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Reinforced earth response to impact loading

M.J.Al-Mosawe
College of Engineering, University of Baghdad, Iraq

H.H.Al-Dobaissi
Baghdad, Iraq

ABSTRACT: The resistance of reinforced earth to impact loading is examined by conducting an impact load test on an instrumented model footing resting on the surface of soil that is reinforced by different types of geogrid reinforcement. The test results revealed that reinforcing the soil improve its resistance to impact loading . This improvement was found to be dependent on the depth of the top most reinforcement layer, number of reinforcement layers , the stiffness and the aperture size of the geogrids.

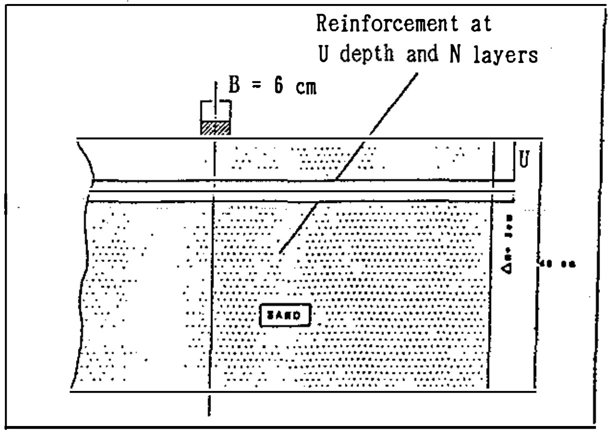
1 INTRODUCTION

Impact load is one of the dynamic load types which is a nonvibratory time-dependent loads. The demand for a better understanding of the behaviour of footings under impact loads has increased recently due to the industrial revolution which produced types of large machine such as forging and steam hammers which develop large impact load applied to their foundation. This paper high lights the resistance of reinforced earth to impact loading and draws the attention on some of the variables that affect its behaviour. This is done by conducting an experimental study on a surface footing resting on soil that is reinforced with different types of reinforcement. The footing is subjected to impact loading and the results were compared with a similar set up without reinforcement.

2 TESTING APPARATUS AND MATERIALS

A general view of the testing equipment is shown in Figure.1 . Five main parts can be observed. The first part is a box of internal dimension 800 x 800 x 610 mm. The dimensions were chosen in such a way to produce a semi-infinite media and make the boundary effect negligible. A double sheet of polythelen separated with a thin film of grease covered the inside box faces are used to reduce the slight friction which might developed on the box sides. The second part is a density control system to obtain a uniform density in the box. The third part is a square footing of dimensions 60 x 60 x 50 mm instrumented by an impact cell to permit measuring the induced forces. The fourth part is impact measurement devices which consist of an impact cell mounted inside the footing model and an LVTD and dial gauges to measure the footing displacement. Two assistance amplifiers circuits of different capacities were used to magnify the transmittal signal from the transducers to a dual beam storage oscilloscope which traces the recieved signals on a screen with time coordinates. An external triggering (photo cell) with appropriate delay time was used to adjust the striking time with the signal tracing time. The fifth part is the impact loading system which consists of the falling weight (a fabricated steel mass weighing 1750 gm) and a guide.

The reinforcement used were polymer meshes (Netlon CE 111 & 121) and polymer grids (Tensar SS1,SS2 & SS3 (Table 1). The soil used



