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Displacement controlled pullout test of geotextile in granular soil

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ABSTRACT: Consideration has been given to evaluate frictional bond characteristics of an Indian made non woven needle punched geotextile by performing a series of pullout tests in a newly developed test setup. More than sixty tests have been carried out in order to evaluate the effect of aspect ratio of the geotextile, surcharge loading, stepped increment in normal loading, flexible footing base, etc. Effectiveness of passive anchorage or prestressing of reinforcement layer(s) at the ends have been investigated by the new experimental setup.

1 INTRODUCTION

Design of soil structures reinforced with planar reinforcing materials such as geotextiles, geogrids are undergoing revolutionary changes with rapidly developing testing methodologies and analytical approaches (Bergado et al, 1992; Wilson-Fahmy et al, 1994; Alfaro et al, 1995). The two more prominent techniques for testing planar reinforcements are the direct shear test and the pullout test, each yielding different interaction parameters. While the pullout tests are more commonly used in conditions where the variation in shear stresses of the planar reinforcement with respect to displacement are to be studied, the direct shear tests are used to derive only local shear stress-shear strain relationship. Attempts have been made to interpret and analyse the test results for design purposes using shear-lag analysis (Abramento and Whittle, 1995a, 1995b).

In a typical reinforced earth structure as shown in Fig. 1, the dashed line shows a potential failure surface and the reinforcement beyond this surface at position A will be subjected to pullout interaction mechanism, while at position B direct shear mechanism is likely to occur. It has also been observed in real cases that the reinforcement layer beyond A may continue over a longer length, preventing mobilisation of the reinforcement after a certain extent, or it may also be anchored at the rear end. However the conventional pullout tests generally leave the rear end of the geotextile free. This results in an uncontrolled stress/displacement boundary condition at the rear end of the inclusion. The reinforcing layers beyond the potential slip line

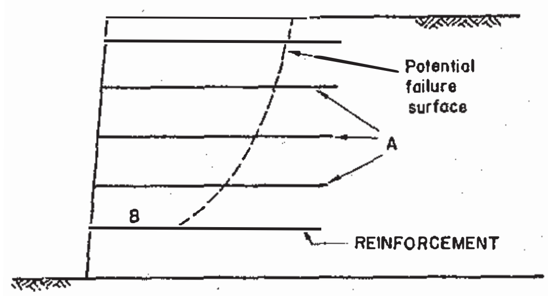

Fig. 1 Typical reinforced slope showing the soil/reinforcement interaction modes. A - pullout; B - direct shear

(e.g. in Fig. 1) can be made more effective when they are anchored or prestressed at the ends. In order to evaluate the effect of end restraint a modified multipurpose pullout test apparatus has been developed. This paper presents the experimental findings obtained from this apparatus including the effect of end restraint, stepped increment in normal loading, flexible footing base, etc. on the pullout response of geotextile.

2 TEST APPARATUS AND SAMPLES

A schematic diagram of the testing apparatus which was used for the tests is shown in Fig. 2. The apparatus was designed and developed at the Geotechnical Engg. laboratory, Institute of Technology, Banaras Hindu University, Varanasi. The advantage of this apparatus in comparison to

