DESIGN OF SUBGRADE FOR EXPANSIVE SOIL

By:

Dr. Mahesh D. Desai

Visiting Prof, S.V.N.I.T., Surat,

Consulting Engineer, EFGE Consultant, Surat.

General:

1. 2001: Passenger traffic (80 %) and goods (60 %) are availing roads transport system

2. Road network 3.3 million km (2^{nd} largest in world)

   Rural connectivity: 99 % for 1500 population

   Rural connectivity: 54 % for less than 1000 population

3. 2000-2010: Investment – 25,000/ - crores (Annual)

   Maintenance – 10,000/- crores (Annual)

Gosh, Pant & Sharma

Alluvial & Expansive soils Sbgrade (CH group)

% Replacement of soil	Dry Density (in t/m^3)	OMC (in %)	CBR @ 0.25 cm penetration
15 %	1.63	19	21 %
25 %	1.60	20	39 %

Admixture is 1 Lime : 4 Fly ash by wt. (North India) Tested in field

Lignitic Fly ash (e.g. GIPCL)

Cal – Allumino Silicate, 15 % soil replacement by

1 L : 4 FA ,CBR = 100 for red soil $W_L = 30$, $I_P = 13$.

IRC References:

IRC 49: Recommended Practice for The Pulverization of Black Cotton Soils for Lime Stabilization

IRC 60: Tentative Guidelines for the Use of Lime-Fly Ash Concrete as Pavement Base or Sub-base

IRC 88: Recommended Practice for Lime Fly Ash Stabilized Soil Base / Sub-base in Pavement Construction .

- # Fly ash unusual GIPCL Fly ash (Class C) Lime 30 –35 % part CaO (3 to 4 !) Part Cal allumino Sillicate, $CaCO_3$, $CaPO_4$, $CaSO_4$, Free Lime?
- # Ukai /Other Bituminous Coal FA has CaO 3 %, Only (Class F)
- # No rouble solling in swelling Subgrade. Subjected to flooding use insitu or fill type stabilized soil.

Modern Trends

CBR > 4

- Better materials in base / subbase
- Asphalt bonded surfacing

CBR < 4 (Reduce Maintanance)

- Improved Subgrade

Geotextile

Insitu lime stabilization

Ground in Moist State

Wet Mixing, CaO

Dry Mixing, CaOH + FA

Ground in Saturated State

Columns of lime (CaO)

Compacting

300 mm to MDD @ OMC

CV – 60/day, Growth 8 % per year, Life 10 years,

Vehicle damage factor 1.5, Design CBR 2 to 3, Width 3.85 m

Rural Road:

Conventional Design: 695 mm

– Poor performance of Subgrade

Use of Geofabric with 50 mm sand : 595 mm

– Better performance of Subgrade.

Geofabric for Roads:

For Soft clays, Cu (kPa) = 30 x CBR %,

For CBR = 2 %, Cu = 0.6 kg/cm^2,

BC Factor,

Nc = 2.8 Conventional

Nc = 5.0 with Geo textiles for repetitive Loads > 1000 cycles

Ruts < 50 mm, Single wheel load 45 kN

e.g. CBR = 2.8, CNc = 60 x 2.8 = 168 → T = 320 mm

with Geotextile CNc = 300 → T = 130 mm

(T= Total thickness of Pavement)

(Based on US Forest Dept.)

Cost of fabric (Additive) saves coarse aggregate minimum 100 mm of metal (Save Rs 100 per m^2 against Rs 80 per m^2 extra cost)

Economically Feasible

Action:

Separation – No sinking of stones / soils in voids
No lateral flow by friction between textile to soil
Takes tension
Permits Water dissipation

3 mm rope net with mesh 50 x 50 mm or 35 x 35 mm or Basket of rope, 100 mm ht.

Base material in basket for poor Subgrade.

Fabric to maximum stress at low strain, failure 15 to 20 % elongation, 300 to 400 g/m^2

Comparative Designs:

Case:

Traffic 10 msa, IRS 37: 2001, Subgrade Clay Soaked CBR < 2.

(Expansive soil up to 2 m depth)

Design Option		Total Pavement Thickness (Buffer + Pavement above subgrade)
Alt - 1	IRC 37: 2001	600 + 760 mm
Alt - 2	(-- Do --) + Subgrade: 300 mm Lime stabilized (CBR = 6)	0 + 660 mm
Alt - 3	(-- Do --) + Subbase: Soil + Add Lime FA(CBR = 20)	0 + 540 mm
Alt - 4	(-- Do --) + Base of (Soil + Lime) & equal aggregates	0 + 450 mm
Alt - 5	Stabilized Subgrade 100 mm FA + Lime + Soil 200 mm Soil + Lime + CA 100 mm Binder Surface	0 + 400 mm

Subgrade Improvement:

Sr.No.	Technique	CBR after Application
1	Compaction of existing Ground: Up to 200 mm @ MDD – OMC	CBR = 4 %
2	Insitu Stabilization: Lime & FA + Compaction up to 200 – 300 mm	CBR = 6 %
3	Plant mix: (Soil + Lime 2 to 3%) + equal Coarse Aggregate	CBR = 100 %
4	GIPCL FA + 20 %pulverized Soil → Drum mixed @ OMC Compacted to MDD up to 300 mm (UET & AS)	CBR = 60 %

Subgrade Improvement:

Reduced Pavement thickness 100-200 mm

(If CBR > 30…………..No Subbase is required)

Save 600 mm CNS Buffer to counter swelling

(Total saving 600 + 100 = 700 mm)

Make up layer of soil → Soil mixed with FA, as borrow pits for CNS are not available.

Use Geofabric

Ground Improvement :

Pre-wetting by 3 to 5 m deep holes in expansive Soil

In monsoon by ponding & shallow holes 4 m c/c (2 to 3 months)

Excavated to required formation level

Stabilized by Lime - FA to CBR > 4

Design Pavement .

Design by NAASRA:

Strain Approach (Ref: Pavement Design (1987))

E_V = 10 x CBR, E_H = ½ E_V, Possion's Ratio

Clayey soils 0.45, Cohesionless soil 0.35

Asphalt over unbound, Bound base

Asphalt - Unbound metal – cemented subbase

Ref: Monfred & R. Hausmann, Eng Principals of Ground modification

e.g. CBR: 3, Traffic: 10msa,

Asphalt E = 2800 Mpa 100 mm,

Unbound Basemetal 100 mm,

Cemented Subbase 280 mm

Failure by fatigue in cemented material.