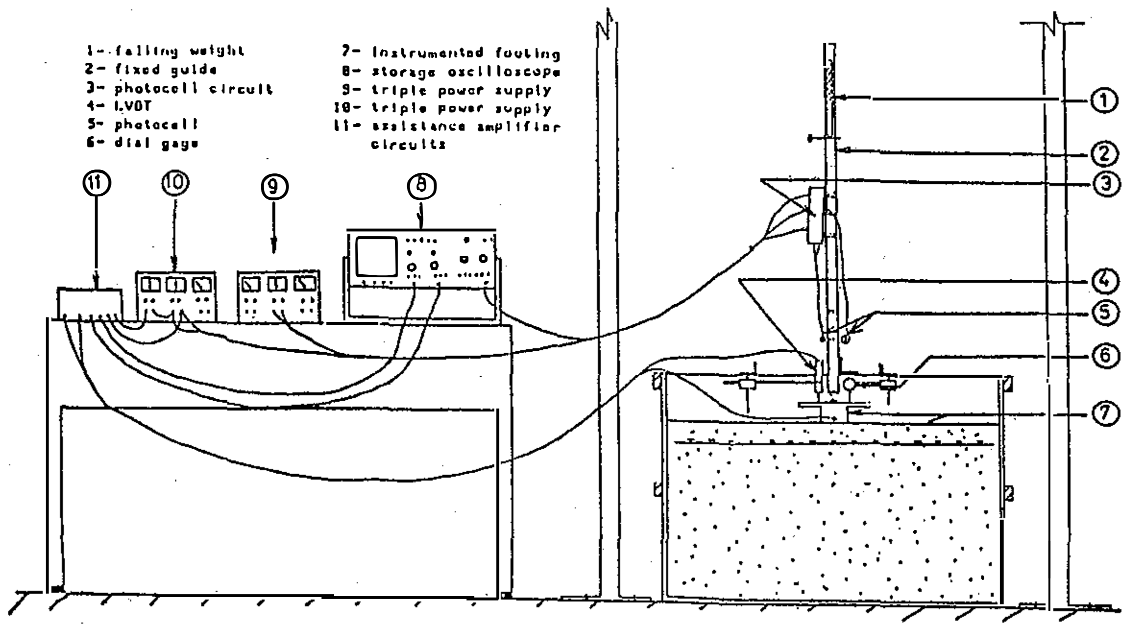


Fig.(1) IMPACT TEST ASSEMPLY & THE DYNAMIC MEASURMENT DEVICES

Table 1. Properties of the geomeshes and geogrids used

	Aperture size mm	Tensile strength KN/m	stiffness KN/m
CE 111	8 x 6	2	16.4
CE 121	8 x 6	7.68	120
Tensar SS1	24.7 x 34.7	12.5	350
Tensar SS2	25 x 37	17.5	420
Tensar SS3	46.6 x 66.7	16.1	260

was uniform sand(γ_d=18.33KN/m^3; ϕ=39^o), For more details on the testing apparatus and materials see AL-Dobaissi (1990).

3 TESTING PROGRAMME AND PROCEDURE

The detailed testing programme involoves 52 impact tests. The variables are 5 types of reinforcement (Table 2) ; number of reinforcement layers(1,3 & 5) and depth of top most reinforcement layer U (U=B/6 ; B/3 ; B/2 & B) . In addition to tests on unreinforced soil are performed for comparison. The testing procedure started by placing the sand in the box in layers. The reinforcement mesh were laid down at the level required. The sand filling operating and the placement of the reinforcement meshes continued to the level of footing. The instrumented footing was placed on the sand surface. The LVDT, dial gauges and the striker weight were mounted in their postion and the instrumentation then connected to the power supply and the storage oscilloscope. The test started when the stopper pin was pulled out and the weight allowed to strike the footing. When the weight fell on the footing , a two signals transmitted from the impact load cell to the "LVDT" which were traced on the osilloscape screen in the form of load and movement Vs.time which can be recorded on special paper. The permanent settlement can also be read by the dial gauge.

4 RESULTS AND DISCUSSION

A typical impact test results on reinforced soil is shown in Fig.2 & Fig.3. The figures show the variation of settlement and stress versus time histories during the impact test for different types of reinforcement. The figures indicate that the stress reached it's peak value in less than(1 ms)then a decay to zero in less than (3 ms). The settlement lagged the begining of stresses in about (0.9 ms) with a peak permanent settlement reached in more than(12 ms). The figures also indicate that the settlement

Table (2): Details of Impact Testing Programme

SUBSOIL TYPE	REINFORCEMENT TYPE	NO. OF LAYERS	DEPTH OF TOP MOST REINF. LAYER (U)	NO. OF TESTS
Unreinf.	-	-	-	2
reinf.	Netlon CE 111	1	B/6;B/3;B/2;B	4
reinf.	Netlon CE 111	3; 5	B/6;B/3;B/2	6
reinf.	Netlon CE 121	1	B/6;B/3;B/2;B	4
reinf.	Netlon CE 121	3; 5	B/6;B/3;B/2	6
reinf.	Tensar SS1	1	B/6;B/3;B/2;B	4
reinf.	Tensar SS1	3; 5	B/6;B/3;B/2	6
reinf.	Tensar SS2	1	B/6;B/3;B/2;B	4
reinf.	Tensar SS2	3; 5	B/6;B/3;B/2	6
reinf.	Tensar SS3	1	B/6;B/3;B/2;B	4
reinf.	Tensar SS3	3; 5	B/6;B/3;B/2	6
Total number of tests				52

