

An Experimental Study on the Stabilization of Sub-Base Layers & Design of Flexible Pavement as per Irc-37 2018 Guidelines

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Research Article

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AN EXPERIMENTAL STUDY ON THE STABILIZATION OF SUB-BASE LAYERS & DESIGN OF FLEXIBLE PAVEMENT AS PER IRC-37 2018 GUIDELINES

ABSTRACT

Soil stabilization techniques are employed to enhance the mechanical properties and stability of soil, making it suitable for various construction applications. These techniques aim to improve the strength, durability, and load-bearing capacity of soil, often by incorporating stabilizing agents such as lime, cement, or fly ash. The selection of an appropriate technique depends on the specific soil type, project requirements, and cost considerations. This paper presents a comprehensive review of the influence of various stabilizers on different soil types to improve their engineering properties, with particular emphasis on soils from the Karnataka region and their relevance to flexible pavement design.

Keywords: Red Soil, Commercial chemical stabilizer (CCS), Optimum Moisture Content (OMC), Maximum Dry Density (MDD), Soil Stabilization, California Bearing Ratio (CBR), Unconfined Compressive Strength (UCS), Flexible Pavement.

1. INTRODUCTION

Soil stabilization is a critical component of geotechnical engineering aimed at improving the engineering properties of in-situ soils to enhance the stability and durability of structures built upon them. Problematic soils, such as expansive clays and weak lateritic formations, pose significant challenges in infrastructure development, particularly in pavement construction. These soils exhibit undesirable characteristics including high plasticity, excessive swelling and shrinkage, low shear strength, and poor load-bearing capacity, which necessitate effective stabilization prior to use as subgrade or sub-base materials.

This review explores various soil stabilization techniques and materials, focusing on their effectiveness in addressing challenges posed by problematic soils. The study examines both traditional and innovative stabilization methods, including chemical additives, natural materials, and emerging commercial technologies. Special attention is given to Cement Treated Base (CTB) and Cement Treated Sub-Base (CTSB) layers and their role in flexible pavement design as per IRC 37-2018 provisions. The findings from relevant literature are systematically reviewed and presented under thematic sub-sections.

2. LITERATURE REVIEW

2.1 Literature on Problematic Soils

U.K. Guru Vittal [1] presented an experimental study on Black Cotton (BC) soil in the context of road construction. BC soil is one of the most problematic soil types in India, exhibiting excessive swelling and shrinkage due to the presence of the clay mineral montmorillonite. The study recommended several stabilization strategies, including the provision of a sand cushion blanket or non-plastic moorum layer of appropriate thickness over the expansive subgrade as a sub-base, which serves as an effective intrusion barrier. The primary advantage of this approach is its adaptability to volumetric changes in the soil. Other methods discussed include the provision of a Cohesive Non-Swelling (CNS) soil layer, fly ash cushion, lime stabilization, combined lime-fly ash stabilization, and moisture barriers, all of which operate on the principle of restricting moisture ingress and volume change.

Rizwan Qayoom Sheikh et al. [2] evaluated the suitability of red soil as a sub-base material through a series of laboratory experiments. The study found that untreated red soil exhibits low Unconfined Compressive Strength (UCS)

and California Bearing Ratio (CBR) values, rendering it unsuitable for use as a sub-base material. Red soil specimens were treated with varying proportions of lime and bitumen, both individually and in combination. The results demonstrated significant improvements in UCS and CBR values at specific stabilizer proportions, satisfying the requirements of the IRC code for rural roads in India. The authors recommended further investigation using alternative stabilizing materials such as cement, fly ash, and cutback bitumen to assess their influence on red soil properties.

Neha Upadhyay [3] conducted a review-based laboratory study on weak soils unsuitable for road construction, using cement as the stabilizing material. The study found that cement addition in varying proportions resulted in significant improvements in Atterberg limits, with higher Maximum Dry Density (MDD) and lower Optimum Moisture Content (OMC) compared to untreated soil. Strength parameters, including UCS and CBR values, also showed progressive improvement with increasing cement content. Direct shear test results indicated that cohesion (c) decreased while the angle of internal friction (Φ) increased with higher cement content. The study concluded that even weak soils can be effectively stabilized with cement for use as road construction material.

2.2 Literature on Stabilization Techniques

S. Gadling et al. [4] investigated the use of commercial chemical stabilizers, TerraSil® and ZycoBond®, in various dosages for modifying soil properties. The findings indicated that the addition of TerraSil® and ZycoBond® reduced the liquid limit and plasticity index while increasing the load-bearing capacity of the pavement subgrade, offering significant economic benefits for road development. TerraSil®-treated soil demonstrated potential as a replacement for clay in landfill liners and capping materials owing to its enhanced strength and imperviousness. A combination of Ground Granulated Blast Slag (GGBS), TerraSil®, and ZycoBond® yielded higher CBR values up to certain dosage levels; beyond the optimum dosage, OMC, MDD, and specific gravity were observed to decrease. Furthermore, the combination of silica fume (SF), Recron fibers (RF), and TerraSil® yielded CBR values 15% higher than those of virgin soil. However, limitations such as dosage sensitivity, soil-type-dependent performance variability, and the requirement for combined application for durability were noted. A key disadvantage is that even at a constant stabilizer dosage, different soil types require different curing durations.

Mane S.R. Rohith et al. [5] compared laboratory test results on BC clay with and without the addition of ZycoBond® and TerraSil® stabilizers. An increase in CBR value of up to 57.21% was recorded under unsoaked conditions; however, this value decreased by 19.63% under soaked conditions. An optimum stabilizer dosage of 0.6 kg/m³ was identified as satisfactory for BC clay. The study concluded that the use of TerraSil® and ZycoBond® offers significant economic advantages in road construction; nevertheless, the long-term behavior and interaction of these nano-chemical stabilizers with various subgrade soil types warrant further investigation.

