New Technology Initiatives in Rural Roads and Use of Marginal Materials

STABILIZATION METHODS FOR LOW VOLUME ROADS

National Rural Infrastructure Development Agency

Ministry of Rural Development

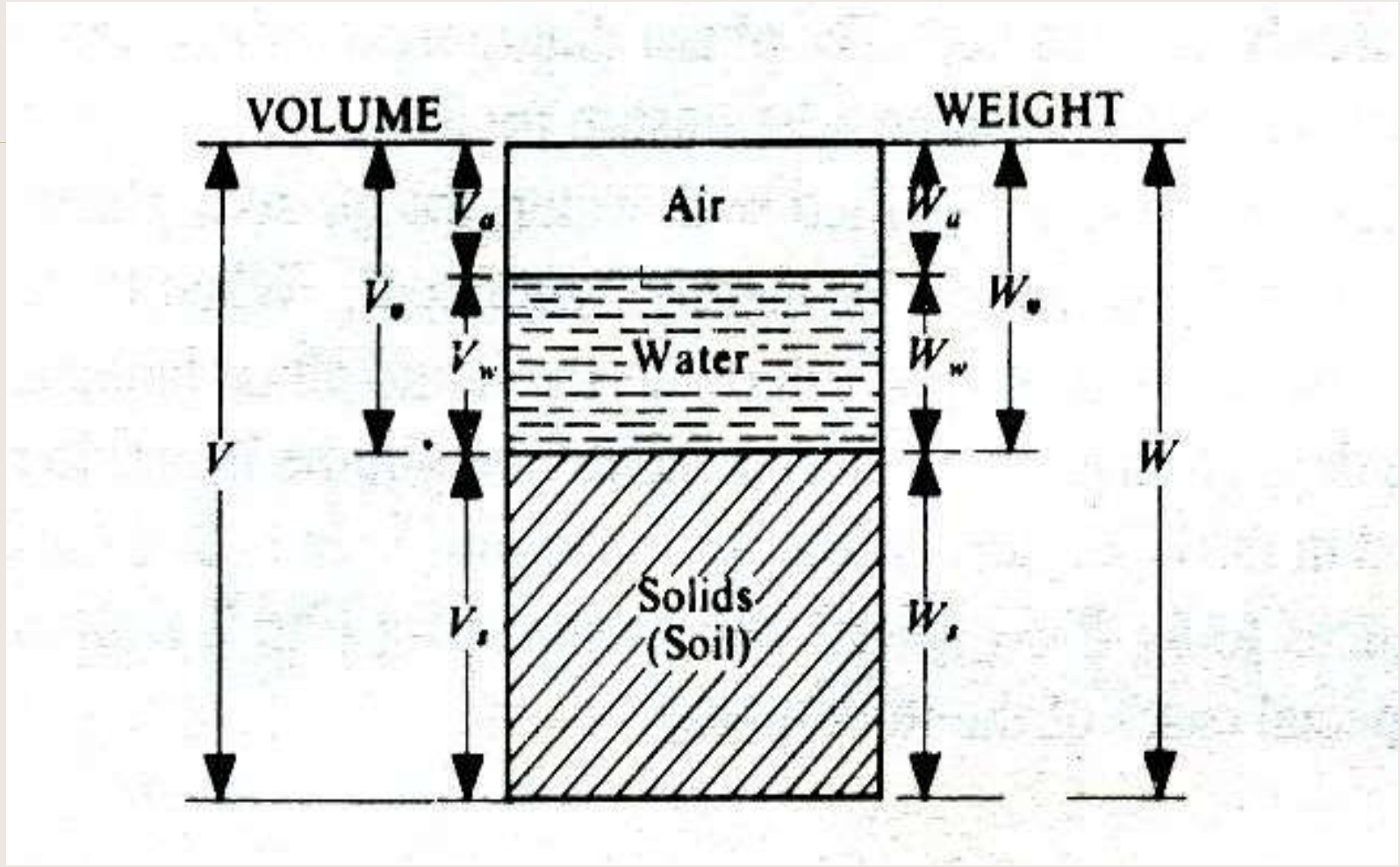
National Institute of Technology

Warangal, Hyderabad

Lecture 4

STABILIZATION METHODS FOR LOW VOLUME ROADS

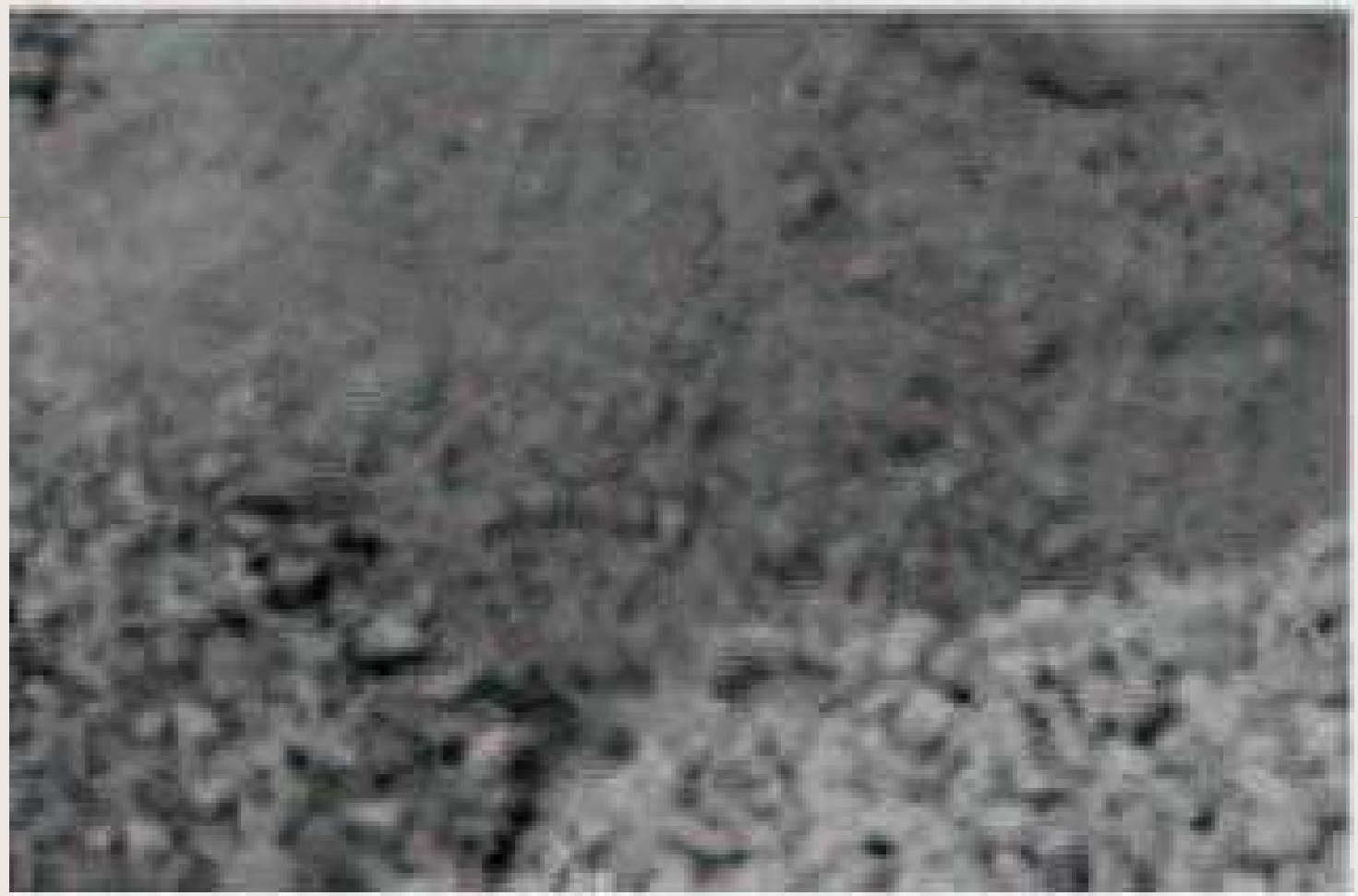
INTRODUCTION



THREE PHASE SOIL SYSTEM

$$\sigma' = \sigma - u$$

Condition of Gravel Road in Monsoon, A.P. (Bhavana Rao, 2005)



Red Earth as Gravel for WBM, A.P.