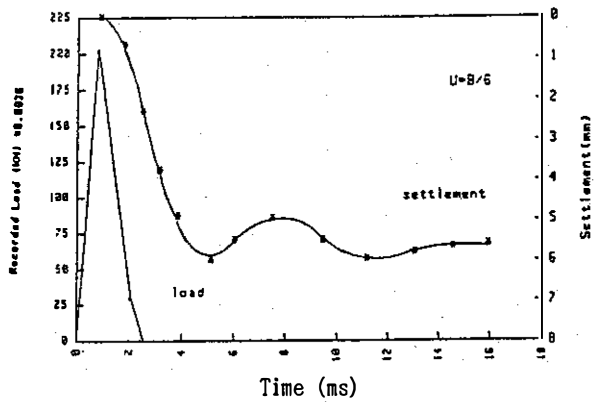


Fig.(2) LOAD & SETTLEMENT Vs. TIME FOR 1st BLOW REINFORCED WITH ONE LAYER OF NETLON CE 111.

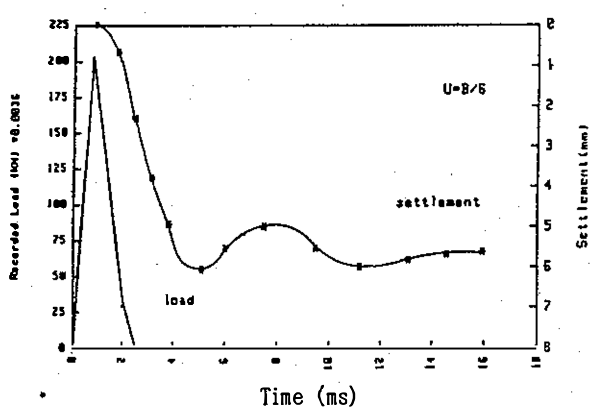


Fig.(3) LOAD & SETTLEMENT Vs. TIME FOR 1st BLOW REINFORCED WITH ONE LAYER OF TENSAR SS1

increased rapidly in the first (4-5 ms)followed by a small recovery after which the settlement continue to increase with low rate. The trend of these curves are very similar to that of unreinforced , soil reported by Al-Saffar (1989), Cunny and Sloan(1961)and Wetzel and Vey (1970) . A comparison between the reinforced and unreinforced soil has indicated that inspite of the same trend obtained, the ratio of settlement recovery in reinforced soil to the permanent settlement is higher. This be attributed to the presence of reinforcement very close to the footing base which increase the penetration resistance.

4.1 Effect of the top most reinforcement layer depth(U)

In order to demonstrate the resistance of reinforced earth to impact loading a factor(η) is introduced to define the efficiency of reinforced earth to such type of loading η = permenent settlement of unreinforced soil/permanent settlement of reinforced soil under the same stress. Figures 4 to 6 display this factor η and U for five different types of reinforcement (see Table1) and different reinforcement layers. A peak point at U = B/3 indicating a very good efficiency is obtained for all types of reinforcement used except for Tensar SS3 where the peak point is different. This peak value(at U = B/3) seems to be independent of the number of reinforcement layers(Fig.7). At a depth of less than B/3 , the position of the top most reinforcement layer is too close to the footing leading to a small imrovement in the capacity of reinforced earth to impact loading. This is propably because of the little soil mass above the first layer that can generate an interlocking resistance between soil particles and the geogrids. When U > B/3 the efficiency is also decreased as the reinforcement at such depths lies in the zone of low stresses coming from the footing and therefore reduce their contributions in carrying the load

4.2 Effect of number of reinforcement layers

Figure 8 indicates the increase in efficiency of reinforced soil with number of reinforcing layers up to a value of three after which there are very little improvement.

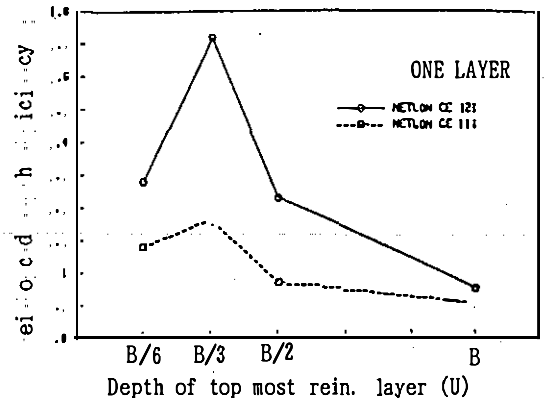


Fig.(4) THE VARIATION OF REINFORCED EARTH EFFICIENCY WITH THE DEPTH OF TOP MOST REIN. LAYER (U)

