Panel discussion: Testing a friction barrette in decomposed granite in Hong Kong

Débat de spécialistes: Essai sur une barrette flottante dans du granit décomposé à Hong Kong

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ABSTRACT: A large section (2.8m by 0.8m by 42m deep) rectangular excavated pile (barrette) is being constructed at Kowloon Bay in Hong Kong. The construction and testing of this barrette form part of a three-year research project to investigate stress transfer mechanisms of friction barrettes. The main objectives of the research include collecting and interpreting some existing relevant instrumented pile test results, performing additional high quality full-scale pile tests. These test results will be used to verify numerical predictions and centrifuge model tests of barrette piles. All data will be analyzed using the state-of-the-art probability and reliability methods.

1 INTRODUCTION

Choice land is extremely expensive in Hong Kong; in order to satisfy the needs for rapid growth in commerce and financial activities, tall buildings are being built to acquire space for development. Hong Kong's skyline changes every year, it is expected that this trend will continue for many years to come. Many of the tall buildings are located along the Victoria Harbor on the Hong Kong Island. The stretch of land from Central to Admiralty has perhaps the highest density of tall buildings in the world.

Tall buildings developed along the Victoria Harbor in Hong Kong are commonly founded on reclaimed land, thus deep foundations are required to resist both vertical and horizontal loads due to the weight of the building and wind. The prevailing foundation type for tall buildings on reclaimed lands is the drilled or excavated piles. These piles are very long, normally in excess of 50 meters. They can be circular or rectangular in shape and must be drilled through the fill, the underlying marine soft deposits and into the deep decomposed granitic soil (saprolite), which is completely and highly weathered in succession. The thickness of the decomposed granite can be up to 80m and in some places, and its depth exceeds 100m measuring from the ground surface. Standard penetration tests (SPT) show that N-value typically varies from 15 at the top of the decomposed granite to exceed 200 at the bottom. According to Hong Kong practice, only the shaft resistance in the decomposed granite layer is considered in estimating the pile capacity. Because of the high ground water table, circular drilled pile with casing is normally used if the pile is less than 40 meters long. For deeper foundations, a large cross-section rectangular excavated pile called "Barrette" is used. Barrettes may be formed in short trenches using conventional diaphragm walling equipment of grab and chisel. Drilling fluids (bentonite) must be used to provide temporary support in an unlined trench. In design of friction barrettes, the designers have two approaches open to them.

a. The traditional approach - simply assuming 10 kPa for value of skin friction as per current design guidelines or

b. By performing at least one full-scale loading test on each site (irrespective to the size of the site or the number of barrettes), to prove that a higher value of skin friction is achievable at the site.

Among the geotechnical engineers and contractors in Hong Kong, it is generally recognized that a skin friction value, which typically varies between 0.8N and 2N (kPa), would be mobilized along the shaft of the barrette and can be used for deep foundation design. However, according to the current guideline, any design value which is more than 10 kPa must be validated by full-scale pile load test on site. Such exercise can be very costly (typically in excess of US$300,000 per test) and time consuming (at least one month of construction and testing; and three months of submission and approval by the authority). The cost excludes interest loss during the construction and testing of the barrette. For a typical US$ 500 million building project at the Central District in Hong Kong, the cost of borrowing is substantial.

