elcohol, and a PVAc homopolymer dispersion. As PVAc was "the most hydrophobic product" they used, uster receilency of the soil particles was not the mechanism of controlled release envisaged. Perhaps the cublished work most closely approximating the system procounded in this thesis was published by Jenvain and de Boodt (1976), where 8 ml of emulvified bitumen (presumably at 50% solids) was mixed with 1 kg of loamy sand. Compound N. F and K fertilizers were then mixed with this modified soil and they believed that the synthetically created soil represates would entrap particles of fertilizer between them, thereby reducing the rate of fertilizer releace.

It became possible to investigate the concept of using ralymer dispersions to create hydrophobic soils for protecting fertilizers in 1975, when a post-graduate student was essigned this project. The author acted as an official advisor for this work, which wat published by Martakie (1977). It was felt that further research would reveal the reasons why he concluded that polymer dispersions were "fixing" fertilizers, thereby rendering them werless in slow release applications. The consequent investigations form the basis of this Chapter.

A. SUGGESTED SYSTEMS FOR CONTROLLING FERTILIZER RELEASE

It was considered that two different forms of controlled release fertilizer using the hydrophobic concept were worth

- 192+

investigation.

These are:

- a <u>wet mixture</u> of dissolved fertilizer and dilute polymer dispersion which is applied to the soil or some inert particulate material.
- (ii) a <u>dry mixture</u> where the fertilizer prills are mixed with dry pre-treated hydrophobic particulate material.

It must be realised that the mechanismoof fertilizer protection in the wet and dry systems are different. In the Let system the fertilizer solution will be an integral part of the polyner dispersion. Thus when the mixture dries (which is necessary to initiate the hydrophobic effect) it is likely that a composite layer will coat the sand grains. The type of polymer and type and concentration of fertilizer (as will be shown later) affect the magnitude of the hydrophobic effect. These variables therefore give a measure of control over the rates at which the fertilizer is discolved. In contrast, the dry mixtures are made up of separate fertilizer and hydrophobic particles. The mechanism of protecting the fertilizer granules is by surrounding them tith a layer of hydrophobic particles so that water is restricted from penetrating to them. The thicker the layer of hydrophobic particles (as is shown later) the longer it takes for water of low hydrostatic head to reach the fertilizer. Figure 8 is an attempt to clarify the main differences between the two systems.

B. MET BLENDS OF FERTILIZER, POLYMER AND PARTICULATE MATERIALS

Controlled release fertilizer should ideally only trigger



1. Form arriving in field

Liguid or wolid

Solid

7. Envisaged methods of preparation

Dilution of fertilizer with low solids polymer dispersion sprayed on to the soil over the planting row. In factory inert particles could be wet mixed with polymer dispersion and fertilizer and then dried. Factory or farm prepared free flowing water repellent particulate material followed by mixing and bagging, or blending the two separate components with a tractor borne implement. In a factory could be dry compressed into pellets.

J. Placement

On surface to facilitate drying.

Preferably drilled to meintain close contact with two compoments.

4. Dieadvantages

Only applicable in conditions conducive to drying and must be applied on to bare soil. Susceptible to volatilization losses due to surface drying conditions.

Increased bulk and possible separation of components in free flowing form. Susceptibility of dry apprepates to disintegrate with vibration.

5. Advantages

Complimentary to spray systems Can b which conserve noisture, in a temperature and soil. Low costs. user.

Can be supplied ready to use in a form familiar to the user.

Figure 8: Comparative accessment of two different systems of controlled fertilizer release, making use of the hydrophobic offect imparted to particulate material by polymers. nutrient release when plants are capable of absorbing them. Furthermore, the rate of release must be of sufficient magnitude to supply the immediate needs of the plant, but not be so great that wastage occurs.

The hydrophobic effect generated by the copolymer indicates that it may be possible to modify soils so that when they are irrigated the extent of wetting is controlled, thus releasing limited grounts of fertilizer.

Influence of copolymer blends and fertilizer levels on water uptakes of sand

In this approach it was considered that the inert particles to be costed with copolymer to produce the hydrophobic effect could be the in situ soil or send. A preliminary study was conducted to check, firstly, the effect of blending hydrophobic and hydrophilic inducing dispersions and, secondly, fertilizer concentrations, on the degree of water penetration into treated sands.

ta. Materials

Graded marine sand (> 250µm and < 750µm) and ordinary commercially available uses and KOL were used. Three blends to give exactly 50% solids were made up using the RVAc homopolymer, the styrene-2EHA copolymer and a 50:50 blend of these.

1b. Experimental procedure

Using only the 50% solids PVAc, the following mixtures were

- As in (2) but 2,5g of each fertilizer was used;
- 4) As in (2) but 3,4g of each fertilizer was used;
- 5) As in (2) but 5,0g of each fertilizer was used;
- 6) As in (2) but 10,0g of each fertilizer was used.

The above six mixtures were again made up using the styrene-2EMA copolymer. Because this dispersion only bands sand weakly, it was mixed 1:1 on a dry basis with a soluble maize dextring. This dextrine is included as part of the styrene-2EMA copolymer solids. Finally, the same blends were made with the 50:50 blend of the two dispersions. These fertilizer/ polymer blends were then mixed with graded marine sand in the ratio of 108g of liquid to 540g of send. Stainless steel moulds from the Richards rupture tester were then used to form briguettes with 215g samples of these mixtures. Three replications of each treatment were prepared. After 24 hours at 550 the bonded sand briquettes were removed from the moulds. Each briguette was placed in 280cc plastic pats of known weight. The pat plus briquette was weighed before 200g of water was poured into each. After 17 hours holes were pricked in the bases of the pots and the water drained out. The pots were egain weighed to determine the weight of water retained in each sand briquette.

1c. Results and discussion

The percentage water uptake on original weight of the sand briquettes after 17 hours submersion is given in Table 36.
Water uptakes of sund briquettes formed by different polymer dispersions and containing different concentrations of fertilizer (Neans of 3 determinations)

	1	0	5					5 W	ater upt	oke M			
% C Pol	Concentrations Polymer : Urea: KCl					PVA 2EH	e : Styr	ene- rine	C.V. (%)	5% N			
							a land	100:0	50:50	0: 100	-		1
٩.	2.4	-	00	10.00	0	(in (on	liquid odded) dry sand)	26,2	13,3	6,8	14,9	1,8	2,4
2.	2.4		0,9		0,9	(in (on	liquid added) dry sand)	29,8	21,3	9,6	10,3	1,8	2,4
3.	2,4		1.7	-	1,7 0,4	(in (on	liquid added) dry sand)	29,4	21,5	14,6	9,0	1,9	2,3
4.	2,4		2,5		2,5	(in (on	liquid added) dry sand)	29,3	19,7	18,6	7,8	1,5	2,0
5.	20,4	1	3,4	-	3.4	(1n (on	liquid edded) dry mand)	27,1	22,0	20,9	7,4	1,4	1,9
6.	20,4	-	5,0	+ +	5,0	(in (on	liquid added) dry sand)	24,5	18,7	20,6	12,1	1,8	2,4

It can be seen from the above table that the amount of water penetrating into a send briquette bound with the styrene-2EHA copolymer can be accurately controlled by either the level of "water sensitive homopolymer present or by the concentration of fertilizer. Both these variables should therefore offer excellent means of controlling the release rate of soluble fertilizers. The absolute linear relationship between rate of fertilizer release and blend ratio of the PVAc homopolymer to the Daxed etabilized styrene-2EHA copolymer is confirmed in Fopendix 26. However, practical considerations necessitate that fertilizer concentrations be maintained as high as possible. The concept incorporating different levels with the polymer dispersion imparting the strongest hydrophobic effect is pursued.

Fertilizer losses from solutions with and without copolymer dispersion

To confirm that the hydrophobic effect could reduce the amount of soluble fertilizer removed from a soil, leaching tests were carried out.

2a. Materials

Urea and KC1 were the fertilizers chosen to be used with the surfactant stabilized styrene-2EHA copolymer dispersion and the graded marine sand.

25. Experimental procedure

To 93g of water 3g of urea and 3g of KC1 were added, with

- 198-

stirring. then discolved, 1g of the 50% solids copolymer was edded. Ten x 280ml plastic pate were each filled with 200g of graded marine sand. On to the surface of these cands 4ml aliguate of the liquid were dripped. The pots were dried at 25C and 50% RH. Holes were then pricked with a pin in the bottome of all ten pots and they were suspended over another ten to collect the leachates. Successive 50ml aliguots of water were then poured over the sends in each pot. The electrical conductivities of the leachates were resourcion a portable conductivity matre and recorded. These were then converted to units of concentration after correlating conductivity readings with salutions of known concentrations. is uses is not ionized, the conductivity results obtained will be elmost exclusively from the KC1. However, as both of these fertilizers are very soluble, it was considered that similar proportions of each would be removed with each leaching.

2c. Recults and discussion

The concentrations of ionized salts were taken as an indication of the relative amounts of fertilizer which had been leached from the sands. To estimate the total amounts of fertilizer removed from the copolymer treatment, the cumulative amounts in successive leachates were expressed as a percentage of the cumulative emounts from the controls. These results are presented in Table 37.

The results in Table 37 show that there is a marked reduction in the rate and total amount of soluble salts removed, where the liquid fertilizer was applied together with the polymer dispersion. The intensity of fertilizer protection, however, is considered too extreme to be useful in agriculture. Therefore,

- 199-

Concentrations and total amounts of ionised salts in successive leachates through sands whose surfaces had received fertilizer solutions with and without a styrene-2EHA copolymer (Means of 5 determinations)

.

		Concentre	tion of ionis	ed salts (%)			
Leach No.	Date	Urea-KCl	Polymer- Uree-KC1	Acc. totals (% of con- trol)	C.V. (%)	5%	D 1%
1	9.2.76	0, 155	0,045	29%	8,5	< 0,001	< 0,001
2	9.2.76	0,058	< 0,000	2 1%	8,4	< 0,001	< 0,001
3	9.2.76	< 0,001	< 0,001	2 1%	17,5	< 0,001	< 0,001
4	10.2.76	< 0,001	0,003	22%	17,1	< 0,001	< 0,001
5	10.2.76	< 0,001	< 0,001	22%	8,4	< 0,001	< 0,001
6	11.2.76	< 0,001	0,003	24%	17,6	< 0,001	< 0,001
7	11.2.76	< 0,001	< 0,001	24%	18,2	< 0,001	< 0,001
в	12.2.76	< 0,001	0,001	24%	16,8	< 0,001	< 0,001
9	12.2.76	< 0,001	< 0,001	24%	18,3	< 0,001	< 0,001
10	13.2.76	< 0,001	< 0,001	24%	4,9	< 0,001	< 0,001

the possibility of reducing the severity of the water repellent effect by increasing the concentrations of fertilizers was investigated.

Effect of fertilizer concentrations on leaching patterns

As was noted in sub-section 1, the ability of sand briquettes bound with the styrene-2EHA copolymer dispersion to hold out water deteriorated as the concentration of fertilizer increased. The possibility of using the concentration of fertilizer to control its own rate of release would be simple and cheap. This was essessed using limestone ammonium nitrate (LAN), esmonium sulphate (NH4,)2504 and potassium chloride (HC1) on their own and with 0.5% dry polymer in the following experiment.

3a. Materials

The following 45 mixtures using LAN (26%N) were prepared with stirring:

(1)	3, LAN: control:	3g of LAN into 97g of water
	3% LAN + polymer:	3g of LAN into 96g of water
		then 1g of 50% LAN styrene-2EMA
		copolymer added
(11)	B% LAN: control:	8g of LAN into 92g of water
	B% LAN + polymer:	Bg of LAN into 91g of water + 1g
		of 50% polymer dispersion
(111)	13% LAN: control:	13g of LAN into 87g of water
	13] LAN + polymer:	13g of LAN into 86g of water + 1g
		of 50% polymer dispersion

(iv)	19% LAN: pentral:	18g of LAN into 82g of water
	18% LAN + polymer:	18g of LAN into 81g of water
		+ 1g of 50% polymer dispersion
(v)	21% LAN: control:	21g of LAN into 79g of water
	21% LAN + polymer:	21g of LAN into 78g of water +
		1g of 50% polymer dispersion
(vi)	25% LAN: control:	25g of LAN into 75g of water
	25% LAN + polymer:	25g of LAN into 74g of water +
		1g of 50% polymer dispersion
(vii)	28% LAN: control:	28g of LAN into 72g of Water
	28% LAN + polymer:	28g of LAN into 71g of water +
		1g of 50% polymer dispersion
(viii)	3 % LAN: control:	31g of LAN into 69g of water
	37% LAN + polymer:	31g of LAN into 68g of water +
		1g of 50% polymer dispersion

Identical mixtures were made up for the $(NH_4)_2SO_4$ (21% N) and FC1 (50% K).

3b. Experimental procedure

24 x 280ml plastic cups were filled with greded marine sand and 5ml of each of the prepared solutions dripped on to the sand surfaces, using three cups for each solution. The cups were left at 25C and 50% RH for 7 days to dry. After pricking holes in the bottoms of the cups they were suspended over other cups and 50ml eliquate of water leached through them. The volumes of leachete collected were noted before their electrical conductivities were measured. The results for five successive leachings through the LAN, summanium sulphate and KC1 treatments are presented in Table 38. The relative rates of release from the increasing concentrations of these fertilizers after 3 x 50ml leachings are illustrated is Figure 9.

-0.07-

Jc. Results and discussion

Setween Fertilizer concentrations of approximately 10% to 25% the rates of solubilization and total amounts removed after 3 x 50ml leachings, are linearly related to the initial concentrations dissolved in the dilute copolymer dispersion. However, a big difference occurs in the total empunts of Fertilizer removed after 5 leachings from the 19%, compared to the 21% levels, for LAN and KC1, and the 25% level for (NHL)250L. On closer inspection of the mixtures it was found that the copolymer dispersion was destabilized with concentrations in excess of about 20, for all 3 fertilizers. As it was haped to combine the fortilizer and moisture conserving effects in one product, it was very desirable to find a stable dispersion. However, all other commercially available dispersions tested also coagulated under these conditions. Attempts to polymerise a dispersion which does not coagulate at high fertilizer concentrations is described later, in sub-section 7.

It is noted in Table 38 that the copolymer treatment with 18% fertilizer only released, on everage, 5% of its soluble components (compared to the controls) after the 5 x 50ml leachings. Martakie (1977), working with the same styrene-2CHA copolymer and marine sand, confirmed this very strong "fixation" of emmonium ions (38,5% recovery after on 18 day soak) when working at extremely low concentrations (0,00% N on sand). He showed that this did not occur with nitrate ions where 90% was released in less than 5 days and suggests that the NH₄+ ion may be chemically interacting with the polymer. Since Martakie -204-

Terle 38

Concentrations of ionized salts in 5 x 50ml successive leachates of water after having passed through sand containing increasing quantities of liquid fertilizers applied with and without a 0.5% solids styrene-2EHA dispersion (Means of 3 determinations)

					Concer	trations	(%) and	accumula	ting soli	ds remo	ved as %s	of contr	ols			
Level of			Leach 1			Leach 2			Leach 3			Leach 4			Leach 5	
dissolved in water or dispersion	fertili- zer	Control	Treated	Acc. total (% of con- trol)	Control	Treated	Acc. total (% of con- trol)	Control	Treated	Acc. total (% of con- trol)	Control	Treated	Acc. total (% of con- trol)	Control	Treated	Acc. total (% of con- trol)
	LAN	0,025	0,006	23	0,002	< 0,001	22	< 0,001	<0.001	22	< 0,001	< 0,001	22	< 0,001	< 0,001	22
3%	(NH4)2504	D,019	0,001	5	0,001	<0,001	5	<0,001	<0,001	5	< 0,001	< 0,001	5	< 0,001	< 0,001	5
	KC1	0,035	0,014	39	0,002	0,005	51	<0,001	0,001	52	< 0,001	< 0,001	52	< 0,001	< 0,001	52
	LAN	0, 119	0,027	23	0,017	0,011	28	< 0,001	0,002	30	< 0,001	< 0,001	30	< 0,001	0,002	31
B %	(NH4)2504	0,235	0,057	24	0,054	0,021	27	0,003	0,003	28	< 0,001	0,001	28	< 0,001	< 0,001	28
	HC1	0,084	0,035	42	0,014	0,022	59	< 0,001	0,007	66	< 0,001	0,002	68	< 0,001	0,007	75
	LAN	0,392	0,051	13	0,019	0,030	17	< 0,001	0,015	21	< 0,001	0,014	24	< 0,001	0,031	34
13%	(NH4)2504	D, 361	0,068	19	0,224	0,024	16	0,026	0,003	16	0,001	0,003	16	0,001	0,001	16
	KC1	0,328	0,065	20	0,028	0,035	28	0,002	0,022	34	< 0,001	0,013	38	< 0,001	0,015	42
	LAN	0,533	0,226	42	0,022	0,089	57	< 0,001	0,019	60	< 0,001	0,015	63	< 0,001	0,032	69
18%	(NH4)2504	0,579	0,100	17	D, 106	0,069	25	0,047	0,024	26	0,001	0,048	33	< 0,001	0,008	34
	501	0,471	0,149	32	0,089	0,063	38	0,005	0,037	44	< 0,001	0,018	47	< 0,001	0,022	50
	LAN	0,672	0,426	63	0,032	0,140	81	< 0,001	0,022	84	< 0,001	< 0,001	84	< 0,001	< 0,001	84
2 1%	(NH4)2504	0,797	0,297	37	0,170	0,097	41	0,045	0,056	44	0,003	0,058	50	< 0,001	0,005	50
	KC1	0,786	0,382	49	0,029	0,226	75	< 0,001	0,032	79	< 0,001	0,049	85	< 0,001	0,012	86
	LAN	0,763	0,763	100	0,035	0,072	105	< 0,001	< 0,001	105	< 0,001	< 0,001	105	< 0,001	< 0,001	105
25%	(NH4)2504	0,828	0,550	66	0,298	0,428	87	0,033	0,014	86	0,003	0,002	86	< 0,001	< 0,001	86
	KC1	1,094	0,572	47	0,039	0,310	78	< 0,001	0,052	82	< 0,001	0,012	83	< 0,001	< 0,001	83
	LAN	1,038	1,083	104	0,060	0,049	103	< 0,001	< 0,001	103	< 0,001	< 0,001	103	< 0,001	< 0,001	103
28%	(NH4)2504	0,934	0,902	97	0,428	0,428	98	0,036	0,027	97	0,003	0,001	97	< 0,001	< 0,001	97
	KC1	0,971	0,510	53	0,104	0,375	62	0,001	0,111	93	< 0,001	0,006	93	< 0,001	< 0,001	93
	LAN	1, 120	1,075	96	0,065	0,051	95	0,002	0,006	95	< 0,001	< 0,001	95	< 0,001	< 0,001	95
315	(NH4)2504	1, 157	1,227	106	0,284	0,273	1B4	0,030	0,023	104	0,001	0,001	104	< 0,001	< 0,001	104
	KC1	1,053	0,375	36	0,032	0,325	65	< 0,001	0,066	71	< 0,001	0, 129	83	< 0,001	0,025	85

Concentrations of soluble salts and total amounts removed by successive leachings through sandy soil which received increasing quantities of (NH4)2504, with and without, the Daxad stabilized styrene-2EHA dispersion (Means of 6 determinations)

÷.,

Concentration			Concentre	stion of	solub)	e salts (%) and c	umulati	ve amounts	removed	(es % of	cumulative	controls)	
of (NH4)2504		Leach	1		Leach	2		Leach	3		Leach 4			Leach S	
	Cont.	Treat	Acc. total (% of control)	Cont.	Treat	Acc. total (% of control)	Cont.	Treat	Acc. total (% of control)	Cont.	Treat	Acc. totsl (% of control)	Cont.	Treat	Acc. total (% of control)
10%	1,272	0,394	31	0,300	0,266	42	0,030	0, 157	51	< 0,001	0,048	54	< 0,001	0,112	61
20%	2,010	0,905	45	0,590	0,889	69	0,023	0, 173	75	< 0,001	0,079	78	< 0,001	0,009	78
40%	2,604	2,005	77	1,572	1,879	93	0,412	0,512	96	< 0,001	0,045	97	< 0,001	0,084	99
50%	1,823	1,568	86	0,860	1,088	99	0,006	0,033	100	< 0,001	< 0,001	100	< 0,001	< 0,001	100
60%	1,223	1, 162	95	0,314	0,344	98	0,070	0,069	98	< 0,001	<0,001	98	< 0,001	<0,001	98

-220-

			Concentr	ations (%) and a	cumulative	totals of solut	le salts	es % of controls		
				2,5g fertil	lizer to 2	Og treated sand	(Ratio 1:	8)		
		Leach 1		Leach 2		Leach 3		Leach 4	Leach 5	overnight drying
	Conc. %	Acc. total (% of control)	Conc. %	Acc. total (% of control)	Conc. %	Acc. total (% of control)	Conc. %	Acc. total (5 of control)	Conc. 🏂	Acc. total (% of control)
Urea • polymer • polymer	0,135 0,627	22	0,218 0,024	54	0,023 < 0,001	58	0,002 < 0,001	58	0,149 5,001	81
LAN + polymer - polymer	0,321 1,349	24	D,619 D,365	55	0,124 < 0,001	62	0,002 < 0,001	62	0,222 < 0,001	75
Amm. 504 + polymer - polymer	0,404 2,006	20	0,237 0,199	29	0,114 < 0,001	34	0,037 < 0,001	36	0,227 < 0,001	46
				2,5g fertil	izer to 1	6,20g treated sa	nd (Ratio	1:6,5)		
Urea • polymer - polymer	0, 172 0,672	26	0,139 < 0,001	46	0,022 < 0,001	50	0,002 < 0,001	50	0,126 < 0,001	69
LAN • polymer - polymer	0,634 1,251	51	0,647 0,952	58	0,022 < 0,001	59	0,003 < 0,001	59	0,001 < 0,001	59
Amm. 504 • polymer - polymer	0,320 2,240	14	0,413 0,196	30	0,080 < 0,001	33	0,038 < 0,001	35	0,002 < 0,001	35
				2,5g fertil	izer to 1	1,1g treated san	d (Ratio	1:4,4)		
Urea • polymer - polymer	0, 191 0,673	28	0,127 0,025	46	0,025 < 0,001	49	0,001 < 0,001	49	0,173 < 0,001	74
+ polymer - polymer	1.023 1,069	96	1, 120 1, 120	96	0,023 < 0,001	99	0,001 < 0,001	99	0,064 < 0,001	102
Amm, 504 • polymer - polymer	0,748	36	0,704 0,400	58	0,118 < 0,001	63	0,015 < 0,001	63	0,203 < 0,001	71

