

An Approach for Design of Flexible Pavements Containing "SoilTech MK III" Stabilized Layer

Prepared by

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1. INTRODUCTION

This report includes results of some of the tests conducted by the Transportation Engineering Section of Civil Engineering Department, IIT Kharagpur on the use of SoilTech MK III for stabilising different types of soils. The SoilTech MK-III polymer based stabilizer was supplied by India Polyroads Pvt. Ltd. A sample of soil collected from IIT Kharagpur campus has been used in this study.

The main objective of this report is to discuss an approach that can be used for designing flexible pavements containing SoilTech MK III stabilised layers.

2. SOME TEST RESULTS

Liquid Limit and Plastic Limit tests were conducted on the soil sample collected from IIT Kharagpur campus. Liquid limit of this soil was determined as 25%. Plastic limit is 13%. The corresponding Plasticity Index (PI) is 12%.

Modified Proctor Compaction test was conducted on the soil sample. This test yielded an optimum moisture content (OMC) of 8.0% and a maximum dry density (MDD) of 2.095 gm /cc.

Unconfined Compression Strength Tests were conducted on cylindrical specimens of 50mm diameter and 100mm height. Specimens were prepared by varying the SoilTech stabilizer content from 0.2% to 0.8% (by weight of dry soil). For the given volume of the cylindrical specimen to be prepared, the quantities of different components – dry soil, water and stabilizer were selected in such a way that the compacted specimen will have the dry density (2.095 gm/cc) obtained in modified Proctor compaction test for unmodified soil. Unconfined strength of 7-day, 28-day cured specimens was determined. Curing was done by keeping the cylindrical specimens (extracted from the mould) exposed to sun light. UCS test results are given in Table 1.

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Table 1 UCS Test Results

Curing Duration	UCS Value (kN/m ²) with varying SoilTech content			
	0%	0.2%	0.5%	0.8%
7 Days	790	4397	3871	5234
28 Days	-	4227	4472	5720
60 Days	-	3725	3819	3918

CBR test was conducted on soil specimens prepared using different SoilTech stabilizer contents. The samples were compacted to have densities corresponding to the maximum dry density obtained from modified Proctor compaction test.

As the SoilTech stabilizer needs to be sun cured, CBR specimens were prepared using spilt moulds and the specimens were extracted from the specimens and kept under sun for curing. After the specimens were cured for the specified number of days 7, 28 and 60, they were kept inside the mould again and were soaked for four days before conducting the test. CBR test results available at the time of reporting are given in Table 2.

Table 2 CBR Test Results

Soil Tech (%)	Soaked CBR (%) obtained for a curing period of		
	7-days	28-days(*)	60-days
0.0	16.8 (**)	-	-
0.2	42.5	32.5	
0.5		30.8	
0.8		37.1	

(*) with accelerated curing method.

(**) 4-days soaked value.

Resilient Modulus values of stabilized specimens were obtained by conducting repeated indirect tensile test on cylindrical specimens. Cylindrical specimens were prepared using optimum moisture content and to achieve the maximum dry density value obtained in the Proctor compaction test. The universal testing machine available in the Transportation Engineering laboratory of IIT Kharagpur was used for conducting these tests. Results of resilient modulus values obtained with different contents of SoilTech stabilizer for different curing periods are reported in Table 3.



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Table 3 Resilient Moduli

SoilTech (%)	ITS Load (N)	Resilient Modulus (MPa) for samples cured for		
		7 days	28 days	60 days
0.2	500	11040	10490	10459
	1000	9855	8192	8195
	1500	9269	7761	7375
	2000	8684	7580	6879
0.5	500	14957	8016	10145
	1000	10365	7947	9419
	1500	8679	7780	8510
	2000	7954	7627	7944
0.8	500	9175	10286	13596
	1000	8223	9374	9692
	1500	7822	8631	8767
	2000	7238	7985	8244

3. BRIEF SUMMARY OF THE RESULTS

It can be seen from the test results obtained in the present study on stabilization of soil (Kharagpur) with a PI value of 12% that the strength of soil increases significantly on modification. The increase in strength is much more evident in terms of the resilient modulus and unconfined compressive strength compared to the soaked CBR values.

