0949

GEOGRID REINFORCED SUBGRADES UNDER SIMULATED EARTHQUAKE LOADING

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SUMMARY

Geosynthetic materials particularly geogrids are widely used as reinforcement for enchancing the performance of the structures and in order to understand its behaviour under dynamic cyclic loading, the dynamic loads (square wave pulse) of frequencies 0.2, 0.6 and 1 hertz and amplitude of 2mm have been applied on to the 15 cm square surface footing made of mild-steel resting on the sandy earthbeds. The settlements of the footing and the corresponding dynamic loads have been recorded.

It has been found that there is no effect of frequency of dynamic loadings on the dynamic bearing capacity of the both unreinforced and reinforced subgrades. There is considerable effect of the number of reinforcement (N), the size of the reinforcement (b) and spacing of the reinforcement (Δz,u)on the dynamic bearing capacity of the subgrades. There is considerable reduction in settlement of the reinforced subgrades.

Also the results of Cyclic-Plate-Load tests show that the coefficient of elastic uniform compression (Cu) reduces by 30 to 40% and depends upon number of reinforcement and its dimension. Therefore, the natural frequency of the reinforced subgrade decreases compared to that of unreinforced. These information are vital for the analysis and design of structures subjected to dynamic loading.

INTRODUCTION

The experimental investigation have revealed that the placing of geogrids horizontally in the subgrades, provide an effective way to increase its bearing capacity (eg., Binquet and Lee 1975 a, Fragaszy and Lawton 1984; Guido et al 1986; Verma and Pandya, 1997). More recently Omar, M.T. et al (1994) have conducted laboratory model tests on a surface square footing on a sandy bed (**Fig.1**) and suggested the critical value of d/B as 1.20.

Das, B.M and Shin, E.C. (1994) have carried out low – frequency dynamic cyclic load test on a strip foundation resting on the geogrid - reinforced saturated clay and concluded that the full depth geogrid reinforcement can reduce the permanent settlement of a foundations by about 20 to 30%. Guido, V.A et al (1994) test results show a positive effect of geogrid reinforcement on a sandy subgrade under dynamic cyclic load. There is considerable variation in the dynamic bearing capacity of the subgrade due to variation in the number of layers of reinforcement (N), size of reinforcement (b) and the frequency and amplitude of the dynamic loading. Chang, D.T. et al (1998) found that the geogrid reinforcement was highly effective in increasing the stiffness of the subgrades. Verma and Santhakumar (1999) has analysed the data of Guido (1994) and given a mathematical relationship between settlement and load cycles.

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EXPERIMENT

A series of static and dynamic plate load tests were performed in a square ferrocement tank 1.0 m wide and 0.90 m deep. The soil used was a poorly graded locally available, river sand. The test tank was filled in lifts by gravity raining technique and the unit weight of the subgrade was found to be 15 KN/m^3. The NETLON CE - 131 geogrids (Table 1) were cut in the square size, varying b/B ratio and placed in the sandy subgrade concentrically below the plate in different layers with no sheet being used more than once. The static loads for the different ratios of b/B, u/B and Δ z/B were applied on two square plates of 100mm and 150 mm. Two dial gauges were placed diagonally opposite on the plate to measure the settlement.

The load - settlement curve was used to calculate the bearing capacity of the reinforced subgrade. From the experimental investigation, the following critical parameters were obtained:-

u/B = 0.25 to 0.35

Δz/B = 0.25 to 0.35

b/B = 3.0

N = 3 to 5

d/B = 1.20

The above critical parameters were maintained for the dynamic loading. The dynamic cyclic loading (square wave pulse) of different frequency and amplitude were applied by an INSTRON hydraulic jack connected to a hydraulic power unit and controlled by a programmable logic converter (P.L.C). The loading system was strain controlled and dynamic loading was applied vertically and concentrically to a square M.S plate 150 mm wide and 30 mm thick located at the surface of the earth-bed. The settlement and corresponding dynamic loads were recorded by P.L.C.

Table 1

Reinforcement type	Size of grid (mm)	Thickness (mm)		Ruputure strength (kN/m)
		Joints	Ribs	
CE-131	27x27	5.7	3.0	5.80

The following series of plate load tests were performed :

Test Series A

This initial test series consisted of static plate loading tests performed on the unreinforced and reinforced sandy subgrade. A plot of bearing pressure versus the settlement ratio (s/B) in %, where s is the average settlement of the plate, yielded a static bearing capacity for unreinforced sand (q_{so}) as40 kN/m^2 and an s/B of 7.5% as shown in test No.S1, S2 in **Table 2.** The static bearing capacity for reinforced sand (q_{sR}) at an s/B of 7.5% are given in **Table 2** (Test number S3 to S9).

Test Series B

This test series consisted of dynamic plate loading tests on unreinforced sand as shown in test number DC1 and DC2 **(Table 2)**. A 5mm initial settlement was given to the plate of 150mm x 150mm and then the dynamic cyclic load (square wave pulse) of amplitude 2mm and of different frequencies were applied for number of cycles. The dynamic loads corresponding to different cycles where recorded. A square wave pulse loading of amplitude (z) 2 mm was used with a frequency (f) of 0.2 and 0.6 Hz for specified number of cycles and the settlement and corresponding dynamic loads for various cycles were recorded by programmable logic converter. A plot of dynamic bearing pressure versus s/B in % yielded dynamic bearing capacity q_{do} of 8 kN/m² at an s/B of 7.5%.

Test Series C

This test series consisted of dynamic plate loading tests on geogrid - reinforced sandy subgrades. The dynamic loads parameters and the geometric parameters of the reinforcement are shown in Table 2 (Test DC3 to DC9). The dynamic bearing capacity of the reinforced soil (q_{dR}) was obtained from the plot of dynamic pressure versus settlement ratio at an s/B of 7.5%.

