Bleeding and channeling problems of tremie concrete in Bangkok

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Abstract
Concrete pouring through tremie pipe is one of the most important procedure for wet-process bored pile construction. It was reported that bleeding and channeling of fresh concrete caused integrity problem for the hardened concrete. This paper presents information of tremie concrete properties adopted in Bangkok. Ordinary Portland cement is partially replaced with fly ash is for reducing cost and increasing workability. Common admixtures are superplasticizer (Type F) and retarder (Type D). At present, fresh concrete property is tested on-site using only slump cone. However, only this type of test may not be adequate for controlling bleeding. Series of tests including visual index, filtration and flow table are required to control potential of concrete segregation, water retention ability and viscosity, respectively. Possible factors relevant to bleeding are analyzed and reported in this paper. A new concrete mix design to minimize bleeding was developed and used in a case study for 100 m deep bored pile construction. According to the results collected, fly ash content of more than 20% and excessive amount of retarder increase the bleeding and channeling potential. Optimum amount of superplasticizer can decrease bleeding, but if the amount is too much, bleeding can be increased significantly. Type of soil also contributes to characteristic of bleeding. For granular soil, water in concrete may cause seepage outside of fresh concrete into the soil. In case of clay, the permeability of soil is very low. Thus, the flow direction is only upward, resulting in larger potential of channeling than those in granular soil.

Keywords: Tremie concrete; Bleeding; Channeling; Bangkok

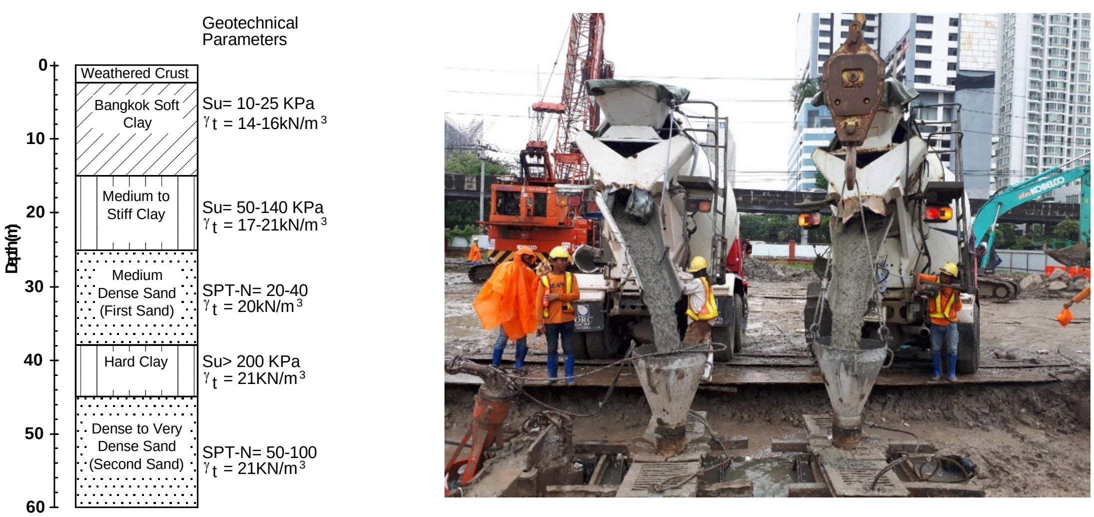
1. Introduction

Tremie pipe is used for casting concrete under drilling fluid for bored pile and cast-in-place retaining wall. Unlike normal concrete that has higher yield value, tremie concrete has lower yield value in order to fill in and pass through rebar cages without any compaction or vibration. Thus, bleeding potential is larger for the latter than the former [1]. Bleeding in fresh concrete is caused by separation of the paste from the aggregate. As the unit weight of aggregate is larger than water, the aggregate settle down and results in upward water flow. Bleeding continues until either aggregate stop settle or setting of concrete occur.
For excessive bleeding, channeling occurs, which creates paths for water to carry cement paste and fine particle through weak spots of fresh concrete. The effects of channeling increase the rate of bleeding significantly [2]. For bored pile and diaphragm wall, the locations of channeling are likely to occur at the tremie pipe and around the reinforcement cage. This is because there is an interface between concrete and tremie pipe or rebar.

Thasnanipan et al. [3] investigated factors that influence the bleeding potential from case studies. It was reported that fly ash, retarder (Type D) and superplasticizer (Type F) have strong impact on bleeding and channeling. However, no testing method or optimized mix design was proposed to identify or minimize bleeding in tremie concrete.
This paper presents factor influenced bleeding potential, recommended tests to identify bleeding for tremie concrete and a case study of fresh concrete designed for 100 m deep bored pile construction without bleeding or channeling.

