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On the Bearing Capacity of Suction Bucket Foundation in Saturated Sand

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The load displacement curves of a suction bucket foundation under vertical, horizontal and combined loadings are studied experimentally. The effects of sand density on the bearing capacity are also investigated. It is shown that, under combined loading, the load conditions under which a foundation fails form a failure locus. The horizontal bearing capacity increases with the increase of the vertical loading if the latter is below a critical value. But the horizontal bearing capacity decreases when it exceeds the critical value. The bearing capacity increases with the increase of the sand density in the range of the experiments in this paper. For the same bucket diam, the horizontal bearing capacity increases with the aspect ratio (H/D). The vertical bearing capacity is influenced by the aspect ratio and the ratio of the height of the sand bed to that of the bucket.

INTRODUCTION

Suction bucket foundations are being extensively used as deepwater anchors for floating structures or foundations for oil platforms (Bye and Erbric, 1995; Lu, Zheng and Zhang, 2003; Randolph, O'Neil and Stewart, 1998; Senpere and Auvergne, 1982) in offshore engineering. Bucket foundations are hollow cylindrical structures with a top plate and a relatively thin wall known as a skirt. Installing a bucket foundation involves initial penetration into the seabed under self-weight and water being trapped inside the bucket between the sand surface and the top plate. The bucket is lowered further by pumping the trapped water, thus driving the bucket further into the sand to its final position (Dyme and Andersen, 1998; Aas and Andersen, 1992).

Although some research has been carried out on the bearing capacity of this type of foundation (Tjelta and Hermstad, 1990; Eide and Andersen, 1997; Allersma, Brinkgreve and Simon, 2000), many other problems remain to be solved.

In order to further investigate effects on bearing capacity, we studied the load displacement curves of the foundation under static vertical, horizontal and combined loadings, and the effects of the aspect ratio (bucket height divided by bucket diam, H/D) of the bucket and the density of the sand. The experiments are carried out in 2 tanks. The height × width × length ratios are, respectively, $1500 \times 800 \times 1400$ mm^3 (No. 1) and $500 \times 500 \times 500$ mm^3 (No. 2).

LAYOUT OF EXPERIMENTS

The effect of sand density on the bearing capacity of a bucket foundation was investigated in the No. 1 tank. The other experiments were carried out in the No. 2 tank.

The model buckets are made of steel. Two of the model buckets used in the No. 2 tank are each 100 mm in diam; they are 100 mm and 50 mm high, respectively. The third model bucket used in the No. 2 tank is 60 mm in diam and 90 mm high. The side wall and the top plate are 2 mm and 15 mm thick, respectively. The main reason to choose this value as the thickness of the top plate is for the convenience of placing the load head on the top plate. The aspect ratios of the model buckets are 1:2; 1.5:1 and 1:1, respectively. The model bucket used in the No. 1 tank is 200 mm in diam and 200 mm high. The side wall and the top plate are 5 mm and 20 mm thick, respectively. The sand is obtained from Zhangzhou, in China's Fujian Province; its grain-size distribution is 0.7∼4 mm (Fig. 1), and its dry density is 1.58 g/mm^3∼2.05 g/mm^3.

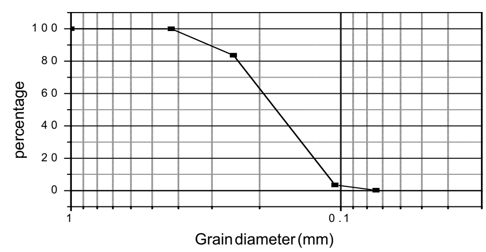

Fig. 1 Grain-size distribution of sand; percentage = dividing weight of grains smaller than a given value by total weight

The No. 2 tank is placed in a triaxial test frame (Fig. 2a). Displacement transducers are installed to measure the horizontal and vertical displacements. The range of each displacement transducer is 0∼50 mm. The vertical load is applied by the vertical load system of the triaxial test frame if it is bigger than 100 N. If smaller than 100 N, weights are placed directly on the bucket's top plate. The load head and the bucket are connected through a pressure transducer whose measuring range is 6000 N. Fig. 2 shows the model layout. The horizontal load is applied by weights. A steel wire connects the bucket and the weights. A pulley is placed at the tank's side wall.

In each experiment, sand is put into the tank layer by layer and compacted by a steel plate. Each layer is 50 mm high. After arriving at the design height, the sand layer is penetrated by water through a hole at the bottom of the tank. A 2-cm-thick coarse sand layer is placed at the bottom of the tank to prevent piping. When the water thickness above the sand layer surface is 1 cm, the sand is left alone for 24 h to allow sufficient time for saturation and settlement. The bucket is pressed into the sand at the beginning

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