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Design of Geocell Reinforced Flexible Pavement

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***Abstract*—Due to repeated application of loads, the performance of the pavement deteriorates and hence damage assessment procedures are carried out to rectify the defects produced in flexible pavement. To provide a cost-effective and permanent solution, the use of geocell has been proposed. The use of geocells increases the stability of the roads and improves its performance by improving the bearing capacity of the soil. The geocell also helps in the reduction in the thickness of the dense bituminous layer of the flexible pavement which in turn results in the reduction of cost of construction of roads. This paper is an effort to do a comparative study between the conventional flexible pavement and geocell reinforced flexible pavement. Both results are compared, analysed and potential conclusions are reported.**

Keywords--Design, Geocell, Flexible Pavement, Reinforcement, IRC 37: 2012

I. INTRODUCTION

Geocells (also called cellular confinement systems) are used in civil engineering for roadway load support, walls and steep slopes, channel protection and erosion control. They are typically made from ultrasonically welded high density polyethylene (HDPE) strips and expanded on-site to form a honeycomb structure which is subsequently filled with sand, gravel, locally available soil or concrete.Geocells walls are typically perforated so as to allow for drainage from one cell to another. These properties help to improve the bearing capacity of the soil and allow lateral distribution of the vertical stresses as the soil is confined within the Geocells.A flexible pavement structure is typically composed of several layers of material. Each layer receives the loads from the above layer, spreads them out, and then passes on these loads to the next layer below. The 4 layers of the flexible pavement are: surface course or bituminous course, base course, sub-base course and subgrade. Geocell reinforced flexible pavements are found to have increased pavement life by approximately 2-4 times as compared to unreinforced pavement. They help in increasing the bearing capacity and decreases deformation of embankments. They help to maintain a good level surface and evenly distribute the vertical loads applied on the pavement due to the application of heavy moving loads. They also reduce the lateral movement of soil particles and form a stiffened mattress to distribute the applied load.

II. RESEARCH OBJECTIVES

The objectives of this study are stated below:

- To plan the layout and thicknessof flexible pavement.
- To analyse and design the geocell reinforced flexible pavement to improve its performance.
- To study the behaviour of geocell flexible pavements in contrast to conventional pavements.

III. LITERATURE REVIEW

Huang et al (2004) explains that the mechanistic–empirical method of design is based on the mechanics of materials that relates an input, such as a wheel load, to an output or pavement response, such as stress or strain. The advantages of mechanistic methods are the improvement in the reliability of a design, the ability to predict the types of distress, and the feasibility to extrapolate from limited field and lab data. It must be noted that the Geocell material can be selected based on the field requirements.

Pokharel*et al* (2009) found through experimental evaluation that the performance of Geocell- reinforced bases depend upon the elastic modulus of the Geocell. The geocell with a higher elastic modulus had a higher bearing capacity and stiffness of the reinforced base.

Rajagopal*et al* (2005, IIT Madras) studied about the role of geocell layers in improving the quality of pavement. Stress analysis programs and both field as well as lab tests were conducted for this purpose. A trial construction was carried out for a certain length of 2m and the pavement performance was evaluated. It was observed that the reinforced section maintained a good level surface whereas the unreinforced section had surface depressions. Pressure (150kN) and settlement (10.47mm) of the soil was obtained. The sub-base layer compacted over the geogrid layer achieved higher dry density.

Latha*et al* (2006) studied the benefits of geocell reinforcement on earth embankments. It was found to help in increasing the bearing capacity and decreasing the deformation of the embankments. Geocell with higher elastic modulus had a higher bearing capacity and stiffness.

Basu et al (2007) wrote in his journal “Design approach for geocell reinforced flexible pavements” that geocell is a comparatively new reinforcing material in civil industry. The unique three dimensional confinement of this material separates it from other geosynthetic reinforcing material, such as woven geotextile, geogrids, etc. The local soil or granular material show better structural properties when confined in geocell with a proper manner. The incorporation of geocell in pavement layers facilitates a better load distribution and reduction in vertical stresses underneath the pavement structure. Hence a significant thickness reduction is possible by using this cellular confinement technology in flexible pavements.

Bender and Barenberg indicated that over ground of low bearing capacity having a CaliforniaBearing Ratio (CBR) less than about 2, the use of a geotextile could enablea 30 percent reduction in aggregate depth. Another 2 to 3 inch (50-70mm)reduction in base thickness was also possible since aggregate loss did notoccur during construction of course, uniform bases on very soft subgrades. Later work by Barenberg and Lai and Robnett emphasized the importance of the stiffness of the geotextile, with greater savings beingachieved with the use of a stiffer reinforcement.