2. Typical geological information of Bangkok and tremie concrete for underground structures

Figure 1a shows Bangkok typical soil profile which consist of a thick marine soft clay layer (about 15 m) locates at the top followed by layers of stiff clays and dense sands. Undrained shear strength of soft clay is ranging between 10-25 kN/m^2, which is too soft for supporting high rise building. For Bangkok aquifers, the current (2019) water table is at 13 m from the existing ground. Due restriction of underground water pumping since year 2000, there is a continuous rising in underground water table every year. It is predicted that water level would reach the ground surface by 2032.
Tremie concrete (as shown in Figure 1b) in Bangkok is generally used for wet process bored pile and diaphragm wall construction. Typical diameter and depth of bored piles are ranging from 0.8 m to 2.0 m and between 35 m and 70 m, respectively. In some special projects, the depth of bored pile can be from 80 m to 100 m. For diaphragm wall, thickness and depth are ranging from 0.6 m to 1.5 m and from 16 m to 70 m, respectively. Some diaphragm wall panels require a casting concrete volume of more 500 m^3.



a) b)

Figure 1. a) Typical soil profile of Bangkok and b) Concrete casting through tremie pipes.

3. Bleeding, channeling and related problems of tremie concrete

Occurrence of bleeding or channeling in bored pile is shown in Figure 2a. It was observed that water upward flow duration was ranging from 10 to 30 minutes, depends on pile depth. The location of bleeding was at the center of the pile, where tremie pipe is placed. When the pile head is exposed (see Figure 2b), unsound and damp concrete was found. To further investigate the defect, cored samples of concrete were taken as shown in Figure 2c. Evidence of segregation was found up to depth of 5 m from the pile cut-off level. If mix design of concrete is inappropriate or concreting is not well-controlled, weak spot or channeling may occur at the center of the pile.

Effects of channeling caused cement paste to flow upward, resulting in void in hardened concrete. Thus, permeability of concrete and diaphragm wall was reduced as shown in Figure 3a. For bored pile, bleeding may occur around the pile's reinforcement as shown in Figure 3b. It was found that the water kept flowing upward until polyurethane foam (PU) was injected to stop the flow. At this interface between fresh concrete and reinforcement, there may be a gap due to channeling. Thus, bond between reinforcement and concrete can be substantially decreased.

For geotechnical aspect, clay has lower permeability than sand. As a result, preferential water flow in fresh concrete is in upward direction. The evidence of upward water flow is shown in Figure 2a, where surrounding soil is clay. For sand, if there is free water in concrete, it is possible that water flow into sand radially rather than upward.

To reduce bleeding, water to binder ratio can be minimized and concrete gradation can be adjusted. However, flow ability, fill ability and passing ability of concrete are also key factors for tremie concrete. Figures 4a and 4b show concrete trapped inside the rebar cage of bored pile and diaphragm wall, respectively. It shows that the rebar clear spacing was too small (less than 100 mm). Thus, to control bleeding, while maintaining the flow ability, viscosity modifier such as superplasticizer should be used. In addition, maximum size of aggregate for dense rebar cage should not be larger than 10 mm, not as large as 20 mm for conventional tremie concrete.

a) b) c)

Figure 2. a) Water flow up to concrete surface in fresh state; b) Unsound and damp concrete at pile head; c) Cored samples of unsound concrete.

a) b)

Figure 3. a) Visible water due to channeling in diaphragm wall and b) Water upward flow around the rebar of bored pile.

a) b)

Figure 4. Effects of dense rebar in a) Bored pile and b) Diaphragm wall.

4. Suitable properties of tremie concrete

4.1. General properties

As stated in the previous section, bleeding and channeling are the serious issue to be addressed for tremie concrete. Unlike normal concrete that can be vibrated, tremie concrete should meet following requirements: excellent fluidity, self-compaction, resistance to segregation, controlled setting time, resistance to harsh environment, resistance to leaching and appropriate strength and stiffness. Typical properties of tremie concrete in Thailand are summarized in Table 1. According to this table, it can be seen that bleeding and channeling potential is not commonly controlled in most of project specification. To tackle this problem, an overcast length of about 1-2 m is specified, taken bleeding and concrete mixed with drilling fluid and sediment at the pile base into account. This overcast concrete is trimmed later when the pile head is exposed.