Concentration of soluble selts in leachates through 200g of marine sand containing 2,5g of % fertilizer, with different amounts of water repellent sand. Controls had 2,5g of fertilizer with no water repellent sand. (Means of 4 replicates)

-130-

Concentrations and cumulative emounts of soluble salts (as % of controls) in successive leachates through 200g of marine sand containing different amounts of LAN blended with free flowing or compacted hydrophobic bagasse powder (Means of 2 replications)

			Concentra	tions (%) and	d cumulative	BROUNTS	of soluble s	elts as % of	controls	
Date	Leach No.	2,5g LA	N + 10g p	rotector	5g LAN	• 10g pro	tector	10g LAN	• 10g pr	otector
		Control	Loose	Compacted	Control	Loose	Compacted	Control	Loose	Compacted
18.11.77	1	1,998	0,036	0,039	1,918	0,144	D, 127	6,720	2,431	1,345
Accum. % o	f Control	100	2	2	100	8	7	100	36	20
18.11.77	2	D, 114	0,373	0,295	2,260	0,981	0,592	2,490	1,599	D,811
Accum. % o	f Control	100	19	16	100	27	17	100	44	23
18.11.77	3	< 0,001	0,130	0,167	< 0,001	8,051	0,352	< 0,001	0,180	0,403
Accum. % o	f Control	100	26	24	100	28	26	100	46	28
21.11.77	4	< 0,001	D, 190	0, 173	< 0,001	0,215	0,420	< 0,001	2, 195	2,668
Accum. % o	f Control	100	35	32	100	33	36	100	70	57
21.11.77	5	< 0,001	0,109	D, 119	< 0,001	0,118	0, 105	< 0,001	0,401	0,618
Accum. % of	f Control	100	40	38	100	36	38	100	74	64

-234-

-24 1-

Table 44

Bry yields and N contents of four successive crops receiving 1.1g of N in different forms with polymer treated and untreated wood flour (Means of 3 determinations)

				CROP	I		CF	UP II		1	CR	0P 111		1		CROP IV		
	Treat and }	nants of wood flour . N in final product	Dry weight yields (g)	55 N	Total N (mg)	Dry weight yields (g)	% N	Total N (mg)	Crop totals (mg)	Dry weight yields (g)	5. R	Total N (mg)	Crop totels (mg)	Dry , weight yields (g)	% N	Total N (mg)	Crop (g)	Totels mg N
DRY	BLEN	20																
a. L	ren:	Uneggregated flour	* -								1	1				1		
(1)	1,1g N in 1:1 blend (23% N)	9,1	3,44	313	6,8	3,22	2 19	532	7,9	2,71	2 14	746	3,9	2,51	98	27,7	B44
(ii)	1,1g N in 1:2 blend (15% N)	12,4	3,42	424	11,3	3,34	377	801	8,7	2,83	246	1 047	4,8	2,43	117	37,2	1 164
(111)	1,1g N in 1:3 blend (12% N)	11,2	3, 18	356	7,8	3,57	279	635	6,2	2,97	184	778	5,0	2,65	133	30,2	952
(10)	As (i) untreated flour	11,3	3,26	268	7.6	3,53	275	643	7,2	2,91	2 10	853	3,4	2,41	82	29,7	935
(v)	1,1g N as Control	5,7	3,42	332	8,2	2,52	2 15	547	3,6	2,31	63	630	3,3	2,13	70	24,8	700
WET	er, End	5										î.						
b. U	res:	Apprepated		1											1			
(1)	1.1g N as 29% N	10,7	3,35	358	3.1	2,57	80	438	2.7	2, 15	58	495	3,3	2,17	72	19,8	568
(11)	1,10 N as 22% N	10,4	2,45	258	2,3	3,04	70	388	1,5	2,47	37	365	2,9	2,09	61	17,1	426
(111)	1, 1g N as 14% N	12,0	2,48	298	2,5	3, 13	78	376	1,9	2,51	48	424	4,0	2,31	92	20,4	5 16
(iv)	As (i) untreated flour	8,3	2,63	218	6,3	2,82	178	396	6,3	2,43	153	549	3,2	2,07	66	24,1	6 15
((0)	1,1g N as Control	9,7	3,42	332	8,2	2,62	2.15	547	3,6	2,31	83	630	3,3	2,13	70	24,8	700
c. N	44103	: Apprecated										1						
(1)	1,1g N as 23% N	10,3	2,57	265	1,5	2,34	37	302	1,5	2,07	31	333	3,2	2,24	72	16,6	405
(ii)	1,1g N as 17% N	11.8	2,59	306	1,8	2,18	39	345	1,5	2,00	30	375	2,9	2,23	65	18,0	450
((11)	1,1g N as 11% N	12,5	2,12	265	2,4	1,94	47	3 12	1,8	2,11	38	350	3,8	2,05	78	20,5	428
((v)	As (i) untreated flour	11,5	2,16	270	2,2	3,22	71	341	1,9	2,36	45	386	2,6	2, 19	57	18,2	44.3
(1)	1, 1g N as Control	13,9	3,40	473	8,3	3, 17	261	734	2,5	2, 13	53	787	4,2	2,05	86	28,9	873
d. (]	H4.22	SOL: Apprepated		1												1		
())	1, 1g N as 112 N	10,4	2,17	226	2,1	3,34	20	296	1,7	2,63	45	341	3,0	1,71	51	17,2	392
(1	1)	1,1g N as 8% N	11,6	2,39	277	2,8	2,09	59	336	2,0	2,34	47	383	3,3	1,96	65	19,7	44≘
()	11)	1,1g N as 5% N	11,8	2,59	306	2,8	2,20	62	368	2,2	2,31	51	4 19	2.7	1,74	47	19,5	466
()	vΣ	As (i) untreated flour	- 1	-	-	-	-	-	-	-	-		-	-	84 <u>8</u>	2	-	-
C.v)	1,1g N as Control	8,4	2,57	2.15	4,2	3,50	147	363	2,9	2, 14	62	425	3,9	1,95	76	19,4	471
c.v.	(%)	· · · · · · · · · · · · · · · · · · ·	18,0	Dupli	cate	29,6	Dupli	cete anely	sis	35.4	Dupli	cate anal	ysis	15,5	Dupli	cate anal	y≡ie o	п
LSD	5%		3,8	analy	sis on	2.4	on co	posite		2,0	on co	spasite	TOP	1,1	compo three	note namp	le fro	m
	1/2		5,2	sampl	e from	3,3	pots	t thur tur	29	2,8	puts	ent run en	Arcie:	1,5	wini ea	pura		

APPENDIX 17

MEAN DAILY SCREEN TEMPERATURE IN C AT DECO HOURS, RELATIVE HUMIDITY 5 (MEANS OF DECO AND 1400 HOURS DATA). SUMEHINE HOURS PER DAY, RUN OF WIND IN KILDMETRES/DAY AND RAINFALL IN MM FOR THE YEAR 1 JUNE 1976 TO 31 MAY 1977 AT MOUNT EDGECOMBE EXPERIMENT STATION, AND THE CORRESPONDING LONG-TERM MEAN.

	1 June 1976 to 31 May 1977													(ong-ter	na Meana			
			te	Soil mperatu	res	Rela-		Run	Évajior	ation		50 years	te	43 years Soil peratu	res	50 years Rela- tive	50 years	42 Veers Evap.	52 ypers Rain-
Max. Screen Temp.	Min. Screen Temp.	Mean Screen Temp.	30 cm	60 cm	120 cm	dity	Sun- shine hours	wind km/day	Class "A" pan	Symons tank	Rain- fall in mm	Nean Screen Temp.	30 cm	60 cm	120 cm	Humi- dity %	Sun- shine hours	from Synons tank	fall in mm
23,2	10,8	17,0	18,0	19,2	20,9	59,3	7.7	105.7	2,8	2,1	Ni1	17.1	17,6	18,9	20,6	61.4	7,4	2,1	34,5
22,9	10,9	16,9	17,2	18,2	19,6	59,2	в,3	114.8	3,0	2,2	15,0	16.7	16,9	17,9	19,2	61.4	7.4	2,1	25,5
21,2	11,6	15,4	17.6	18.1	19, 1	70,0	6,7	158,0	3,2	2,2	53,1	17.4	18,0	18,5	19,D	65,6	7,2	2,5	39,4
23,2	14,8	19,0	20,6	20,3	19,8	73,9	6,2	755,5	3,9	2,7	50,7	18,7	19,9	20,0	19,8	65,1	6,2	3,1	56,6
23,8	16,1	20,0	22,1	21,8	21,1	73,5	6,1	180,4	4,9	3,7	143,5	20,0	21,6	21,5	21,0	70,2	5,6	3,6	83,6
25,7	17,6	21,7	24.0	23,4	22,0	70,6	6,1	200,4	5,3	4,0	65,9	21,3	23,1	22,9	22,3	71,2	5,5	4,1	103,7
27.7	19,8	23,6	27,0	26,2	24,7	72,6	6,2	178.7	6,2	4,6	90,4	22,7	24,9	24,5	23,4	71,7	5,8	4,6	105.4
27,7	20,7	24,2	27.1	26,5	24,8	76,6	5,7	121,8	5,4	3,9	2 18,4	23,5	26,1	25,9	24,6	72,7	6,1	4,7	112.6
28,0	21,4	24.7	28,0	27,3	25,5	80,0	7,3	143,7	5,5	4,5	274,4	23,7	26,4	26,2	25,3	74.1	6,6	4,5	116,3
26,1	15,6	22,4	26,2	26,5	25,8	75,7	5,6	133, 3	4,5	3,6	87,3	22,9	25,7	25,9	25.4	75,3	6,5	3,9	115,5
26,5	17,5	22,0	25,6	25,8	25,1	75,9	7,9	107,2	3,9	2,8	21,6	21,1	23,6	24,3	24,5	72.3	6,9	3,0	74,0
24,7	13,5	19,1	21,5	22,7	23,7	63,0	8,1	100,8	3,4	2,6	27,9	15,9	20,6	21,7	22,7	67,9	7,1	2,3	51,2

(iii) 150 kg N/ha (327 kg urea with 360 kg of hydrophobic saudust).

The rainfall figures for the duration of the experiment are given in Appendix 22.

4f. Results and discussion for the 1977 - 78 season

The ear leaf samples were taken at tasseling for nutrient analysis. The cobs + grain and whole plants were harvested and weighed on 16th May 1978. The ratios of grain to cob and moisture content of grain were determined from representative samples from each plot. The actual dry grain weights were determined using the shelling factor and then adjusted to 12,5% moisture. The results are presented in Table 39, where the split dressing treatment of 50 kg/ha of N is taken as the base against which all other treatments are statistically compared. Figure 10 illustrates the grain yield results graphically.

Grain yields

The grain yields show that only one treatment gave a statistically significant increase over the 50 kg/ha split N control. This was the 2 000 £/ha copolymer dispersion mulch treatment with split conventional (NH₄)₂50₄ dressings at a total of 150 kg N/ha. This gave 514 kg/ha, or 6,7%, more grain than the 150 kg N/ha control and 1 179 kg/ha, or 16,9%, more than the 50 kg N/ha control. The other mulch treatment at the 150 kg/ha of N (the 0,5% solids copolymer dispersion at 3 000 £/ha with 19,2% of (NH₄)₂50₄ dissolved in it) also came close to being

Leaf N % values and grain, grain + cob and stover yields in a maize experiment designed to improve the efficiency of N fertilizer (Means of 3 replications)

1.1	Treatments	Leaf	Cob counts x 10 ³	Grain yielda tona/ha	Cob + grain tons/ha	Stover yields tons/ha	Total plant yields tons/he
			/ha	12,5% H20	Not	corrected	for ents
А.	Control - split dressing						
	(1) 50 kg N/hs (11) 100 kg N/hs (111) 150 kg N/hs	2,66 2,79 2,90	58,0 61,4 61,7	6,987 7,831 7,652	8,396 9,530 9,298	7,976 8,507 8,630	16,372 18,037 17,928
8.	Control - one application	19.5			1.1		17.00
	(1) 50 kg N/ha (11) 100 kg N/ha (111) 150 kg N/ha	2,43 2,91 2,93	61.1 65,2* 66,5*	7,030 8,116 7,656	8,480 9,857* 9,407	5,849 9,939 8,385	14,329 19,796 17,792
c.	Liquid fert one application	1			1.		1485
	(1) 50 kg N/ha (11) 100 kg N/ha (111) 150 kg N/ha	2,40 2,76 3,18**	57,6 63,8 64,5	6,738 7,614 8,081	8,180 9,203 9,857*	7,280 7,270 10,430	15,460 16,483 20,287
D.	Mulch - fertilizer eplit	1			1000		
	(1) 50 kg N/ha (11) 100 kg N/ha (111) 150 kg N/ha	2,50 2,66 2,86	59,3 63,5 68,3.	6,606 7,687 8,166	8,262 9,284 9,898	7,567 8,712 10,061	15,829 17,996 19,959
ε.	Solid fert one application						
	(1) 50 kg N/ha (11) 100 kg N/ha (111) 150 kg N/ha	2,85 2,57 2,81	64,8° 60,0 65,5°	7,400 7,349 7,741	9,121 9,080 9,530	9,612 7,812 10,430	18,733 16,892 19,960
· ···	(0)>	-		1		1.22.2.5	

-211



Figure 10:

Relationships between applied N and grain yields with different treatments - 1977 - 1978 season statistically significant. It produced 429 kg/ha, or 5,6%, more grain. It seems that the plants that received the surface mulch could take use of the extra N at the 150 kg/ha, whereas those without it could not.

As in the 1976 maize trial, these results indicate that the mulch has a beneficial effect on yield, irrespective of whether or not the (NH4)2504 is dissolved in it, providing that the N supply is sufficiently high. In contrast to the beneficial effects of the copolymer mulch at the highest application of N, it means to have a depressive affect on grain yields at lower levels (4,8) less at 50 kg N/hs and 4,0) less at 100 kg N/hs). This was not reflected in the leaf N % values of the 1976 - 77 trial and further experiments will be necessary to confirm it.

Another grein yield result worthy of note in Table 39 and Figure 40 is that of the 50 kg/ha N application of the dry controlled release fertilizer. This was 443 kg/ha, or 5,9%, greater than the yield from the 50 kg N/ha conventional fertilizer treatment. This treatment is discussed more fully in subsection 82.

The high grain yield obtained from the 100 kg/ha N control, which received all its fertilizer at planting, is also noted. This yielded 5.7% more grain than the 150 kg level and 3.6% more than the equivalent conventional split dressing. An unusually high leaf N % is also noted in this treatment but, in contrast, at the 50 kg/he level a much lower value is obtained for the single, compared to the split N,dressing. In the previous year's experiment at the same site the leaf N % values

-243-

and tatel plant yields with the single applications should no such peaking at 100 kg/ha N (Appendix 22). No exploration can be offered as to why the single application at this specific level gave such high values.

-_ . . t.

(11) Nitragen uptakes

The leaf N 5 results shown in Table 39 are presented graphically in Figure 14. Only the samples from the liquid copolymer fertilizer treatment incorporating 450 kg N/he contain statistically (45 level) more N than those from the 50 kg N/he control with split dressings. Thus, elthough earlier results indicated that the liquid mulch could produce more grain then control plots irrespective of whether the (NH4)2504 was dissolved in it or not, this later result indicates that its inclusion can give greater fertilizer efficiency. However, it must also be remembered that this plot received 505 more copolymer than the mulch treatment.

The greater N uptake is more pronounced if it is noted that, as with sugar case and the previous maize experiment, a greater yield of total plant material also exists where the mulch was applied. This is illustrated in Figure 42. Accepting that the results have not been corrected for moleture content, and that the leaf N % values are representative of the N status of the whole plants, then same 24% more N (20,287 tons plant yield x 3,19) leaf N = 64,5) was taken up by plants in these plats than was the case in the plats receiving the conventional 150 kg N/ha application (17,928 tons plant yield x 2,90% leaf N = 52,0). Furthermore, whereas the N uptakes and total plant yields of the control plate level out from the 100 to the 150 kg N/ha² applications, the opplymer treatments continue to increase







Relationships between applied N and total plant yield (uncorrected for moisture) with different treatments -1977 - 78 season

linearly up to the 150 kg N/ha level. This implies that the optimum level of N for greatest total plant yield and N uptake (in the presence of a copolymer mulch) has not yet been reached. Such high yielding, high N containing crops would be of interest for silage production.

The one disturbing feature of the above experiment is that the benefits of copolymer treatment only apply at the 150 kg N/hs. It is noted in Table 38 that in the 21% (NH4)2504 + copolymer treatment only 50% of the soluble salts (compared to control) were removed after 5 x 50 leachings. From the results of the above maize trial it was considered essential that this rate of fertilizer release be increased to match the requirements of the crop more closely.

5. Highly concentrated systems to match plant requirements

From the field trials it was indicated that a very mild, but definite, form of fertilizer retention is required to reduce leaching losses and yet still satisfy the needs of the meize crop. Since increased release rate can be achieved by higher fertilizer concentrations, a dispersion was sought that would not coequiate in such conditions. All the commercially available grades of copolymer dispersion tested failed to meet the requirements, so a number of unconventional grades were polymerised for experimental purposes. The Daxad stabilized dispersions, found earlier to be unique among polymer dispersions in imparting both band strength and water repellency to sand, were also found to be unique in remaining stable with very high concentrations of fertilizer. For example, although in 60% concentrations of (MH4)2504 these dispersions areamed to the top of the liquid, they readily redispersed with mild However, the film of the Daxed stabilized styrene-2EHA dispersion which gives optimum performance in road base applications, was too hard to impart water repellency to sand unless dried above its mft of 23C. A copolymer dispersion with a lower styrene level was therefore polymerised, which had a less critical mft of 6C. The fertilizer release curves from sandy soils treated with this dispersion, containing concentrations of (NH4)2504 from 10% to 60%, were compared.

5s. Materials

The Daxad stabilized styrene-2EHA copolymer dispersion described above was used with a sandy red soil (4% clay).

5b. Experimental procedure

The following mixtures were prepared using the SC mft Daxed stabilized dispersion:

- (1) 10g of (NH₆)₂SD₆ were added to 89g of water with stirring and, when discolved, 1g of the 50% solids styrene-2EHA dispersion was added;
- (11) As above but the ratios were 20g (NH4)2804 : 79g water : 1g copolymer dispersion;
- (111) As above but with 40g (NH₄)₂SO₄ : 59g water : 1g copolymer dispersion;
- (iv) As showe but with 50g (NH₄)₂SD₄ : 49g water : 1g copolymer dispersion;
- (v) As above but with 60g (NH4)2804 : 39g water : 1g copolymer dispersion.

3 further not of 5 mixtures as above was prepared without the

inclusion of the capelymer dispersion. 60 x 280ml plastic pote were filled with 200g of the bandy soil. Aliquets of 19ml, 15ml, 12ml, 6ml and 3ml of the above solutions for the 10%, 20%, 30%, 40%, 50% and 60% (NH4)2504 solutions respectively were dripped onto the sand. Three replications of each treatment were prepared. The cupe were air-dried for 1 week and hales were then pricked in their bases. Successive 50ml sliquots of water were then poured into the cups and the leachates collected. The electrical conductivities of these leachates were then measured and converted to concentrations.

2.45-

Sc. Results and discussion

The concentrations of soluble selts in the successive leachates are presented in Table 40 and the relationships between the initial fertilizer levels dissolved and the cumulative amounts removed in the first, third and fifth leachates are illustrated in Figure 13.

The above results show that in the first leach the release of $(NH_{4})_2SO_{4}$ from the soil treated with the 0.5% solids Daxad stabilized copolymer is closely related to the initial concentration of fertilizer discolved, even up to the 60% level. However, at initial concentrations of about 40% and above, all the soluble salts are fairly easily removed with further leaching while at initial levels of about 20% and less, a proportion is stubbornly retained. From these results, and those of the previous field experiment with maize, it is suggested that the optimum $(NH_{4})_2SO_{4}$ concentration is about 40%. Further field triats will be necessary to confirm this.

An interesting observation made during the above laboratory



and an and a star



experiment was that after 3 leachings the soils in the control pots containing high levels of $(NH_4)_2SO_4$ slaked so badly that it was very difficult to get water infiltration. No such problems occurred in the polymer containing treatments. This effect, as well as the mild soil aggregation achieved, indicates that the copolymer containing liquid fertilizer might also help to reduce water and wind erosion.

C. HERBICIDE INVESTIGATIONS

The concept of protecting water sensitive materials from being washed out of the soil too quickly can be extended to other materials such as pre-emergent herbicides and insecticides (Appendix 27). Although disappointing results were obtained with 2-4-D in a replicated field experiment planted with sugar cane in July (when herbicides would not normally be applied) (Appendix 23), remarkable results were obtained in two other observational field trials. The first of these was on maize lands and the second with sugar cane.

1. Maize

This trial was conducted at "Soetvelde Farms" near Vereeniging in October 1977.

1a. Materials

A commercially available flowable dispersion of Atrazine (Geseprim 500FW marketed by Ciba-Geigy of Beale, Switzerland) was used with, and without, the Daxad stabilized styrene-2EHA copolymer. The soil was of the Avalon series.