Test Series D

The Cyclic – Plate – Loads test were performed on the both unreinforced and reinforced subgrades and the coefficient of elastic uniform compression (Cu) calculated from the test results are given in **Table3**.

Table 2

Tests Name	No.of reinforcement	u/B or Δ z/B	q_{so},q_{sR} (KN/m²)	B.C.R. = q_{sR}/q_{so}	f (Hz)	z (mm)	q_{do},q_{dR} (KN/m²)	DBCR = q_{sR}/q_{do}
S1/DC1	0	-	40	-	0.2	2	8	-
S2/DC2	0	-	40	-	0.6	2	8	-
S3/DC3	1	0.25	60	1.5	0.6	2	16	2.0
S4/DC4	1	0.35	78	1.95	1.0	2	15	1.88
S5/DC5	2	0.25	143	3.57	0.6	2	23	2.88
S6/DC6	4	0.25	175	4.37	0.2	2	32	4.0
S7/DC7	4	0.25	175	4.37	0.6	2	35	4.38
S8/DC8	4	0.35	-	-	0.2	2	24	3.0
S9/DC9	4	0.25	175	4.37	1.0	2	38	4.75

Table 3

Sl No	Test's Name	B (mm)	N	u/B	Δz/B	b/B	Cu (kg/cm3)	Remarks
1	C-1	100	-	-	-	-	25	Unreinforced Subgrade
2	C-2	100	5	0.25	0.25	3	30.83	Reinforced Subgrade
3	C-3	100	5	0.50	0.50	3	17.40	-DO-
4	C-4	100	5	0.50	0.50	5	19.68	-DO-
5	C-5	150	5	0.26	0.33	2	15.8	-DO-

TEST RESULTS

Effect of Number of Layers of Reinforcement (N)

The dynamic bearing capacity ratio (D.B.C.R) which is defined as the ratio of q_{dR} to q_{d0} increases linearly for the increase in the number of reinforcement as can be seen in **Fig. 2**, for u/B = 0.25 = Δz/B and frequency of the dynamic load, f = 0.6 Hz. The rise in D.B.C.R. for N = 4 is 4.75 which proves the effectiveness of geogrid reinforcement in the dynamic environment.

There is a reduction in settlement by 75% for N = 4.

Cu value is considerably reduced due to increase in number of reinforcement.

Effect of Frequency (f)

The dynamic bearing capacity ratio (D.B.C.R) do not seem to get influenced much by the frequency of the dynamic load and for N = 4 and u/B or Δ z/B = 0.25, there is almost horizontal straight line for various values of frequency (**Fig. 3**). Thus there is no appreciable change in DBCR due to change in frequency of the dynamic - cyclic load.

Effect of vertical spacing

The change in u/B and Δz/B affect the dynamic bearing capacity ratio and the optimum value of DBCR need to be found out. There is considerable variation in Cu values due to change in u/B and Δz/B.

CONCLUSION

The following conclusions can be drawn from the test results :-

- There is increase in the dynamic load carrying capacity of the sandy subgrade when the number of geogrid used as reinforcement increases.
- There is considerable reduction in the settlement of the footing due to inclusion of the reinforcement.
- The size and spacing of the reinforcement does affect the behaviour of the subgrade.
- Frequency of the dynamic load does not appreciably affect the dynamic bearing capacity of the sandy subgrade.
- The elastic behaviour of the reinforced subgrades becomes more pronounced and therefore this composite systems can be more effective as vibration isolator for the machine foundation subgrade and can resist the earthquake and other dynamic loads more effectively.

ACKNOWLEDGEMENT

This research work was carried out at the Structural Dynamics Laboratory of Structural Engineering Research Centre, Madras and the support and facility extended for the same is gratefully acknowledged.

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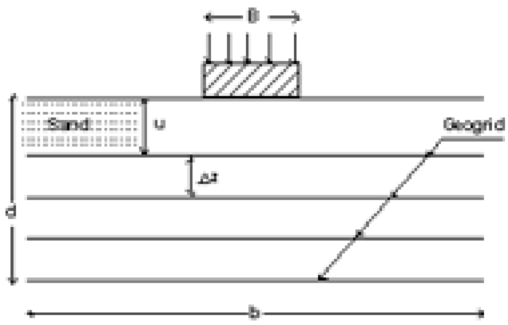

Fig. 1 Geometric Parameters for a foundation

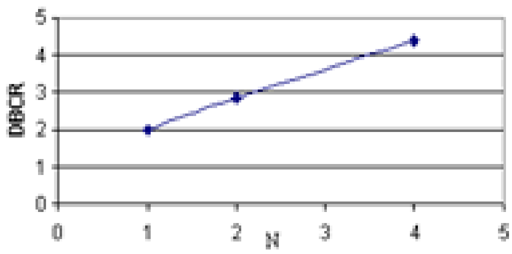

Fig. 2 Variation of Dynamic Bearing capacity ratio versus No. of Reinforcement for u/B= 0.25 = Δz/B and f = 0.6 Hz

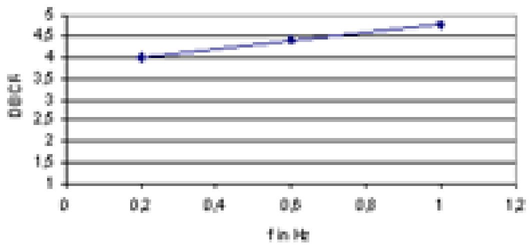

Fig. 3 DBCR versus f for N=4 and u/B (or Δz/B) = 0.25