An Essential Foundation Control for the Design of Rubble Mound Breakwaters on Soft Soil

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ABSTRACT: The penetration of individual rock particles of breakwaters into soft seabed prevents rock particles to acts as a foundation so a large volume of materials sinks into seabed. This paper describes a laboratory research, which has been undertaken to study the penetration of rock particles, used as core material in rubble mound breakwaters, into soft marine deposits. Included in the research was the development of a new test procedure to determine the susceptibility of rock particles size and the influence of soft soil deposit. The research results show that the penetration or sinkage of core materials can be reduced by using fine material as a mattress, so an equation is proposed for estimating the thickness of mattress layer.

KEY WORDS: breakwater, mud cake, penetration, soft soil

INTRODUCTION

The bearing capacity mechanism associated with the construction of embankments on soft ground has been discussed by Jewell (1996). The construction of structures on a soft seabed can pose more difficult problems due to very low shear strength of soft marine deposits, (Azaraiah et al., 1999; Kulkarni et al., 1983; Lianqing, S., 1983).
The following subjects need to be considered when assessing the constructability of breakwaters over soft soils:
1. The yield stress and viscosity of the seabed, Fakher et al. (1999).
2. The bearing capacity and settlement of the seabed overlaid by a thin layer of breakwater (Fakher and Jones, 1996 and 2001).
3. The penetration of individual aggregates/ rock particles into the seabed.
The latter has not been fully investigated and be a critical case where large size aggregates are used to constructing core in rubble mound breakwaters. Even when the overall bearing capacity of the seabed is adequate, the penetration of individual rock particle into seabed needs to be checked for design.

EXPERIMENTAL STUDAY

A research programme has been undertaken to study the penetration of aggregates, used as core in rubble mound breakwaters, into soft marine deposits. Included in the research was the development of a new test apparatus and test procedure. Early experimental results of research have been reported by Amhadi et al. (2002). The presented research reports complete results and also an equation to design thickness of mattress.

Apparatus

The test apparatus consists of a steel cylinder with an internal diameter 100mm, a perforated loading plate and a loading system, Fig. (1). The loading system is the same as that used for the conventional California Bearing Ratio (CBR) test. As a result the proposed apparatus can be assembled easily in most soil mechanics laboratories. The diameter of the perforated loading plate is 2mm less than the internal diameter of steel cylinder to ensure ease of movement; the loading plate has 20mm thick and four perforations, each 5mm diameter. The loading plate is rigidly screwed to the load piston of the CBR test apparatus.

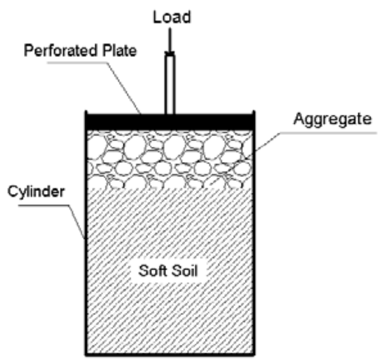

Fig. 1. Test apparatus

It should be noted that the proposed test is not the same as scaled physical models loading test used to determine bearing capacity. In a model testing to determine bearing capacity, the action of loading plate is to create a failure mechanism of foundation. In the proposed test the action of a loading plate is to push aggregated into the soft clay and create "mud cakes". The test is conceptually similar to a consolidation test where deformation is studied. Therefore the diameter of the loading plate is almost equal to the internal diameter of steel cylinder.

Material and sample preparation

The soft soil used in the tests was prepared by mixing fine soils (classified as CL has a LL=42 and PL=20) with water for 20 minutes at 25 ° C. The water content was change to produce sample with different shear strength in different tests. The shear strength of very soft soil such as marine clay has been shown to be a function of the liquid limit and water content, Fakher et al (1999).
The soft marine sample was placed in the test cylinder and a layer of aggregates was prepared and placed. The aggregates were first rained from a small height of 50 mm onto a plastic plate placed on the top of the steel cylinder. The plastic plate was quickly removed in a horizontal direction and the aggregates fell on the top of soft soil in the cylinder. Seven sizes of aggregates were used in the research, Table 1.

Table 1. Aggregates type

Aggregate Number	D_{10}	D_{30}	D_{50}	D_{60}
	(percentage of aggregate passing)			(mm)
1	19.6	21.7	22.0	22.6
2	16.1	16.7	17.4	17.65
3	5.6	7.2	10	11.3
4	4.07	4.21	4.4	4.43
5	3.42	3.57	3.67	3.73
6	2.88	2.95	3.0	3.13
7	2.07	2.2	2.38	2.46

Test procedure

Once the soft soil and aggregate were placed, the perforated plate was placed on top of the upper layer of the aggregate and pushed downward, Fig.1. The force required to push the plate and the underlying aggregates into the soft soil was recorded and the test was terminated when soft soil material was seen to extrude through the perforations in the loading plate. After the test, the sample was examined and the penetration of the aggregates into the soft soil was established.

