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Analysis of Geocell Reinforcement of Base Course in Flexible Pavement – Case Study

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***Abstract*: Roads are one of the main media for transportation of goods as well as people. India has a huge network of over 6.4 million km comprising of national and state highways and urban and rural roads. National highways carry over 40% of total traffic but account for only 2% of total road network, while remaining road network consist of state highways and rural and urban roads. National highways are important for development of country, but rural roads are also very important for connecting the villages to the main road networks. Hence for this cause Indian government launched Pradhan Mantri Gram Sadak Yojana in 2000. The main objective of this scheme is to provide connectivity to unconnected habitations as part of poverty reduction strategy. Currently stage three of this scheme known as PMGSY-III is undergoing in India. Under the PMGSY-III it is proposed to consolidate 125000 km road length in states between 2019-20 to 2024-25. To maintain the connectivity uninterrupted, good quality of roads are to be constructed. Stability of the road pavement mainly depend on the sub-base of pavement. Hence to increase the stability of pavement subbase has to be stabilized by various methods like Lime stabilization, Cement stabilization, Stabilization using polymeric materials. In this report Geocell is used as such polymeric material. By using geocell CBR of soil can be increased to sufficient value resulting in reduced pavement thickness. As pavement thickness decreases cost also decreases resulting in more economic design. Geocell also helps in improving the drainage capacity of soil. Under the PMGSY-III the road Khandbara to Kholghar in Navapur Taluka, Nandurbar District, Maharashtra is selected for use of Geocell in subbase for soil stabilization.**

***Keywords*: California Bearing Ratio, Flexible Pavement, Geocell Reinforcement, PMGSY.**

1. Introduction

India is among the fastest developing countries. India's human population of 1.2 billion covered about 17% of the earth's total population. As it is indicated that India covered almost 17% of the world's population, its requirement for transportation of goods and people is very large. There are four main modes of transportation by Road, by Airways, by Waterways and by Railways. As airways and waterways are not significant compared to the population in India main weightage of transportation falls on roadways and railways. But there are also limitations in case of railways as they cannot connect the extremely rural areas, hilly areas, etc. hence roadways are the most commonly used means of transport used by common people.

According to Ministry of Road Transport and Highways, as of March 2020, India had about 138,531 kilometer of national highways and expressways, plus another 176,818 kilometer of state highways. District Roads in India are approximately 632,154 kilometer. Rural roads form a substantial portion of the country's road network, forming 72.97% of the total of roads, as of March 2020.India has all-weather roads and mud roads which are inaccessible during the rainy season. The plains have a dense network of roads whereas hilly areas are having less dense networks. We have a large network of National Highways in India but most of the village roads in India are still not all-weather roads.

To develop the rural roads in India, Government of India started Pradhan Mantri Gram Sadak Yojana (PMGSY) in the year 2000 by then prime minister Atal Bihari Vajpayee.

The primary objective of the PMGSY is to provide connectivity, by way of an All-weather Road (with necessary culverts and cross-drainage structures, which is operable throughout the year), to the eligible unconnected Habitations in the rural areas with a population of 500 persons and above in Plain areas. In respect of the Hill States (North-East, Sikkim, Himachal Pradesh, Jammu & Kashmir and Uttarakhand), the Desert Areas (as identified in the Desert Development Program), the Tribal (Schedule V) areas and Selected Tribal and Backward Districts the objective would be to connect eligible unconnected Habitations with a population of 250 persons and above. Currently phase three of the said scheme is under works known as PMGSY-III. On the same concept Maharashtra Government started a similar scheme named Mukhya Mantri Gram Sadak Yojana (MMGSY) in 2015 to develop the remaining rural roads in state.

Most of the rural roads have alignment through black cotton soil, hilly areas or having heavy rainfall. The subbase of the pavement is an important factor for sustainability of pavement. Geocells are widely used in construction for erosion control, soil stabilization on flat ground and steep slopes, channel protection, and structural reinforcement for load support and earth retention. Geocell products are three-dimensional, expandable panels made from high-density polyethylene (HDPE), polyester or another polymer material. Geocell-reinforcement in ground improvement is being used very extensively in present days. It is a three-dimensional

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honeycombed confinement system, made of geosynthetics, which significantly improves the bearing capacity of soft soils, specially, in foundations, and pavements applications.

In this paper the effect of geocell reinforcement on subbase of flexible pavement is analysed by conducting CBR test on reinforced and unreinforced soil samples.

2. Literature Review

The main issue related to wear and tear on road is due to lack of suitable subbase of soil. In hilly areas and areas with black cotton soil due to soil erosion flexible pavement is damaged. By using geocell polymer as reinforcement in subbase the life of pavement can be increased.