Typical Express Highway Japan:

Asphalt Concrete	40 mm (Seal)
Asphalt binder	60 mm
Upper Asphalted Treated Base	100 mm
Lower Asphalted Treated Base	100 mm
Cement Treated Subbase	200 mm
Subgarde: Clayey loam	Lime Stabilised

Machine / Plants:

Subbase Base	300 t/hr
Asphaltic Concrete Pavement	125 m^3/hr

Drum Pug mill mixers one operation stabilizing process up to 600 mm depth

PLOWS / BACKHOSE / RIPPER / DOZER

Drainage:

1. Granular Subbase (GSB): To surface drains or Base Top Grouted by 5 kg/m^2
2. Complete road before rains. One season (not two stages)
3. Surface drain must drain (not pond)

   (Dahej – Cracks, Longitudinal & up to 3 m depth)
4. Drain Subgrade / No back water if soil is expansive.
5. Drains 2 m away from toe in expansive soils. Surface drains in c/s to long drain with adequate fall.

Pre-wetting in Deep Black Soil Area:

Cut 800 mm

Bores - Sand fill, 250 mm dia

Store water - Oct rains

Water 225 L/m^3

Subsoil 1125 L/m^2 → 2 to 3 months.

Excavate loose soil to Formation level.

Add 2 to 3 % Lime & Fly Ash 4 times Lime, Mix – Dry – Roll

C C Roads:

Good Practices Proven (In Germany as per my view)

Item	A	B	C
CC (QLC) Pavement (mm) Flexural Strength 5.5 N/mm^2 Min. Cement – 350 kg/m^3	260	270	300
Cement Bonded Base (DLC) Flexural Strength 15.0 N/mm^2	150	150	300 (Unbound aggregates Base < 300 mm)
Frost Blanket (Not required in Gujarat)	490	480	300
Drainage blanket provided where required	300	300	300

If Subgrade has k > 5 to 6 kg/cm^3, Examine reducing DLC /

Provide 200 mm Leveling Subbase of Soil + (Lime + FA) + Coarse aggregates or

GIPCL FA + Clay Pulverized Drum Mixed compacted to MDD at OMC (CBR > 60)

260 mm	QLC
150 mm	Lime + FA Concrete or PCC or Lean Concrete
200 mm	Improved soil layer or GSB
	k < 3 to 4

Dropped GSB if k > 6 kg/cm^2

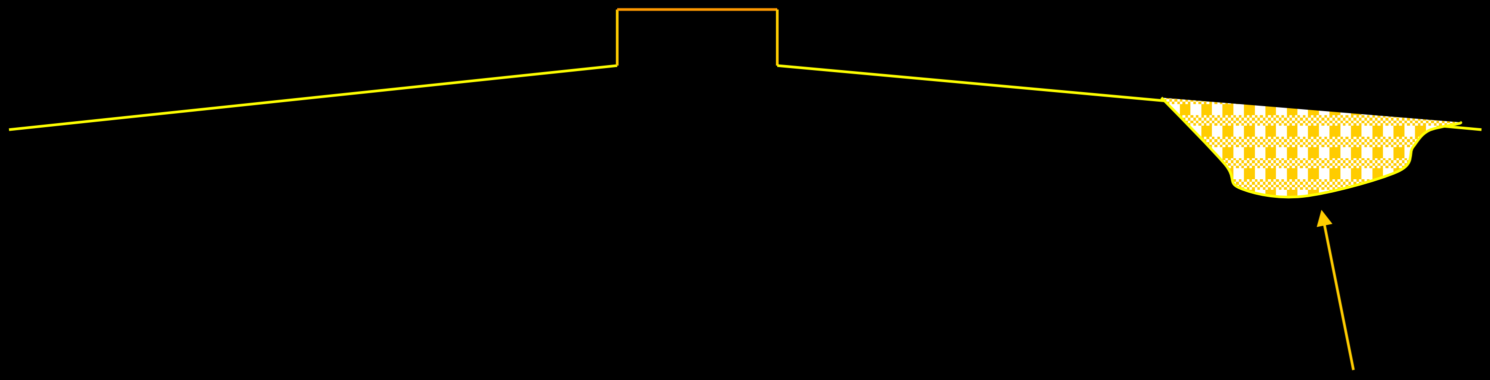
GSB in flooded, non draining area can be disastrous:

Surat – Dumas Road.

Case Study – I:

CC Road (Surat – Bardoli road):

Roadside widths, Shoulders – Drain, Backfill up to 1 to 1.5 m, Mixed soil + Waste of textile & plastics



CC Road

How deep to treat Subgrade?

Stress Transfer from 4.5 m x 3.5 m free panel – 260 mm thick crust

DLC M10 - Strain by Differential Displacement – Compressibility

GSB – Drainage Layer (?) to Subgrade or Leveling Subbase

→ No WT

→ Cohesive Moist – Wet Soil with scattered variable fillings non-degradable waste.

Treat as potholes:

Back fill with earthwork

Fill, Easy to compact

Depth empirically 300 mm (?, How, R& D Topic)

Case Study – II:

Fly Ash react with soil with time.

→ Fly ash stabilized by expansive pulverized CH soil was checked for use in dykes, fills, sub-grade and sub-base by, Nehal Desai (2007) M-Tech thesis .

→ The result are interesting as discussed.

→ All tests are on Proctor Compacted Fly ash of Nani Naroli with CH Expansive soil mixture at OMC to MDD.

