Experimental Study on Pavement Stabilization Using Geosynthetic Solution

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Abstract - *Major investments are required to build a road. Accurate technical design can save significant investment and deliver dependable performance.*

Today reinforced road structures, with the suitable stiffness, have been introduced to improve and optimize the performance of traditional road building materials. The performance of reinforced road structures relies heavily on the condition of surrounding materials and on the traffic loads and therefore each design requires specific analysis and calculations.

To achieve the economy along with long lasting performance of pavement. This demands the adoption of innovative technologies with less carbon footprint. One of such revolution is Geosynthetic. The extruded biaxial polypropylene geogrid is proposed for stabilizing the pavement. The inclusion of extruded biaxial polypropylene geogrid in granular layer shall support for increasing the modulus of granular layer and thereby reduces the thickness of bituminous and granular layer. In the similar way, thickness reduction is also possible in the case of service road. This is widely used for reducing the layer thickness and for strengthening the pavement. In the IRC: SP 59-2019, extruded biaxial polypropylene geogrid is mentioned for reducing the thickness and reinforcement of pavement.

The reinforced sections can be designed by introducing the geogrid at granular layer. The reinforced pavement, which is composition of bituminous course, granular base, and granular sub-base. Thickness is worked out based on IRC:59-2019 Guideline and input received. Biaxial geogrid is proposed at granular base layer and Sub-base layer of Pavement Section.

Key Words: **Geogrid, Geosynthetic Stabilization, Pavement Design, Calculate LCR & MIF Values, FWD Test, and PLT Test.**

1. INTRODUCTION

This report contains the detailed description of the work done during the final year project namely "Project Detail: Development and Maintenance of Dantiwara-Pipar-Merta City Section of SH-21 in the State of Rajasthan on Engineering, Procurement & Construction (EPC) Mode". Procedures are given for the characterization of the pavement materials both by laboratory/field testing and by typical values and/or correlation studies. The purpose of the laboratory testing program is to classify the properties of sub-grade, GSB, WMM, DBM and BC material and evaluate support properties and moisture sensitivity that can affect long-term pavement performance. Testing programs consist of classification testing (i.e., gradation analysis & Atterberg's Limits) and engineering properties testing (i.e., Proctor test, California Bearing Ratio Test & Marshall Mix Design test).

Flexible pavements fail due to rapid vehicle traffic growth. There are many ways for a system to fail, but rutting and fatigue are among the most important. We are decided to develop new construction materials to solve these problems. In this flexible pavement failure, we decided to use Geosynthetic materials. Most Geosynthetic are made from polypropylene, polyester, or synthetic polymers of polyethylene, PVC, natural fibers. The word is derived from: Geo = earth or soil + Synthetics = man-made.

The Benefit of reinforcement in pavement in quantified in terms of the Layer Coefficient Ratio (LCR). LCR of the unreinforced and reinforced pavement in quantified using a dynamic loading test apparatus that closely represents the field condition.

1.1 Problem Statement

India's road construction usually faces many problems that cause the road to fail, such as rutting, fatigue on the road, and other problems that result in road failures.

Generally speaking, a rut is defined as a vertical depression in the vehicle wheel tracks that occurs as a result of traffic loading. It is a type of surface defect that is more evident in the outer wheel track of the vehicle. Rutting is caused by the permanent deformation in any of a pavement's layers or sub grade usually caused by consolidation or displacement of the pavement edge due to traffic loading. Permanent deformation of pavement may occur that if the pavement binders do not have sufficient elasticity. Because a poor elastic binder does not return to its original position after removing wheel loading.

The process of stabilizing soil with lime and cement is very costly and a very lengthy one that requires many stages. Our goal is to reduce the cost of stabilizing soil by using

Geosynthetic Biaxial Geogrid as a reinforced material over the Granular Sub-base Layer to reduce the cost of stabilization.

1.2 Highway Material

Subgrade Soil (Borrow Soil): -

Poorly graded sand, commonly available in the state of Rajasthan, India, was used for the construction of 500 mm of compacted subgrade. The soil was non-plastic with an average liquid limit of 21.6%. The maximum dry density, optimum moisture content, and the California bearing ratio (CBR) was found to be 1.960 gm/cm3, 9.13%, and 17.15%, respectively.

Granular Sub-Base (GSB): -

200 mm of granular sub-base (GSB), grading V, as per the specification of MoRTH (MoRTH 2013) was used over the subgrade. The gradation of the GSB material is shown in figure 2. The physical properties of the aggregates, as per the requirements of MoRTH.