-222-

1b. Experimental procedure

Four alternate blocks of 6 x 100 metre lines of newly planted maize were treated with Atrazine, at the rate of 3 L/ha diluted with 200 L/ha of water, as prescribed by the manufacturer. The application was complete cover from a conventional tractor borne herbicide spray unit. The other 4 blocks were sprayed in the same way, but the 3 L/ha of Atrazine were diluted with 600 L/ha of the copolymer dispersion at 0.5% solids.

Results and discussion

At hervest, some 5 months later, a thick growth of various weeds was present in the block that received Atrazine only. Most prevalent was <u>Tagetes minute</u> (khaki weed), which was some 1,5 metres high; but also present were a number of grasses such as <u>Eleusine indica</u> (Jongos), <u>Panicum laevifolium</u>, <u>Digitaria</u> <u>sanguilanis</u> and a species of <u>Urochlos</u>, which according to the manufacturers are not normally controlled by Atrazine. The blocks which received Atrazine plus copolymer, however, were almost totally devoid of all types of weeds.

No differences in the condition of the maize in the two treatments were discernible.

2. Sugar cane

This trial was conducted at Natal Estates near Durban in early September 1978.

-223-

The herbicides being used by the sugar estate, and adopted for this trial, were a blend of 2-4-D (3 1/hs), paraquot (2 1/hs) and Lesso, manufactured by Monsanto, 800N, St. Louis, Missouri 63166, U.S.A. (5 1/hs). The Daxad stabilized styrene-2EHA copolymer was the dispersion used and the soil was of the Milkwood series (48% clay).

2b. Experimental procedure

Two alternate blocks, each of 6 x 10 metre lines of newly planted cane, were sprayed with the above herbicide mixture diluted with 600 l/ha of water. The intermediate blocks were sprayed with the same mixture, but the diluent was 600 l/ha of the copolymer dispersion at 0,5% solids content. The different treatments were sprayed simultaneously from knapsack sprayers with the walking speeds of the two operators syncronised. The cover was overall.

2c. Results and discussion

The dramatic difference in weed control achieved by the two treatments on 15 November (10 weeks later) is illustrated in Plate 52. The blocks treated with the standard herbicide application showed strong weed growth, once the expected 6 week period of control expired. The block treated with herbicide plus copolymer, however, continued to exhibit good control of weeds up until the time of writing (mid January 1979).



<u>Plate 52</u>: Differences in weed control of a herbicide treatment alone (to the right of the marker post) and in combination with a styrene-ZEHA copolymer dispersion (to the left of the marker)

D. GENERAL DISCUSSION AND CONCLUSIONS

Polymer dispersions which impart the hydrophobic effect to soils definitely seem to have potential to improve the efficiency of fertilizers by reducing leaching losses. However, the rate of release is critical - it must be sufficiently slow to reduce leaching losses, but sufficiently fast to satisfy the needs of the crop. In addition, all the fertilizer must be released with a reasonably small amount of leaching. It is suggested that the optimum release rate for maize is indicated by a laboratory test in which some 70% of the fertilizer is removed from marine sand with a 1 x 50ml leaching, and 100% after 4 x 50ml leachings. While the blending of hydrophilic with hydrophobic inducing dispersions can achieve such reductions in the holding forces (Appendix 26) they also reduce the beneficial mulching effect. The inclusion of higher concentrations (say 30 to 40%) of fertilizer is the most convenient means of optimising the release rate. Leboratory tests (not reported here) showed that once these initially high concentrations of fertilizer are removed, the soil assumes a strong hydrophobic, and hence mulching, effect.

Of the three commercial forms of N fertilizers available in South Africa, (NH4)2SO4 appears to be the most suitable for use in conjunction with copolymer for the manufacture of liquid fertilizers. This is due to its acidic pH, its easy solubility and its ability to dry out at ambient temperatures. The one disadvantage is its low active N content (21%). Ures with 46% N may be too hygroscopic at high concentrations to allow the treated soil to dry out and become hydrophobic. Field trials to confirm this are necessary in view of the advantages offered by the higher N levels. LAN, because of its alkaline pH and in-

-226-

complete solubility, cannot be used in liquid fertilizers.

The benefits of the prolonged supply of herbicide, together with the elevated soil moisture and temperature conditions, created by the copolymer, would account for the enhanced performance of the herbicides. The majority of pre-emergent herbicides are systemic and function best when plants are actively growing. This would be one possible reason why the result of the trial executed with 2-4-D in July (mid-winter), when growth is minimal and herbicide is not normally used, was disappointing. The expectations of performance by copolymer additives must obviously not be over-extended.

From the results obtained in the last two Chapters an over row spray containing 3% solids of the Daxed stabilized copolymer dispersion, 35% soluble fertilizer and 0,3% of a pre-emergent herbicide would seem to have several beneficial effects over conventional practices. These would include:

- (i) Earlier germination and tillering, where appropriate, owing to higher soil moisture and wet soil temperature effects;
- Greater plant yields, due to a better soil moisture status;
- (iii) The elimination of post-emergent herbicide applications, due to the langer lasting effects of pre-emergent herbicides;
- (iv) The need for only one application of fertilizer
 because of lower leaching losses and an earlier developed
 root system, due to advantages (i) and (ii) above;
- Reduced fuel and labour costs because of fewer passes through a field;
- (vi) Reduced wind and water erosion of soil.

E. SOLID CONTROLLED RELEASE FERTILIZER

The possibility of using the hydrophobic mechanism to produce a solid controlled release fertilizer was investigated. Two different techniques seemed possible. The first was to dry blend pre-treated inert hydrophobic powdered materials with the fertilizer and the second was to mix the copolymer dispersion, fertilizer and inert powder, and then dry the mixture. The latter method has the advantage of being able to be aggregated if the right copolymer dispersion is used.

Dry blends using inorganic hydrophobic particles

Initial studies were again concentrated on N fertilizers. The effects on rate of nutrient release of different amounts of graded hydrophobic marine sand dry blended with fertilizers were assessed.

Leaching rates of N fertilizers

(i) Materials

Urea, LAN and (NH4)2504 were used with graded marine sand and the surfactant stabilized styrene-2EHA copolymer.

(ii) Experimental procedure

Hydrophobic marine sand was prepared by slurrying 1 800g of sand with 340g of the copolymer dispersion at 0, 1% solids content and then drying. Different amounts of this sand were then blended with 2,5g of each of the fertilizers (irrespective of their N contents) as follows:

(1)	2,5g with 20g of hydrophobic sand (1:8)
(11)	2,5g with 16,2g of hydrophobic sand (1:6,5)
(111)	2,5g with 11,1g of hydrophobic send (1:4,4)
(1v)	2,5g with 20g of untreated sand (1:8)
(v)	2,5g with 16,2g of untreated sand (1:6,5)
(v1)	2,5g with 11,1g of untrested sand (1:4,4)

B. LAN

Six samples as above but 2,5g LAN in place of urea.

C. (NHA)2504

Six samples as above but 2,5g of (NH4)2504 in place of ures.

Four replications of each treatment were prepared and wrapped in tissue paper. 72 x 280ml plastic pots were filled with 200g of ordinary marine sand and the fertilizer mixtures buried in them. Holes were pricked in the bottoms of the cups and successive 50ml sliquots of water were poured on to the sand. The electrical conductivities of the successive aliquots collected were determined and converted to concentrations and cumulative amounts (as % of controls), as before.

(11) Results and discussion

The results are presented in Table 41. As with the liquid system, the pre-treated hydrophobic sand reduced the rate of fertilizer release. With usea, the effect of increasing amounts of hydrophobic sand on rate of release seemed slight. For example, after 3 leachings approximately two thirds of usea are removed from all three fertilizer to sand ratios. The LAM release rate was linearly correlated with amount of hydrophobic sand present at leach No. 1 and it is nated that there is an and the second sec

the sector of the particular sector is a sector of the sec

STATISTICS IN THE REPORT

A state of the sta

1 A 911 5 MU

A second s

reduction in the amounts removed at the 1:4,4 ratio. $(NH_{4})_{2}SD_{4}$ egain seems to be strongly held and even at the 1:4,4 ratio only 7% of the fertilizer is removed after 5 x 50ml leachings. From the earlier correlations between the liquid fertilizers and maize yields it would seem that for uses and $(NH_{4})_{2}SD_{4}$ lower levels of modified and give optimum results.

2. Slends using organic hydrophobic particles

The high weight ratio of hydrophobic sand to active plant nutrient content makes its incorporation in elow release fertilizers impractical. However, it was observed that lighter, insoluble, organic particles, such as soudust, could also be rendered hydrophobic by treatment with copolymer. Further advantages of using such products are that they can be compressed into aggregates and, because they are more absorbant, they are capable of forming fertilizers with higher active levels of plant nutrients.

The possibility of using organic materials to reduce leaching losses of solid fertilizers was investigated.

2a. The effectiveness of loose, dry blends in reducing leaching losses

Typical densities of dry powders were found to be for cellulose (e.g. sawduet) 0,01, silica (e.g. marine sand) 1,40 and fertilizer crystals (e.g. HCl) 1,10. Therefore, on a weight basis it seemed very likely that less hydrophobic cellulose than sand would be required to protect the same amount of granular fertilizer. However, although the weight factor would be reduced, pawdered cellulose is very bulky. The ultimate sim would be to create a blend of fertilizer and hydrophobic organic powder compressed into pellets, which could be broadcast.

The comparative leaching losses of fertilizers using hydrophobic organic particles - either free flowing or as compacted dry pellets - was therefore investigated.

(i) Materials

Bagasse, a fibrous by-product of crushed sugar cane, was dried and then ground in a hammer mill to pass through a 25 mesh screen. The surfactant stabilized styrene-2EHA copolymer and LAN was used.

(11) Experimental procedure

"kg of powdered begasse was slurried with "kg of copolymer containing 0,4% solids. The meterial was dried at 550 until it showed the hydrophobic effect when a drop of water was placed on it. After being passed through a 50 mesh slave to break down lumps, the hydrophobic powder was dry blended in various ratios with LAN prills. One set of blends was left free flowing while another was compacted into tablets 45mm in diameter. The equipment used to compact the dry blends into tablets is illustrated in Appendix 24. The weights of hydrophobic bagasse powder and LAN used in the blends were as follows:

 2,5g of LAN prills only
 2,5g of LAN + 10g of hydrophobic bagasse powder, free flowing
 2,5g of LAN + 10g of hydrophobic bagasse powder,
(iv) 5.0g of LAN only

- (v) 5,0g of LAN + 10g of hydrophobic bigasse powder,
 free flowing
- (vi) 6,0g of LAN + 10g of hydrophobic bagasse powder, compressed into a tablet

(vii) 10g of LAN only

- (viii) 10g of LAN + 10g of hydrophobic bagasse powder, free flowing
- (ix) 10g of LAN 10g of hydrophobic bagesee pouder, compressed into a tablet

Three replications of each of the above fertilizers were prepared and wrapped in tissue paper. 27 x 280ml plastic pots with pin holes in their bases were filled with marine sand and the fertilizer blends buried in them. Successive 50ml alignets of water were then poured over the sand in such cup and the electrical conductivities of the individual leachates measured.

(iii) Results and discussion

The concentrations and cumulative amounts of soluble salts (as > of controls) in the leachates from the above treatments are presented in Table 42.

These results show that the hydrophobic begasse powder effectively reduces the leaching losses of LAN. Even at a weight to weight ratio of 1:1, only 64% of the soluble materials are released after 5 leachings. The rate of fertilizer release from the compacted material is slightly slower than that of the free flowing form. However, for practical purposes they can be considered to be similar.



-239-

2b. The effectiveness of wet aggregated briquettes in reducing leaching losses

Although dry formed briquettes made under pressure offer a prectical means of hendling an otherwise very bulky system, the briquettes so formed are weak. With normal transport and handling they quickly break down. If the briquettes could be wet moulded and redried, it would then be possible to produce a product of adequate strength. Furthermore, a very abaorbant powder, such as wood flour (particle size 400 µm), would give fertilizers with a high concentration of N.

The effectiveness of wet blends to reduce leaching losses was investigated.

(i) Materials

Urea, LAN and (NH4)2SO4 were used with wood flour and the Daxad stabilized styrene-2EHA copolymer dispersion.

(ii) Experimental procedure

2,5g of urea were dissolved in 2,5g of the dispersion at 0,5% solids and then mixed in with 1,5g of wood flour. The damp mixture was moulded by hand into a briquette and dried at 250 and 50% R.H. for 2 weeks. The process was duplicated, but 2,5g of water replaced the dilute copolymer dispersion. Three replications of each treatment were prepared.

The above six camples were repeated but the 2,5g of urea

- (111) 55,0ml of 10% (NH4)2504 solution + 0,05g of styrene-2EHA . copolymer at pH 4,0 mixed with 16g of wood flour end briquetted;
- (iv) Control with ordinary wood flour omitted by accident;
 (v) 13,7ml of 50% (NH_b)₂SO_b in water.

One of the above fertilizer blends was buried about 3cm deep in each of the 51 containers. Three replications of each treatment were prepared. 2g of superphosphate and 2g of KC1 were worked into the top 5cm of the soil and then 4 maize seeds were planted in each pot. The plants were kept watered to excess (water percolated from the drainage holes) and frum time to time a composite trace element mixture was applied. After 6 weeks the plants were harvested, dried, weighed and analyzed for N.

A second crop wee grown after planting 4 more meize seeds, and a further 2g of superphasphate and 2g of KCl were worked into the soil. No further N was applied. At six weeks the plants were hervested, weighed and analysed. The cycle was repeated for a further two crops. Although the high C.V. (%) values indicate that exactly equal quantities of water should have been applied to each container when watering, the yield differences obtained are considered to be sufficiently interesting to be recorded in Table 44.

3c. Results and discussion

The results in Table 44 show that the dry-blended urea wood flour treatments gave far greater and more prolonged yield increases and N uptakes then ony of the wet blends. The dry blends of 1g of urea with 2g of wood flour showed the greatest

primary react is reaching investing in a consideration becaused with a super-respected in a constant amount of a constant of a super-respected in a constant amount of a constant of a constant of a constant amount of a constant of a constant of a constant amount of a constant of a constant of a constant amount of a constant amount of a constant of a constant of a amount of a constant of a constant of a constant amount of a constant of a constant of a constant amount of a constant of a constant of a constant of a amount of a constant of a constant of a constant of a amount of a constant of a constant of a constant of a amount of a constant of a constant of a constant of a amount of a constant of a constant of a constant of a amount of a constant of a constant of a constant of a amount of a constant of a constant of a constant of a amount of a constant of a constant of a constant of a amount of a constant of a constant of a constant of a amount of a constant of a constant of a constant of a amount of a constant of a constant of a constant of a amount of a constant of a constant of a constant of a amount of a constant of a constant of a constant of a amount of a constant of a constant of a constant of a amount of a constant of a constant of a constant of a amount of a constant of a constant of a constant of a amount of a constant of a constant of a constant of a am

Lies Land Ama, mo.

It is a state of the entities gain (M, 1) pulliate a state of the entities gain (M, 1) pulliate a state of the entities gain (M, 1) pulliate a state of the entities gain (M, 1) pulliate a state of the entities for the entities of the entits of the entits of the entities of the entit

Loss fact binat a second and and analysis of the construction of the construction of the billion of the second second fraction of the second billion of a second billion of the second parts, which all a second down a billion of the billion of the second second billion of the billion of the billion of the second billion of the billion of the billion of the billion of the second billion of the billion of the billion of the billion of the second billion of the billion of the billion of the billion of the second billion of the billion of the billion of the billion of the second billion of the second billion of the b yield increase (25%) over the control treatment incorporating ures with ordinary wood flour.

In contrast to the dry blends, the wet blends incorporating ures in the presence of polymer gave dramatically depressed yields in Grops 2 and 3, when compared to the ures - ordinary wood flour briquettes. The facts that at Grop 1 the wet polymer had a beneficial effect on the performance and that the leaching results in Table 43 with LAN and (NH4)₂SO4 gave no hint of such large losses, indicate that the loss is gradual. This suggests that more volatilization, microbial assimilation or mineralisation of N is occuring, owing to the fertilizer being held closer to the surface in a humid-alkaline environment. An analysis of these briquettes at the end of the experiment revealed that they contained virtually no N. This, combined with the poor yields, indicates that the N was lost from the soil.

The blending of NH4ND3 with either ordinary wood flour or with polymer treated wood flour had a depressing effect on yield, compared to ordinary fertilizer. The (NH4)2SD4, in contrast to the urea and NH4ND3, in wet applications in the presence of the copolymer (see Table 39, page 214), produced a beneficial effect on yield at Crop 1 (38% more than control where a 20% (NH4)2SD4 solution was used).

The fact that none of the wet treatments containing copolymer showed increases in yield after Crop 1 indicates that these systems have no value as long term, slow release fertilizers. In dry blended systems, urea can give improved uptakes of N in the presence of copolymer, while in wet systems, $(NH_4)_2SO_4$ seems the most suitable form of N to use.

-242-

A dry urea - hydrophobic - wood flour treatment and a wet (NH4)2504 copolymer treatment were therefore included in field experiments with maize.

4. Field experiments with maize

The two experiments with maize described in subsection 84 of this Chapter (pages 207 and 208) each had a dry controlledrelease N fertilizer treatment included in them. In the trial planted in 1976 (NH₆)₂SO₆ was dry blended with hydrophobic marine sand in a weight ratio of 1:4,4. This loose dry blend was drilled about 3cm deep and 5cm away from the planting line. Details of the treatments and results of the leaf N concentrations and total dry plant weights are reported in Appendix 22. The leaf analyses show that at all three fertilizer levels the N % from the plats receiving (NH₆)₂SO₆ blended with hydrophobic sand were slightly lower, though not statistically so, then where (NH₆)₂SO₆ alone was applied. This observation confirms the low total nutrient release (7.%), with this fertilizer to sand ratio (Table 41).

Therefore, in the next trial plented in October 1977, urea was used with hydrophobic wood flour at a weight ratio of 1:1,1. This blend was again drilled about Jom deep and about Jom away from the plenting line. Details of the treatments, leaf N concentrations and grain and total plent yields are presented in Table 39.

The results show that at the 50 kg N/ha level this treatment use the only one to give a statistical increase over control in grain yield. The grain yield use 413 kg/ha or 5,0% more than the split application control receiving the some amount In addition to the higher grain yield, the leaf N % values and total plant yields were all significantly higher than the 50 kg N/ha controlm. However, this increase in efficiency was not maintained at the 100 and 150 kg N/ha levels. At the highest N levels the modified dry fertilizer recovered an average of only 5% more N than the control, compared to 13% for the wet fertilizer treatment and 1% for the polymer mulch application.

In order to try to explain these observations more fully it is necessary to detail the individual leaf N % results for the dry urea - hydrophobic wood flour blends.

			Le	of N Co	ntents	(2))	
Wood flou	r : Urea	N level	Replications				
	kg/ha	122	11	2	3	Meens	
120	: 109	50	2,88	2,78	2,92	2,86	
240	: 218	100	2,34	3,00	2,36	2,57	
360	: 327	150	3,22	3,02	2,20	3,12	

It is noted that agreement between the 3 replications at the 50 kg N/ha level is good. Mowever, at the 400 N and 450 N levels it is poor, with 3 out of 5 N % values being abnormally low. These extremely low results point to the "fixing" effects suggested by Martakis (1977), and the results recorded in Table 42, where increasing ratios of hydrophobic begasse powder to LAN severely reduced the total amounts of LAN colubilized after 5 x 50ml leachings. It is suggested that the same reason responsible for these low recoveries of LAN is cousing the sporadic poor N uptakes shown in the above table: that is, that the total quantity of hydrophobic

-244-

meterial is excessive, thus preventing soil water of low hydrostetic head from permeating it. This concept, therefore, suggests that in these dry free-flowing blends, the volume or surface area of hydrophobic material is more important than the concentration of fertilizer present. This is in contrast to the wet systems, where fertilizer concentration is still considered to be the main factor controlling release rate.

From the above maize field experiment it would seem that at the 100 and 150 kg N/he levels variations in the thickness, i.e. exposed surface of the drilled wood flour bands, determines the amount of urea stabilized. The distribution of urea through this hydrophobic mass is another variable. However, at the 50 kg N/ha level variations in thickness are unimportant because the volume of wood flour is sufficiently low to allow complete permeation of water. Figure 13 is an attempt to illustrate the above variations schematically.

The critical level of wood flour is suggested as being somewhere between 120 and 240 kg/hs when applied in the manner of the experiment. Until this is more accurately determined it is suggested that levels of hydrophobic wood flour should not exceed 120 kg/hs, irrespective of the amount of urea blended with it.

It would seem from this first attempt to correlate observed leboratory leaching losses with practical crop responses, that, for both solid and liquid fertilizers containing copolymer dispersions, it is better to have the supply rates too fast (but slower than control) and ensure complete release, than to have them too low and starve the plants. Further field trials will be necessary to confirm these

-245-



Figure 13: Suggested explanation for erratic leaf N % results from dry blend control release fertilizers

-246-

conclusions.

5. Summery and discussion

Insoluble powders (organic or inorganic) were shown to be rendered strongly hydrophobic after mixing with low concentrations of copolymer dispersion and then drying. These modified powders retard the movement of water through them and therefore reduce the leaching losses of any soluble materials they may contain. In situ soils, for example, can be made to give a more gradual release of nutrients if liquid fertilizers applied to them contain low concentrations of a copolymer dispersion. Solid conventional fertilizers can also be solubilized more gradually if dry-blended with pre-treated hydrophobic powder.

In the Let systeme where the fertilizer and hydrophobic particles are an integral system, the concentration of Pertilizer dictates the rate of nutrient release, whereas in the dry free-flowing blends the total amount, or surface area, of hydrophobic material present is all important. These two governing factors seem to have critical levels above which release is absolute, but at a slower rate than conventional fertilizers. It is under these conditions that most benefit from added fertilizer is obtained.