SOFT AGGREGATE WITH HIGH FINES & PLASTICITY IN NH-5

RED EARTH USED AS GRAVEL IN NH-43

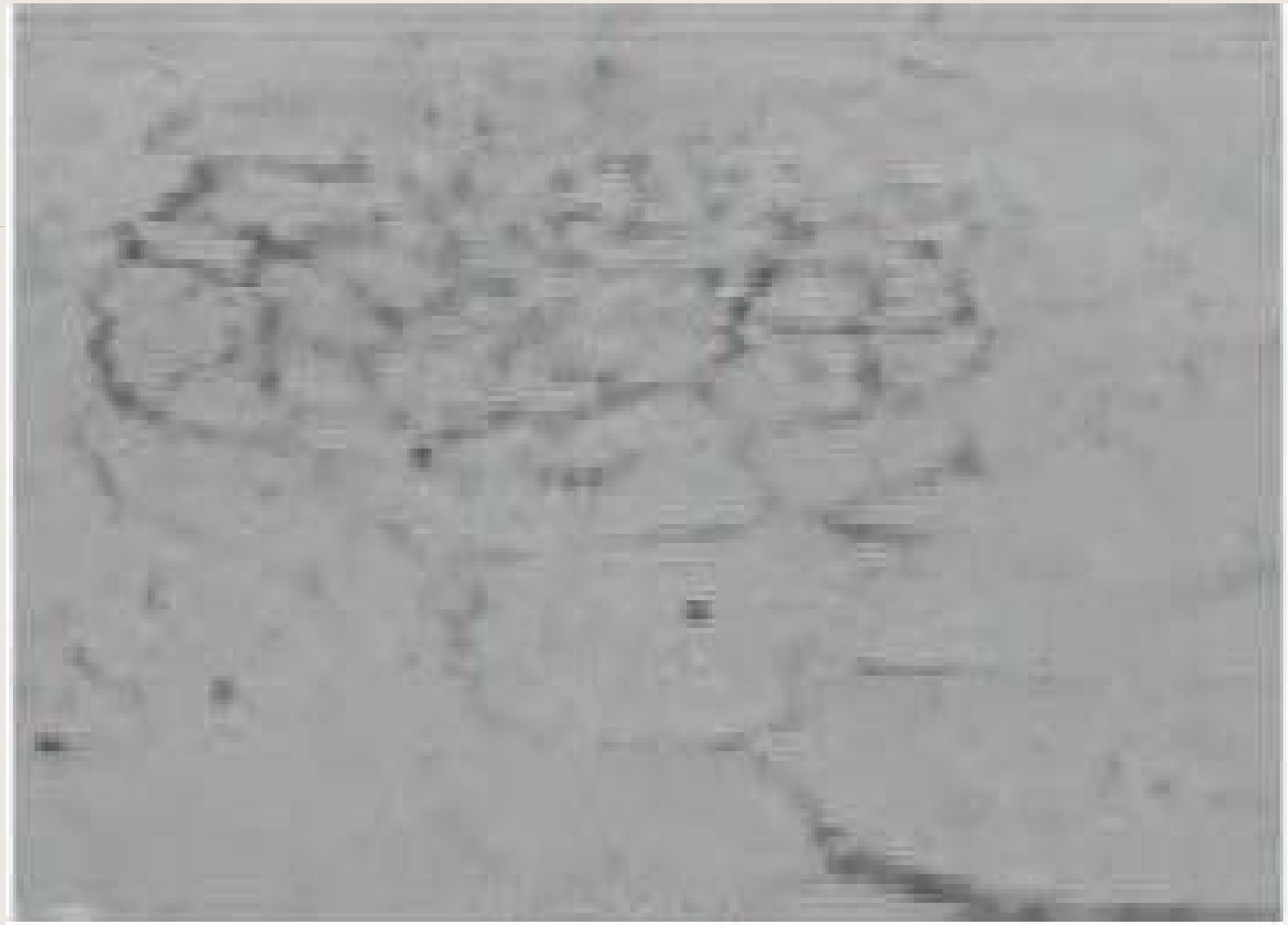
HIGHLY PLASTIC RUBBISH USE IN ROAD CONSTRUCTION, VIJAYAWADA

DAMAGED ROAD IN WEST GODAVARI DUE TO HIGH PLASTIC GRAVEL

HIGH PLASTIC SOIL USE NEAR VIJAYAWADA

DISTRESS TO NH-9, VIJAYAWADA LIMITS

HIGH PLASTIC SOIL USE IN PORT ROAD VIZAG



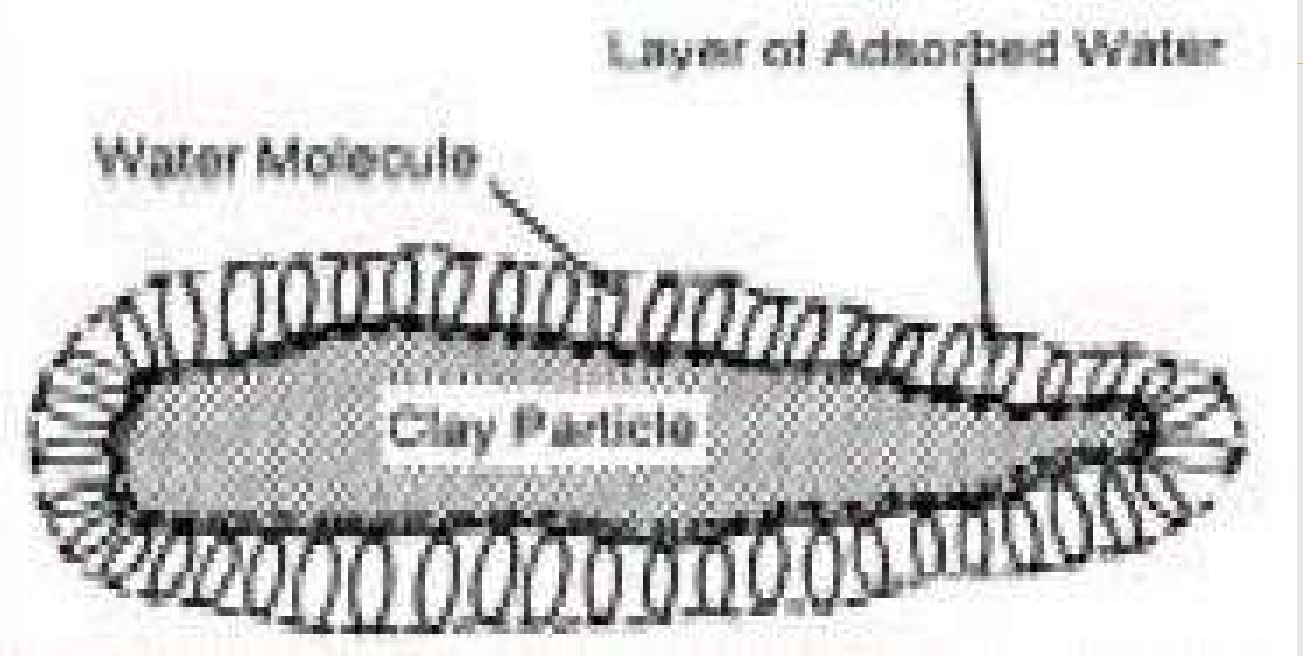
CONDITION OF NH-9, VIJAYAWADA LIMITS

DAMAGED CONNECTING ROAD TO NH-5, VIJAYAWADA LIMITS

DAMAGED ROAD WITH RED EARTH BLINDAGE, W GODAVARI

DAMAGED ROAD IN WG DUE TO RED EARTH USE

Crushed Rock Base, NH-5



CLAY PARTICLE BEHAVIOUR

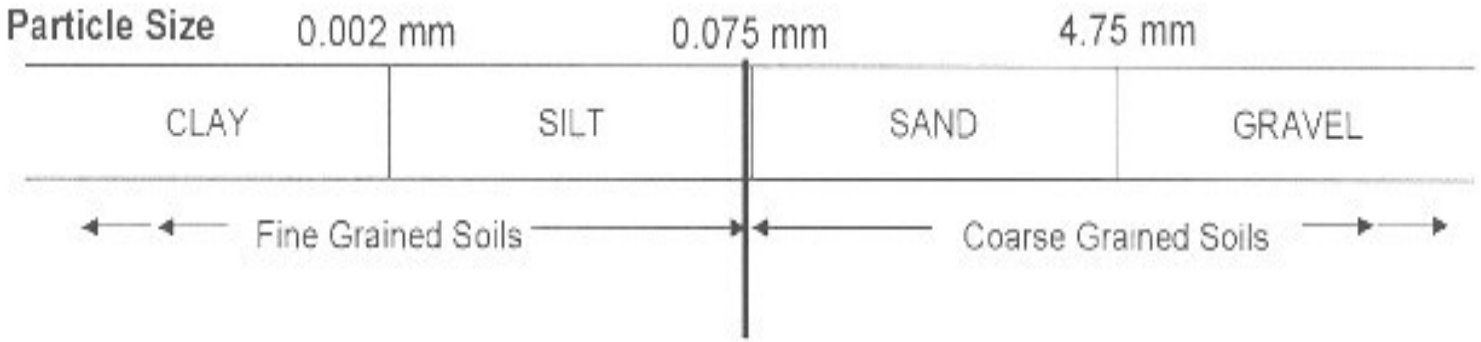
TABLE 2. TEST RESULTS ON GRAVEL SAMPLES FROM APPROVED QUARRIES IN WEST GODAVARI, KRISHNA, GUNTUR AND PRAKASAM DISTRICTS OF ANDHRA PRADESH

Sl. No.	Location of Quarry	% passing 75m sieve	Liquid limit in %	Plasticity index in %	CBR in %
1.	Kunkudu quarry Km 67/500 of Narasapur – Aswaraopet Road	31	36	14	11
2.	Road side quarry Km 91/440 of Narasapur – Aswaraopet Road	32	39	17	12
3.	Road side quarry Km 36/500 of E.G.K Road	35	37	17	9
4.	Quarry at Km 26/000 of Eluru – Jangareddy Gudem Road	32	39	16	13
5.	Janampeta quarry at Km 11/600 of E.M Road + 0.200 Km CT	33	38	16	10
6.	Quarry at Km 16/900 of P.K Road + 0.800 Km CT	34	38	16	8
7.	Gajjaram quarry at Km 2/508 of P.K Road	34	38	12	12
8.	Arugolanu quarry at Km 2/800 of P.N Road + 3.000Km CT	33	38	17	12
9.	Quarry at Km 135.180 of M-N-K Road	34	41	12	11
10.	Quarry at Km 8.30 of SN Road + 0.40 Km CT	34	39	11	12
11.	Quarry at Km 8.65 of Y.S.Road	32	37	13	10
12.	Quarry at Km 11.60 of V.V.Road +0.2 CT	33	36	16	9
13.	Jakkampudi Quarry at Km 10.80 + 0.40 CT 1.0 of VV Road	36	37	13	10
14.	Purushotapatnam Quarry at Km 4.830 V.V.Road	34	37	12	11
15.	Gollanapalli Quarry at Km 23.80 with 2.20 CT to TVV Road	33	40	15	12
16.	Quarry at Veerapanenigudem at Km 35.4 of V.V.Road	35	41	13	10
17.	Ammanabrolu quarry Km 39/700 on Chirala – Ongole Road	36	37	13	13
18.	Dronadula quarry Km 0/0 on DTC road	28	47	11	14
19	Ongole – Nanadyala Road Km 4/830+1.000 Km CT	24	38	16	10

TABLE 3. TEST RESULTS ON GRAVEL MIXED WITH FINE SAND (ZONE III) IN DIFFERENT PROPORTIONS

Sl. No.	Location of Quarry	Item	Percentage passing 75m IS Sieve	L.L %	P.I. %	CBR %
1.	Road side Quarry in Km 36/5 of E.G.K road W.G. District	Natural Gravel	35	37	17	9
		NG 90% + Sand 10%	34	35	16	10
		NG 85% + Sand 15%	32	32	16	11
		NG 80% + Sand 20%	31	30	12	14
		NG 75% + Sand 25%	30	28	11	15
		NG 70% + Sand 30%	28	25	NP	17
		NG 65% + Sand 35%	26	22	NP	18
		NG 60% + Sand 40%	25	19	NP	18
2.	Quarry in Km.5.88 of A.V Road in Krishna District	Natural Gravel	34	37	18	9
		Gravel 90% + Sand 10%	33	36	16	10
		Gravel 85% + Sand 15%	31	32	14	13
		Gravel 80% + Sand 20%	30	32	14	14
		Gravel 75% + Sand 25%	29	28	10	15
		Gravel 70% + Sand 30%	27	25	9	17
		Gravel 65% + Sand 35%	26	24	NP	17
		Gravel 60% + Sand 40%	25	22	NP	18

METHODS OF STABILISATION



MECHANICAL STABILISATION

BITUMEN STABILISATION

CEMENT STABILISATION

LIME STABILISATION

Reinforced deep mixing retaining wall (Porbaha et al, 2005)

Top: Trench excavation railroad for an Alameda corridor project. Bottom: Structural cutoff wall during construction of new facility at Harvard University, Cambridge (Porbaha et al, 2005)

APPLICATIONS OF MECHANICAL STABILISATION TO LOW VOLUME ROADS

Table 2(a): Gradation Requirements for Subbase Aggregate

Sieve Size	Percent Passing Designated Sieve	
	A	B
63 mm	100	
50 mm	97-100	100
37.5 mm		97-100
25 mm	65-79	
19 mm		
12.5 mm	45-59	
9.5 mm		
4.75 mm	28-42	40-60
0.425 mm	9-17	
0.075 mm	4-8	0-12

Liquid Limit not to exceed 25

Table 2(b): Gradation Requirements for Base Aggregate

Sieve Size	Percent Passing Designated Sieve		
	A	B	C
50 mm	100		
37.5 mm	97-100	100	
25 mm		97-100	100
19 mm	67-81		97-100
9.5 mm		56-70	67-79
4.75 mm	33-47	39-53	47-59
0.425 mm	10-19	12-21	12-21
0.075 mm	4-8	4-8	4-8

Liquid Limit not to exceed 25 and PI not to exceed 6.

Table 3: Gradation and Plasticity Index Requirements for Surfacing

Sieve Size	Percent Passing Designated Sieve
25 mm	100
19 mm	97-100
4.75 mm	41-71
0.425 mm	12-28
0.075 mm	9-16
Plasticity Index (PI)	*4-12*

Liquid Limit not to exceed 35

SAND-CLAY MIXES

- Clayey soil for sands &gravels = 10-35%
- Sand for silty soils = 15-30%
- Sand for B.C. soil = 40-60%
- LL < 25% , PI < 6% , Min. CBR = 20%

SAND-GRAVEL MIXES

Sand-murrum mixes are popular in India.

Specifications are similar to soil-aggregate mixes

- **Availability of Sand?**

STABILISATION OF SOIL WITH SOFT AGGREGATE (MEHRA'S METHOD)

70% SOIL + 30% AGGREGATE

Soil: P.I.=8-11%; Sand ≥ 33%

2. LIME STABILIZATION

Suitability of lime & Soils :

CaO >70%

-425μ = 15%

-75 μ = 10%

PI > 10%

Sulphates < 0.20%

Degree of pulverization:

-4.75 mm = 80%

-25 mm = 100%

Lime Reactivity: UCC 3 kg/cm² @ 7 days

AMOUNT OF LIME

Alluvial Soil / Murrum (PI : 10-15%) = 3%

Clay / BC (PI : 15-30%) = 3-5%

Highly Expansive Clay (PI > 30%) = 5-6%

For sub-base : Min. CBR = 20-30%

For base : Min. CBR = 80-100%

Due to doubtful quality control 2/3 rd laboratory CBR is taken for field.

COMBINATIONS:

LIME, LIME-CEMENT, LIME-PUZZOLANA WITH SOILS: Soils of medium plasticity (PI 5-20) and clayey soils not reactive to lime can be stabilised with lime and flyash

- Lime-flyash alone can be used for Base/Sub –Base course, avoiding soil.

- Mix proportions are designed to obtain minimum unconfined compressive strength of 1.5 MPa after 28 days curing

Chemical Requirements of Flyash (IS 3812 (Part 1) : 2013)