2.3 Literature on Cement Treated Base (CTB) and Cement Treated Sub-Base (CTSB)

P. Prashanth Reddy et al. [6] conducted laboratory studies on native soil and soil-cement-additive combinations. Based on compaction test results, 5% cement and 4% additive by weight of cement were found to be the optimum proportions, yielding improved strength in terms of UCS and CBR. Pavement design carried out as per IRC 37-2018 guidelines demonstrated that the stabilized pavement thickness (380 mm) was significantly less than that of the conventional pavement (560 mm), resulting in a fivefold reduction in aggregate consumption for the stabilized layer. The overall findings indicated higher strength, improved durability, and reduced permeability, contributing to reduced pavement thickness, lower construction costs, diminished CO₂ emissions, and an enhanced pavement service life. Potential limitations include shrinkage cracking, mixing difficulties with highly plastic soils, and compatibility issues with organic-rich soils.

Aher D.D. et al. [7] conducted a comparative study of flexible pavement incorporating a CTSB layer against conventional pavement through laboratory experiments. The study recorded an MDD of 2.38 g/cm³ and a maximum compressive strength of 5.8 MPa with 4% cement and 8% water content. Incorporation of the CTSB layer in the flexible pavement design reduced the overall pavement thickness by 36% and the construction cost by 42.7% per kilometre of road length. However, the authors noted that while CTSB is economically advantageous for long stretches of road construction, it may be uneconomical for shorter road sections.

2.4 Literature on Flexible Pavement Design Incorporating CTB/CTSB Layers

Anirban Chakraborty et al. [8] designed and analyzed Cement Treated Base (CTB) flexible pavements in accordance with IRC 37-2018. The study included fatigue damage factor analysis for CTB and CTSB layers, which was found to be satisfactory as per code requirements. Economic analysis revealed an approximate 43.5% reduction in construction cost per kilometer of road length compared to conventional pavement. A noted limitation of the study was the time-intensive nature of fatigue damage factor analysis in the absence of precise fatigue models for pavement damage assessment.

Subrat Kumar Sahoo and Jyoti Prakash Giri [9] demonstrated that the incorporation of industrial steel slag in CTSB mixtures contributes to a more durable and sustainable pavement system by recycling industrial by-products. Laboratory studies confirmed superior compressive strength, abrasion resistance, and overall durability, making steel slag a viable alternative to conventional materials. The study also highlighted potential cost reductions due to material availability and reduced dependence on natural aggregates. Steel slag-based CTSB mixtures demonstrated excellent load-bearing capacity suitable for both low- and high-traffic road applications. Key limitations include the expansion tendency of steel slag due to the presence of free lime and magnesium oxides, which may cause volumetric expansion and pavement cracking upon hydration, as well as increased transportation costs attributable to the higher density of steel slag compared to natural aggregates.

Vaibhav P. Patil et al. [10] reviewed the concept of CTB and CTSB in flexible pavement design, encompassing design methodology, cost analysis, field performance, and failure modes in comparison with conventional pavement. The study concluded that CTB and CTSB approaches offer savings in transportation, fuel consumption, and heavy machinery requirements during road construction and maintenance. The CTB/CTSB method was found to reduce bitumen consumption and decrease pavement thickness by up to 100 mm, resulting in an overall cost reduction of 21.6% per kilometer of road length, with improved resistance to pavement distress such as fatigue cracking and rutting.

2.5 Literature on Commercial versus Traditional Soil Stabilizers

Ali Akbar Firoozi et al. [11] provided a comprehensive review of the fundamentals of soil stabilization, demonstrating that stabilization effectively enhances the mechanical and durability characteristics of problematic soils through chemical and mechanical modification. Cement and lime stabilization were found to improve shear strength and reduce plasticity and volume change, while fly ash and fiber reinforcement contribute to stiffness enhancement and crack mitigation. The authors emphasized that stabilization performance is strongly influenced by soil type, mineralogy, and environmental conditions, particularly in sulfate-rich and organic soils where durability issues may arise. Proper selection of stabilizing agents based on soil behavior and exposure conditions is essential for achieving long-term geotechnical performance.

Azura Md Zahri et al. [12] presented an overview of both traditional and non-traditional stabilizers for soft soil improvement. The study indicated that traditional stabilizers such as cement and lime are widely used and reliable, while non-traditional stabilizers offer superior environmental benefits and enhanced engineering performance in many applications. Among non-traditional methods, polymer-based stabilizers have attracted significant research interest owing to their effectiveness even at relatively small dosages. The study concluded that non-traditional stabilizers present promising alternatives for sustainable and efficient soft soil stabilization.

3. RESEARCH GAPS IDENTIFIED

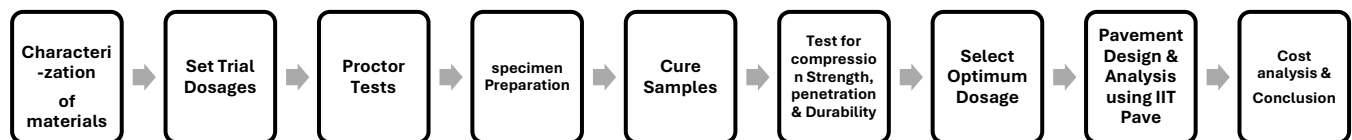
Although substantial research has been conducted on traditional soil stabilizers such as cement, lime, fly ash, and steel slag, notable gaps remain regarding their long-term performance in highly plastic soils, particularly under cyclic wetting-drying environments. Most existing investigations emphasize conventional stabilizing agents under controlled laboratory conditions, with limited consideration of regional soil variability and field-based performance assessment. Furthermore, the applicability and efficiency of commercially available stabilizers for locally available soils in the Karnataka region have not been comprehensively established.