Granular Base (WMM): -

Table -1: Physical Properties of Aggregates used in WMM

Property	Value	Requirements as per MoRTH
Aggregate Impact Value	10.97	Max 30
Liquid Limit of Material Passing 425 Mic Sieve, %	21.4	
Plasticity Index of material passing 425 Mic Sieve, %	Non-Plastic	Max 6
Optimum Moisture Content, %	5.29	
Maximum Dry Density gm/cm3	2.298	
Combined Flakiness and Elongation, %	28.3	Max 35

Bituminous Layer: -

Dense bituminous macadam (DBM), grading II, as per the standards of MoRTH, was used on the top of WMM. The sieve size distribution of the aggregates used for the construction of DBM is shown in Figure 2. The mix design of DBM was done as per the standard Marshall Method (Asphalt Institute 2014) with a viscosity grade (VG) binder, VG 40. The optimum binder content (OBC) of the mix was found to be 4.68%. Crushed angular aggregates were used for the production of bituminous mixture, and it was ensured that the aggregate and bitumen properties satisfy the requirements of MoRTH.

Geogrid: -

A bi-axial UV stabilized polypropylene geogrid (by Maccaferri), having an ultimate tensile strength of 30 x 30 KN/m, was used for this study. Fig. 1 shows representative pictures of the geogrid placed at the interface of granular sub-base and base layer.

Fig -1: Laying Geogrid at Site

2. Review of Literature

Murad Abu-Farsakh, et.al (2012) In their research paper, they conducted a test experimental in that, the study carries out by repeated load triaxial (RLT) test evaluated the flexible and permanent deformation of Geogrid with the granular base specimens. In that the five geogrids specimens were used such as three rectangle or biaxial and two triangles or triaxial in different tensile modulus and aperture geometry. After the test result found the geogrid arrangement/ location on the specimen it had largest improvement, and also in the effect of moisture content was also higher improvement, but in the resilient deformation/ resilient modulus had not appreciable improvement of the specimens.

Jie Han, et.al. (2014) In their paper, the Geosynthetic material used of recycled aggregate for improve the mechanical properties and long-term durability. Also, they found Permanente formation, creep deformation, degradation, stress distribution, and crack propagation. In that reviews there search work is done on the use of Geosynthetic to stabilize Recycled Aggregate including Recycled Asphalt Pavement (RAP), Recycled Concrete Aggregate (RCA), and Recycled Ballast (RB). These RAP, RCA, and RB is used for base course materials for sustainable roadway construction and also used for the construction of the load-bearing layer in the railway track.

Satish Pandey, et.al (2015) In their research paper, they discussed the use of Geosynthetic materials like geogrid and geotextile for the bituminous pavement and for road infrastructure. In this the Geosynthetic material was used in subgrade for separation and stabilization, in concluded that the geogrid reinforcement in the pavement was placed in a base course and subgrade layer it decreases the vertical strain and in the bottom of the reinforcement it reduces the horizontal tensile strain in the bituminous pavement surface. This paper shows that Geosynthetic material improved service life, reduce the thickness of the pavement, and easy to build it.

3. Design Impletion

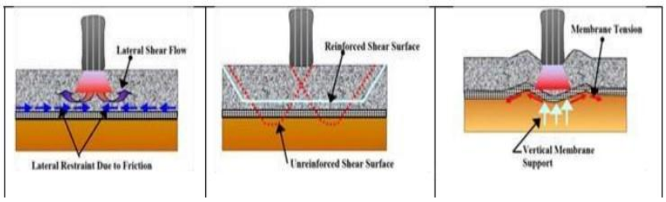
Proposed Solution Mechanism

Mac-Grid EG (Extruded biaxial PP geogrid) shall reinforce the granular layer and basic mechanism of reinforcing can be identified as (a) lateral restraint, (b) improved bearing capacity, and (c) tensioned membrane effect.

Lateral restraint refers to the confinement of the aggregate material during loading, which restricts lateral flow of the material from beneath the load. Since most aggregates used in pavement systems are stress-dependent materials, improved lateral confinement results in an increase in the modulus of the base course material.

The effect of increasing the modulus of the base course is an improved vertical stress distribution applied to the subgrade and a corresponding reduction in the vertical strain on the top of the subgrade. Fig.2 (a) illustrates the lateral restraint reinforcement mechanism. The second mechanism, improved bearing capacity, is achieved by shifting the failure envelope of the pavement system from the relatively weak subgrade to the relatively strong base course material.