RESULTS AND DISCUSSION

The results of tests are presented to show the influence of different parameters on the aggregate penetration. In all curves the vertical and horizontal axes are shown the force exerted by loading system and vertical displacement respectively. The effect of aggregate size on the increase of resistance to penetration of aggregate is shown in Fig. 2. The penetration resistance decreased when the aggregate size increased. The displacement also increases while the aggregate size increased. The larger size aggregates have a larger void space so a large vertical displacement of the loading plate is required for the voids to be filled by the soft soil.

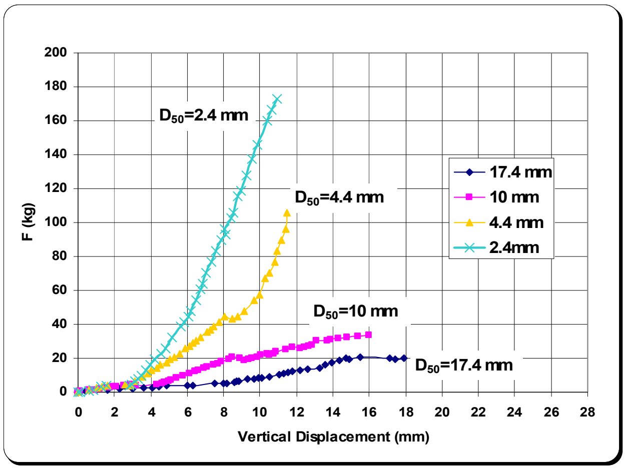

Fig. 2. The effect of aggregate size (D_{50}) on the resistance to penetration

The effect of soft soil water content is shown in Fig. 3. The increase in water content is caused a decrease on the penetration resistance.

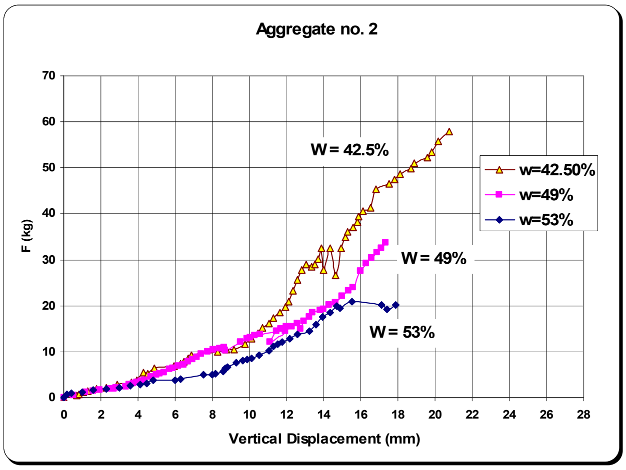

Fig. 3. The effect of soft soil water content on the resistance to penetration.

The effect of aggregate thickness is also considered in some tests. So a number of tests were performed with different aggregate thickness and an example of results is shown in Fig. 4. The penetration resistance increased when the aggregate thickness increased.

Considering the result curves shown in Fig. 2 to Fig. 4, it can be understood that the curves approximately have three stages as shown in Fig. 5.

The first stage having mild slope can be created because of sitting the aggregate onto soft soil or the influence of sitting loading plate on aggregate. The third stage that has steep slope also can be influenced from the perforated plate and a friction between soil and perforated plate. Therefore part 2 is less influenced than part 1 and part 3 by initial and boundary condition of tests.

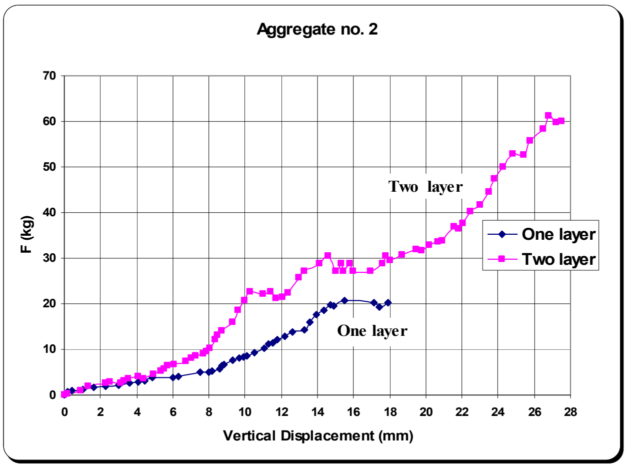

Fig. 4. The effect of aggregate thickness on the resistance to penetration
(The thickness of each layer = 25 mm)