In recent years, CTB and CTSB layers have gained increasing prominence in pavement design owing to their capability to achieve enhanced structural strength with reduced layer thickness. While several studies have addressed the mechanical behavior and design aspects of CTB and CTSB systems, the application of commercial stabilizers within these layers remains at a nascent stage. Systematic investigations focusing on material characterization, durability assessment, and long-term field performance are limited, thereby necessitating comprehensive evaluation to facilitate reliable and large-scale implementation of these technologies in practical pavement construction.

4. OBJECTIVES

1. To characterize the selected soil types and justify its suitability for stabilisation.
2. To arrive at the optimum dosage of commercial stabilizer for soil subgrade stabilization.
3. To identify optimum dosage of commercial stabilizer in the Cement Treated Sub base (CTSB) blend.
4. To analyse and design pavements as per IRC guidelines using the stabilized soil mixtures.
5. To evaluate the feasibility of amended soil mixtures for durability, cost effectiveness and environmental impact.

5. METHODOLOGY



6. LABORATORY TESTS & RESULTS OBTAINED

1. Characterization of the materials to be used in the study is done as per the code IS 2720, IS 2386 & IS 4031 and scrutinized whether it suitable for the purpose or not.
2. Trial Dosages of the materials like soil, aggregate cement & stabilizers were done based on trial & error method.
3. Modified proctor Tests were done on the trial mixes, and the soil Aggregate proportion is obtained by selecting the mix that gives maximum dry density and lower OMC.
4. Further, specimens were prepared for different cement and CCS doses with the chosen soil-aggregate blend and kept for controlled moisture curing as per the codal procedure.
5. Cured specimens were tested for UCS, permeability & Durability (wet & dry cycles) to choose the optimum Dosage of cement & CCS and the final Blend of soil, aggregate, cement & CCS is obtained.
6. Flexible pavement Design is done using IIT pave using the obtained test results and analysis is done for Rutting & Fatigue & pavement layer thickness are finalized.
7. Conclusion is given by having economic analysis and comparison is done for the technology road & conventional road.

6.1 TEST RESULTS ON SOIL

SL NO	Test conducted	IS Code	Results	Reference
1	Specific gravity	IS 2720 Part-3	2.49	-
2	Wet sieve analysis	IS 2720 Part-4	Gravel = 0.4% Sand = 41.6% Fines = 58%	Silt/clay Fraction >50% clayey soil
3	Liquid limit	IS 2720 Part-5	47.5%	30%-50% Intermediate, >50% highly plastic
4	Plastic limit	IS 2720 Part-5	25.40%	PI ≥ 17 highly plastic
5	Plasticity index	IS 2720 Part-5	22.10%	
6	Modified Proctor test MDD g/cc & OMC %	IS 2720 Part-8	1.71 & 17.50	-
7	Unconfined compression strength test (28 th day) Kpa	IS 2720 Part-10	92.058	As per IRC SP:89[28] Minimum UCS 1.5 MPa for stabilized bases CTSB
8	Direct shear test Cohesion, C Kpa	IS 2720 Part-13	21	Medium-soft clay 7 to 28 Kpa
9	Angle of internal friction ϕ°	IS 2720 Part-13	15°	Silty - clay 5° to 35°
10	California bearing ratio for 2.5mm & 5.0mm penetration (CBR) in %	IS 2720 Part-16	4.67 & 3.85	As per IRC-37 2018 Soaked CBR ≥ 5%
11	Permeability test cm/s	IS 2720 Part-17	1.40*10 ⁻⁵	Low permeable 10 ⁻⁵ to 10 ⁻⁷
12	Free swell index	IS 2720 Part-40	14.5 %	<20 % Low, >50% very high
13	Wet & dry cycle test	IS 4332 Part-4	0	Naturally non-durable (specimen has to sustain for 12 cycles)
Soil type			Intermediate compressible silty clay-CI	(based on Atterberg limits & UCS chart)
		Based on AASHTO soil classification system	Criteria satisfied PI>LL-30 PI=22.1% A-7-6	(Based on HRB soil classification)

Observations:

- ✓ Wet sieve analysis indicates that the soil contains 58% fines (silt/clay) and is classified as fine-grained soil.
- ✓ Based on Atterberg limits and HRB classification, the value of clayey red soil falls under the A-7 (clayey) group with a liquid limit of 47.5%, indicating intermediate plasticity (CI) and a fair-to-poor rating.
- ✓ Strength test results show low values (UCS 7 day = 0.055 MPa, direct shear = 0.021 MPa, CBR = 4.67% at 2.5 mm), classifying the soil as poor to fair and unsuitable for road construction without stabilization.
- ✓ Durability test results reveal failure to withstand even one wet-dry cycle, confirming the need for stabilization to meet durability requirements.

6.2 TEST RESULTS ON AGGREGATES

Sl No	Test conducted	IS code	Test result				Reference range as per IS code
1	sieve analysis (Particle size distribution)	IS 2386-part 1 Re-affirmed 2021	Well graded Coarse aggregate				obtained steep S curve indicating a good mix of particle sizes for maximum density
2	(Shape tests) Flakiness index %		16.4				Max 35% if used in CTSB as per IS & MoRTH table 400-6
	(Shape tests) Elongation index %		12.5				Max 15% as per IS, IRC & MoRTH
3	Combined Index (F+E) %		28.9				maximum limit 30%.
Material passing through IS sieve size in mm			53 ↓	26.5 ↓	9.50 ↓	4.75 ↓	
4	Specific gravity	IS 2386-part 3 Re-affirmed 2021	2.68	2.66	2.63	2.57	Between 2.5 to 3.0 as per IS
5	Water absorption test in %		0.30	0.38	0.42	0.93	Not more than 2%
6	Aggregate crushing value in %	IS 2386-part 4 Re-affirmed 2021 (12.5mm passed retained on 10mm IS sieve)	19.5				should not exceed 45%
7	Aggregate Impact value in %		24.5				
8	Abrasion value %	IS 2386-part 5 Re-affirmed 2021	28.5				should not exceed 30%

Observations:

- ✓ The chosen material, conforming to codes of **IS 2386**, was subjected to laboratory testing, validating its conformity to standards and can be used for the proposed study.