Fig.2 (b) shows the improved bearing capacity concept. The third fundamental reinforcement mechanism has been termed the "tensioned membrane effect." The tensioned membrane effect is based upon the concept of an improved vertical stress distribution resulting from tensile stress in a deformed membrane. Fig.2 (c) illustrates the tensioned membrane effect.



(a) (b) (c)

Fig -2: (a) Lateral Restraint (b) Improved Bearing Capacity (c) Tensioned Member Effect

Solution Component (Extruded Biaxial Polypropylene Geogrid)

Extruded biaxial geogrids are polypropylene geogrids produced by an extrusion process characterized by a tensile resistance both in the longitudinal and cross direction that exhibits high modulus and high strength at low elongations providing tensile reinforcement to soil and aggregate structures.

All soils, whether cohesive or granular, have poor resistance to tensile stresses, making them prone to movement and potential failures. Mac-Grid EG has high junction strength hence it distributes applied loads over a greater area to reduce vertical pressure on the subgrade.

This reinforces and stabilizes the base course materials and reduces the thickness of the layer required. Geogrid shall be resistant to installation damage, long term degradation and chemicals found in most soil environments. The high tensile strength and junction efficiency of biaxial geogrids confines and restrains aggregate from lateral movement, ensuring proper distribution of imposed stresses and ultimately extending the service life. Extruded geogrids exhibit better interlocking properties, junction stiffness and very high modulus which means this will pick up the stresses quickly with little or no movement in the overlying base materials compared to other geogrids.

Fig -3: Mac-Grid EG Rolls

4. Pavement Design

General

New pavements have been designed for the Flexible pavement on existing alignment, Reconstruction stretches, Realignment sections & Bypass section with respect to traffic and CBR of available borrow soil and ROW area soil.

Factors Affecting Pavement Design

The principal factors that will govern the design of new pavements are:

- Strength characteristics of the ROW and borrow area soil.
- Traffic loading that the pavement has to withstand during its design life.
- Availability of materials for pavement layers.

Material Investigation

The objective of surveying the project corridor for construction materials – soil & aggregate, and investigating their properties is to:

- The objective of surveying the project corridor for construction materials – soil & aggregate, and investigating their properties is to:

- The potential borrow pit locations were identified along the project corridor for embankment and Subgrade material. Their quantity and suitability for use were determined.
- The original ground soil along the project corridor was collected and their suitability as foundation for the embankment/Subgrade construction was determined.
- The Sand Quarries in the project location were identified and their suitability for use in pavement layers was determined.
- The Aggregate Quarries in the vicinity of project location were located and their suitability for use in concrete, non-bituminous and bituminous pavement layers were determined.
- The sources for Granular Sub base layer (GSB) were identified and their suitability for use was ascertained.

Crust Composition of Existing Pavement

Table -2: Crust Composition of Existing Pavement

Trial Pit No.	Location	Thickness in mm		Remarks
		BT Layer	Granular Material	
1.	83+500	80	200	Sandy Loam with Hard Gravel
2.	79+750	75	400	Sandy Loam with Hard Gravel
3.	67+500	70	340	Sandy Loam with Hard Gravel
4.	66+300	60	300	Sandy Loam with Hard Gravel
5.	64+700	100	320	Sandy Loam with Hard Gravel
6.	60+550	100	300	Sandy Loam with Hard Gravel
7.	50+600	70	280	Sandy Loam with Hard Gravel
8.	44+200	30	180	Sandy Loam with Hard Gravel
9.	37+400	45	210	Sandy Loam with Hard Gravel
10.	30+300	60	370	Sandy Loam with Hard Gravel
11.	27+300	80	300	Sandy Loam with Hard Gravel
12.	21+000	90	310	Sandy Loam with Hard Gravel
13.	14+500	100	340	Sandy Loam with Hard Gravel
14.	12+200	90	310	Sandy Loam with Hard Gravel
15.	07+150	80	280	Sandy Loam with Hard Gravel

Fig -4: Trial Pit of Existing Pavement

Borrow/ROW Soil Properties

8 borrow area locations having CBR between more than 12% were identified. Test results for the Borrow/ROW area soil are given in Table 27 and 28. All locations are not plastic soil, having CBR over 15% at 97% MDD.

