Screw Plate Insertion Disturbance in Sand

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SUMMARY Laboratory tests in clean dry sand using an embedded screw plate and a screw plate inserted under the control of a threaded rod having the same pitch as the screw plate are described. The values of Young's modulus obtained from these tests are compared in order to estimate the effects of insertion disturbance on the results.

1. INTRODUCTION

The flat plate loading test is widely used for in-situ determination of soil compressibility in materials such as sands which cannot readily be sampled without altering the soil properties. As discussed in Brown and Abdel-Latif (1992), when carried out at the bottom of a borehole, there may be problems with the flat plate loading test in obtaining satisfactory bedding of the plate, and errors in modulus due to the stress relief of the soil just beneath the bottom of the borehole.

The screw plate test is designed to eliminate these two disadvantages of the flat plate. However when the insertion of the screw plate is carried out under the control of a threaded rod having the same pitch as the screw plate, with the aim of achieving perfect contact between the screw plate and the soil, there is a pressure increase beneath the plate during insertion. Such a pressure increase may increase both the mechanical disturbance and the stress disturbance due to insertion and both effects are likely to change the values of modulus obtained from screw plate tests.

The purpose of the two series of tests described in this paper was to determine the nature of the screw plate insertion disturbance, and its effect on values of modulus obtained in normally consolidated clean dry sand at various relative densities and subject to a range of surcharge pressures, by comparison with values obtained from tests using an embedded screw plate.

2. DESCRIPTION OF TESTS

Two series of tests were carried out in dry Sydney sand using a screw plate 30 mm diameter, 1.5 mm thick, with a pitch of 4.2 mm mounted on a 6 mm diameter shaft. The first series was carried out in a container 450 mm diameter and 650 mm deep, similar to that shown in Fig. 1 of Brown and Abdel-Latif (1992) except that no provision for drainage was required. In these tests the torque required for screw plate insertion under the control of a threaded rod with the same pitch as the screw plate, and the resulting thrust developed beneath the screw plate, were measured. The torque was measured by means of a spring balance at the end of the torque arm. The thrust was measured by means of a strain-gauged disc and strain bridge, so that the displacement of the measurement system would be small and would cause a minimal reduction in the development of thrust. For the lower levels of thrust the strain-gauged disc displacement was 1.0 mm/kN and for the larger thrusts the displacement of the thicker disc was 0.4 mm/kN.

The second series of tests was carried out in a similar container 320 mm diameter and 340 mm deep. In these tests a screw plate was embedded at a depth of 150 mm during the process of sand raining, or a screw plate was inserted by rotation to a depth of 150 mm, and then the screw plate was loaded continuously and the load and displacement were measured and recorded automatically, to provide results from which the initial modulus could be obtained. The geometry of the tests is shown in Fig. 1.

In the case of the inserted screw plate, any thrust built up during insertion was released before commencement of the modulus test. Calculation of the modulus involved allowance for the bending of the screw plate (Brown, 1991).

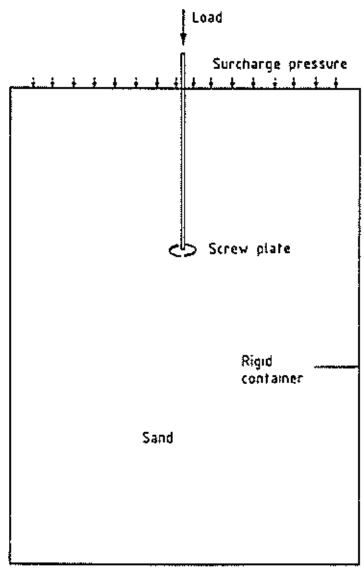

Figure 1. The geometry of the tests.

Tests were carried out at relative densities of about 15%, 65% and 85% (based on γ_{min}=14.1 kN/m^3 and γ_{max}=16.2 kN/m^3), with surcharge pressures (σ_v) ranging from 35 kPa to 200 kPa. However tests were not carried out with the inserted screw plate for the higher densities at the higher surcharge pressures for fear of breaking the screw plate.

3. THRUST TEST RESULTS

The variation of torque and thrust with depth for a screw plate inserted from the surface of the sand is shown by the lower pair of curves in Fig. 2. It will be seen that both torque and thrust increase quite rapidly with depth until they reach a maximum and then decrease slightly.

