iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 12 **Issue:** VII **Month of publication:** July 2024

DOI: https://doi.org/10.22214/ijraset.2024.63505

Effects of 3D Geocells on Flexible Pavement Foundations

Chandrakant Soni[1], Dr. Bablu Kirar[2]
[1]M. Tech Scholar, [2]Assistant Professor, Department of Civil Engineering, Samrat Ashok Technological Institute, Vidisha, M.P. India

Abstract: The current below study examines the effects of adding a Cubic Three-dimensional Geo-synthetics material known as Geo-cells to the foundation layer of flexible Bitumen pavements. In this study, the test of California bearing ratio (CBR) of 5% is used to compare the steel reinforced and unreinforced pavement made sections built on that subgrade. To comprehend the impact of Geo-cell reinforcement upon the pavement section's load-carryings mechanism under static and repetitive loading circumstances, a number of model tests were conducted. The following characteristics were examined: surface deformation profile the test sections, real rut subgrade level, load-settlement response of the pavement sections, and pressure is transmitted into the subgrade soil beneath into the Geo-cell reinforced foundation layer.
***Keywords**: Geocell. Flexible Pavements, IIT Pave, Reinforcement.*

I. INTRODUCTION

Axle weights and traffic volume are both constantly rising, placing heavy pressures on the current road network. The tensions that are created between the layers quickly cause cracks to emerge, and any local differential settlements may cause the higher layers to settle later. These stresses cause local differential settling, or rutting, as well as the production of surface layer cracks (also known as fatigue). The types of soil found worldwide vary from very dense to very loose, and from rigid to very weak. Despite some soils being fragile, the availability of ideal construction sites is limited. Therefore, when these sites cannot be avoided, improvements must be made to them.

Geosynthetics have been used for several decades already. The use of geosynthetics has gained significant advantages over other improvement methods in recent decades, particularly in the pavement industry. The use of geocells in pavement layers has recently demonstrated significant performance improvement because they can add lateral confinement to the infill material in addition to the reinforcement functions offered by traditional geo-synthetics. When granular infill is applied over weak subgrades under monotonic loading circumstances, geocell reinforcement has demonstrated success. as demonstrated by numerous research studies in the past. Studies on flexible pavements under static and repetitive loads, with and without a geocell reinforced base layer However, the literature contains limited information about repeated stress testing with sophisticated instrumentation on pavement sections reinforced with geocells.

II. REVIEW OF LITERATURE

The study on geo-synthetic reinforced soil and pavement constructions under static and recurrent traffic loading is the subject of this chapter, which was conducted by a variety of practitioners and researchers. Studying how geocell reinforced pavements behaved under various load circumstances was the main focus.

As the main goal of this study is to comprehend the behavior of geocell mattresses under various loading circumstances, important papers on geocells are included.

An extensive body of research examined the possible application of geo-synthetics, including geo-grids, geo-nets, geo-textiles, composites, and geocells, as reinforcement in pavement layers for low traffic roads in order to mitigate the possibility of rutting phenomena. Typically, geosynthetic reinforced foundations and pavement constructions for static and repeated loads employ the bearing capacity improvement factor and traffic benefit ratio (TBR) as performance indicators. The total load repetitions for the reinforced beds must be divided by the total load repetitions for the unreinforced beds in order to determine the TBR for a specific rut depth.

III. METHODOLOGY

All paragraphs must be indented. All paragraphs must be justified, i.e. both left-justified and right-justified.

The characteristics of the different type of materials utilized and the methods for sampled preparation employed in the current investigation are outlined. After a comprehensive discussion of the sample preparation techniques, the properties of the materials are presented. These resources serve as the foundation for the study.

1) Clayey sand is utilized for preparing the subgrade.
2) A base course made of wet mix macadam (WMM).
3) Macadam with bitumen as the top layer.
4) Geocell mattress provides reinforcement for the foundation layer.

The description of each material in further detail is covered below.

a) Atterberg's limits

According to IS-2720 (Part4-1972), Atterberg's limitations, including into the liquid limit (LL) and plastic limit (PL), were conducted [33]. In Fig.3.2a, pictures of the testing equipment are shown. Figure 3.2b depicts the soil's flow curve. The soil's maximum tolerance for liquid and plastic is discovered to be 47% and 21%, respectively. The difference between LL and PL, or the soil's plasticity index, is calculated to be 26%.