Table -3: Borrow/ROW Soil Properties

S. no.	Location	% passing through I.S. Sieve				% Silt & Clay Content	% of Sand Content
		4.75 mm	2.00 mm	425 mic.	75 mic.		
1.	06+500	84.2	60.1	31.8	4.6	4.6	79.6
2.	12+800	87.8	71.4	21.0	2.3	7.0	80.8
3.	21+400	86.9	69.6	35.1	2.0	2.0	84.9
4.	36+700	78.3	63.6	45.4	7.4	7.4	70.9
5.	46+100	64.4	40.1	21.1	4.3	4.3	60.1
6.	59+500	92.7	71.9	30.6	3.1	3.1	89.6
7.	71+300	87.8	73.7	34.2	2.4	2.4	85.4
8.	80+120	76.5	57.3	39.9	4.0	4.0	72.5

S. no.	Location	Atterberg's Limits			Field Moisture (%)	M.D.D. (gm/CC)	O.M.C. (%)	C.B.R. (%) Soaked
		L.L.	P.L.	P.I.				
1.	06+500	26.0	21.8	4.2	11.6	2.086	10.6	14
2.	12+800	25.5	21.9	3.6	12.8	1.957	10.7	15
3.	21+400	26.3	20.4	5.9	14.8	2.078	11.6	17
4.	36+700	28.1	22.9	5.2	13.7	2.073	11.3	18

5.	46+100	27.8	22.9	4.9	13.1	2.150	10.4	19
6.	59+500	25.3	21.0	4.3	14.4	1.993	11.5	16
7.	71+300	27.2	21.9	5.3	15.7	2.004	11.8	15
8.	80+120	26.8	22.2	4.6	15.7	2.015	11.5	17

Properties of Existing Soil

Test results of existing Subgrade soil are summarized in Table 29 and 30. Pavement subgrade at majority of the locations is composed of Sandy Loam with Hard Gravel and CBR over 12% along the project alignment.

Table -4: Soil Properties for Existing Soil

S. no.	Location	% passing through I.S. Sieve				% Silt & Clay Content	% of Sand Content
		4.75 mm	2.00 mm	425 mic.	75 mic.		
1.	83+500	82.9	56.2	43.0	13.2	13.2	69.7
2.	79+075	90.8	65.4	47.0	18.4	18.4	72.4
3.	67+500	81.5	65.9	58.1	7.8	7.8	73.7
4.	66+300	85.9	59.7	35.6	24.1	24.1	61.8
5.	64+700	89.6	66.2	42.9	23.3	23.3	66.3
6.	60+550	75.1	58.7	47.0	11.7	11.7	63.4
7.	50+600	79.9	52.1	37.9	14.2	14.2	65.7
8.	44+200	83.0	60.9	53.8	7.1	7.1	75.9
9.	37+400	77.7	51.8	44.7	7.1	7.1	70.6
10.	30+300	83.1	64.2	50.4	13.8	13.8	69.3
11.	27+300	83.6	59.0	49.1	9.9	9.9	73.7
12.	21+000	80.1	55.4	46.1	9.3	9.3	70.8
13.	14+500	81.9	59.0	46.8	12.2	12.2	69.7
14.	12+200	81.4	56.8	42.2	14.6	14.6	66.8
15.	07+150	75.0	53.0	44.0	9.0	9.0	66.0

S.no.	**Location**	**Atterberg's Limits**			**Field Moisture (%)**	**M.D.D. (gm/CC)**	**O.M.C. (%)**	**C.B.R. (%) Soaked**
		L.L.	**P.L.**	**P.I.**				
1.	83+500	30.7	24.3	6.4	1.5	1.924	11.7	12
2.	79+075	26.3	20.6	5.7	2.4	1.890	11.0	13
3.	67+500	28.2	23.3	4.9	2.0	2.008	10.6	13
4.	66+300	25.6	20.6	5.0	2.3	1.906	11.0	14
5.	64+700	30.9	23.6	7.3	1.8	1.901	11.9	13
6.	60+550	27.3	22.7	4.6	2.9	1.955	11.1	12
7.	50+600	30.9	24.6	6.3	1.0	1.955	11.4	12
8.	44+200	28.2	21.1	7.1	2.9	2.021	10.3	14
9.	37+400	30.7	24.2	6.5	2.2	1.933	11.8	13
10.	30+300	25.8	21.7	4.1	2.3	1.990	11.8	16
11.	27+300	30.9	24.1	6.8	3.0	2.027	11.9	14
12.	21+000	29.0	23.1	5.9	1.4	2.043	11.3	15
13.	14+500	29.0	23.2	5.8	1.1	1.967	10.8	13
14.	12+200	27.9	24.8	3.1	2.6	1.996	10.9	14
15.	07+150	28.1	21.6	6.5	1.1	2.011	11.5	17