If the thrust pressure exerted by the plate is assumed to be uniform, and a friction angle of 15° between the smooth steel screw plate and the sand is assumed, (Standards Australia, 1990), a Mohr circle construction shows that the sand immediately beneath the plate is in a state of failure by the end of the first revolution of the screw plate. It seemed probable that a zone of failed sand formed beneath the screw plate and expanded with further insertion until the failure zone had reached the upper surface of the sand. This idea is supported by the results of an additional test in which insertion was commenced after the screw plate had been embedded at a depth of 100 mm. The results from this test are shown as the upper curves in Fig. 2, and it will be seen that the values of thrust are much higher than occurred in the case of insertion from the surface.

The values of thrust arising during insertion were found to increase with both sand density and surcharge pressure, as well as with the depth at which insertion commenced. In the case of insertion beneath the bottom of a borehole, because of the diffence in shape of the geometrical boundary, the actual values of thrust which arise may differ from those measured in these tests. Also the measured values of thrust are probably influenced by the proximity of the side walls of the container. However

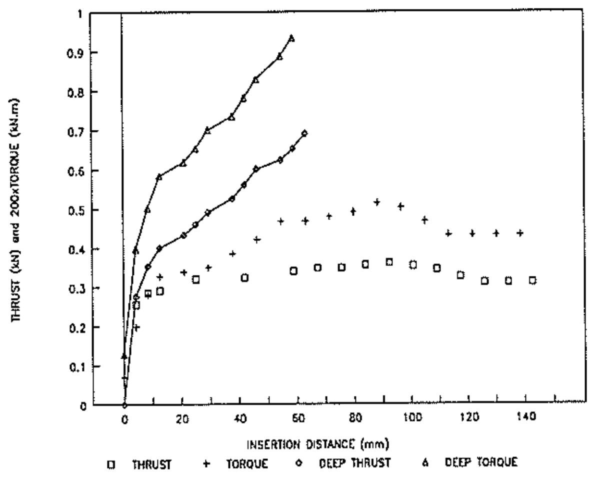

Figure 2. Thrust and torque during screw plate insertion into medium density sand with σ_v = 100 kPa.

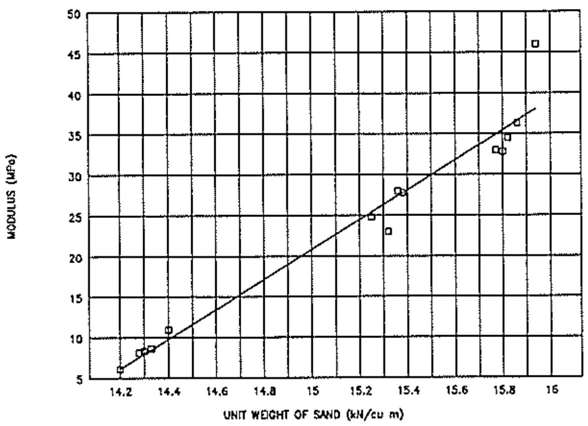

Figure 3. Values of modulus using a buried screw plate and σ_v = 35 kPa.

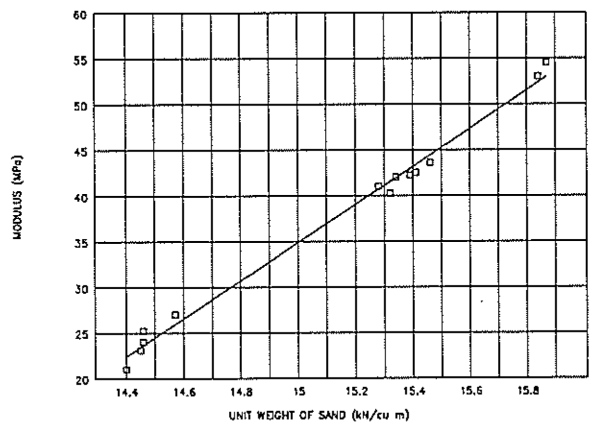

Figure 4. Values of modulus using a buried screw plate and σ_v = 100 kPa.

these tests indicate that significant thrusts may be built up and then released before the modulus test, so that the sand immediately beneath the screw plate will have been sheared, compressed and unloaded before the modulus test is carried out.

4. MODULUS TEST RESULTS

Fig. 3 shows the values of initial modulus obtained from tests carried out using an embedded screw plate for a range of sand densities and a surcharge pressure of 35 kPa. The two important features of this diagram are the very significant variation of modulus with sand density, and the small scatter of the results about the fitted regression line. The latter indicates that the tests were carried out with little variation of results due to random effects. Fig. 4 shows the corresponding results from tests with a surface surcharge pressure of 100 kPa. In this case the rate of change of modulus with unit weight is the same as in Fig. 3 although it is less obvious, and the results show a similar small scatter about the regression line.

