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ADJUSTMENT OF SUB GRADE USING GEOSYNTHETICS

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Many of the pavement structures fail well before their design life owing to the poor quality of construction materials, inadequate compaction, inadequate preparation of the subgrade, overloading, etc. Two options are available to improve the longevity of the pavement. The first option is by increasing the thickness of different pavement layers and the other option is by increasing the rigidity of the layers within the system so as to reduce the stresses transferred to the lower layers. Of these two methods it has been widely observed that increasing the strength and rigidity of the pavement layers is a more efficient method to lower the stresses on the pavement layers thereby increasing the life of the pavement. Geogrid reinforcement is gaining acceptance as an effective way of improving on the properties of naturally occurring soils for road pavement construction. In many tropical countries, weak lateritic subgrades are common and often rejected after proof rolling during construction due to poor strength. A natural lateritic subgrade soil was selected and tested without reinforcement. Then by placing a layer of a tri-axial geogrid above the third layer within the sample height, the effects of geogrid reinforcement on California Bearing Ratio values are investigated. This was undertaken for two strengths of geogrid in both soaked and unsoaked conditions. The California Bearing Ratios of the soil–geogrid subgrade was used to determine the pavement layer thicknesses for a low volume paved road using the Transport Research Laboratory Road Note 31 method of pavement design. The results indicate that base course layer thickness reduction as a result of geogrid reinforcement for a subgrade decreases with increasing traffic class. A minimum of 15% base course layer thickness reduction was observed for a surface dressed road with natural gravel base course.

Introduction

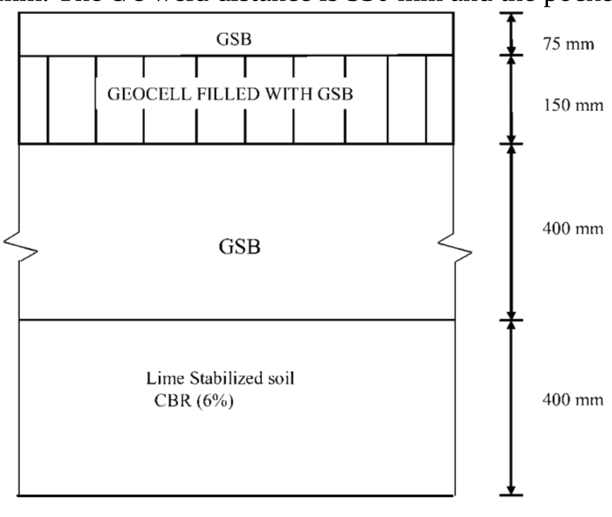
The performance of highway pavements is governed by the strength and stiffness of the pavement layers. The cost
and duration of construction are dependent on the availability of aggregate materials for construction. Scarcity of natural resources often delays the projects or escalates the costs due to large lead distances from the borrow areas. Hence, it is essential to look at alternatives to achieve improved quality of pavements using new materials and reduced usage of natural materials, Giroud and Han (2004). This paper reports on the studies of the performance of geosynthetic-reinforced flexible pavements. Different types of geosynthetics like planar(geogrids and geotextiles) and three dimensional (geocells)
can be employed for strengthening the pavement bases. The geocells are three-dimensional honeycomb geosynthetic products that provide all round confinement to the soils. The geocell-confined soil acts like a semi-rigid mat in distributing the surface loads over a wide area of the foundation soil. The performance of the geocells as surface confinement layers and as reinforcement layers has been reported by several researchers in the past. Low volume paved and unpaved roads usually serve as access roads to rural areas, towns and districts. They play a very important role in rural economy, resource industries (forest, mining) and transportation to agricultural production areas. When low volume roads are built on poor subgrade soils, large deformations can occur, which increase maintenance cost and lead to interruption of traffic service. Leng (2002) states that in general, deterioration of unpaved and paved roads is faster than road replacement. The increasing material and construction costs, make it important to explore alternative construction methods with longer service life but at the same time cost efficient. Geosynthetics have been found to be a cost effective alternative to improve poor sub-soils in adverse locations, especially in situations where there may be non-uniform quality and/or non-availability of desired soils with applications in almost all geotechnical engineering projects such as airport and highway pavements.