The value of the hydronhobic concept in true slow release Pertilizers for trees, pastures and other long term vegetation, seems limited unless mudified to ensure that N held in situ for long periods is not volatilized or consumed by soil microbes. thesis would be as follows: Of the N fertilizers dry blended with hydrophobic particles, uses should be the form used. If hydrophobic wood flour is used and drilled in nerrow bends approximately im opert, the amount should not exceed 120 kg/hs, irrespective of the smount of uses present.

For the liquid systems, (NH₆)₂50% at approximately 35% concentration is suggested as ideal, as rates of release below about 20% are inadequate. This concentration of 35% should remain constant and will dictate the amounts of liquid soplied per area. To obtain the added benefits of the mulching effect, the surface area saturated should be as continuous as possible. However, where low levels of fertilizer are required in crops such as wheat, whose seeds are broadcast or planted close together, it is unlikely that the low volume of liquid required would cover the whole soil surface. In such cases the fertilizer would probably have to be sprayed in macrow lines, and the advantages of moisture conservation sporificed.

Comparing the liquid and solid systems, it would seem that additional benefits obtained from using the former include moisture conservation; increased temperatures in wet soils; controlled release of other soluble soil additives, such as herbicides; reduced soil erosion; and increased efficiency through incorporating several operations into one.

One advantage of the solid system is that it is more conventional in Southern Africa and therefore stands a greater chance of being accepted. The disadvantage of possible separation in the bag of dry free-flowing blends could perhaps be overcome by adding the fertilizer and polymer treated naterial into separate happens on the back of a tractor. Each

-248-

hopper would be fitted with a screw delivery mechanism metering the two components into a very short common fertilizer drill. CHAPTER X

GENERAL SUMMARY AND CONCLUSIONS

SIGNIFICANCE OF POLYMER DISPERSION COMPOSITIONS

The initial laboratory investigations with a Wide range of different polymer dispersions revealed two potentially useful properties which some of them impart to sand. These were, firstly, the ability to bond individual sand grains into thick, strong aggregates and, secondly, the ability to make the sand hydrophobic. All individual commercially available dispersions tested could impart one or other of these effects, but never both. However, by blending approximately 15 parts of a hydrophobic-inducing polymer dispersion with 85 parts of a strong bonding type it was possible to produce sand aggregates with strong water repellent properties. Thus, using combinations of these dispersions, an ordinary sand could take on 3 modified forms. These were:

- a hard, thick, consolidated crust which would allow water to percolate through it;
- (11) a herd, thick, consolidated crust which would still be dry inside after many days submersion in a low head of water, and
- (111) a loose, free-flowing form on which water would pool without ever percolating into it.

Following further work to try to understand and optimise what ingredients or properties of the dispersions were responsible for inducing theon two different effects in sond, the

-250-

following conclusions were drawn: the type of stabilizer used during the polymerisation reaction determines the ability of the final dilute dispersion to bond sand. It would seem that those stabilizers preventing the polymer particles from coming together through ionic forces form weak bonds, while those types relying on stearic forces produce strong ones. The observation that reducing levels of one such stearic stabilizer (a natural gum) produced bonds with increasing strength indicates that a form of dispersion instability is necessary for bond formation. Lower levels of stabilizer also produce dispersions with largerpolymer particles. These two facts indicate that relative dimensions are important in locating the polymer at the points of sand grain contact. It is this locating mechanism which makes some polymer dispersions extremely efficient at bonding sand, thus permitting them to compete with far cheaper bonding materials such as cement, lime and bitumen.

The amount of copolymer dispersion needed to induce the hydrophobic effect was even lower than the levels needed for bonding. Certain commercially available types at polymer solids contents of 50% were able to produce hydrophobic sand even after being diluted 1 000 times with water. This high efficiency permitted the effect to be considered further in cost critical spriculturel applications.

Laboratory tests showed that the PVAc homopolymer dispersions failed to induce the water repellent effect even after solubilizing the polymer in methanol. This was taken as en indication that the ability to impart the hydrophobic effect is a function of the polymer itself and not, as is suggested with the mechanism of bonding, of the stabilizing system.

-251-

When the VAc was copolymerized with any of the less water soluble monomers (even as little as 15%), the water repellent effect was generated. Films of such copolymers were also shown to be relatively resistent to hydrolysis by dilute caustic solution, whereas the PVAc homopolymer films were completely decomposed by it. It is suggested therefore, that the hydrophabic effect is caused by an infinitely thin costing of water-insoluble polymer around the grains of sand. The presence of any water sensitive materials such as PVAc homopolymer and play (which swell) or salts (which dissolve) was shown to reduce the hydrophobic effect. Because these relationships are linear they offer a means of controlling the intensity of water repellency. Potential applications of such effects could therefore be considered.

In addition to the hydrophobic sand restricting the movement of water as a liquid, it also reduced eveporation by inhibiting the novement of moisture vepour. This was achieved in a wide range of soil types at low rates of copolymer addition.

9. GRADING OF FEASIBLE APPLICATIONS

 Conservation of moisture, fertilizers and herbicides in spricultural applications

Of all the potential uses for polymerised dispersions considered in this thesis, the reduction in evaporation of uster from agricultural soils (with its associated benefits of increased wet soil temperatures and increased fertilizer and herbicide efficiencies) is considered the most likely to find practical application. One reason for this conclusion

-252-

is that the benefits can be quantitatively measured. For example, in pot plant experiments it was shown that where the sand surface had received a copolymer dispersion treatment, 32% more dry plant matter was produced from the same amount of water. Total plant yields from two separate replicated field trials with maize were greater (40, % and 11,3%) where 40 kg of dry copolymer per hectare were applied with adequate N. More important is that 514 kg/hs or 6,7% more grain was also produced. This represents an increased profit of some 40 rand/hs for a copolymer dispersion cost of about 20 rand/hs.

In a field trial with sugar case on a weak, sundy soil, an over row application of 33 kg/he of dry copolymer (value approximately 66 rand) yielded 13 tons/he more case and 2,3 tons/he more sugar (value approximately 200 rand). In two other trials on soils of higher water holding capacities, similar significant increases in case yields were obtained using only 10 kg/he of dry copolymer, thus returning even greater relative economic gains. Because, of the levels used to date case yield has proved to be linearly related to the emount of copolymer applied, it seems probable that the maximum benefit could be considerably greater.

The increases in suger case yields were indicated early in the crop by the greater populations of shorts (39% more at 5 months). This earlier tillering effect was even achieved with much lower levels of copolymer (5 kg/ha dry), elthough finel yield increase did not follow. However, earlier development is accompanied by side effects which could bring financial benefit through cost savings. These include the reduction in number of wead eradication accretions and the prount of re-

-253-

planting necessitated by the occurance of temporary droughts.

-254-

Further savings could be schieved by the increased efficiency of water consitive soil additives such as fertilizers, herbicides and insecticides. For example the leaf N % values were 7, % higher and the indicated total emounts of N recovered by a maize crop 25% greater, where plots received their 150 kg of N/hs as a 19,2% (NH₆)₂SO₆ liquid fertilizer containing 0,5% of a styrene-2EMA copolymer dispersion. The extra stability offered by the Daxed stabilized copolymer dispersions makes the mixing and application a simple and infallible operation.

Withough the empont of copolymer applied is infinitesimal compared to the mass of the soil in a field, consideration may have to be given to the possibility of accumulation of polymer with repeated use. A solution to this potential problem would be to use a butadiene containing polymer, without added antioxident. This would result in oxidation of the unsaturated bonds present in the butadiene molecule (see page 7) and the destruction of the polymer. With the elevated temperatures and exposure to UV light at the soil surface, this decomposition would be fairly repid. The addition of copper or iron would accelerate the breakdown further. Sin degredeeble versions of the other polymers could no doubt be developed, if demend warranted it.

Solid controlled release fertilizers

The blending of dry fertilizers with hydrophobic eand or ground up cellulose offers a checp and apparently successful way of improving the officiency of fertilizers. This could be perticularly useful in sendy soils watered by erratic rainfalls, where losses of fertilizer by leaching are greatest. In a maize trial on a Clovelly soil (14% clay) 109 kg/hs of urea dry blended with 120 kg of hydrophobic wood flour yielded 413 kg, or 5,9%, more maize than did a standard treatment receiving the same amount of N as (NH4)2504. The extra grain yielded was worth approximately 33 rand/hs, while the 2,4 kg dry copolymer necessary to treat the wood flour cost less than 5 rand. Even doubling this cost to allow for the expense of grinding, mixing and sun drying the wood or straw, the profit seems attractive.

The cost of rendering 120 kg of sand hydrophobic would be as low as 1,7 cents (South African) because of the lower absorbancy of this material. Furthermore, using sand in the place of wood eliminates the grinding operation and allows the material to be air dried more easily because there is **less** risk of it being blown away. Sand, as the inert carrier on which to generate the hydrophobic effect, seems well suited for use in small scale farming. However, in affluent, organised agricultural systems it is possible that the hydrophobic material would be produced in the more controlleble conditions of a factory. Transport considerations would then possibly favour the use of the lighter, compressible organis powders.

Load bearing epplications

As more yield results become available, the applications under headings 1 and 2 above will undoubtedly be modified. However, they are needy for implementation in their present

-255-

form. In contrast, load bearing applications of polymer dispersions will be limited until their observed tendencies to soften under wet conditions are overcome. However, because of the urgent need for roads and low cost housing, and the great expense involved, the feasibility of this application being accepted in the future must be ranked fairly high. Suggested lines of future polymer research would include the investigation of, firstly, polymerising of monomers of even lower solubility than styrene and 2EHA with the Daxad type stabilizers and, secondly, the incorporation of solvents to give complete coalescence of the films.

In its present form the Daxad stabilized styrene-2EHA copolymer dispersion with an mft of 23C could be useful in arid, remote areas. Its advantage over other building materials would be its much lower transport costs. For example, a 2001 drum of the concentrate at 70% solids content would be diluted on site with 1 200 1 of water. This would aggregate some 17 tons of dry sand. The load-bearing properties of such aggregates will increase with the level of clay present. This ability to bond all types of soil irrespective of the quality of the dilution water means that only the concentrated copolymer dispersion would need to be imported.

Another factor that will delay the acceptance of this bonding system is the slow drying rate. Apart from adding the minimum amount of water when mixing in the dispersion, changes in present building techniques could also facilitate quicker drying. For example, roads could be raised like railway lines, instead of being excavated down into damp layers. Similarly, instead of meking bricks or blocks which have to be dried and then bonded together, a vapour permeable system of shuttering would

-256-

allow whole walls to be cast in one operation in situ. Such modified building systems will require the co-operation of civil engineers, specifications officials and local authorities, and this could well be a lengthy process.

Control of water erosion on embankments

Although some specific copolymer dispersions have been advocated for this application for many years, the cost effectiveness of the benefits they impart is debatable. Certainly the hydroseeders in South Africa are disillusioned with their performance. It is perhaps presumptious to think that the improvements indicated by the findings in this thesis will overcome this prejudice, however the observed improvements in erosion control on the highly erodable slimes dumps when using fairly high levels (51/m2) of low concentrations of polymer dispersions (1%) may be relevant in this sphere. The use of a soft Daxad stabilized copolymer dispersion at the above rates should give maximum surface soil bonding, elevated temperatures in wet soils and some extra moisture conservation. A separate, very light, application of the same copolymer dispersion containing (NH4)2504 and KC1 at a combined concentration of about 30% might give a more prolonged supply of N and K. Benefits that may ensue are: protection against erosion until grass is established, earlier and better germination of seeds where temperatures are marginal, and better growth and reseeding under conditions of erratic rainfall.

5. Control of wind erosion in confined areas

Where the total area of loose sand or sandy soil is

sufficiently small to be completely treated in a short space of time, the application of polymer dispersions has merit. This is especially true where the cost of overcoming the problem forms only a small part of a capital intensive project. These areas are often surrounded by hebitable buildings and an advantage of the polymer sprey over the more conventional methods of spreading topsoil, esh, brushwood, spraying bitumen and similar treatments is that it is a rapid, clean and odcurless technique which does not senthetically change the environment.

5. Control of wind erosion over extensive areas

Although this was the first of several potential applications considered in this thesis, it appears to be the one with least chance of being generally accepted. The main reasons for this are the high costs involved and a lack of proven deformance when compared to other accepted systeme (such as the spreading of brushwood, reeds, topsoil and similar materials). Enly the treatment of several large scale areas could supply positive evidence of permanent success and even the most confident contractor would be reluctant to guarantee success on such a scale. Houever, because the objective in most areas requiring stabilization against wind prosion is ultimately the establishment of vegetation, results gained from research into polymer dispersions carried out for this thesis could be used to compliment existing procedures. For example, so a surface epray in conjunction with bruchwood barriers. The barriers would reduce the velocity of wind blown send, while the correct dispersion would enhance the growth of vegetation through, firstly, consolidating the cand within the burriers and preventing it and seed being removed, secondly, conserving water through reduced suscerstion and.

-258-

PHYSICAL PROPERTIES OF THE 10 COMMERCIAL DISPERSIONS USED

Dispersion type	Total solids (%) (approximate)	Viscosity (cps at 20C)	рН	Surface tension (dynes/cm)	Minimum film forming temperature (C)	Average particle size (microns)	Polymer S.G.
PVAc(1) homopolymer	56,5	150 190	4,5 - 5,5	52	18	1,0	1,18
PVAc(2) homopolymer	56,5	160-190	4,5 - 5,5	52	18	1,0	1, 18
PVAc(3) homopolymer	56,0	5-7 paise	4,5 - 5,5	50	18	1.1	1, 18
PVAc(4) homopolymer	56,5	500-600	4,5 - 5,5	46	18	1,0	1,18
PVAc-ZEHA copolymer	56,0	275-375	4,5 - 5,5	444	6	· 0,7 · · ···	1,18
PVAc-VeoVa copolymer	55,0	450-550	4,5 - 5,5	44	9	0,8	1, 15
Styrene-2EHA	51,0	500-900	8,5 - 9,5	35	8	0,2	7,04
MMA-ZEHA	50,0	180-375	8,5 - 9,5	50	3	0,3	1,08
SBR Carb.	50,0	275 cps	8,5 - 9,5	49	В	0,12	1,00
SBR Uncarb.	65,0	500 cps	8,5 - 9,5	32	0	0,13	1,00

-259-

PHYSICAL PROPERTIES OF EXPERIMENTAL DISPERSIONS POLYMERISED

Monomers	Stabilizer	Total solids (%)	Viscosity Met cup 4 (cps)	Surface tension (dynes/cm)	Particle size (microns)	рH	mft (C)	Briquette modulus of rupture (mb)
100 VA	Gum	57,8	175	51	1,8	4,9	15	3670
100 VA	Gum + oil	56,0	121	50	1,8	5,1	16	3310
70 MMA/30 EHA	Gum + oil	44,7	135	48	0, 12	5,5	Est 41	1860
60 MMA/40 EHA	Gum + 011	43,2	135	50	0,59	5,7	Est 21	1320
51 MMA/49 EHA	Gum + oil	44,3	121	= 53	0,21	5,7	4	940
87 VA/13 EHA	Gum + oil	46,6	94	45	1, 1	5,9	15	1426
50 MMA/50 BA	PUDH	49,8	254	51	0,46	5,4	5	840
100 VA	Nonionic surfactant	49,4	150	41.	0,62	5,3	16 .	: 0
52 St/48 EHA	Polywet KX4	48,6	170	64	0,23	4,9	8 -	730
49 St/51 EHA	Polywet KX4	47,9	138	59	0,27	4,7	4	670
100 VA	HEC	54.3	134	49	0,76	5.4	16	1060

METHODS OF PHYSICAL ANALYSIS OF DISPERSIONS

A. SURFACE TENSION

Polymer dispersions were diluted 1:1 with demineralized water to avoid skinning and then measurements were taken using the du Nouy tensiometer. The ring was used in preference to the plate.

The instrument was first standardized using the control liquid provided. The diluted polymer dispersion was then poured into a clock glass and this was placed on the circular table. The height of the table was raised, using the clamp provided, until the liquid level was about 1cm below the ring. The pointer and the boom were both set to zero. The liquid was raised, using the fine acrew provided, until it touched the ring. The torsion head was turned until the boom was again on zero and the liquid was then lowered slowly. At the same time the torsion head was turned so that the boom re, mained on zero.

The surface tension was read off the pointer reading when the ring suddenly left the liquid. Three readings were taken and averaged for each sample.

B. AVERAGE PARTICLE SIZE

About 10ml of demineralized water was poured into a 100ml glassstopped volumetric flask. Less than 1g of the polymer dispersion was accurately weighed into it. The flask was shaken to disperse the particles and then the contents made up to volume with demineralized water. After further shaking, the flask was put in an ultrasonic bath for 5 minutes to disperse any agglomerates present. The flask was then cooled and turbidity measurements of samples immediated taken, before coagulation could take place. The test sample was place in a 1cm Spectrophotometer cell and the light absorbance measured at the 3 appropriate wavelengths (1 000, 450 and 330 mµ). If the reading exceeded 1,0 then the sample was further diluted to give a reading between 0,2 and 0,4. If the reading fell below 0,1 then either a longer cell was used or the sample remade using more dispersion. The spectrophotometer is most sensitive between readings of 0,2 to 0,4.

The weight average particle diameter is calculated from the specific turbidity, t/c.

$$\frac{t}{c} = \frac{A \lambda c}{f w s}$$

where A is the absorbance as measured directly on the spectrophotomete >-is the wavelength in mu as set

f is the appropriate factor for the polymer type

w is the weight of dispersion diluted to 100ml

s is the fraction (ω/ω) of the dispersion which is polymer.

By looking up the specific turbidity value on the correct m table the corresponding average particle size value is found.

C. pH

These measurements were conducted on the undiluted dispersions, using a single electrode pH meter after the instrument had been calibrated at pH values of 4 and 9.

D. GRIT LEVEL

The grit level is the weight of dry material retained on a 120 mesh sieve after passing 100 cc of dispersion through it.

E. VISCOSITY

The time taken for the dispersion at 20C to flow through a commercial available Metrovick flow cup 4 was measured. The first change from a continuous to a broken stream was taken as the end point. By using the tables supplied by the manufacturers the times recorded in seconds were converted to viscosity values in centipoises.

F. TOTAL SOLIDS

Approximately 5g of the dispersion under test was poured into an aluminium cup. The cup, which had been previously weighed to 4 decime point places, was reweighed. The cup and contents were then left in a forced draft oven at 120C for 3 hours. After cooling in a dessicator the cup and contents were reweighed. From the loss in weight, the tot solids content of the dispersion was calculated.

-264-

APPENDIX 4

ASSESSMENT OF PVAc HOMOPOLYMER DISTRIBUTION

A. INTRODUCTION

One way of trying to determine the polymer concentrations down a profile of marine sand would be to take samples and determine the weight losses at, say 300C. However, it was felt that the breakdown of any calcareous, or organic matter present would introduce errors. The following test was therefore conducted in an effort to assess the distribution of polymer.

8. MATERIALS AND PROCEDURE

The PVAc homopolymer dispersion at 1% solids and graded marine send (> 250 mµ < 750 mµ) were used.

Eight of the stainless steel moulds (5cm x 3,5cm x 0,95cm) used in the Richards rupture test were taped together to form a rectangular hollow shaft. Wooden match stick spacers were placed between each mould so that the metal did not make contact. The shaft was stood upright on a suspended nonwoven fabric and completely filled with loose, dry sand. The gum stabilized PVAc dispersion was then dripped evenly over the exposed surface of the sand until it percolated out through the bottom. The column was then dried at 25C and 50% RH for 21 days before the tapes were removed. The spacers were pulled out and a hacksaw blade used to carefully cut through the columns of sand. The 8 resulting sand briquettes were numbered from top to bottom and their modulus of rupture strengths determined. The results of the 8 successive briquettes taken down the column of sand are presented in the following table.

Tensile strengths of successive sand briquettes cut from a column of sand where the PVAc dispersion was applied to the surface (Means of 2 determinations)

	Briquette No. from top								
	1	2	3	4	5	6	7	8	
Tensile strength in millibars	3201	1945	2118	4249	6491	6 190	6191	6 193	

These results indicate that there is very little filtering out of PVAc homopolymer as the briquettes from the lower half of the cylinder are the strongest. The higher strength may be due to, firstly, the draining of the polymer containing liquid to lower depths and, secondly, a better "packing" of the sand due to the weight of sand and liquid above. The weaker second and third briquettes, relative to the surface one, indicates that there has been some migration of the polymer upwards to the surface on drying out.

-265-

-266-

APPENDIX 5

THE EFFECTS OF pH AND SALT CONCENTRATION

. MATERIALS AND PROCEDURE

Hydrochloric acid and potassium hydroxide were used to make up a series of solutions with pH values of 3, 4, 5, 6, 7, 8, 9 and 10.

Solutions of sodium chloride, celcium chloride and ferric chloride were also made up. These were diluted to give concentrations of 0,05, 0,10, 0,24, 0,48, 0,96, 1,91 and 2,87%.

The above four sets of solutions were used separately to dilute the gum stabilized PVAc homopolymer from its original solids of 56% down to 1.0%. 34g of each of these liquids were then mixed with 180g of graded marine send and moulded in the Richards rupture test moulds. Four replications using each liquid were prepared. The moulds were dried at 55C for 17 hours. When cool the bonded send samples were removed from the moulds and the tensile strengths measured.

B. RESULTS AND DISCUSSION

1. pH

The modulus of rupture strengths on the samples made with the PVAc homopolymer dispersions at different pH values were us follows.

3

Effect of pH of the dilution water on tensile strengths of sand briguettes containing D, 19% polymer (Means of 4 determinations)

рН	3	4	,5	6	7	8	9	10
Tensile strength (milli- bars)	1211	1231	- 1913	1964	1740	2259	1872	1872 .
	c.v.	(%) =	8,5%;	LSt	5% =	153	1% =	214

Although the PVAc homopolymer is remarkably stable to pH change, there is a definite fall-off in bonding performance as the pH falls below 5. In practical applications alkali should be added to the dispersion if the pH falls below this level.