Design CBR

Effective CBR of the subgrade has to be derived based on the investigation of Barrow Area samples and embankment soils (OGL soil), the design should be based on effective CBR.
As per IRC: 37 - 2018, pavement design is based on the Effective CBR of the subgrade. Where there is significant difference between the CBRs of the select subgrade and Embankment soils, the design should be based on Effective CBR.
The effective CBR of the subgrade is determined as per the procedure given in clause 6.4.1 of IRC: 37-2018.

$$MRS = 2(1 - \mu 2)pa/\delta$$

- MRS = Resilient Modulus of Equivalent single layer,
- P=contact pressure = 0.56 MPa
- a = radius of circular contact area, which can be calculated using the load applied (40,000 N) and the contact pressure 'p' (0.56 MPa) = 150.8 mm
- μ = Poisson's ratio
- δ = maximum surface deflection computed using the IITPAVE for a two-layer system of 500mm thick subgrade layer over the semi-infinite embankment layer by applying a single wheel load of 40,000 N and a contact pressure of 0.56 MPa. The Subgrade and Embankment Modulus values have been estimated using the equation 6.1 and 6.2 of IRC:37-2018 using their laboratory CBR values. **As the project alignment has ROW soil and Borrow area soil CBR More than 12%, so Design is carried out with 12% CBR.**

Design Methodology

Flexible pavement design as per IRC: SP 59-2019 (Clause No. 3.1.2)
Geogrid reinforced flexible pavement section is designed based on LCR design approaches. This design approach is described in the IRC SP: 59-2019. The approach to flexible pavement design according to modified AASHTO method is similar for reinforced and unreinforced pavements and can be divided into two steps:

- Determination of structural number for a given traffic load, project conditions and arriving unreinforced section thickness for individual pavement layers.
- Determination of reduced thickness by incorporating the effect of Geosynthetic in the form of improvement factor in the obtained SN.

Design Considerations & Proposed Solution Analysis Details

Table -5: Design Consideration for Analysis

	Design Traffic 50 & 40 MSA	Reference
Design Period	20 Years	
Effective Subgrade CBR	12 %	As per Calculation of Borrow area soil sample
Average annual Pavement Temperature	35	Clause-9.2 IRC-37 2018
Resilient modulus of Bituminous Layer	3000 MPa	Table-9.2 IRC-37 2018
Mix Type of BC & DBM Layer	VG-40	Table 9.1 IRC-37 2018
Percentage volume of air void in the mix	3.50 %	As per calculation in laboratory testing
Percentage volume of effective bitumen in the mix	11.50 %	As per calculation in laboratory testing

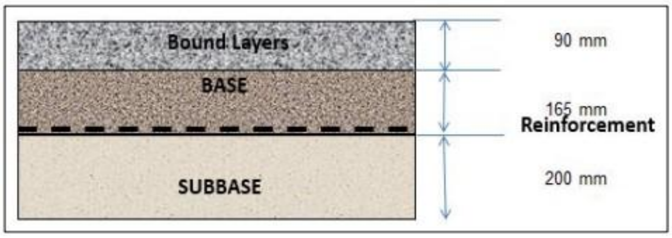
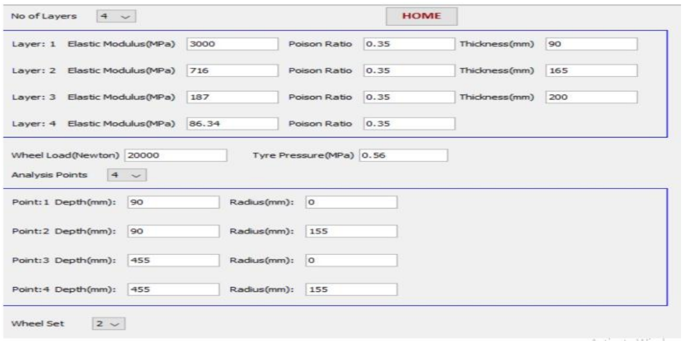


Fig -5: Pavement Composition for 50MSA and 12% CBR.