Over the years various researchers have done performed the experiments on the behaviour of geocell reinforced soils. Mandal et al (1993) researched the stability of geocell reinforced soil which resulted that the smaller the opening size smaller the settlement of structure. In case of reinforced soil sample at initial stage, settlement increases linearly with load and, after a certain point slope of the curve, decreases gradually. Again, beyond a certain point it becomes a straight line. Mamatha et al (2017), did Performance evaluation of geocell-reinforced pavements, A series of repetitive load tests were performed on unreinforced and geocell-reinforced model pavement sections with varying sub-base thickness and aspect ratio. In both unreinforced and geocell-reinforced pavement sections, plastic settlement accounts for 85–90% of the total settlement and elastic settlement is only10–15% of the total settlement. Sharma et al (2016) identified the benefits of geocell using finite element analysis. This study resulted that reinforcing the base layer with geocell reduces the permanent deformation and stresses in the pavement. The benefit of using geocell reinforced base layer was not evident when a good base quality material was used. Tanyu et al (2013) researched about Laboratory evaluation of geocell-reinforced gravel subbase over poor subgrades. In that they performed. Large-scale experiments with cyclic loading were conducted to determine how incorporation of high-density polyethylene (HDPE) geocells affects the rutting properties of working platforms and resilient properties of a subbase in a pavement structure over soft subgrade. The current study showed that the presence of geocells improved the resilient modulus by 40–50% in both 225 mm and 450 mm thick sections, with the exception of 225 mm thick test with GW (20)150. In that test, the improvement was 30%. Hastuty et al (2017) performed California Bearing Ratio (CBR) test on stabilization of clay with lime addition. The conclusions derived from the experiments were such as Laboratory CBR value test done gives the highest value for soil is at 6.29. From the research done the highest CBR value is at 10% K variation, which gives CBR value 8.75. S.K. Pokharel et al (2009) done Experimental study on bearing capacity of geocell-reinforced bases in this study, laboratory tests were conducted to investigate the behaviour of geocell-reinforced bases under static and repeated loading This study also evaluated the permanent deformation and the percentage of elastic deformation of geocell-reinforced Kansas River sand and quarry waste compared with unreinforced bases. The test results show that the single geocell reinforcement can increase the bearing capacity, stiffness, and percent of elastic deformation for each cycle and reduce the permanent deformation. Wang et al (2008) done tests to conclude that the behaviours of stress-strain on both unreinforced soil and reinforced soil by large-scale direct shear tests are nonlinear. When the normal stress comes up to 1.0 GPa, there is a quasi-elastic characteristic on the behaviour of shear stress and displacement for the geocell reinforced cement stabilizing soil. The shear stiffness increases with increasing normal stress for all tests. With the reinforcement of geocell, the cohesive strength of silty gravel soil considerably increases and it increases much more highly for the cement stabilizing soil. Rajgopal et al, (2012) reported the effect of geocell reinforcements where they found out that use of geocell layer in the flexible pavements increases the structural stiffness of the pavement system. It also reduced the thickness of granular layers by as much as 50%. The total cost of the pavement system per unit area was lowered even with the use of expensive geocell layer. The increase in stiffness improves the performance of the pavement and increases the service life of the pavement. Reddy et al (2020) studied Cost Economics of Geocell Reinforced Flexible Pavements on Intermediate Compressible Clayey Subgrades in 2020, study focuses upon geocell confinement of subbase and base layers of flexible pavements. Geocell reinforced base flexible pavement section has resulted in reduction of pavement construction cost by about 7.75% for 25msa and 12.5% for 50msa traffic and reduction in design pavement thickness by about 10% for 25msa and 12% for 50msa traffic. Kolathayar et al (2020), done Comparative Study for Performance of Soil Bed Reinforced with Jute and Sisal Geocells as Alternatives to HDPE Geocells. The soil bed reinforced with jute cell and sisal cell showed a uniform increase in the settlement with increase in the applied pressure. The soil reinforced with HDPE geocell, however, showed a sudden rise in the settlement at higher pressure. Sisal mat used for developing the geocell was found to have greater tensile strength, followed by jute mat over HDPE material. Soil reinforced with sisal cells could bear larger stresses at lower strain compared to HDPE geocell.

G. Sridevi et al (2018), evaluated Strengthening of Weak Subgrade Using Geocell. Study focuses on the behaviour of flexible pavement reinforced with and without Geocell which resulted into Considerable reduction in pavement thickness is observed in Geocell reinforced pavement. Apart from saving the cost of construction, it also reduces the resource consumption.

3. Case Study

National highways are important for development of country, but rural roads are also very important for connecting the villages to the main road networks. Hence for this cause Indian government launched Pradhan Mantri Gram Sadak Yojana in 2000. The main objective of this scheme is to provide connectivity to unconnected habitations as part of poverty reduction strategy. Currently stage three of this scheme known as PMGSY-III is undergoing in India. Under the PMGSY-III it

is proposed to consolidate 125000 km road length in states between 2019-20 to 2024-25. Under the PMGSY-III the road Khandbara to Kholghar in Navapur Taluka, Nandurbar District, Maharashtra is selected for use of Geocell in subbase for soil stabilization. As the location of proposed road passes through agricultural land the sub base available for road is mostly black cotton soil. The CBR of said soil is between 3 to 4. Also because of black cotton soil small rainfall can make this road inaccessible.