2. Salt concentrations

The modulus of rupture strengths obtained with the sand briquettes formed using the PVAc homopolymer with different soluble salt concentrations were as follows.

The effects of increasing concentrations of monovalent, divalent and trivalent ions on sand aggregated with 0,19% PVAc homopolymer (Means of 5 determinations)

				Salt	conce	entrat	ian ((%)			
Salt type	D	0,05	0, 10	0,24	0,48	0,96	1,91	2,87	C.V. (%)	L8 5%	5D 1%
			Ter	sile	stren	ngth (milli	bars))		
Sodium chloride	2890	2422	2686	2493	2249	2035	1903	1659	9,4	193	265
Celcium chloride	2707	2259	2 127	1648	1475	1018	509	305	9,5	132	173
Ferric chloride	2330	1323	1547	977	1282	722	265	92	13.8	132	183

It would seem that the presence of trivalent ions, even at very low levels, seriously affects the bond strengths. Divalent ions have a lesser, but still significant, effect; while the bond strengths are not seriously affected by low levels of monovalent ions.

-269-

APPENDIX 6

A CRUDE TEST TO ASSESS RESISTANCE OF SAND BRIQUETTES TO SAND BLASTING.

A. INTRODUCTION

Various means of simulating the effect of natural sand blasting were considered. Although the spraying of sand under pressure from a modified spray gun gave the right effect, control over the system was difficult.

B. MATERIALS AND PROCEDURE

2kg of 2mm diameter lead shot were allowed to fall from a height of 160mm and strike the face of the sand briquetten which were supported at an angle of 45°. The erosion was expressed as the percentage loss in weight of the sand briguette measured before and after treatment.

C. RESULTS AND DISCUSSION

Typical values for the gum stabilized PVAc dispersion and an SBR carboxylated copolymer were as below

5

Reductions in weight of synthetically bound sand samples when subjected to a test intended to simulate the eroding effect of wind blown sand (Means of 6 determinations)

Concentration of	Binder Type					
dispersion	PVAc	SBR				
%	% loss in sample weight					
1	15	56				
2	8	14				
3	6	0				
4	5	0				

It is interesting to note that although the PVAc dispersion is far more efficient at low concentrations, the SBR applied at 3% solids resists erosion completely.



Gold/Gourf 1207 1200 G 308 Diamonds/Diamante D Prototo in the law Coal/Strenkopl Ċ 10004 Copper/Koper ĸ Distic of Carriedon/Strassestatasetting 2000-0 v lean/Yster DESERVATIONAL 120.hm M Manganese/Mangaaa DCATION Parterillaria 0-400-А Ashestos/Ashes 5 · Zegerala Pogabori Citrus/Sitrus S Traffich # 1-habbe 75 W Wheat/Koring 9 7 Tobacco/Tabak Sugar/Soiker PRETORIA 5 Yum. Boundary of Wheat Farming Anothiol? TES EXPERIMENTS. Grees: Koringhoerdery 111-24 Carleborulles Children . Boundary of Maize Farming Grens: Mieliebondery WARDAN Sector and MAERE Boundary of Viticulture Control 1 Grens: Wynboerdery Managasta 74. Lapan Maize Quadrant Y. Loter SAND Minlin-vierboek G - Mainan WERE Mr. Contractions Kiniberter STABL IZING Contrainer's Blog CONDUCTED Monntontuir/w 0 XOURBAN 310 200 L'altractatta straterat D Or Ase WINTER BEINORAENOL Great Chains Sec. as making Wildling South 24 CG CG CLOORDA - Liberto Can Limitelle CAPE TOWNE

1.1

4. 1. 25.27

A. . .

LAYOUT OF PLOTS AT THE SAND STABILIZATION

DESERVATIONAL TRIAL AT MUIZENBURG


-273-

APPENDIX 9 ATTEMPTS TO DETAIN AN AIR DRYING FDAM MULCH

A. LIQUID FDAMING COMPOUND

1. Introduction

A number of chemical and physical methods of foaming were investigated. The most practical system would be a chemical one in which the polymer containing liquid could have a blowing agent drawn into it as it left the hose, thus causing it to foam on the soil. However, all types investigated had the disadvantage of requiring heat for foam initiation. Perhaps a heat generating applicator could be devised. The most reliable method of foam production was found to be the use of a mechanical foaming machine, such as is employed in the production of sponge rubber carpet backings. While it is relatively simple to produce a polymer based foam with a high solids content that would air-dry without collepsing, the cost makes it unfeasible. The maximum total polymer solids content considered to be acceptable was about 2%.

Materials and procedure

A number of blends of polymer dispersions, foaming aids, thickeners and gelling agents were prepared. Combinations tested to give partially destabilized systems at room temperatures were: mild acids with natural rubber latex, borax with polyvinyl alcohol stabilized dispersions, alkali with alkali thickenable polymer dispersions or alkali thickenable celluloses, and the thickening interactions between groups of natural modified gums. The polymer dispersion mixtures prepared were mechanically foamed in an ordinary household kitchen mixer until the density of the foam was 20% of that of the original liquid. Two 6mm thick glass plates were placed 10cm apart on a jute cloth. A glass rod was then supported across the space between the plates and used to spread a blob of foam into a layer 6mm thick. These spreads were left to air dry and their resistance to collapse noted.

Results and discussion

The most promising results were obtained with a mixture incorporating a gelling agent. The formulations of the two parts which would be metered separately into a mechanical foaming machine were as follows:

Part A Water, PVAc homopolymer (10% plasticiser), Guar gum and nonionic surfactant.

Part B 10% Potassium dichromate and green chrome oxide dye.

However, even this best mixture collapsed noticeably before drying to give a layer of about 1mm thick.

8. MECHANICAL FDAMING MACHINES

Commercially available foaming machines consist essentially of a monopump, a mixing head (where air from a compressor is monitored into the compound) and a long delivery hose. These systems are, however, very unwieldly (see Plate 50). Although such a machine was used for trials, a much smaller portable machine not requiring a separate compressor is also available (see Plate 51). Unfortunately seeds cannot be included in the foam mixture as this portable machine has an eccentric pump which crushes even the

-274-

smallest grass seeds. A need exists for a portable foaming machine through which grass seeds can pass undamaged.

-

-276-

foaming machine



Plate 51: Polymer-containing foam being produced by a generator driven carpet backing foamer. Note the large generator necessary.



Plate 52: A portable petrol driven foaming unit. Note intake of green gelling agent. _air

-foan head

> /deli hose



APPARATUS USED FOR DETERMINING RELATIVE HARDNESS OF POLYMER FILMS



APPENDIX 11

-278-

THE EFFECTS OF VARIOUS ADDITIVES TO POLYMER DISPERSIONS ON THE SUBSEQUENT TENSILE STRENGTHS OF SAND BRIQUETTES

A. MATERIALS AND PROCEDURE

The various modified polymer dispersions were blended with graded marine sand (>250 μ m <750 μ m) at the levels required. These mixtures were used to fill the stainless steel briquette moulds of the Richards rupture tester and then dried at 55C overnight. The bonded sand samples were removed from the moulds and duplicate samples tested dry and after submersion in water for 17 hours. The modulus of rupture results obtained on the Richards rupture tester are listed below. The gum stabilized PVAc dispersion was used.

B. RESULTS

		Tensile strength (millibars)		
Poly	ymer types and levels of additives	Dry	After 17 hours soaking	
1)	PVAc at 0,57% + 3% commercial wax emulsion (50% active)	4263	733	
2)	PVAc at 0,57% + 2% commercial wax emulsion (50% active)	4457	763	
3)	PVAc at 0.57% + % commercial wax emulsion (50% active)	10256	834	
4)	PVAc at 0,57% + 0,5% commercial wax emulsion (50% active)	16026	1302	
5)	PVAc at 0,57% + 0,4% commercial wax emulsion (50% active)	17298	1099	
6)	PVAc at 0,57% + 0,3% commercial wax emulsion (50% active)	1806 1	10.18	
7)	PVAc at 0,57% + 0,2% commercial wax emulsion (50% active)	18234	1010	
8)	PVAc at 0,57% + 0,1% commercial wax emulsion (5D% active)	20269	906	

		Tensile strength (millibara)			
Poly	mer types and levels of additives	Dry .	After 17 hours soaking		
	2	201.74	DEE		
9)	PVAc at 0,57% only	20431	665		
10)	with ordinary sand	2951	763		
11)	MMA-BA et 5,0% + 0,5% wax with water repellent sand	4396	1547		
12)	PVAc at 0,56% + 0,5% silicone	18651	753		
13)	PVAc at 0,38% + % methano1	not determined	570		
14)	PVAc at 0,38% + 5% methanol	not determined	5 19		
15)	PVAc at 0,35% + Butyl carbitol acetate at 7% dried at 550	not determined	468		
16)	PVAc at 0,35% + Butyl carbitol acetate at 2% dried at 55C	not determined	478		
17)	PVAc at 0,35% + Butyl carbitol acetate at 3% dried at 55C	not determined	448		
18)	PVAc at 0,35% + Butyl carbitol acetate at 4% dried at 55C	not determined	4 17		
19)	PVAc at 0,35% + Butyl carbitol acetate at 5% dried at 55C	not determined	407		
20)	PVAc at 0,35% + Butyl carbitol acetate at 10% dried at 550	not determined	437		
21)	PVAc at 0,35% + Sutyl carbitol acetate at 20% dried at 550	not determined	387		
22)	PVAc at 0,35% + Butyl carbitel acetate at 2% air dried 7 days	not determined	315		
23)	PVAc at 0,35% + Butyl carbitol acetate at 2% air dried 14 days	not determined	285		
24)	PVAc at 0,35% + Butyl carbitol acetate at 2% air dried 21 days	not determined	326		
25)	PVAc at 0,35% dissolved in methanol	not determined	1282		
26)	90 MMA : 10 2EHA surfactant stabilized 0,57% + 1% MEK	855	153		
27)	90 MMA : 10 2EHA surfactant stabilized 0,57% + 3% MEK	773	173		
28)	90 MMA : 10 2EHA surfactant stabilized 0,57% + 6% MEK	784	112		
29)	70 MMA : 30 2ENA gum stabilized 0,55% + 1% MEK	15263	1038		
30)	70 MMA : 30 2EHA gum stabilized 0,55% + 3% MEK	13401	1252		
31)	70 MMA : 30 2EHA gum stabilized	2 166-18	1170		

		. Tensile strength (millibars)		
Poly	mer types and levels of additives	Dry	After 17 hours socking	
32)	70 MMA : 30 2EHA gum stabilized 0,55% + 1% BCA	13655	1048	
33)	70 MMA : 30 2EHA gum stabilized	12800	845	
34)	70 MMA : 30 2EHA gum stabilized 0,55% + 6% BCA	4314	722	
35)	70 MMA : 30 2EHA gum stabilized 0,55%	14672	600	
36)	70 MMA : 30 2EHA gum stabilized 0,55% + 0,5% wax emulsion	3317	631	

2

APPENDIX 12

THE EFFECTS OF BITUMEN ADDITIONS TO POLYMER DISPERSIONS ON THE SUBSEQUENT TENSILE STRENGTHS OF SAND BRIQUETTES

A. MATERIALS AND PROCEDURE

The PVAc homopolymer stabilized with natural gum (A) was used. Graded marine sand (>250 μ m < 750 μ m) was used with different bitumen types, amounts and mixing procedures. Sand briquettes were prepared as shown before in Appendix 11 and the modulus of rupture strengths determined on them. Duplicate samples were tested dry and after submersion in water for 17 hours. The results of various briquettes containing 0,5% dry polymer on a dry sand basis are tabled below.

8. RESULTS

								Tensil (mil	Tensile strengt (millibars)		
	Polymer types and levels of bitumen							Dry	After 1 hours sosking		
1.	Bite	men la	ev	<u>e1</u>	13.07						
	1)	PVAc	:	Emulsified	bitumen	(1:1)			15263	1393	
	2)	PVAc	:	Emulsified	bitumen	(1:0,8)			15904	1374	
	3)	PVAc	:	Emulsified	bitumen	(1:0,7)			17298	2 106	
	4)	PVAc	;	Emulsified	bitumen	(1:0,6)			16280	1903	
	5)	PVAc	:	Emulaified	bitumen	(1:0,5)			1806 1	2117	
2.	pH E	ffect									
	6)	PVAc	:	Emulsified	bitumen	(1:0,3)	рH	5.0	17577	885	
	7)	PVAc	:	Emulsified	bitumen	(1:0,3)	pH	5,2	16280	845	
	8)	PVAc	:	Emulsified	bitumen	(1:0,3)	pH	5,4	16840	895	
	9)	PVAc	:	Emulsified	bitumen	(1:0,3)	pH	5,8	16840	1007	
1	10)	PVAG	:	Emulsified	bitumen	(1:0,3)	pH	6,2	16433	916	
	11)	PVAc	:	Emulsified	bitumen	(1:0,3)	pH	6,2	16534	10 17	
				41 41 2		122					

		Tensile stren (millibars)		
	F	olymer types and levels of bitumen .	Dry	After hour soaki
3.	Diff	ferent dispersions		
	13)	PVAc : Emylsified bitumen (1:0,3)	15771	661
15	14)	Styrene :- 2EHA gum stabilized (1:0,3)	13228	641
4.	Diff	ferent production batches of PVAc		
	15)	PVAc : Emulsified bitumen (1:0,3) Batch A	16555	631
	16)	PVAc : Emulsified bitumen (1:0,3) Batch 8	15263	550
	17)	PVAc : Emulsified bitumen (1:0,3) Batch C	15263	621
	18)	PVAc : Emulsified bitumen (1:0,3) Batch D	15772	600
	19)	PVAc : Emulsified bitumen (1:0,3) Batch E	16023	570
5.	Bitu	amen in solvent		
	20)	PVAg : bitumen in toluene (20:1)	2 1368	1343
6)	Dest	tabilization of bitumen in liquid blend		
	21)	PVAc : Emulsified bitumen (1:0,3) stirred nil time	15263	254
	22)	PVAc : Emulsified bitumen (1:0,3) stirred 5 minutes	15771	366
	23)	PVAc : Emulsified bitumen (1:0,3) stirred 10 minutes	155 17	427
	24)	PVAc : Emulsified bitumen (1:0,3) stirred 20 minutes	155 17	407
	25)	PVAc : Emulsified bitumen (1:0,3) stirred 30 minutes	15771	407
	26)	PVAc : Emulsified bitumen (1:0,3) + 0, % alum	16280	1200
	27)	PVAc : Emulsified bitumen (1:0,3) + 1,0% alum	16585	1160
	28)	PVAc : Emulsified bitumen (1: .3) + 2,0% alum	16840	12 10
	29)	PVAc : Emulsified bitumen (1:0,3); 0,1% NaCl in liquid	13736	651
	30)	PVAc : Emulsified bitumen (1:0,3); 0,25% NaCl in liquid	14245	458
	31)	PVAc : Emulsified bitumen (1:0,3); 0,50% NaCl in liquid	15263	437

2

		Tensil (mil)	a streng libars)
	olymer types and levels of bitumen	Dry	After hourn soakin
32)	PVAc : Emulsified bitumen (1:0,3); 1,0% NaCl in liquid	13736	356
33)	PVAc : Emulsified bitumen (1:0,3); 1,2% NaCl in liquid	14245	407
34)	PVAc : Emulsified bitumen (1:0,3); 1,3% NaCl in liquid	14245	570
35)	PVAc : Emulsified bitumen (1:0,3); 2,0% NaCl in liquid	13228	417
36)	PVAc : Emulsified bitumen (1:0,3); 3,0% NaCl in liquid	122 10	163
37)	PVAc : Emulsified bitumen (1:0,3); 4,0% Natl in liquid	3083	D
38)	Well washed sand	14754	865
Dest	abilization of bitumen in sand		
39)	PVAc : Emulsified bitumen (1:0,3); mixing hand no compaction	13736	539
40)	PVAc : Emulsified bitumen (1:0,3); mild rolling in mould	13736	265
41)	PVAc : Emulsified bitumen (1:0,3); severe rolling in mould	13736	478
42)	PVAc : Emulsified bitumen (1:0,3); severe compaction in mould	14245	458
43)	PVAc : Emulsified bitumen (1:0,3); hand mixed	14245	234
44)	PVAc : Emulsified bitumen (1:0,3); slow speed 1 minute	14245	153
45)	PVAc : Emulsified bitumen (1:0,3); slow	46290	463

46) PVAc : Emulaified bitumen (1:0,3); high speed 6 minutes 14245

0

7.

-283-

-284-

APPENDIX 13

THE EFFECTS OF WATER LEVEL ON TENSILE STRENGTHS OF SUBSEQUENT POLYMER BOUND SAND BRIQUETTES

A. INTRODUCTION

Although the surfactant stabilized water resistant dispersions failed to aggregate sand at 0,19% polymer, at 0,5% they were able to do so. To try to reduce the migration of these polymers to the surface of the sand, the effect on bond strength of the use of lower levels of mixing water was investigated.

8. MATERIALS AND PROCEDURE

Graded marine send as mentioned in Appendix 11 was used. Dispersions chosen for study were the PVAc homopolymer, an 80:20 blend of this dispersion with the surfactant stabilized styrene-2EHA copolymer, and the styrene-2EHA copolymer alone. The amounts of dry polymer to dry sand were maintained at 0,5%, but the water was adjusted to give 2,0%, 5,0%, 7,5%, 10,0% and 20,0% by weight on dry sand. The polymer dispersions were prediluted with these quantities of water before they were mixed into the sand. Briquettes were formed as before (Appendix 11) and subjected to modulus of rupture tests. Dry briquettes and briquettes submerged for 4 hours in water were tested.

C. RESULTS AND DISCUSSION

The tensile strengths of the various briquettes prepared as above are tabled below.

Tensile strengths of sand-polymer briquettes made using different ratios of liquid to sand at 0,5% polymer on sand, before and after soaking (Means of 2 replicates)

Level of water (% on sand)	i Surfa stebi MMA- . copo	ctant lized 2EHA lymer	Coll surfa stabi Styren copo	oid + ctant lized e-2EHA lymer	Gum stabilized PVAc homopolymer		
	-	Tens	ile stren	gth (mil	libers)		
	Dry	Wet	Dry	Wet	Dry	Wet	
2,0	2249	611	1465	285	could not mi		
5,0	2116	550	3643	712	20523	944	
7,5	1374	468	4223	1364	19587	904	
10,0	1028	397	3032	875	20350	931	
20,0	824	275	1902	722	20523	938	

Although there is some improvement in dry bonding performance with the addition of varying levels of water, the strengths imparted by the all-acrylic and styrene-acrylic copolymers are still very much below those of the gum stabilized PVAc homopolymer. It would seem that the greater water resistance of the polymer films are of little value without a stabilizing system which allows the polymer to be located.

APPENDIX 14

PHYSICAL PROPERTIES OF DAXAD

STABILIZED STYRENE-ACRYLIC COPOLYMER

Grade	Physical properties							
	Total solids (%)	Surface tension (dynes/ cm)	mft (c)	рН	Vis- cosity (cps)	Grit (%)	Avera partic size (mu)	
Daxad stabilized Styrene-2EHA copolymer	50,8	54	21	3	100	0,5	D, 15 -	

APPENDIX 15

EFFECT OF DIFFERENT COALESCING SOLVENTS ON THE UNCONFINED COMPRESSIVE STRENGTHS OF SAND CORES BOUND WITH DAXAD STABILIZED STYRENE-ACRYLIC COPOLYMER

A. INTRODUCTION

Films produced from polymers dissolved in solvents resist softening in water far more effectively than those produced from polymer dispersion. This indicates that the separate polymer particles of the dispersion are not completely integrated. A number of coalescing agents were therefore tested with the hard Daxad stabilized styrene-2EHA copolyme dispersion to try to increase its bond strengths after sosking.

B. MATERIALS AND PROCEDURE

A range of commercially available solvents was selected. Various amounts of these were added to the copolymer dispersion very slowly, with high speed stirring. After a 24 hour period to permit complete plasticisation of the polymer particles, the dispersions were used to make sand cores as described in Chapter VII. Because over drying of the samples influences the rate of solvent evaporation relative to water, a series of cores was air dried for 21 days before testing. The unconfined compressive strengths were determined on dry samples, samples that had been submerged for 4 hours and, in some cases, that had been submerged for 4 days. The results of these strengths are listed below.

C. RESULTS AND DISCUSSION

1. Air dried for 21 days

Coalescing solvent (level on polymer)		mft (C)	Unconfined compressive strength (kPa)			
			Dry	4 hours soak	4 day soak	
	(0%)	22	16 10	322	not determined	
Hexylene glycol	(6%)	13	1064	515	322	
Ethylene glycol	(6%)	14	1161	464	333	
Polysolvan 0	(6%)	6	1161	367	258	
Dalpad A	(3%)	13	1288	258	not determined	
Dalpad A	(4%)	11	1546	386	not determined	
Dalpad A	(5%)	9	1224	322	not determined	
Dalpad A	(6%)	7	902	258	142	
Dalpad A	(10%)	not determined	1159	386		
Dalpad A	(20%)	not determined	966	386	not determined	
Dalpad A	(30%)	not determined	580	193	not determined	
Dalpad A	(40%)	not determined	0	o	not determined	
Dalpad A	(50%)	not determined	0	0	not determined	
Butyl dioxitol	(3%)	15	1224	193	not determined	
Butyl dioxitol	(4%)	14	1352	386	not determined	
Butyl dioxitol	(5%)	13	1087	386	not determined	
Butyl dioxitol	(6%)	12	1288	258	not determined	
Oxitol acetate	(3%)	15	1674	515	not determined	
Oxitol acetate	(4%)	13	966	580	not determined	
Oxitol acetate	(5%)	12	708	386	not determined	
Oxitol acetate	(6%)	9	902	386	not determined	

-288-

Coalescing solvent	Unconfined compressive strength (kPa)			
(level on polymer)	Dry	4 hour soak		
Nil	1739	644		
5%	1095	258		
10%	1030	193		
20%	580	129		
30%	193	64		
40%	0	D		
50%	0	٥		

2. Oven dried at 55C for 17 hours

All the above coalescing solvents reduced the load bearing properties imparted to sand by the copolymer dispersion, when used at levels greater than 3%. It would seem that oxitol acetate at 3% on polymer solids produces the most suitable compromise between mft and load bearing properties.

