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Practical installation of stanchions for top-down construction in Bangkok subsoil
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PRACTICAL INSTALLATION OF STANCHIONS FOR TOP-DOWN CONSTRUCTION IN BANGKOK SUBSOIL

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ABSTRACT

Top-down construction method has been used for construction of deep basement at major projects in Bangkok, Thailand. To be able to apply top-down construction method, structure elements are required to sustain the construction load and to utilize as a part of bracing system. Prefabricated steel columns known as stanchions embedded in bored piles or barrettes are commonly used for this requirement. This paper presents some experiences in the practical installation of the different stanchion types in large diameter deep-seated bored piles and barrettes in Bangkok. The problems encountered during the actual installation of the stanchions and solutions to them are also discussed.

INTRODUCTION

Conventionally, buildings with underground basements are built by bottom-up method where sub-structure and super-structure floors are constructed sequentially from the bottom of the sub-structure or lowest level of basement to the top of the super-structure. Though this conventional method, also called as bottom-up method, is simple in both design and construction, it is not feasible for the gigantic projects with limited construction time and/or with site constraints. Top-down construction method which provides the significant saving of the overall construction time has been adopted for some major projects where time factor is of primary importance. To be able to apply top-down construction method, rigid permanent retaining wall and pre-founded structural columns are required. Diaphragm wall is normally used as basement retaining wall whereas prefabricated steel stanchions embedded in bored or barrette piles are utilized to sustain the construction load as well as to form as a permanent column at later stage. The common length of the stanchions used in Bangkok ranges from 15 to 30m for excavation depth of 12 to 25m. Installation of heavy and lengthy stanchion with stringent positional tolerance in the boreholes or excavated trenches filled with drilling fluid in prevailing subsoil condition of Bangkok is a challenging job for the foundation contractors.

SUBSOIL CONDITION AND PILE CONSTRUCTION METHOD

Bangkok subsoil is featured by alternating clay and sand layers of thick Quaternary deposits. As characteristics and properties of Bangkok subsoil layers have been well documented in many literatures, only a general description of Bangkok subsoil is presented in this article as follows.

Made-Ground consists predominantly of Fill-Materials, Clayey Sand or Silty Clay with some cement block rubble and rock fragments, is commonly found up to 4m depth. Soft to very soft, highly compressible dark gray marine clay lies beneath Made-Ground and in some
areas it lies under weathered crust layers of 2m thick. Depending on the location, this layer is extended up to 12-18m. About 2m thick Medium Clay layer can be observed between Soft Clay and underlying Stiff Clay. Generally Stiff Clay layer occurs directly underneath Medium Clay and its depth goes up to 22m. Below Stiff Clay layer, First Sand layer 5-8m in thickness can be found. This First Sand layer, however, is absent in some areas. Stiff to Hard Clay layer underlies First Sand and it is found to be about 5m thick. Second Sand layer generally occurs at depths between 45 to 65m.

Stanchions are mainly installed in the large diameter deep-seated bored piles and barrettes founded in first or second sand layer. Bored piles of diameter 1.50m to 1.8m and rectangular-shape barrettes of 0.80x2.8m to 1.5x3.0m (thickness x width) founding at depth between 50m and 60m are commonly used to accommodate the stanchions. Wet process method is always used for construction of these large bored piles and barrettes in Bangkok. For bored piles, temporary casing of 14-15m in length is used as a support in soft clay layer. Soil inside the casing is normally excavated by auger applying rotary drilling method and drilling is continued with the bucket under the slurry from the top of sand layer to the final depth. A cable-hung-grab mounted on crawler crane is used for excavation of trench with slurry support in barrette construction. Guide walls having a minimum depth of 1.2m are commonly used for initial guiding of grab excavation at the top of the trench. Tremie concreting is necessary for casting both bored piles and barrettes.