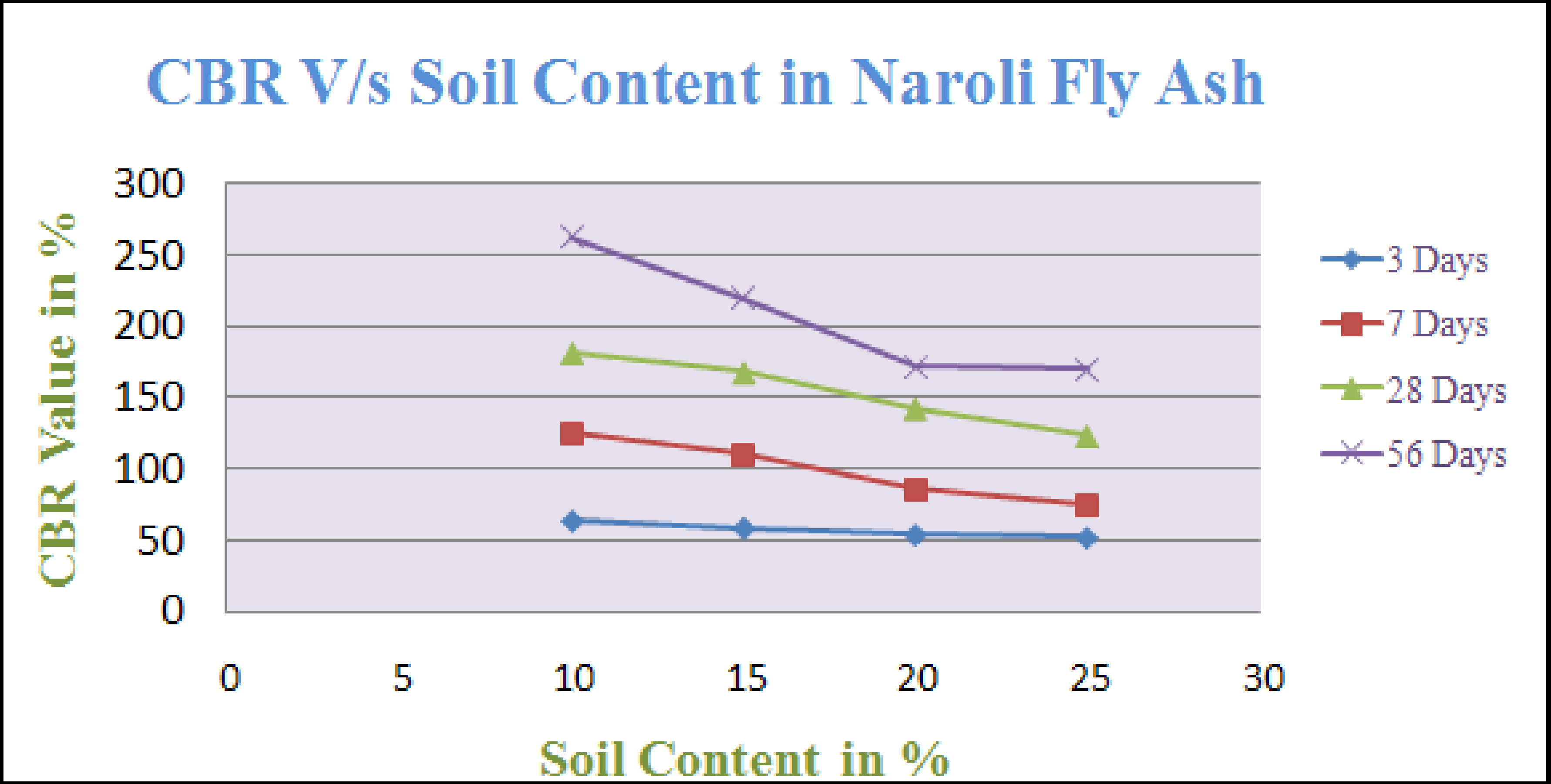
Permeability Test Result

Mix Proportion	Permeability in cm/sec
90:10	5.56×10^{-5}
85:15	4.58×10^{-5}
80:20	2.66×10^{-5}
75:25	1.23×10^{-5}

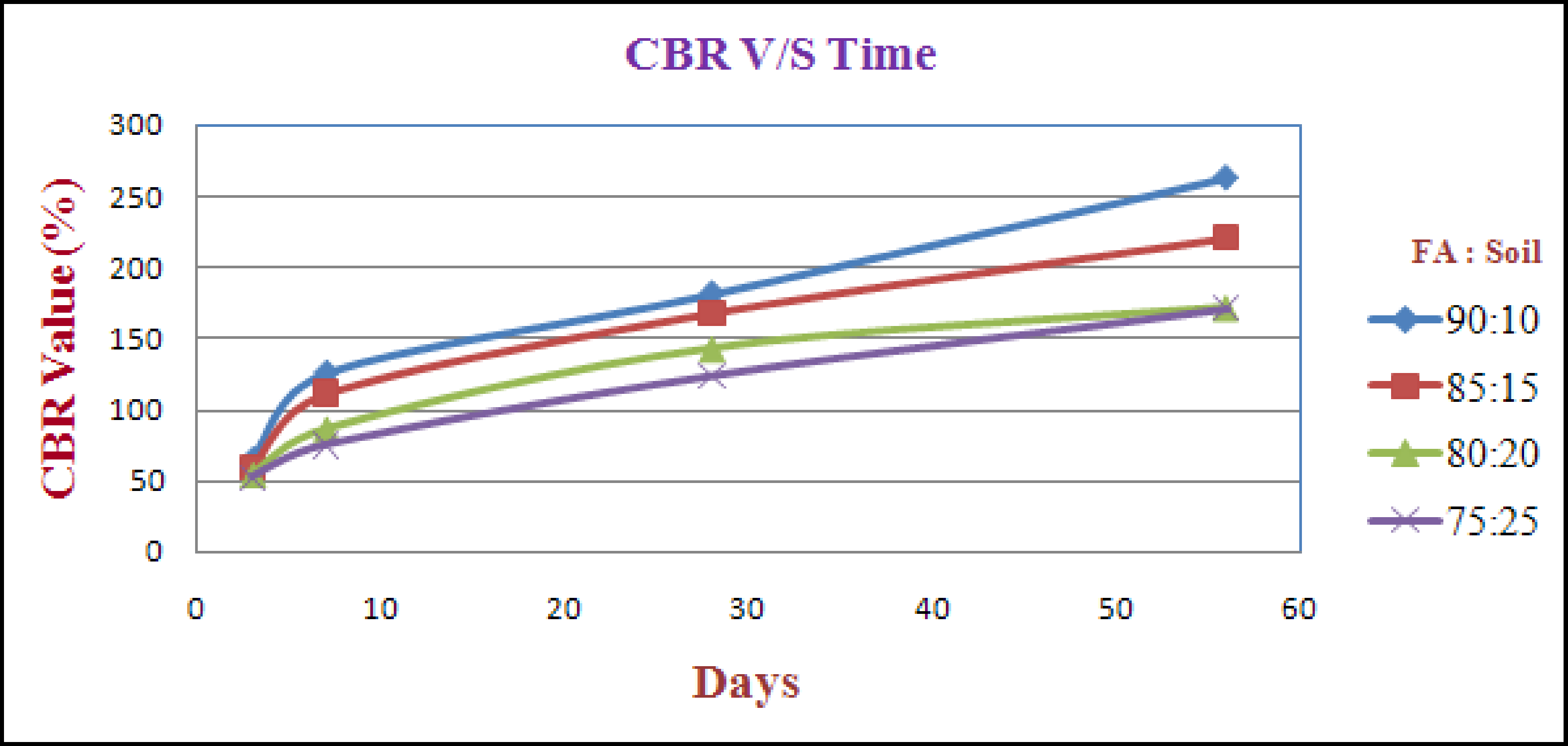
Box Shear Test Result

Mix Proportion	Direct Shear Test							
	3 Days		7 Days		28 Days		56 Days	
	C in Kg/cm^2	Ø in Degree	C in Kg/cm^2	Ø in Degree	C in Kg/cm^2	Ø in Degree	C in Kg/cm^2	Ø in Degree
90:10	4.45	45.03	6.03	41.71	8.69	36.53	11.11	30.76
85:15	4.13	40.66	5.76	36.73	8.09	32.40	9.85	27.04
80:20	3.87	39.24	5.25	36.85	7.79	30.11	8.39	23.98
75:25	2.51	35.12	3.98	31.29	5.84	25.04	7.04	19.13