-290-APPENDIX 16

SUGAR CANE RANDOMISED BLOCK EXPERIMENT WITH

DIFFERENT MDISTURE CONSERVING TREATMENTS

1. Field layout and plot sizes

Location: Field 4 C.F.S. Mount Edgecombe



Statistical analysis 2.

45 51 50 47
45 53 50
53
45
48
- 47
Tota

Source	Degrees of freedom	Sums of squares	Mean squares	t (20 5%	DF)
Blocks	4	608			
Treatments	5	778	155,6	14,4	19,9
Error	20	2446	122,3		
Total	29	3832			

Standard error of a single plot = 11,05. C.V.(%) = 11,3 Significant at the 10% level.

2b. Analysis of variance of stalk populations x 10³/hectare at harvest

Plot numbers in same sequence as above.

Tre	atments					Totals
А	122	105	114	109	130	581
8	102	106	102	121	117	548
С	106	118	120	112	113	569
D	114	124	119	130	124	611
E	123	117	127	118	117	602
F	110	112	116	118	112	568
	677	683	698	708	713	3479

Source	Degrees of freedom	Sums of squares	Mean squares	t (20 5%	DF) 1%
Blocks	4	151			
Treatments	5	547	109,4	8,9	12,2
Error	20	925	46,3		
Total	89	19	10000		

Standard error of a single plot = 6,80. C.V. (%) = 5,8

20.	Analysis of	variance of	stick	lengths (in	cm) at	t harvest
	Plot numbers	as in 2a	-			

1 -

Trea	atment					Totals
A -	205	182	189	185	187	948
8	178	174	197	2 18	205	972
С	170	175	184	187	177	893
D	181	187	189	2 14	196	967
Ε	199	186	186	180	201	952
F	193	195	175	198	197	958
	1126	1099	1120	1182	1163	5690
_		and the second se				

Source	Degrees of freedom	Sums of squares	Mean squares	t (20 5%	DF) 1%
Blocks	4	759			
Treatments	5	815	163,2	14,5	19,8
Error	20	2452	122,6		
Total	29	4027			

Standard error of a single plot = 11,07 C.V. (%) = 5,8



APPENDIX 18

FIELD LAYOUT AND INCREASES IN SHOOT POPULATIONS OF RATOON

CANE RECEIVING A SPRAY OF DILUTE COPOLYMER DISPERSION

1. Site treated in mid winter

Location:	Undloti section,	Huletts	Estates
Soil:	Clansthal series		
Variety:	NCo : 376		

Lines 1,2 metres apart



Sprayed + 60cm over row = 3,6 tons/hectare

ROAD

Treatments	Mean number of shoots per 23 metre line				
	20/5/77	28/6/77	25/6/77	10/11/77	
Polymer - Rous A-D	274	400	355	373	
Control - Rows F-J	290	342	352	350	
Folymer - Rows L-M	301	437	400	440	
Control - Rows Q-T	278	320	280	308	

2.	Site treated in early summer							
	Situation:	Umhloti section : Huletts Estate. Sandwich Field						
	Soil type:	Clansthal						
	Cane variety:	NCo 805						
	Ratoon cane:	4 months old						



(i) Shoot counts

100 T 100

Raw No.	Row lengths (metres)	Shoot	Counts	20	per hectare
		7/9/77	10/11/77	Increase	x 103
1	80	380	960	258	92
2	80	387	1225	317	118
3	81	467	1118	239	106
4	81	500	1109	222	105
5	82	507	1185	234	111
6	83	524	1228	234	117
7	85	463	1295	280	117
8	88	446	1290	289	113
9	89	461	1197	250	104
10	90	646	1280	198	110
11	90	819	1649	201	141
12 Cont	90	718	1755	244	150

-296-

Row	Row lengths	Shoot	Counts	%	per hectare	
No.	(metres)	7/9/77	10/11/77	Increase	× 10 ³	
13 (missed)	91	687	128 1	187	108	
14	91	595	12 13	204	103	
15	92	585	1528	278	136	
16	92	646	1689	262	141	
17	93	584	1748	299	245	

(ii) Cane yields (13/11/78)

Row No's	Treatment	Tons cane/ha	Means	
1 - 4	Water	75,7	72,7	
5 - 8	Water	69,7		
9 - 12	Copolymer	64,8	66,6	
14 - 17	Copolymer	68,4		
19 - 21	Control	64,1	68,4	
22 - 25	Control	72,7		
C.V. (%) = 7,6	LSD = !	5% = 12.9: 10	6 = 19.5	

APPENDIX 19 LAYOUT OF PLANT CANE TRIAL WHERE COPOLYMER DISPERSION WAS APPLIED BY TRACTOR

...

-298-

Layout of trial 1.

Location: Umhloti section - Huletts Estate

Soil: Clansthal series



CANE BREAK

NE

2. Statistical analysis

(1) Count on 11/11/77 (ell 8 lines)

	Plot 1	2	3	4	
Row 1	190	130	172	130	622
2	191	159	179	114	643
3	189	174	185	150	698
4	164	128	160	167	619
5	185	130	173	170	658
6	162	118	156	130	566
7	190	172	198	155	715
n				No.16	24.2

	-	-	-	
-	9	1.2	-	-
-	£.,	2	-	-
			-	

Source	Degrees of freedom	Sums of squares	Mean - square	EMS
Treatments	3	4332		
Blocks orks	7	6733		1.16
Error	21	5976	284,6	16,9
Total orm	31	17041	201	1

C.V. (%) = 10,6LSD: 5% = 71% = 9

(ii) Counts on 20/1/78 (Centre 3 lines in each plot)

Control	467	503	536	5 16	537	491	3050
Treated	67 7	649	723	613	645	693	4000
	1144	1152	1259	1129	1182	1184	7050

Source	Degrees of freedom	Sums of squares	Mean square	EMS	
Treatments	1	5988			
Blocks	5	75208			
Error	5	5331	1066,2	32,6	
Total	11	86527			

C.V. (%) = 5,6

LSD $5\% = 67,3 \times 223 = 15 \times 10^3$ t(SDF) $1\% = 91,1 \times 223 = 21 \times 10^3$ (iii) Counts on 27/2/78 (Centre 4 lines in each plot)

	C	T	C	T
2477	566	6 12	607	692
2 193	528	5 15	560	590
2397	562	660	535	640
2241	541	589	503	608
9308	2 197	2376	2205	2530

Source	Degrees of freedom	Sums of squares	Mean square	EMS	
Treatments	3	13 188			
Blocks	3	18849	5		
Error	9	10500	1167	34,2	
Total	15	42537	982		

C.V. (%) = 5,9LSD: $5\% = 49,9 \times 223 = 11 \times 10^3$ t(9DF) $1\% = 67,6 \times 223 = 15 \times 10^3$

(iv) Stalk populations at harvest, 9/11/77 (Centre
4 lines in each plot)

	Sta	lk popula	tions (x	10 ³ /ha)	Set 8
	T	C	т	C	Letter 1
1	104	113	107	101	425
	123	120	95	81	4 19
	118	109	110	115	452
	117	114	113	112	456
	462	456	425	409	1752

_		
-		
	_	

Source	Degrees of freedom	Sums of squares	Mean square	EMG	
Treatments	3	478			
Blocks	3	263			
Error	9	839	99,22	9,96	
Total	15 -	1634	4r		

C.V. (%) = 9,1 LSD: 5% = 15,0 t(9DF) 1% = 20,8

(v) Yield (Centre 4 lines in each plot)

T	C	т	C	
74,2	61,6	71,4	68,1	295,3
95,9	85,0	73,1	63,5	317,5
84,8	80,0	68,5	73,1	306,4
87,9	76,6	71, 1	63,6	299,2
342,8	323,2	284,1	268,3	12 18,4

Source	Degrees of freedom	Sums of squares	Mean square	EMS
Treatments	3	885,8		1.5
Blocks	3	71,3	31, 13	5,58
Error -	9	280,2	-	
Total	15	1237,32		

C.V. (%) = 7,3 LSD: 5% = 8,4 t(9DF) 1% = 11,6

-302-

APPENDIX 20

APPLIED AND REDUCED EVAPORATION OF SOIL WATER

1. INTRODUCTION

Three possible ways of increasing the amounts of polymer per unit area of soil were apparent. These were

- to apply increasing volumes of water containing the same level of copolymer;
- (ii) to increase concentrations of copolymer in the same volume of water, and
- to apply dry pre-treated hydrophobic sand in increasing amounts.
- 2. MATERIALS AND PROCEDURE
- 2a. Increasing volumes of the same concentration of copolymer

280ml plastic containers were filled with 200g of dry soil of the Clansthal series. The surfactant stabilized styrene-2EHA copolymer dispersion was diluted fifty times to a polymer solids content of 1% and then different amounts equivalent to 0,7, 1,1, 1,4 and 1,8 ℓ/m^2 were dripped onto the soil surfaces. The soils were dried in a constant temperature (25C), relative humidity (50% RH) room for one week then weighed. Exactly 30ml of water was then poured onto each. The cups were weighed immediately after being in the constant temperature - RH room and again every 24 hours thereafter, to determine the rate of moisture loss. Three replications of each treatment were included and the mean results are tabled below. 2b. The same plastic drinking cups as above were filled with

200g of graded marine sand. The copolymer dispersion was diluted to give solids contents of 0%, 0,5%, 0,7%, 1,0%, 2,0%, 5,0% and 10% and a constant amount of liquid (equivalent to 0,71/m²) was dripped onto the sand surfaces. There were three replications of each treatment and the sand was air dried, as above, before 30ml aliquots of water were added and the relative rates of evaporation determined.

2c. 25 of the same plastic cups as above were filled with 200g

of graded marine sand. 10g samples of 3 different types of sand were then sprinkled onto the surfaces. These were: ordinary sand, sand pre-treated to give the hydrophobic effect with 0,05% styrene-2EHA copolymer (on a dry polymer to dry sand basis) and sand pre-treated with 0,05% of the PVAc homopolymer. This sand formed layers about 1mm thick. The procedure was repeated, but the amounts of sand applied were increased to 30g which gave layers about 3mm thick.

30ml aliquots of water were then poured into each cup and these were weighed. All cups were re-weighed at 24 hour intervals after being kept in the constant temperature room. The changes in weight with time are tabled below.

RESULTS AND DISCUSSION

The losses of moisture with time for the various treatments were as follows:

-303-

3a. Moisture retention of a Clansthal sand at 25C and 50% RH, which received a % solids styrene-2EHA copolymer in increasing amounts (Means of 3 determinations)

Amount of 1% dispersion added over 45 cm ²	% Retention of 30ml of added water (after drying polymer containing soil)							
	24 hours	48 hours	72 hours	96 hours	120 hours	192 hours	216 hours	241 hou
0	60,1	49,8	38,5	30,6	22,3	8,3	6,0	4,
3,0m1 (0,71/m2)	69,0	59,9	53,4	46,6	40,8	20,7	15,6	11,3
4,5ml (1,11/m ²)	71,3	65,2	57.4	51,3	46,3	26,7	21,7	15,
6,0ml (1,41/m ²)	74,7	69,8	62,1	56,5	51,2	32,9	27,2	22,
7,5ml (1,81/m ²)	79,0	74,0	67,7	62,3	59,0	43,0	38,3	33,
C.V. (%)	2,9	3,9	4,7	6,0	7,1	5,8	6,4	8,
LSD 5%	3,3	4,3	4,5	5,1	5,5	2,6	2,4	2,1
150	4,2	5,8	6,2	6,9	7,4	3,6	3,3	3,1

3b. Moisture retention of marine sand at 25C and 50% RH having rece 3ml of a surface mulch of styrene-2EHA copolymer dispersion at increasing concentrations (Means of 3 determinations)

120 hours	144	46.0	100
1027	hours	168 hours	26 hour
21	14	12	
42	31	22	1
44	32	22	
48	38	29	1
52	43	34	
60	52	43	1
60	52	44	1
10,8	15,0	17,6	26
9	10	9	4
12	13	12	6
	hours 21 42 44 48 52 60 60 60 10,8 9 12	hours hours 21 14 42 31 44 32 48 38 52 43 60 52 60 52 10,8 15,0 9 10 12 13	hourshourshours21141242312244322248382952433460524360524410,815,017,69109121312

3c. Moisture retention of marine sand at 25C and 50% RH having surface mulches of dry polymer treated sand (0,05% dry styrene-) acrylic on dry sand) (Means of 3 determinations)

	% Ret	ention of in	nitial wate:	r added		
	3,6 kg/m ² of loose sand					
	24 hours	48 hours	72 hours	96 hot		
Control	65,3	37,2	20,0	9,1		
Styrene-2EHA sand mulch	66,0	40,0	28,3	15,1		
PVAc homopolymer sand mulch	66,0	39,6	28,0	15,3		
	10,8 kg/m ² of loose sand					
Styrene-2EHA send mulch	84,4	71,2	64,1	58,6		
PVAc homopolymer sand mulch	68,4	41,3	28,1	22,1		
C.V. (%)	4,3	6,3	8,0	9,		
LSD 5%	4,0	3,8	4,8	4,2		
150	5,4	5,2	6,5	5,		

In all cases increased amounts of copolymer dispersion increased the amounts of soil water conserved. However, while the relationship ser linear in case 2a. above, the relative effectiveness at high copolyme concentrations (10%) seems to fall off. The use of thicker layers, containing lower levels, seems preferable. Such thick layers would all be less easily ruptured and therefore the effect would be more permanent. Although the dry hydrophobic sand needed to be applied in fairly thick layers before it became effective, its cost will be extremely low. This is because sand requires much less copolymer to be rendered hydrophobic than soil does.

APPENDIX 21

-306-

DETAILS OF EXPERIMENT TO TEST THE EFFECT OF DIFFERENT CONCENTRATIONS OF A STYRENE-ZEHA COPOLYMER DISPERSION ON EARLY TILLERING OF SUGAR CANE

1. Layout of trial

Situation:	Illovo Eston	Sugar	Company,
	(Midlar	(abr	

Soil type: Ostadale series

Cane variety: NCo 376

1	2	3	4 8	5	6	7
C	G	E		F	A	D
8	9	10	11	12	13	14 8
F	A	C	D	E	G	
15	15	17	18	19 A	20	21
E	8	G	F		C	D
22	23	24	25	26	27	28
D	F	A	C	8	E	G

Treatments: 30cm wide bands over the row

A : Control : 15001/ha at 0,5% polymer solids 8 : 10004/ha at 0,5% polymer solids C : 10001/ha at 0,75% polymer solids D 10002/ha at 1,0% polymer solids ε . 5001/ha at 1.0% polymer solids : 5001/ha at 2,0% polymer solids G :



8 lines



NA

2. Statistical analysis

- (i) Shoot counts 14/12/77

	1		1 1	hari	1 år
A	- 110	128	101	77	416
8	104	109	118	62	413
С	151	114	91	- 77	433
D	103	119	94	95	411
ε	122	130	151	80	483
F	115	126	111	98	450
G	139	93	104	101	437
	844	819	770	610	3043

Source	Degrees of freedom	Sums of squares	Mean square	EMS
8locks	3	989	1	
Treatments	6	4733		
Error	18	5164	286,9	16,9
Total	27	10886	1	

C.V. (%) = 15,6 LSD 5% = 17 t(18DF) 1% = 24

(ii) Shoot counts 27/1/78

E	192	177	166	169	704
0 F	165	140	157	152	625
C	222	156	162	171	711
8	190	160	183	172	705
A	148	145	138	146	577

	-	2	10	
-	- 5	21	25	-
	-	-		

Source	Deg fr	reedo	of m	Sums of squares	Mean square	EMS
Blocks		3	\$	2867		
Treatments	1.	6	÷	. 4915	3 1	
Error		18		2390	133	11,5
Total	v	27		10172	1/14	

C.V. (%) = 6,8LSD 5% = 12t(18DF) 1% = 16

小田田町

(iii) Stick counts at harvest (number per 4 x 10m lines)

1	1	Rep				
Treatments	1	2	3	4	Totals	Mean x 10 ³ /ha
Α.	551	486	491	473	2001	114
8	521	556	550	415	2042	116
C	384	495	513	534	1926	110
D	520	531	546	492	2089	119
E	610	564	557	509	2240	127
F	501	614	493	548	2 156	123
G	508	550	474	505	2037	115
Totals	3595	3796	3624	3476	14491	1.55

Source	Degrees of freedom	Sums of squares	Mean square	EMS
Blocks	3	74,75		11
Treatments	6	160,07		
Error	18	413,05	22,95	4,79
Total	27	647,87	No. 19	×1878

C.V. (%) = 9,3% LSD 5% = 7,006 x 227,3 = 16 x $10^3/ha$
(iv) Cane	yields at	harvest	(kgs per	4 x 1	Om lines)
-----------	-----------	---------	----------	-------	-----------

1 I		Replications					
Treatments	1	2	3	-4	Totals	Mean	tons/ha
A	451	435	373	405	1664	-	94,6
8	453	434	411	412	1710		97,3
C T	350	419	413	423	41605	-	91,1
D	454	451	440	439	1784	1	01,4
ε	550	445	468	427	1890	1	37,5
F	435	509	399	478	1821	1	13,4
G	426	434	373	399	1632		92,7
Totals	3119	3127	2877	2983	12 106	2	

Source	Degrees of freedom	Sums of squares	Mean square	EMS
Blocks	3	6128		
Treatments	6	16695		
Error	18	20499	1138,83	33,8
Total	27	43322		

C.V. (%) = 7,8% LSD 5% = 49,1 x 227,3 = 11,2 t(18DF) 1% = 66,8 x 227,3 = 15,2

9

APPENDIX 22

DETAILS OF PLOT DESIGN, SOIL DESCRIPTION, RAINFALL AND STATISTICAL ANALYSIS OF A MAIZE TRIAL DESIGNED TO GIVE GREATER YIELDS THROUGH CONSERVATION OF MDISTURE AND/OR FERTILIZER.

1976-1977 season 1.

1a. Layout of trial

Location: Government Experimental Farm, Dundee, Natal Soil series: Avalon (analytical details follow)

		11-11-11-11-11-11-11-11-11-11-11-11-11-		Treatments
36 B	35 F	34 1	33 C	A. 238 kg/ha of (NH4)2504 ove row (50 kg N)
32 J	31	30 G	29 D	 B. 476 kg/he of (NH₄)₂SO₄over row (100 kg N) C. 714 kg/ha of (NH₄)₂SO₄ ove row (150 kg N)
28 K	27 Н	26 A	25 E	 D. As in A dry blended with 9 kg of repellent sand - dri E. As in B dry blended with 1
24 6	23 B	22 H	21 I	<pre>kg of repellent sand - dri F. As in C dry blended with 2 kg of repellent sand - dri G. As in A dissolved in 10004</pre>
20 C	19 К	18 F	17 E	of 0,5% styrene-2EHA - ove H. As in 8 dissolved in 2000/ of 0,5% styrene-2EHA - ove
16 D	15 ມ	14 A	13 L	I. As in C dissolved in 3000£ of 0,5% styrene-2EHA - ove J. 750£/ha of 0,5% styrene) 7 2EH6 - over row
12 J	11 Н	10 G	8	<pre>K. 1500l/ha of 0,5% styrene)(-2EHA - over row) L. 2250l/ha of 0,5% styrene) !</pre>
a c	7 8	6 D	5 E	-2EHA - over row)
4 L	3 F	2 A	1 I	Net 4 rows x 0,9 x 6,8 = 24,8



ib. Description of soil

FARINA, M.P.W., 1970. Potassium studies on an Avalon medium sam losm. Ph.D. Thesis. University of Natal, Pietermaritzburg.

Selected physical and chemical characteristics of six soil horizon of an Avalon medium sandy loam.

	Horizon (cm)						
	0 - 15	15 - 30	30 - 45	45 - 60	60 - 75	75 -	
	1	Particle :	size distr	ibution % ((hydromete:	r)	
c. sand	12	12	12	9	7	6	
m. sand	27	24	27	18	12	11	
f. sand	43	45	31	33	30	. 28	
silt	4	4	6	6	B	8	
clay	14	15	24	34	42	46	
	Extract	table catio	ons in me%	(N NH40	Ac pH 7)		
Na	0,02	0,02	0,03	0,12	0,28	0,34	
К	0, 16	0, 15	0, 14	0,12	0,36	0,58	
Ca	0,56	0,63	0,69	0,69	0,94	1,40	
Mg	0,22	0,26	0,81	1,87	4,19	4,56	

	Horizon (cm)							
	0 - 15	15 - 30	30 - 45	45 - 60	60 - 75	75 -		
s value (me%)	0,96	1,06	1,67	2,80	5,77	6,88		
+C.E.C. (me%)	1,61	1,70	3,24	4,58	8,43	9,00		
% base satn	59,5	62,5	51,5	61,0	68,5	76,5		
pH N KC1 (1:2)	3,9	3,9	3,9	4,0	4,5	4,9		
(1:2)	4,9	4.7	4.6	5.0	6.1	6.4		

-312-

1c. Reinfalls for 1976-77 and 1977-78 seasons

1976 - 1	977	1977 - 19	78
Month	Rainfall (mm)	Month	Rainfall (um)
July 1976	0,0	July 1977	0,0
August 1976	1,4	August 1977	7,4
September 1976	22,7	September 1977	104,7
Detober 1976	113,6	October 1977	117,9
November 1976	77,2	November 1977	86,8
December 1976	176,2	December 1977	93,4
January 1977	131,4	January 1978	190,0
February 1977	31,3	February 1978	140,0
March 1977	88,9	March 1978	89,3
April 1977	19,3	April 1978	54,0
May 1977	5,4	May 1978	2,5
Total	667,4	Total	880,0

1d. Leaf N% and total plant weights

2.1

	Treatments	Lear N %	Total plant dry weights (kg/hectare)	Relative total N uptake Leaf N% x Total Dry Yield 300
A.	50 kg N	2,21	9 7 16	215 = 100%
	100 kg N	2,46	9 300	229 = 107%
	150 kg N	2,57	8 675	223 = 104%
8.	50 kg N + Sand	2,25	9 577	215 = 101%
	100 kg N + Sand	2,37	9 7 16	230 = 107% =
	15D kg N + Sand	2,51	8 397	211 = 98%
с.	50 kg N in 1 000 lit. 0,5% emulsion	2,29	9 508	218 = 101%
	100 kg N in 2 000 11t. 0,5% emulsion	2,50	10 271	257 = 120%
	150 kg N in 3 000 lit. 0,5% emulsion	2,58	8 953	231 = 107%
D.	750 lit. 0,5% emulsion	2,55	9 369	239 = 111%
	1500 lit. 0,5% emulsion 150 kg N	2,57	10 132	260 - 121%
	2250 lit. 0,5% emulsion	2,57	8 675	223 = 104%
C.V	. (%)	6,B	18,7	18,0
LSD	5%	0,28	2 398	70
	1%	0,38	3 021	95

.