According to the Indian Standard Soil Classification System, the soil is categorized as well-graded sand containing clay (SC).

b) Specific gravity

The specific gravity test is carried out in accordance with IS-2720 (Part3-1980) [34], and the result is 2.65. The results of this test, which was carried out using the density bottle method, are shown in Fig. 3.3.

Figure 3.1 Images of the LL and PL test

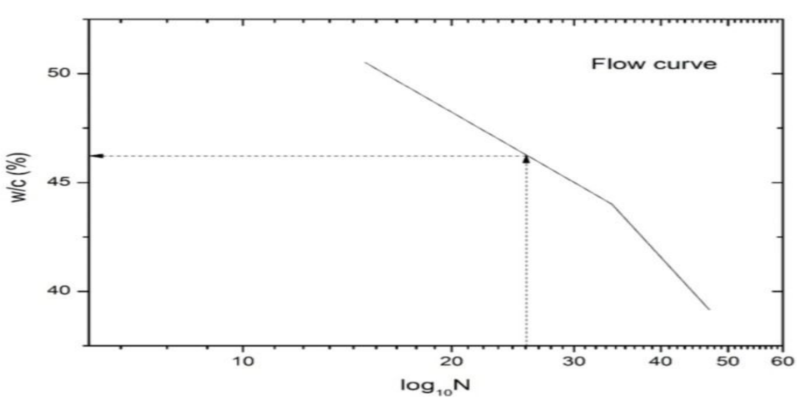


Figure 3.2 Flow curve of clayey soil

ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 12 Issue VII July 2024- Available at www.ijraset.com

Figure 3.3 Specific gravity test by density bottle method

c) Compaction Characteristics

The Standard Proctor compaction type test, which is carried out in accordance with IS-2720 (Part7-1980) [35], is a laboratory technique for determining the optimum moisture content (OMC) and maximum dry unit weight (MDU). The process calls for compacting the soil in three layers, each receiving 25 blows came from a conventional hammer that weighs 2.6 kg and has a 310 mm falling height. This compacting mould has a 948 cc volume.

Figure 3.4 Mold and hammer used in standard proctor test

Figures depicting the test equipment are provided in Figures 3.4 and 3.5, respectively, additionally, a correlation between unit weight and moisture content is provided. The graph illustrates that the maximum dry unit weight (MDU) is 18.25 kN/m3, and the optimum moisture content (OMC) is 13.9%.

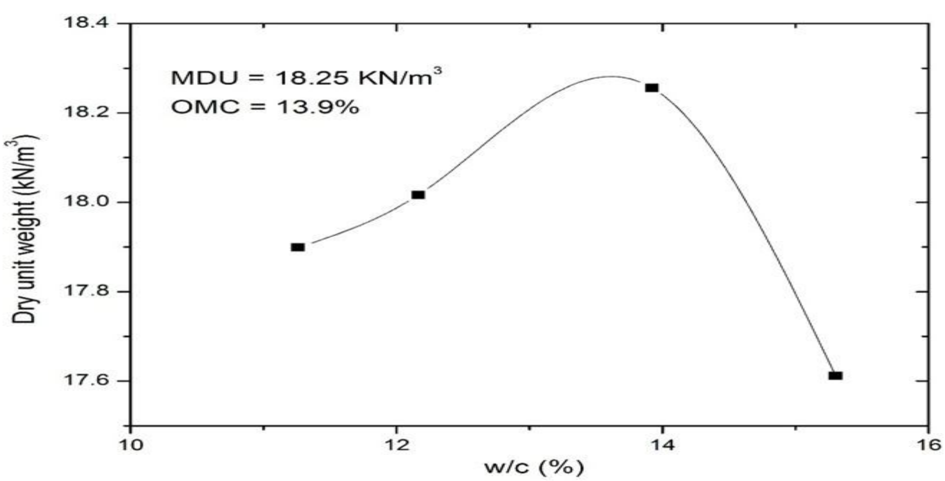


Figure 3.5 Compaction characteristics of the subgrade soil

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 12 Issue VII July 2024- Available at www.ijraset.com

d) Characteristics of Geo cell

High-density polyethylene (HDPE) strips are ultra-sonically welded at the joints of Geocell, a three-dimensional geosynthetic material that is expanded at site to form a honeycomb structure. The infilled material is bound by Geocell, which also offers lateral constraint to loading. The HDPE polymer used to manufacture the Geocell mattress in this study proves a density ranging from 0.935 to 0.965 g/cm³ and a weld spacing of 356 mm. Throughout the test series, the cell height or depth is maintained at 200 mm, with a minimum cell strength of 2100 N. Figure 3.8 shows a typical geocell mattress used in the study.

