

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.



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:

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- 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

Trial	Location	Thickr	iess in mm	Domarka
Pit No.	Location	BT Layer	Granular Material	Neillai KS
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

Table -2: Crust Composition of Existing Pavement

				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

			9	6 passi	ng throu	igh I.S. S	Sieve		% of
S.	Locat				0			% Silt &	San
no	Locat	10	4	.75	2.00	425	75	Clay	d
	11		r	nm	mm	mic.	mic.	Content	Cont
									ent
1.	06+50	00	8	4.2	60.1	31.8	4.6	4.6	79.6
2.	12+80	00	8	37.8	71.4	21.0	2.3	7.0	80.8
3.	21+40	00	8	6.9	69.6	35.1	2.0	2.0	84.9
4.	36+70	00	7	'8.3	63.6	45.4	7.4	7.4	70.9
5.	46+10	00	6	4.4	40.1	21.1	4.3	4.3	60.1
6.	59+50	00	9	2.7	71.9	30.6	3.1	3.1	89.6
7.	71+30	00	8	37.8	73.7	34.2	2.4	2.4	85.4
8.	80+12	20) 76.5		57.3	39.9	4.0	4.0	72.5
			A +	to who are	20				C D
1			Αι	terber	gs		MD		С.В.
S.			At	Limits	g s 5	Field	M.D		с.в. R.
S. n	Loca		At	Limits	g s 5	Field Moist	M.D .D.	O.M.C	с.в. R. (%)
S. n o	Loca tion	T	АL	Limits		Field Moist ure	M.D .D. (gm	0.M.C . (%)	с.в. R. (%) Soa
S. n o	Loca tion	L.	L.	Limits P.L.	P.I.	Field Moist ure (%)	M.D .D. (gm /CC	O.M.C . (%)	C.B. R. (%) Soa ked
S. n o	Loca tion	L.	L.	Limits P.L.	P.I.	Field Moist ure (%)	M.D .D. (gm /CC)	O.M.C . (%)	C.B. R. (%) Soa ked
S. n o	Loca tion	L.	L.	Limits P.L.	P.I.	Field Moist ure (%)	M.D .D. (gm /CC) 2.08	0.M.C . (%)	C.B. R. (%) Soa ked
S. n o	Loca tion 06+ 500	L. 26	L.	P.L.	P.I. 4.2	Field Moist ure (%) 11.6	M.D .D. (gm /CC) 2.08 6	0.M.C . (%)	C.B. R. (%) Soa ked
S. n o ·	Loca tion 06+ 500 12+	L. 26	L.	P.L.	P.I. 4.2	Field Moist ure (%) 11.6	M.D. .D. (gm /CC) 2.08 6 1.95	0.M.C . (%) 10.6	C.B. R. (%) Soa ked 14
S. n o 1.	Loca tion 06+ 500 12+ 800	L. 26 25	AL. .0 .5	P.L. 21.8 21.9	P.I. 4.2 3.6	Field Moist ure (%) 11.6 12.8	M.D. .D. (gm /CC) 2.08 6 1.95 7	0.M.C .(%) 10.6 10.7	C.B. R. (%) Soa ked 14
S. n o · 1.	Loca tion 06+ 500 12+ 800 21+	L. 26 25	L.	P.L. 21.8 21.9	P.I. 4.2 3.6	Field Moist ure (%) 11.6 12.8	M.D. .D. (gm /CC) 2.08 6 1.95 7 2.07	0.M.C .(%) 10.6 10.7	c.B. R. (%) Soa ked 14 15 17
 S. n o 1. 2. 3. 	Loca tion 06+ 500 12+ 800 21+ 400	L. 26 25 26	L. .0 .3	P.L. 21.8 21.9 20.4	P.I. 4.2 3.6 5.9	Field Moist ure (%) 11.6 12.8 14.8	M.D. .D. (gm /CC) 2.08 6 1.95 7 2.07 8	0.M.C . (%) 10.6 10.7 11.6	C.B. R. (%) Soa ked 14 15 17
S. n o 1. 2. 3.	Loca tion 06+ 500 12+ 800 21+ 400 36+	L. 26 25 26	L. .0 .3	P.L. 21.8 21.9 20.4	P.I. 4.2 3.6 5.9	Field Moist ure (%) 11.6 12.8 14.8	M.D. .D. (gm /CC) 2.08 6 1.95 7 2.07 8 2.07	0.M.C . (%) 10.6 10.7 11.6	 c.B. R. (%) Soa ked 14 15 17 18
 S. n o 1. 2. 3. 4. 	Loca tion 06+ 500 12+ 800 21+ 400 36+	L. 26 25 26	.0 .3	P.L. 21.8 21.9 20.4 22.9	P.I. 4.2 3.6 5.9	Field Moist ure (%) 11.6 12.8 14.8 13.7	M.D. .D. (gm /CC) 2.08 6 1.95 7 2.07 8 2.07	0.M.C . (%) 10.6 10.7 11.6	C.B. R. (%) Soa ked 14 15 17 17