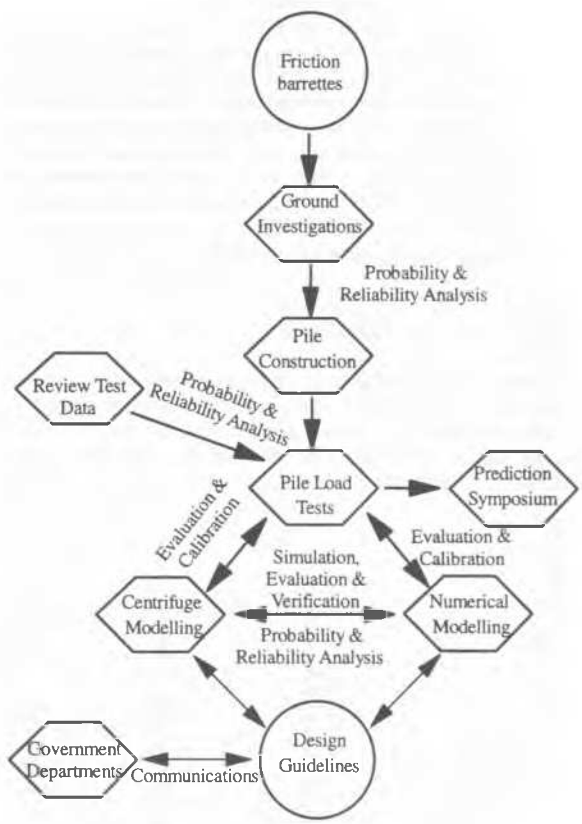

Figure 1. Research Strategy and Implementation Plan

The estimation of skin friction development along a long pile shaft is a very difficult task. It is affected by the method of construction, workmanship, the use of slurry, the concrete to be tremied, etc. so any attempt to increase the design skin friction value must be done with caution. A task force has recently been formed, with participants from the government, the industry and our university, to carefully study this problem aiming at the development of a more reasonable design guideline for deep pile foundation in Hong Kong. This is a 3-year project involving the tasks as illustrated in Figure 1. The one that is now underway is the pile load test which is heavily instrumented, and its loading behavior monitored. The prime objective of the instrumentation is to investigate the load transfer mechanism and load-settlement characteristics of the barrette. In addition, it is intended to study ground deformations due to the construction of the barrette, which is similar to a diaphragm wall construction.

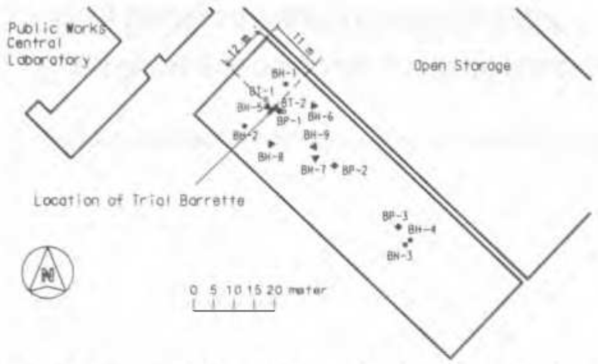

Figure 2. Location of the trial barrette at Kowloon Bay, Hong Kong

2 SITE LOCATION AND GROUND CONDITIONS

The site is located on the Kowloon peninsular of Hong Kong, adjacent to a runway for the Kai Tak international airport. Figure 2 shows the location of the test barrette and the locations of boreholes. Based on a large number of boreholes close to the barrette, a soil profile with SPT-N values can be summarized and is given in Figure 3. The site is on reclaimed land and the ground level is at approximately 4.48 mPD. The ground water level is at about 3.2m below ground surface. The fill material is about 6m thick and it overlies layers of marine deposit and alluvium. The weathered granite is located approximately 25 meters below the sea level; its properties vary from extremely weak to strong. It is a medium grained granite, slightly to completely decomposed. At elevation - 38.5mPD the SPT-N value is 100 or more. Based on results of drained triaxial compression tests, effective cohesion and angle of friction were found to be 0 and 39°, respectively.

3 DETAILS OF CONSTRUCTION

The test barrette will be excavated using a traditional cable operated grab. The size of the excavated trench is 2.8m by 0.8m on plane and 41.8m deep (see Figure 3). During construction, the trench will be temporarily supported by bentonite. Soil spoil, suspended in the bentonite slurry, is pumped to a desanding unit at the ground surface. After desanding, the bentonite will be returned to the trench. When the excavation reaches its final level, instrumented reinforcement cage will be lowered into the trench, which is then concreted subsequently. The construction method of the barrette, in fact, is very similar to the construction of a typical diaphragm wall panel.

At the upper half of the reinforcement cage, a sheathing layer will be formed to minimize skin friction developed between the pile and the surrounding soil. This sheathing layer consists of a steel plate, which is welded onto the reinforcement cage, a flexible and weak "voltex" layer (i.e., wooden cardboard infilled by sodium bentonite), and a thin sheet of plywood. These three materials are sandwiched together to provide a low frictional interface. It is expected that shearing would take place along the weak "voltex" layer.

