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SYNOPSIS Barrettes become not an uncommon foundation element used to support multi-storey buildings, elevated expressways and underground station boxes in Bangkok, Thailand. The demand for barrettes is necessitated mainly by constraints of site conditions, construction method, equipment and extensive bearing capacity requirement, etc. This paper presents construction practice and the performance of barrette constructed in Bangkok metropolis. Trial trenching near a canal for assessment of trench stability and soil deformation are presented. Choice of barrette and common defects found in barrette are also discussed.

INTRODUCTION

Recently published papers indicate that barrettes become a common foundation type used in various soil conditions to carry very high load for sky scrapers. Development of properties and infrastructures such as construction of multi-storied buildings, elevated expressways, subway railway stations, etc. demand deep foundations with large bearing capacity in Bangkok metropolis, Thailand. Bangkok is well known for its subsoils constraints especially, by the presence of thick soft clay on the top, followed by a series of alternating stiff clay or hard clay and dense or medium dense sand layers. Due to not only the subsoil conditions, but also non-availability of adequate construction area and overlapping developments above and underground, barrettes become common to replace the usual large diameter bored cast in-situ piles in circular shape. The earliest barrettes of 0.82m x 2.98m-3.0m with toe depth of 50m were constructed in Bangkok around 1985 for International Trade Centre building in conjunction with diaphragm wall for basement construction. The first static load test on a barrette (0.82 x 2.7 x 61.8m) in Bangkok was carried out in 1992 for a 55 storey building on Silom Road, Bangkok.

CONSTRUCTION METHOD

Normally a cable hung grab mounted on crawler crane is used for trenching under supporting fluid which is commonly bentonite slurry. Concrete pouring is carried out under bentonite slurry using tremie pipes. Properties of

slurry used for trenching in Bangkok subsoil usually comply with DFCP-4 of the Oil Companies Materials Association and the Institution of Civil Engineers' (ICE) Specification for Piling and Embedded Retaining Walls. The usual bentonite slurry properties specified are 1.10g/ml for density, 30-50sec for viscosity (Marsh' cone), 8-11.5 for pH and not more than 4% for sand content. Usually 3m to 6m long sections of steel tremie pipe of 25cm in diameter are joined together to form a continuous pipe with required length for concrete pouring under the slurry.

Cast-in-situ reinforced concrete, pre-cast concrete and temporary steel box guide walls appropriate for site conditions are used for trenching. In normal site conditions, guide walls with a minimum depth of 1.2m are commonly used. Base grouting is also used to improve the capacity and performance of barrettes if necessary.

Generally an average rate of excavation about 10-15m²/hr is achieved with mechanical grab in Bangkok subsoil. Usually, excavation rate decreases with increment in excavation depth, having non-linear relationship between excavation time and depth. Figure 1 illustrates excavation time and rate vs. excavation depth for barrettes of 1.50 x 3.00 x 55.00m. with no site constraint and idling time.

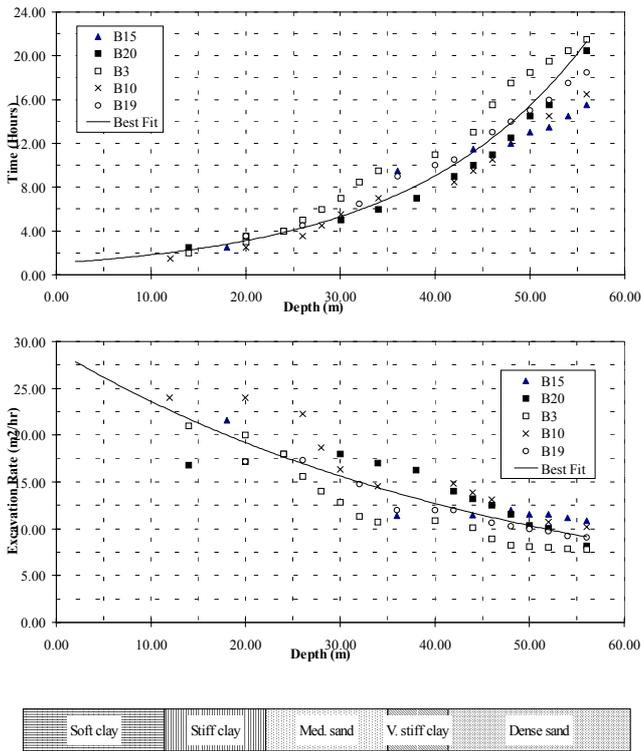


Figure 1. Excavation time, rate vs. depth for barrettes 1.5mx3.0m.