The results shown in these two figures have been adopted as the best available values of initial modulus for Sydney sand from plate loading tests. An attempt was made to carry out flat plate loading tests using embedded discs, but it was not found possible to overcome the problems of providing a flat bearing surface without altering the properties of the sand.

Fig. 5 shows the values of initial modulus obtained from tests using an inserted screw plate and a surcharge pressure of 35 kPa, together with the regression line previously shown in Fig. 3 for an embedded screw plate. It will be seen that the values of modulus obtained from the inserted screw plate are in some cases quite conservative, being only about 60% of those obtained with the embedded screw plate. Fig. 6 shows the corresponding results of modulus tests carried out using an inserted screw plate and a surcharge pressure of 100 kPa, together with the regression line previously shown in Fig. 4 for an embedded screw plate. It can be seen that the modulus values obtained from the inserted screw plate tests range from about 70% to 110% of those obtained with the embedded screw plate.

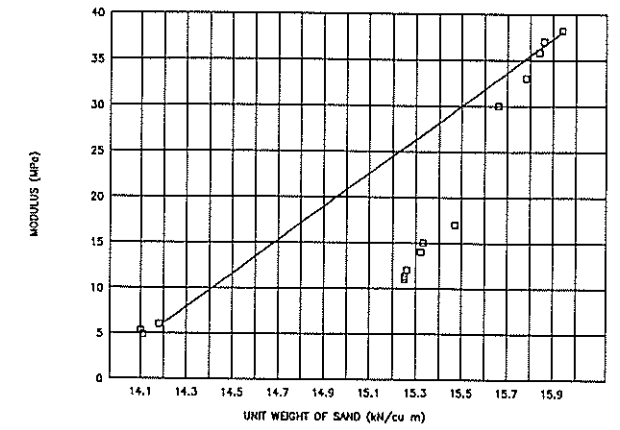

Figure 5. Comparison of modulus values for σ_v = 35 kPa.

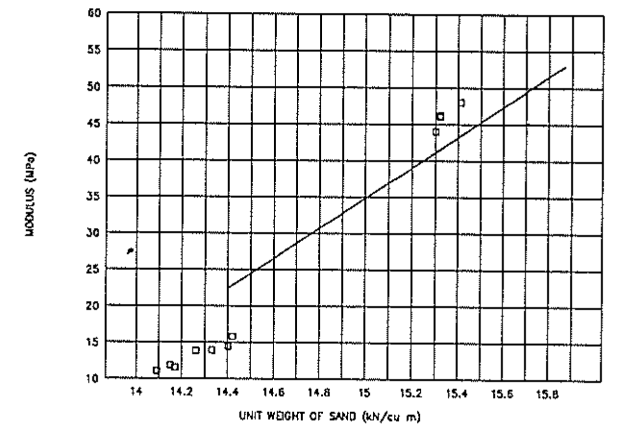

Figure 6. Comparison of modulus values for σ_v = 100 kPa.

5. DISCUSSION OF RESULTS

It seems probable that the sand, both above the screw plate and a small distance below the screw plate, has been very extensively sheared and is in the critical state. The actual density of the sand in each region will depend on the pressure conditions applying at the time of shearing, but dilation and reduction in density will certainly occur with the medium and dense sand.

The other effect which must influence the results is that the vertical stress beneath the screw plate, induced by the insertion process, particularly just below the plate, will cause an increase in horizontal stress which will not be released when the screw plate is released at the end of the insertion. Thus the sand beneath the screw plate is subject to higher horizontal stresses as a result of the insertion. Higher all-round stresses are known to cause an increase in modulus, but higher differences in horizontal and vertical stress may cause a decrease in modulus, so the resulting effect is uncertain.

6. CONCLUSIONS

Laboratory tests using a miniature screw plate show that when a screw plate is inserted into the sand under the control of a threaded rod having the same pitch as the screw plate, there may be considerable thrust developed beneath the screw plate.

In the case of loose sand at a surcharge pressure of 35 kPa, corresponding to depths of 2 - 3 m., the effect of the insertion disturbance on the values of modulus obtained appears to be negligible but may be appreciable in the case of greater depths and denser sands. However most of the values of modulus obtained were accurate or conservative, though some values were up to 10% high.

The effect of insertion disturbance could probably be reduced by allowing the screw plate to enter the soil free of control by the threaded rod until near the desired test depth, and engaging the threaded rod only for the final revolution in order to ensure good contact with the soil.

The insertion disturbance effects discussed appear to arise from dilation and hence will probably be reduced by the presence of silt in the sand.

7. REFERENCES

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