SOIL – LIME REACTIONS

HYDRATION

FLOCCULATION

CEMENTATION

CARBONATION

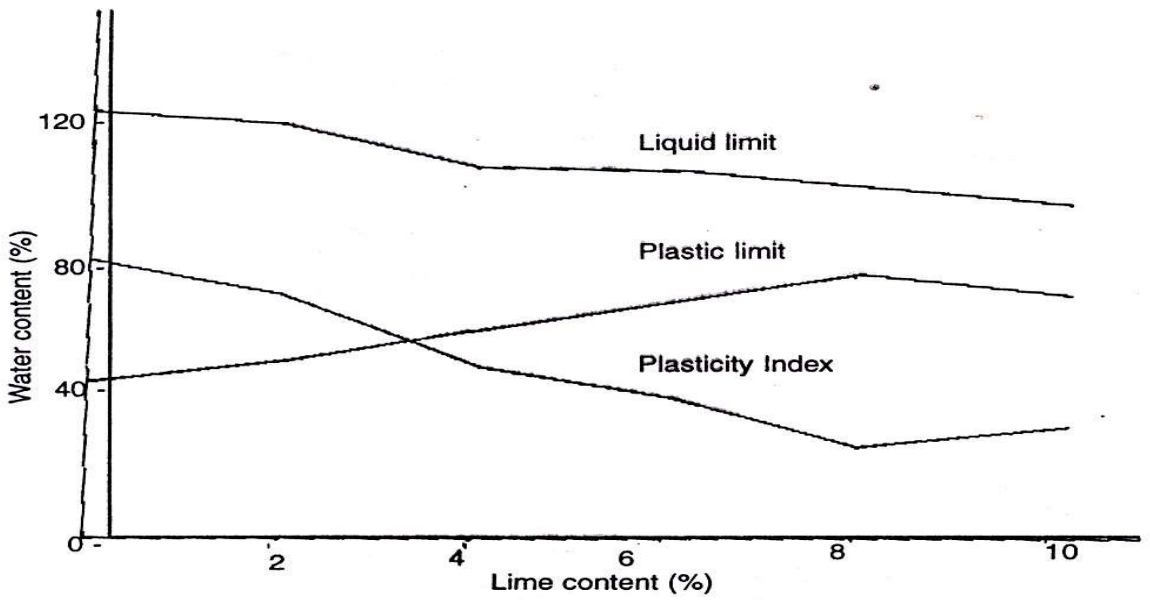
BENEFITS : 1. REDUCED PLASITICITY

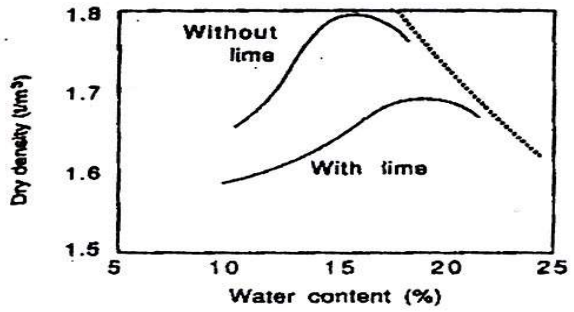
2. IMPROVED WORKABILITY

3. INCREASED STRENGTH

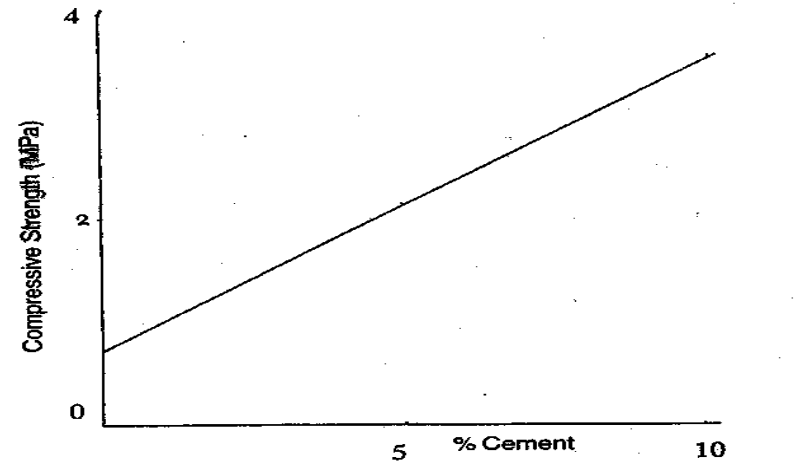
4. INCREASED PERMEABILITY

5. REDUCED SWELLING & SHRINKAGE





Effect of Lime on Plasticity and Compaction of soil



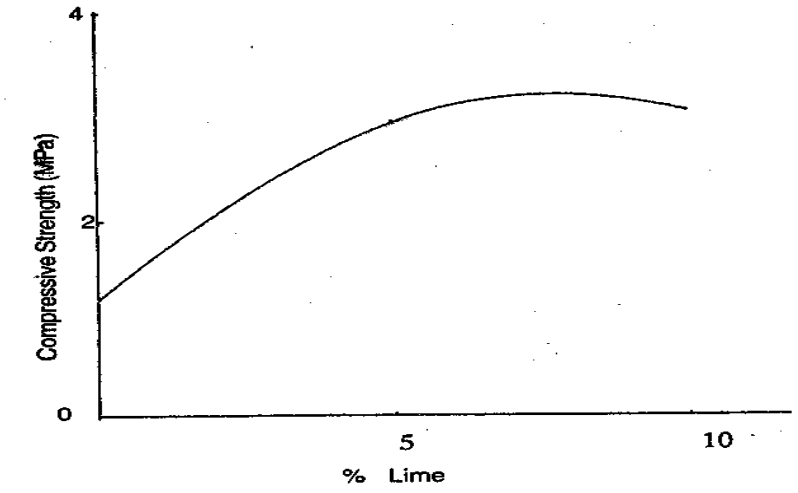
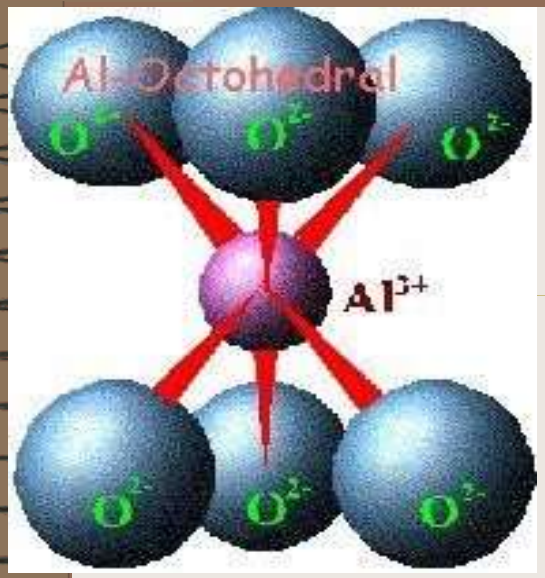
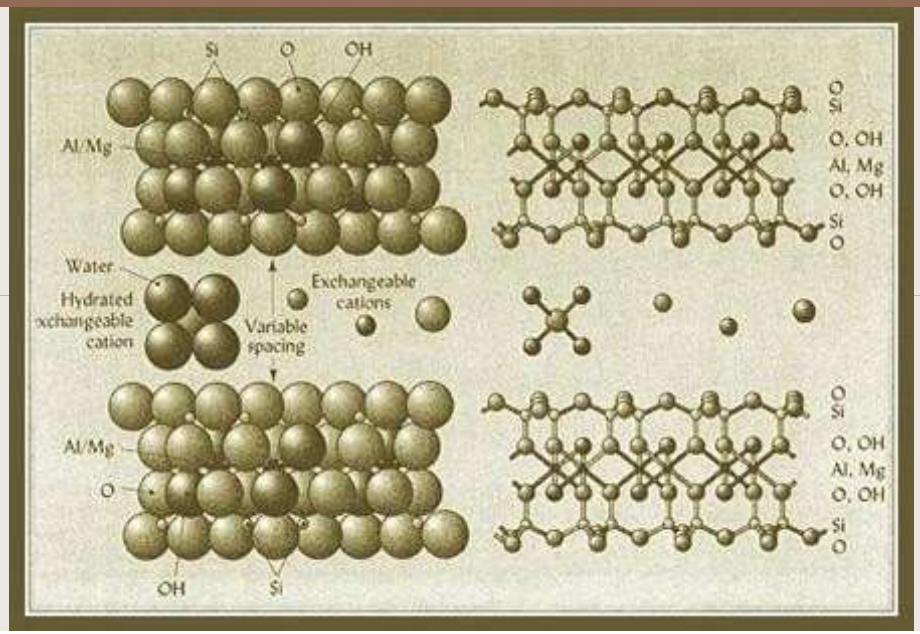


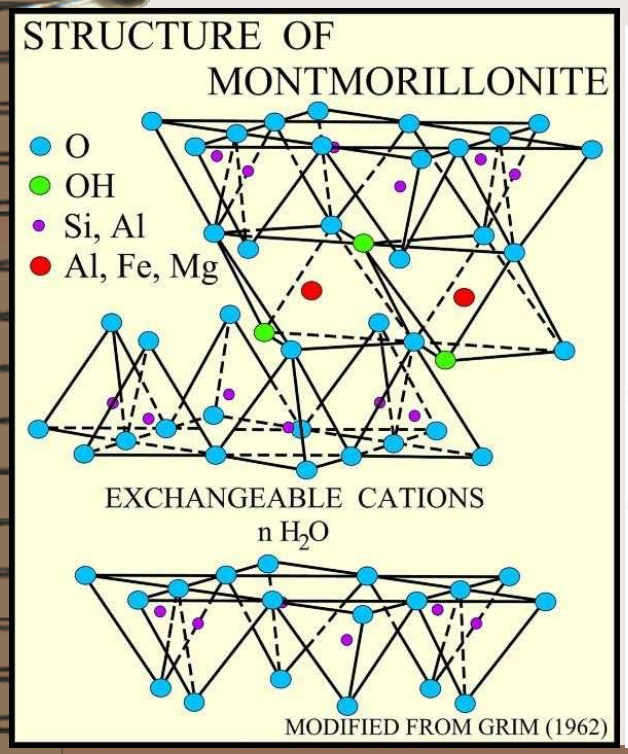
Fig. 8.01 Strength Gain of a Typical Soil with Cement and Lime

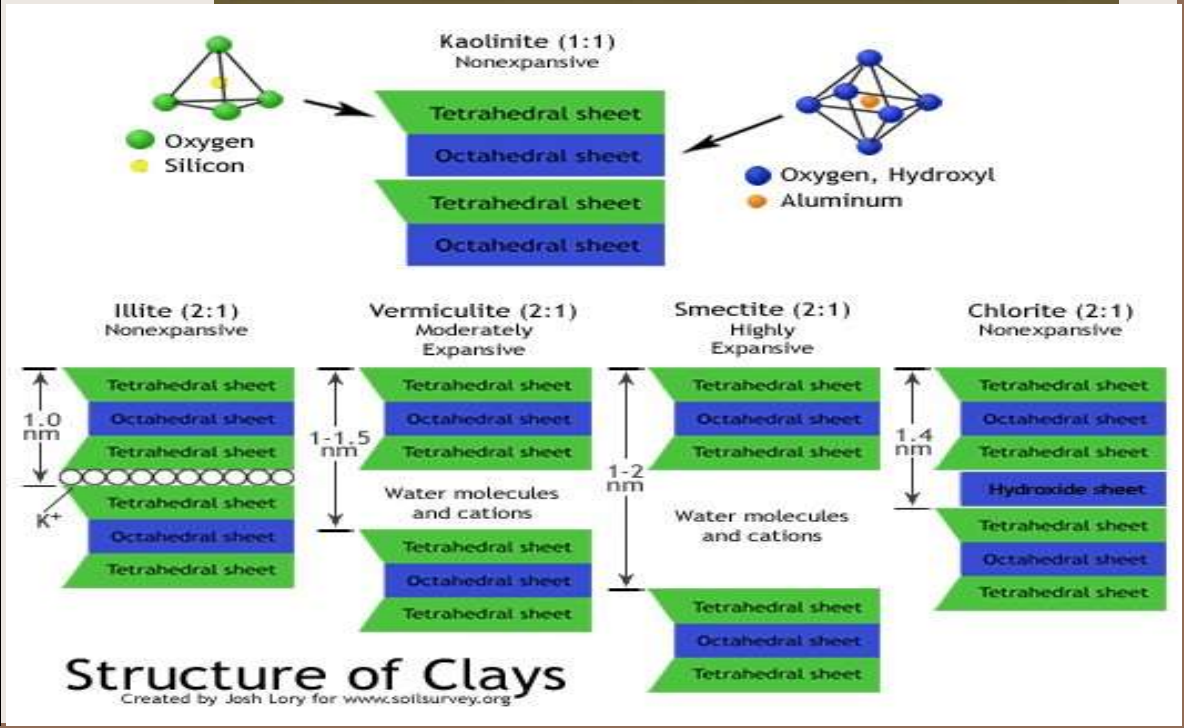
Strength Gain of a Typical Soil with Cement and Lime

