Evaluating the capacity of the Multi-Plate Mechanical Anchors in Granular Soils

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ABSTRACT

Nowadays, humans have thought of creating structures and platforms onshore and offshore to provide energy. Until now, various anchors with different shapes have been introduced for strength and stability of platforms, for offshore and onshore applications. In this research, a new type of expendable multi-plate anchors is proposed with the ability to expand the plates in the soil with lower energy. As these anchors are recently introduced, their bearing capacity has not been extensively evaluated. In this research, the behavior of these anchors was investigated experimentally. The evaluated parameters are soil compaction and distance between plates on the maximum pull-out capacity of them. Firstly the performance of single plate anchors was compared with the double plate anchors with equivalent areas then the effect of above mentioned parameters was determined for double plate anchors Based on the experimental results, single-plate shows higher bearing capacity in high soil compaction, but in low soil compaction, the bearing capacity of the double plate capacity is increased. The effect of the distance between the plates on the final bearing capacity has been far greater than the effect of the change in soil density. Also, 4 different soil compaction and distance between two plates for a double plate were investigated. Overall the effects of distance between two plates have more impact on bearing capacity in comparison to soil compaction

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1. Introduction

Different types of mooring systems are utilized in the sea, each designed for varying installation conditions. In some cases, these conditions make their use cost-effective. Consequently, many researchers have endeavored to identify the best type of mooring system by examining parameters such as penetration depth, opening speed, locking mechanism, and final load capacity under different conditions. Various mooring systems have been proposed based on their apparent shape, which has led to differences in their load-carrying capacity. Among the mechanical mooring systems used both on land and at sea, we can mention simple horizontal, inclined, and vertical flat plate moorings, fixed moorings, multi-page moorings, cross moorings, opening moorings, spiral moorings, angle moorings, vertically loaded moorings (VLA), moorings with embedded suction plate (SEPLA), deep placement flat plate moorings (DEPLA) such as Omni-max moorings, and dynamic moorings, volume moorings (caisson), gravitational attraction moorings, and so forth [1-6].

Kumar and Kozar[7] investigated the load-bearing capacity of several mooring systems with shallow horizontal plates in soil. They stated that if the distance between mooring systems placed next to each other is more than twice the depth of placement in the tangent of the internal friction angle of the soil, no interference occurs between the rupture discs. However, if the spacing of the plates is less than the specified amount, interference occurs between the rupture discs, leading to a reduction in load-bearing capacity.

Amjadi et al [8] numerically examined the behavior of multi-page mooring systems and evaluated methods such as finite element analysis, extended finite element analysis, and separate elements. The comparison of numerical and experimental results showed that the extended finite element method provides a more accurate prediction of the behavior of these mooring systems. In this study, parameters such as the geometry of the mooring, soil density, spacing between plates, and the number of plates were evaluated. Numerical modeling results indicated that with an increase in the number of plates, the outward extension capacity increases from a single plate state to a double plate state, but there is little change in the outward extension capacity when transitioning from a double plate mooring to a triple plate mooring.

Methodology

The mooring plates are made of steel and have a thickness of 3mm to prevent deformation. The size of the plates in both single-plate and double-plate conditions is the same, and the dimensions used for the single-plate and double-plate conditions are 28.3 * 28.3 cm and 20*20 cm (total area = 800 cm²). The 20*20 cm plates form the double-plate mooring system, equivalent to a single-plate mooring system with dimensions of 28.3 * 28.3 cm. To connect the plates to the mooring rod, 4 rivets were used, which are welded on both sides of the plates. These rivets are connected to a circular-shaped movable and fixed holder piece on the mooring rod using screws. The movable piece is screwed onto the mooring rod at the desired height, where previously drilled holes for screwing and connecting the movable piece on it have been considered to prevent movement of the sleeve after selecting the desired distance. The test chamber consists of a soil box with dimensions of 1*1*1 (m³) and a steel frame for positioning the loading device at a specific height. The loading device is equipped with a 1.5 horsepower (hp 5/1) motor operating at 1420 rpm, a gearbox with a power of 5.7 kg, and a data logger for controlling speed and data extraction. The force is measured by a force sensor with a capacity of 2 tons and a precision of 1/0 g. Furthermore, a digital ruler with a length of m1 and a precision of mm1/0 is used to measure the displacement of the plates. A rod transfers the force from within the gearbox to the bottom, where it is connected to the force sensor. At the bottom of the force sensor, the mooring rod is positioned, and the plates are mounted on the mooring rod. Both the force sensor and the digital ruler are paired to ensure highly accurate results. The data logger regulates the motor speed to prevent it from exceeding or falling below the permissible limits. To enhance measurement accuracy, a display is used for measuring force.