6.3 TESTS RESULTS ON CEMENT

Sl No	Test conducted	IS code	Test result	Reference range as per IS 8112: 2013 clause 6
1	Fineness test in %	IS 4031-part 1	4	Should not exceed 10%
2	Fineness by Air Blaine test in kg/m ²	IS 4031-part 2	358.8	Not less than 225kg/m ²
3	Soundness test in mm (Le-Chatelier's method)	IS 4031-part 3	1	Should not exceed 10mm
4	Standard consistency or Normal consistency in %	IS 4031-part 4	31	-
5	Initial setting time in min	IS 4031-part 5	126	Should not be less than 30 min
6	Final setting time in min		283	Should not be more than 600min
7	Compressive strength N/mm ² test (28 th day)	IS 4031-part 6	48.30	Shall not be less than 43.0N/mm ²
8	Specific gravity Test	IS 4031-part 11	3.15	-

Observations:

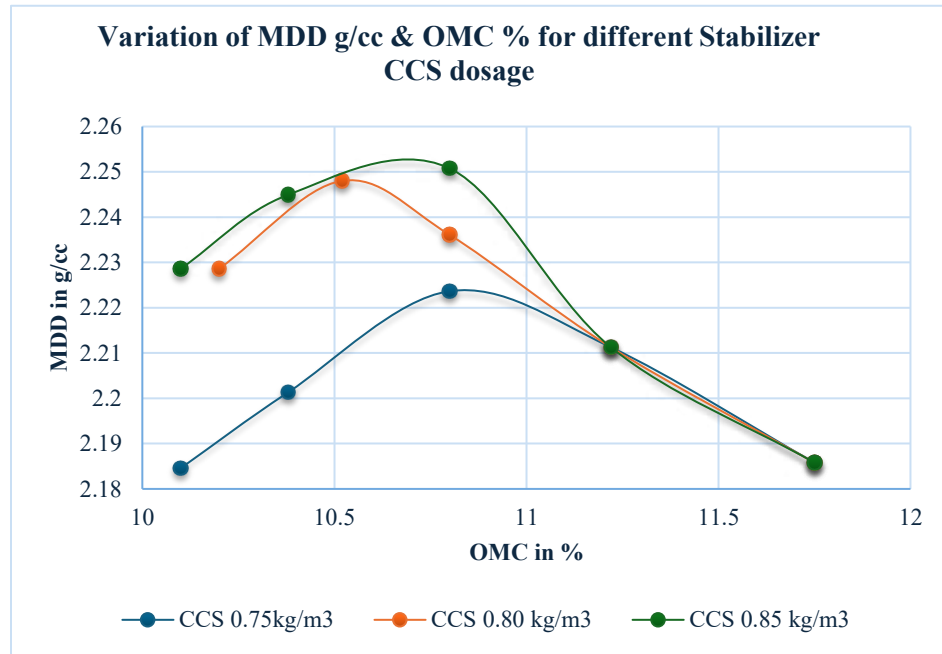
- ✓ The chosen cement, conforming to codes of **IS 4031**, Ordinary Portland Cement (OPC 43) was subjected to laboratory testing, validating its conformity to standards and can be used for the proposed study.