Expansive Soils









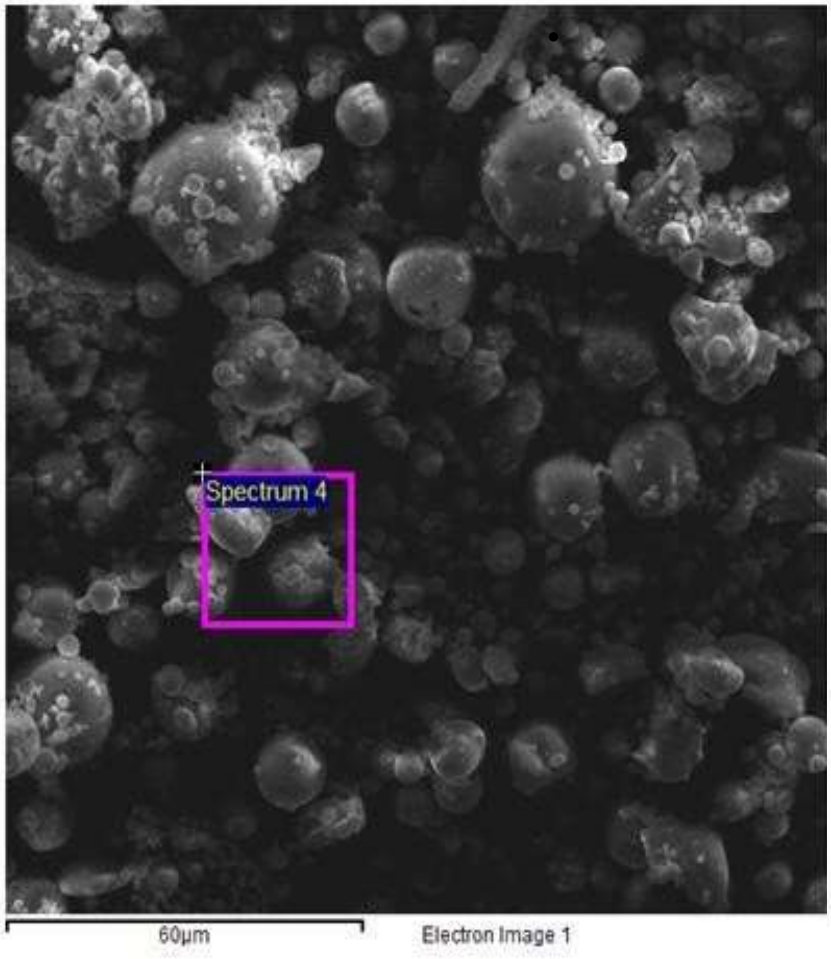
STUDIES AT NIT- WARANGAL

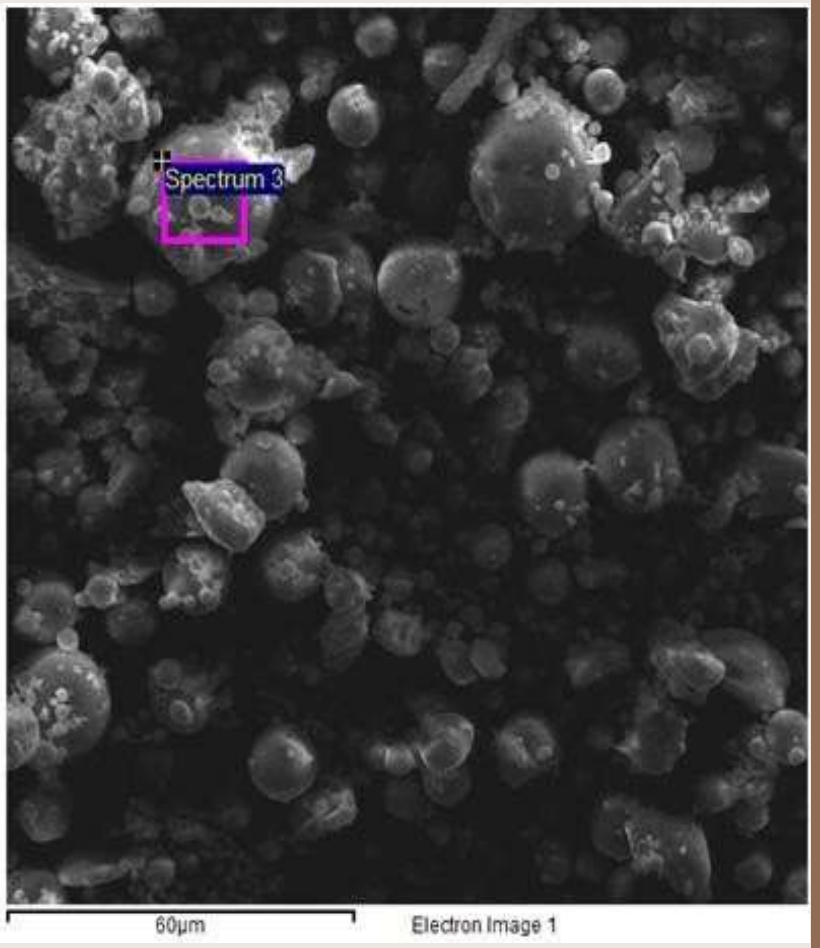
Chemical compositions of Fly-ash used are

Chemical Composition	Fly ash
CaO	4.00
SiO_2	60.11
Al_2O_3	26.53
Fe_2O_3	4.25
SO_3	0.35
MgO	1.25
Na_2O	0.22
LOI	0.88

Fly ash is classified as Grade 1 (fine) according to the IS 3812 - 2013 (revised).Class-F fly ash based on their chemical composition.

SEM Report of fly-ash

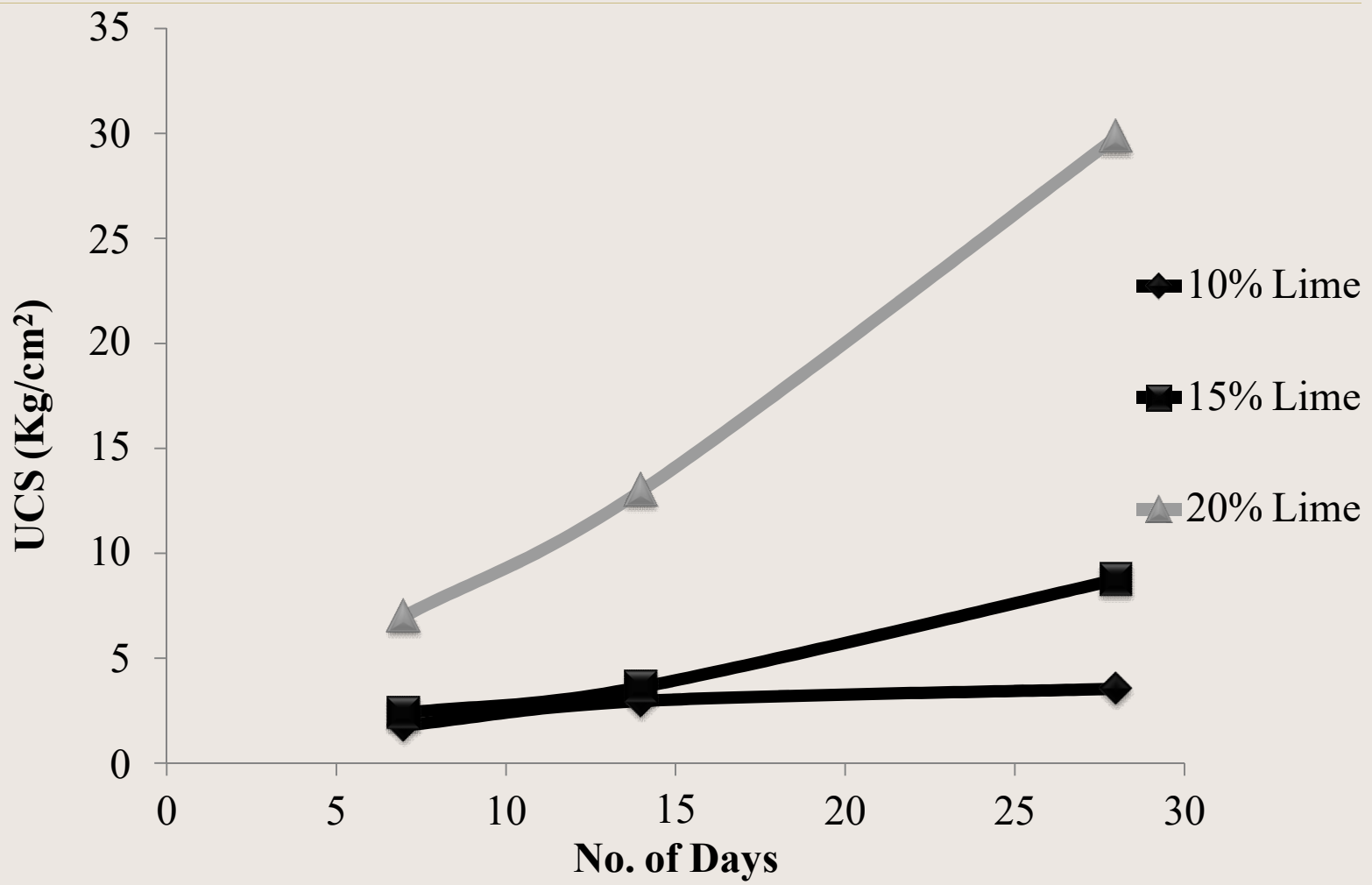




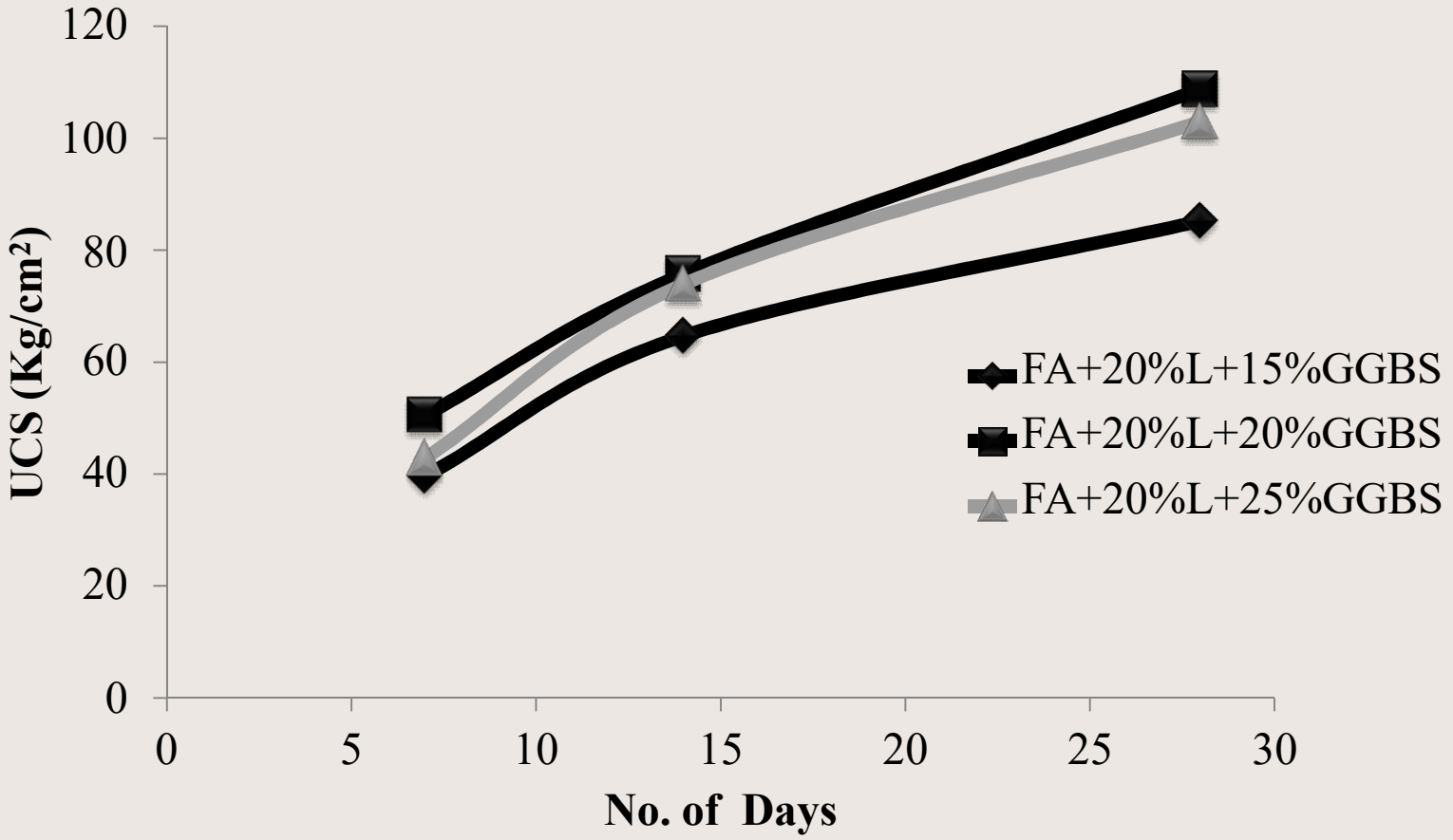
Chemical compositions of GGBS used are

Chemical Composition	GGBS
CaO	32.6
SiO_2	34.06
Al_2O_3	20
Fe_2O_3	0.8
SO_3	0.9
MgO	7.89
Na_2O	-
LOI	.Nil

