# Cost Economics of Geocell Reinforced Flexible Pavements on Soft Soils by using Kenpave Software

**T V Viswa Teja, Ch Vineel , D ManiKumari**

***Abstract*****: *The improvement of any nation depends on accessibility and interconnectivity to distinctive places via well connected transportation network. Road transportation is the most adaptable mode of transport under various prerequisites of topography and therefore top priority is given to enhance avenue transportation amenities all through the world by allocating large capital investments. About 40% of total land in India is blanketed by clayey soils and inevitably the roads have to pass via such sub grades. Generally, flexible pavements are favored to rigid pavements due to less preliminary cost, smooth driving surface and convenient maintenance. The design pavement thickness over clay sub grades is large due to their low soaked CBR values and so the execution cost is high. In spite of imparting large pavement thickness, common debacles noticeable in flexible pavements over clayey soils are immoderate rutting, wavy surface, longitudinal cracking alongside wheel track and shear failure in edge region. Further, expansive clays pose serious issues to construction of pavements due to their shrink-swell behaviour with moisture fluctuations and also make pavement construction steeply-priced due to their very low strength in saturated condition ensuing from swelling. Efforts are being made via researchers from time to time to enhance the strength and stability of the clay sub grades in regular and expansive soils in specific via stabilization, reinforcing, moisture manipulation and soil substitution techniques. The advent of geo synthetics has drawn the interest of motorway engineers to contemplate them for use in pavement development to enhance performance. Particularly, geo-synthetics like geogrids, geocells and geotextiles due to their multi-functional behaviour has been used in the control of reflection cracking in overlays, as separator- filter - drain at clay sub grades, as reinforcing factor in soft-soils. The current study focuses upon geocell strengthened flexible pavements over soft soils using KENPAVE software. The present study concludes to suggest Geocell strengthened sub-base flexible pavements in which a decrease of the pavement section by approximately 13%.***

***Keywords*****: Geocell, KENPAVE, Reinforcement, Geosynthetics.**

Manuscript published on 30 September 2019
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## I. INTRODUCTION

For rapid development of any country accessibility and inter connectivity is essential. Road transportation is the most adoptable method mode of transport. In India about 40% of land area is covered by clayey soil where, the roads have to pass through these weak clayey sub grade soils. As it is unavoidable to lay pavements on these soils there is a necessity for a design methodology which ensures safety of pavement against these sub grades. The construction of pavements over clay sub grades is expensive, as they require large pavement thickness due to lower CBR values in wet condition. Pavement failures are often noticeable in pavements constructed over clay soil despite building pavements with large thickness. Swelling of sub grade is seen in low traffic roads whereas heavy traffic roads are affected by excessive settlements or shear failures in the edge regions. The pavements give poor service when there is volume instability of the sub grade and they also require periodic maintenance after every rainy season. Pavement constructions are classified as flexible pavements and rigid pavements. Premature failures are common in flexible pavements over clay sub grade. Failures like large pavement thickness, instability of pavement.

Shear failure in shoulder region, undulated pavement surface, deterioration of pavement, stripping of bitumen, volume instability. We can overcome the above-mentioned failures by introducing geo synthetics. The sub grade soil can be treated with various materials to improve the strength and stiffness characteristics of the soil. Soil stabilization can be done either using mechanical methods like adding more gravel, blending and using geo textile or by adding admixtures like port land cement, lime, fly ash, bituminous etc. Or by using water proofers. Blending gravel and, more recently, recycled pavement material with poorer quality soils can also provide a working platform. The gravel acts as filler, creating a dryer condition and decreasing the influence of plasticity. However, if saturation conditions return, the gravel blend can take on the same poorer support characteristics of the sub grade. Geo textiles and geo grids reduce the extent of stress on the sub grade and prevent base aggregate from penetrating into the sub grade, thus reducing the thickness of aggregate required to stabilize the sub grade.