Usually 1.0m or more over casting of concrete above designed cutoff level is practiced. Observation of 3 completed projects indicates that concrete over break of barrettes was found to be in a range of 6% to 14% for barrettes with about 2.0m over casting.

TRENCH STABILITY

In general site conditions, Bangkok soft clay layer with undrained shear strength value of 15- 20 kPa does not pose a particular problem for trench stability during barrette excavation under bentonite slurry. However trenching in the close vicinity of the river or canal/khlong required careful assessment of soil properties, especially sensitivity and natural water content of the soft clay and presence of permeable soil layers connecting the river bed with high pore pressure. Normally, higher guide wall with adequate slurry pressure and reinforcement of the surrounding soft clay by sheet piles placed perpendicular to the alignment of the planned barrette and driven to a stiffer soil layer, overcome the instability of the trench.

TRIAL TRENCH PERFORMANCE

A trial trench (0.8mx2.7mx14m), with above mentioned soil reinforcement close to the canal and high slurry head, was carried out to study the feasibility in construction of barrettes to support the elevated expressway across the Canal. The major concern was stability of 11.0m thick soft clay layer (Fig. 2) which has a very low shear strength less than 15 kPa and natural water content of up to 80%. The planned trench was about 1.5m away from the canal water and four reinforced sheet piles were installed between the trench and the canal prior to excavation. In addition to the reinforced sheet piles, a temporary sheet pile wall was also constructed for protection of slurry spillage into the canal as the local authorities strictly required.

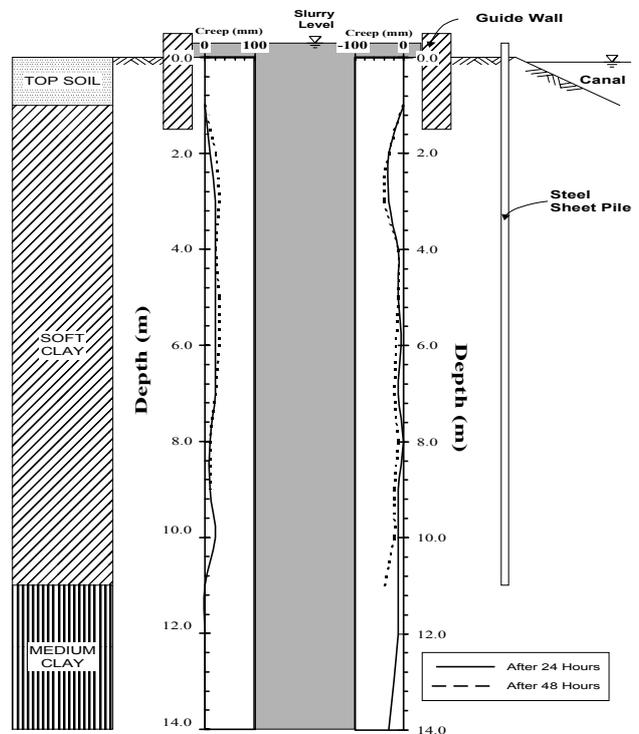


Figure 2. Soil movements on opposite faces of trial trench

The trial trench filled with bentonite slurry was open for 48 hour after excavation down to 14m. Lateral movements of trench face along the depth were studied with graphs of the trench profiles plotted by a Koden drilling monitoring equipment stationed at a fix position on the guide wall at every 6 hour interval. Trench profiles plotted were compared and changes were manually measured using the reference scales shown on the graph. The recording accuracy of the equipment is in a range of +/- 0.2% (in this case the accuracy would be within 2-3mm). 20mm to 30mm lateral soil movement inward the trench was observed on the monitoring records on non-reinforced soil side after 24 hours

and 48 hours respectively in the soft clay layer. For trench face close to the canal, observed movements of the soil being reinforced with sheet piles are generally less than those of non reinforced soil and some movements are considered induced by the sheet pile wall installed for canal water protection. A profile of trench showing soil movement plotted from the monitoring records is presented in Figure 2.

There is no particular problem associated with trench stability in the sand layers 20 to 45m of typical Bangkok subsoil below the ground level. The drilling monitoring records show no collapse of trench surface along the depth section (Fig. 3).