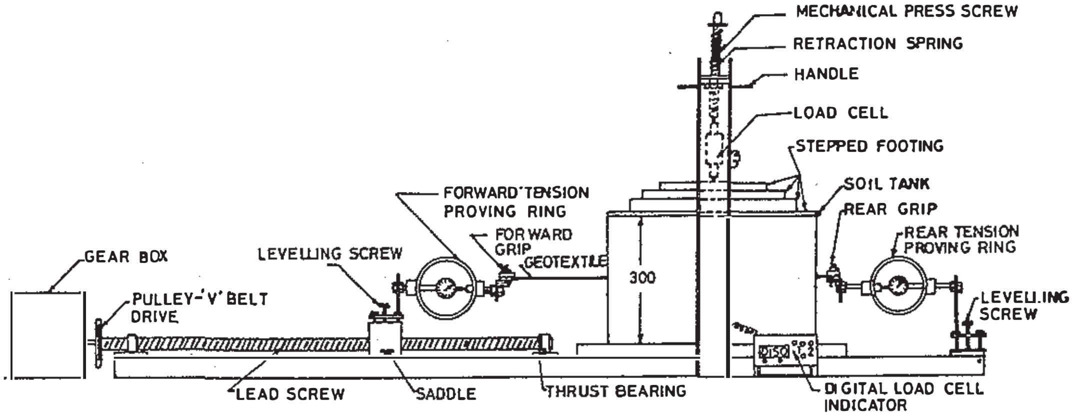

Fig.2 Schematic of pullout apparatus

the conventional apparatus, is its operational simplicity and versatility which enables to conduct conventional as well as modified pullout tests.

The apparatus has the facility to pass the geotextile through and through the soil matrix contained inside a rigid tank, 300mm deep, 300 mm wide and 500mm long. The tank containing soil is positioned inside an inbuilt loading frame which has the facility of applying normal load on the soil matrix perpendicular to the plane of reinforcement through stepped rigid footing plates. A layer of commercially available foam, (50 mm thick; density, 0.33 kN\m^2; stiffness coefficient, 2.3kN/m) was placed below the rigid footing plate to attain flexibility. Since the geotextile used was soft and flexible the grip devised was a semicircular teeth rack cut in matching on the gripping faces of two rigid mild steel plates with fasteners at the ends. The geotextile coming out of the front face is gripped between the plates and it is connected to a tension proving ring which is in turn fixed to a saddle. The saddle is mounted on a lead screw and guide shaft. It moves gradually in forward or backward direction as the lead screw is rotated using a multi speed gear box by a pulley 'V' belt mechanism. In the present test setup the inclusion can be gripped at the rear end via another tension proving ring for measuring rear end tension.

The soil used was locally available Ganga river sand with the properties listed below:

Type of sand	SP
D_{10}	0.155 mm
D_{30}	0.190 mm
D_{60}	0.260 mm
Maximum dry density	16.2 kN/m^3
Minimum dry density	14.3 kN/m^3
Angle of shear resistance	34^o

For each test the tank is filled up with sand by pouring it from a constant height in stages forming 20 mm thick layer in each step and tamping it manually to maintain a constant density of 15.36 kN/m^3.

The planar inclusion used was a 100% polypropylene needle punched non woven geotextile (Indian made), 2.8 mm thick and with unit weight of 2.13 N/m^2 which is layed horizontally at the mid height of the tank. Normal load at the top of the box is provided through load cell.

3 TEST PROGRAM

Pullout tests were carried out in four different categories. For all the tests geotextile specimens were cut from the roll with 50 mm, 100 mm, 150 mm and 200 mm wide and each having 700 mm length. The first class of tests were carried out with the geotextile being left hanging outside freely at the rear end through the slit provided on the rear face of the tank. The loading pattern for this class was stepped application of normal load till failure occurred either by slip or by tensile failure of the geotextile. In the second class of tests the effect of flexible footing base was studied by varying the depth of sand bed over the geotextile and at the same time maintaining a constant interface normal pressure of 7.2 kN/m^2. The third class of tests was with the measurement of tension in the rear end of the geotextile. Finally in the fourth class of tests, conventional pullout tests were performed. The normal load applied in different tests varied from 5 kN/m^2 to 20 kN/m^2.

4 DISCUSSIONS OF TEST RESULTS

4.1 Load-extension behaviour of geotextile

In Fig. 3, the load-extension response of the geotextile specimen (about 700 mm in length which is the minimum required length for the test apparatus) is shown for various widths. Same size of