The common types of debacles encountered in flexible pavements are as follows.

1. Large Pavement Sections
2. Shear Failure for soils in the Shoulder region
3. Capillary rise of Water Table
4. Undulation on the Pavement surface

## II. REVIEW OF LITERATURE

Existing Sub grade Treatment Methods:

Replacement

Das (2004) expresses that the first precaution of foundation construction on swelling clays as replacement of the expansive soil with a less expansive material.

Controlled Compaction

West (1995) states that the bearing capacity of a sub grade soil can be improved by densification or compaction of the soil.

Pre-wetting

Petry and Little (2002) suggested from their study that pre-wetting had become a proven method by the end of the 1970's. McKinney, Kelly and McDowell (1974), Steinberg (1977) and Poor (1978) anticipated that pooling water on a foundation reduces the future swell initially, often controlled by moisture barrier installation.

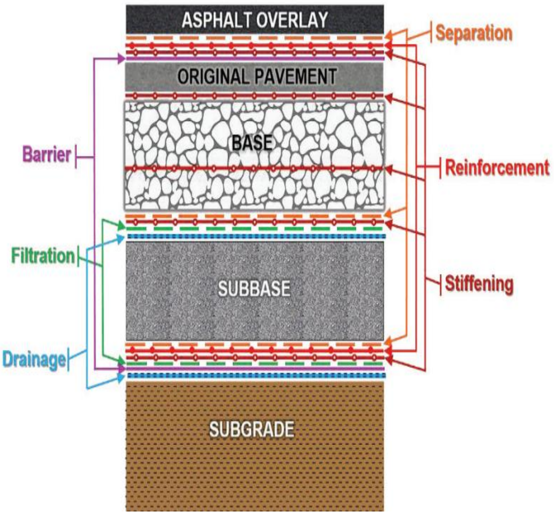
Stabilization of Sub grade

After conducting various tests Chen (1988) reported that among stabilizers including Portland cement, lime/cement mixtures and lime shows the greatest improvement to compressibility, CBR and swelling. In-situ it is extremely difficult to uniformly mix the clay and lime due to the presence natural moisture content.

Ramanujan and Jones (2007) explained that the main drawback of subgrade cement stabilization is the high stiffness and a tendency for the overlying pavement to develop cracks.

Need for Geosynthetics

Geosynthetics are synthetic products used to stabilize terrain, they are generally polymeric products used to solve civil engineering problems. These include geotextiles, geogrids, geonets, geomembranes, geocells, geocomposites etc which are multi-functional like separation, filtration, Reinforcement, Erosion Control, Drainage.




**Jorge G. Zornbe (2017) suggested the benefits of the inclusion of geosynthetics in pavements.**

- To enhance the performance of unpaved roads on soft sub grade soils.
- To reduce reflective cracking in asphalt overlays.
- To fulfill the intended functions of that Geo synthetic material.
- The attraction of this application lies in the possibility of reducing the thickness of the base course layer such that a roadway of equal service life results or in extending the service life

Cancelli et al. 1996, Collin et al. 1996, Haas et al. 1988, Miuraet al. 1990, Perkins et al. 1997a/b, and Webster 1993), research has shown that the required base course thickness for a given design may be reduced by using geogrid in pavements.

Experimental Study on Geo Cell-Reinforced Pavement Bases under Static and Cyclic Loading by Jitendra Kumar Thakur (2007) Geocells are a three-dimensional interconnected honeycomb type of geosynthetics used to reinforce weak soils and base courses of roads and are ideal for soil confinement.

## III. METHODOLOGY

Characterization of clay subgrade

| Laboratory Test | Corresponding Test Results |
|---|---|
| Specific Gravity | Expressed as ratio |
| Moisture Content | Expressed as percentage |
| Atterberg Limits | $W_L, W_P, W_S$ |
| Gradation | $C_U, C_C$ |
| CBR (Soaked) | Expressed as percentage |
| Compaction Characteristics | IS light compaction(g/cc) |
| DFS | Expressed as percentage |

IRC Design Method for flexible pavements

Utilizing the Plates given as per IRC – 37-2001; for a soaked CBR value and msa the thickness of the unreinforced flexible pavement is finalized.