Table -6: Design Report for 50MSA, 12% CBR

1.	Input	
a.	Design Traffic (Dt)	50 MSA
b.	Subgrade CBR	12%
c.	Type pf Bitumen to be used (VG)	VG40 (As per Cl. 9 of IRC 37-2018)
d.	Temperature of Pavement (T)	35 Degree Celsius
2.	Resilient Modulus (MR)	17.6xCBR^(0.64) (As per Cl. 6.3 IRC 37-2018)
a.	Resilient Modulus of Subgrade Soil	86.34 Mpa
b.	Resilient Modulus of Bituminous Layer (MR_Bitumen)	3000 Mpa (As per Table 9.2 of IRC 37 – 2018)
3.	Fatigue Model (As per Cl. 3.6.2 IRC 37 – 2018)	
	Reliability Percentage (%)	90%
	By Marshall Method (Nf) Where: - C = 10^M M = 4.84 x ((Vbe/va+Vbe)-0.69) Va = Percentage Volume of air voids in mix used in the bottom bituminous layer = 3.5 Vbe = Percentage Volume of effective bitumen in mix used in the bottom bituminous layer = 11.5 M = 0.371 C = 2.3500	0.5161 x 10^(-4) x C x (1/Et)^(3.89) x (1/MR_Bituminous)^(0.854) Et = 1.78E-04 (by Calculation)
4.	Rutting Model (As per Cl. 3.6.1 of IRC 37-2018)	
	Reliability Percentage (%)	90%
	By Marshall method (Nr)	1.41 x 10^(-8) x (1/Ev)^4.5337 Ev = 3.72E-04 (By Calculation)
	Poison Ratio (Mu)	0.35 (As per Cl. 7.3.1 of IRC 37 -2012)
	Wheel Load (W)	20000 N (As per IRC 3 (Half of 6 Tonne Axle Load))
	Tyre Pressure (Mpa)	0.56 Mpa (As per Cl. 13 part vii of IRC 37 -2012
	Analysis Points	4
	Wheel set	2 (Assume)
	LCR Mac-Grid EG	
	LCR for Base Layer (LCR2)	1.35
	LCR for Sub-Base Layer (LCR3)	1
5.	Modified Layer Thickness Values	
	Modified layer Thickness for Base (mm)	165 mm

	Modified layer Thickness for Sub-Base (mm)	200 mm
6.	Modified layer MR Values	
	Modified MR Values for Base layer (Mpa)	373 Mpa
	Modified MR Values for Sub-Base layer (Mpa)	167 Mpa
7.	Calculations for layer coefficients for modified thickness	
	Layer Coefficient for Surface Layer (a1)	0.171 X (LN(MR))-1.784 (As per AASTHO 1993) a1 = 0.436 (MR_Bitumen converted from MPA to PSI)
	Layer Coefficient for base Layer (a2)	0.249 x (LOG10 (MR_Base))-0.977 a2 = 0.202 (MR_Base converted from Mpa to PSI)
	Layer Coefficient for Sub-base Layer (a3)	0.227 x (LOG10 (MR_Subbase))-0.839 a3 = 0.168 (MR_Subbase converted from Mpa to PSI)
8.	Modified Layer Coefficients	
	Modified Layer Coefficients for Surface Layer (a'1)	0.438
	Modified Layer Coefficients for Base Layer (a'2)	0.272
	Modified Layer Coefficients for Sub-Base Layer (a'3)	0.168
9.	Calculation of Modified Elastic Modul for IITPave	
	Modified Elastic Modul for Base Layer (MR_base')	10^(a'2+0.977)/0.249 MR_Base' = 716 Mpa
	Modified Elastic Modul for Base Layer (MR_Subbase')	10^(a'2+0.839)/0.227 MR_Subbase = 187 Mpa
10.	Revised section from IIT Pave While Limiting Permissible Strains	
	Revised Thickness of Bound Layers (BC+DBM) (H bit')	90 mm
	Revised Thickness of Base Layer (H bas'e)	165 mm
	Revised Thickness of Sub-Base Layer (H Subbase')	200 mm
11.	Comparison of Revised Strains	
	Permissible Tensile Strain for Given design traffic (Et permissible)	1.78E-04 (As per fatigue model calculated before)
	Permissible Vertical Strain for Given design traffic (Ev permissible)	3.72E-04 (As per fatigue model calculated before)
	Maximum Induced Tensile strain (Et induced')	1.32E-04 (From IIT pave)
	Maximum Induced Vertical strain (Ev induced')	3.64E-04 (From IIT pave)
	Check for Tensile Strain Et Permissible > 1.78E-04 > Check for Vertical Strain Ev Permissible > 3.72E-04 >	Et induced 1.32E-04 Hence, Safe Ev induced 3.64E-04 Hence, Safe