2. Results and Discussion

In Figure 1, the difference between the minimum and maximum forces applied on single and double-plate mooring systems is depicted. It was observed that the increase in density had the greatest impact on increasing the load-bearing capacity on the double-plate condition with a plate spacing of .5B, and the least impact on the double-plate condition with a plate spacing of 2B. In the single-plate condition, the increase in density resulted in a force increase of 39.6%, which, when compared with other conditions (as shown in Figure 1), indicates that the increase in this condition (single-plate condition) was greater than all double-plate conditions (except for the double-plate condition with half-width spacing, where the effect of density on force increase was approximately 52.4%, due to the inability of the plates to open continuously at a density of 35%). As mentioned, the highest force achieved in the double-plate condition was in states 1B and .5B, as indicated by Figure 1, showing that the effect of density on force increase in state 1B was less than in state 1.5B. However, the force obtained in mooring B1 was 10% higher than in state 1.5B. In the single-plate condition, the difference between the minimum and maximum forces varied by 39.6% across different densities, which was greater than in state 2B. Considering the information provided, it can be concluded that the distance relative to density plays a more significant role in increasing load-bearing capacity; since the greatest difference between forces was caused by the increase in density in state .5B. This can also be illustrated by comparing state 1B and 1.5B (the difference between the minimum and maximum forces in state 1.5B was greater than in state 1B).

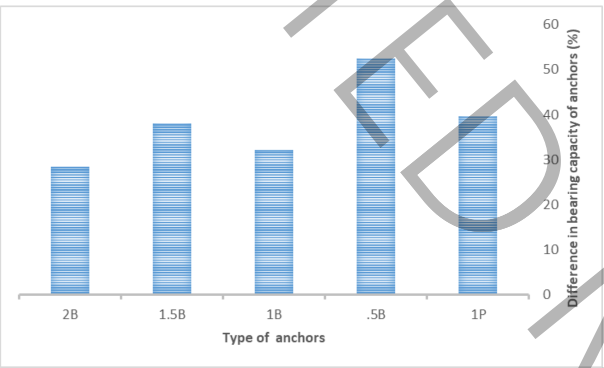

Fig. 1. Difference in bearing capacity of anchors and type of anchors

In summary, the rate at which mooring systems open is a fundamental factor in determining the load-bearing capacity of these systems, and any factor that changes the rate of opening can directly and significantly affect the load-bearing capacity; an effect that will be even greater than factors such as area and density. The greatest displacement for the opening of mooring systems occurred in the double-plate mooring system with a plate spacing of B2 (approximately mm145 at a density of 80%), and the least displacement for the double-plate mooring system with a plate spacing of B5/1 (approximately mm4/20 at a density of 70%). By comparing the displacement required for the single-plate and double-plate conditions, it can be inferred that generally, the displacement required in the single-plate condition is greater than in the double-plate condition, except in a case where the spacing between the plates is twice the width, which can be attributed to the lesser amount of soil above the upper plate (the plate closest to the ground level). By averaging the different spacings of each mooring system at various densities and when the mooring system has opened and reached its maximum force, a general examination of the opening rate of the mooring system can be conducted.

3. Conclusions

[1] In the single-plate mooring system, after reaching its maximum capacity, it experiences a steeper decline compared to the double-plate system. In densities of 80%, 70%, 60%, 50%, and 35%, the double-plate system's diagram descends at a much gentler slope, and in some density conditions, there is no significant difference between the maximum load-bearing capacity and the total load-bearing capacity of the diagram, indicating the stabilizing effect of the second plate on the slope of the diagram and preventing the decline in load-bearing capacity.

[2] Based on the diagram of the single-plate mooring system with dimensions of 283*mm², it can be stated that density has a greater impact on the single-plate condition. The greatest effect of density on .5B is about 52.4%, which increases the force. The reason for this can be attributed to the small spacing between the plates, which allows more soil particles to be placed between the two plates with higher density, preventing the formation of empty spaces between the plates.

4. References

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