-313-

te. Statistical analysia

(1) Leaf N %

Source	Degrees of freedom	Sums of squares	Mean	EMS
Blocks	2	0,0497		
Treatments	11	0,6088	- *	1 all
Error	12	0,3345	0,0279	0, 1670
Total	35	0,9930		

C.V. (%) = 6,8 LSD 5% = 0,28% t(120F) 1% = 0,38%

(ii) Total plant yield

Source	Degrees of freedom	Sums of squares	Mean square	EMS
Blocks	2	6		
Treatments	11	12		
Error	12	21	1,75	1,32
Total	35	39		

C.V. (%) = 18,7% LSD 5% = 2398 t(12DF) 1% = 3021

(iii) Indicated absolute N uptake

Source	Degrees of freedom	Sums of squares	Mean square	EMS
Blocks	2	64		-
Treatments	11	65	17, 17	4,1
Error	12	205	-	
Totel	35	335	SVS NO	3

C.V. (%) = 18,8%

2. 1977-1978 season

28. Layout of trial

Location: - Government Experimental Farm, Dundee, Natal Soil series: Avalan

45 D	44 L	43 . F	42 j	41 M
40	39	38	37	36
В	н	Die .	A	U
35	34	33	32	31
G	К	C	ε	Р
30	29	28	27	26
н	а	Ρ	8	ε
25	24	23	22	21
A	C	М	L	К
20	19	18	17	16
N	D	D	G	F
15	14	13	12	11
p	В	G	M	C
10	9	8	7	6
L	F	A	н	N
5	4	3	2	1
З	К	0	D	J

4 TOWS x 6,8 x (24,8m2 8曲

Plot size

Net



Treatments

- H) Liquid fertilizer in 2500£ mulch 100 kg N/ha as (NH4)2504
 J) Liquid fertilizer in 3760£ mulch 150 kg N/ha as (NH4)2504
 K) 2000£ Reverseal mulch/ha and normal fertilizer split 250 kg N/h
- (NH_) 504
- L) 2000% Reverses1 mulch/ha and normal fertilizer split 100 kg N/h (NH,),50,
- M) 2000£ Reverseal mulch/ha and normal fertilizer split 150 kg N/h (NHL)250L
- N) Solid controlled release fertilizer buried 50 kg N/ha as urea
- 0) Solid controlled release fertilizer buried 100 kg N/ha as urea
- D) Solid controlled release fortilizer buried 150 kn N/ha as urea

-315-

2b. Statistical analysis

(1) Grain yields

Source	Degrees of freedom	Sums of squares	Mean square	EMS
Blocks	2	119,65		
Trestment	14	995,54		
Error	28	1392,25	49,72	7,85
Total	44	2507,44		

C.V. (%) = 9,4

LSD 5% = 11,58 x 100 = 1158

t(280F) 1% = 15,44 x 100 = 1544

(ii) Cob counts

Source	Degrees of freedom	Sums of squares	Mean square	EMS
Blocks	2	134		
Treatment	14	3521		1.1
Error	28	3751	134	11,58
Total	44	7506		

C.V. (%) = 6,3 LSD 5% = 19 x 343 = 6517 t(280F) 1% = 25 x 343 = 8575

(iii) Leaf N %

Source	Degrees of Freedom	Sums of squares	Mean square	EMS
Blocks	2	0, 182	-	
Treatment	14	2,098		
Error	28	1,567	0,056	0,237
Tatal	Li 14	3,847	1000	

C.V. (%) = 8,6 LSD 5% = 0,389 t(28DF) 1% = 0,519

Linus 1

(iv) Cob + grain

Source	Degrees of freedom	Sums of squares	Mean square	EMS
Blocks	2	20	n T	
Treatments	14	81	-5-24	
Error	28	112	4	2
Total	44	213		-

C.V. (%) = 8,9 LSD $5\% = 3,282 \times 403 = 1323$ t(28DF) $1\% = 4,376 \times 403 = 1764$

(v) Plant weights minus cobs and grain

Source	Degrees of freedom	Sums of aquares	Mean square	EMS
Blocks	2	1507		-
Treatments	14	458		
Error	28	622	22,2	4,7
Total	1,14	2587		

C.V. (%) = 22,5LSD $5\% = 7,22 \times 403 = 2910$ t(28DF) $1\% = 10,3 \times 403 = 4151$

(vi) Total plant yields

Source	Degrees of freedom	Sums of squares	Mean square	EMS
Blocks	2	686	1	
Treatment	14	1655	114	
Error	28	1085	38,8	6,23
Total	44	3426		

C.V. (%) = 14,3 LSD $5\% = 10,2 \times 403 = 4111$ t(28DF) $\% = 13,6 \times 403 = 5480$

APPENDIX 23

FIELD TRIAL INVESTIGATING THE EFFECT OF COPOLYMER DISPERSION SPRAYS ON THE CONSERVATION OF MOISTURE, FERTILIZER AND HERBICIDE CIPE

A. INTRODUCTION

A five replicated randomised block experiment was put down at the Glendale Sugar Company on a week, sandy Oakleaf form soil under overhead irrigation in order to try to reduce: leaching losses of N and K fertilizers, evaporation in the extremely hot environment, and leaching losses of herbicide. The site chosen was characterised by extremely variable growth and it was hoped that one of the treatments applied might improve the low yielding patches.

B. MATERIALS AND PROCEDURE

The following treatments were applied in June 1976:

- (a) Normal planting. Six litres of 2,4-D per hectare on the row only. Top dressing with 300kg urea and 250kg muriate of potash per hectare three months after planting.
- (b) A mixture of 62kg styrene-2EHA polymer containing 50% solids and six litres of 2,4-D in 4 00D litres of water per hectare sprayed in a band 20cm wide over the came row after planting. Top dressing as in (a).
- (c) A mixture of 300kg urea and 250kg muriate of potesh dissolved in 2 600 litres of water, combined with 62kg of polymer dispersion, watered in a narrow band over the cane setts at planting. Herbicide treatment as in (a).

- (d) The same treatment as (c), but application made three months after planting.
- (e) A mixture of 300kg urea, 250kg muriate of potash, 6 litres of 2,4-D and 62kg of polymer diluted to 4 000 litres with water, applied per hectare in a band 20cm wide over the cane row after planting.

Irrigation was started one week after planting. Shoot counts, height measurements and leaf samples were taken at intervals and final cane yields were recorded. Results of an experiment to assess the effects of copolymer dispersion treatments on the shoot populations, N and K uptakes, herbicide efficiency and final yield of sugar cane.

		St	noot counts/	hectare x 1	03	1	.eaf e	nalya	19	Vield tons
Treatments		10.9.76	6.10.76	19.11.76	5.1.77	15. N	3.77 К	21. N	9.77 % K	cane per hectare on 29.9.77
Α.	Control	29	43	125	180	1,68	1,60	1, 12	1,35	65
	% of Control	(100)	(100)	(100)	(100)	-				1.1
8.	Mulch + 2-4-D	32**	46	145	179	1,66	1,59	1,07	1,36	56
	% of Control	(112)	(107)	(115)	(99)		-			
с.	Thin fertilizer + polymer strip st plent	26	45	137	182	1,66	1,61	1,07	1,33	62
	% of Control	(95)	(105)	(109)	(101)					
D.	Thin fertilizer + polymer strip applied on 6.10.76	28	41	130	178	1,65	1,58	1,08	1,31	53
	% of Control	(96)	(97)	(104)	(99)					Server and
Ε.	Complete treatment	34**	50**	153**	182	1,65	1,58	1, 11	1,32	74
	% of Control	(118)	(115)	(121)	(102)		1.5			
C.V	. (%)	10,7	10,2	18,9		3,9	3,3	4,6	5,3	29,1
LSD	5%	3	4	27		0,06	0,05	0,07	0,09	25

The above results indicate the following:

- (i) As in all previous trials, a wide band of dilute polymer emulsion resulted in a significant increase in shoot counts (21% more than control) from the 3rd month until the sixth month (December). This was most significant in Treatment E, indicating that the early application of fertilizer is beneficial.
- (ii) Leaf analyses at 8 months showed no statistically significant differences between plots receiving N, K and polymer at planting and those receiving N and K at 3 months. The levels were 1,66% N and 1,59% K, but because there were no plots receiving N and K only at planting, it cannot definitely be said that the polymer reduced losses by leaching.
- (iii) No obvious differences between the efficiencies of the herbicide could be noted.

The tremendous variation in yields across the site persisted, making any statistical conclusion impossible. (Yields from different replications of Treatment A varied between 85 and 40 tons/ha. The use of the polymer did not eliminate the poor growth areas and this experiment can be taken as a typical example of "the over extension and over enthusiasm" quoted by W.H. Gardiner in the Introduction of this dissertation.

-321-

APPENDIX 24

LABORATORY APPARATUS USED FOR COMPRESSING DRY POWDERS INTO BRIQUETTES

1

-322-

3

Access hole to add dry powders when steel plate removed

Removable steel plate against w compression tak place Steel sleeve we into position. -Angle iron fram ٤. Plunger attache jack to give cl fit in sleeve Pressure indica (100 MPa) inser into line Commercial pneumatic jack

APPENDIX 25

THE EFFECT OF LEVEL OF PVAC HOMOPOLYMER ON WATER

A. MATERIALS AND PROCEDURE

Graded marine sand (> 250 µm < 750 µm) and the Gum A stabilized PVAc homopolymer dispersion were used. The concentrated PVAc homopolymer (56,5% molids content) was diluted with the required amounts of water to give dispersions with the following molids contents, 3,0%, 2,5%, 2,0%, 1,5%, 1,0%, 0,5%, 0,4%, 0,3%, 0,2% and 0,1%.

285ml of each of these dilutions were then mixed with 1 500g of sand. Five replications of each slurry were poured into Richards rupture test moulds, smoothed off and dried overnight in an oven at 55C.

When dry, each briquette was put into a tared 280ml plastic pot and weighed. Next, 200ml of water was added, so that the briquette was completely immersed. After 17 hours holes were pricked in the bases of the pots and the water drained out. Any residual water was removed using an absorbant paper tissue. The cups and contents were then reweighed and the mass of water absorbed by the sand-polymer samples determined.

-323-

The % uptakes of water by the dry sand-polymer samples (after correcting for polymer contents) are given in the following table.

Solids content of dis- persion	Polymer content on send	Mater	uptake	(% of :	sand we	ight)	Means
(%)	(9.)	1	Rep	nlicatio	ns		
3,0	0,57	27,4	30,4	26,4	29,6	26,6	28,1
2,5	0,47	29,1	28,0	28,2	27,7	28,8	28,4
2,0	0,38	27,6	28,4	29,3	29,3	27,4	28,4
1,5	0,28	29,3	28,9	30,3	29,1	29,3	29,4
1,0	0, 19	29,3	29,6	28,7	29,2	27,5	28,9
0,5	0,09	28,7	26,8	28,3	28,8	30,2	28,6
0,4	0,08	25,5	24,3	24,8	23,8	25,8	24,9
0,3	0,06	23,5	23,5	23,6	24,3	24,3	23,8
0,2	0,04	24,3	24,3	24,7	23,4	24,2	24,2
0,1	0,02	20,3	20,2	20,7	20,7	19,0	20,2
Control	0	23,1	22,3	22,3	22,0	22,3	22,4

The amounts of water absorbed by the sand-PVAc homopolymer briquettes increase as the polymer concentration rises from 0,1% to 1,0% dry polymer on dry sand.

3

-324-

APPENDIX 26

-325-

THE INFLUENCE OF POLYMER BLENDS ON THE INFILTRATION . RATES, FERTILIZER RELEASE RATES AND EVAPORATION RATES OF SANDS MODIFIED WITH THEM

A. INTRODUCTION

Having noted that polymer dispersions can be divided into two groups, depending on whether they impart hydrophilic or hydrophobic properties to soils, the possibility of using blends of them to impart intermediate properties to sand was investigated. Infiltration rates, evaporation rates and leaching rates of fertilizers of modified sands were considered.

B. INFILTRATION RATES

Materials and procedure

Two separate sets of dispersion blends were prepared. In the first, the levels of the PVAc (Gum A stabilized) homopolymer were gredually decreased at the expense of the styrene-ZEHA copolymer (Dexed stabilized), so that the total solids contents were maintained at 0,5%. In the second series, only the copolymer was added, so that its total concentration was gradually being reduced. 40ml aliquots of the above blends were slurried with 200g of marine send and then dried at 70C For 17 hours. When dry, depressions were formed in the loose send and 5ml aliquots of water pipetted into them. The time taken for the water to percolate into the send was recorded. The results are presented in the following table.

Times taken for 5ml samples of water to percolate into sands modified with various polymers

Polymer ratio Copolymer :	os homopolymer	Level of dry polymer on dry sand (%)	Infiltration time
100 :	O	0,100	> 48 hours
80 :	20	0,100	> 48 hours
75 :	25	0,100	> 48 hours
70 :	30	0,100	> 12 hours
65 :	35	0,100	> 12 hours
60 :	40	0,100	> 12 hours
55 :	45	0,100	6 hours
50 :	50	0,100	100 minutes
50 :	O	0,050	> 48 hours
45 :	55	0,100	38 minutes
40 :	60	0,100	43 minutes
45 :	65	0,100	11 minutes
30 :	70	0,100	17 minutes
25 :	75	0,100	14 minutes
25 :	0	0,025	> 48 hours
20 :	80	0,100	11 minutes
20 :	O	0,020	> 48 hours
15 :	0	0,018	> 48 hours
15 :	85	0,100	8 minutes
14 :	0	0,014	> 48 hours
10 :	0	0,010	> 48 hours
8:	D	0,008	8 hours
6 :	0	0,006	2 hours
4 :	0	0,004	12 minutes
2:	D	0,002	3 minutes
D :	100	0,100	1 minute
ordinary	sand	D	0 seconds

-326-

The PVAc homopolymer has an adverse effect on the ability of the copolymer to render and hydrophobic. The results confirm that the higher the ratio of the PVAc to copolymer, the higher the infiltration rate of water into the modified sand.

The rate of water infiltration is inversely proportional to the amount of copolymer alone that is added between the levels of 0,010% and 0,002% dry copolymer to dry sand. However, at such low rates of addition, changes in the sizes of particles in the sand will have effect on the infiltration rates.

The addition of low levels of copolymer dispersion, nevertheless, offers an economical technique to reduce the infiltration rate of water into sand and sandy soils. An advantage of reduced infiltration rates would be the possible reduction of leaching losses of fertilizers.

C. FERTILIZER RELEASE RATES

1. Materials and procedure

Different blends of the PVAc homopolymer and Dexad stabilized styrene-2EHA copolymer dispersions at combined solids contents of 0,5% were prepared. % of dry (NH4)2SO4 and % of dry KC1 were dissolved in each of the blends. 100ml aliquots of these mixtures were slurried with 500g of marine sand and air dried. When dry, 2 x 200g samples of each modified soil were poured into 280ml volume pots with holes pierced in their bases. These pots were suspended over other containers and successive 50ml quantities of water passed through them. The conductivities of the successive leachates were measured and converted to 2. Results and discussion

The results obtained are tabled below.

Concentrations and total amounts of fertilizers removed with 4 x 50ml leachings from polymer treated marine sand (Means of 2 determinations)

						Lead	h number			
				1	2		3		4	
Folys ratic copol FVAc	y y	ner:	Conc. (%)	Acc. total (% of con- trol)						
100	:	O	0,025	13	<0,001	13	0,002	14	<0,001	14
20	:	80	0,057	30	0,002	31	0,003	33	<0,001	33
18	:	82	0,067	35	0,002	36	0,002	37	<0,001	37
16	:	84	0,069	36	0,003	38	0,001	38	<0,001	38
14	;	86	0,068	36	<0,001	36	0,002	37	<0,001	37
12	:	88	0, 128	67	0,002	68	0,001	69	<0,001	69
10	:	90	0, 124	65	<0,001	65	0,001	66	<0,001	66
8	:	92	0, 139	73	<0,001	73	0,001	73	<0,001	73
6	:	94	0, 166	87	0,002	88	0,002	89	<0,001	89
4	:	96	0,205	107	<0,001	107	<0,001	107	<0,001	107
2	:	98	0, 176	92	<0,001	92	<0,001	92	<0,001	92
0	:	100	0, 190	100	<8,001	100	<0,001	100	<0,001	100
Conta	:01	1	0, 191	100	<0,001	100	<0,001	100	<0,001	100

The amounts of fertilizer released at the first leaching are inversely proportional to the amount of copolymer present. The total amounts removed after 4 x 50ml leachings are also strongly inversely correlated to the amounts of copolymer in the blends.

-328-

At these very low fertilizer addition levels it would seem that, for a reasonable rate of fertilizer release, a very small addition of copolymer to PVAc is required; 5 parts to 95 parts dry is suggested. This could be applied where relatively low levels of fertilizer are used, for example dune and veld reclaimation, hydroseeding, wheat cultivation and others.

Another approach worthy of further investigation is the addition of extremely small amounts of copolymer dispersions to liquid fertilizers to give approximately 0,005% dry on dry soil.

D. EVAPORATION RATES

24

Materials and procedure

The effects of reducing levels of a styrene-2EHA copolymer on evaporation rates of soil water was investigated in Appendix 20, subsection 3. In the present investigation, the levels of the PVAc (Gum A stabilized) homopolymer ware gradually decreased at the expense of the styrene-2EHA copolymer (Daxad stabilized), so that the total solids contents ware maintained at 0,5%. 10ml aliquots of each of these blends ware dripped onto untreated send (200g) contained in 280ml volume pots. Four replicates of each treatment ware prepared and kept at 55C for 48 hours. When the contents ware dry, the pots ware weighed then 30ml aliquots of water ware added to each prior to being reweighed. The pots ware then stored at 25C and 50% RH and ware reweighed every 24 hours in order to determine the water lost by evaporation.

-329-

The results are tabled below

Losses of water from marine sands at 25C and 50% RH, which received surface treatments of various polymer blends at 0,5% solids contents (Means of 3 replicates)

Polymer blends	96 La	oss of 30ml	of added w	ater
PVAc : styrene-2EHA	24 hours	48 hours	72 hours	96 hours
Control send	35	68	91	97
100 : 0	37	60	79	90
90 : 10	33	50	63	70
80 : 20	28	44	55	63
70: 30	22	28	36	44
60 : 40	21	37	46	54
50 : 60	22	34	44	52
40 : 60	21	29	36	43
30 : 70	13	20	26	32
20: 80	17	24	30	35
10 : 90	19	23	29	35
0:100	11	19	26	32
c.v. (%)	31	41	24	21
LSD 5%	12	25	19	19
100	17	34	26	26

The rate of evaporation increases linearly as the ratio of PVAc to styrene-ZEHA copolymer increases from between 30 : 70 to 100 : 0. The PVAc alone imparts a slight, but not statistically significant, reduction in the rate of water evaporation.

-330-

-331-

APPENDIX 27

THE EFFECTS OF COPOLYMER DISPERSION ON THE LEACHING LOSSES OF HERBICIDES AND INSECTICIDES FROM SAND

A. HERBICIDES

1. Materials and procedure

A commercially available 50% active flowable dispersion of atrazine herbicide, (Gesaprin 500FW) was diluted in the following ways;

(a) 1g of atrazine dispersion plus 100ml of water.

(b) 1g of atrazine dispersion plus 100ml of water plus 1g of the Daxad stabilized styrene-2EHA copolymer dispersion at 50% solids content.

8 x 280ml plestic pots were filled with 200g of marine sand. 5ml aliquots of the dilution (a) were applied to 4 of these and 5ml aliquots of dilution (b) were applied to the other 4. The sands were kept overnight in an oven at 55C. Next morning pinholes were pierced in the bottoms of the cups and 5 x 50ml aliquots of water were leached through them. The individual leachates were collected and the volumes and electrical conductivities of each one measured.

Results and discussion

The conductivity results are tabulated below.

Electrical conductivities of successive leachates through sands which received strazine with, and without, copolymer (Means of 4 determinations)

Leach No.	Electrical (micromol	Electrical conductivity (micromobs x 103/m1)				
	Atrezine + water	Atrazine + copolymer				
1	18	15				
2	22	17				
3	18	17				
4	12	14				
5	10	11				
C.V. (%) =	5,7 LSD 5% =	1,6 1% = 2,1				

The release of soluble materials in the copolymer containing treatment is much more gradual than that from the herbicide only treatment. Because carry over effects of herbicides are sometimes undesirable, dissolved salts or a PVAc dispersion could be added to the copolymer to ensure complete herbicide release in a reasonable time.