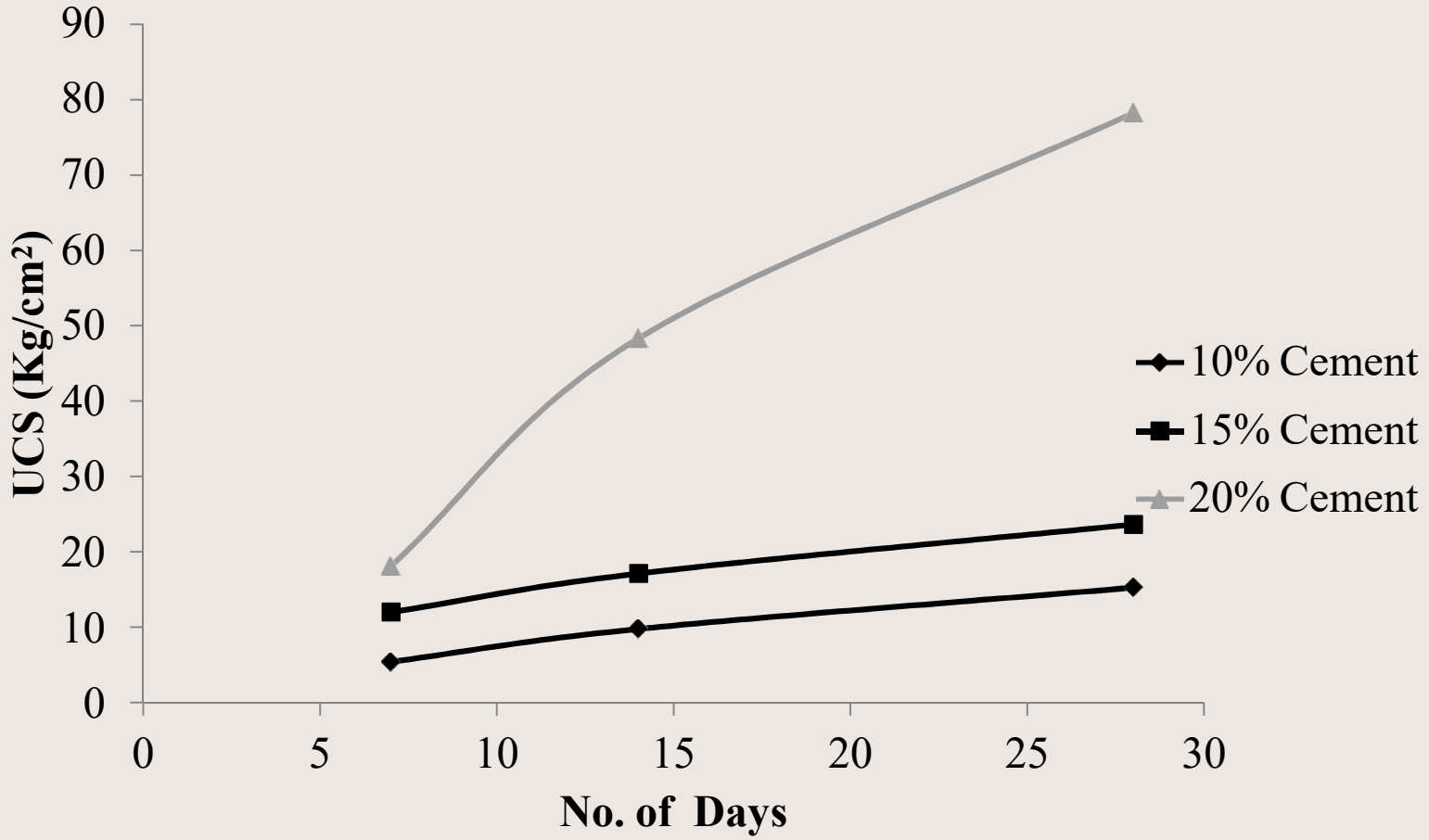
Fly ash + Lime…


35
30
25
20
15
10
5
0
UCS (Kg/cm²)
0
5
10
15
20
25
30
No. of Days
10% Lime
15% Lime
20% Lime

Fly ash + Lime + GGBS



Fly ash + Cement



Comparison with the Standards..

Indian Standard Values			Tested Values	Mix proportions	Curing	Water
Class of brick	UCS(kg/cm²)	W.A(%)	UCS (kg/cm²)		(days)	Absorption (%)
I	100	12 to 15	108.8	FA+20%L+20%GGBS	28	9.75
			103	FA+20%L+25%GGBS	28	6.47
II	75	20	85.21	FA+20%L+15%GGBS	28	12.4
			75.76	FA+20%L+20%GGBS	14	9.75
			78.25	FA+20% Cement	28	7.85
			74	FA+20%L+25%GGBS	14	6.474
III	50	22	64.7	FA+20%L+15%GGBS	14	12.4
			50.52	FA+20%L+20%GGBS	7	9.75
IV	35	25	39.67	FA+20%L+15%GGBS	7	12.4
			40.3	FA+20%L+25%GGBS	7	6.474
			48.33	FA+20% Cement	14	7.85

Comparison of test results with the Standard Values according to *IRC 37-2012* for flexible pavement construction

3. CEMENT STABILISATION

TYPES OF SOIL – CEMENT MIXES

1. **NORMAL SOIL – CEMENT: 5-14% Cement & Sufficient Moisture Content For Compaction and Curing – For Base & Sub-base Courses.**
2. **PLASTIC SOIL – CEMENT: 5-14% Cement & Mortar consistency**
3. **MODIFIED SOIL – CEMENT: < 5% Cement – Generally for Sub-grade Stabilization. CBR can be greater than 25% making the material suitable for sub-base/base course.**

Grading of Materials for Soil-Cement

IS Sieve(mm)	Sub –base(Finer than)	Base(Range)
53	100	100
37.5	95	95-100
19	45	45-100
9.5	35	35-100
4.75	25	25-100
0.60	8	8-65
0.30	5	5-40
0.075	0	0-10

Pulverization Requirement for soil :

-26.5 mm = 100%

-5.6 mm = 80%

SUITABILITY OF SOIL – CEMENT

1. TYPES OF SOIL: Ideal for Well graded Coarse Grained Soils.

- A useful rule for soil selection is that the plasticity modulus (product of PI and fraction passing 425 micron sieve) should be less than 250 and that the uniformity coefficient should be greater than 5. Sulphate < 0.25%

- **Preferably for soils with LL< 45% & PI< 20%**

2.CEMENT CONTENT FOR BASE COURSE

(UCC @ 7 days= 1700 kPa – Old)

(UCC @ 7days= 2800 kPa – Revised)

For Sub base – 1700 kPa @ 7days at present.

3.QUALITY & AMOUNT OF WATER

4.MIXING, COMPACTION & CURING

5.ADMIXTURES – $CaCl_2$ FOR ORGANIC SOILS

- LIME FOR HIGH PLASTIC CLAYS

-FLY ASH FOR SP SOILS

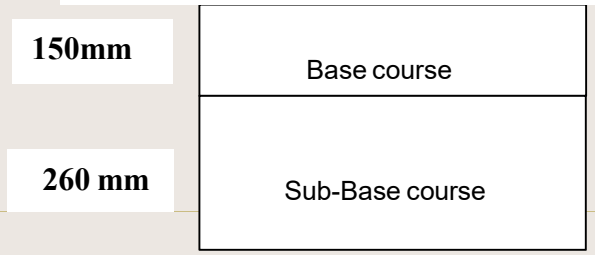
BENEFITS OF CEMENT STABILISATION

1. REDUCED PLASTICITY BY CEMENTATION AND FLOCCULATION
2. IMPROVED DENISTY & REDUCED O.M.C.
3. IMPROVED STRENGTH
4. REDUCED SWELLING & SHRINKAGE

Experiments at NITW

63 mm – 45 mm, Grade-2

Construction of Test Stretches

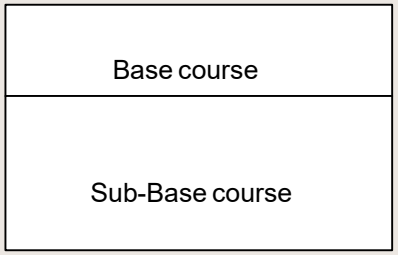


150mm

260 mm

Grade 2 metal + Murrum screenings

Murrum sub-base

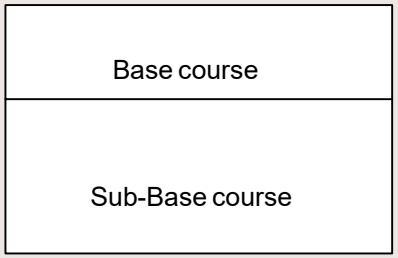


150 mm

260 mm

Grade 2 metal + Murrum screenings treated with 6 % cement content

Murrum sub-base treated with 2% cement content



150 mm

260 mm

Grade 2 metal + Murrum screenings treated with 12%cement content

Murrum sub-base treated with 2% cement content

Cross-section details of different test streches

Properties of Murrum Soils and subgrade soils

S.No.	Property	Murrum	Sub-grade soil
1	Grain size distribution		
	Gravel (%)	10	0
	Sand (%)	69	55
	Fines (%)	21	45
2	Atterberg limits		
	Liquid limit (%)	Non-	35
	Plastic limit (%)	plastic	14
	Plasticity index (%)		21
3	IS soil classification	SM	SC
4	Compaction properties		
	OMC (%)	13	16
	MDD (g/cc)	1.98	1.81
	CBR (%) values		
	Unsoaked	12	10
	Soaked	7	5