BhagabanAcharya*et al* (2007)**(**Tribhuvan University), proved through experimental studies that geogrid reinforced flexible pavements increased pavement life by approximately 2-4 times with respect to unreinforced pavement. They help to distribute vertical load over a wider area of the subgrade and reduces lateral movement of soil particles there by increasing the bearing capacity.

IV. RESEARCH METHODOLOGY

The methodology of the study is described and explained based on the objectives and the aims of the study. As the result of literature study the properties and behaviour of geocell was known. The methodology adapted for this research is outline in the fig.1.

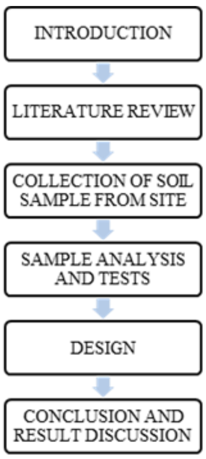

Fig. 1 Methodology

A. *Data Collection.*

Soil sample was collected from site (Kattankulathur, Chennai) from the depth of 50 cm.

B. *Sample Analysis and Tests.*

Tests were conducted in the laboratory to classify the type of soil and determine the water content of the soil. These values are important factors to be kept in mind while designing the flexible pavement with/ without reinforcement (geocell). Standard proctor compaction test is conducted to find bulk density, dry density and optimum moisture content.California Bearing ratio test was carried out to determine the CBR value of the soil sample collected. This data plays a major role in the design as it indicates the type of soil available in the desired location and to determine the thickness of various layers of the flexible pavement. A high value of CBR indicates that the soil has a good bearing capacity and therefore there can be a reduction in the thickness of the pavement thereby making it economical.

V. RESULT OF TEST

In this chapter results of the test conducted for the purpose of construction of pavement is discussed.

From Standard proctor compaction test the value of the optimum moisture content of the soil sample is obtained as 14.68% and the maximum dry density as 1.78g/cm^3.

C.B.R value of the soil specimen is observed to be 7.3%.

VI. DESIGN

A. *Design of flexible pavement*

Design of flexible pavement is done as per the recommendations made in IRC: 37 (2012). The traffic load was obtained as 153.12msa from the traffic survey conducted at the selected site. The thickness of the various layers of flexible pavement are given in table I.

Table I. Thickness of layers of flexible pavement

layer	BC	DBM	Base	Sub-base
Thickness (mm)	50	140	250	230

B. *Design of geocell reinforced flexible pavement*

Following steps are followed in design of geocell reinforced flexible pavement.

i. *Determination of CBR of the subgrade*
ii. *Determination of design traffic load (in msa)*
iii. *Selection of conventional pavement from IRC:37 design catalogue for specific subgrade CBR and design traffic.*
iv. *Determine the elastic modulus and Poisson’s ratio of the subgrade, sub-base and base layers.*
v. *Calculation of stresses and strain*
vi. *Modified modulus of base layer due to geocell confinement*

vii. Calculation of fatigue failure and rutting failure.

From the California Bearing Ratio test conducted in the laboratory, the CBR value for the soil sample was obtained as 7.3%. This indicates that the soil has a good bearing capacity.

The traffic load was obtained as 153.12MSA from the traffic survey conducted at the selected site.

The conventional flexible pavement was designed as per IRC:37 (2012) with total thickness of 670 mm. The thickness of the layers are given in table I.

The elastic modulus of the subgrade is calculated from following equations from IRC37:2012.

Esubgrade = 10*(CBR)0.64 for CBR <5%

Esubgrade = 17.5*(CBR)0.64 for CBR >5%

Since the CBR value was obtained to be 7.3% the elastic modulus of the subgrade is 62.45 MPa.

The elastic modulus of base and sub-base layer is determined from the elastic modulus of underneath layer and thickness of the same layer.

$$E_i/E_{i+1} = 0.2*(h_i)^{0.64} \text{ and } (2 < E_i/E_{i+1} < 4)$$

Elastic Modulus and Poisson's Ratio forDifferent Layers of Conventional Sectionis tabulated in table II.