4. SUGGESTED DESIGN APPROACH FOR PAVEMENTS WITH SOILTECH STABILIZER LAYERS

Indian Roads Congress guidelines (IRC: 37-2001) are generally followed for design of flexible pavements in India. These guidelines consider typical pavements with bituminous surfacing, granular base, granular subbase and subgrade. Three major modes of distress have been identified in IRC: 37-2001. These are :- (a) rutting in the wheel paths caused by permanent deformation in subgrade layer and (b) rutting in the wheel paths caused by permanent deformation in bituminous layers and (c) cracking in bituminous layers caused by fatigue due to repeated application of traffic loads.

As per IRC:37-2001, trial pavement sections are to be analyzed using linear elastic layered theory and maximum vertical strain on subgrade and maximum tensile strain at the bottom of bituminous layer are computed for a standard load. Design



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thickness combination is so selected that the computed critical strain values, which correspond to the initial condition of the pavement, are less than the limiting strain values given by the performance criteria adopted in the guidelines. Limiting strain criteria have been given in IRC: 37 for two major distresses: - rutting along wheel paths and fatigue cracking in bituminous layers. No separate criterion is available for rutting in bituminous layers. The criteria for rutting and fatigue cracking in bituminous layers are given as Equations 1 and 2 respectively.

Subgrade Strain Criterion:-

$$N_R = 4.1656 * 10^{-08} (1/\epsilon_z)^{4.5337} \quad (1)$$

Where N_R is the number of standard axle load (80kN) repetitions required to cause rutting of 20mm in the wheel paths and ϵ_z is the vertical strain on top of subgrade computed using linear elastic layered theory.

Fatigue Strain Criterion:-

$$N_F = 2.21 * 10^{-04} (1/\epsilon_t)^{3.89} (1/E_{mix})^{0.854} \quad (2)$$

Where N_F is the number of standard axle load (80kN) repetitions required to cause 20% cracking in pavement surface and ϵ_t is the tensile strain at the bottom of bituminous layers and E_{mix} is the elastic modulus of the mix (MPa).

While the appropriateness of these criteria for designing pavements with new technologies and new materials can only be assessed after significant amount of performance data is collected, use of these criteria is the best option available, at present, until revised criteria are developed.

Bituminous pavements with stabilized bases may fail due to subgrade rutting (through the vertical strains on subgrade reduce significantly due to provision of strong stabilized bases), fatigue cracking of stabilizer base/ subbase and fatigue cracking of bituminous layer and reflection cracking of bituminous layer due to propagation of cracks in stabilizer base.

The following steps are proposed for design of bituminous pavements with Soiltech stabilized layers.



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1. Selection of design subgrade CBR value as per IRC:37-2001 guidelines.
2. Estimation of design traffic as per IRC:37-2001 guidelines.
3. Computation of allowable tensile strain in bituminous layer and vertical strain in subgrade using the IRC performance criteria given by equations 1 and 2 respectively. Appropriate elastic modulus value of the mix (E_{mix}) may be selected as per the guidelines available in IRC:37-2001 or by conducting laboratory tests for evaluation of the resilient moduli for appropriate average pavement temperature.
4. Selection of trial pavement thicknesses. Depending on project traffic volumes, thin or thick bituminous layers can be considered. IRC:37-2001 guidelines may be used for selection of minimum surfacing layer thickness for different traffic levels.
5. It is proposed to provide a granular subbase of appropriate thickness varying from 100mm to 200mm depending on subgrade strength and design traffic level. It is desirable to provide a granular subbase to provide a working platform and to serve as drainage layer.
6. The following model may be considered for analysis of the pavement for computation of critical strains.