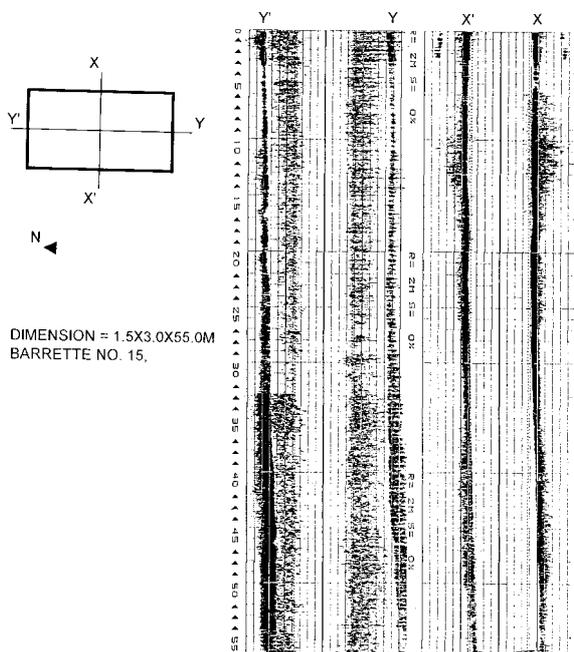


Figure 3. Trench profile of barrette (1.5m x 3.0m x 55m) plotted by Kodan drilling monitoring equipment

LOAD BEARING CAPACITY OF BARRETTES

Common type of barrettes constructed in Bangkok area is rectangular shape with dimensions ranging from 0.6m x 2.7m to 1.0m x 2.7m. These barrettes have been mostly constructed incorporated into diaphragm walls for deep basements of high rise buildings. However, individual larger barrettes (1.2m x 2.7m and 1.5m x 3.0m) are also currently in use to support large column loads as the grabs of large dimensions are currently available in the market. A number of load test on such large barrettes will be carried out in the near future. Maximum bearing capacity of barrettes is usually designed up to allowable concrete stress of 5MPa. Toe depth of barrettes are limited by subsoil conditions and required load

capacity with safety factor of 2.0 to 2.5. The toe depth of constructed barrettes ranges from 45.0m to 60.0m. Concrete cube strength of 30MPa to 40MPa are commonly used for barrettes. Minimum reinforcement of 0.5% of the cross sectional area of barrette is usually provided for either full length or partially as per load requirements.

Barrettes can be constructed with flexible layout plan for both vertical and lateral loads. The layout pattern of barrettes can be arranged in a continuous row or column, radial, alternating long and short axis of barrette and a combination of two or more of such patterns. One type of equipment can be used for constructing both barrettes and diaphragm walls in particular projects thus reduces the mobilization cost. In addition to the large bearing capacity requirements, on site difficulties such as limited head room, also demands the barrettes. Piling rigs cannot be utilized under such situations like presence of high voltage power cables overhead, existing overpasses or structures for elevated expressways and planned subway stations.

A summary of observation on barrettes of 19 projects completed, with respect to selection criteria is presented in Table 1.

Table 1. Summary of Barrette Selection

Criterion	No. of Project	Remarks
High Load Capacity	4	incorporated with bored piles
Minimise Construction Equipment	6	Alternative for bored piles
Limited Head Room for Excavation	2	Elevated Highways under or above existing structures/power lines
Combination with Diaphragm Wall	10	As diaphragm wall legs
Foundation as well as portion of column	3	provision for the future requirement

Since basic shape of the cross section of barrette is rectangular, certain dimensions of barrette can provide a greater perimeter for skin friction than that of the conventional bored pile (in circular shape) with equivalent cross sectional area. Hence, for friction piles, more load carrying capacity per unit volume of concrete can be achieved by a barrette than that of a circular bored pile.

Figure 4 illustrates that typical barrette of 2.7m with various thickness can give 12 to 30% higher friction area than that of circular piles with corresponding equivalent sectional area.

