Three Dimensional Geocell Structure: Performance under Repetitive Loads

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ABSTRACT: The performance of the geocell structure underlain by a soft clay subgrade subjected to repetitive loading has been investigated vis-a-vis planar horizontal inclusion and unreinforced cases. Details of the experimental work and results are discussed. The results of these tests indicate that the geocell structure performs distinctly better compared to the planar horizontal inclusions. Equations have been suggested for settlements for a given number of load applications.

1 INTRODUCTION

Geotextiles have been used extensively in reinforcement applications. It helps in improving the performance of the structure by two mechanisms. At low rut depths (settlements) the load transfer depends upon the geotextile modulus and frictional properties (tensioned membrane (Houlsby et al., 1989) while at high rut depths the transfer takes place due to the modulus of the geotextile (catenary action, tensile member). For structures where allowable rut depths are low (eg. paved roads) a three dimensional geocell structure emerges as an attractive alternative.

The efficacy of the geocell structure against static, monotonic loading conditions vis-a-vis horizontal inclusions has been already investigated by Mhaiskar (1993) and Mhaiskar and Mandal (1992). Limited investigations have been carried out to study the performance of the geocell structure to repetitive loading. Kazerani and Jamnejad (1987) have studied the efficacy of the geocell structure underlain by a granular base subjected to repetitive loading. The present investigations were, therefore, aimed at studying the performance of the geocell structure underlain by a soft clay subgrade subjected to repetitive loading.

2 EXPERIMENTAL INVESTIGATIONS

The experimental investigations were planned to investigate the performance of the three dimensional geocell structure underlain by a soft clay subgrade vis-a-vis horizontal inclusions when subjected to repetitive loading.

2.1 Soil

The geocell was backfilled by Mumbra sand. The sand had a maximum and minimum dry densities of 18.1 kN/cu.m. and 16.05 kN/cu.m. respectively, a uniformity coefficient of 4.6 and a coefficient of curvature of 0.8.

The soft clay subgrade consisted of marine clay having a Liquid Limit of 73.0% and a Plastic Limit of 62.0% with a clay content of 62.0%. It had a Modified Proctor density of 13.15 kN/cu. m. and an Optimum moisture content of 31%.

2.2 Geotextiles

The geocell was made up of woven HDPE geotextile. This geotextile was also used as a planar inclusion and a mass per unit area of 180 gm,/sq.m., thickness of 0.28 mm., wide width tensile strength of 8.7 kN/m. The geotextile was coated with bitumen to protect from UV ray deterioration.

The geocell was formed by stitching two strips of woven geotextile with nylon threads. The stitches were in three columns. Such a method of stitching yielded a seam strength of 16 kg. for a height of 10 cm. The geometry of the woven geocell used in this test was optimised in earlier experiments. (Mhaiskar, 1993) The optimum b/B (cell width to loaded area width) was found to be 0.625 while the optimum B/a (loaded area width to cell width) was found within a range of 2.5 - 3.5 (average 3.0) However, in the present investigations the B/a was 1.60 and the b/B ratio and the b/B ratio used was 0.8. The plate used in the plate load test had dimensions of 25 cm. by 35 cm. These dimensions represent the contact area of a 80 kN wheel load with a tyre pressure of 6.2 kg./sq.cm.

2.3 Soil Compaction

The dimensions of the tank used in the experiments were 110 cm. by 105 cm. by 75 cm. (depth). Air dried pulversied marine clay was used to form the soft clay subgrade. The marine clay was compacted in eight layers each layer having a thickness of 6 cm. to make up a thickness of 48 cm. The quantity of wet soil required to form a layer was calculated on the basis of a dry density of 1.315 gm./cc. and a moisture content of 40.0%. For compacting the soil in the rectangular tank a base plate of 15 cm. was used. A modified proctor hammer was used to impart six blows on the base plate. Once compacted the subgrade was saturated by flooding with water for seven days. Such a method of compaction and saturation yielded an average undrained cohesion value of 14.5 kPa and an average degree of saturation of 93.0%.

Sand was used as backfill/overlay in the geocells and over the woven planar horizontal inclusions and it was underlain by clay. It was compacted to achieve a relative density of 85.0%. The compaction was done by rodding the sand with a rod having weight of 500 gm. The effort (roddings) required to achieve a relative density of 85% was determined with the help of initial experiments.

2.4 Test setup and procedure

The hydraulic jack used in the static load test was replaced by a pneumatic cylinder which had a ram movement of 75 mm. and a maximum force of 9 kN at a pressure of 520 kN/sq.m. The ram movement, the period and the applied force was controlled by a specially designed set up consisting of a pressure regulator, solenoid valves etc. (Fig. 1) A 4.0 kN load was applied at a rate of 5 applications per minute to simulate traffic conditions. Settlement after every 100 cycles of load applications was observed. The total number of cycles applied was 10,000 in each case. In all the three tests (geocell reinforced, horizontal inclusion and unreinforced cases) a uniform thickness of 20 cm. sand was maintained. The plate (25 cm. by 35 cm.) was directly placed on this sand overlay.