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5.	46+ 100	27.8	22.9	4.9	13.1	2.15 0	10.4	19
6.	59+ 500	25.3	21.0	4.3	14.4	1.99 3	11.5	16
7.	71+ 300	27.2	21.9	5.3	15.7	2.00 4	11.8	15
8.	80+ 120	26.8	22.2	4.6	15.7	2.01 5	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

c			% j	pas	assing through I.S. Sieve			%	Silt	% of		
3. no	Locat	tion	4.75	2	00			75		&	Clay	Sand
110.			т.75 mm	r n	nm	n n	nic.	mi	, C.	Coi	ntent	Content
1.	83+5	500	82.9	5	6.2	4	3.0	13.	2	1	3.2	69.7
2.	79+()75	90.8	6	5.4	4	7.0	18.	4	1	8.4	72.4
3.	67+5	500	81.5	6	5.9	5	8.1	7.8	3	- 7	7.8	73.7
4.	66+3	300	85.9	5	9.7	3	5.6	24.	1	2	4.1	61.8
5.	64+7	700	89.6	6	6.2	4	2.9	23.	3	2	3.3	66.3
6.	60+5	550	75.1	5	8.7	4	7.0	11.	7	1	1.7	63.4
7.	50+6	500	79.9	5	2.1	3	7.9	14.	2	1	4.2	65.7
8.	44+2	200	83.0	6	0.9	5	3.8	7.1	L	7	7.1	75.9
9.	37+4	100	77.7	5	1.8	4	4.7	7.1	l	7	7.1	70.6
10.	30+3	300	83.1	6	4.2	5	0.4	13.	8	1	3.8	69.3
11.	27+3	300	83.6	5	9.0	4	9.1	9.9)	Ç	9.9	73.7
12.	21+(000	80.1	5	5.4	4	6.1	9.3	3	Ģ	9.3	70.8
13.	14+5	500	81.9	5	9.0	4	6.8	12.	2	1	2.2	69.7
14.	12+2	200	81.4	5	6.8	4	2.2	14.	6	1	4.6	66.8
15.	07+1	150	75.0	5	3.0	4	4.0	9.0)	Ç	9.0	66.0
S			Atterb	er	gʻs		Fie	eld	M	1.D		C.B.R.
•	Loca		Lim	its		Moist		•	D.	O.M	(%)	
							1.1.1	,			~	1,01
n	tion			r		r	u	re	(gm	.C.	Soak
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n o 1 2 3	tion 83+5 00 79+0 75 67+5	L.L 30. ⁷ 26.1	. P.1 7 24 3 20	L. .3 .6	P.I	I. 4 7	1 2	.5 .4	() / 1	gm CC) .92 4 .89 0 .00	.C. (%) 11.7 11.0	Soak ed 12 13
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n o 1 2 3 4	tion 83+5 00 79+0 75 67+5 00 66+3	L.L 30. ⁷ 26. ² 28. ²	. P.1 7 24 3 20 2 23	L. .3 .6 .3	P.I	I. 4 7 9	1 2 2	.5 .4 .0	() / 1 1 2 1	gm CC) .92 4 .89 0 .00 8 .90	.C. (%) 11.7 11.0 10.6	Soak ed 12 13 13 13
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n o 1 2 3 4 5 6	tion 83+5 00 79+0 75 67+5 00 66+3 00 66+3 00 64+7 00 60+5	L.L 30.7 26.7 28.7 25.0 30.9	P.1 7 24 3 20 2 23 6 20 9 23 3 22	L. .3 .6 .6 .6	P.1 6.4 5.7 4.9 5.0 7.3 4.9	1. 4 7 9 0 3	1 (%) 1 2 2 2 1 1 2	.5 .4 .3 .8	() / 1 1 2 1 1 1 1	gm CC) .92 4 .89 0 .00 8 .90 6 .90 1 .95	.C. (%) 11.7 11.0 10.6 11.0 11.9	Soak ed 12 13 13 13 14 13 12 13