At the bottom of the barrette, a "soft" base will be formed. This is done by lowering a 2.8m x 0.8m x 0.2m in height steel box to the bottom of the trench. 3mm thick steel plate is used to form the box, which is then filled with fine and rounded sand. After concreting, the sand-filled steel box is drilled through via two cast-in flushing pipes inside the barrette (see Figure 4). Pressurized water is pumped into one of the pipes to flush the rounded fine sand out of the box. Great care will be taken to ensure that most of the infilled sand is flushed out to form a "soft base" (i.e., void) underneath the barrette.

4 INSTRUMENTATION

Figures 4 and 5 show the various instrument and their locations in and around the test pile. The instrumentation installed is summarized in Table 1.

Table 1. A summary of instrumentation

Inside the Barrette	Outside the Barrette
Strain gauges	Magnetic extensometers
Rod extensometers	Inclinometers
In-place inclinometers	Pneumatic piezometer
Pneumatic piezometers	Settlement markers
Earth pressure cells	

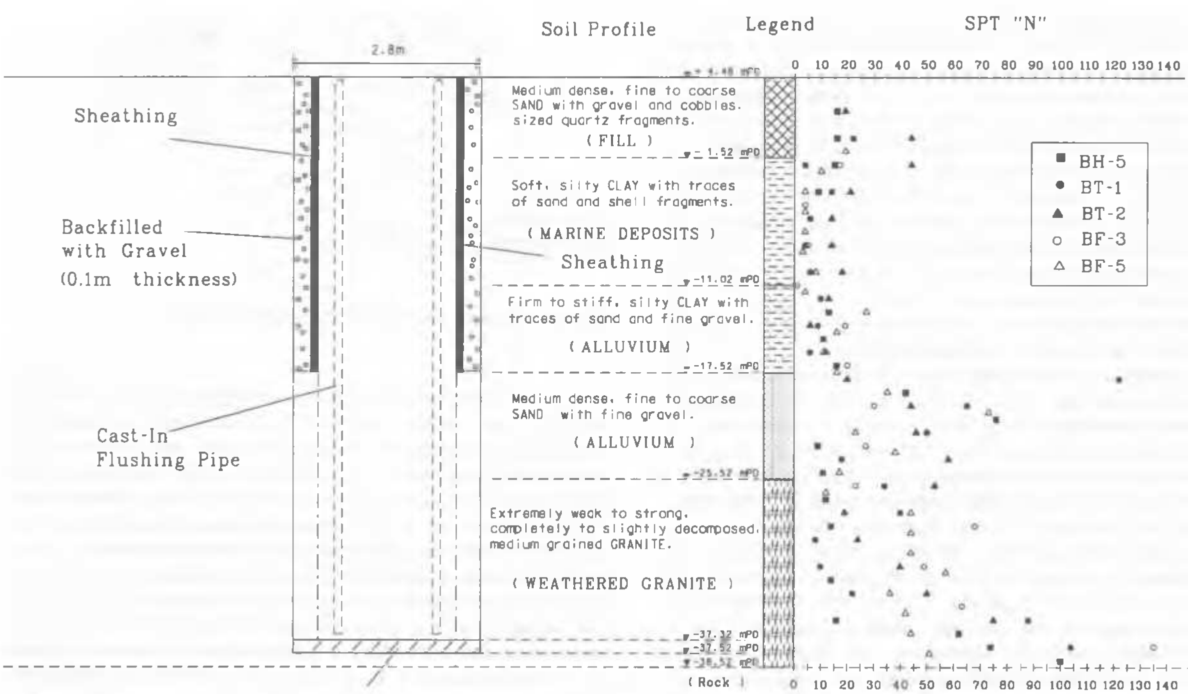

Figure 3. Borehole logs and SPT values at Kowloon Bay, Hong Kong

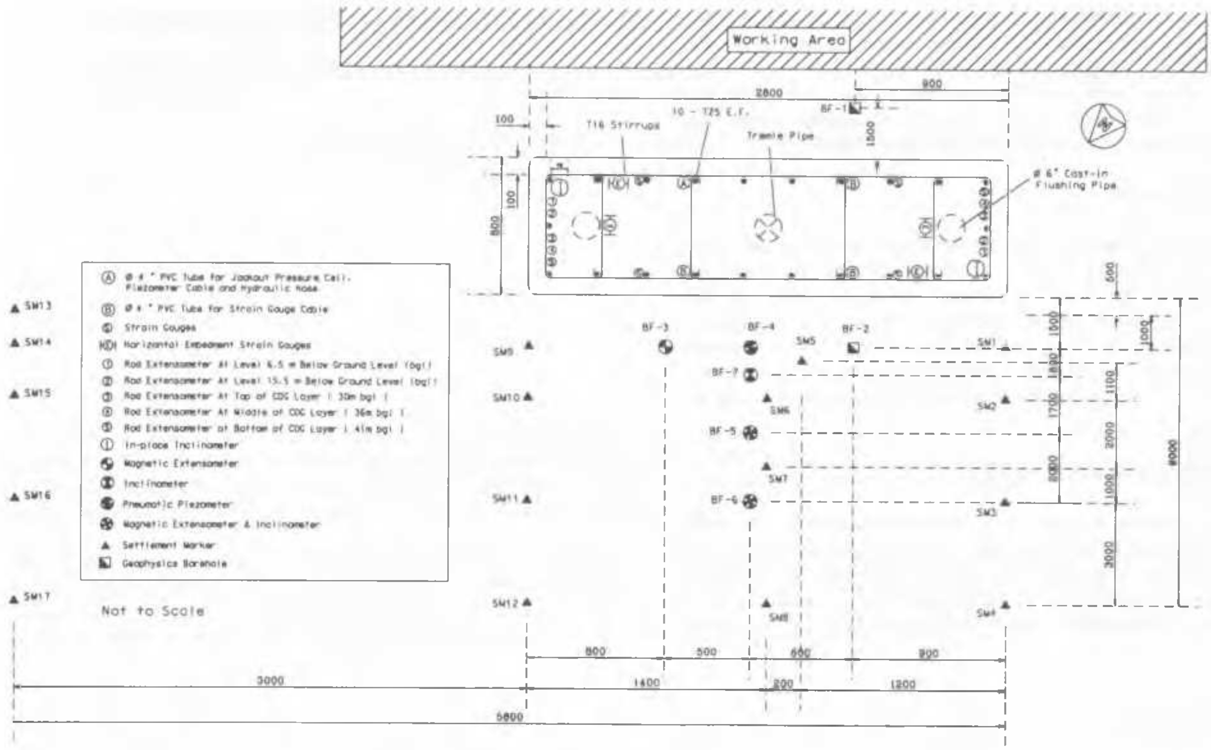

Figure 4. Layout of instrumentation (plan view)

4.1 *Vibrating Wire Strain Gages with Temperature Sensors*