The purpose of this research was to determine the effect of tri-axial geogrids on road pavements. The specific objectives of the research were to 1) Determine the effect of strength of geogrid reinforcement material on the California Bearing Ratio (CBR) of a sample of relatively poor lateritic sub grade material under soaked and unsoaked conditions. 2) Establish the effect of geogrid reinforcement on the design thickness of low volume paved roads in the tropics.

Field studies on geosynthetic flexible pavements

Geocell-reinforced pavements

The internal access roads at Govind Dairy Factory in Phaltan, Maharashtra required frequent repairs. The foundation soil is typically black cotton soil, which undergoes severe swelling and shrinking. The properties of this soil are given in Table 1. The roads are typical unpaved roads with thick layers of water-bound Macadam (WBM) and granular subbase (GSB) materials. Nearly 200 m long stretch of this road was treated with 150 mm thick geocell layer on an experimental basis to study the performance improvement. Based on the soil properties and the traffic data, the following designed section of pavement as shown in Fig. 1 was used for reconstructing the road using geocell reinforcement. The geocell pockets were filled with GSB materials. Water-bound Macadam layers were not used within this stretch of road where geocell was used as a reinforcement layer. The bottom most layer was treated with 4% lime (hydrated lime) in order to stabilize the expansive foundation soil. Addition of 3% lime itself was found to reduce the plasticity index substantially. Hence, slightly higher percentage of 4% lime addition was recommended in order to account for any losses during installation and service life. The geocell is 150 mm high and made of a polymeric alloy. The thickness of the geocell walls is approximately 1?2 mm. The c/c weld distance is 330 mm and the pocket



Cross-section of the pavement section at Govind Dairy Factory

Opening dimensions are approximately 2106250 mm. The tensile strength of the geocell material in strip tension test was found to be 0?25 kN (ASTM D638-2003) and the peel strength of the weld is 0?2 kN from ASTM D6392-99 standard tensile strength tests. There was no change of dimensions when pieces of the geocell were exposed to 100uC temperature in an oven for 1 h duration (ASTM D1204).The construction at the site proceeded by excavating the soil to the required depth. The hydrated lime was spread on the soil and mixed by a tractor with a plow attachment. The lime was mixed in proportion of 4% by weight. This percentage was decided based on prior experience with similar soils in India. The addition of 3% lime was found to drastically reduce the plasticity index values by as much as 50%. Hence, 4% lime mixing was recommended to account for some loss during and after the construction. After the compaction of the lime-treated soil and the granular subbase layers were completed, the geocell layer was spread on the road section and held in place by use of stakes driven into ground at 485 mm c/c spacing. The geocell pockets were filled with GSB material by a tipper truck and spread using a dozer. Care was taken to make sure that the vehicles do not pass directly on unfilled geocell section. After the geocell pockets were filled with GSB material and 75 mm cover material was placed, the entire section was compacted using normal 10-ton vibro roller passes. The photographs in Figs. 2–5 illustrate the construction procedure adopted at the site.

In order to differentiate the strength of the pavement sections, plate load tests were performed at the site as per IS 1888–1988 in the geocell-treated area and the unrein-forced areas. Two tests were performed in geocell-reinforced area (R-1 and R-2) and two tests were performed in unreinforced pavement area (UR-1 and UR-2). One test was performed at subgrade level for comparative purposes. All the tests were performed at surface level after scraping the top 50 mm of pavement material. The observed pressure–settlement responses are shown in Fig. 8. The pressure–settlement responses of both the tests performed in geocell-treated pavement were very close to each other. The responses from the unreinforced areas are also very similar. The unreinforced pavement area was repaired several times by dumping large size stones, which are in excess of 200–300 mm in size. The test plate may have been located inadvertently over a large size stone in UR-2, which gave a stiffer response than the tests performed in geocell-treated area.