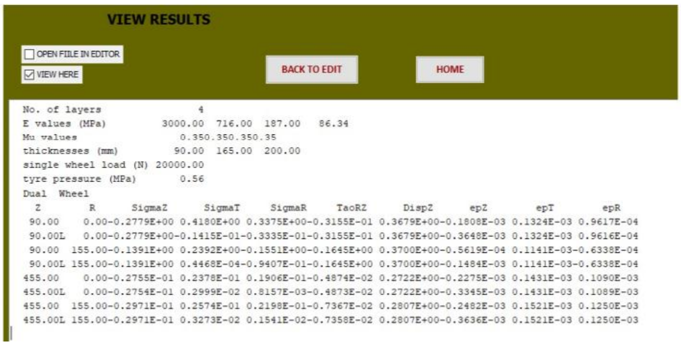


Fig -6: IIT Pave Report

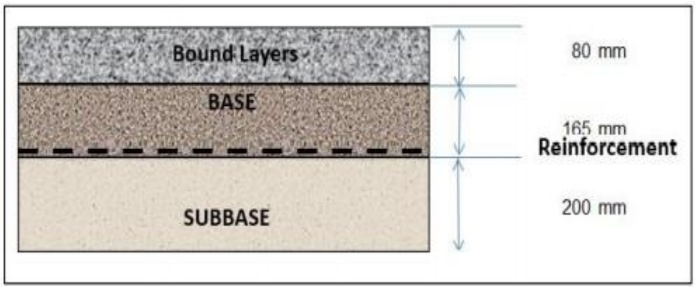
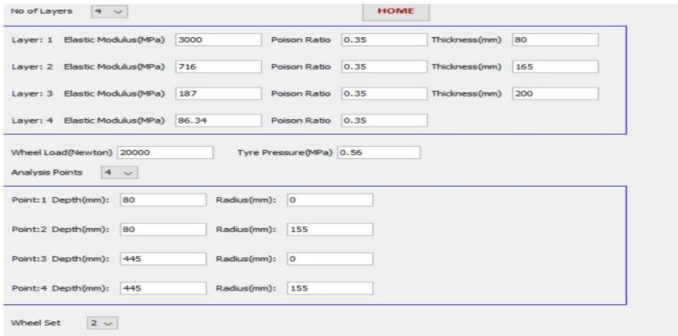


Fig -7: Pavement Composition for 40MSA and 12% CBR

Table -7: Design Report for 40MSA, 12% CBR

1.	Input	
a.	Design Traffic (Dt)	40 MSA
b.	Subgrade CBR	12%
c.	Type pf Bitumen to be used (VG)	VG40 (As per Cl. 9 of IRC 37-2018)
d.	Temperature of Pavement (T)	35 Degree Celsius
2.	Resilient Modulus (MR)	17.6xCBR^(0.64) (As per Cl. 6.3 IRC 37-2018)
a.	Resilient Modulus of Subgrade Soil	86.34 Mpa
b.	Resilient Modulus of Bituminous Layer (MR_Bitumen)	3000 Mpa (As per Table 9.2 of IRC 37 – 2018)
3.	Fatigue Model (As per Cl. 3.6.2 IRC 37 – 2018)	
	Reliability Percentage (%)	90%
	By Marshall Method (Nf) Where: - C = 10^M M = 4.84 x ((Vbe/va+Vbe)-0.69) Va = Percentage Volume of air voids in mix used in the bottom bituminous layer = 3.5 Vbe = Percentage Volume of effective bitumen in mix used in the bottom bituminous layer = 11.5 M = 0.371 C = 2.3500	0.5161 x 10^(-4) x C x (1/Et)^(3.89) x (1/MR_Bituminous)^(0.854) Et = 1.89E-04 (by Calculation)
4.	Rutting Model (As per Cl. 3.6.1 of IRC 37-2018)	
	Reliability Percentage (%)	90%
	By Marshall method (Nr)	1.41 x 10^(-8) x (1/Ev)^4.5337 Ev = 3.90E-04 (By Calculation)
	Poison Ratio (Mu)	0.35 (As per Cl. 7.3.1 of IRC 37 -2012)
	Wheel Load (W)	20000 N (As per IRC 3 (Half of 6 Tonne Axle Load))
	Tyre Pressure (Mpa)	0.56 Mpa (As per Cl. 13 part vii of IRC 37 -2012
	Analysis Points	4
	Wheel set	2 (Assume)
	LCR Mac-Grid EG	
	LCR for Base Layer (LCR2)	1.35
	LCR for Sub-Base Layer (LCR3)	1
5.	Modified Layer Thickness Values	
	Modified layer Thickness for Base (mm)	165 mm
	Modified layer Thickness for Sub-Base (mm)	200 mm
6.	Modified layer MR Values	
	Modified MR Values for Base layer (Mpa)	373 Mpa
	Modified MR Values for Sub-Base layer (Mpa)	187 Mpa
7.	Calculations for layer coefficients for modified thickness	
	Layer Coefficient for Surface Layer (a1)	0.171 X (LN(MR))-1.784 (As per AASTHO 1993) a1 = 0.436 (MR_Bitumen converted from MPA to PSI)
	Layer Coefficient for base Layer (a2)	0.249 x (LOG10 (MR_Base))-0.977

