Design and application of cone penetration test equipment in shoal water

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In order to provide the academic and industry with a cost-effective cone penetration test (CPT) equipment with particular emphasis on testing in shoal water, we designed the shoal-water CPT equipment. The buoyancy system distinguishes the shoal-water CPT equipment from others. Before the test, the shoal-water CPT equipment can be towed by a small boat with the buoyancy system charged. Having reached the scheduled site, we bleed the buoyancy system. The shoal-water CPT equipment sink to the seafloor with no enough buoyancy. We conducted a test at the Yellow River subaqueous delta, China. The CPT equipment works well.

[Keywords: cone penetration test; shoal water; buoyancy system; sediment strength; submarine landslide]

Introduction

With the flourishing exploitation and development of the ocean energy engineering, port engineering, submarine communication engineering as well as the coastal reclamation engineering, quite a number of engineering geological problems have been encountered in the process of design, construction, operation, and maintenance1.

Marine sediments are usually soft with low strengths at the surface2, leading to more difficulties and cost in recovering high quality sediment samples. Therefore, the in-situ test is a believable method for the determination of sediment parameters. As the energy exploration and engineering construction move into sea, more and more structures are placed on the seafloor. Consequently, there is a strong need for in-situ tests of seabed sediment strength. The cone penetration test (CPT) has become one of the most important in-situ test techniques for offshore site investigations3,5.

However, too more emphases are placed on deep water while little placed on the shoal water. In the past 50 years, the cone penetration test equipment has been designed successfully to test in water depths near 4000m on huge floating barge or advanced vessel5,7. Given the deep draught for a huge vessel, it is difficult to conduct the cone penetration test in shoal water zone. Moreover, there is a growing need for cost-effective shoal-water cone penetration test equipment.

This paper describes our cone penetration test equipment with particular emphasis on testing in shoal water. The offshore cone penetration test equipment can float and sink flexibly in shoal water by charging and bleeding the buoyancy system. The CPT tests can be done on a small boat without a crane.

Materials and Methods

The shoal-water CPT equipment is composed of four major sections: penetration system, hydraulic system, control system and the variable-buoyancy system. Generally, the ordinary CPT equipment used on land also has the former three systems. The penetration system is used to push the probe (rod and cone) into the soils/sediments. The probe contains sensors that record tip resistance and side friction. The hydraulic system serves as the heart that provides power for other systems. The under-water direct-current motor and hydraulic drive units are the main components of the hydraulic system. The control system is used for monitoring the equipment status, such as the water depth and penetration depth.

The buoyancy system distinguishes the shoal-water cone penetration test equipment from others (Figure 1, Figure 2). The variable-buoyancy system is composed of 24 symmetrically distributed units and each unit consists of the tubular casing and air float (Figure 2). Each unit can provide greatest buoyancy of 90 kg and total buoyancy the variable-buoyancy system can provide is 2 140 kg.
The study area was located at the Yellow River subaqueous delta, China. There are many oil platforms in the Yellow River subaqueous delta. Therefore, it is important to obtain the sediment strength in this area for the construction of oil platforms and submarine pipelines.

The average water depth of the study site (118.92°N, 38.17°E) is 6.8 m. The location and the water depth can be seen in the figure 3. From this figure, we can know the rough geography, high in the southwest and low in the northeast. We also obtained some sediment samples and made some geotechnical tests in laboratory. Here are the results: the sediments in the study site is mainly silt, with water content of 21.54%, density of 2.01 g/cm³, void ratio of 0.64 and plasticity index of 6.

We conducted the CPT test on April 22, 2015. Before the test, the shoal-water CPT equipment was towed by a boat with the buoyancy system charged (Figure 4). Having reached the study site, we bled the buoyancy system. The shoal-water CPT equipment therefore sank to the seafloor with no enough buoyancy. Then the CPT equipment worked on the seafloor automatically.

**Results and Discussion**

The probe penetrated the seabed up to 2.5 m. The side friction and cone tip resistance were
obtained, which can be seen from figure 5. Within the depth of one meter, both the side friction and tip resistance increase roughly along depth. The maximum side friction is near 160 kPa and the maximum tip resistance is about 7 MPa. With the depth deeper than one meter, both the side friction and tip resistance begin to increase along depth. Judging from the side friction, tip resistance and friction-resistance ratio, we can find sediment strength stratification at the depth of one meter. The sediment strength interface may be the potential surface of submarine landslide in the Yellow River subaqueous delta.

Conclusions

By charging and bleeding the buoyancy system, the CPT equipment can float and sink flexibly in water. Given the small draught for a small boat, the CPT equipment can work in shoal water. The buoyancy system makes us do the CPT tests easily on a small boat without a crane system.

The potential surface of submarine landslide in the Yellow River subaqueous delta may be at the depth of about one meter.

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