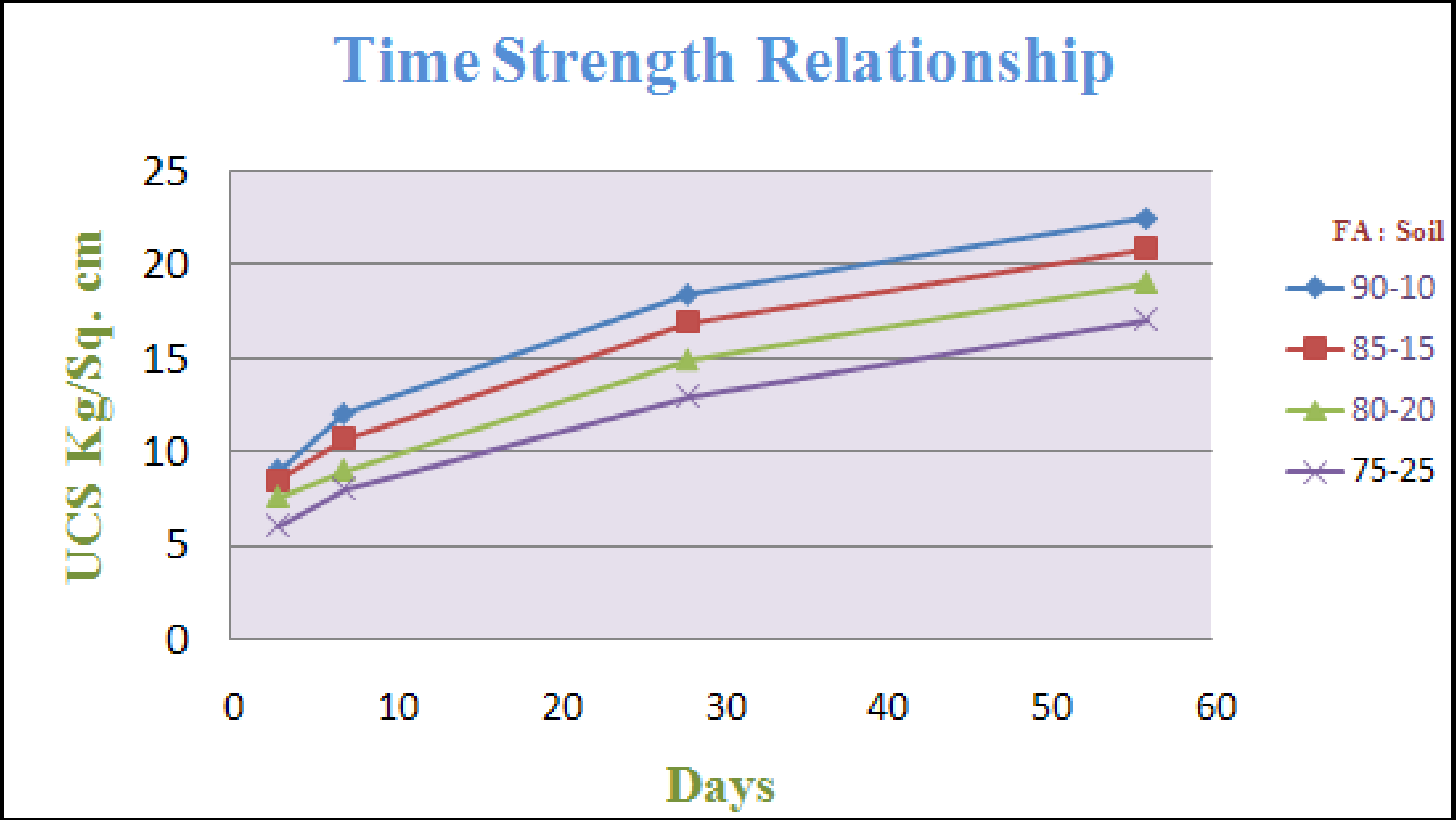
CBR v/s Soil Content Relationship



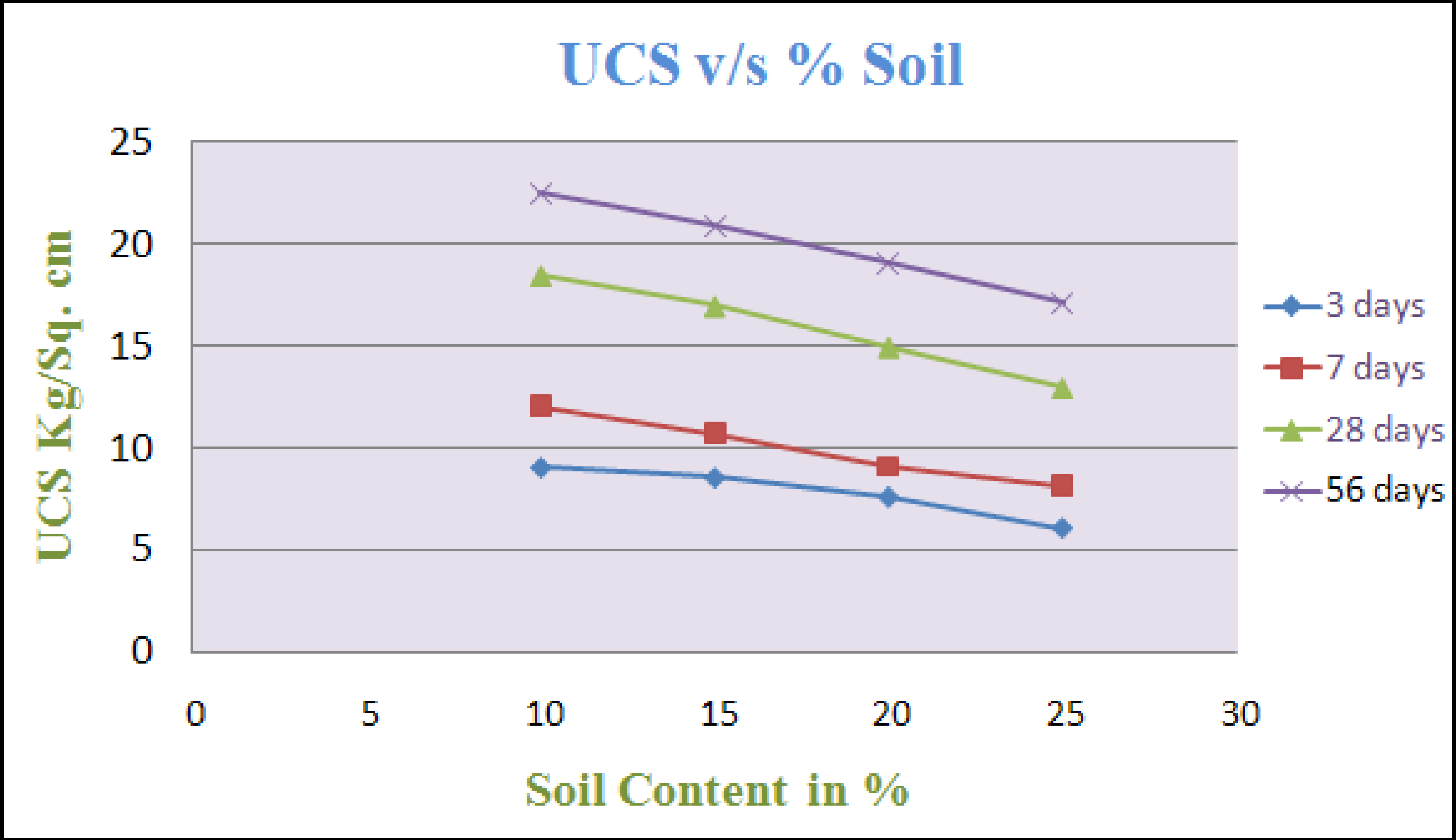
CBR v/s Time Relationship



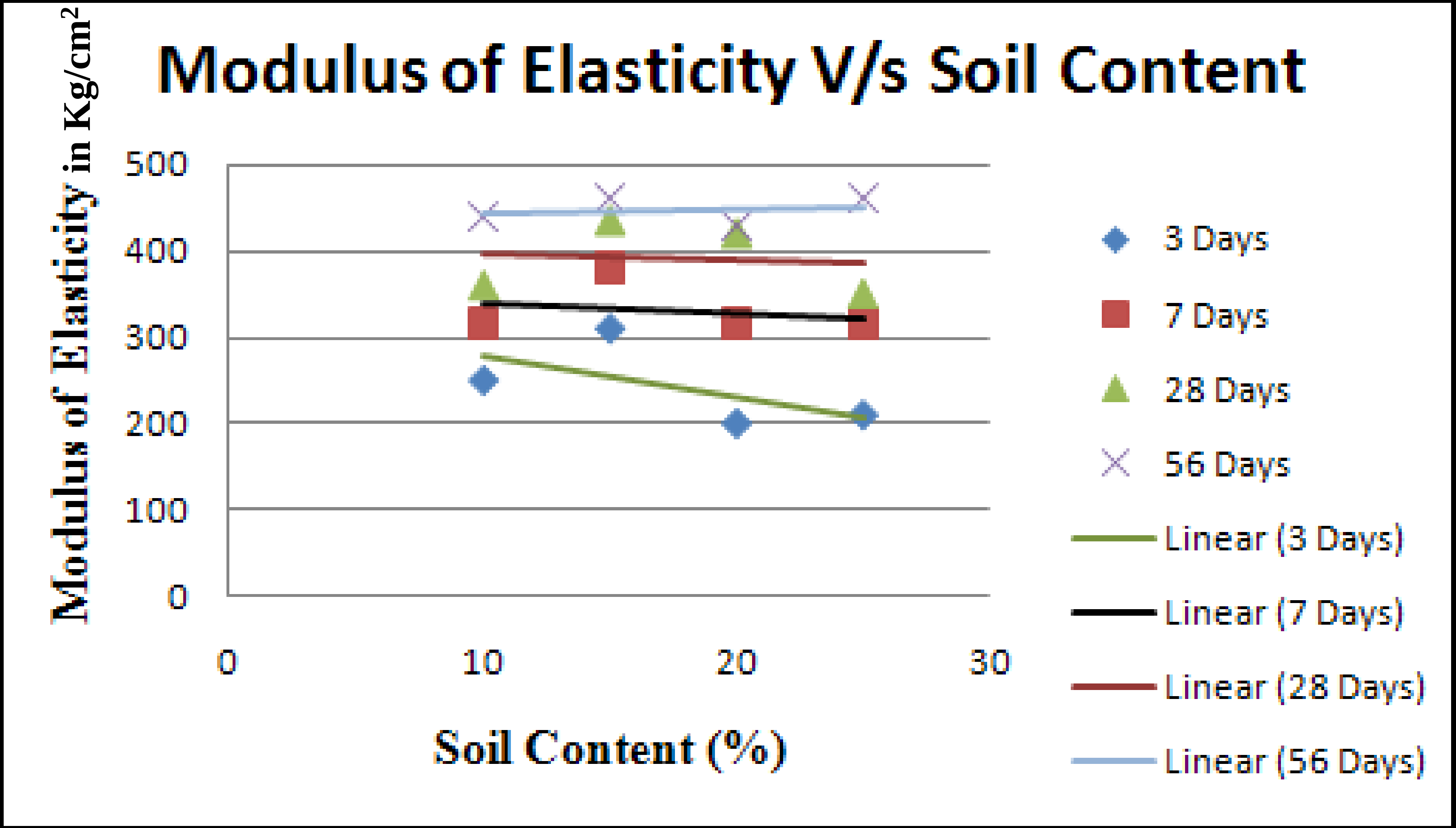
UCS v/s Time Relationship



UCS v/s Soil Content Relationship



Modulus of Elasticity v/s Soil Content



Need for Application of Mind with Theory backup:

The design of pavement rigid & flexible is based on CBR value of sub-grade natural ground profile.

1) The common practice of 3 to 4 samples for km of road along proposed alignment at G.L. is many time irrelevant for final site because:
   a) Alignment change,
   b) Road formation is in cutting or embankment,
   c) Samples tested do not represent the entire length in alluvial coastal regions.