Loading :- Dual wheel load set (two wheels with c/c spacing of 310mm. each of 20kN magnitude) with 0.56 MPa contact pressure.

Elastic Moduli of different layers :-

- (i) Bituminous layers – either determined in the laboratory using appropriate test method and at appropriate test temperature or to be selected as per IRC : 37-2001 guidelines.
- (ii) Granular subbase modulus (provided as a drainage layer) can be estimated using Shell equation adopted by IRC : 37-2001 given as Eq.3

$$E_{Granular} = E_{subgrade} * [0.2 * (h_{granular})^{0.45}] \quad (3)$$

Where $E_{Granular}$ = Elastic modulus of granular layer (MPa)

$E_{subgrade}$ = Elastic modulus of subgrade (MPa) = $10 * (CBR)$

- (iii) Elastic modulus of Soiltech stabilizer layer will depend on the nature of soil and the amount of stabilizer used. For a given project, this value has to be determined in laboratory using appropriate resilient modulus



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test. It may be noted that in the case of Kharagpur soil investigated in the present study, the resilient moduli values ranged between 7000MPa and 14000MPa depending on the load applied and duration of curing. Considering the possibility of shrinkage and fatigue cracks during the service life of the pavement and the effect of moisture, it may be prudent to adopt smaller values of Soiltech stabilizer layer moduli compared to those obtained in the laboratory. It is recommended that 25% of the laboratory determined resilient moduli may be considered for the purpose of analysis and design.

7. Computation of vertical subgrade strain (on top of subgrade along the axis of symmetry of the dual wheel loads) and tensile strain at the bottom of bituminous layer.
8. Comparison of the computed strains with allowable strains and repeat the design trials if necessary.

5. DESIGN EXAMPLE

Appendices 1 and 2 present typical analysis and thickness design carried out for two different cases. A summary sheet showing the comparison of traditional and alternate designs for different subgrade CBR and traffic conditions is also included in this report.

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SUGGESTED APPROACH FOR DESIGN OF FLEXIBLE PAVEMENTS CONTAINING SOILTECH STABILISED LAYERS

Sl no	Subgrade CBR (%)	MSA	LAYER	As Per IRC:37-2001 Layer Thk.(mm)	Alt. Design Layer Thk.(mm)	Poisson's Ratio	Resilient Modulus of Diff. Layers (MPa)	REMARK
1	10	10	BC	40	40	0.45	1,695.00	For 60/70 grade bitumen, Temp 35 ° C
2			DBM	50				
3			STABILIZED SG (SSG)		150	0.30	1,500.00	20% of the Modulus value obtained from laboratory testing on Kharagpur soil has been considered as a conservative value
4			WMM	250		0.45	240.15	Estimated from empirical relations given in IRC:37
5			GSB	200	150			
6			SG	500	200	0.45	76.83	