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n o 1 2 3 3 4 5 6 7	tion 83+5 00 79+0 75 67+5 00 66+3 00 66+3 00 64+7 00 60+5 50 50 50 60+6	L.L 30. ² 26. ² 28. ² 25.0 30. ⁹ 27. ² 30.9	P.1 7 24 3 20 2 23 6 20 9 23 33 22 99 24 99 24	L. .3 .6 .6 .6 .7	P.J 6.4 5.7 5.0 7.3 4.0 6.3	I. 4 7 9 0 3 6 3	1 (%) 1 2 2 2 2 1 1 2 1	.0 .0 .0 .0 .0	() 1 1 1 1 1 1 1	gm CC) .92 4 .89 0 .00 8 .90 6 .90 1 .95 5 .95 5	.C. (%) 11.7 11.0 10.6 11.0 11.9 11.1 11.4	Soak ed 12 13 13 13 14 13 12 12 13 14
n o 1 2 3 4 5 6 7	tion 83+5 00 79+0 75 67+5 00 66+3 00 66+3 00 64+7 00 60+5 50 50 00	L.L 30.' 26.' 28.' 25.' 30.' 27 30.'	P.1 7 24 3 20 2 23 6 20 9 23 33 22 99 24		P.I 6.4 5.7 5.0 7.3 4.0 6.3	I. 4 7 9 0 3 6 3	1 (9 1 2 2 2 1 2 1	.0 .9 .0 .0 .0 .0 .0		gm CC) .92 4 .89 0 .00 8 .90 6 .90 6 .90 1 .95 5 .95 5 .95	.C. (%) 11.7 11.0 10.6 11.0 11.9 11.1 11.4	Soak ed 12 13 13 13 14 13 12 12 12 12
n o 1 2 3 4 5 6 7 8	tion 83+5 00 79+0 75 67+5 00 66+3 00 66+3 00 64+7 00 60+5 50 50+6 00 44+2 00	L.L 30.' 26 28 25 30.' 27 30.' 27 28	P.1 7 24 3 20 2 23 6 20 9 23 33 22 99 24 20 21	L. .3 .6 .3 .6 .7 .6 .1	P.I 6.4 5.7 5.0 7.3 4.0 6.3 7.7	I. 4 7 9 0 3 6 3 1	1 (%) 1 2 2 2 2 2 1 1 2 2 1 1 2 2	.5 .5 .4 .0 .3 .8 .9 .0 .9	() 1 1 1 1 1 1 1 1 1 1 1 1 1	gm CC) .92 4 .89 0 .00 8 .90 6 .90 1 .95 5 .95 5 .02	.C. (%) 11.7 11.0 10.6 11.0 11.9 11.1 11.4 10.3	Soak ed 12 13 13 13 14 13 12 12 14 13 12 14
n o 1 2 3 4 5 6 7 8 8 0	tion 83+5 00 79+0 75 67+5 00 66+3 00 66+3 00 64+7 00 60+5 50 60+5 50 60 44+2 00	L.L 30. ⁷ 26. ³ 28. ³ 25. ¹ 30. ⁹ 27. ³ 30. ⁹ 28. ³	P.1 7 24 3 20 2 23 6 20 9 23 3 22 9 23 9 24 2 21	L. .3 .6 .6 .6 .7 .1	P.I 6.4 5.7 5.0 7.2 4.0 6.3 7.2	I. 4 7 9 3 6 3 1	1 (9 2 2 2 1 2 2 1 2 2 1 2 2 1 2	.5 .5 .4 .0 .3 .8 .9 .0 .9	() 1 1 1 1 1 1 1 1 1 1 1 1 1	gm CC) .92 4 .89 0 .00 8 .90 6 .90 1 .95 5 .02 1 1 0 2	.C. (%) 11.7 11.0 10.6 11.0 11.9 11.1 11.4 10.3	Soak ed 12 13 13 13 14 13 12 14 13 14 13 14 14 13 12 12 14 13
n o 1 2 3 4 5 6 7 8 9	tion 83+5 00 79+0 75 67+5 00 66+3 00 64+7 00 60+5 50 60+5 50 60 50+6 00 44+2 00 37+4 00	L.L 30. ⁷ 26. ³ 28. ³ 30. ⁹ 27. ³ 30. ⁹ 28. ³ 30. ⁹	P.1 7 24 3 20 2 23 6 20 9 23 3 22 9 23 9 24 2 21 7 24	L. .3 .6 .6 .6 .7 .6 .1 .2	P.J 6.4 5.7 5.0 7.3 4.0 6.3 7.1 6.5	I. 4 7 9 0 3 6 3 1 5	1 (%) 1 2 2 2 2 1 1 2 2 1 1 2 2 2 2	.5 .5 .4 .0 .3 .8 .9 .0 .9 .9 .2	() / 1 1 1 1 1 1 1 1 1 1 1 1 1	gm CC) .92 4 .89 0 .00 8 .90 6 .90 1 .95 5 .95 5 .02 1 .93 3	.C. (%) 11.7 11.0 10.6 11.0 11.9 11.1 11.4 10.3 11.8	Soak ed 12 13 13 13 14 13 12 14 13 12 14 13 12 12 13 12 14 13 12 12 14 13