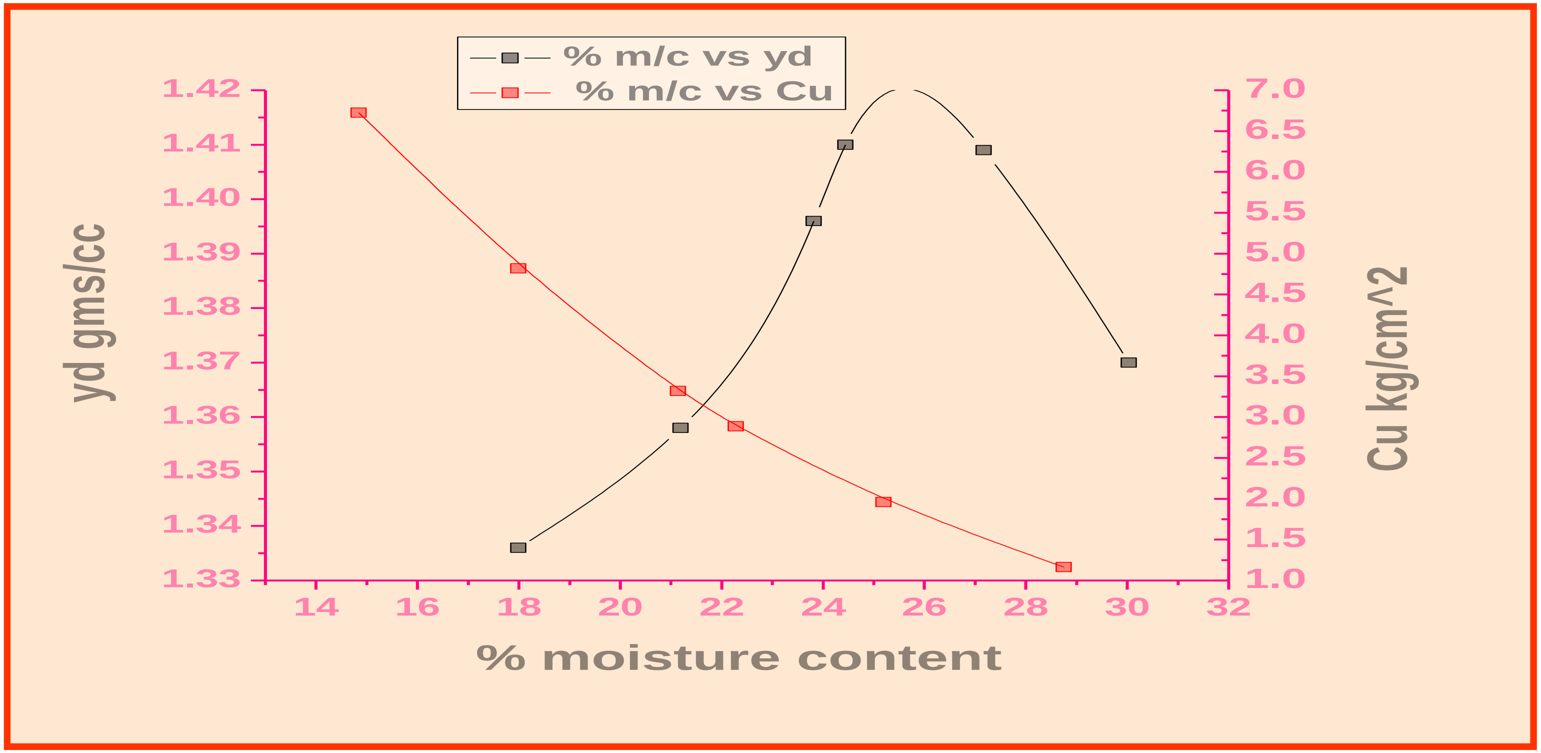
2) Study shows for South Gujarat region for CH / SM expansive soil & non plastic silt soaked CBR of UDS & remoulded samples varies from 1 to 2 % in most of the cases. Commonsense & logic do not accept this.

There is need for Testing & Review.

3) The design of 600 to 1000 mm soil capping is automatically provided as per IRC for expansive soils subjected to flooding – wetting.

This is not engineering and economical.