Figure 3.6 Typical geocell used in the study

e) Characteristics of Bituminous Course (BC) Layer

Visco-elastic bituminous type of concrete is used as a plane surface course. The ideal bitumen concentration ranges from 5 to 6%, and penetration grade PG 60/70 bitumen was used. In Table 3.2, the composition of aggregates, or the particle gradation, used in bitumen concrete is shown.

Table 3.1 Grading requirements of aggregates for bitumen Layer

IS sieve (mm)	Cumulative % by weight of total aggregate passing
26.5	100
19	79-100
13.2	59-79
9.5	52-72
4.75	35-55
2.36	28-44
1.18	20-34
0.6	15-27
0.3	10-20
0.15	5-13
0.075	2-8

f) Test

a) Subgrade Preparation

The soil was added to the big test tank to prepare the subgrade, and it was compacted with limit 50 mm thick layers until the appropriate height was obtained. The quantity of soil needed for each layer to obtain the target unit weight of 18.25 KN/m3 was weighted & added to tank. To achieve the required unit weight, the soil is compacted using a 5 kg drop weighted hammer, applying a pre-calibrated number of strikes (8 blows). Level was checked after the compaction of each layer.

ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 12 Issue VII July 2024- Available at www.ijraset.com

b) Base Course Preparation

The Wet Mix Macadam was poured in test tank and compacted upto 50 mm thick layers until the appropriate height is reached to create the unreinforced test bed. The amount of aggregate needed for each layer to obtain the necessary bulk unit weight of 22.48 kN/m3 was weight out and added to the test tank using a metal scoop. After that, a vibrator was used to gently level and condense the granular base course. The level was examined following the compaction of each layer.

g) Preparation of Bitumen layer

The aggregates were prepared in accordance with the previously described grading criteria, and a bitumen content of five was then mixed in. After a tack coat is sprayed on top at the base course layer, the bitumen concrete mix was applied. The layer was then compacted used by a drop hammer. The material was compressed to a layer height of 50 mm. The surface layer will continue to be 800 mm 800 mm 50 mm in size. The entire viewpoint of test section is shown in Fig. 3.11.

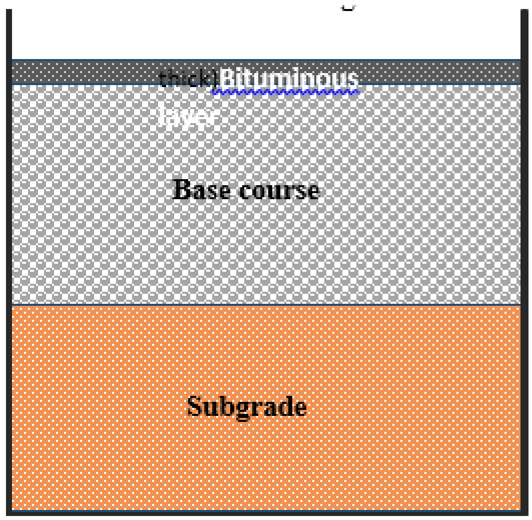


Figure 3.7 A typical section shows the different layers

In the first image, a test tank with a volume of 1 m3 is shown empty. In the second type stage, the soil is be compacted to form the subgrade level bed. In third stage, pressure cells are installed on top of subgrade. In fourth stage, the plate rod is assembled and geocell type mattress are installed. In fifth stage, the layer of base is compacted until the required density is achieved. In sixth stage, four plates are to be arranged in a triangular formation, then bituminous concrete type material is poured and thoroughly compacted to create a level surface. Finally, a tack coat is sprayed on top of base course layer to ensure a strong bonding between the surfaced layer and the base layer.