1 0	30+3 00	25.8	21.7	4.1	2.3	1.99 0	11.8	16
1 1	27+3 00	30.9	24.1	6.8	3.0	2.02 7	11.9	14
1 2	21+0 00	29.0	23.1	5.9	1.4	2.04 3	11.3	15
1 3	14+5 00	29.0	23.2	5.8	1.1	1.96 7	10.8	13
1 4	12+2 00	27.9	24.8	3.1	2.6	1.99 6	10.9	14
1 5	07+1 50	28.1	21.6	6.5	1.1	2.01 1	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:

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3.

(MR_Bitumen)

Fatigue Model (As

per Cl. 3.6.2 IRC 37

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- 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	Doforonco
	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	3000 Mpa (As per Table 9.2 of IRC 37 – 2018)

- 2018) Reliability 90% Percentage (%) By Marshall 0.5161 x 10^(-4) x C x Method (Nf) (1/Et)^(3.89) x (1/MR_Bituminous)^(0.854) 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 = 3.5Et = 1.78E-04 (by Calculation) Vbe = Percentage Volume of effective bitumen in mix used in the bottom bituminous layer = 11.5 M = 0.371C = 2.35004. Rutting Model (As per Cl. 3.6.1 of IRC 37-2018) Reliability 90% Percentage (%) By Marshall 1.41 x 10⁽⁻⁸⁾ x (1/Ev)^{4.5337} method (Nr) Ev = 3.72E-04 (By Calculation) Poison Ratio (Mu) 0.35 (As per Cl. 7.3.1 of IRC 37 -2012) 20000 N (As per IRC 3 (Half of 6 Wheel Load (W) Tonne Axle Load)) Tyre Pressure 0.56 Mpa (As per Cl. 13 part vii of IRC 37 -2012 (Mpa) Analysis Points 4 Wheel set 2 (Assume) LCR Mac-Grid EG LCR for Base Layer 1.35 (LCR2) LCR for Sub-Base 1 Layer (LCR3) 5. Modified Layer **Thickness Values** Modified laver 165 mm Thickness for Base (mm)