Relation between % *M/C*, γ_d and C_u *(For Soil under Consideration)*

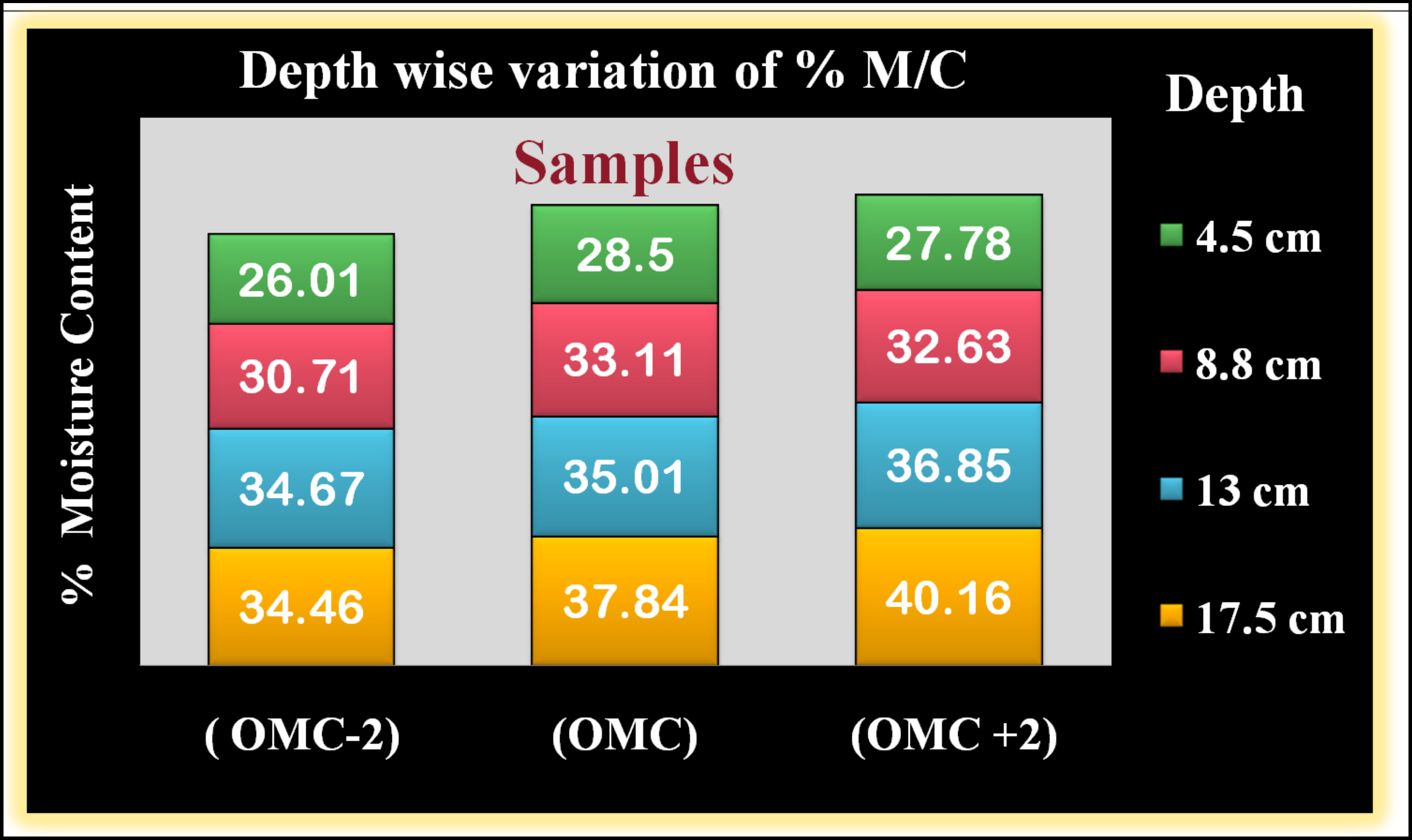


➢The value of C_u is determined by *UCC* test and the relation between % Moisture Content, γ_d and C_u is as shown in figure.

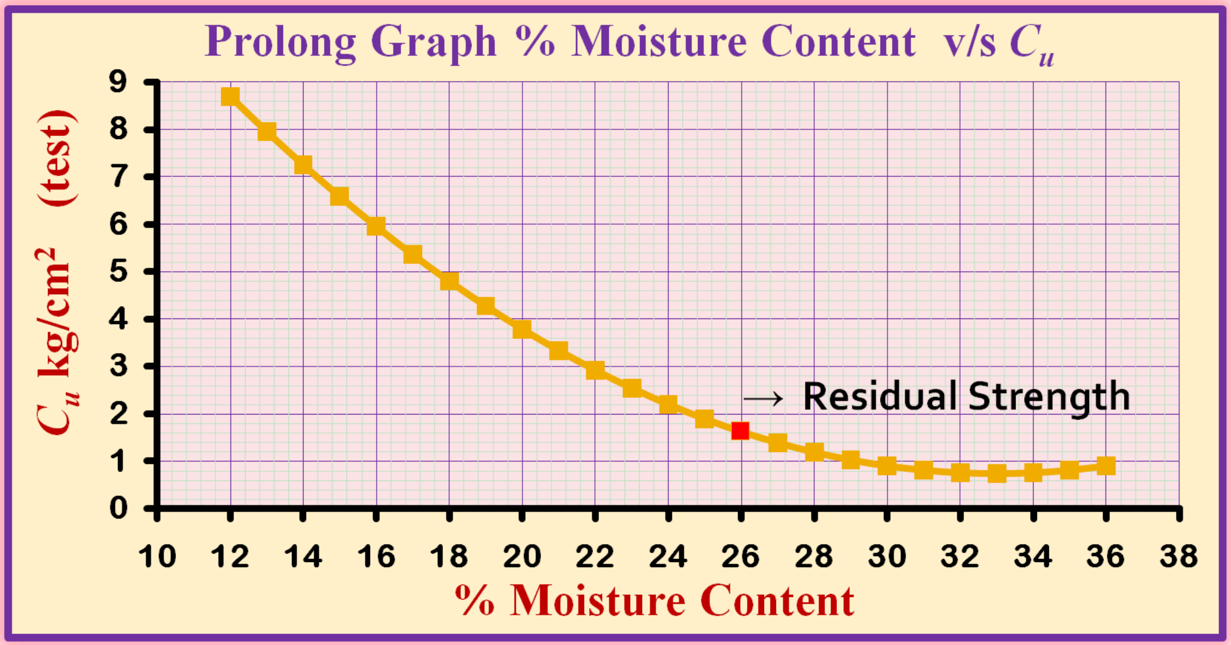
4) The 4 days soaked CBR value was design code criteria. Experimental verification of compacted CH soil at OMC (25.5 %) shows CBR = 7.8 % unsoaked & 3.5 % under soaked condition. At moisture + 2% OMC, CBR was 6.5 % and 3.5 % respectively.

The sample on soaking shows moisture varying from 40 to 26 %, thus it do not ensure soaked saturated state.

DEPTH WISE MOISTURE VARIATION OF THE *CBR* MOULD



5) The unconfined compressive strength of compacted sample at OMC was 3.0 kg/cm^2. C_u is very sensitive to moisture content of compacted clay.



- ❑ Estimated W_{sat} for G = 2.6 for soil was average 26%.
- ❑ The analysis shows that C_u attains residual strength beyond w = 26% which corresponds to W_{sat} for sample on an average.