3. RESULTS AND DISCUSSIONS

A plot of number of cycles versus cumulative settlement is shown in Fig. 2. Regression analysis was used to obtain the best fitting curves. A high coefficient of corelation of 0.99 was obtained. The equations of these three curves as obtained from the regression analysis are

a) woven geocell reinforced sand

$$y = 2.376 * \ln(x) + 0.5065 \quad .. (1)$$

b) woven horizontal inclusion at interface

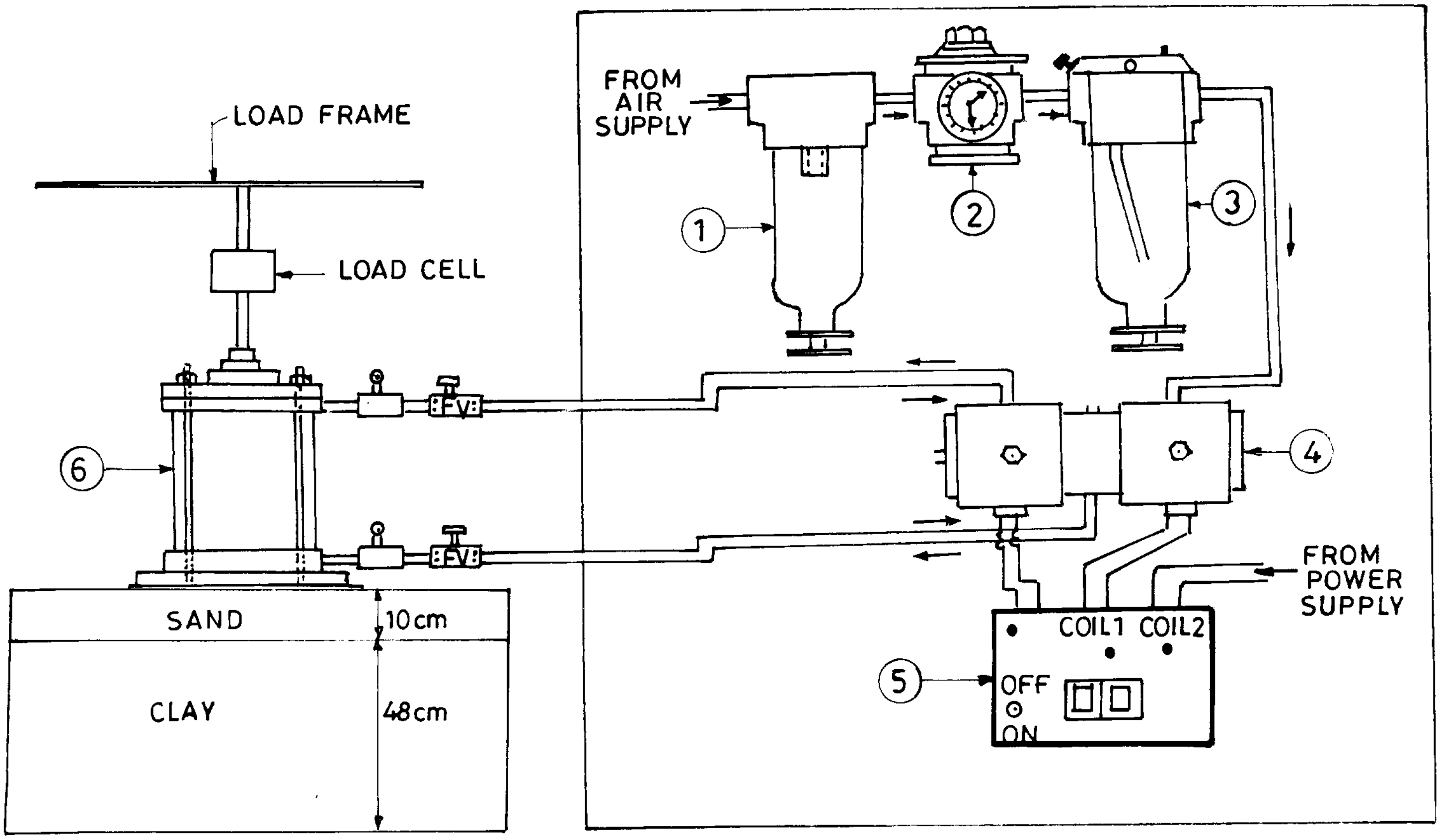
$$y = 3.6965 * \ln(x) - 3.496 \quad .. (2)$$

c) unreinforced case

$$y = 7.8498 * \ln(x) - 12.007 \quad .. (3)$$

The above equations 1,2,3 and Fig.2 clearly show the large benefit obtained by reinforcing the sand with a geocell compared to planar horizontal inclusion and unreinforced cases.