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	Modified layer	200 mm
	Thickness for Sub-	
	Base (mm)	
6.	Modified layer MR	
	Modified MP	272 Mpa
	Values for Base	575 Mpa
	laver (Mpa)	
	Madified MD	167 Mag
	Values for Sub	107 Мра
	Page layer (Mpa)	
7	Calculations for	
7.	lavor coofficients	
	for modified	
	thickness	
	Laver Coefficient	0.171 X (I N(MR))-1.784 (As per
	for Surface Layer	
	(21)	AA31110 1993J
	(a1)	
		a1 = 0.436 (MR_Bitumen converted
		trom MPA to PSI)
	Layer Coefficient	0.249 x (LOG10 (MR_Base))-0.977
	tor base Layer (a2)	
		a2 = 0.202 (MR_Base converted
		from Mpa to PSI)
	Layer Coefficient	0.227 x (LOG10 (MR_Subbase))-
	for Sub-base Layer	0.839
	(a3)	
		a3 = 0.168 (MR_Subbase converted
		from Mpa to PSI)
8.	Modified Laver	
-	Coefficients	
	Modified Laver	0.438
	Coefficients for	
	Surface Layer (a'1)	
	Modified Layer	0.272
	Coefficients for	
	Base Layer (a'2)	
	Modified Layer	0.168
	Coefficients for	
	Sub-Base Layer	
	(a'3)	
9.	Calculation of	
	Modified Elastic	
	Modul for IITPave	
	Modified Elastic	10^(a'2+0.977)/0.249
	Modul for Base	
	Layer (MR_base')	MR_Base' = 716 Mpa
	Modified Elastic	10^(a'2+0.839)/0.227
	Modul for Base	- "
	Layer	MR_Subbase = 187 Mna
	(MR_Subbase')	
10.	Revised section	
	from IIT Pave	
	While Limiting	
	Permissible Strains	
	Revised Thickness	90 mm
	of Bound Layers	
	(BC+DBM) (H bit')	
	Revised Thickness	165 mm
	of Base Layer (H	
	bas'e)	

	Revised Thickness	200 mm
	of Sub-Base Layer	
	(H Subbase')	
11.	Comparison of	
	Revised Strains	
	Permissible Tensile	1.78E-04 (As per fatigue model
	Strain for Given	calculated before)
	design traffic (Et	
	permissible)	
	Permissible	3.72E-04 (As per fatigue model
	Vertical Strain for	calculated before)
	Given design traffic	
	(Ev permissible)	
	Maximum Induced	1.32E-04 (From IIT pave)
	Tensile strain (Et	
	induced')	
	Maximum Induced	3.64E-04 (From IIT pave)
	Vertical strain (Ev	
	induced')	
	Check for Tensile	
	Strain	
	Et Permissible >	Et induced
	1 78E-04 >	1 32E-04
	1001 017	
		Hongo Cafe
		Hence, Sale
	Check for Vertical	
	Strain	
	Ev Permissible >	Ev induced
	3.72E-04 >	3.64E-04
		Hence Safe
		fictice, sale