Table 1. Typical concrete properties for bored pile in Bangkok

Property	**Range**	**Testing method**
Slump	150 – 200 mm	Slump test
Flow diameter	400 mm	Flow table
Initial setting time	Casting time plus 2 hours	Timing
Compressive strength	28-45 MPa (cylinder)	Unconfined compression

4.2. Cementitious material and admixtures

In early days, tremie concrete in Thailand comprised Ordinary Portland cement (OPC), aggregate and water only. However, to meet the requirement of concrete properties as summarized in Table 1, some cement replacing materials and admixtures are incorporated. In Thailand, fly ash is used as cement replacing material as it is more economical than OPC. In addition, it increases flow ability of fresh concrete and reduce heat in hardened concrete. The replacement of fly ash to OPC can be as high as 35-40% for tremie concrete. This high content of fly ash causes adverse impact on concrete bleeding and channeling. Laboratory test result carried out by Junaid et al. [4] reported that adding fly ash up to 20% reduces degree of bleeding by 25%, given the same workability of concrete. Later experimental result by Supakitwattana and Parichatprecha [5] confirmed that adding fly ash up to 20% helps reducing in bleeding. However, if the amount of fly ash reaches 30%, the rate of bleeding increases substantially. It is confirmed by Thasnanipan et al. [3] for bored pile construction in field that using fly ash content by 30% caused bleeding. After revising the mix design by not replacing fly ash to OPC in the same project, bleeding was not observed.

4.3. Admixtures

Common admixtures used for tremie concrete in Thailand are summarized as follows:

- Retarder (Type D): Design initial setting time of tremie concrete shall be the time consume for transportation, pouring and contingency time. This is to provide adequate workability, flow ability and fill ability of fresh concrete. However, the longer time the concrete is in the fluid state, the higher potential bleeding and larger volume of water upward flow may occur. A case study reported in Thasnanipan et al. [3] suggested that by reducing Type D retarder by 33%, bleeding was minimized.
- Superplasticizer (Type F): Increase flow ability of concrete and reduced water to binder ratio. Optimum amount of superplasticizer can help reducing the bleeding potential as the free water in fresh concrete can be decreased. However, excessive amount of superplasticizer (Type F) causes reduction in viscosity, resulting in water separation of concrete. Thus, bleeding can be increased significantly.

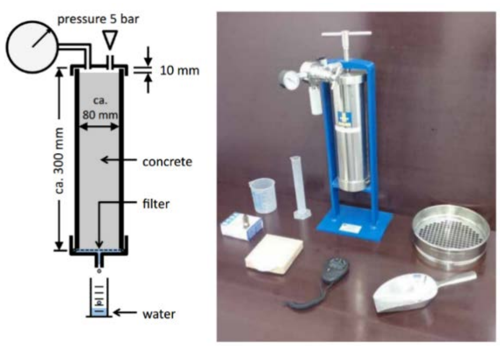
5. Quality control and testing

5.1. Fresh concrete

A basic testing method of fresh concrete on site is only slump test with acceptance range summarized in Table 1. However, slump height alone cannot fully identify the flow ability of concrete as concrete with the same slump height may have different characteristic of segregation. To identify the characteristic of suitable fresh concrete for tremie casting, additional tests are required.

Flow table test and visual inspection (VSI) tests can be performed on site. Suitable range of flow diameter are from 400 to 550 mm [1]. These diameters are specified to control flow ability for the former and the bleeding potential for the latter. For VSI test, only Category VSI 0 (highly stable) and Category VSI 1 (stable) should be adopted as acceptance criteria.

For very deep pile (i.e., from 80 m to 100 m deep) filtration test should be carried out as shown in Figure 5a. This is because the water pressure both outside the borehole and inside the fresh concrete can be very high. Thus, water retention ability should be tested. For comparison between normal concrete and special mix concrete, a standard filtration apparatus for drilling fluid was tested on fresh concrete (see Figure 5b) in some projects in Bangkok.



a)