1 Equation for Estimation of Resilient Modulus of Subgrade:

Head INPUT
Const 10.00 If CBR IS SMALLER THEN EQUAL TO 5
17.60 If CBR IS GREATER THEN 5
0.64 CONSTANT FOR POWER

$$E_{\text{subgrade}} = 17.6 \cdot (\text{C.B.R.})^{0.64}$$

$$E_{\text{subgrade}} = 76.83 \text{ MPa}$$

2 Equation for Estimation of Resilient Modulus of Granular Layer

$$E_{\text{gsb \& wmm}} = E_{\text{subgrade}} \cdot 0.2 \cdot h^{0.45}$$

$$E_{\text{gsb \& wmm}} = 240.15 \text{ MPa}$$

3 Equation for Resilient Modulus of GSB for Alternate Crust:

$$E_{\text{alt gsb}} = E_{\text{subgrade}} \cdot 0.2 \cdot h^{0.45}$$

$$E_{\text{alt gsb}} = 145.48 \text{ MPa}$$

4 Allowable Strain ie Fatigue (Cracking in BT Layer)

$$N_f = 2.21 \cdot 10^{-4} \cdot (1/E_1)^{2.85} \cdot (1/E_2/E_1)^{0.854}$$

$$10000000 = 0.000221 \cdot (1/E_1)^{2.85} \cdot 0.001746985$$

$$= 3.9E-07 \cdot (1/E_1)^{2.85}$$

$$2.6E+13 = 1^{2.85} / E_1^{2.85}$$

$$E_1^{2.85} = 3.9E-14$$

$$E_1 = 3.563E-04 = 356.3 \cdot 10^{-4}$$

5 Allowable Stress ie Rutting (Failure of SG)

$$N_r = 4.1645 \cdot 10^{-8} \cdot (1/E_2)^{4.5337}$$

$$10000000 = 4.1645E-08 \cdot (1/E_2)^{4.5337}$$

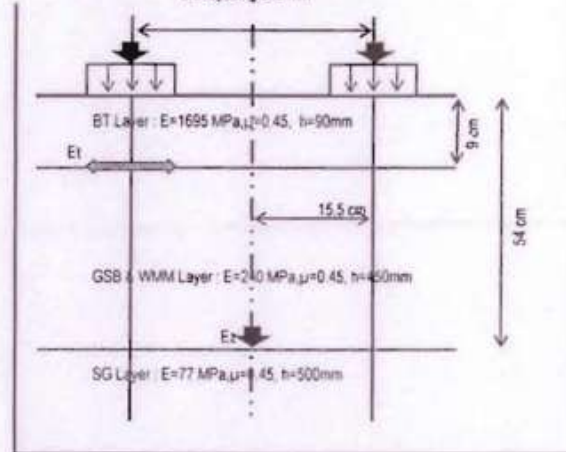
$$2.40119E+14 = 1/E_2^{4.5337}$$

$$E_2^{4.5337} = 4.1645E-15$$

$$E_2 = 6.731E-04 = 673.1 \cdot 10^{-4}$$

Analysis for IRC : 37, 2001 Design

Each Wheel Load of 20kN, Contact Pressure 560 kPa
C/c Spacing 310 mm



Computed Tens. Strain E_1 for Alternate Design -4.964E-05

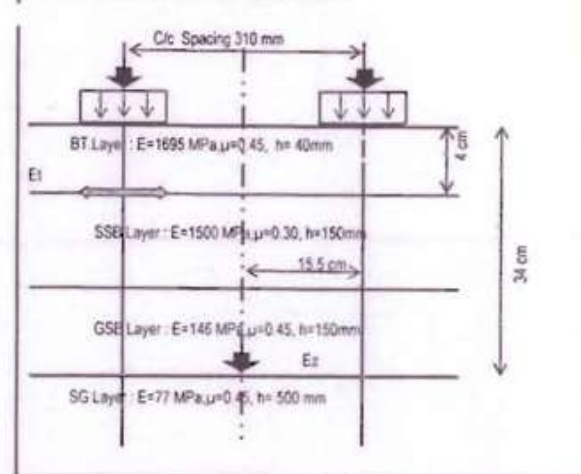
As the thickness of Bit layer is small, the strain is compressive

Computed Comp Strain E_2 for Alternate Design -4.978E-04

ALTERNATE DESIGN WITH SOILTECH III STABILISED LAYER IS OK

Analysis for Alternate Design

Each Wheel Load of 20kN, Contact Pressure 560 kPa



Allowable Tensile Strain E_1 3.563E-04

Allowable Compressive Strain E_2 6.731E-04



Sl no	Subgrade CBR (%)	MSA	LAYER	As Per IRC:37-2001 Layer Thk.(mm)	As Per Alt Design Layer Thk.(mm)	Poisson's Ratio	Resilient Modulus of Diff. Layers (MPa)	REMARK
1	10	150	BC	50	40	0.45	1,695.00	For 50/70 grade bitumen, Temp 35 °C
2			DBM	150	60			
			STABILIZED BASE LAYER		175	0.30	1,500.00	20% of the Modulus value obtained from laboratory testing on Kharagpur soil has been considered as a conservative value
3			WMM	250		0.45	240.15	Estimated from empirical relations given in IRC:37
4			GSB	200	150			
5			SG	500	200	0.45	76.83	