Geocell reinforced base/sub-base approach

In this approach of design of reinforced flexible pavements, geocells are utilized in reinforcing the base and sub-base layer consequently to check for reduction in vertical tensile strains and compressive stresses computed with using KENPAVE software. When the geocells are placed in a particular layer to reinforce it, its modulus of elasticity is improved by a coefficient called MIF (Modulus Improvement Factor) and the subsequent top layer thickness is gradually reduced checking the vertical strains and compressive stresses to that of the conventional section of the pavement finalized using the IRC method of design of unreinforced flexible pavements.

**Fig.1. California Bearing Ratio Loading Frame**

**Fig.2. Modified CBR Mould with Subgrade & Geocell**

The analysis of pavement thickness is carried out by using **KENPAVE** software developed by Dr. Yang H, Huang, P.E., University of Kentucky.

## IV. RESULTS AND DISCUSSIONS

Characterization of clay subgrade

| S. No. | Engineering Properties | Subgrade Soil |
|---|---|---|
| 1 | Specific Gravity | 2.70 |
| 2 | Grain Size Analysis<br>a) Gravel (%)<br>b) Sand (%)<br>c) Fines (%) | <br>0<br>23.0<br>77.0 |
| 3 | Atterberg Limits<br>a) Liquid Limit (%)<br>b) Plastic Limit (%)<br>c) Shrinkage Limit (%) | <br>45.0<br>27.0<br>16.0 |
| 4 | IS Classification | CI |
| 5 | Compaction Characteristics (IS Light Compaction Test)<br>a) OMC (%)<br>b) MDD (g/cc) | <br>15.8<br>1.78 |
| 6 | CBR (Soaked) | 3.5% |

IRC Design Method for flexible pavements

Design parameters considered:

1. Soaked CBR value = 3.5 %
2. CVPD) = 300
3. Growth rate = 7.5%
4. Design Period = 20years
5. VDF = 3.5
6. LDF = 75%

Utilizing the Plates given as per IRC – 37-2001; for a soaked CBR value of 3.5 % and 13 msa the thickness of the unreinforced flexible pavement was finalized to be 760 mm and its constituent layers with their corresponding thickness are BC-40mm; DBM-90mm; BASE-250mm and SUB BASE-380mm.

Geocell reinforced base/sub-base approach

**Table.1. Analysis of Unreinforced Pavement Section**

| Unreinforced Section (mm) | Tensile (Micro Strain) | Compressive (Micro Stress) |
|---|---|---|
| BC – 40 | 269.49 | 329.31KPa |
| DBM – 90 | | |
| BASE – 250 | | |
| SUB-BASE – 380 | | |
| TOTAL – 760 | | |

**Table.2. Analysis of Sub-basal Reinforced Pavement**

| Sub-Base Reinforced Section (mm) | Tensile (Micro Strain) | Compressive (Micro Stress) |
|---|---|---|
| BC – 40 | 207.16 | 593.62KPa |
| DBM – 90 | | |
| BASE – 150 | | |
| SUB-BASE – 380 | | |
| TOTAL - 660 | | |

**Table.3. Analysis of Basal Reinforcement Pavement**

| Base Reinforced Section (mm) | Tensile (Micro Strain) | Compressive (Micro Stress) |
|---|---|---|
| BC – 40 | 222.43 | 490KPa |
| DBM – 60 | | |
| BASE – 250 | | |
| SUB-BASE – 380 | | |
| TOTAL - 730 | | |

Thus, geocell as a reinforcing and modulus improving element is more effective when placed in the sub-base layer then that in the base layer. But, ultimately significant decrease in the pavement thickness can be observed with the utilization of geocells as reinforcing and modulus improving element.