Plate 3.1 Rolling of Base course using 2 tonne stone roller

Plate 3.2 Completed WBM test stretches

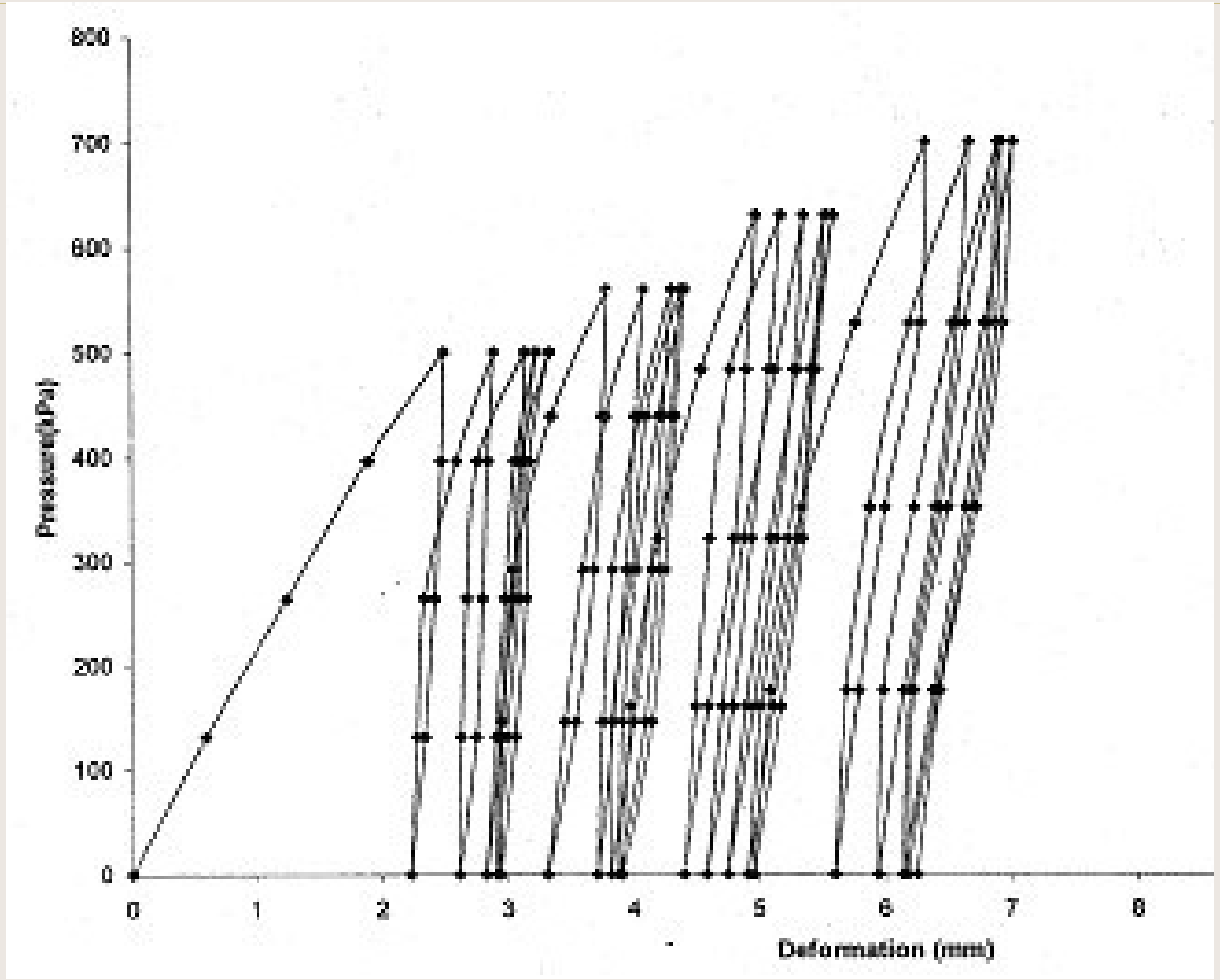
FIELD TESTING

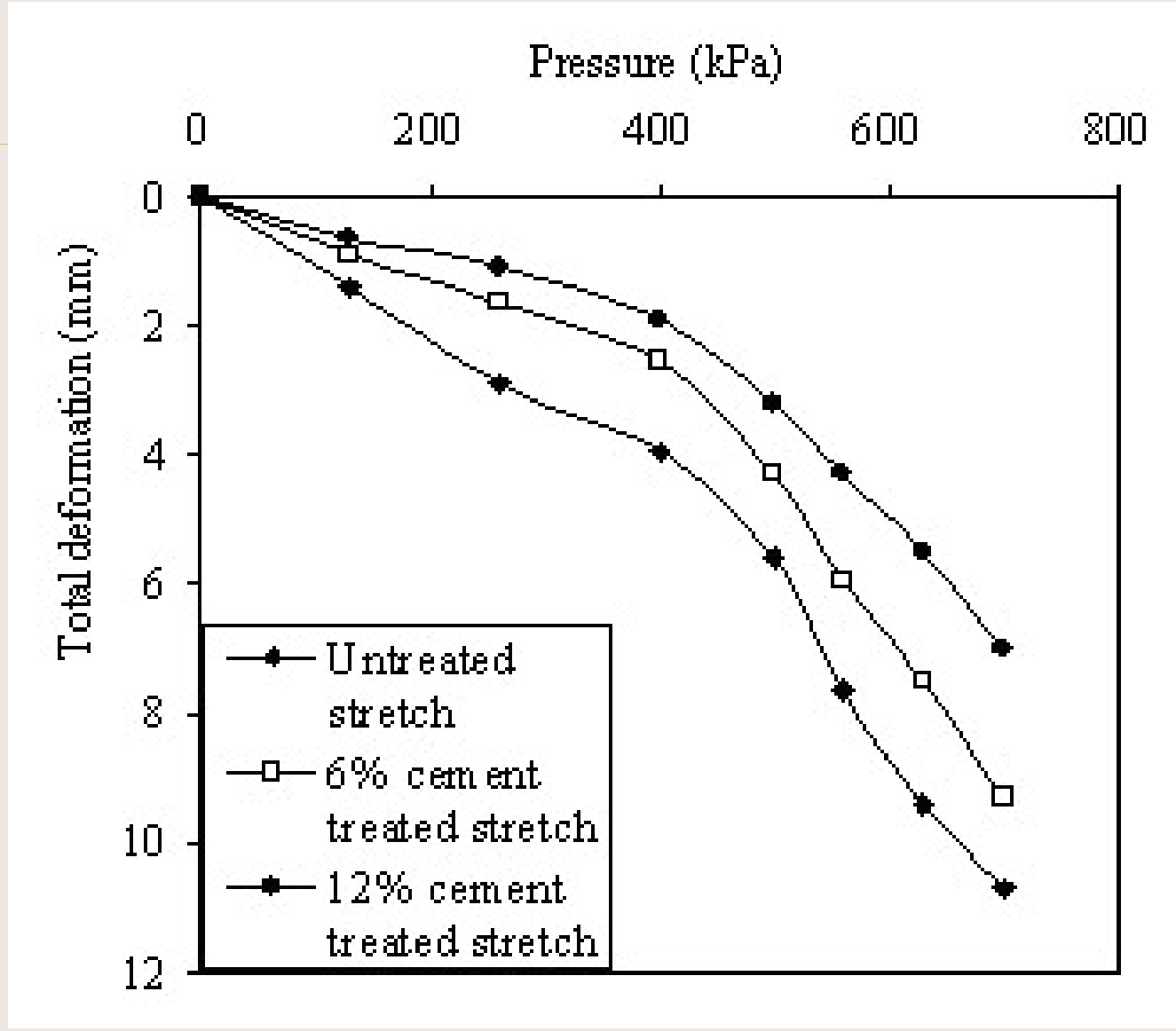
Plate 3.4 Recording the values of Pressure and Deformation

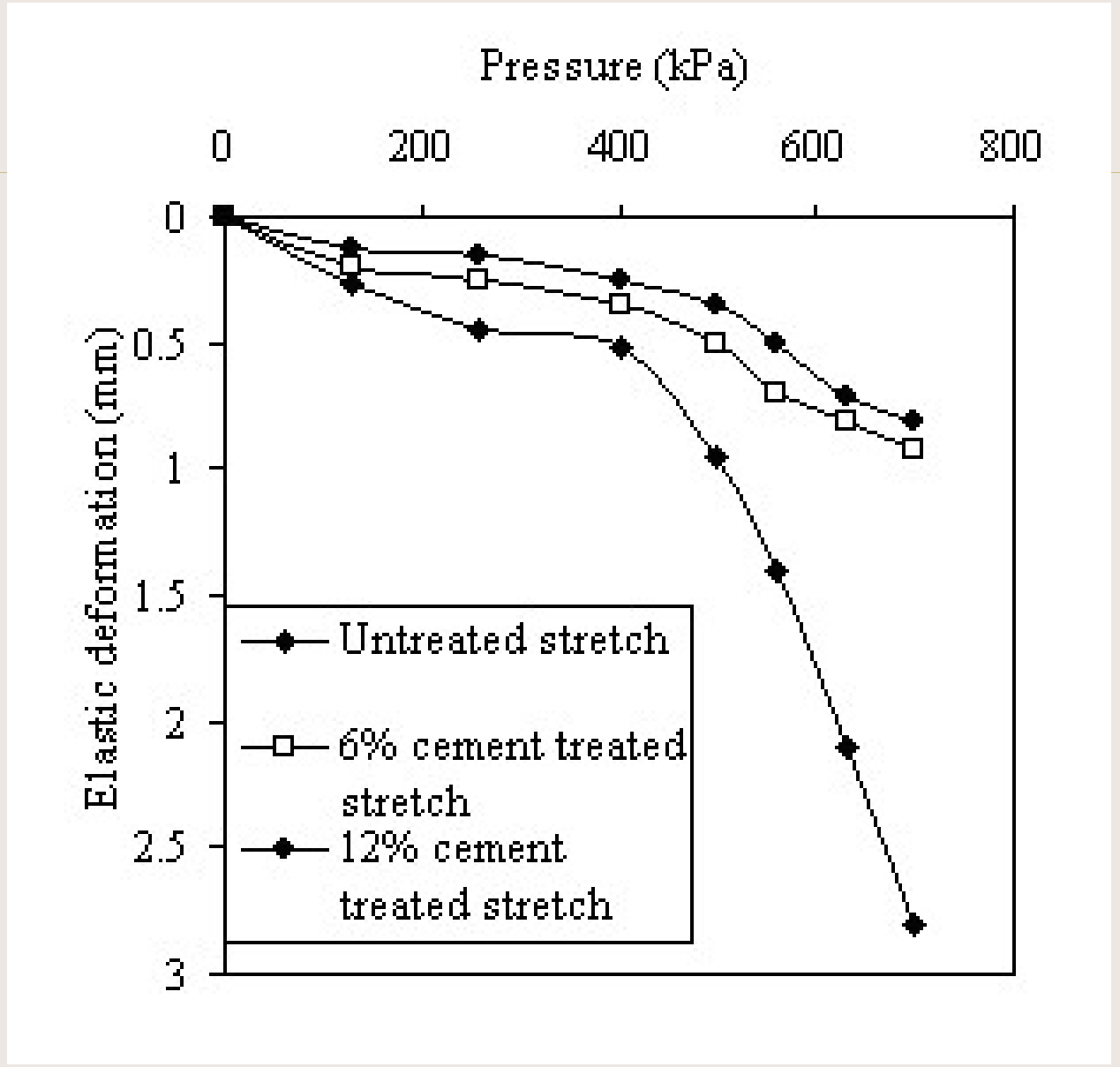
Plate 3.5 Recording the Instant CBR value using Clegg Impact tester

DISCUSSION ON TEST RESULTS

Cyclic Pressure Deformation Plots




Pressure (kPa)
0
200
400
600
800
Total deformation (mm)
0
2
4
6
8
10
12
Untreated stretch
6% cement treated stretch
12% cement treated stretch


Pressure (kPa)
0
200
400
600
800
0
0.5
1
1.5
2
2.5
3
Elastic deformation (mm)
Untreated stretch
6% cement treated stretch
12% cement treated stretch

S.No	Treatement system	Ultimate pressure (kPa)	Settlement (mm)	BCR*	SR**
1	Untreated stretch	410	4.1	--	--
2	6% cement treated stretch	420	2.6	1.024	0.63
3	12% cement treated stretch	440	2.0	1.073	0.48

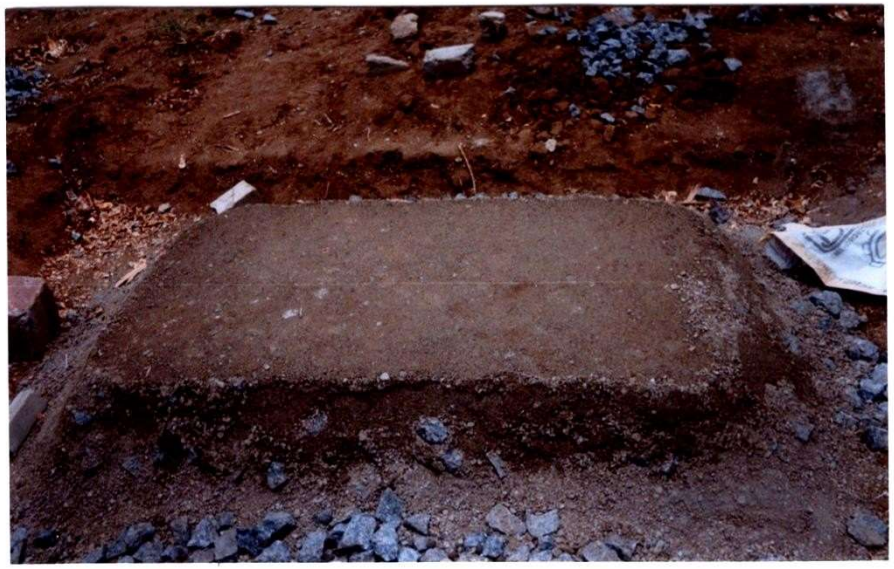
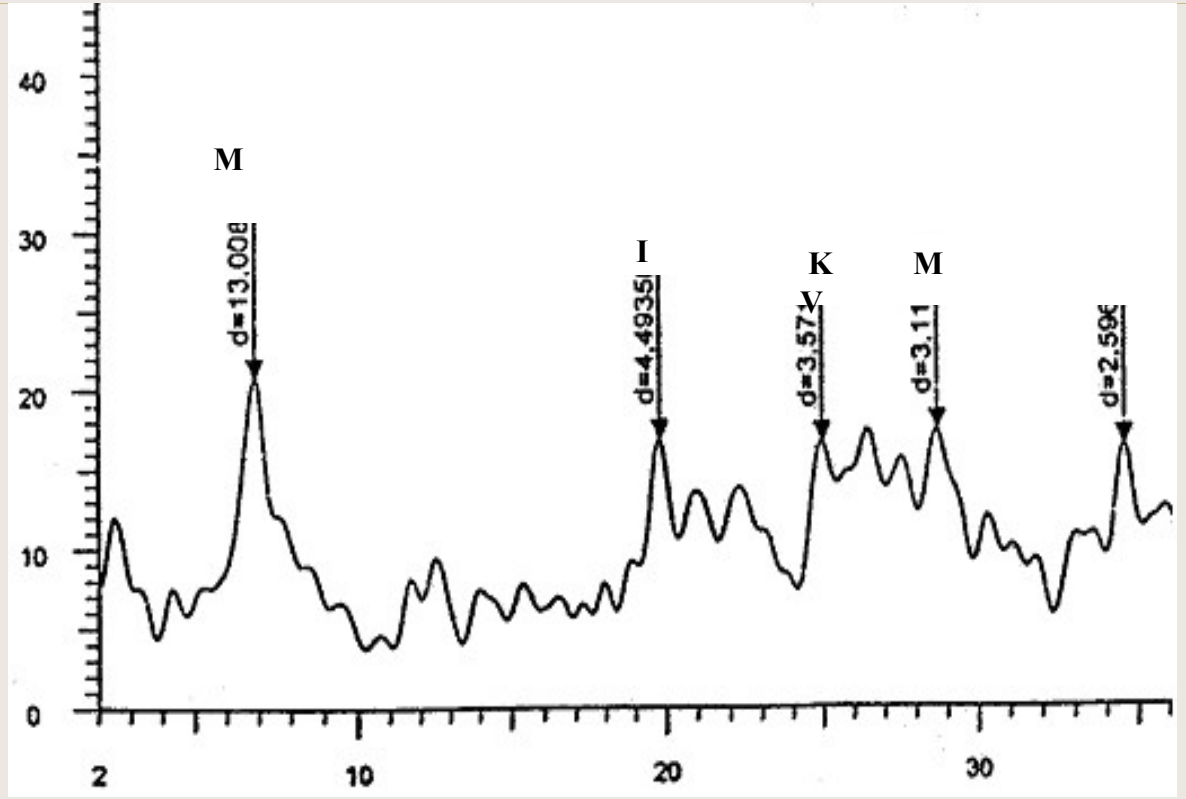


Plate 4.1 Untreated WBM stretch before monsoon rains

Plate 4.2 Untreated WBM stretch after monsoon rains

Plate 4.3 Cement stabilized WBM stretch after monsoon rains

STUDY ON MURRUM SOILS



XRD Pattern for Murrum soil (LL=62%)