Strain gauges will be placed at 28 levels in a reinforcement cage. On each level, either four surface mounted or four embedded strain gauges are installed vertically. These types of strain gauges are placed in alternative layers. Moreover, four levels of horizontally embedded strain gauges, with four numbers in each level, and another five levels of dummy gauges, which has a total of 10 gauges, are installed in the same cage. A total of 138 gauges are installed which would be used to determine strain distributions along the entire depth and along the width at certain levels of the barrette and hence deduce skin friction and Poisson's ratio effects and possibly end bearing capacity in CDG, in which strain gauges are installed at one meter interval.

4.2 *Rod Extensometers*

Ten rod extensometers will be installed within the cage in five levels. They are used to measure the displacement at each corresponding level along the depth of the barrette. A steel plate is welded on the top of each rod extensometer in order to provide a flat reference datum. Dial gauges are used to measure any movement of the rod extensometers. The details of the location plan and the end levels of each rod extensometer are shown in Figures 4 and 5, respectively.

4.3 *In-place Inclinometers*

A total of 38 biaxial servo-accelerometer sensors will be installed at 19 levels (most of them at 2m-interval) in two cast-in tubes inside the barrette. The locations of the in-place inclinometers and the levels of sensors are indicated in Figures 4 and 5, respectively. The bottom of the inclinometers is installed in rock. These in-place inclinometers are designed to measure rotations and hence horizontal movements of the barrette during loading.