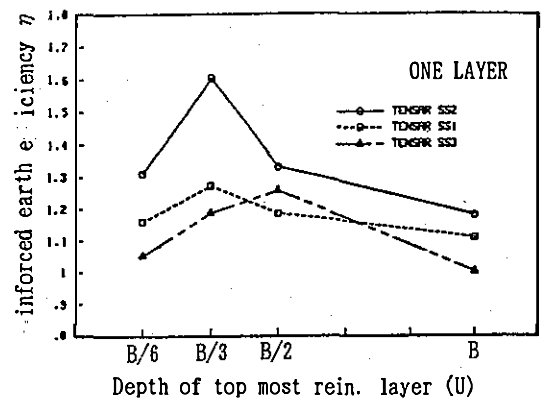


Fig.(5) THE VARIATION OF REINFORCED EARTH EFFICIENCY WITH THE DEPTH OF TOP MOST REIN. LAYER (U)

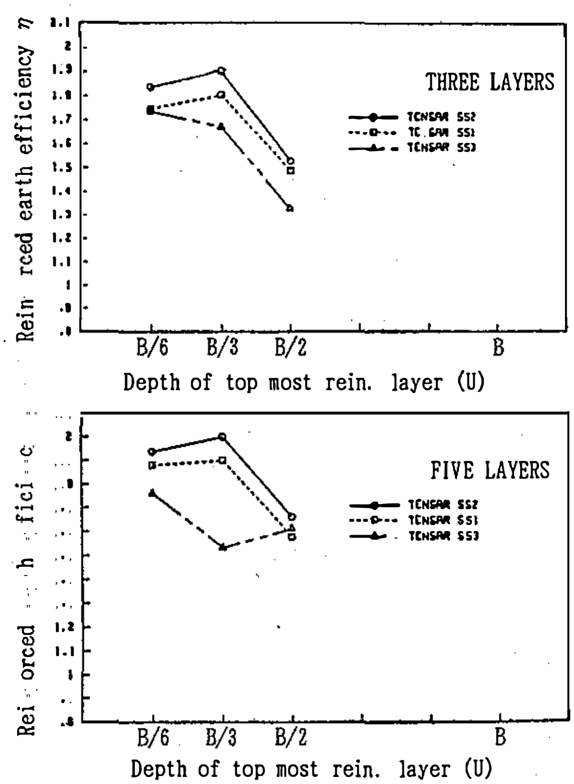


Fig.(6) THE VARIATION OF REINFORCED EARTH EFFICIENCY WITH THE DEPTH OF TOP MOST REIN. LAYER (U)

The test results revealed that regardless of the reinforcement type, the layers should be spreaded within a depth ≤ B below the footing base to gain a very good efficiency of reinforced earth when subjected to impact loading. The reason of increasing (η) with number of layers is the action of reinforcement which bring the soil to a more stable mass against footing penetration. The same trend of behaviour was reported for static tests on reinforced earth (Binquet and Lee 1975, AL-Mosawe and AL-Saffar 1980).

4.3 Effect of stiffness of the reinforcement

Two sets of test results are choosen for comparison in each of which the type of reinforcement has the same aperture size while the stiffness is different(Netlon CE 111 & 121 and Tensar SS1 , SS2 & SS3). This comparison is presented in figures 4 to 8 .The figures indicate that the reinforcement which have higher stiffness (Table 1) gave higher efficiency provided that the aperture size is same . Also the weakness of the one type of reinforcement could be overcome by increasing the number of reinforcement layers. In figure 8 the efficiency of soil reinforced by the Netlon CE 111 which have low stiffness increased from 1.18 to 1.58 (i.e.34%) when the number of reinforcement layer increased from 1 to 3 .

4.4 Effect of the aperture size

To study the effect of the aperture size on the efficiency of reinforced earth subjected to impact loading, Fig.9 presented a comparison between the tests results obtained by using reinforcement of different sizes of apertures(Table 1) .
The figure indicates that although Netlon CE 121 has small tensile strength (7.68 KN/m) and small aperture size (8 x 6 mm), its efficiency (η) is much higher than that of Tensar SS1 which posses higher strength (12.5 KN/m) but larger aperture size. Also Tensar SS1 gave slightly higher capacity