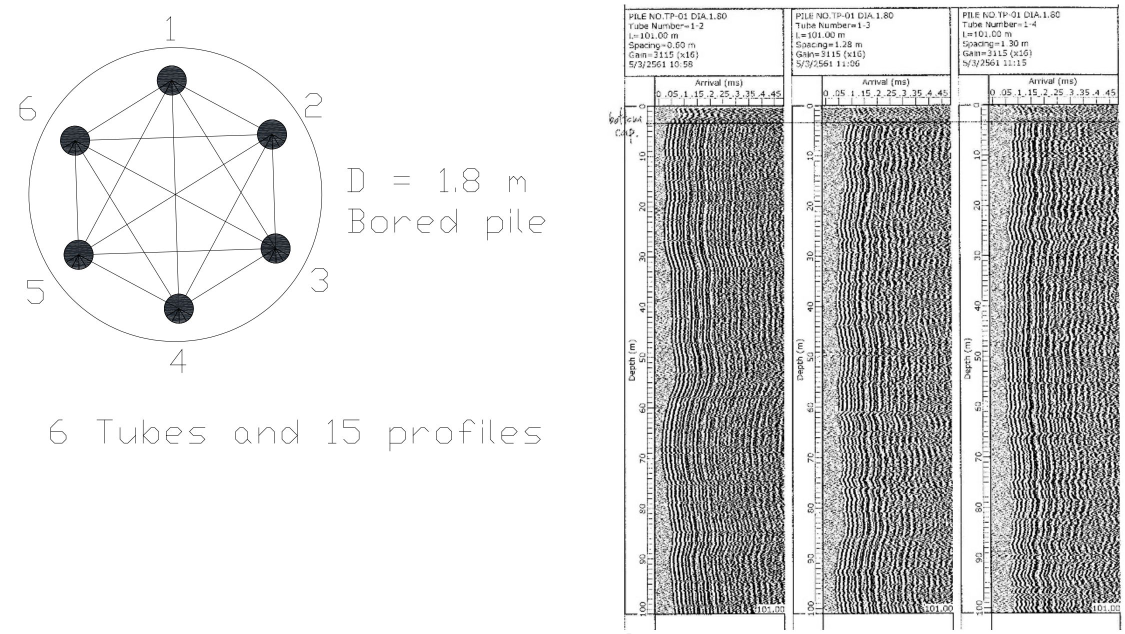
b)

Figure 5. a) Filtration test for concrete [1] and b) Filtration test for drilling fluid.

5.2. Hardened concrete

Typical testing of hardened concrete is unconfined compressive strength of samples collected prior to pouring through tremie pipe. After collecting, the sample can be tested at 3, 7, 14 or 28 days after completion of concreting. This test is for evaluation whether the concrete strength is adequate to carry the load apply at the pile head.

In-situ test to assess the integrity of each pile is cross-hole sonic logging test. The principle of testing is to transmit the sonic wave from one tube to another as shown in Figure 6a. If the concrete integrity is sound, there is no delay in signal (see Figure 6b).



a) b)

Figure 1. a) Layout of sonic logging tubes and b) 3 out of 15 profiles of test results.

6. Case study of 100 m deep tremie concrete casting

A cast-in-situ bored pile with diameter of 1.8 m and depth of 100 m was constructed as a test pile for a sky scraper in Bangkok. This pile was subjected to vertical compression static load test up to 70,400 kN. The required compressive strength, slump and initial setting time of concrete were 45 MPa, 175 mm and 10 hours, respectively. To achieve these properties, mix design was adjusted to minimize the bleeding and channeling potential. Total binder was 500 kg/m^3 and fly ash content was limited to 20%. Water to binder ratio (W/B) was 0.35 by adding superplasticizer (Type F). This W/B was lower than typical range of 0.45-0.48 of normal tremie concrete. Retarder (Type D) was incorporated into the concrete to prolong the setting time. Concrete casting time of this pile group (5 piles) were ranging from 6 to 7 hours. Thus, the initial setting time was specified at 10 hours.
During casting of concrete, no sign of bleeding and channeling was observed. Based on the result of integrity testing using cross-hole sonic logging (as shown in Figs. 6a and 6b), no anomaly was encountered. Average unconfined compressive strength at 28 days was 63 MPa (cylinder), exceeding the required strength of 45 MPa.

7. Summary and conclusion

According to the records, factors affecting the chance of bleeding and channeling are summarized as follows:

- Fly ash content more than 20% of total binder may increase the chance of bleeding. This is because fly ash water absorption is not as good as Ordinary Portland cement, resulting in free water in fresh concrete.
- For suitable amount of superplasticizer (Type F), bleeding can be minimized as water to binder ratio can be decreased. However, excessive superplasticizer substantially reduces the viscosity causing higher chance of water flow.
- Too high amount of retarder (Type D) causes concrete remains in fluid state for too long, resulting in decrease in water retention ability and thus cause bleeding.
- There are also effects of surrounding soil on bleeding characteristic. For granular soil, free water in concrete may cause seepage into the surrounding soil. In case of clay, the permeability of soil is very low. Thus, the flow direction is only upward, resulting in larger potential of channeling than those in granular soil.
- Suitable testing methods to identify bleeding and channeling potential should be incorporated for tremie concrete. Apart from slump test that is usually specified for quality control, visual inspection, flow table and filtration test should be carried out.

8. Acknowledgement

The Authors would like to acknowledge executives and staff of Seafco Public Company Limited for supporting of information and suggestions for this paper.

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