4.4 *Earth Pressure Cells and Pneumatic Piezometers*

Earth pressure cells will be installed at four levels, with two on each face of the barrette. The levels of the earth pressure cells are shown in Figure 5. All earth pressure cells are installed in the lowest steel cage to measure total horizontal pressures at the soil-wall interface in the CDG stratum. In order to measure pore water pressures at the locations

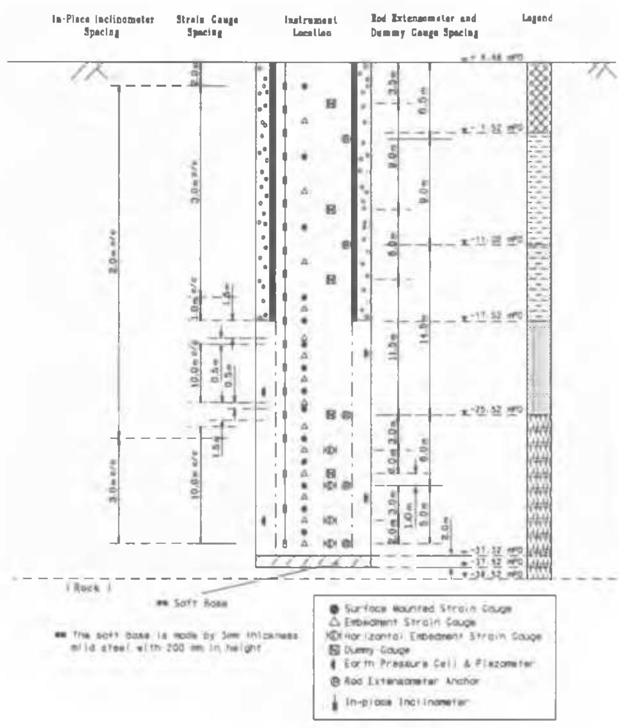

Figure 5. Layout of instrumentation (cross-section)

of the earth pressure cell, four pneumatic piezometers are installed at about 150mm below them.

In addition, one pneumatic piezometer is installed inside borehole BF-4 (see Figure 4) at 35m below ground in the CDG stratum to monitor pore water pressure changes.

4.5 *Magnetic Extensometers*

The magnetic extensometers consist of a datum magnet, a PVC access tube and spider magnets and they are installed into boreholes BF-3, BF-5 and BF-6 (see Figure 4). The datum magnet is installed in rock. There are totally 20 spider magnets in borehole BF-3, and 8 spider magnets in both boreholes BF-5 and BF-6. Soil movements are measured by monitoring the location of each magnetic target (i.e., difference between spider magnet and the datum magnet).

4.6 *Inclinometers*

Three MK4 inclinometers system are installed in boreholes, BF-5, BF-6, and BF-7, as shown in Figure 4. The bottom of the inclinometers are located in rock. The MK4 inclinometer system consists of a PVC access tube, torpedoes, operating cable and readout units. It is used to measure rotations and hence the lateral movement of the soil around the trial barrette. The readings will be taken at 0.5m interval to the depth of 47m below ground level in order to obtain soil deformation profiles.

4.7 *Surface Settlement Markers*

A total of 17 settlement makers are installed around the trial barrette, as shown in Figure 4. The settlement monitoring system consists of a steel probe, which is installed in a hole of 1.5 m depth below ground level. They are used to measure settlements of the ground due to the construction of barrette (i.e., similar to the construction of a diaphragm wall).

5 SUMMARY

At the time of submission of this paper, instrumentation outside the barrette has been just completed. The construction of the barrette will start at the end of November 1997 and the testing will commence at the middle of December 1997.

It is anticipated that one or two more pile load tests will be performed in the coming year, which together with another 15 or so available full-scale testing records will form the basis for further analysis and interpretation of shaft resistance capacity of deep piles. Because of the complexity of this problem, probability and reliability analysis of the data will be carried out, in conjunction with investigations of the pertinent parameters affecting shaft resistance in decomposed granite using centrifuge modeling and numerical simulation.

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