Geogrid-reinforced pavements

Two sections of a highway under construction near Chennai were reinforced with two different types of geogrids (flexible and stiff). Both geogrids are biaxial type having tensile strengths in the same range. The flexible geogrid was a knitted polyester geogrid having tensile strength of 100 kN m^{21} at a strain of 10%. The stiff geogrid was an extruded and welded polyester geogrid, which is much heavier and stiffer. The stiff geogrid had a tensile strength of nearly 130 kN m^{21} at a strain of 6%. The geogrid layers were placed within the subbase layer of the pavement at a depth of 200 mm below the surface. These two trial stretches were constructed next to each other so that the subgrade soil is similar. The subgrade soil at this site has a soaked CBR value of 8%. The pressure– settlement data of test performed at subgrade level is also shown for comparison. Two tests were performed on top of 200 mm thick granular subbase material without any geogrid reinforcement and one plate load test was performed within each of the two different types of geogrids. The observed pressure–settlement data is shown in Fig. 9. It could be seen that the response with the geogrid layers is stronger compared to the unreinforced sections. The observed pressures with stiffer geogrid are higher than those with flexible geogrid owing to the higher modulus of the stiff geogrid.

Laboratory tests

Moisture-density of raw and treated/stabilized soils

Standard Proctor tests of the raw soil as well as mixture of soil and stabilizers were performed in accordance with ASTM D 698 standard procedure to evaluate the maximum dry density and the optimum moisture content associated with that density. The compaction energy of 12.4 ft.lb/ft^3 was applied by dropping 5.5 lb hammer from a height of 12 inch in three different layers with 25 number of blows/layer. The automatic compactor (Figure 3.2) was used to compact the raw soils as well as treated soils. The lime-treated soils were compacted in proctor after few hours of mixing to allow the mellowing period, whereas cement-treated soil specimens were compacted immediately after mixing.

Unconfined compressive strength (UCS) tests in the laboratory

Unconfined compressive strength tests (UCS) were performed on the raw soils at different moisture contents to draw the soil strength versus moisture content to evaluate the threshold moisture content at which soil treatment is required. The UCS tests were also conducted on treated/stabilized soils to evaluate the suitability of the particular stabilizer for particular soil and the recipe (% of stabilizer) needed to achieve the target strength values of 50 psi and 150 psi. Three moisture contents were selected for each soil type that gave a raw soil the UCS of 25 psi or less to simulate the field condition during construction of working platform for heavy equipment and/or for preparation of subgrade in pavement. The soils were mixed with various stabilizers (described earlier) dosages and compacted at three moisture contents selected based on the result of raw soil strength. The UCS tests of treated/stabilized soils were then performed at different dosage of stabilizers to evaluate the stabilizer dosage required to achieve the minimum UCS of 50 psi and 150 psi for working platform and subbase, respectively.

The untreated soil samples were tested immediately after compaction, whereas the treated/stabilized soil samples were cured in humid room for 7 days prior to testing. All the samples were molded in a mold having 5.6 inch in height and 2.8 inch in diameter. The molded samples were placed in airtight plastic wrapper, and kept in a 100% humid room in accordance with ASTM standard procedure. ASTM D 2166-06, ASTM D 5102-09, and ASTM D 1632 were followed to compact and test the raw, lime, and cement treated/stabilized soils, respectively. After 7 days of curing period, the soil samples were removed from the plastic wrapper. Cement treated/stabilized samples were submerged in the water bath for approximately 3 to 4 hour (ASTM D 1633-00) prior to testing; whereas lime treated/stabilized soils were kept above porous stone for capillarity suction for about 8 to 10 hours prior to testing based on literature review. All the samples for UCS tests were compacted in five layers with 9 number of blows/layer to achieve approximately uniform energy that is equivalent to Standard Proctor test (12.4 ft.lb/ft^3). The selected number of layers is consistent with the AASHTO T-307 for resilient modulus testing of cohesive soils. The number of blows per layer was determined by equating the compacting energy from 3 layers and 25 number of blows/layer of Standard Proctor test with the energy produced by five layers of soils in 2.8 inch diameter and 5.6 inch high mold while keeping the hammer weight as well as drop height constant. The following energy equation is used to calculate the required number of blow per layer.