6.3 TEST RESULTS ON SOIL-STABILIZER MIXES

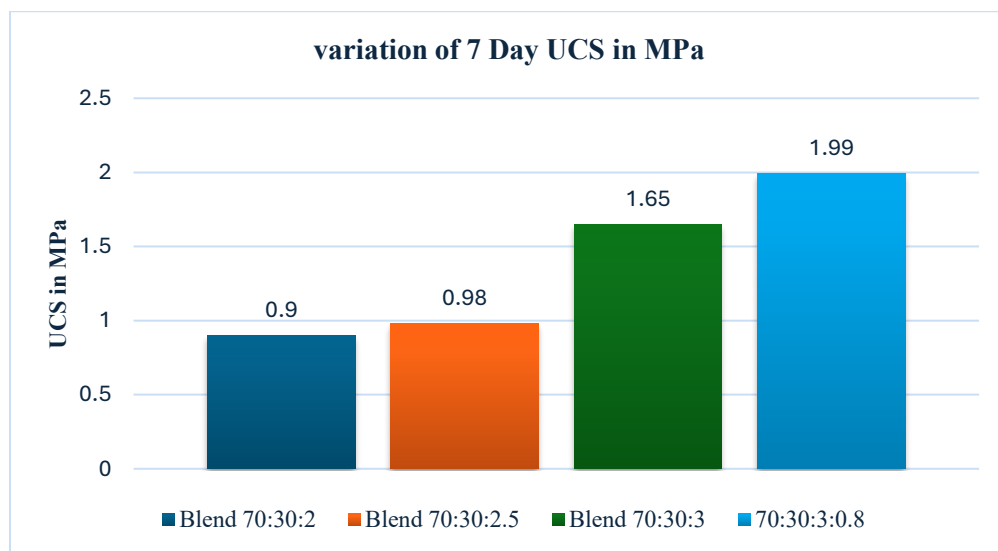
Sl No	Tests	Method	Results				
1	Aggregate Gradation	Trial & Error	Material size in mm				
			53-26.5	26.5-12.5	12.5-4.75	4.75-0.075	Grade 5 in MORTH 401
2	AtterBerg Limits	Blend Ratio (soil:fines)	Liquid Limit	Plastic Limit	Plasticity Index	Reference	
	Casagrande test apparatus	80:20	39	18.35	20.65	PI <20 is preferable as per IRC SP 89	
		70:30	33.5	17.08	16.42		
		60:40	28.5	14.64	13.86		
3	Modified Proctor Test	Blend (soil:agg)	MDD in g/cc	OMC in %	Remarks		
		80:20	2.035	15	Blend Beyond 70:30 is not considered to avoid granular Domination		
		70:30	2.03	13.89			
		60:40	1.977	13.0			
4	Modified Proctor Test for Blend 70:30	Cement %	MDD in g/cc	OMC in %	UCS 7 Day strength in MPa	Remarks	
		2	2.059	12.55	0.9	3% cement is considered having Higher MDD and Lower OMC with higher UCS value	
		2.5	2.089	13.0	0.98		
		3.0	2.19	13.15	1.65		
5	Modified Proctor Test for Blend 70:30:3	CCS Dosage in kg/m³	MDD in g/cc	OMC in %	UCS 7 days strength in MPa	UCS 28 days strength in MPa	Reference
		0.75	2.2	10.85	1.79	2.4	1.5 MPa to 3.0 MPa for CTSB as per IRC 37 2018
		0.80	2.248	10.52	1.99	3.62	
		0.85	2.25	10.45	1.94	3.634	
6	Permeability Test for the Blend	Blend	Co-efficient of permeability K in cm/s		Remarks		
		70:30	1.12 x 10 ⁻⁵		Blend with CCS 0.8kg/m3 shows higher Impermeability compared.		
		70:30:3	1.03 x 10 ⁻⁶				
		70:30:3:0.8	2.53 x 10 ⁻⁷				
7	Durability Test (Wet & Dry Cycles)	Blend	No. of cycles completed	% Mass Loss	Reference		
		70:30	Fails at 7 th cycle		Loss should be < 7% for CH type soil as per IRC SP 89		
		70:30:3	Completes 12 cycles	10.52			
		70:30:3:0.8	Complete 12 cycles	6.66			
8	Residual strength	Blend	UCS in MPa	Reference			
		70:30:3	1.01	Residual UCS should not be less than 20% of 28-day UCS as per IRC SP 89			
		70:30:3:0.8	1.33				

Abbreviations with description details given for the material Blend

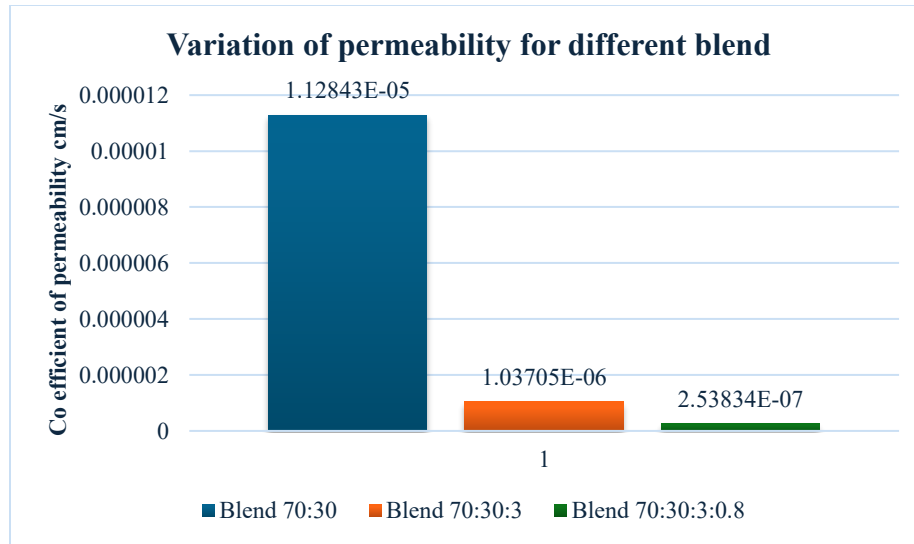
1. 80:20 = 80% clayey red soil & 20% Graded aggregates.
2. 70:30 = 70% clayey red soil & 30% Graded aggregates.
3. 60:40 = 60% clayey red soil & 40% Graded aggregates.
4. 70:30:3:0.8 = 70% clayey red soil, 30% Graded aggregates, 3% cement & 0.8Kg/m³ CCS



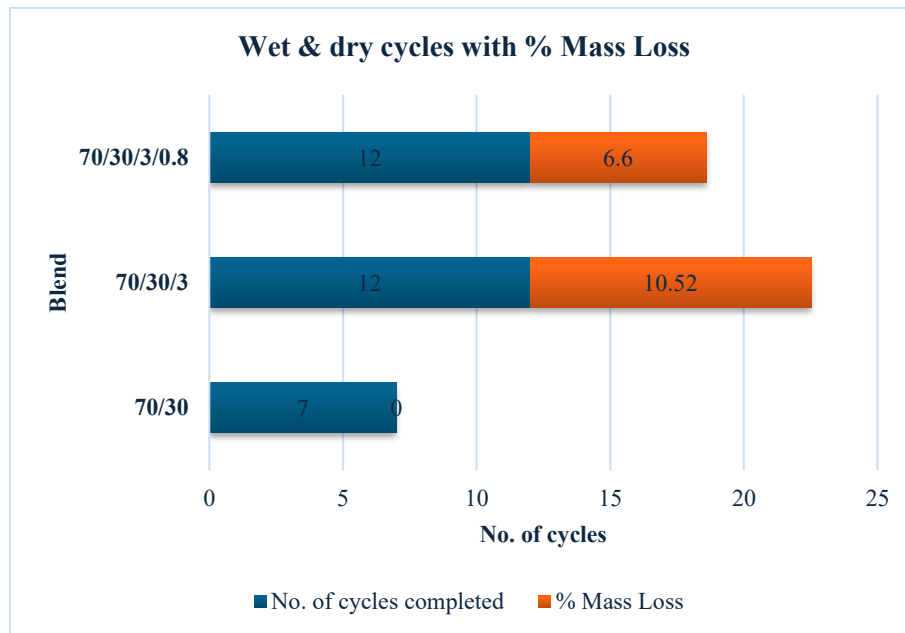
Graph 1.0 Graph showing variation of MDD with CCS Dosage