Table II. Elastic Modulus and Poisson's Ratio forDifferent Layers of Conventional Section

Layer	Elastic modulus (MPa)	Poisson's ratio
Asphalt layer (BC+DBM)	1384.4	0.5
Base layer	346.28	0.5
Sub-base layer	144.32	0.5
Subgrade	62.45	0.5

The stress-strain relationship can be determined either manually (theory of elastic layer system) or with the help of software's such as IITPAVE, KENPAVE etc.

The modulus of the base layer is increased due to geocell confinement. This can be determined from the following equation:

$$E_{\text{reinforced base layer}} = MIF * E_{\text{unreinforced base layer}}$$

MIF = Modulus improvement factor

The MIF value obtained from the field test (plate load test) conducted was 2.75. MIF is the increase in the modulus of the base layer.It ranges from 1.5-5.0 depending on the material of infill, subgrade and the position of the confined layer.

The increased modulus is applicable only for the reinforced zone. The confinement action is extended to 2-3cm above and below the reinforcing the layer due to interlocking of particles. Hence, the fully confined zone is extended to 25mm above the geocell and 20mm below the geocell. Therefore,Total thickness of the confined base layer = height of geocell (to be assumed) + 25mm above geocell + 20mm below geocell i.e. 180mm.

$$E_{\text{composite base}} = \{(E_{\text{reinforced base}} * H_{\text{confined base}}) + (E_{\text{unreinforced base}} * H_{\text{unconfined base}})\}/(H_{\text{confined}} + H_{\text{unconfined base}})$$

The calculated Elastic modulus of subgrade, sub-base base and asphalt layers for reinforced section are tabulated in table III.

Table III. Elastic Modulus and Poisson's Ratio forDifferent Layers of Geocell reinforced Section

Layer	Elastic modulus (MPa)	Poisson's ratio
Asphalt layer (BC+DBM)	1384.4	0.5
Geocell reinforced Base layer + unreinforced base layer	794.71	0.5
Sub-base layer	144.32	0.5
Subgrade	62.45	0.5

By trial and error method, the thickness of DBM is decreased such that at tensile strain at bottom of asphalt layer is less than the conventional section. AssumeDBM thickness reduction = 75mm. The reduced reinforced section is tabulated in table IV.

Table IV. Thickness of the various layers of the reinforced section

Layer	BC	DBM	Base	Sub-base
Thickness (mm)	50	65	250	230

The computed tensile strain at the bottom of the asphalt layer for geocell reinforced section is lesser than the conventional section's strain. Hence, the section is structurally better in Fatigue resistance.

If the strain is higher than the conventional section's strain the design has to be revised by increasing the thickness of the DBM layer by trial and error method.

The fatigue resistance (N_F) and the rutting resistance (N_R) are obtained as per the formulas given in

IRC: 37 (2012).

VII. CONCLUSION AND RESULT DISCUSSION

At the end increase in bearing capacity and decrease in the deformation of the embankments is noted in geocell reinforced flexible pavement. Also it is found that geocell with higher elastic modulus had a higher bearing capacity and stiffness.The overall thickness reduction is very less (11.19% only). But since this thickness reduction is in costly asphalt layer hence geocell technology provides significant initial construction costs saving. The construction time saving because of reduced thickness and long service life are added bonus points. Geocell when used properly in flexible pavements may yield a significant reduction in bituminous layers and thus can reduce the overall cost of pavements. The comparison of the thickness of both the pavement is tabulated in table V. It is seen from the table V that the thickness of all layers expect DBM is same in both the pavement. The thickness of DBM is reduced by 75 mm (53.57 %).

Table V. Summary of Geocell and conventional

Layer	BC	DBM	Base	Sub-base	Total Thickness (mm)
Flexible Pavement	50	140	250	230	670
Reinforced Pavement	50	65	250	230	595

REFERENCES

[1]. Bhagabanacharya (Tribhuvan University, 2007), Experimental Study on Geocell- Reinforced Flexible Pavements, pp 42-51.
[2]. ChandanBasu&Jitendra Kumar Soni,Design approach for geocell reinforced flexible pavements.
[3]. Design of Flexible pavement IRC37:2012.
[4]. Guidlines for Capacity of Urban Roads in Plain Areas IRC106:1990.
[5]. G.L.ShivakumarBabu (IISC Bangalore, 2012) and Pawan Kumar, An approach for evaluation of use of geocells in flexible pavements, pp1-4.
[6]. K.Rajagopal (IIT Madras), Geosynthetics in Flexible Pavements and Carbon Foot Print Analysis, pp 2-56.
[7]. Mathew and Rao (2013), “Introduction to Transportation Engineering”.