Cost Economics

The cost estimation of the flexible pavement under study is carried out calculating the quantities of required items of work and rates adopted from the Government of Andhra Pradesh SoR 2013 – 2014, also the rate of the geocell utilized under the present study is adopted from respective manufacturer TenCate Geosynthetics. The abstract estimates are presented below.

**Table.4. Rate analysis for Unreinforced Section**

| S. No | Item of Work | Total Amount (Rs) |
|---|---|---|
| 1 | Earth Work | 8,31,675/- |
| 2 | Base &Sub Base | 71,442/- |
| 3 | DBM | 51,63,750/- |
| 4 | Bituminous Surface Course | 1,29,000/- |
| **Total** | | **61,95,867/-** |

**Table.5. Rate analysis of Sub-basal Geocell reinforced pavement**

| S. No | Item of Work | Total Amount (Rs) |
|---|---|---|
| 1 | Earth Work | 7,22,244/- |
| 2 | Base &Sub Base | 60,102/- |
| 3 | DBM | 51,63,750/- |
| 4 | Bituminous Surface Course | 5,160/- |
| 5 | Geo cell | 29,08,500/- |
| **Total** | | **88,83,596/-** |

**Table.6. Rate analysis of Basal Geocell reinforced pavement**

| S. No | Item of Work | Total Amount (Rs) |
|---|---|---|
| 1 | Earth Work | 7,98,846/- |
| 2 | Base &Sub Base | 71,442/- |
| 3 | DBM | 34,42,500/- |
| 4 | Bituminous Surface Course | 5,160/- |
| 5 | Geo cell | 29,08,500/- |
| **Total** | | **72,26,448/-** |

## V. CONCLUSION

1. The subgrade characteristics under the study is classified as intermediate compressibility soil with low soaked CBR value (3.5%).
2. The clay subgrade (CI) under study requires reinforced flexible pavements to reduce the high design thickness of the pavement and to ensure safety against shear failure and settlement failure.
3. Geocell reinforced sub-base flexible pavement has resulted in decrease of the pavement section by approximately 13% and that of base reinforcement is approximately by 4%.
4. Among the methods, the geocell reinforced sub-base is to be preferred because it serves as a base stiffener and spreading the load over a large area and results in an increased pavement performance and life.

## REFERENCES


1. Das, BM 2004, Principles of Foundation Engineering, 5th edn, Thomson, Brooks/Cole 97
2. Cancelli A, Rimoldi P, Togni A (1992). Frictional characteristics ofgeogrids by means of direct shear and pull-out tests, Proc. of ISKyushu 92 Int. Symposium on Earth Reinforcement Practice,Fukuoka, Japan, pp. 51-56
3. Chen, F.H (1988), "Foundations on Expansive Soils", Elsevier Publishing Co., Amsterdam.
4. Petry, T.M., and Little, D.N. (2002). "Review of stabilization of clays and expansive soils in pavements and lightly loaded structures- History, Practice and Future", Journal of Materials in Civil Engineering, 14(6), 447-460.
5. Ramanujam, J & Jones, J 2007, `Characterization of Foamed-bitumen Stabilisation', International Journal of Pavement Engineering, Vol. 8, No. 2, pp.111-122
6. West, T R 1995, Geology Applied to Engineering, Prentice Hall. Workplace Health and Safety Queensland 2007, Risk Management Code of Practice 2007, Supplement 1 -Hazard Identification
7. Collin, J. G., Kinney, T. C., and Fu, X. ~1996!. ''Full scale highway load test of flexible pavement systems with geogrid reinforced base courses.'' Geosynthet. Int., 3~4!, 537–549.
8. Transportation Geotechnics and Genecology, TGG 2017, 17-19 May 2017, Saint Petersburg, Russia. Functions and applications of geosynthetics in roadways by Jorge Kornberg.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