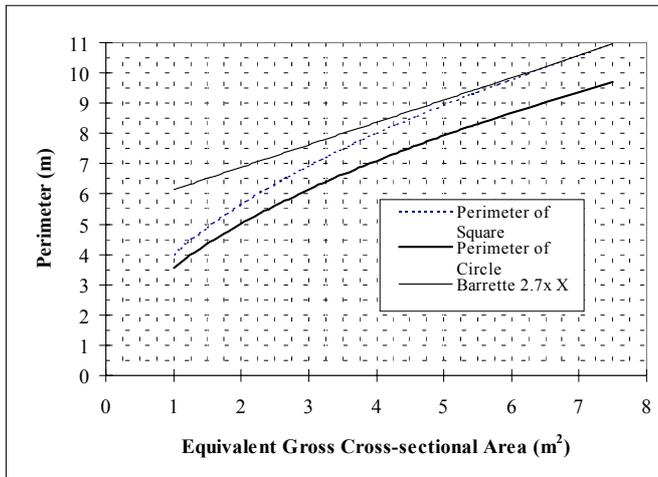


Figure 4. Comparison of shape effect between barrette and circular pile

QUALITY CONTROL

Construction tolerance allowed for barrettes are generally identical to that for bored piles. Normally verticality of 1:100 is allowed in barrette construction in Thailand. Drilling monitoring is employed to check the verticality of the trench on random barrettes or on all barrettes.

After construction, integrity testing such as sonic integrity (low strain dynamic test) and sonic logging tests and concrete coring are sometimes applied. Common defects found in barrettes constructed in Bangkok subsoils are presented in Table 2.

Table 2. Common Defects Found in Barrettes

Defect found	Possible Causes
Concrete cover	improper cage position, provision of inadequate spacers
Bentonite slurry inclusion or poor quality concrete	improper tremie concrete pouring, improper desanding and recycling of slurry, inadequate concrete slump
Reinforcement cage deviation	inadequate supervision
Uplift of reinforcement cage	improper tremie concrete pouring (with very long tremie pipe embedment in concrete poured) in partially reinforced barrettes

PERFORMANCE OF BARRETTES

Available load test results, 4 nos of static load test and one dynamic load test, are summarized below in Table 3.

Table 3. Summary of Barrette Load Test

Project	Barrette Dimension (m)	Test Load (kN)	Total Settlement (mm)	Permanent Settlement (mm)
A	0.82x2.70x 61.80*	14000	4.83	0
		28000	12.56	0
		35000	17.63	3.47
B	0.82x2.70x 44.00	12000	5.65	0.15
		24000	34.15	24.72
C	0.80x2.70x 55.00	12900	4.46	0.24
		25800	11.01	2.10
		30140	12.35	2.17
D	0.80x2.70x 50.00	11000	3.07	0.21
		27500	7.97	0.15
E	1.00x2.70x 48.94**	20555	14.00	3.0

Note: * with base grouting
** load test by dynamic load

All the barrettes tested, except the barrette of project B were founded in dense sand layer with embedment more than 5m into it. The barrette of project B was embedded into about 0.5m in dense sand layer and failed under the maximum test load of 24MN. Base grouting was employed for the barrette of project A. A soil profile and load vs. settlement graph of test barrette of project A are presented in Figures 5 and 6 respectively.

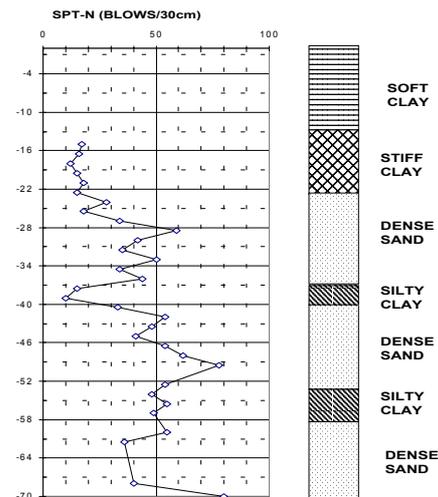


Figure 5. Soil profile at project A site

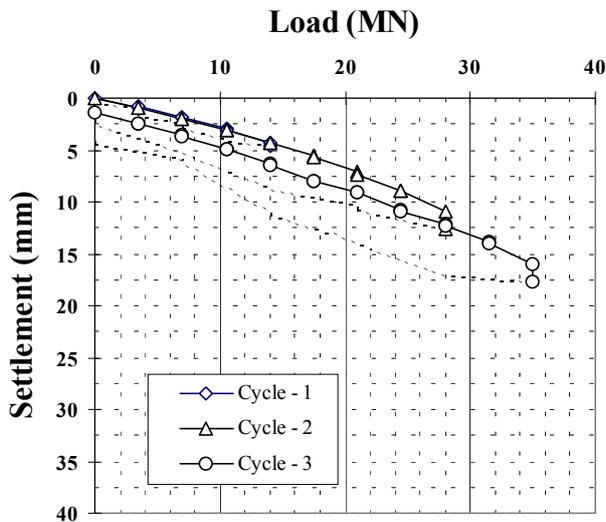


Figure 6. Load vs. settlement graph of barrette load test - Project A.