Table 2. Properties of lime stabilized murrum soils

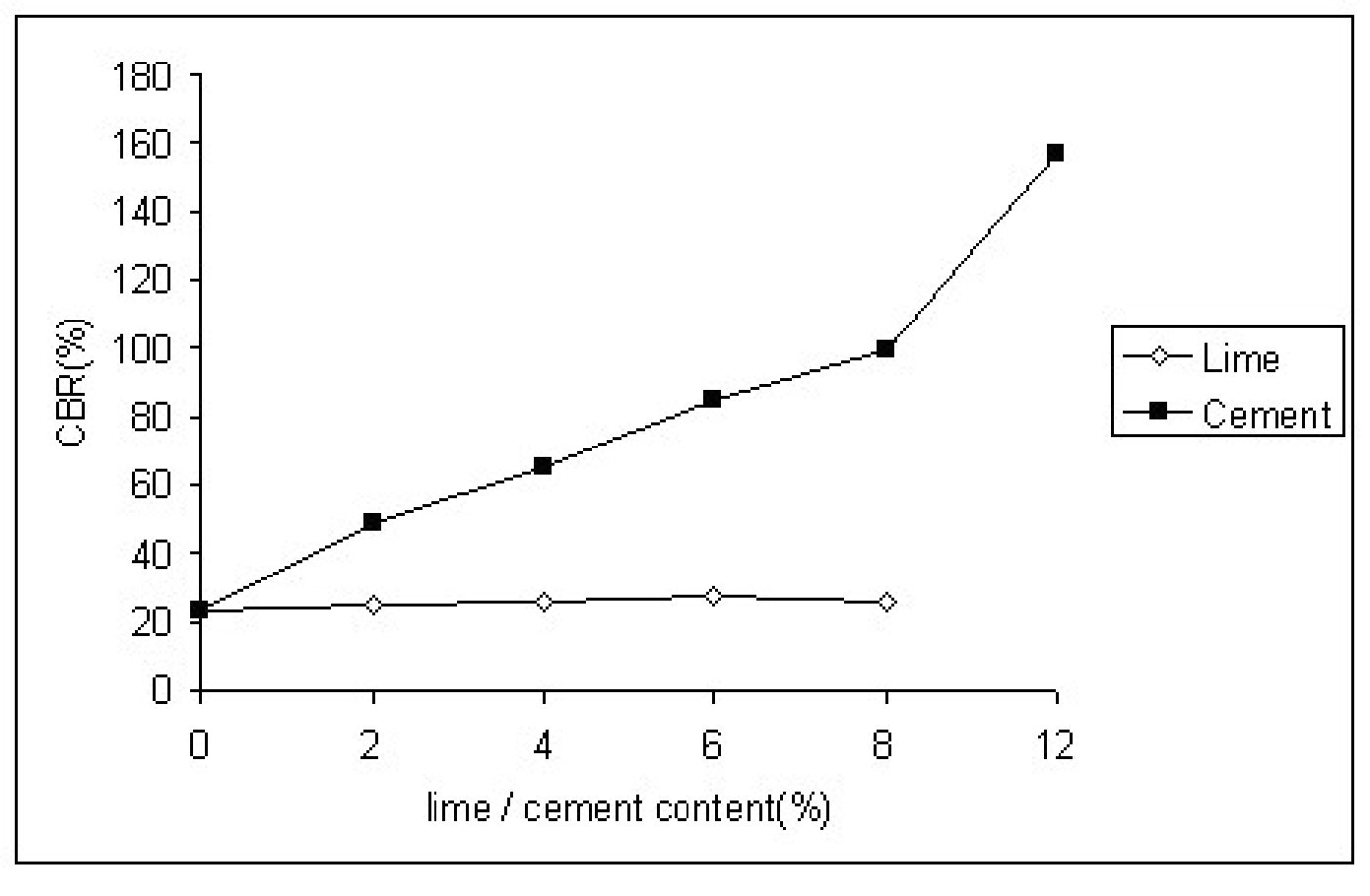
S No	Murrum-Lime mix details	Atterberg Limits: Immediate effect w_1 (%)	w_2 (%)	w_3 (%)	Pre-treatment effect w_1 (%)	w_2 (%)	w_3 (%)	OMC (%)	MDD (g/cc)	Unsoaked CBR (%)	Soaked CBR (%)
1	Murrum 1 + 0% Lime	35	21	19	NP	NP	NP	11.5	1.96	24	23
2	Murrum 1 + 2% Lime	31	21	20	NP	NP	NP	12	1.95	25	25
3	Murrum 1 + 4% Lime	30	22	21	NP	NP	NP	11	1.95	26	26
4	Murrum 1 + 6% Lime	28	23	22	NP	NP	NP	12	1.94	28	27
5	Murrum 1 + 8% Lime	27	23	23	NP	NP	NP	12	1.94	29	26
6	Murrum 2 + 0% Lime	43	21	15	---	---	---	13.5	1.89	17	5.6
7	Murrum 2 + 2% Lime	41	22	19	36	22	20	14	1.88	20	7
8	Murrum 2 + 4% Lime	39	22	21	35	23	22	14	1.88	21	8.9
9	Murrum 2 + 6% Lime	38	23	22	32	24	23	14	1.88	23	11
10	Murrum 2 + 8% Lime	37	24	23	31	26	25	15	1.87	24	4
11	Murrum 3 + 0% Lime	62	23	16	---	---	---	14	1.86	21	4.5
12	Murrum 3 + 2% Lime	50	24	20	45	25	22	14	1.86	27	7
13	Murrum 3 + 4% Lime	48	24	22	44	26	24	14	1.85	24	13
14	Murrum 3 + 6% Lime	46	26	24	41	27	26	15	1.85	29	16
15	Murrum 3 + 8% Lime	43	26	25	39	28	27	15.5	1.84	30	12

Table 3. Properties of cement stabilized murrum soils

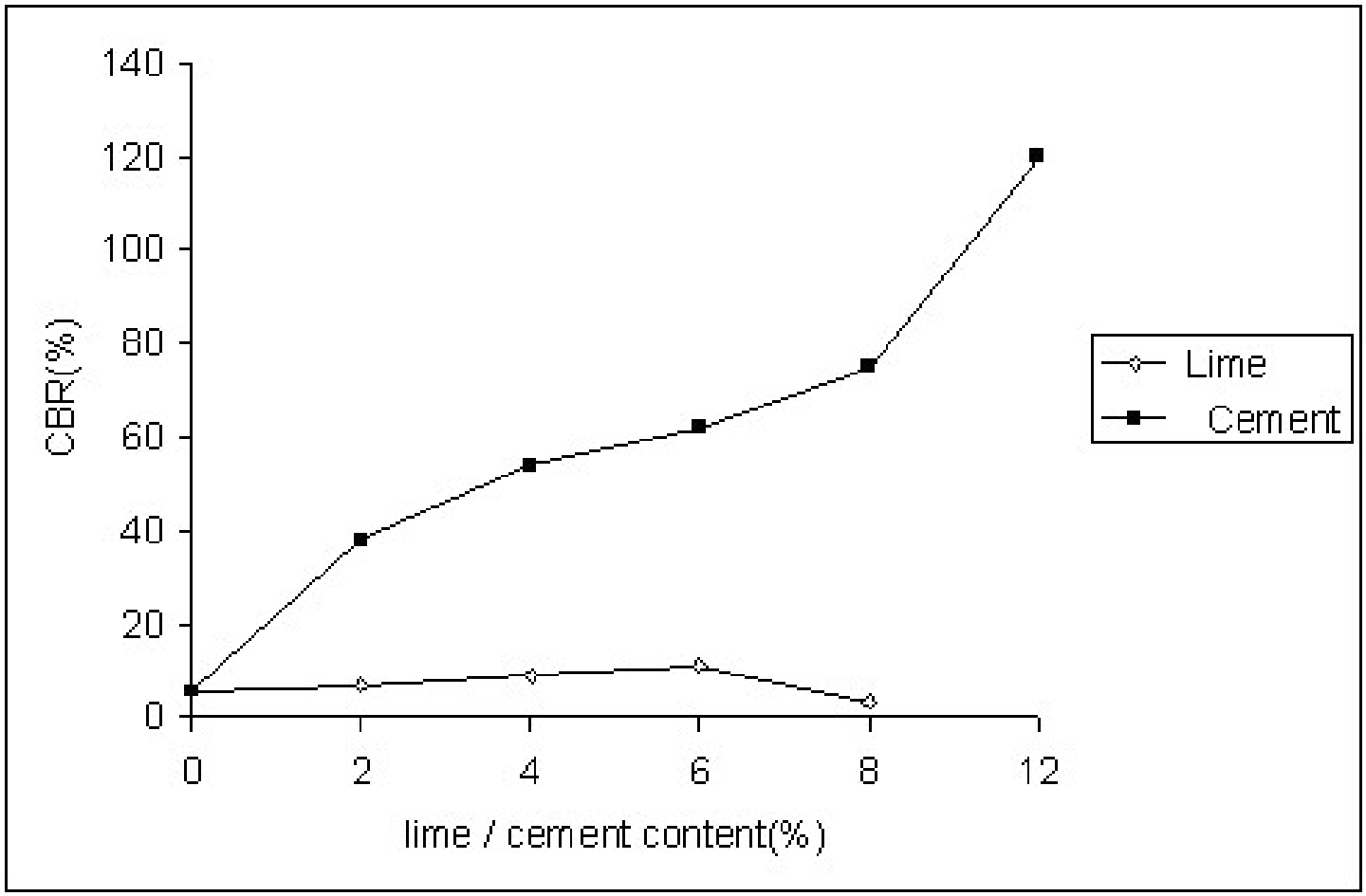
S.No	Murrum-Cement mix details	Percent Fines	Atterberg Limits w_L (%)	w_P (%)	w_S (%)	OMC (%)	MDD (g/cc)	Unsoaked CBR (%)	Soaked CBR (%)
1	Murrum 1 + 0% Cement	14	35	21	19	11	1.96	24	23
2	Murrum 1 + 2% Cement	14	30	215	20	11	2.00	39	49
3	Murrum 1 + 4% Cement	14	29	22	21	10	2.10	45	65
4	Murrum 1 + 6% Cement	14	28	23	22	9	2.10	71	85
5	Murrum 1 + 8% Cement	14	27	23	23	10	2.20	76	99
6	Murrum 1 + 12% Cement	14	NP	NP	NP	13	2.20	87	157
7	Murrum 1 + 0% Cement	24	38	18	16	14	1.88	25	17
8	Murrum 1 + 2% Cement	24	36	22	17	13	1.89	27	46
9	Murrum 1 + 4% Cement	24	35	22	19	14	1.89	34	64
10	Murrum 1 + 6% Cement	24	33	22	20	14	1.90	52	85
11	Murrum 1 + 8% Cement	24	30	22	21	15	1.93	63	98
12	Murrum 1 + 12% Cement	24	NP	NP	NP	16	1.96	70	120
13	Murrum 1 + 0% Cement	34	42	18	15	15	1.84	19	9
14	Murrum 1 + 2% Cement	34	39	20	17	14	1.86	23	41
15	Murrum 1 + 4% Cement	34	38	22	19	15	1.87	24	58
16	Murrum 1 + 6% Cement	34	36	22	21	16	1.89	44	79
17	Murrum 1 + 8% Cement	34	34	23	21	16	1.92	53	88
18	Murrum 1 + 12% Cement	34	29	22	21	18	1.97	58	109
19	Murrum 2 + 0% Cement	20	43	21	15	13	1.89	13	5.6
20	Murrum 2 + 2% Cement	20	38	23	21	13	1.90	17	38
21	Murrum 2 + 4% Cement	20	37	24	22	13	1.90	20	54
22	Murrum 2 + 6% Cement	20	34	25	24	13	1.90	26	62
23	Murrum 2 + 8% Cement	20	32	26	25	13	1.90	27	75
24	Murrum 2 + 12% Cement	20	NP	NP	NP	13	2.00	49	120
25	Murrum 2 + 0% Cement	30	48	21	15	15	1.82	28	2.5
26	Murrum 2 + 2% Cement	30	47	20	17	15	1.84	30	18
27	Murrum 2 + 4% Cement	30	45	21	19	16	1.85	26	35

TABLE CONTD..