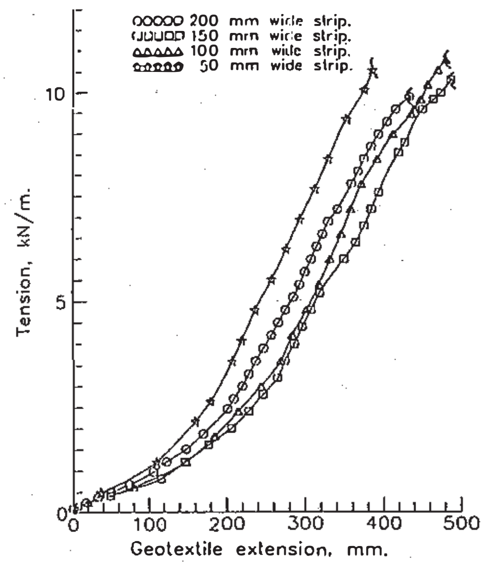

Fig.3 Plot of tensile force vs. extention for various widths of geotextile

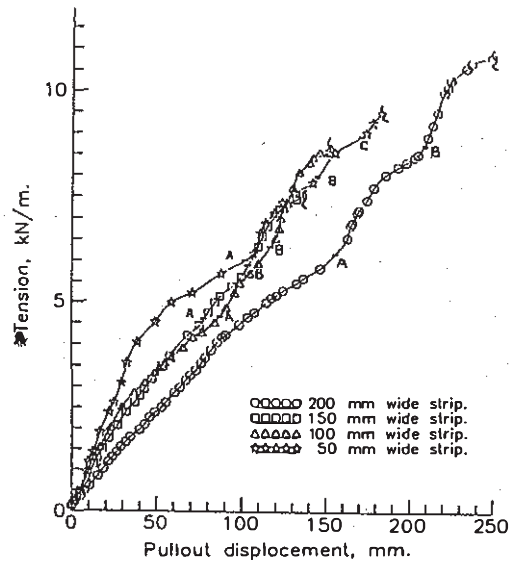

Fig.4 Tensile force vs. pullout displacement- Effect of stepped increment in normal load till failure

the geotextile specimen was also taken for the pullout tests in sand. Since the aspect ratio of the specimen is very high, tensile force does not increase much due to the initial slackness. It increases almost linearly with the increase in axial strain beyond 20%. All the tests have been performed till failure of the specimen in tension.

4.2 *Pullout shear under stepped increment in normal loading*

In order to simulate the staged construction over the reinforcement layer pullout test have been conducted for stepped increment in normal loading. Fig.4, shows the plot between tensile force and pullout displacement for 50 mm, 100 mm, 150 mm and 200 mm wide geotextile specimen with the rear end left freely hanging outside the box. Initially a normal load of 0.75 kN was applied through the rigid footing at the top of the box and pullout displacement was recorded till slippage occurred. These stages are marked 'A' in Fig.4. In the next step normal load was increased to 1.5 kN and displacement records were made till the slippage of the geotextile (see mark 'B' in Fig. 4). For 50 mm wide strip normal load was increased to 2.25 kN (see mark 'C' in Fig. 4) which finally led to tension failure of the geotextile outside the tank.

4.3 *Effect of flexible footing base*

Commercially available foam has been used for making a flexible base over which normal load was applied via rigid footing resting on it. Fig. 5 shows the pullout test results for a 150 mm wide strip.

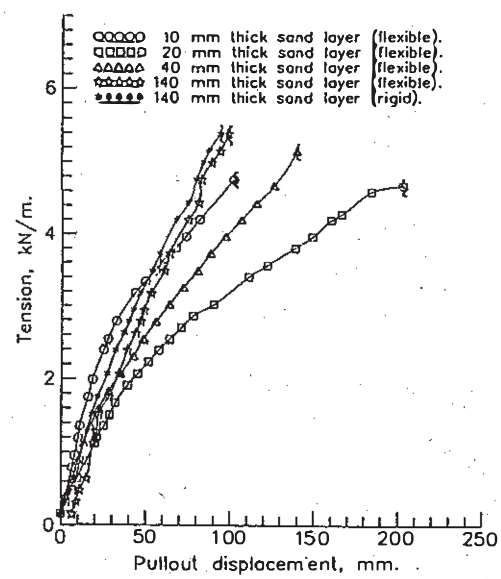

Fig.5 Tensile force vs. pullout displacement- Effect of depth of soil bed over geotextile at constant normal interface pressure (7.2kN/m^2).