Figure 3.8 various stages for the preparation of the test section

IV. RESULTS AND DISCUSSION

A. *Design Approach*

In flexible pavements, wheel loads are distributed over a larger area through the layered system, transferring the loads to the underlying layers. Utilizing linear elastic models, the stresses and strains at crucial places are calculated. The pavements must be planned such that they will function effectively for the duration of their design life. Fatigue cracking and the formation of ruts, both visible on the pavement surface, are common causes of failure in flexible pavements.

a) Vertical compressive strain at the top of the subgrade can induce deformation, potentially causing long-term surface deformation in the pavement.

b) The bituminous layer may fracture due to horizontal tensile strain and or stress at the bottom of the layer.

The next stages outline the design technique used in the current study (as per IRC 37-2012).

1) *Step 1: Determining the permitted rutting and fatigue strains at key sites.*

Fatigue cracking in the bituminous layer is indicated by the horizontal tensile strain (t) at the bottom of the bituminous bonded layer, referred to as the fatigue strain. Rutting strain, represented by the vertical strain on top of the subgrade (v), is believed to be the main contributor to the ongoing deformation of the subgrade (Figure 4.1). The following models, which are listed in IRC37-2012, are used to calculate the allowed fatigue and rutting strains.

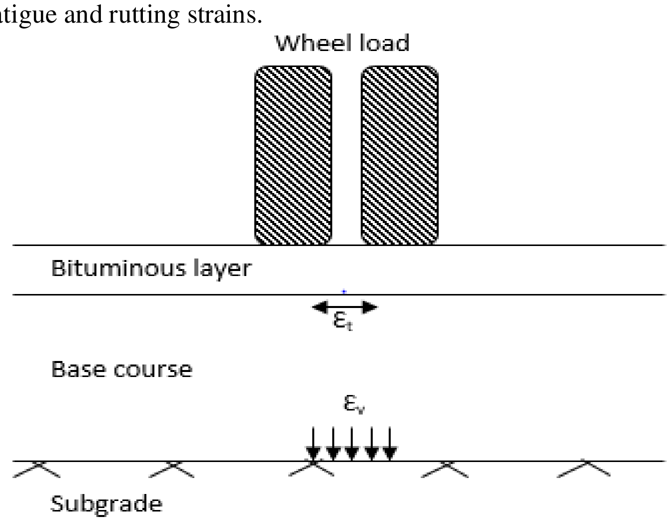


Figure 3.9 Locations of critical strains

Fatigue equation for 90% reliability is given as:

$N = 0.711X10^{\square 4\ Xt} \} 3.89 \quad M_R \} 0.854$

Where, Nf = fatigue life in number of cycles

Ɛt= Maximum tensile strain at the bottom of bituminous layer Mr= Resilient modulus of bituminous layer

Rutting equation for 90% reliability is given as:

$N=1.41 X 10^{\square 8}\ v\} 4.5337$

Where, N = Number of cumulative standard axles Ɛv= Vertical strain in subgrade

The fatigue equation in the context of material science and engineering, especially in the analysis of flexible pavements, typically relates to the number of cycles a material can endure before failure due to repeated loading. One common form of the fatigue equation is:

Nf=1/k1·(ϵt)n

Where:

- Nf is the number of load cycles to failure.
- K1 and n are material-specific constants determined through empirical testing.
- ϵt is the tensile strain at the bottom of the asphalt layer.

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 12 Issue VII July 2024- Available at www.ijraset.com

For asphalt pavements, the fatigue life can also be expressed using the Asphalt Institute's equation:

Nf=k1·(εt)^−3.291 ·(E)^−0.854

- E is the modulus of elasticity of the asphalt layer.
- k1 is a material constant.

2) Step: 2 choosing the proper pavement layer thickness from the design charts (CBR Plates)

The design catalogues provided in IRC are used to calculate the pavement layer thicknesses for the applicable traffic and subgrade conditions.

3) Step 3. Using IITPAVE, you may identify the rutting and fatigue strains.

As previously mentioned, the strains at the crucial sites are discovered using IITPAVE, a computer programme created by IIT Kharagpur and depicted in Fig. 4.1. The fatigue and rutting strains for the chosen pavement segment are computed using the aforementioned trial thickness in the IITPAVE programme, and they are compared to the permitted strains.