Graph 2.0 Graph showing variation of 7-day UCS with different Blends



Graph 3.0 Graph showing variation of co-efficient of Permeability obtained for different Blend



Graph 4.0 Variation of durability cycles completed with % mass loss for different Blends

Observations:

- The 70:30 soil-Aggregate blend with 3% cement exhibited improved density, strength, permeability and Durability characteristics.
- The Addition of chemical stabilizer significantly enhanced the 28th Day UCS with 3.63 MPa achieved at 0.85L/m³ dosage.
- A Dosage of 0.80L/m³ provided the optimum balance, satisfying the durability criteria with 6.66% mass loss and achieving 3.62 MPa 28-day UCS.

Hence, 70:30 soil-aggregate mix with 3% cement and 0.80 Kg/m³ stabilizer is recommended as the optimum CTSEB composition.

7.0 Design of Flexible pavement as per IRC 37-2018 Guidelines for the subgrade soil having CBR 4.87 (Clayey Red soil) – Conventional pavement

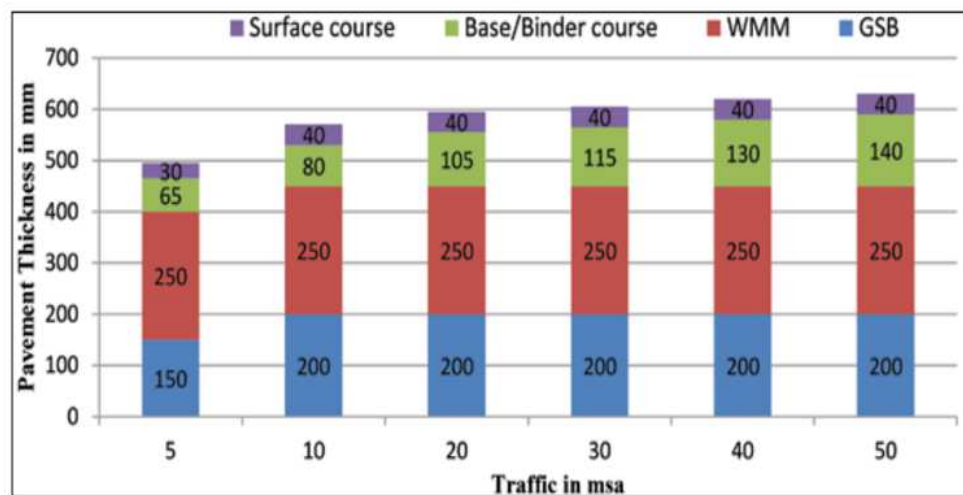
As per IRC 37-2018 Guidelines, following design considerations are taken.

1. Design Traffic = 10MSA (Low Volume roads)
2. Design Life = 15 Years (As per IRC: SP:72 Design life period of 10 years has been recommended to ensure that neither the strengthening will need to be carried out too soon nor will the design for a very long design period be unduly expensive by way of high initial investment required)
3. IRC Guidelines = IRC 37 2018 Guidelines (Fourth Revision)
4. Pavement Type = Flexible Pavement
5. Obtained CBR of clayey red soil = 4.87 %

Thickness of Pavement Layers for conventional Design

1. Bituminous concrete, BC = 40mm
2. Dense Bituminous Macadam, DBM = 80mm
3. Wet mix Macadam, WMM = 250mm
4. Granular Subbase, GSB = 200mm

Total Thickness = 570 mm as shown below in Fig 1 below over compacted subgrade as per IRC Requirements.



Catalogue for Pavement with Bituminous Surface Course with Granular Base and Sub-base - Effective CBR 5% (Plate-1)

Fig 1. Thickness of various layers in conventional Road from IRC 37 2018

7.1 Cost Considerations for the Respective Design of Flexible Pavement as per KPWD SoR 2025-26

Cost Estimate per km Two-Lane Road

1. Road Width = 7.0 m
2. Length = 1000 m (1.0KM) = Total Pavement Area = 7000 m²

Sl No	Pavement Layer	Thickness in mm	Quantity in m3	KPWD SoR in Rs/m3	Amount in Rs
1	Bituminous Concrete BC VG 30	40	280	7,735	21,65,800/-

2	Dense Bituminous Macadam DBM VG 30	80	560	8,692	48,67,520/-
3	Wet Mix Macadam WMM	250	1750	2,559	44,78,250/-
4	Granular subbase GSB Grade V	200	1400	2,487	34,81,800/-
5	Subgrade (With 1.5m shoulder on either side)	300	3000	493	14,79,000/-
	Total Thickness (including 300 mm subgrade)	870			164.72 Lakhs 1.64 Cr/Km

Observation:

Based on the Karnataka PWD Unified Schedule of Rates (Roads & Bridges), the estimated initial construction cost of the conventional flexible pavement designed as per IRC:37-2018 for a 10 MSA traffic category is **approximately ₹1.64 crore per kilometre** for a 7.0 m wide two-lane carriageway. The WMM and DBM layers together account for nearly **62%** of the total pavement cost, indicating that optimization of the base and sub-base layers can substantially reduce overall construction expenditure.