APPLICATION OF TOP-DOWN CONSTRUCTION METHOD

Top-down construction method as the name implies, is a construction method, which builds the permanent structure members of the basement along with the excavation from the top to the bottom. Top-down method is mainly used for two types of urban structures, tall buildings with deep basements and underground structures such as car parks, underpasses and subway stations. For tall buildings with deep basements, a full application of top-down method enables superstructure to build concurrently with excavation and construction of the basement giving a significant advantage in reducing the overall construction time. Top-down method is the most appropriate solution in minimizing the duration and disruption to surface traffic and other urban activities, for the construction of the underground car parks, underpasses and subway stations where the structure is located directly underneath the existing roads.

Application of top-down method offers three main advantages as outlined below.

- It allows early commencement of super-structure construction without the need to wait for excavation reaching the bottom level. Overall construction duration can be significantly less than that of conventional method thereby saving the cost.
- It does not require temporary bracing system so that time requirement and cost for temporary works (both material and labor costs) are eliminated, in turn significantly saving cost.
- Minimize soil movement induced by excavation works which is an important factor for some sensitive locations.

STRUCTURAL MEMBERS REQUIRED FOR TOP-DOWN CONSTRUCTION

Design and construction principles for top-down method primarily call for two major structural elements.

- Columns with sufficient capacity must be pre-founded in bored piles or barrettes to sustain the construction load and to utilize as part of bracing system.
• Excavation for basement must be carried out with the support of permanent retaining wall so that basement floor slabs can be utilized as lateral bracing. Diaphragm wall of 0.8m to 1.2m in thickness with sufficient embedment in firm soil layers is commonly used as a retaining wall whereas prefabricated steel columns known as stanchions embedded in either large diameter deep-seated bored piles or barrettes are utilized as structural columns. Figure 1 illustrates the top-down construction method with utilization of stanchions and diaphragm wall.

Figure 1. Top-down construction with stanchion and diaphragm wall

TYPES OF STANCHION AND THEIR APPLICATION IN BANGKOK

Pre-fabricated “H” section steel columns and steel built-up-section columns are mainly used as pre-founded structural columns or stanchions. Pre-cast reinforce concrete columns are very seldom used (Manoharn S. & Aye Z. Z. , 1994). For the purpose of convenient reference throughout the paper, the type of stanchion is categorized by size and capacity as presented in the table below.

Table 1. Technical data, application and limitation of three types of stanchion

<table>
<thead>
<tr>
<th>Type of Stanchion</th>
<th>Material &amp; Example Size</th>
<th>General Information</th>
<th>Limitation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Light stanchion</td>
<td>Steel H-beams 350x350x137kg/m</td>
<td>• For semi top-down construction</td>
<td>Limited capacity of light stanchion does not allow for construction of super structure until completion of basement construction</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• For temporary decking</td>
<td></td>
</tr>
<tr>
<td>Medium-sized stanchion</td>
<td>Steel H-beams 350x350x390 kg/m</td>
<td>For semi and full top-down construction of shallow to medium deep excavation</td>
<td>Limited number of superstructure floors construction</td>
</tr>
<tr>
<td>Heavy stanchion</td>
<td>• Steel H-beams 508x457x738kg/m</td>
<td>Full top-down construction in deep excavation</td>
<td>Depending on the loading condition, numbers of superstructure floors can be constructed before completing basement excavation</td>
</tr>
<tr>
<td></td>
<td>• Composite steel columns built up by 2 or more small to medium size H-beams</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Large section pre-cast RC column (seldom use)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Embedded length of stanchion usually ranges from 1.5 to 5m depending on the loading condition applied in design and construction.

ALLOWABLE TOLERANCE FOR POSITION OF STANCHIONS

Allowable tolerance for stanchions is usually called by the designer and it is mainly governed by the structural tolerance of the steel as well as required position of the finished columns. In most projects, allowable vertical and horizontal deviation of stanchion are specified as 25 to 50mm whereas verticality is required between 1:200 and 1:400. There are a number of constraints to get highly accurate position of heavy and lengthy stanchions which have to be installed in deep-seated foundation piles constructed by wet process in Bangkok subsoil as described in the following sections.