Repeated load Triaxial (RLT) tests

The laboratory molded specimens were loaded through series of triaxial tests in material testing system (MTS 810) machine to characterize the materials at different moisture contents and different additive contents selected as per soil type as described in section 3.5. A load cell of 5000 lbf was used to measure the magnitude of the applied load and two linearly variable differential transducers (LVDTs) were used inside the chamber to measure the deformation of the specimens during loading condition. The air was used as a confining continuum inside the chamber to confine the samples that were covered with membrane to protect probable damage from the confining pressure and clamped on the

base plate. All the tests were performed in
Drained condition by opening all the drainage valves. After setup the sample inside the chamber, the conditioning of sample was achieved by applying 1000 load cycles for the resilient modulus as well as for the permanent deformation tests. The conditioning of the specimens is essential as it is supposed to remove unevenness during preparation of the samples at both ends

Back calculation of elastic modulus of the system

- Elastic finite element analyses were performed to estimate the equivalent elastic modulus of the unreinforced and reinforced pavement systems.
- The finite element analyses were performed by using axi-symmetric model and 15-node triangular elements. The rough, rigid footing was simulated by applying uniform settlements at the nodes corresponding to the footing and restraining their lateral deformations.
- The equivalent elastic modulus was determined by trial and error by matching the finite element calculated footing pressure at 1?5 mm settlement (equal to 1% of plate diameter) with the measured pressures in the laboratory tests.
- It is assumed that the response of the system at a small settlement equal to 1% of the footing diameter is within the elastic limit.
- The elastic modulus value of the continuum was varied until the estimated pressure matches with the experimentally measured values. The results of the monotonic plate load tests were used for these analyses..
- The modulus improvement factor for the reinforced cases is calculated as the ratio between the modulus of the reinforced system and the corresponding modulus of the unreinforced cases. These values are reported in Table 12. It is interesting to note that these improvement factors fall within the same range as those estimated using the cyclic load test results. Hence, it may be possible to utilize the results from static load tests for preliminary design purposes without incurring too much of an error. However, the designs will not be conservative as the modulus improvement factors from static load tests are about 15% higher than those from cyclic load tests.
- The modulus improvement factors are required in mechanistic-based design of flexible pavements in which the modulus values of each pavement layers are to be given as input values, e.g. CIRCLY program for design of pavements.
- These modulus improvement factors can be used to represent the equivalent behavior of the geosyn-thetic-reinforced pavement sections.
- The use of higher modulus for the pavement layers results in lesser thickness for the layers as the pressure transmitted to the subgrade reduces with increase in the modulus values.
- By using different modulus improvement factors in the CIRCLY program, Iniyan (2012) has studied the influence of geocell and geogrid layers on the thickness of the pavement layers. Reduced thickness of the pavement layers results in lesser total cost of the pavement and lesser construction times.
- This will also lead to lesser carbon footprint as reduced quantities of natural aggregate materials are required for construction.

Discussion on field test results

It is interesting to note the following points from the field test results (Figs. 8 and 9):

1. The improvement of the response with geogrid reinforcement layers is practically nil at low settle-ment levels.

2. The marginal improvement with geogrid layers is seen only at large settlement levels.

3. The improvement with geocell reinforcement is substantial even at low settlements.

4. The improvement at large settlements is substantial with geocell reinforcement

Conclusion

- This paper has presented some results from field and laboratory tests on the performance of pavements with different types of geosynthetic reinforcements.
- It is seen that both the strength and stiffness of the pavement system can be improved by the use of geosynthetics.
- The performance under repeated loads is also better with geosynthetic reinforcement layers.
- The improvement in the overall performance is by distributing the applied loads over a much wider area of the subgrade thus reducing the stresses at the subgrade level. The geocell reinforcement gives much higherimprovement in the pavement performance as compared to the planar type products like geotextiles and geogrids.

- The modulus improvement factors obtained from both monotonically applied tests and the cyclic load tests are close to each other. Significant improvement is observed for all types of geosynthetic reinforcement systems. The modulus improvement factor is seen to be higher for monotonic loading as compared to the cyclic load tests. This could be due to the loose packing of the GSB layer in laboratory tests leading to continuous compressions within the GSB layer under cyclic loading.

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