1 Equation for Resilient Modulus of Subgrade:

Head INPUT
Const 10.00 // CBR IS SMALLER THEN/EQUAL TO 5
17.60 // CBR IS GREATER THEN 5
0.64 CONSTANT FOR POWER

$$E_{\text{subgrade}} = 17.6 \cdot (\text{C.B.R.})^{0.64}$$

$$E_{\text{subgrade}} = 76.83 \text{ MPa}$$

2 Equation for Resilient Modulus of GSB & WMM Compound :

$$E_{\text{gsb}} = E_{\text{subgrade}} \cdot 0.2 \cdot h^{0.45}$$

$$E_{\text{gsb}} = 240.15 \text{ MPa}$$

3 Equation for Resilient Modulus of GSB for Alternate Crust:

$$E_{\text{Alt gsb}} = E_{\text{subgrade}} \cdot 0.2 \cdot h^{0.45}$$

$$E_{\text{Alt gsb}} = 146.48 \text{ MPa}$$

4 Allowable Strain in Fatigue (Cracking in BT Layer)

$$N_f = 2.21 \cdot 10^{-4} \cdot (1/E_t)^{3.89} \cdot (1/E_{\text{bitu}})^{0.954}$$

$$150000000 \cdot 0.000221 \cdot (1/E_t)^{3.89} \cdot 0.001746985$$

$$3.9E-07 \cdot (1/E_t)^{3.89}$$

$$3.9E+14 \cdot 1^{3.89} / E_t^{3.89}$$

$$E_t^{3.89} \cdot 2.6E-15$$

E_t	1.776E-04	= 177.6 * 10 ⁻⁶
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5 Allowable Stress in Rutting (Failure of SG)

$$N_r = 4.1646 \cdot 10^{-8} \cdot (1/E_z)^{4.5337}$$

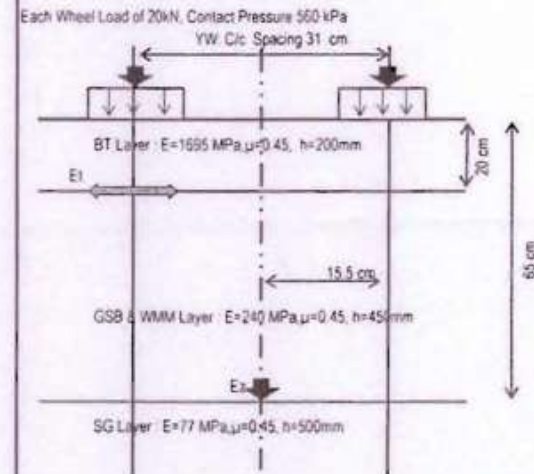
$$150000000 \cdot 4.1646E-08 \cdot 1/E_z^{4.5337}$$

$$3.6018E+15 \cdot 1/E_z^{4.5337}$$

$$E_z^{4.5337} \cdot 2.7764E-16$$

E_z	3.704E-04	= 370.4 * 10 ⁻⁶
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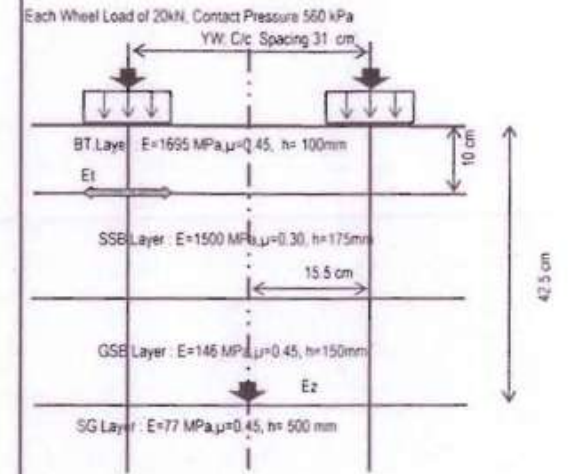
Analysis for IRC : 37, 2001 Design