STANCHION INSTALLATION METHODS

Stanchion installation method is usually selected by the piling contractor who take into consideration three main factors such as installation depth, size of stanchion and size of bored or barrette piles. Though installation details may be different from one contractor to another, stanchion installation can be categorized under two main methods, post-concreting or plunging installation and pre-concreting installation or placing stanchion prior to concreting.

Post-concreting installation or plunging method

In this method, stanchion is installed immediately after completion of bored pile concreting process. General construction sequence involved in this method is demonstrated in Figure 2. Guide frame is used to install the stanchion at the correct position.

Pre-concreting or pre-placing installation method

In this method, stanchion is installed immediately after completion of drilling and reinforcement lowering prior to concreting process. In some projects stanchion is attached to the last section of reinforcement and installed together with the reinforcement. General construction steps involved in this method are demonstrated in Figure 3.
Figure 3. General construction sequence of pre-concreting installation method

Figure 4 shows the installation of a 24m long built-up steel stanchion into the pile borehole prior to concreting.

Figure 4. (a,b) Installation of 24m long stanchion into borehole prior to concreting

Guide Frame for stanchion positioning

Guide frame is used for positioning of stanchion in both installation methods. Effectiveness of guide frame plays one of the important roles in achieving positional accuracy of stanchion. Figure 5 (a,b) shows the guide frame used for pre-concreting installation method in one major project constructed by Seafco Co., Ltd.
REVIEW OF THE STANCHION INSTALLATION METHODS USED IN OTHER PARTS OF THE WORLD

The stanchion installation methods used in other parts of the world have been presented in some published papers. Among these, Findlay (1989) reviewed a number of stanchion installation methods used in construction of large diameter bored piles for top-down construction particularly in UK. The author reported that steel columns can be placed with better accuracy by dry process bored piling method than wet process method (with support fluid).

Hollingsworth (1991) demonstrated the installation of stanchions by plunging into concrete with the aid of an adjustable guiding frame called Cemloc (European Patent No. 0302717) for seven levels basement of 25m deep constructed by top-down technique in London.

Ressi di Cervia and Tamaro (1991) briefly explained the stanchion installation method used for construction of an underground garage with top-down technique in Boston, USA. Steel columns were installed prior to concreting in load bearing elements (LBE) or barrette excavated by cable-hung mechanical clamshell buckets. The authors cited that using the same equipment for construction of diaphragm wall and load bearing elements minimized the congestion on site and streamlined the schedule.

Crawley and Stones (1996) presented the installation of 30m long composite steel columns for top-down construction applied for Westminster Station in Central London. Columns were placed with the aid of guide frame followed by concrete pouring. Accuracy of ±25mm at the top of column with verticality of 1:200 was achieved as stated by the authors.

Arz (1989) presented an installation of heavy composite columns fabricated from six steel H-beams encased by concrete (cast during fabrication) for construction of six storey building with five basement using top-down method in Germany. Due to the high accuracy requirement of 25mm, adjustable guide frame equipped with three hydraulically control arms were used. Stanchions were installed prior to concreting as reported by the author.

From the available literatures it is noted that pre-concreting method is more common in use than post-concreting method.

PROBLEMS ENCOUNTERED IN POST-CONCRETING INSTALLATION METHOD

The major problem commonly encountered in this installation method is inability to install the stanchion at the design position due to one or combination of the following causes.

- Inclination of the borehole / trench
- Stanchion can not be inserted up to the required depth as concrete becomes hard due to the premature setting.
- During lowering, stanchion is stuck by reinforcement cage and due to the hardening of the concrete, extraction of stanchion becomes impossible for reinstallation.

As the installation of the stanchion is often associated with many unforeseen problems, it is likely in many cases that concrete becomes stiff or prematurely set during the installation. In Bangkok, premature setting of concrete is usually found to be attributed by:
- long delivery time due to traffic conjunction
- inappropriate mix
- severe weather
- disruption in concreting / equipment breakdown

PROBLEMS ENCOUNTERED IN PRE-CONCRETING INSTALLATION METHOD

Using this method can minimize some problems encountered during installation provided that adequate clearance is available between pile reinforcement and the stanchion for tremie pipes lowering. Inclination of borehole is also important for this installation method. Proper planning in concrete ordering is required to avoid unnecessary waiting of concrete trucks for stanchion placing which may affect the total batching time limitation. As stanchion has to be hung in the position until completion of concrete placement, appropriate and sufficient capacity of the hanging and positioning device should be provided to avoid falling and deviation of stanchion in the borehole. Temporary casing should not be used as a hanging system without additional support for the large stanchion.