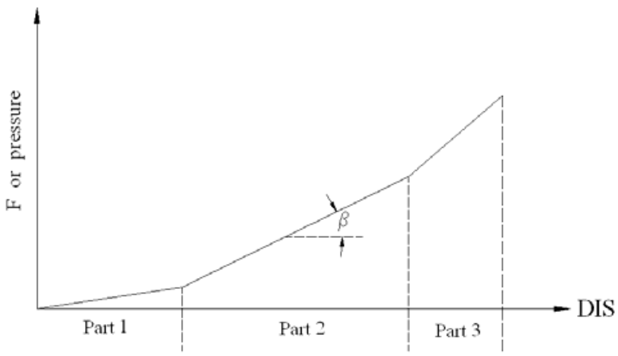

Fig. 5. Different stages in each result curve

To find the force or pressure required penetrating aggregate into soft soil, the mean slope of part 2 in the pressure-displacement curve shown with α in Fig. 5, could be selected. Based on this slope, (α); obtained from the pressure-displacement curve, Equation (1) can be presented between a pressure exerted on the breakwater bed and displacement.

$$\alpha = \tan\beta$$

$$\alpha = \frac{\Delta(\frac{F}{A})}{\Delta DiS} \rightarrow (\frac{F}{A}) = \alpha t \rightarrow p = \alpha t \qquad (1)$$

p: Pressure exerted on breakwater bed
α : Penetration resistance parameter (Table 2)
t : Mattress layer thickness as shown in Fig. (6)
F: Force exerted on bed
A: Cross-section area
Dis: Displacement

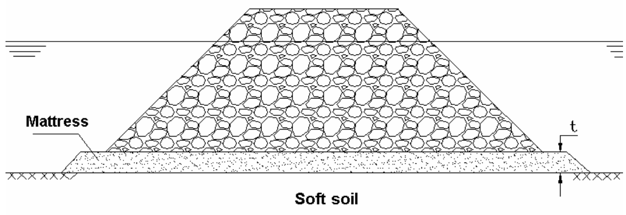

Fig. 6. Mattress layer

The value of α in Equation (1) is determined from test results. The α values are presented in Table 2 for different aggregate types and soft soil specification.

Table 2. Values proposed for α

Liquid Limit of soft soil	Moisture of soft soil	Aggregate diameter (mm)	α
42	53	17.4	0.23
42	53	10	0.35
42	53	4.4	0.89
34	43	17.4	0.12
34	43	10	0.25
34	43	4.4	0.78

CONCLUSIONS

The following conclusions can be drawn from the research study:
1. The proposed penetration test can be used to simulate the phenomena of aggregates penetration into soft soils.
2. The penetration of the breakwater aggregates can be reduced by use of smaller size aggregates as mattress layer.
3. The primary equation is proposed for determining mattress layer characteristics (thickness and particle size).

REFERENCES

Ahmadi, H., et al. (2002). Individual penetration of aggregates into soft seabed and the effects of geosynthetics. Geosynthetics – 7th – Delmas & Girard (eds), 1379-1381.
Azaraiah, I., Dhat, N.R., Gupta, R.P., Chhatre, M.V. (1999). Foundation problems in soft marine clays for breakwater. GEO shore, Porc. Of Int. Conf. on Offshore and Nearshore Geotechnical Eng., 371-376.
Fakher, A., Jones, C.J.F.P. (1996). Bearing capacity of rectangular footing on geogrid reinforced sand. Journal of Geotechnical and Geoenviromental Eng., ASCE, 326-327.

Fakher, A., Joens, C.J.F.P. and Clarke, B. G. (1999). The yield stress of super soft clays. Journal of Geotechnical and Geoenviromental Eng., ASCE, 125, 499-509.

Fakher, A., Jones, C.J.F.P. (2001). When the bending stiffness of geosynthetic reinforcement is important? Geosynthetic International Journal, 8, No. 5, 445-640.

Jewell, R. A. (1996). Soil Reinforcement with geotextiles. CIRIA. 332 p.

Kulkarni, S.P., Bapaye, D.R., Paliwal, S.T., Mokhashi, S.L. (1983). Breakwater on soft soil at Kakinada-a case study. Porc. of Int. Conf. on Coastal and Port Eng. in Developing Countries, Colombo, 888-902.

Lianqing, S. (1983). Soft soil basement and its treatment of the coastal levee engineering. Porc. Of Int. Conf. on Coastal and Port Eng. in Developing Countries, Colombo, 903-909.