Barrettes of project E were constructed on both side of water supply canal and one barrette was tested with high strain dynamic load test as no anchor piles were available. A 200kN steel hammer was dropped at a height of 2.6m above the pile cap. A graph of dynamic load test signal analysis and simulated load settlement curve are shown in Figures 7 and 8 respectively.

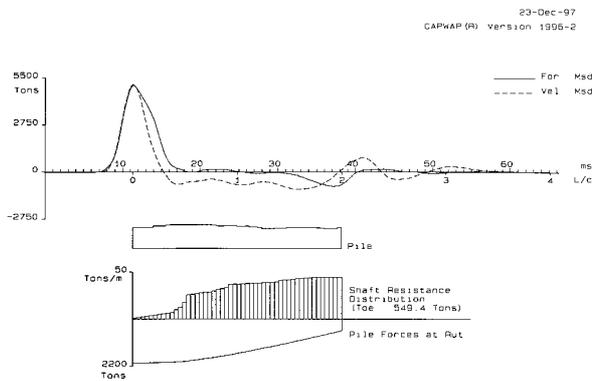


Figure 7. High strain dynamic load test signal (force and velocity) and PDA analysis - Project E

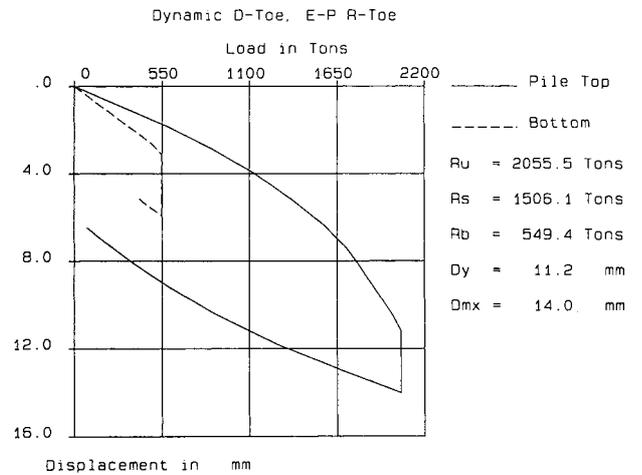


Figure 8. Project E - Simulated load settlement curves (PDA)

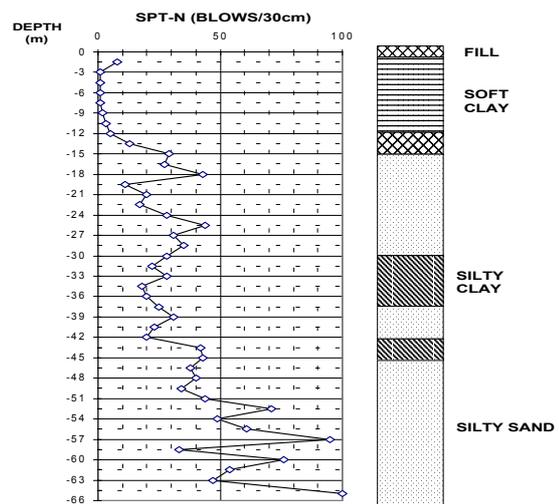


Figure 9. A soil profile of Project E site

Load test results listed in Table 3 indicate that all barrettes tested are able to carry the design load with Factor of Safety of 2 or higher. From the available load test results, the end bearing capacity of test barrettes cannot be estimated. However, all barrettes are considered as friction piles, except for project A in which base grouting was used to improve the end bearing of barrette. For test barrette of project A, no permanent settlement was observed under test load of 28MN which is 200% of the design load and base grouting is considered contributed in good performance of barrette.

Barrette load tests with full instrumentation devices such as strain gauges and magnetic extensometers are planned to be carried out for subway stations in the near futures. The

performance of barrettes in Bangkok subsoil can then be evaluated with a great accuracy.

CONCLUSION

Construction practice adopted in the foundation industry for barrette installation in Bangkok subsoil has been discussed in this paper. There is no indication of trench instability under bentonite slurry in Bangkok subsoil for barrette construction with proper site preparation. This is evidenced by trial trenching and profiles plotted by drilling monitoring equipment. To achieve a good end bearing capacity for barrette founded in sand, base grouting is recommended. Performance of barrettes has been discussed with available load test results, and found to be satisfactory with load bearing performance.

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