Layer: 1 Elastic Mod	dulus(MPa)	3000	Po	ison Ratio	0.35	Thickness(mm)	90
Layer: 2 Elastic Mod	tulus(MPa)	716	Po	ison Ratio	0.35	Thickness(mm)	165
Layer: 3 Elastic Mod	lulus(MPa)	187	Po	ison Ratio	0.35	Thickness(mm)	200
Layer: 4 Elastic Mod	tulus(MPa)	86.34	Po	ison Ratio	0.35	1	
Wheel Load(Newton) Analysis Points 4	20000		Tyre Pres	isure(MPa)	0.56		
Wheel Load(Newton) Analysis Points 4 Point: 1 Depth(mm):	20000 ~ 90	Radi	Tyre Pres us(mm):	sure(MPa)	0.56		
Wheel Load(Newton) Analysis Points 4 Point: 1 Depth(mm): Point: 2 Depth(mm):	20000 ~ 90 90	Radi	Tyre Pres us(mm): us(mm):	o 155	0.56		
Wheel Load(Newton) Analysis Points 4 Point: 1 Depth(mm): Point: 2 Depth(mm): Point: 3 Depth(mm):	20000 90 90 455	Radi	Tyre Pres us(mm): us(mm): us(mm):	o 0 0	0.56		



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	VIEW RE	SULTS							
OPEN FILLE IN EDI	OR			BACK T	O EDIT	но	VIE		
No. of layers		4							
E values (MPa)	3	000.00	716.00	187.00	86.34				
Mu values		0.350.	350.350	0.35					
thicknesses (m	m)	90.00	165.00	200.00					
single wheel 1	oad (N) 20	000.00							
tyre pressure	(MPa)	0.56							
Dual Wheel									
Z R	SigmaZ	Si	gmaT	SigmaR	TaoRZ	DispZ	epZ	epT	epR
90.00 0.00	-0.2779E+0	0 0.4180	E+00 0.	.3375E+00-	0.3155E-01	0.3679E+00-0	.1808E-03	0.1324E-03	0.9617E-04
90.00L 0.00	-0.2779E+0	0-0.1415	E-01-0.	3335E-01-	0.3155E-01	0.3679E+00-0	.3648E-03	0.1324E-03	0.9616E-04
90.00 155.00	-0.1391E+0	0 0.2392	E+00-0.	1551E+00-	0.1645E+00	0.3700E+00-0	.5619E-04	0.1141E-03-	0.6338E-04
90.00L 155.00	-0.1391E+0	0 0.4468	E-04-0.	9407E-01-	0.1645E+00	0.3700E+00-0	.1484E-03	0.1141E-03-	0.6338E-04
455.00 0.00	-0.2755E-0	1 0.2378	E-01 0.	1906E-01-	0.4874E-02	0.2722E+00-0	.2275E-03	0.1431E-03	0.1090E-03
455.00L 0.00	-0.2754E-0	1 0.2999	E-02 0.	8157E-03-	0.4873E-02	0.2722E+00-0	.3345E-03	0.1431E-03	0.1089E-03
455.00 155.00	-0.2971E-0	1 0.2574	E-01 0.	2198E-01-	0.7367E-02	0.2807E+00-0	.2482E-03	0.1521E-03	0.1250E-03
ARE 007 185 00	-0 29715-0	1 0 3273	F-02 0	1541E-02-	0.7358E-02	0.2807E+00-0	3636E-03	0.1521E-03	0.1250E-03





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%
с.	Type pf Bitumen to be	VG40 (As per Cl. 9 of IRC 37-
	used (VG)	2018)
d.	Temperature of	35 Degree Celsius
	Pavement (T)	
2.	Resilient Modulus	17.6xCBR^(0.64) (As per Cl.
	(MR)	6.3 IRC 37-2018)
a.	Resilient Modulus of	86.34 Mpa
	Subgrade Soil	
b.	Resilient Modulus of	3000 Mpa (As per Table 9.2 of
	Bituminous Layer	IRC 37 – 2018)
	(MR_Bitumen)	
3.	Fatigue Model (As per	
	Cl. 3.6.2 IRC 37 – 2018)	
	Reliability Percentage	90%
	(%)	
	By Marshall Method	0.5161 x 10^(-4) x C x
	(Nf)	$(1/Et)^{(3.89)}x$
		(1/MR_Bituminous)^(0.854)
	Where: -	
	C = 10^M	
	M = 4.84 x	
	((Vhe/va+Vhe)-0.69)	
	Va - Dorcontaga	
	Valumo of air voids in	
	volume of all volus in	