Computed Tens. Strain E_t for Alternate Design	5.438E-05
(or Fatigue Failure Limit)	
Computed Comp Strain E_z for Alternate Design	3.115E-04

ALTERNATE DESIGN WITH SOILTECH III STABILISED LAYER IS OK

Analysis for Alternate Design

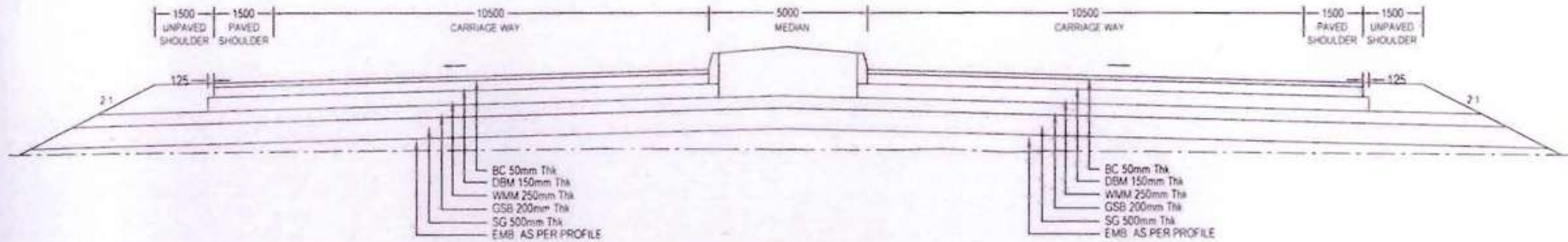


Allowable Tensile Strain in E_t	1.776E-04
Allowable Compressive Stress in E_z	3.704E-04

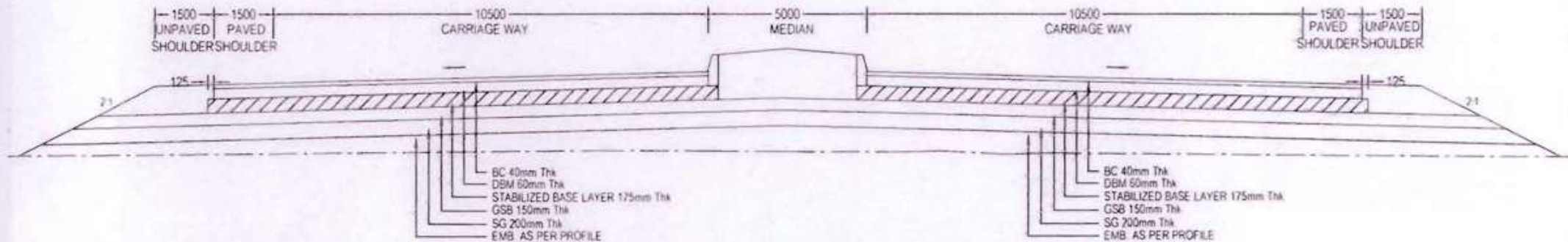
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TYPICAL CROSS SECTION FOR NEW CONSTRUCTION OF 6 LANE DRAWING OF CRUST COMPOSITION IRC: 37 VS ALTERNATE DESIGN



CROSS SECTION AS PER IRC 37, DESIGN CRUST
(CBR 10 & MSA 150)



CROSS SECTION AS PER ALTERNATE, DESIGN CRUST
(CBR 10 & MSA 150)



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