4) Step 4. Arriving at the final thickness

To ensure safe and effective pavement conducting system, the fatigue and rutting strains (derived in step 3) should be below the limiting last fatigue and rutting strains (determined in step 1). The chosen pavement section thicknesses can be used if the measured strains are so less than the limiting strains.

Based on the aforementioned design process, the CBR plate illustrated in Fig. 4.2 is referenced to in order to determine the design pavement section thicknesses Considering a subgrade soil CBR of 5% and traffic is equivalent to 2 million standard axles (MSA). The design catalogue of IRC 37:2012 provides pavement thickness recommendations based on the subgrade condition and the expected traffic volume.

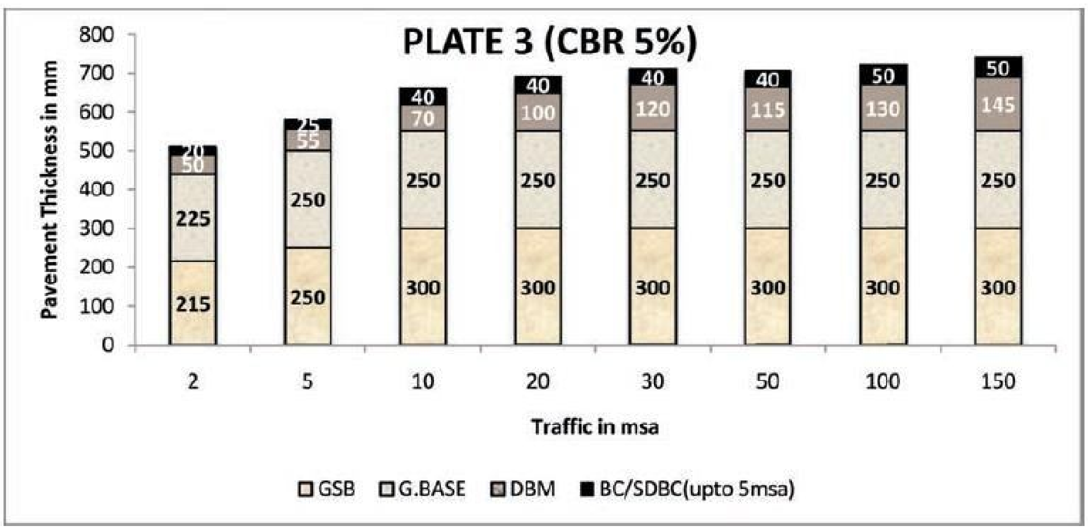


Figure 3.10 Typical pavement design chart for subgrade CBR of 5% (IRC 37:2012)

Table 4.1 Test summary

Stage	Test program	Configuration
1	Static load test	Unreinforced test section with a 440 mm thick base course, and reinforced test section with a base course thickness reduced from 440 mm to 250 mm.
2	Repeated load test	The unreinforced test section has a base course thickness of 440 mm, while the reinforced test section has a base course thickness of 250 mm.

B. Cost analysis

Table no 4.2 Cost analysis of some km stretch of un-reinforced flexible pavement

S.No.	Description of items	Length (m)	Width (m)	Thickness (m)	Quantity of material (m3)	Rate per unit	Price (Rs.)
1.	Wet Mix Macadam	1000	4	0.45	1800	3000/m³	54,00,000
2.	Bituminous layer	1000	4	0.05	200	7000/m³	14,00,000
	Total						68,00,000

V. CASE STUDY

Several days of torrential rain at march 2016 completely destroyed a section of National highways no 44 (NH-44). The road is the main corridor for commercial used traffic in the state Tripura. The Road section is failed that was in the Assam side at Assam – Tripura Border area. A geocells is supported the road section was specified to repair the road which is damaged quickly. The region needed fast response. NH-44 road is essential and important transit role that meant any impassability meant spikes in fuels and food costs. The Geocell sheet solution was able to be applied in just 15-18 days from beginning of the construction works to reopening of roadways.