7.2 Design of Flexible pavement by incorporating CTSB Layer replacing GSB & WMM (Granular foundation) as per IRC SP:89-2018 requirements. (Technology Road)

Based on CTSB laboratory results, the stabilized layer satisfies the requirements of IRC:SP:89-2018 for Cement Treated Sub-Base:

- 28-day UCS = 3.62 MPa (≥ 1.7 MPa and within the typical CTSB range)
- Permeability = 2.411×10^{-7} cm/s
- Durability = Passed 12 wet-dry cycles with 6.68% mass loss
- Residual UCS = 1.49 MPa ($>20\%$ of 28-day UCS)

Therefore, it is technically appropriate to replace the conventional 200 mm GSB + 250 mm WMM with a CTSB layer, provided the design is verified mechanistically as required by Design standards IRC:37-2018

1. Design Traffic = 10MSA (Low Volume roads)
2. Design Life = 15 Years
3. Stabilized subgrade CBR = 8.23 %
4. Pavement Type = Flexible Pavement.
5. Design standards for Geo composite Drainage Layer = IRC:59 2019
6. Design standards for CTSB = IRC: SP:89 2018
7. Bituminous surfacing = BC + DBM

Proposed Flexible Pavement Section (CTSB replacing WMM and GSB)

1. Bituminous concrete, BC = 30mm
2. Dense Bituminous Macadam, DBM = 50mm
3. Cement Treated Subbase CTSB = 220mm (Minimum Thickness as per IRC)
4. Geo composite Layer = 10mm (minimum thickness as per standards)

Total Thickness = 310 mm as shown graphically below in Fig 2 over compacted subgrade as per IRC Requirements.

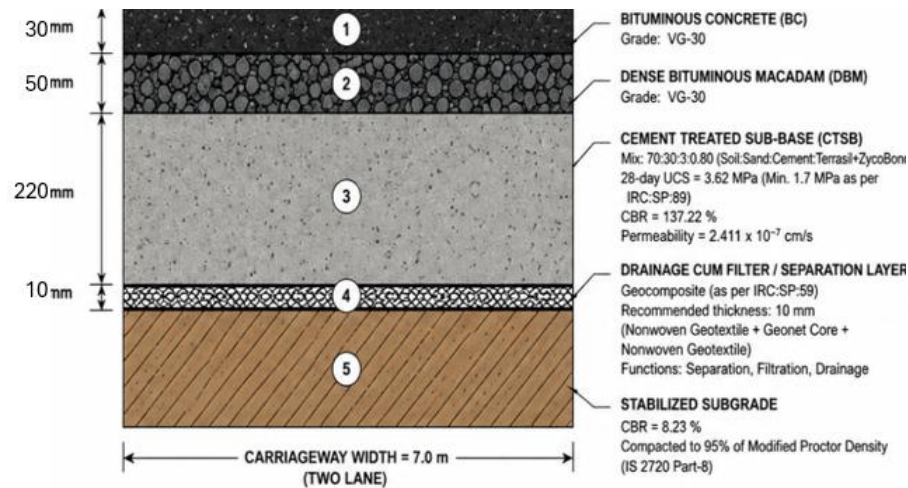


Fig 2 Thickness of various layers in Technology Road

7.3 Analysis of Technology Roads (CTSB structured pavement) by using IIT PAVE software.

1. Resilient modulus of Subgrade

$$\begin{aligned}
 M_{RS} &= 17.6 \times (\text{CBR})^{0.64} \\
 &= 17.6 \times (8.23)^{0.64} \\
 &= 67.82 \text{ MPa}
 \end{aligned}$$

2. Resilient Modulus of Granular Layer.

$$\begin{aligned}
 MRS_{\text{Granular}} &= 0.2 (h)^{0.45} \times MRS_{\text{support}} \\
 &= 0.2(200)^{0.45} \times 67.82 \\
 &= 147.571 \text{ MPa or For Obtained UCS)}_{28} \\
 E_{\text{CTSB}} &= 1000 \times \text{UCS)}_{28} \\
 &= 1000 \times 3.62 \\
 &= 3620 \text{ MPa}
 \end{aligned}$$

3. Resilient Modulus of Bituminous mixes $MRS = 3000 \text{ MPa}$

A) Check for Allowable Rutting Criteria on Subgrade

Considering 90% Reliability,

$$\begin{aligned}
 N_R &= 1.41 \times 10^{-8} (1/e_v)^{4.5337} \\
 10 \times 10^6 &= 1.41 \times 10^{-8} (1/e_v)^{4.5337}
 \end{aligned}$$

$$e_v = 556.40 \mu \text{ (Vertical compressive strain)}$$

B) Check for allowable Fatigue criteria on Bituminous mixes

$$\begin{aligned}
 N_f &= 0.5161 \times 10^{-4} \times C \times (1/e_t)^{3.89} \times (1/MRS)^{0.854} \\
 10 \times 10^6 &= 0.5161 \times 10^{-4} \times 1.786 \times (1/e_t)^{3.89} \times (1/3000)^{0.854}
 \end{aligned}$$

$$e_t = 251.10 \mu \text{ (Horizontal tensile strain)}$$

7.4 Results from the IIT PAVE Analysis

Data Given for Pavement Analysis

1. Nos of Layers = 3
2. Single Wheel load N = 20,000
3. Tyre Pressure = 0.56
4. Wheel set = 2 (Dual wheel)
5. Poisson's ratio taken as per IRC Considerations for the respective layers