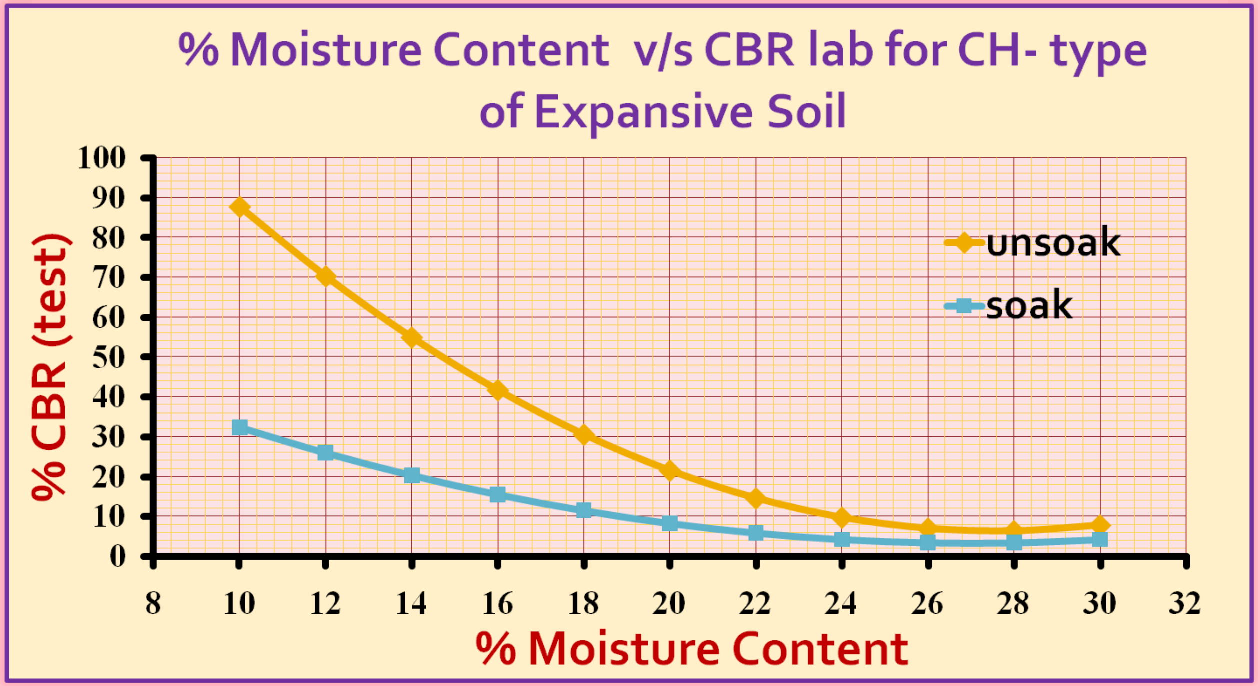
Strength Property of *CH*-Type of Expansive Soil (*UCC* test – C_u v/s % *M/C*)

- The strength of *CH*-type of soil was evaluated in terms of C_u value and soaks and unsoaks *CBR* values.

In-situ Density, Moisture Content, Dry Density, q_u & C_u

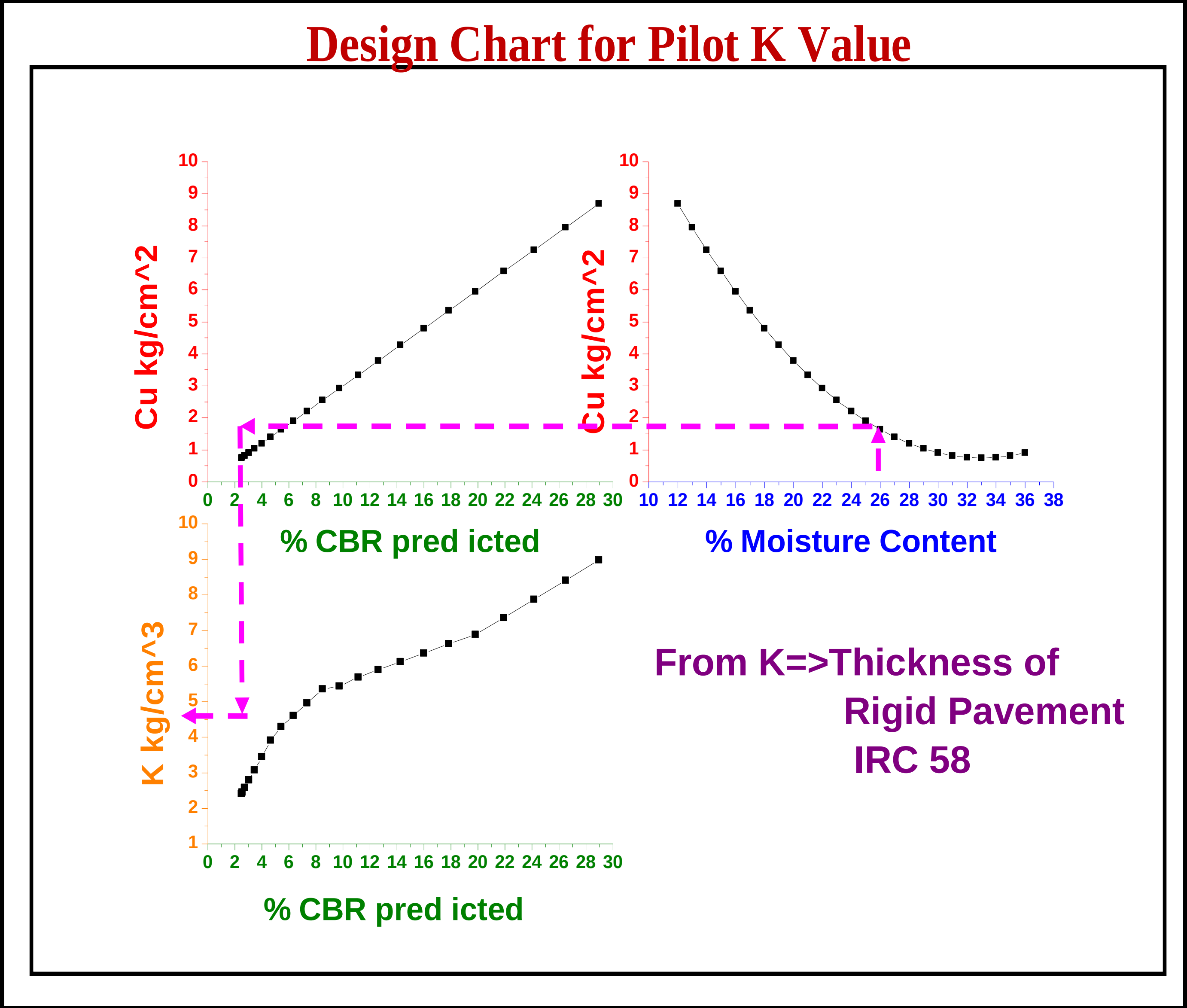
% *M/C*	Bulk density (gms/cc)	Natural moisture content %	Dry density (gms/c)	q_u (kg/cm^2)	C_u (kg/cm^2)
18	1.77	14.84	1.54	13.45	6.725
20	1.83	17.99	1.55	9.64	4.82
24	1.90	21.14	1.56	6.64	3.32
26	1.93	22.28	1.58	5.77	2.885
28	1.90	25.19	1.52	3.92	1.96
32	1.89	28.75	1.47	2.33	1.165

6) The CBR value predicted from C_u of compacted clay and experimental data for both soaked & unsoaked state are shown in Fig.



❑ **The value of *CBR* is directly determined from % Moisture Content and the figure shows the relationship. And it is applicable for the *CH*-type of compacted expansive soil only.**

Jigisha Vashi (2008) obtained a preliminary correction of w – C_u – CBR – k subgrade modulus for first pilot information.



Thank You