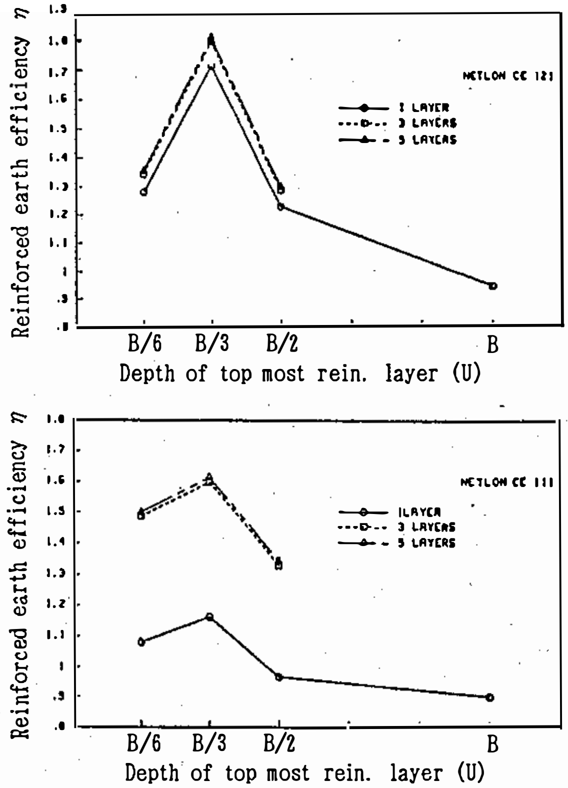


Fig.(7) THE VARIATION OF REINFORCED EARTH EFFICIENCY WITH THE DEPTH OF TOP MOST REIN. LAYER (U)

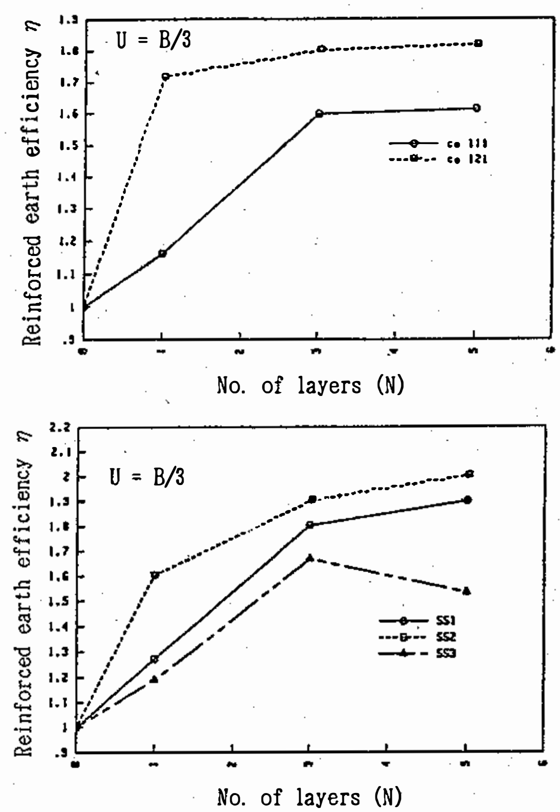


Fig.(8) THE VARIATION OF REINFORCED EARTH EFFICIENCY WITH NO. OF REINFORCEMENT LAYERS FOR DIFFERENT TYPES OF REINFORCEMENT

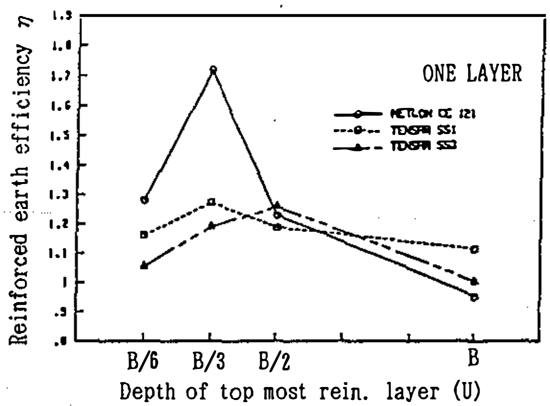


Fig.(9) THE VARIATION OF REINFORCED EARTH EFFICIENCY WITH THE DEPTH OF TOP MOST REIN. LAYER (U)

than Tensar SS3 inspite of the latter strength (16.1 KN/m) but larger aperture size. This means that as the aperture size decreases, the efficiency (η) increases provided that the tensile stresses in the geogrid due to the applied impact load is less than the tensile strength of the geogrid itself. This is mostly because of the interlocking mechanism between soil particles and the geogrids which increases as the aperture size reduced.

5 CONCLUSIONS

Reinforced earth proves to be a good technique to improve soil resistance to impact loading. The improvement increases with the number of reinforcement layers, with small aperture size and when the top most reinforcement layer U =B/3. In some cases the improvement is about two folds that of unreinforced soil for the same impact energy used.

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