FACTORS EFFECTING THE POSITIONAL ACCURACY OF THE STANCHION

It is hardly possible to install a stanchion so that its position and verticality is always as designed. As-built position of stanchion is found to be generally influenced by the installation method. The factors affecting the positional accuracy for two different methods are summarized in the Table 2 and 3.

<table>
<thead>
<tr>
<th>Factors affecting accuracy</th>
<th>Discussion</th>
<th>Recommended measures to improve accuracy</th>
</tr>
</thead>
</table>
| Verticality of piles      | Due to the use of fixed guide arm for guiding stanchion against borehole wall, its verticality is solely influenced by the verticality of borehole. | Use adjustable guide
Maintain good horizontal position of drilling rig and verticality of temporary casing
Perform drilling monitor test after completion to check verticality prior to stanchion installation |
| Concrete stiffening or hardening during installation | Due to the stiffening or hardening of concrete, stanchion may not be able to place at the right elevation. Using vibro-hammer to force down stanchion can cause stanchion to deviate from the position. | Use concrete with appropriate admixture to achieve longer setting time |
| Inappropriate backfill material | Large aggregates backfill can cause locking up casing with stanchion upon casing extraction which create stanchion to deviate | Use appropriate backfill such as sand / fine aggregates. |
| Improper backfilling       | Back filling from one side of stanchion can cause deviation of stanchion. | Maintain equal distribution of back fill around stanchion |
| Improper temporary casing extraction | Stanchion deviation in both horizontal and vertical can be caused by improper temporary casing extraction. | Apply proper equipment and method in casing extraction to suit the site condition and design requirement |
Table 3. Pre-concreting installation method – factors effecting positional accuracy

<table>
<thead>
<tr>
<th>Factors effecting accuracy</th>
<th>Discussion</th>
<th>Recommended measures to improve accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Verticality of piles</td>
<td>In this method stanchion position may be independent from borehole verticality prior to concreting. However due to poorer borehole verticality in comparison with that of stanchion, clearance between stanchion and borehole wall becomes smaller with depth at one side of stanchion. Thus during the tremie pipe lowering and extraction, stanchion is pushed by tremie causing stanchion to move horizontally.</td>
<td>• Maintain good horizontal position of drilling rig and verticality of temporary casing</td>
</tr>
<tr>
<td>Concrete flows pushing at stanchion during tremie concreting</td>
<td>During pouring of concrete from tremie pipe, force induced by concrete flow tends to move stanchion in both horizontal and vertical direction.</td>
<td>• Use appropriate fixing (lock) at top</td>
</tr>
<tr>
<td>Improper back filling</td>
<td>Same as post-concreting installation method presented in above Table 2</td>
<td>Same as post-concreting installation method presented in above Table 2</td>
</tr>
<tr>
<td>Improper temporary casing extraction</td>
<td>Same as post-concreting installation method presented in above Table 2</td>
<td>Same as post-concreting installation method presented in above Table 2</td>
</tr>
</tbody>
</table>

Skill and experience of the contractor plays a major role in achieving positional accuracy of the stanchion provided that the installation is practical with the design elements such as size of foundation piles in relation to size of stanchion.

Figure 6. View of stanchions embedded in bored piles at final excavation level

STANCHION POSITION EFFECTED BY EXCAVATION

In Bangkok, post-installation movement (horizontal movement) of the stanchion is frequently encountered and it is mainly caused by excavation induced soil displacement particularly at initial stage of excavation where diaphragm wall deflection is characterized by large cantilever rotation within Soft Clay layer. In some projects, deviated stanchions had to be pushed or jacked back to the original position and restrained by means of temporary support until permanent slab was cast.