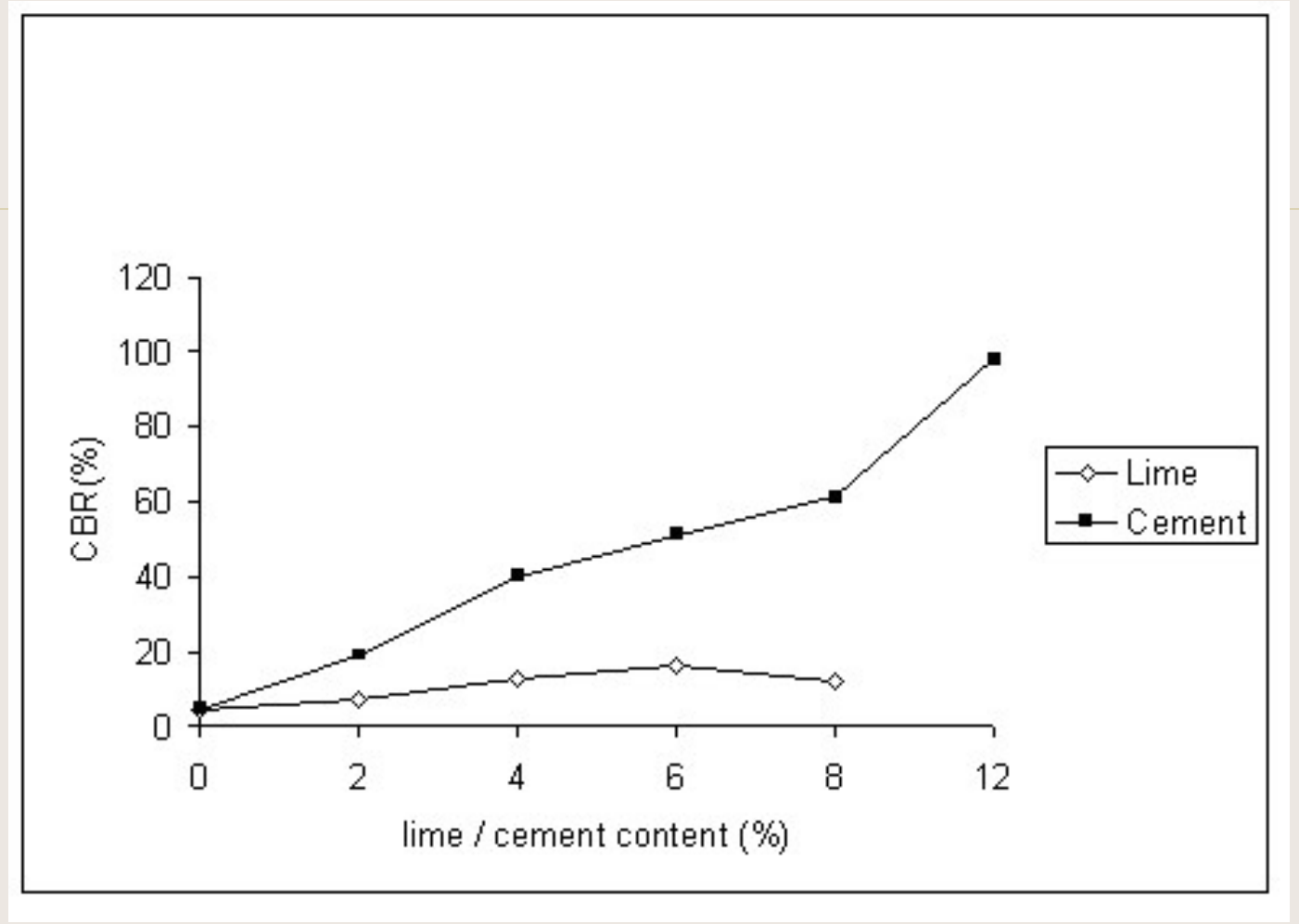
28	Murrum 2 + 6% Cement	30	44	22	21	16	1.87	32	48
29	Murrum 2 + 8% Cement	30	42	23	22	17	1.89	44	57
30	Murrum 2 + 12% Cement	30	36	23	22	18	1.92	52	75
31	Murrum 2 + 0% Cement	40	55	21	14	17	1.80	20	2
32	Murrum 2 + 2% Cement	40	53	22	16	16	1.82	22	15
33	Murrum 2 + 4% Cement	40	50	22	19	17	1.84	24	29
34	Murrum 2 + 6% Cement	40	46	23	21	18	1.86	33	37
35	Murrum 2 + 8% Cement	40	43	22	21	18	1.87	39	48
36	Murrum 2 + 12% Cement	40	38	23	21	20	1.93	43	67
37	Murrum 3 + 0% Cement	25	62	23	16	14	1.86	21	4.5
38	Murrum 3 + 2% Cement	25	48	25	23	13	1.90	26	19
39	Murrum 3 + 4% Cement	25	46	26	24	12	1.90	33	40
40	Murrum 3 + 6% Cement	25	43	28	26	10	1.90	41	51
41	Murrum 3 + 8% Cement	25	41	28	27	11	1.90	50	61
42	Murrum 3 + 12% Cement	25	NP	NP	NP	12	2.00	72	98
43	Murrum 3 + 0% Cement	35	69	23	16	15	1.80	42	2
44	Murrum 3 + 2% Cement	35	66	23	18	15	1.81	43	22
45	Murrum 3 + 4% Cement	35	63	24	20	16	1.83	25	41
46	Murrum 3 + 6% Cement	35	58	24	22	16	1.85	29	58
47	Murrum 3 + 8% Cement	35	54	24	23	16	1.88	35	71
48	Murrum 3 + 12% Cement	35	48	25	23	18	1.91	40	92
49	Murrum 3 + 0% Cement	45	77	23	15	16	1.78	14	2
50	Murrum 3 + 2% Cement	45	74	24	17	15	1.80	17	20
51	Murrum 3 + 4% Cement	45	69	24	20	16	1.81	27	31
52	Murrum 3 + 6% Cement	45	64	23	22	17	1.83	34	39
53	Murrum 3 + 8% Cement	45	58	24	22	17	1.86	32	47
54	Murrum 3 + 12% Cement	45	52	24	22	20	1.89	37	63



Relative influence of lime and cement on CBR of murrum soil with liquid limit=35% and fines=14%

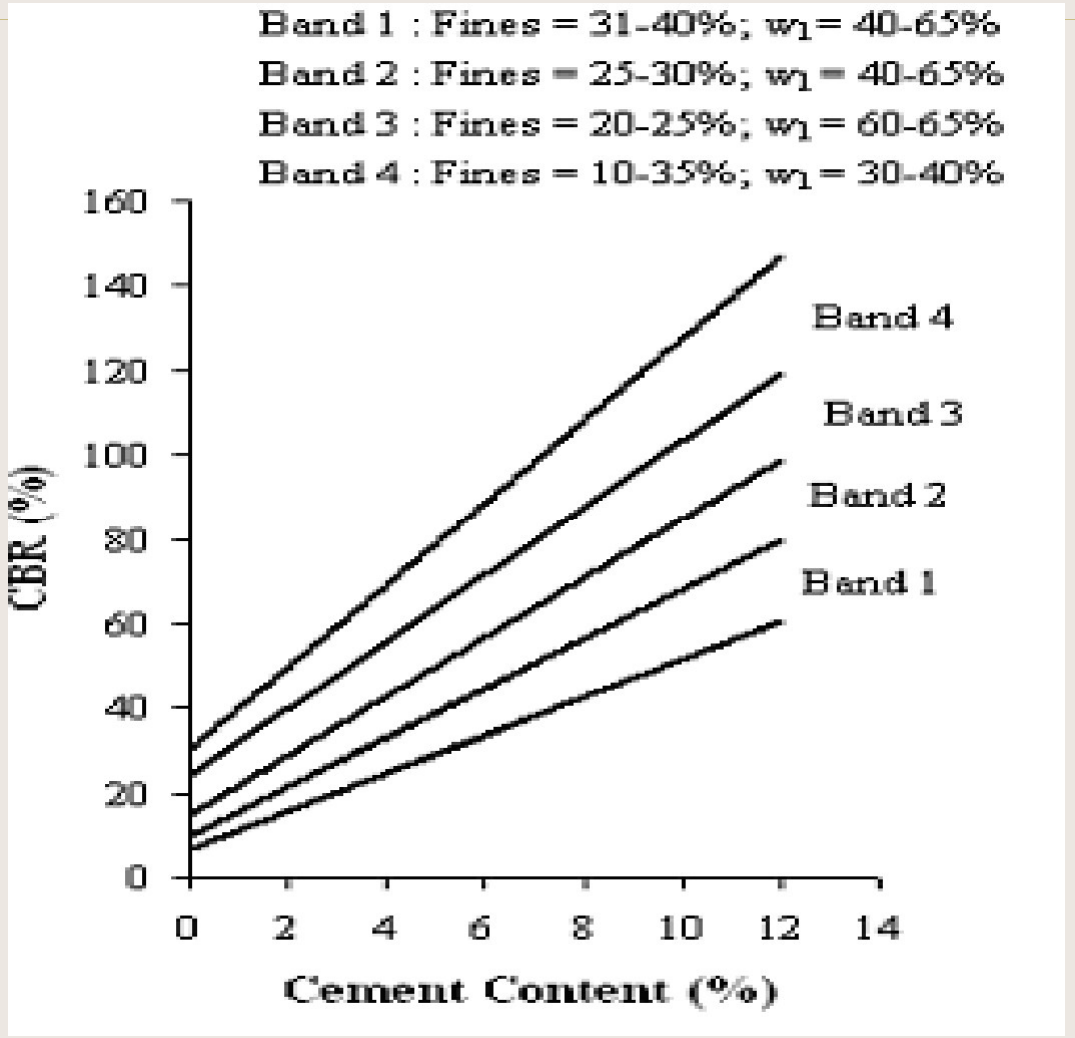


Relative influence of lime and cement on CBR of murrum soil with liquid limit=43% and fines=20%

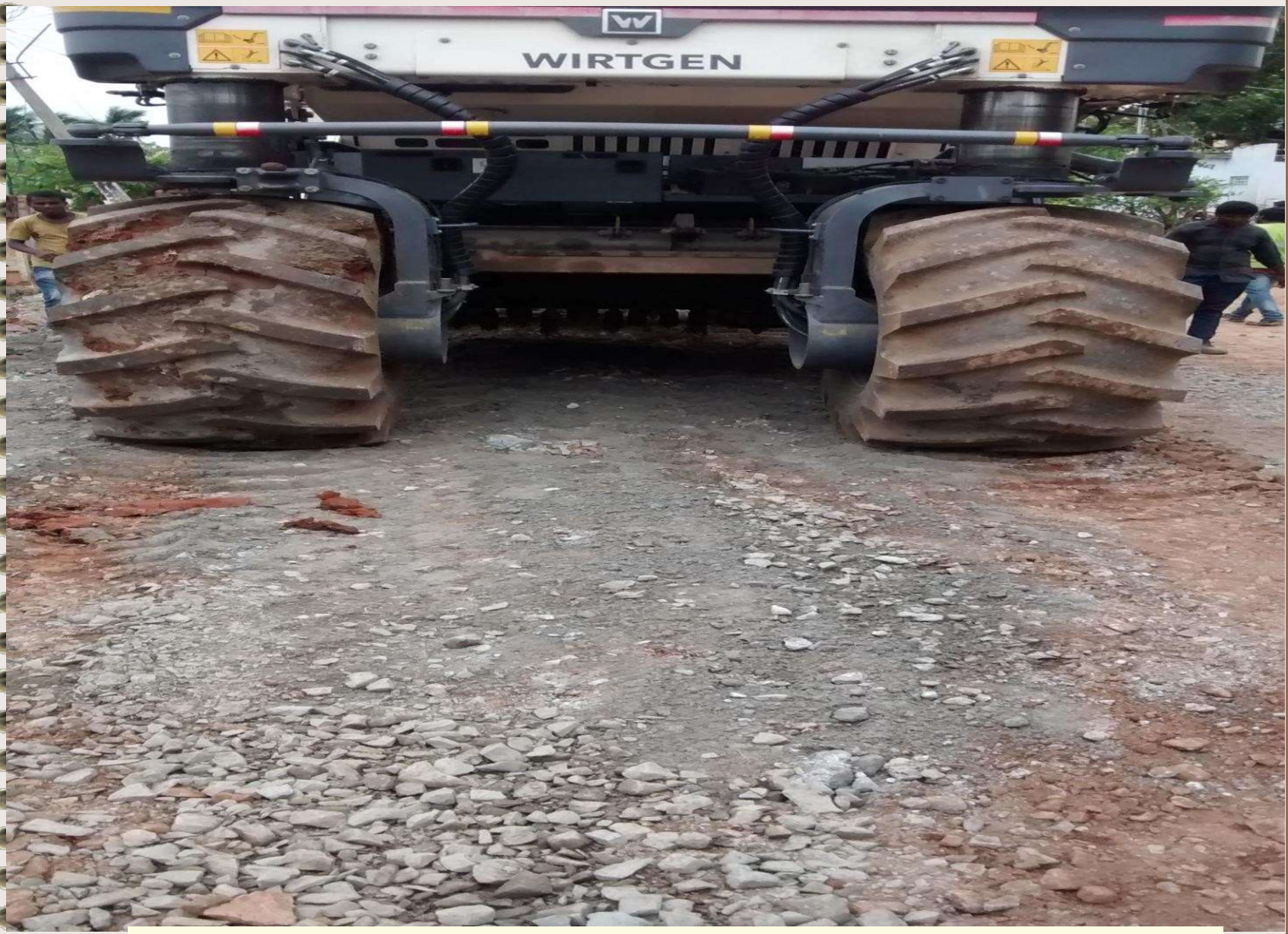


Relative influence of lime and cement on CBR of murrum soil with liquid limit=62% and fines=25%

DEVELOPMENT OF CBR DESIGN CHART



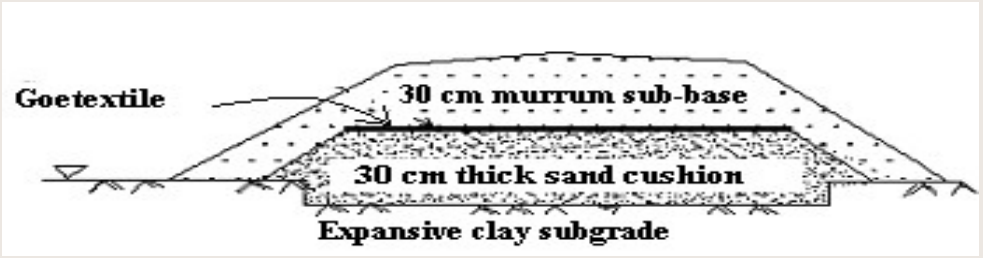
Spreading of Cement + Stabil © Road Compound, Vijayawada



Stabil © Road Construction Equipment

Stabil © Road Base Course @ Poranki, Vijayawada

Attempt for Cement stabilisation Near Repalle, Guntur District


Goetextile
30 cm murrum sub-base
30 cm thick sand cushion
Expansive clay subgrade

30cm sand + 30cm thick murrum cushion.

10% Lime treatment +60 cm murrum cushion .

6% Cement Stabilized Subgrade + 60cm Thick Murrum

30cm Sand + 30 cm Murrum and Geotextile Reinforcement

1% $CaCl_2$ Stabilized Subgrade + 60cm Thick Murrum Cushion

Geotextile + 60 cm Thick Murrum Cushion