In view of the distinct benefit offered by the geocell reinforced sand (both under static and repetitive loading conditions) it merits applications to pavements and embankments. Laboratory CBR experiments



① FILTER, ② REGULATOR, ③ LUBRICATOR, ④ SOLENOID VALVE, ⑤ TIMER, ⑥ AIR CYLINDER

Fig. 1. System for imparting cyclic load

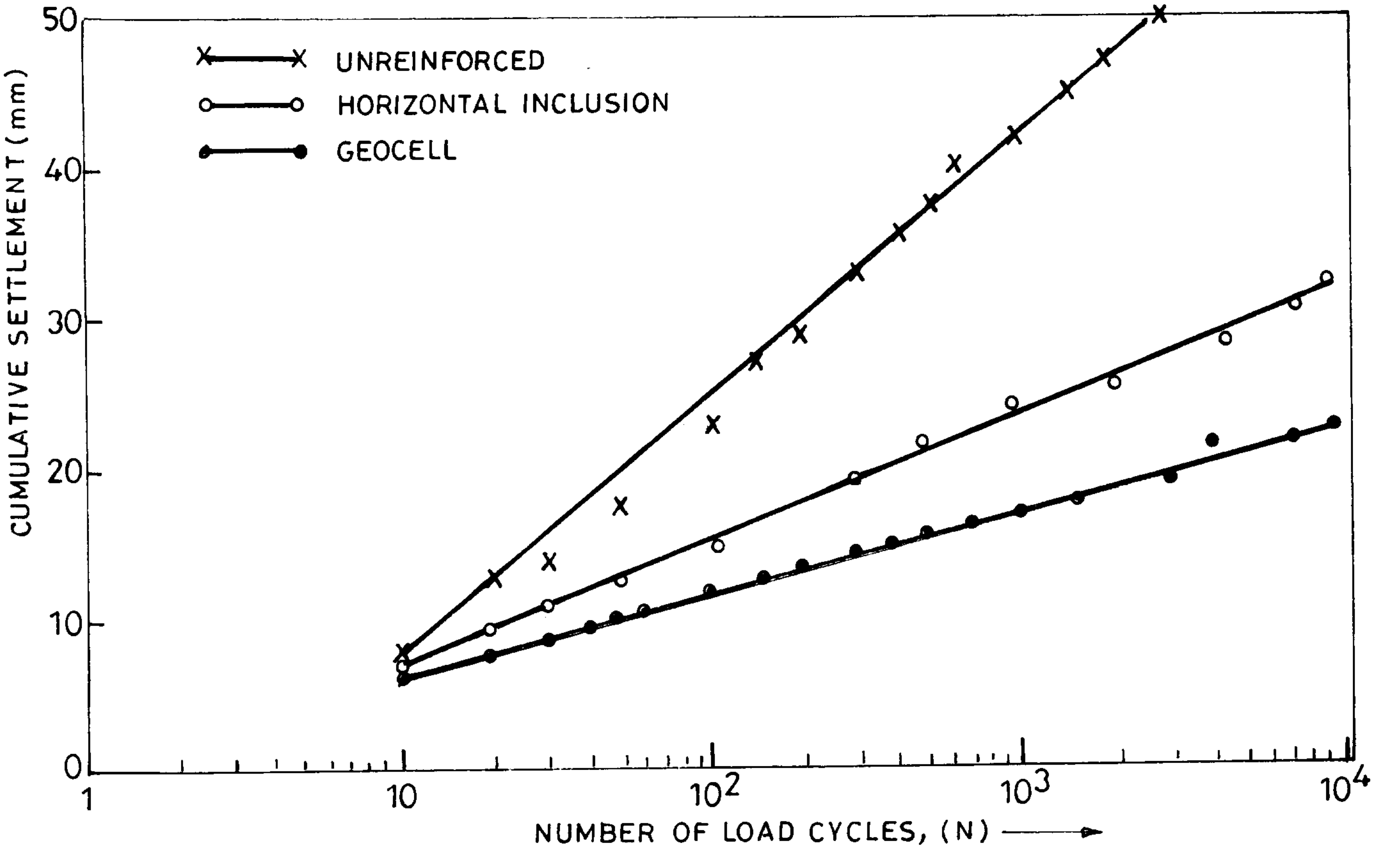


Fig. 2. Cumulative settlement versus number of cycles for geocell/ horizontat reinforced sand inclusion and unreinforced sand resting on a soft clay subgrade(c=14·5KPa)

carried by Mhaiskar (1993) have indicated that the geocell reinforced sand yielded a structural coefficient of 0.13, while the unreinforced sand yielded a coefficient of 0.09. The increase in the structural coefficient was due to the higher CBR of the geocell reinforced sand. Using the AASHO method of pavement design (Yoder, (1972) it can be shown that the geocell reinforced sand can bring about a saving of 35%. However it should be noted that the structural coefficient needs to be verified with extensive field tests.

4. CONCLUSIONS

It can be concluded from the repetitive loading tests that the geocell reinforced sand performs distinctly better compared to the planar inclusions and the unreinforced sand. Equations for settlement with number of load applications have been suggested. In view of the large benefits offered by the geocell structure it merits application to pavements where it can bring substantial savings in the sub-base/ base course.

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