VI. CONCLUSION

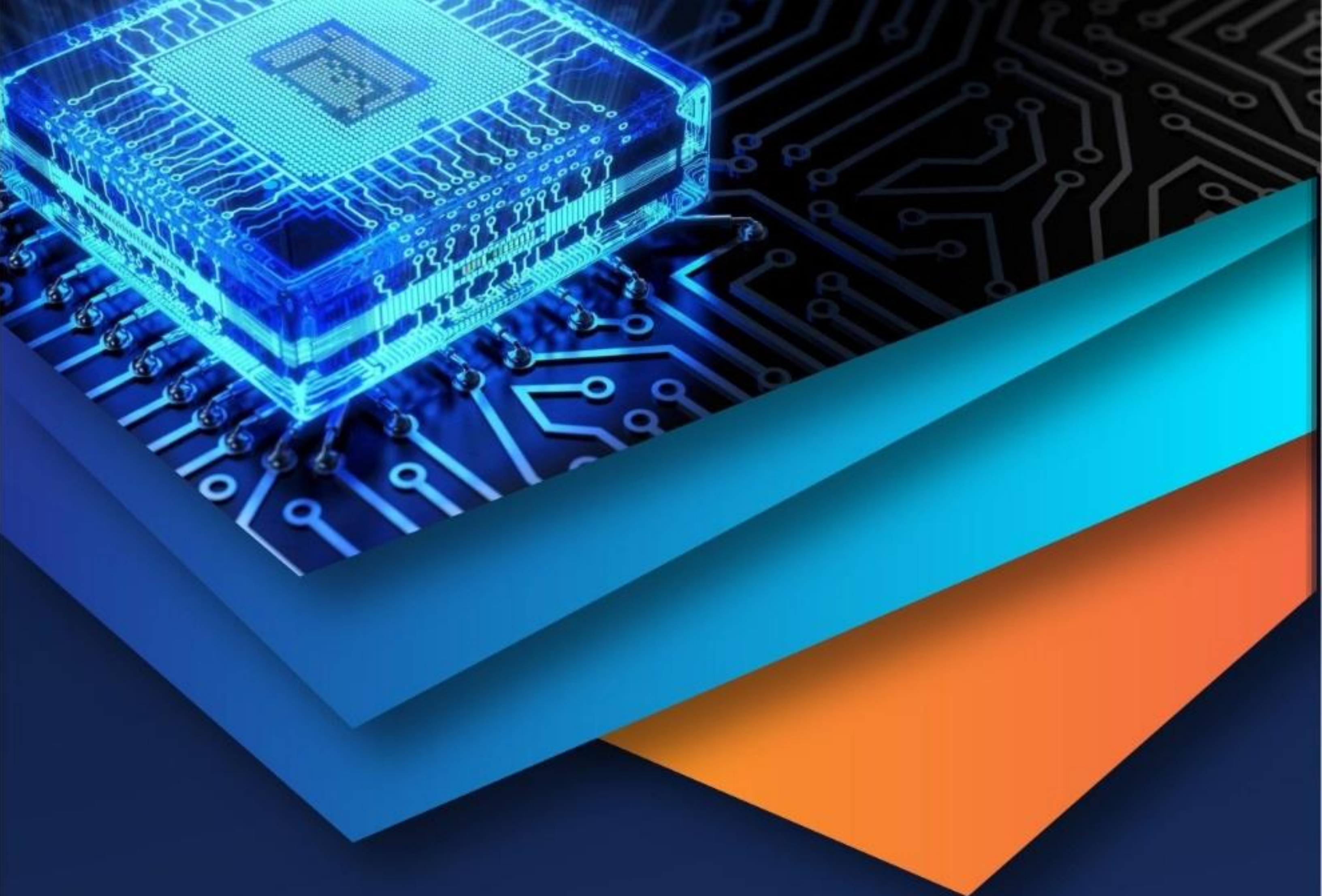
Considering cost is paramount in any civil engineering Endeavor. Upon examining the cost analysis presented in the previous chapter, it becomes apparent that for every kilometre of single-lane road construction, reinforced pavement entails a 10.15% reduction in costs compared to unreinforced pavement. Integrating geocell into the base layer results in a 43% reduction in base thickness compared to the unreinforced configuration. This reduction minimizes the demand for scarce virgin materials. Moreover, by enhancing the elasticity of the respective layers, geocell helps reduce the pavement's permanent deformations. In the reinforced scenario, there was a 13% decrease in total observed permanent deformation. The recorded rut benefit ratio (RBR) of 13% and rut depth reduction (RDR) of 19% demonstrate the geocell's effectiveness in distributing the load over a wider area, leading to reduced rutting at the subgrade level. Moreover, despite its reduced thickness, the reinforced pavement section exhibits greater stiffness compared to the unreinforced section, as indicated by the measured equivalent modulus improvement factor, which is 1.3 times higher than that of the unreinforced pavement section.