		a2 = 0.202 (MR_Base converted from Mpa to PSI)
	Layer Coefficient for Sub-base Layer (a3)	0.227 x (LOG10 (MR_Subbase))-0.839 a3 = 0.168 (MR_Subbase converted from Mpa to PSI)
8.	Modified Layer Coefficients	
	Modified Layer Coefficients for Surface Layer (a'1)	0.438
	Modified Layer Coefficients for Base Layer (a'2)	0.272
	Modified Layer Coefficients for Sub-Base Layer (a'3)	0.168
9.	Calculation of Modified Elastic Modul for IITPave	
	Modified Elastic Modul for Base Layer (MR_base')	10^(a'2+0.977)/0.249 MR_Base' = 716 Mpa
	Modified Elastic Modul for Base Layer (MR_Subbase')	10^(a'2+0.839)/0.227 MR_Subbase = 187 Mpa
10.	Revised section from IIT Pave While Limiting Permissible Strains	
	Revised Thickness of Bound Layers (BC+DBM) (H bit')	80 mm
	Revised Thickness of Base Layer (H bas'e)	165 mm
	Revised Thickness of Sub-Base Layer (H Subbase')	200 mm
11.	Comparison of Revised Strains	
	Permissible Tensile Strain for Given design traffic (Et permissible)	1.89E-04 (As per fatigue model calculated before)
	Permissible Vertical Strain for Given design traffic (Ev permissible)	3.90E-04 (As per fatigue model calculated before)
	Maximum Induced Tensile strain (Et induced')	1.33E-04 (From IIT pave)
	Maximum Induced Vertical strain (Ev induced')	3.84E-04 (From IIT pave)
	Check for Tensile Strain Et Permissible > 1.89E-04 > Check for Vertical Strain Ev Permissible > 3.90E-04	Et induced 1.33E-04 Hence, Safe Ev induced 3.84E-04 Hence, Safe



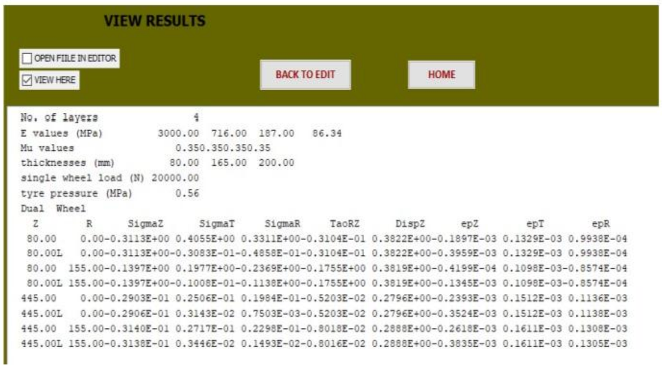


Fig -8: IIT Pave Report

Conclusion

Geogrid reinforcement has increase significantly the bearing capacity of soils. However, allowable settlements, and not ultimate bearing capacity, generally dictate the design of spread foundations on cohesionless soils. The CBR of marine clay increases by 50-100% when it is reinforced with a single layer of geo-grid. The amount of improvement of strength depends upon the type of soil and position of geo-grid.

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