	mix used in the bottom	
	bituminous layer = 3.5	
	Vbe = Percentage	
	Volume of effective	Et = 1.89E-04 (by Calculation)
	bitumen in mix used in	
	the bottom bituminous $lawer = 11$ E	
	layer = 11.5	
	M = 0.371	
	C = 2.3500	
4.	Rutting Model (As per	
	2018)	
	Reliability Percentage	90%
	(%)	
	By Marshall method	$1.41 \times 10^{(-8)} \times (1 \times 10^{-10}) \times 10^{-10}$
	(Nr)	(1/EV)~4.5337
		Ev = 3.90E-04 (Bv
		Calculation)
	Poison Ratio (Mu)	0.35 (As per Cl. 7.3.1 of IRC 37
	Wheel Load (W)	-2012) 20000 N (As por IPC 3 (Half of
	Wheel Load (W)	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 for Base Laver	1 35
	(LCR2)	100
	LCR for Sub-Base Layer	1
-	(LCR3)	
5.	Thickness Values	
	Modified layer	165 mm
	Thickness for Base	
	(mm) Madifiad lawar	200
	Modified layer	200 mm
	(mm)	
6.	Modified layer MR	
	Values Modified MR Values for	272 Mpc
	Base laver (Mna)	<i>37</i> 3 ™µa
	Modified MR Values for	187 Mpa
	Sub-Base layer (Mpa)	
7.	Calculations for layer	
	modified thickness	
	Layer Coefficient for	0.171 X (LN(MR))-1.784 (As
	Surface Layer (a1)	per AASTHO 1993)
		a1 = 0.436 (MR_Bitumen
	Laver Coefficient for	$0.249 \times (LOG10 (MR Base))$ -
	base Layer (a2)	0.977



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		a2 = 0.202 (MR_Base
		converted from Mpa to PSI)
	Layer Coefficient for	0.227 x (LOG10
	Sub-base Layer (a3)	(MR_Subbase))-0.839
		a3 = 0.168 (MR_Subbase
		converted from Mpa to PSI)
8.	Modified Layer	
	Modified Lever	0.420
	Mourileu Layer	0.430
	Lever (a'1)	
	Layer (a 1)	0.272
	Modified Layer	0.272
	Coefficients for Base	
	Layer (a'2)	
	Modified Layer	0.168
	Coefficients for Sub-	
	Base Layer (a'3)	
9.	Calculation of Modified	
	Elastic Modul for	
	IITPave	
	Modified Elastic Modul	10^(a'2+0.977)/0.249
	for Base Layer	
	(MR_base')	MR Base' = 716 Mna
	Modified Elastic Modul	10^(a'2+0.839)/0.227
	for Base Laver	10 (4 2 0 0 0 0)) 0 121
	(MR Subbase')	
10		MR_Subbase = 187 Mpa
10.	Revised section from	
	III Pave While Limiting	
	Permissible Strains	00
	Revised Thickness of	80 mm
	Bound Layers	
	(BC+DBM) (H DIL)	165
	Revised Inickness of Base Laver (H bas'e)	165 mm
	Revised Thickness of	200 mm
	Sub-Base Laver (H	200 mm
	Subbase')	
11	Comparison of Revised	
11.	Strains	
-	Permissible Tensile	1 89F-04 (As per fatigue
	Strain for Given design	model calculated before)
	traffic (Et permissible)	model calculated beforej
	Permissible Vertical	3 90E-04 (As per fatigue
	Strain for Given design	model calculated before)
	traffic (Ev permissible)	
<u> </u>	Maximum Induced	1.33E-04 (From IIT nave)
	Tensile strain (Et	• • • • • • • • • • • • • • • • •
	induced')	
	Maximum Induced	3.84E-04 (From IIT pave)
	Vertical strain (Ev	(FO)
	induced')	
	Check for Tensile	
	Strain	
	Ft Dormicaible >	Et induced
	Et r et missible >	Li muuccu
	1.89E-04 >	1.33E-04
	Charle for Vartical	
1	Check for Vertical	