REVIEW OF THE COMPLETED PROJECTS

The authors were involved in a number of projects constructed by Top-down method in Thailand particularly in Bangkok.
Table 4 shows the summarized technical information of some major projects with different stanchion type, size and installation depth.

### Table 4. Summarized technical information of stanchion application in some major projects in Thailand

<table>
<thead>
<tr>
<th>Project No.</th>
<th>Stanchion Type and Size</th>
<th>Pile Type and Size</th>
<th>Installation Method</th>
<th>Basement Excavation Depth (m)</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Built-up steel column</td>
<td>Bored pile φ1.5x60m</td>
<td>Pre-concreting</td>
<td>-20.0m</td>
<td>Silom Road Bangkok</td>
</tr>
<tr>
<td></td>
<td>850x850mm, L=24m</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>built-up by 4 H-beams</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>270x248x157kg/m</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>H-section steel column</td>
<td>Bored pile φ1.8x65m</td>
<td>Post-concreting</td>
<td>-29.5m</td>
<td>Rama IV Road Bangkok</td>
</tr>
<tr>
<td></td>
<td>508x457x738 kg/m, L=30m*</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>H-section steel column</td>
<td>Barrette pile 1.2x3.0x47m</td>
<td>Pre-concreting</td>
<td>-24m</td>
<td>Ratchadapisek Road Bangkok</td>
</tr>
<tr>
<td></td>
<td>419x407x390kg/m, L=24.7m*</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>H-section steel column</td>
<td>Bored pile φ1.8x65m</td>
<td>Pre-concreting</td>
<td>-14.5m</td>
<td>Payathai Road Bangkok</td>
</tr>
<tr>
<td></td>
<td>414x405x232 kg/m, L=18m</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Pre-cast RC column</td>
<td>Bored pile φ1.5x35m</td>
<td>Pre-concreting</td>
<td>-11.5m</td>
<td>Haadyai</td>
</tr>
<tr>
<td></td>
<td>500x1000mm, L=15m</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>500x1500mm, L=15m</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Bored pile φ1.8x35m</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: * Top levels of stanchion in Project 2 and 3 are 3m and 1.8m below ground level respectively.

A view of heavy stanchions (built-up sections) exposed after excavating to the first basement level is presented in Figure 7. Pre-concreting installation was used to install the stanchions in this project.

![Figure 7. View of built-up stanchions exposed after excavation to the first level of basement](image)

**COMPARISON OF AS-BUILT POSITIONAL TOLERANCE ACHIEVED BY TWO INSTALLATION METHODS**

Although the as-built position of stanchions installed by two different methods have yet to be statistically analyzed, field survey data of Projects 2 and 3 indicated in above Table 4 suggested that stanchions could be more accurately installed by pre-concreting method. Stanchions with as-built horizontal deviation greater than 100mm installed by two methods (expressed by percentage) are presented in the table below.
Table 5. Comparison of as-built position of stanchions by two installation methods

<table>
<thead>
<tr>
<th>Project</th>
<th>Installation Method</th>
<th>Depth of Measurement</th>
<th>As-built Position of Stanchions with Horizontal Deviation &gt;100mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>Post-concreting Method</td>
<td>15.5m B.G.L</td>
<td>20 %</td>
</tr>
<tr>
<td>3</td>
<td>Pre-concreting Method</td>
<td>13.5m B.G.L</td>
<td>4 %</td>
</tr>
</tbody>
</table>

CONCLUSION

Two common stanchion installation methods have been presented with particular emphasis on the common problems encountered by each method and recommended measures to alleviate them. According to the author’s experience, pre-concreting installation method provided fewer problems in practical installation and achieved better positional accuracy. A comparison of as-built position of stanchion between two projects also suggested that stanchions could be more accurately installed by pre-concreting installation method.

The designers such as structural engineers and architects should be aware of the accuracy achievable by practical installation method and take it into consideration at the design stage.

Stanchion installation contractor should select the appropriate method, equipment as well as experienced personnel plus a well-formed plan with the consideration of all potential problems to achieve the successful construction of foundation structure, which is of primary importance for top-down technique.

REFERENCES