AASHTO states that for the same traffic repetitions, the unreinforced pavement section should ideally have a thickness of 553 mm instead of 440 mm. The robust modulus of the base layer, computed in accordance with IRC norms, relies solely on the CBR of the subgrade. In contrast, AASHTO determines and designs the robust modulus of each layer based on actual acquired values, providing a more accurate approach compared to the IRC method.

REFERENCES

[1] https://en.wikipedia.org/wiki/Geo-synthetics, accessed on 20/06/2017.
[2] Webster, S. L. (1981). Investigation of Beach Sand Trafficability Enhancement Using Sand- Grid Confinement and Membrane Reinforcement Concepts. Report 2. Sand Test Sections 3 and 4(No. WES/TR/GL-79-20). ARMY ENGINEER WATERWAYS EXPERIMENT STATION VICKSBURG MS GEOTECHNICAL LAB.
[3] Carter, G. R. and Dixon, J. H. (1995). Oriented polymer grid reinforcement. Construction and Building Materials, 9(6), 389-401
[4] Biabani, M. M., Ngo, N. T., and Indra Ratna, B. (2016). Performance evaluation of railway subballast stabilised with geo-cell based on pull-out testing. Geotextiles and Geomembranes, 44(4), 579-591.
[5] T V Viswa Teja, Ch Vineel , D ManiKumari. Cost Economics of Geocell Reinforced Flexible Pavements on Soft Soils by using Kenpave Software. Sept 2019.
[6] Yash Singh, Ravi Shankar S. Anakha Jayan, Design of Geocell Reinforced Flexible Pavement. March 2015.
[7] K. Rajagopal1, A. Veeragavan2, and S. Chandramouli3. STUDIES ON GEOCELL REINFORCEDROAD PAVEMENT STRUCTURES. December 2012 Thailand.
[8] Tina Jose1, Basil K Alias2, Deepanjaly S Shaju3, Sagar Tomy4, Sreelakshmi R5 A CASE STUDY ON THE DESIGN OF GEOCELL REINFORCED FLEXIBLE PAVEMENT. May 2020.
[9] D.V.ARUL MOZHI BHARATHI, 2E. DHANALAKSHMI, 3R. SALEEMA BEGUM, 4K. MUTHU KUMAR. DESIGN OF FLEXIBLE PAVEMENT USING GEOCELL. April 2018.
[10] Ajit Raj Singh*1, Vijay Kumar Srivastav*2, Amit Kumar Yadav*3,Ankur Kumar Gupta*4, Jai Kumar Yadav*5. DESIGN OF GEOCELL REINFORCED PAVEMENT. June 2020.

[11] Kim, Y. J., Jo, S. H., Lee, S. H., & Kim, N. (2013). Field Applications on Environment- Friendly Permeable Pavements Reinforced by Geo-cell.Journal of Korean Society of Hazard Mitigation,13(2), 143-149.
[12] Giroud, J. P., and Noiray, L. (1981). Geo-textile-reinforced unpaved road design. Journal of Geotechnical and Geoenvironmental Engineering, 107. (ASCE 16489).
[13] Barker, W. R. (1987). Open-Graded Bases for Airfield Pavements (No. WES/MP/GL-87-16). ARMY ENGINEER WATERWAYS EXPERIMENT STATION VICKSBURG MS GEOTECHNICAL LAB.
[14] Haas, R., Walls, J., & Carroll, R. G. (1988).Geo-grid reinforcement of granular bases in flexible pavements (No. 1188). TRB, National Research Council, Washington, DC, USA, 19- 27.



10.22214/IJRASET

45.98

IMPACT FACTOR: 7.129

IMPACT FACTOR: 7.429

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY