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A Modified Screw Plate

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Summary The advantages expected from use of a screw plate for in-situ measurement of modulus of sand are discussed. The modulus results from laboratory tests of a screw plate are then compared with those from a buried flat disc. The reason for the differences in values is discussed and a modified form of screw plate which should minimise these differences is described. The results of modulus tests using the modified screw plate are then presented, and these demonstrate that the modified screw plate eliminates most of the effects of dilation.

1. INTRODUCTION

The obvious simple method for in-situ measurement of the modulus of sand is the flat plate loading test. However when modulus values are required at some depth, the tests need to be carried out at the bottom of a borehole, which gives rise to some difficulties. Firstly there is the problem of obtaining satisfactory bedding of the plate, and use of a flat-bottoming auger may not give adequate results. Secondly there is the fact that excavation of the borehole will have caused some stress relief in the sand at the bottom of the hole, as shown by Galle and Wilhoit (1962). This will tend to reduce the measured value of modulus. Use of a screw plate would be expected to eliminate problems of unsatisfactory bedding. Also, if the screw plate is inserted 1-2 diameters below the bottom of the borehole it will have largely avoided the stress-relieved zone of sand, as shown in Fig 1.

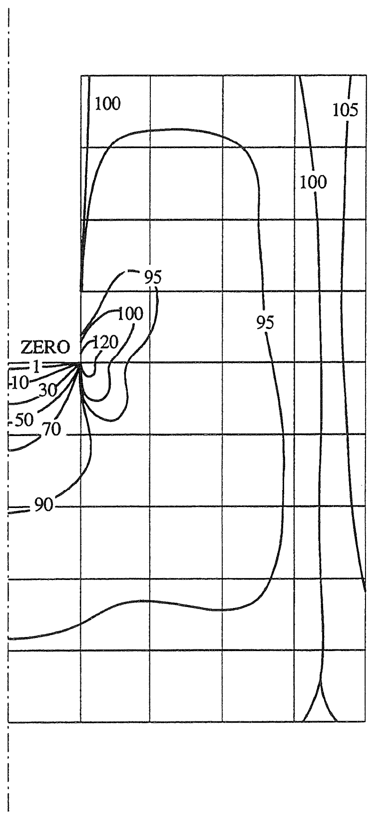

Figure 1. Vertical Stresses after excavation of a bore hole.

The aim of the present study was to compare values of Young's modulus determined using various forms of plate under controlled laboratory conditions.

2. LABORATORY TESTS

Laboratory tests for modulus determination in Sydney sand were carried out using a buried flat disc, a screw plate and the modified form of screw plate, with a wide range of sand densities. The soil used in the tests was normally consolidated, dry Sydney quartz sand, whose grains are rounded and have a mean diameter of 0.3 mm, a coefficient of uniformity $C_c=D_{60}/D_{10}=1.47$, and a specific gravity of solids of 2.65. The maximum and minimum dry unit weights γ_{max} and γ_{min} are 16.2 and 14.3 kN/m^3.

3. TEST EQUIPMENT

The tests were carried out in a cylindrical steel container 320 mm in diameter and 350 mm deep, shown on Fig 2. Although the presence of the base and side boundaries of the container reduced the plate displacements by about 6%, the purpose of the tests was the comparison of values of Young's modulus obtained with various forms of plate, not determination of exact values of modulus.

A rubber membrane was located between the sand and the lid which contained pressurised water, which for the reported series of tests was maintained at a pressure of 100 kPa.

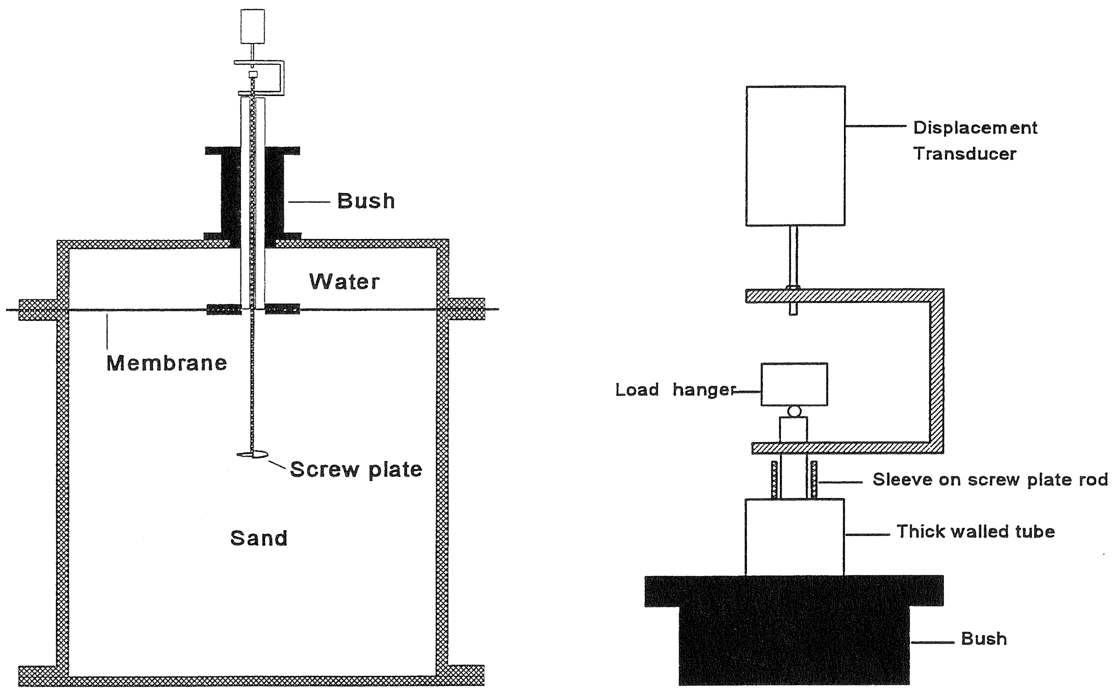

Figure 2. The laboratory test equipment.

The flat disc and the screw plate were 30 mm diameter. The screw plate consisted of two half flights, which led to balanced torque during insertion. The screw plate, which is shown in Fig 3, was 1.5 mm thick and had a pitch of 4.2 mm per revolution. Friction between the 6 mm diameter screw plate rod and the sand was prevented by means of the sleeve shown in Fig 2, more details of which are given by Brown (1995). The sleeve passed through a thick-walled tube located in a bush on the container lid and sealed onto the membrane to prevent leakage of water into the sand. Variation of the surcharge pressure applied to the sand due to friction between the thick tube and the bush was minimised by injection into the bush of oil at the same pressure as that of the water inside the lid.

Loading of the screw plate was carried out by application of dead loads to a load hanger. Displacements due to the hanger load were measured. This was possible because the displacement transducer was not connected to the top of the hanger (see Fig 2). The loads were applied at a rate of one increment per minute.

4. TEST PROCEDURE

Beds of sand were prepared by raining from a sieve with mesh sizes ranging from 7 mm down to 1 mm, which was covered with a plastic sheet that could be pulled horizontally from beneath the sand. Sand densities were measured using a small tin placed about 100 mm below the level of the test plate.

The first series of tests was carried out using a flat disc 5 mm thick, 30 mm diameter at the base, but bevelled to be 20 mm diameter at the top surface to reduce side friction. A small load cell was mounted on top of the disc to measure the exact load applied to the disc, thus eliminating the effect of any friction between the rod and sleeve. The results were to be used as the reference values of Young's modulus.

The second series of tests was carried out with the screw plate inserted by rotation but unconstrained in

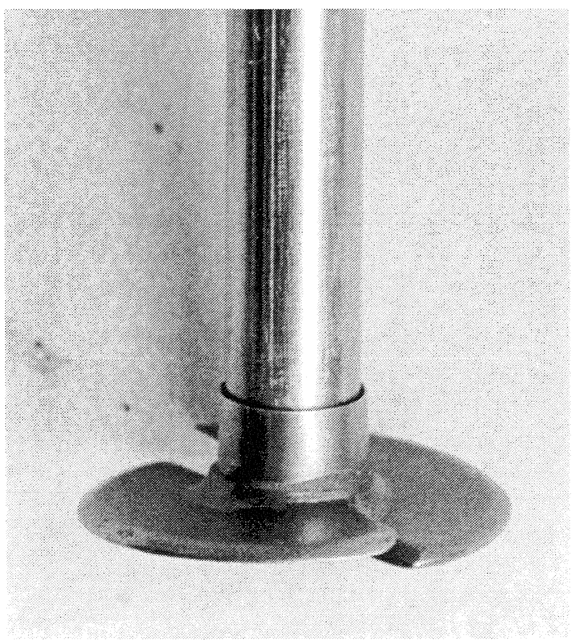

Figure 3. The screw plate used.

its rate of penetration. It was not found possible to design a suitable load cell for the case of the screw plate due to the torque associated with the insertion. The third series of tests was carried out with the screw plate having its rate of penetration controlled by a threaded rod whose pitch was equal to the pitch of the screw plate. The first three series of tests were carried out at a depth of 150 mm. Other tests were carried out at depths of 30 mm and 20 mm as will be discussed later.

5. MODULUS EVALUATION

Due to the variability in results for the first increment of loading, it was decided to calculate values of tangent Young's modulus when the displacement of the screw plate was 0.01 mm. The values of displacement, measured 1 minute after the application of the load, were first corrected for compression of the screw plate rod. The Young's modulus of the sand was then evaluated by interpolating between the results produced by an elastic finite element analysis of the circular screw plate embedded in a half-space at the appropriate depth, for various selected values of soil modulus. A similar analysis for a larger screw plate has been described by Brown (1991). A similar analysis was carried out for the rectangular screw bar using soil displacement influence factors for finite depth.

6. RESULTS OF TESTS AT 150 MM DEPTH

Values of Young's modulus for a range of sand densities from the flat disc tests are shown in Fig 4 with the line of best fit for these results. Values of Young's modulus using a screw plate inserted with no constraint on the rate of insertion are shown in Fig 5, with the regression line for the flat disc tests included for comparison. The values of Young's modulus using a screw plate inserted under the control of a threaded rod with a pitch equal to that of the screw plate are shown in Fig 6, with the regression lines for the previous two test series. Tests on dense sand using a threaded rod were not carried out for fear that the considerable thrusts would break the screw plate.

7. DISCUSSION OF 150 MM TEST RESULTS

It appears that the reason that values of modulus determined by use of the screw plate are higher than those for the flat disc is the dilation of the sand during insertion, and the consequent increase in stress around the screw plate. Consideration of the shape of the screw plate around the cutting edge, as shown in Fig 7, shows that there will be enormous shear strains involved in the passage of the sand from the lower side of the plate to the upper side. However the effect of these strains depends on the way in which the insertion is controlled. When the insertion is unconstrained, the

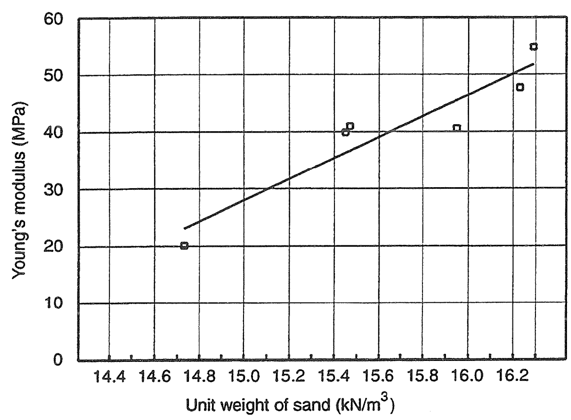

Figure 4. Values of Young's modulus determined from flat disc tests.

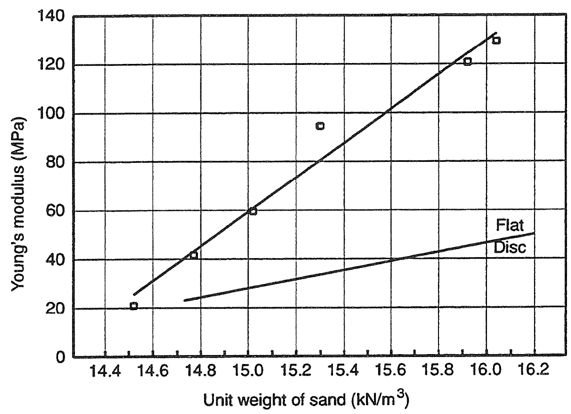

Figure 5. Values of Young's modulus determined from tests with a screw plate with unconstrained insertion.

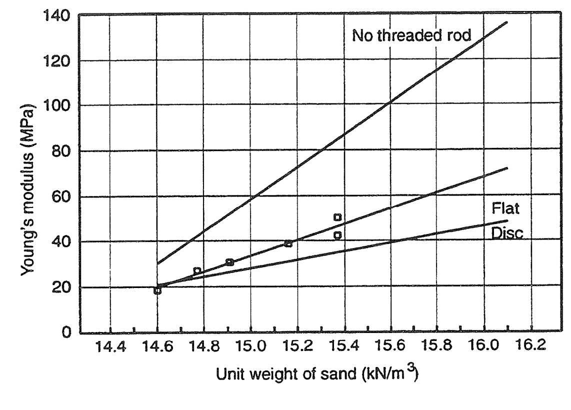

Figure 6. Values of Young's modulus determined from tests with a screw plate inserted with a threaded rod.

upward thrust on the plate must be balanced by an increase in stress in the sand above the plate, and this pair of stresses will still apply during the modulus test. However when the insertion is controlled by a threaded rod, most of the upward thrust on the plate is balanced by the thrust developed in the screw plate rod, and at the end of insertion this thrust is removed, so the stress increase applying during the modulus test consists mainly of the residual horizontal stresses caused by the increase in vertical stress. Thus the increase in the value of measured modulus is much smaller when a threaded rod is used to control the insertion.

8. MODIFICATION OF THE SCREW PLATE

Since the large values of modulus for dense sand which are measured with the screw plate have been attributed to dilation, it seemed logical to modify the shape of the screw plate so that its insertion would cause the minimum possible shear strains. This has been carried out firstly by wide separation of the cutting and trailing edges, and secondly by modifying the shape of the cutting edges. The result is the rectangular screw bar shown in Fig 8.

9. RESULTS OF TESTS AT SHALLOW DEPTHS

Screw plate tests are not usually performed in sand at depths of 5 diameters, depths of 1 to 2 diameters being more usual. Because the thrust which can be developed beneath the screw plate is reduced when the plate is at a smaller depth, values of modulus closer to those from flat plate tests should be obtained when screw plate tests are carried out at shallow depths.

Tests were carried out at a depth of 30 mm using a screw plate inserted without the use of a threaded rod, and the results are shown in Fig 9. It can be seen that somewhat smaller values of modulus were obtained for dense sand than from the corresponding tests at a depth of 150 mm.

Tests were also carried out at a depth of 20 mm using the modified screw plate or screw bar, and the results are shown in Fig 10, with the regression line for the flat disc tests included for comparison. These tests were carried out without using a threaded rod because the screw bar has no single inherent pitch which could have been matched by the pitch of a threaded rod. It can be seen that the values of modulus obtained for dense sand are on average about 10% higher than those for the flat disc. This suggests that the effect of dilation has been largely eliminated.

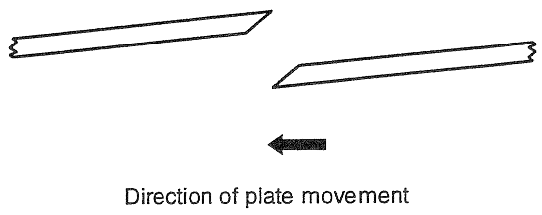

Figure 7. Cutting and trailing edges of a screw plate.

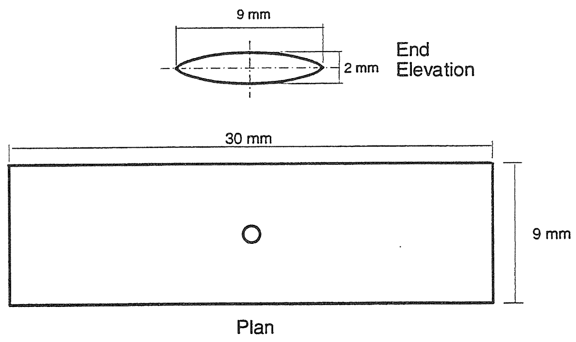

Figure 8. The modified form of a screwplate, or screw bar.

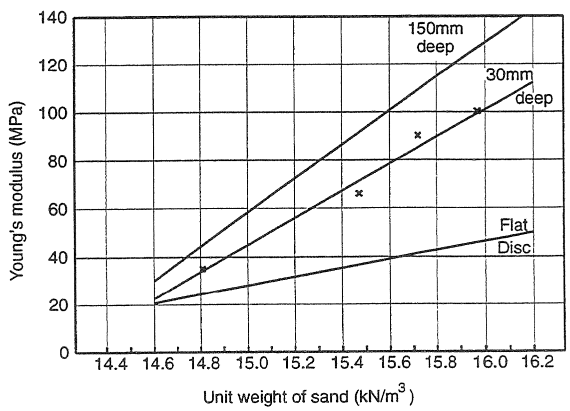

Figure 9. Values of Young's modulus from tests at 30mm depth using a screw plate with unconstrained insertion.

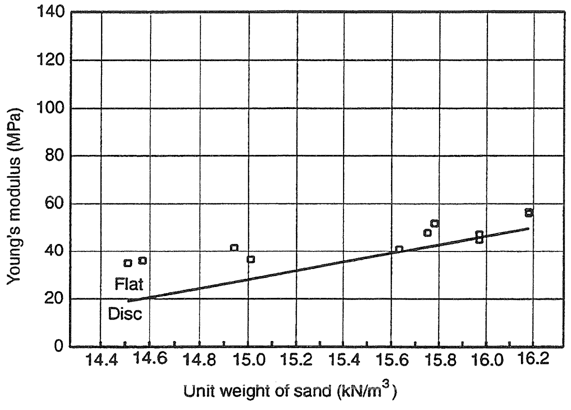

Figure 10. Values of Young's modulus from tests at 20 mm depth using the modified screw plate.

However the modulus values for loose sand are much less satisfactory, and since dilation is unlikely to have a significant effect in the loose sand, further investigation will be required.

10. CONCLUSION

A modified form of screw plate has been developed with the aim of reducing the erroneously large values of modulus measured in dense sand using a normal screw plate. Laboratory test results indicate that this new form of screw plate, or screw bar, has been successful in eliminating most of this dilation effect thus leading to improved values of modulus.

11. ACKNOWLEDGEMENT

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