INSECTICIDES

1. Materials and procedure

A commercially available wettable powder insecticide ("25% Externathion", marketed by Agricura Limited, Silverton, Tranavaal) was used. This product contains mercaptothion and is recommended for application onto soils. Two different dilutions were prepared; (a) 30g of Externathion plue 1200ml of water (b) 30g of Externathion plus 1200ml of water plus 0,5g of styrene-26HA copplymer (Daxad stabilized).

8 x 280ml plastic pots were filled with 200g of marine sand. Sal aliquots of dilution (a) were applied to 4 of these and to the other 4, Sal of dilution (b) was applied. The cups were dried overnight at 55C. Next, pinholes were pierced in the bottoms of the cups and 5 x 50ml aliquots of water were leached through them. The individual leachates were collected and the volumes and electrical conductivities of each one measured.

2. Results and discussion

The conductivity results are tabulated below.

Electrical conductivities of successive leachates through sands which received Mercaptothion with, and without, copolymer (Means of 4 determinations)

Leach No	Electrical conductivity (micromobs x 103/ml)				
	Extermathion + water	Extermathian + copolymer			
1	20	14			
2	11	10			
3	8	10			
4	7	8			
5	7	7			
C.V. (%) :	= 5,7 LSD 5% =	1,6 % = 2,2			

The copolymer significantly reduced the amount of insecticide released at Leach 1. It may be necessary to add either a soluble selt or a PVAc dispersion to ensure that all the

-333-

-334-

APPENDIX 28

THE COMBINED EFFECTS OF A COPOLYMER DISPERSION MULCH AND A CHEMICAL RIPENER ON SUGAR CONTENTS OF CANE

A. INTRODUCTION

The use of chemicals which increase the concentrations of sugar in cane are now widely used in the industry. These are known as "ripeners", and they are applied, usually by aeroplane, onto the foliage some 3 weeks before harvest. A marked increase in the effectiveness of one such ripener was noted where a styrene-2EHA copolymer dispersion mulch had been applied over the row at planting.

B. MATERIALS AND PROCEDURE

In December 1977, 4 x 1,5 hectare randomly allocated blocks of newly planted cane received 2 0001/ha of a styrene-22HA copolymer sprayed in 30cm wide bands over the planting furrows. 4 other interspersed blocks of the same size were left as controls. The site was on the property of the Glendale Sugar Company which is situated to the north of Durban, and the soil was a heavy alluvium. The field was flat and the crop received regular suplementary irrigation from overhead aprinklers. In late November 1978 a commercial cane ripener "Mon 8000" (supplied by Monsanto, 800N. Lindbergh Blvd., St. Louis, Missouri 63166, USA) was applied by aeroplane at a rate of 0,4 acid equivalents per hectare over all blocks. Representative cane samples taken from each block at harvest (mid December 1978) were analysed for sucrose, fibre and purity. The intended recording of cane yields from each block was thwarted by congestion and confusion at the weighbridge. The yield for the 8 blocks was 1 097 tons

C. RESULTS AND DISCUSSION

The chemical analysis of the cane samples from the individual blocks are tabled below.

Sucrose, fibre, purity and estimated recoverable raw sugar % cane from crops with and without a styrene-2EHA copolymer over-row mulch.

Field No	Treatment	Sucrose (%)	Fibre (%)	Purity (%)	ER5 (%)
M12 (1)	Mulch	14,78	13,6	85,7	12,6
M12 (2)	Control	13,55	12,1	84,0	11,4
M12 (3)	Mulch	14,68	12,0	85,2	12,6
M12 (4)	Control	13,96	12,8	85,0	11,8
M12 (5)	Mulch	14,68	12,3	85,2	12,5
M12 (6)	Control	13,66	12,9	84,3	11,5
M12 (7)	Mulch	14,89	12,9	84,0	12,6
M12 (8)	Control	12,55	13,0	83,2	10,4
Means	Mulch Control	14,76** 13,43	13,0 12,7	85,6** 84,1	12,6**
	C.V. (%) 5%	3,6 0,82	5,8 1,2	0,5	4,1 0,7
	7%	1, 19	1,8	1,0	1,1

Statistically significant at 5% level

Statistically significant at 1% level

The cames from the blocks treated with the styrene-2EHA copolymer dispersion at planting had statistically higher purity and concentration of sucrose than the cames from blocks untreated at planting. As a result, the estimated recoverable sugar contents were also greater. The more succulent stalks in the copolymer mulch treatments would appear to contain more material for the chemical ripener to convert to sucrose.

-335-

REFERENCES

ALLISON, L.E. and MODRE (1956)

Soil and plant responses to VAMA and HPAN soil conditioners

in the presence of high exchangeable sodium.

Soil Sci. Soc. Am. Proc. 20(2)

ARMSRUST, D.V. and J.D. DICKERSON (1971)

Temporary wind erosion control. Cost and effectiveness

of 34 commercial materials.

J. Soil Water Conservation. 26 : 154 - 157.

ARMBRUST, D.V. and L. LYLES (1976)

Soil stabilizers to control wind erosion.

Soil Sci. Soc. Am. Proc. Special Pub.

7 : 77 - 82

BAXENDALE, J.H., EVANS, M.G. and J.K. KILHAM (1946)

J. Polym. Sci. 1 : 465 - 478

BISHOF R.T. (1964)

Improved tissue diagnostic techniques for sugar came. M.Sc. Thesis. Dept. of Soil Sci. Natal University

: 64

BLACKLEY, D.C. (1975)

Emulsion Polymerisation - Theory and practice

Allied Science Publishers Ltd. London

BOWERS, S.A. and J. HANKS (1961)

Effect of DDAC on evaporation and infiltration of soil moisture

Soil Sci. 93 : 340 - 346

CHEPIL, W.S., WOODRUFF, N.P., SIDDOWAY, F.H. and L. LYLES (1960) Anchoring vegetative mulches

Agric. Eng. 41 (11) : 754 - 755, 759

CHEPIL, W.S., WEDDRUFF, N.P., SIDDOWAY, F.H., FRYREAR, D.M. and D.V. ARMBRUST (1963)

> Vegetative and non-vegetative materials.to control wind and water erosion

Soil Sci. Am. Proc. 27 : 86 - 89

CLARE, K.E. (1954)

The use of stabilized soil for road construction in the U.S.A. Dept. of Scientific and Industrial Research, Road Research Laboratory No. 29

CLARK, K.G., YEE, J.Y. and K.S. LOVE (1948) New synthetic nitrogen fertilizer. Ind. Eng. Chem. 40 : 1178 - 1183

CLARK, K.G., YEE, J.Y., LOVE, K.S. and T.A. BOYD (1951) Preparation and properties of urea - form. Ind. Eng. Chem. 43 : 871 - 875

COOKE, W. (1972)

Turning the gold mines green.

Reprint from 1972 broadcasts on the S.A. Broadcasting Corp.

COOLING, L.F. and H.Q. GOLDER (194)

Portable apparatus for compression tests and clay soils.

Enginering, London, 140 (3862) : 57 - 59

DAHNKE, W.C., ATTOE, O.J., ENGELBERT, L.E. and M.D. GROSKGPP (1963) Controlling release of fertilizer constituents by means of coatings and capsules.

Agron. J. 55 : 242 - 244

DAVIDEON, D.T. and Associates (1960)

Soil stabilization with chemicals. Joint publications Bulletin 193 Iowa Engineering Expt. Stn. and 22 Iowa Highway Research Board. DE BOODT, T.M. (1972)

Improvement of soil structure by chemical means : 43 - 45. In. D. Hilel (ed.) Optimising the soil-physical environment

toward greater crop yield.

Academic Press, Inc., New York and London

DE BOCDT, M. (1976)

Use of soil conditioners around the World.

Soil Sci. Soc. Am. Proc. Special Pub. 7: 1 - 12

DE LA PENA, E and D. GABRIELS (1976)

Evaluation of soil conditioners for protection of steep slopes from water erosion

Third Int. Symp. on Soil Conditioning - Ghent 3:327 - 334 DE VLEESCHALMER, D. and D. GABRIELS (1976)

The effect of a polyacrylamide treatment on the germination of sugar beets in a heavy sand loam

Third Int. Symp. on Soil Conditioning - Ghent 3 : 321 - 326

DOYL, J.J. and F.G. HAMLYN (1960)

Effects of different cropping systems and of a soil conditioner VAMA on some soil physical properties and on growth of tomatoes

Canada J. Soil Sci. 40 : 89 - 98

DULEY, F.L. (1956)

The effect of a synthetic soil conditioner (HPAN) on inteke, run off and erosion

Soil Sci. Soc. Am. Proc. 20 : 420 - 422

EINHORN, A. and A. HAMBURGER (1908)

Die methylolverbindungen des Larnstoffs.

Gerichte de Deutschen Chemischen Gesellschaft. 41 : 24 - 29
EL GALA, A.M., EL DAMATY, A.H., TALHA, M. and I.S. ABU-ZAYED (1975)
The effect of krilium and alfalfa on improving properties
of virgin calcareous soil.

Third Int. Symp. on Soil Conditioning - Ghent. 3: 233 - 240

ERICKSON, A.E., HANSON, C.M., and A.J.M. SMUCKER (1968)

The influence of subsurface asphalt barriers on the water properties and the productivity of sand soils

Trans. 9th Int. Cong. Soil Sci. 1: 35 - 43

FLAIG, W., SOCHTIG, H. and C. SOMMER (1975) Observations about the effect of oxidatively ammonified lignosulfonates on physical soil properties 3rd Int. Symp. on Soil Conditioning - Ghent 3: 41 - 48

FINK, D.H. and G.W. FRASIER (1976)

Water harvesting from watersheds treated for water repellency Soil Sci. Soc. Am. Proc. Special Pub. 7: 173 - 182

GABRIELS, D. (1975)

Preventing erosion with butadiene - styrene copolymer or polyurethane.

3rd Int. Symp. on Soil Conditioning - Ghent 3 : 361 - 372

GABRIELS, D., DE BOODT, M. and G. MAESSCHALCK (1976)

The evaporation process in a sandy and clayey soil as affected by treatments with a bitumen emulsion and a polyacrylamide solution: A laboratory study Meded. Fak. Landbouwwetenschappen, R.U.G. Ghant

GABRIELS, D. and M. DE BOODT (1975)

Erosion reduction factors for chemically treated soils: (a) laboratory experiment.

Soil Sci. Soc. Am. Proc. Special Pub. <u>7</u>: 95 - 102 GARDINER, W.H. (1972)

> Use of synthetic soil conditioners in the 1950s and some implications to their further development. Proc. Symposium on Fundamentals of Soil Conditioning - Shent 2 : 1046 - 1061

> > 3

-339-

-340-

GERSHEERG, D. (1965)

A.I. Ch.E. - I. Chem. E. Symposium No. 3

London: Instn. Chem. Engrs.

GLANVILLE, W.H. (1954)

The use of stabilized soil for road construction in the U.S.A.

Dept. of Scientific and Industrial Research, Road Research Leboratory No. 29 : 17 - 19

London: Her Majesty's Stationery Office

GODR, G.E., BERNAERT, M., SADONES, M., CALLEBAUT, F. and F. SCHAMP (1976)

> The influence of chemical and physical properties of synthetic polymer emulsions on soil conditioning. 3rd Int. Symp. on Soil Conditioning - Ghent 3 : 107 - 181

GORING, C.A.I. (1962m)

Control of nitrification by 2-chloro-6-(trichloromethyl) pyridine.

Spil Sci. 93 : 211 - 218

GORING, C.A.I. (1962b)

Control of nitrification of ammonium fertilizers and urea by 2-chloro-6-(trichloromethyl) pyridine.

Soil Sci. 93 : 431 - 439

GREBENNIKOV, N.V., VASYLIEV, E.V. and T.P. MALYGINA (1975) Application of conditioner based on sulphate lignin in saline soils of Golodnaya steppe

3rd Int. Symp. on Soil Conditioning - Ghent 3: 61 - 64 GREENLAND, D.J. (1972)

Interaction between organic polymers and inorganic soil particles.

Proc. Symposium on Fundamentals of Soil Conditioning - Ghent <u>2</u>: 915 - 922 JUNG, J. (1960)

Uber die Nährstoffanlieferung aus mit Kunststoff umhülten Dungergranulaten Z. Pflanzenernähr. Düng. <u>91</u>: 122 - 130 KERCHEV, G., GALEVA, V. and R. DILKOVA (1976)

Improvement of physical conditions of calcareous chernozem with alkyl-ammonium chloride and polyethylene sheet. 3rd Int. Symp. on Soil Conditioning - Ghent <u>3</u>: 261 - 266

KITA, D. and K. KAWAGUCHI (1961)

The mechanism of dispersion and flocculation induced in soil suspension by polyacrylic acid. 1. The bonding of soil particles by linear polyelectrolytes.

J. Sci. Soil Tokyo. 32 : 419 - 426

KNOTTNERUS, D.J.C. (1976)

Stabilization of a wind erodeble surface by hydroseeding (town refuse compost)

3rd Int. Symp. on Soil Conditioning - Ghent 3 : 69 - 72

KOWSAR, A., BOERSMA, L. and G.D. JARMAN (1969)

Effects of petroleum mulch on soil - water content and soil temperature

Soil Sci. Soc. Am. Proc. 33 : 783 - 786

KREBS, R.D. and R.D. WALKER (1971)

Highway Materials : 241 - 244

McGrow-Hill Book Company, New York.

LABOFINA, N.V. (1973)

Agglomeration of particulate materials. Brit. <u>1</u>: 311 - 392 LAW, J.P. (1964)

> The effect of fatty alcohols and a nonionic surfactant on soil moisture evaporation in a controlled environment. Soil Sci. Soc. Am. Proc. 28 : 695 - 699

LENVAIN, J.M., DE BOODT, M. and SUMARD30 (1975)

The effect of small quantities of hydrophobic soil conditions on the decrease of evaporation and the beneficial development of <u>Vetiveria Zizanoides (L) stapf</u> in the tropics

3rd Int. Symp. on Soil Conditioning - Ghent <u>3</u>: 201 - 209 MACLEAN, D.J. (1948)

The effect of the soil foundation on the road surface.

Dept. of Scientific and Industrial Research, Road Research Laboratory, London.

MARTAKIS, G.E. (1977)

Studies on slow release fertilizers using various organic poly

M.Sc. Thesis. Dept. of Soil Sci. Natal University

MARSHALL (1970)

Marshall stabilization and flow test.

Asphalt Handbook (1970) 4 (March) : 40 - 42

Asphalt Institute - U.S.A.

MARTIN, J.P. and W.W. JONES (1954)

Greenhouse plant response to vinyl acetate - maleic acid cope in natural soils and prepared soils containing high percentage of sodium or potassium.

Spil Sci. 78 : 317 - 324

MASAAKI AKAHANE, AKIRA KUROSAWA and HIRDKD YAND (1964)

Lignosulphonates for soil treatment.

Kogyo Kaguku Zasshi. 67 : 1047 - 1050

MAUDE, R. (1977)

DRENNAN, MAUD and PARTNERS

Consulting Civil Engineers

Personal communique

MAUSBACH, M.J. and W.D. SCHRADER (1976)

Influence of soil treatment of selected subsoil materials on infiltration and erosion.

Soil Sci. Soc. Am. Proc. Special Pub. 7 : 83 - 93

MILLARD, E.W. (1974)

Plastic mulching of sugar cane.

SASTA Proc. 48 : 53 - 57

MOLDENHAUER, W.C., HOLMBERG, G. and W.D. SHRADER (1962)

Establishing vegetation on exposed subsoil in the Monona-Ida-Hamburg soil association area of Kansas, Iowa, Missouri and Nebraska

U.S. Dept. of Ag. Information Bulletin 251.

MOLDENHAUER, W.C., MADDY, J., SCHMIDT, B.L. and W.D. SHRADER (1964) Establishing vegetation on exposed subsoil in southern Iowa and northern Missouri.

U.S. Dept of Ag. Information Bulletin 280.

MOLDENHAUER, W.C. and D.M. GABRIELS (1972)

Some uses of soil stabilizers in the U.S.A.

Proc. Symposium of Fundamentals of Soil Conditioning - Ghent

2 : 1076 - 1085

HORTENSEN, J.L. (1957)

Absorption of hydrolysed polyacrylonitrile on kaolin : 1.

Effect of exchange cation and anion.

Soil Sci. Soc. Am. Proc. 21 : 385 - 388

NATAL ROADS DEPARTMENT SPECIFICATIONS (1970)

Material Standards Section C. Sub Base : June

DGLESBY, C.H. (1975)

Highway Engineering. Third Edition : 542 - 544

John Wiley and Sons, New York

OLSEN, S.R., WATANABE, F.S., CLARK, F.E. and W.D. KEMPER (1964) Effect of hexadecanol on evaporation of water from soil Soil Sci. Soc. Am. Proc. 97 : 13 - 18

PARR, J.F. (1964)

Possible approaches to the development of new nitrogen fertilizers. Soil and Fertilizer Nitrogen Research Symposium Proc. PARR, J.F. (1967)

Biochemical considerations for increasing the efficiency of nitrogen fertilizers.

Soils and Fertilizers 30 (3) : 207 - 213

PARR, J.F. and A.G. NORMAN (1964)

Effects of non-ionic surfactants on root growth and cationic uptake.

Pl. Physiol 39 : 502 - 507

PLA, I. (1972)

Effect of bitumen emulsion and polyacrylamide on some physical properties of Venezuelan soils

Soil Sci. Soc. Am. Proc. Special Pub 7 : 35 - 46

PRASAD, R., RAJALE, G.B. and B.A. LAKHDIVE (1973)

Nitrification retarders and slow release nitrogen fertilizers.

Indian Agric. Res. Inst., Division of Agronomy, New Delhi

PRIEST, W.J. (1952)

J. Phys. Chem., Ithaca, 56 : 1077

PUGH, A.L., VOMOCIL, J.A. and T.R. NIELSEN (1960)

Modification of some physical characteristics of soils with VAMA, ferric sulfate and triphenylsulfonium chloride.

Agron. J. 52 : 399 - 402

RAU, S. and E.W. MILLARD (1975)

Further studies on the use of a polyethylene mulch in the growing of sugar cane.

SASTA Proc. 49 : 182 - 186

RICHARDS, L.A. (1953)

Modulus of rupture as an index of crusting of soil Soil Sci. Soc. Am. Proc. <u>17</u>: 321 - 322
RIGOLE, W. and F. DE BISSCHOP (1972)

The formation of adhesive links between granular particles by means of emulsions.

Proc. Symposium on Fundamentals of soil conditioning -Ghent 2 : 939 - 954

RDDSE, E.J. (1976)

Natural mulch or chemical conditioner for reducing soil erosion in humid tropic areas.

Soil Sci. Soc. Am. Proc. Special Pub. 7 : 131 - 138

RUKER, A. and P. EDGERTON (1931)

Studies on sugar cane roots.

Louisianna Sugar Exp. Stn. Bull. No. 233

SADDNES, M., CALLEBAUT, F., GDDR, G. and N. SCHAMP (1975) The effect of surfactants on the distribution of soil

conditioners in soil.

3rd Int. Symp. on Soil Conditioning - Ghent 3: 193 - 200 SARGICUS, M. (1975)

Pevements and surfacings for highways and airports : 66 - 68 Applied Science Publishers, Barking, England

SAVAGE, S.M. (1976)

Occurance and phenomenon of natural and fire-induced soil water repellency.

Scil Sci. Soc. Am. Proc. Special Pub. <u>7</u> : 165 - 172 SCHAMF, N. (1975)

Chemicals used in soil conditioning

3rd Int. Symp. on Soil Conditioning - Ghent 3: 13 - 18 SCHAMF, N. and J. HUYLEBRDECK (1972)

Physico-chemical interaction of polyacrylamide on clay particles.

Proc. Symposium on Fundamentals of Soil Conditioning - Ghent 2: 923 - 937 SCHAMF, N. and J. JUYLEBROECK (1972)

The use of polymers as soil conditioners.

Proc. Second Asean Soil Conf. 2: 73 - 79

SCHMIDT, B.L. (1961)

Methods of controlling erosion on newly seeded highway backslopes of Iowa.

M.Sc. Thesis, Iowa State University, Ames, Iowa

SIMMONS, P. and W.J. ARMSTRONG (1965)

A new method of soil stabilization.

Sci. Ind. 3 (4) : 282 - 291

STRICKLING, E. (1975)

Effect of cropping systems to VAMA on soil aggregation,

organic matter and on yields.

Soil Sci. 84 : 489 - 498

SUMNER, M.E. and E.C. GILFILLAN (1971)

Asphalt barriers to improve productivity of sandy soils a preliminary assessment.

5ASTA Proc. 45 : 165 - 168

THE COMMONWEALTH AGRICULTURAL BUREAU - March (1976)

Controlled release fertilizers

Annotated Bibliography No 58 1767

TIMM, H., BISHOP, J.C., PERDUE, J.W., GRIMES, D.W., VOSS, R.E.

and D.N. WRIGHT (1971)

Soil crusting effects on potato plant emergence and growth California Agriculture 25 (8) : 5 - 7

VAN DARLEN (1970)

Roads Division, Cape Divisional Council, R.S.A.

Personal communique

VASYLIEV, E.W. (1975)

Lignin derivatives as basis for confitioner creation 3rd Int. Symp. on Soil Conditioning - Ghent <u>3</u>: 55 - 60

- 346-

VERPLANCKE, H., HARTMANN and M. DE BOODT (1975)

The effect of soil conditioners on the water transmission properties of different textured soils.

3rd Int. Symp. on Soil Conditioning - Ghent 3 : 211 - 218 WARKETIN, B.P. and R.D. MILLER (1958)

Conditions affecting formation of the montmorillonite - polyacrylic acid bond.

Soil Sci. 85 : 14 - 18

WEBBER, L.R. (1959)

Note on the aggregate - size distribution and aggregate stability in Haldimand clay treated with four different additives

Canada J. Soil Sci. 39 : 252 - 253

WILLIAMS, B.G., GREENLAND, D.J. and J.P. QUIRK (1966)

Absorption of polyvinyl alcohols by natural soil aggregates Aust. J. Soil Res., <u>4</u>: 131 - 144