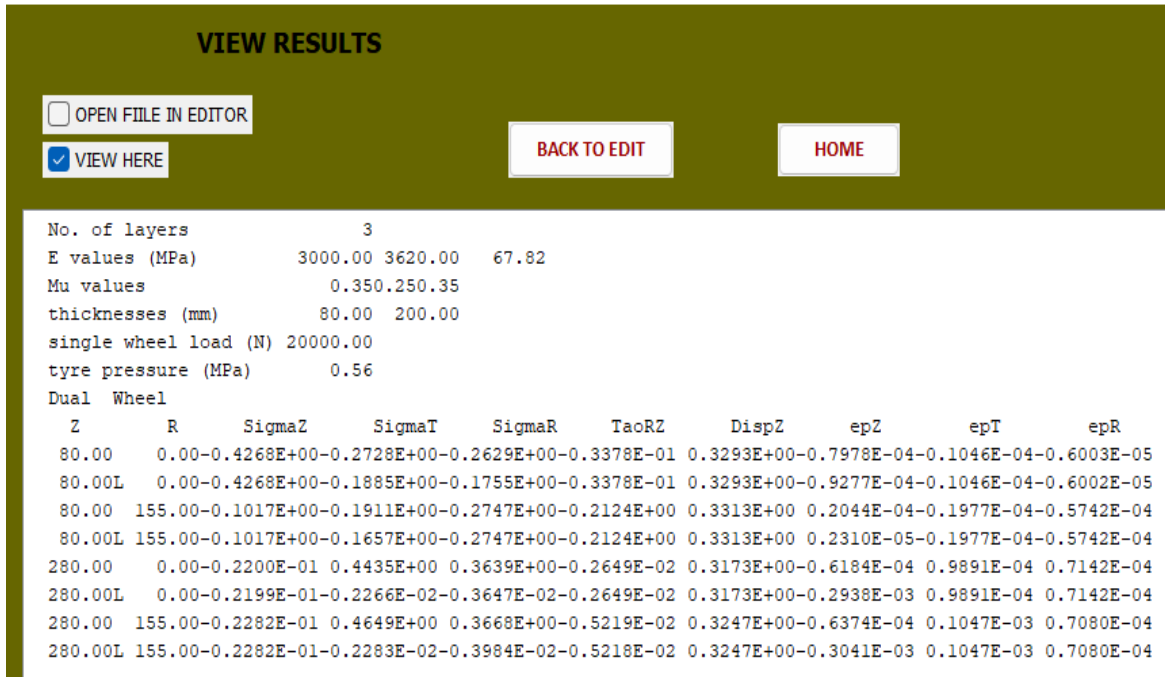


Fig 3 Results obtained from the analysis of CTSB structured pavement using IIT-PAVE

From the Results obtained from IIT-PAVE analysis as shown in Fig 3,

A. Actual Rutting criteria of subgrade

$\epsilon_v = 304.1\mu$ (Verticle compressive strain) Less than Allowable strain (556.4 μ)

B. Actual Fatigue criteria of Bituminous mix

$\epsilon_t = 197.7\mu$ (Horizontal tensile strain) Less than Allowable strain (251.10 μ)

Hence the Technology Road Design is safe.

7.5 Cost Considerations for the Design of Flexible Pavement, considering CTSB over GSB & WMM as per KPWD SoR 2025-26

Cost Estimate per km Two-Lane Road

1. Road Width = 7.0 m
2. Length = 1000 m (1.0KM) = Total Pavement Area = 7000 m²

Sl No	Pavement Layer	Thickness in mm	Quantity in m3	KPWD SoR in Rs/m3	Amount in Rs
1	Bituminous Concrete BC VG 30	30	210	7,735	16,24,350/-
2	Dense Bituminous Macadam DBM VG 30	50	350	8,692	30,42,200/-
3	Stabilized soil-Aggregate Layer CTSB 3% cement	220	1540	3,920	60,36,800/-
4	Commercial chemical stabilizer CCS for CTSB Layer used with 30% soil	1400*3	420m ³	Rs1,200/L	4,03,200/-
5	Geo-Composite Layer 10mm thick (Geo Net & Geo textiles)	10	7000m ²	Rs 275/m ²	19,25,000/-
6	Subgrade (with 1.5m shoulder on either side)	300	3000	493	14,79,000/-
7	Commercial chemical stabilizer CCS	150m ³	0.8L/m ³	Rs 1200/L	1,44,000/-
	Total Thickness (including 300 mm subgrade)	610			148.54 Lakhs 1.48 Cr/Km

Observations:

The optimized section achieved a 33.5% reduction in structural thickness and an estimated almost 12.31% reduction in Initial construction cost (₹18 lakh/km), while providing enhanced structural capacity, improved drainage, greater durability, and reduced maintenance. The CTSB–Geocomposite pavement is therefore recommended as a sustainable and cost-effective alternative for medium-volume roads constructed on stabilized clayey subgrades.

8.0 CONCLUSION:

- The experimental study established that commercial stabilizers effectively improve the engineering properties of weak clayey red soil.
- The optimum dosage of commercial stabilizer for the subgrade soil was 0.80 L/m³, providing improved strength and stability with minimum stabilizer content.
- For CTSB, the optimum blend was identified as 70% clayey red soil + 30% Grade-IV aggregate + 3% cement + 0.80 L/m³ commercial stabilizer.
- The optimized CTSB achieved a 28-day UCS of 3.62 MPa, satisfying the specified IRC requirements.
- The CTSB blend demonstrated good durability, successfully completing 12 wet–dry cycles with only 6.68% mass loss with Residual UCS of 1.49 MPa indicating satisfactory post-Durability strength retention.
- The CTSB layer can effectively replace the conventional GSB and WMM layers in the proposed flexible pavement section, subject to mechanistic design verification.
- IIT-PAVE analysis showed that the proposed CTSB-based flexible pavement satisfies both rutting and fatigue criteria, indicating adequate structural performance for the considered traffic level.
- The technology pavement achieved approximately 33.5% reduction in structural thickness, reducing the pavement section from the conventional configuration.
- The estimated initial construction cost was reduced by approximately 12.31% (about ₹18 lakh/km) compared with the conventional flexible pavement.
- Overall, the CTSB–Geocomposite flexible pavement system demonstrates potential as a technically viable, durable, economical, and sustainable alternative for pavement construction over weak clayey subgrades

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