	Strain	Hence, Safe
	Ev Permissible > 3.90E-04	Ev induced 3.84E-04
		Hence, Safe
ivers		номе

ayer: 1 Elastic Modulu	s(MPa)	3000	Poison Ratio	0.35	Thickness(m	m) 80	
ayer: 2 Elastic Modulu	s(MPa)	716	Poison Ratio	0.35	Thickness(m	m) 165	
ayer: 3 Elastic Modulu	s(MPa)	187	Poison Ratio	0.35	Thickness(m	m) 200	
ayer: 4 Elastic Modulu	s(MPa)	86.34	Poison Ratio	0.35			
Vheel Load(Newton) 20	000	Tyre	Pressure(MPa)	0.56			
Vheel Load(Newton) 20 Inalysis Points 4 ~	000	Tyre	Pressure(MPa)	0.56			
/heel Load(Newton) 20 nalysis Points 4 v oint: 1 Depth(mm): 80	000	Tyre I Radius(mr	Pressure(MPa) n): 0	0.56			
Vheel Load(Newton) 20 unalysis Points 4 oint: 1 Depth(mm): 80 oint: 2 Depth(mm): 80	000	Tyre I Radius(mn Radius(mn	Pressure(MPa) n): 0 n): 155	0.56			
Vheel Load(Newton) 20 unalysis Points 4 Point:1 Depth(mm): 80 Point:2 Depth(mm): 80 Point:3 Depth(mm):	000 0 0 0	Tyre i Radius(mn Radius(mn Radius(mn	Pressure(MPa) n): 0 n): 155 n): 0	0.56			

VIEW	RESULTS			
OPEN FILLE IN EDITOR		BACK TO EDIT	HOME	
No. of layers	4			
E values (MPa)	3000.00 716.00	187.00 86.34		
Mu values	0.350.350.350	0.35		
thicknesses (mm)	80.00 165.00	200.00		
single wheel load (N)	20000.00			
tyre pressure (MPa)	0.56			
Dual Wheel				
Z R Sig	maZ SigmaT	SigmaR TaoRZ	DispZ epZ	epT epR
80.00 0.00-0.3113	E+00 0.4055E+00 0.	3311E+00-0.3104E-01	0.3822E+00-0.1897E-03	0.1329E-03 0.9938E-04
80.00L 0.00-0.3113	E+00-0.3083E-01-0.	4858E-01-0.3104E-01	0.3822E+00-0.3959E-03	0.1329E-03 0.9938E-04
80.00 155.00-0.1397	E+00 0.1977E+00-0.	2369E+00-0.1755E+00	0.3819E+00-0.4199E-04	0.1098E-03-0.8574E-04
80.00L 155.00-0.1397	E+00-0.1008E-01-0.	1138E+00-0.1755E+00	0.3819E+00-0.1345E-03	0.1098E-03-0.8574E-04
445.00 0.00-0.2903	E-01 0.2506E-01 0.	1984E-01-0.5203E-02	0.2796E+00-0.2393E-03	0.1512E-03 0.1136E-03
445.00L 0.00-0.2906	E-01 0.3143E-02 0.	7503E-03-0.5203E-02	0.2796E+00~0.3524E-03	0.1512E-03 0.1138E-03
445.00 155.00-0.3140	E-01 0.2717E-01 0.	2298E-01-0.8018E-02	0.2888E+00-0.2618E-03	0.1611E-03 0.1308E-03
445.00L 155.00-0.3138	E-01 0.3446E-02 0.	1493E-02-0.8016E-02	0.2888E+00-0.3835E-03	0.1611E-03 0.1305E-03



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 geogrid.

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