Equivalent normal load intensity of 7.2 kN/m^2 at geotextile-soil interface was maintained for all the tests. Thickness of the sand bed over the geotextile layer was varied as 10 mm, 20 mm, 40 mm and 140 mm. In each of the test normal load was applied taking into account the equivalent surcharge due to the sand bed plus applied normal load through the adjustment of load cell. Test results show the little effect due to flexible as well as apparently rigid footing base. It is also not known clearly the effects of variation in sand bed thickness. For 10mm thick sand bed lying below the foam, the soil might have been subjected to unaccountable soil-geotextile interface shear which may even be found prominent for 20 mm thick sand bed. For 40 mm and higher thickness of sand bed pullout response in fairly closer to the normal tests results.

4.4 *Effect oj rear end restraint on the pullout behaviour*

In an attempt to observe the effect of constant length pullout response with rear end being restrained several tests have been conducted. Fig. 6 shows the pullout response for a 100mm wide geotextile strip for various normal load intensities. The response curves clearly indicate that for higher normal loads tensile force recorded in the front end proving ring are transmitted through the embedded strip to the rear end. It is also observed that (Fig. 7) tension in the rear end increases almost linearly with the increase in tension in the front end. For $5kN/m^2$ normal load intensity no tensile force was generated at the rear end till the tensile force of 3.8 kN/m was recorded in the front end. With the increase in normal pressure rear end tension has been found to increase by about 10% of the applied normal load.

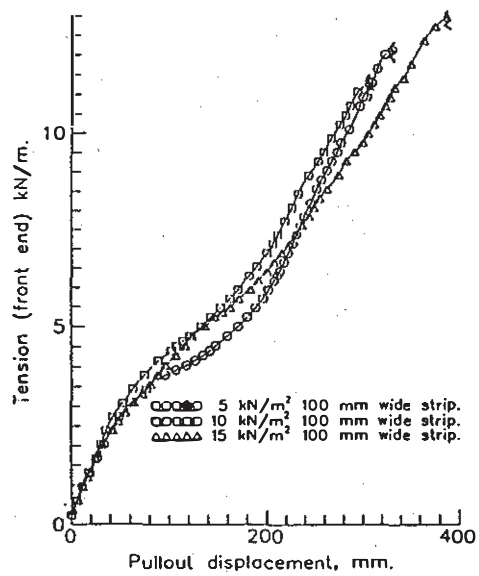

Fig.6 Tensile force (front end) vs. pullout displacement with rear end being restrained

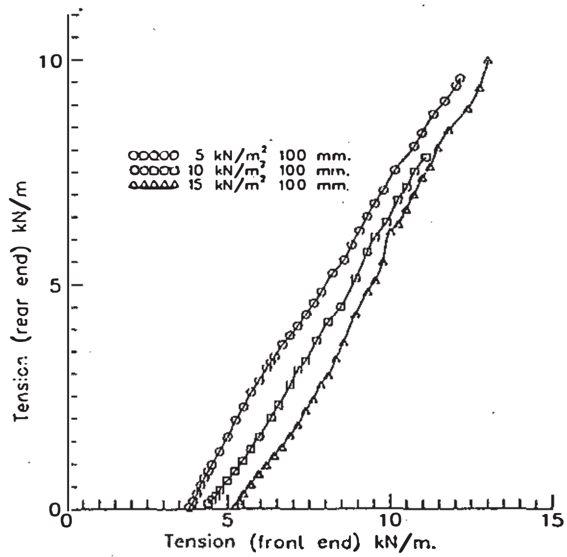

Fig.7 Plot of tensile force (front end) vs. tensile force (rear end).

5 CONCLUSIONS

In a newly developed pullout test apparatus, a series of tests have been conducted for the evaluation of soil-geotextile friction characteristics. Boundary conditions at the rear end of the geotextile have been varied and results have been discussed in accordance with the field situation. Effectiveness of reinforcement in case of staged construction (e.g. reinforced earth retaining wall) has been evaluated by carrying out pullout tests under stepped increment in normal loading. Flexibility of the footing base does not affect much on the pullout response, excepting that at smaller thickness of sand bed over geotextile results do not give any feasible trend for which more tests have to be conducted.

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