Present condition of the road is as shown in pictures below.

Fig. 1. Present condition of road

4. Test Performed on Soil Sample

The soil sample was collected from site and the engineering properties of soil sample was as below:

Table 1
Sieve analysis of soil sample

Clay / Silt (-75 micron) (%)	66.73%
Sand (-4.75mm, +75 micron) (%)	21.08%
Gravel (-40 mm, +4.75 mm) (%)	12.19%

Table 2
Engineering properties of soil sample

Maximum Dry Density (MDD)	1.591 gm/cc
Optimum Moisture Content (OMC)	16.50%
Liquid Limit	31.20%
Plastic Limit	24.00%
Plasticity Index	7.20%

The CBR test was conducted for the unreinforced soil and modified subgrade having geocell reinforcement. The CBR value of unreinforced soil was 3.80%, but when Geocell is used, the CBR of soil increases to 8.71%.

5. Results

As per IRC SP 72: 2015, the standard provision is selected according to CBR of soil and traffic intensity. For present condition the CBR of soil is between 3 to 4. Traffic intensity at given road is T-6. Hence, the ideal section for this type of road have total thickness of 475 mm. the standard cross section for this thickness is shown in fig. 3. By using Geocell as subbase the CBR of soil will increase significantly. For the modified CBR of 7 to 9 and same traffic intensity T-6 the required cross section of road will have thickness of 325 mm as shown in fig. 4.

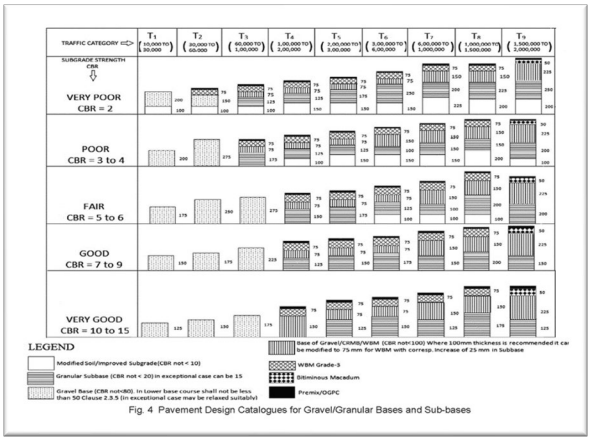

Fig. 2. IRC SP-72 pavement design catalogues

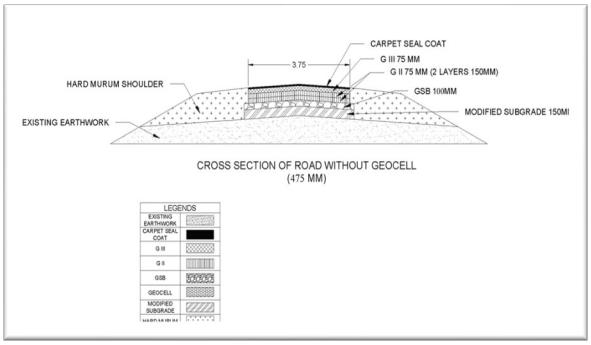

Fig. 3. Cross Section of road without Geocell

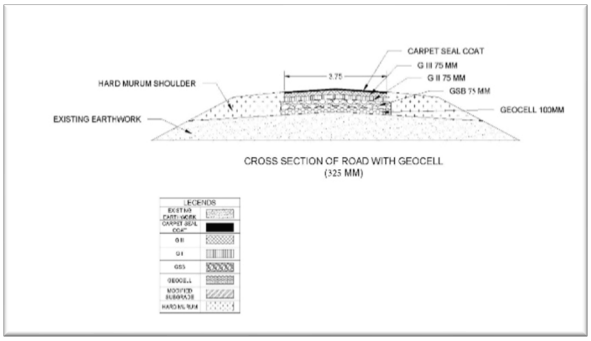

Fig. 4. Cross Section of road with Geocell

6. Conclusion

The objective of this study was to identify the effect of geocell reinforcement on soil stabilization which was used in subbase of flexible pavement. Tests were conducted to find out the change in CBR of unreinforced and reinforced soil. Results points towards following conclusions.

1. The CBR of soil has been increased by significantly larger margin while using Geocell in the subbase of road pavement.
2. The cost of Geocell reinforced pavement is lower than the cost of unreinforced pavement as thickness of the pavement is reduced by a larger margin.
3. Hence it can be stated that, the use of geocell in road pavement is advantageous to reduce the cost of project and also it can increase the life of road pavement.

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