**Strength Characteristic of a Chemical Binder Treated Marine Clay as Compared with the Use of Cement**

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**ABSTRACT:** In recent years, marine clay has been used as a fill material for land reclamation in Singapore. The technique adopted to improve the strength properties of marine clay plays a critical role in land reclamation projects. In this study, a series of laboratory tests have been conducted to determine the potential to use a chemical binder to stabilize marine clay in Singapore. Test results show that the chemical binder could offer shorter curing period and higher strength. With the same dosage, the unconfined compressive strength of chemical binder treated marine clay is about 1.2-1.4 times of cement treated marine clay at 14 and 28 curing days. At 14 curing days, the strength of chemical binder treated marine clay can reach 80% of the maximum value. This proves that 14 curing days is enough to make the chemical binder treated marine clay obtain sufficient strength. Furthermore, chemical binder treated marine clay has no slaking behaviour in underwater environmental. This also indicated chemical binder treated marine clay has a good cohesiveness.

**KEYWORDS:** Land reclamation; Marine clay; Chemical binder; Unconfined compressive strength; Durability test

1. **Introduction**

Land reclamation projects are being conducted in coastal regions in some countries like Singapore, Japan, Vietnam and China (Bo et al., 2003; 2005; He at al., 2016). In Singapore, land reclamation has been a major method for land creation since the 19\(^{th}\) century. Much of the old Singapore port area and the old city around the Kallang and Geylang river estuaries were built on reclaimed land (Bo and Choa, 2004; Chu et al., 2016). More than 100 km\(^2\) of new land has been created since 1970s when economic expansion was accelerated. Another about 100 km\(^2\) land reclamation will be reclaimed until 2030 in Singapore (Chu et al., 2006).

However, land reclamation has become more challenging in Singapore due to lack of available granular fill materials. One method to solve this problem is to use soft clay as a fill material as soft clay materials are cheap and more easily obtained (Chu et al., 2016). However, marine clay in Singapore has very poor engineering properties according to engineering practice in Changi East reclamation project and a pilot field trial in Jurong Island West Extension reclamation project (He at al., 2016). How to improve the soft soil to enhance
its shear strength and reduce the ground settlement in land reclamation becomes a challenge (Chu et al., 2000; 2005; 2012).

Various methods have been adopted for the treatment of soft soil. A review of some methods is given by Chai & Miura (2005) and Chu et al. (2009). In this paper, an experimental study is conducted to investigate the possibility of using a chemical binder to stabilize the soft marine clay. The marine clay used in this study is obtained from a land reclamation site in Singapore. The unconfined compressive strength of chemical binder treated marine clay was compared with cement treated marine clay and pure marine clay. The slaking behavior of chemical binder treated clay in underwater environmental was also discussed.

2. Materials

Marine clay used in this study was obtained from Jurong Island West Extension Reclamation Project of Singapore. The slurry was dredged from the nearby seabed and pumped into the pit. The marine clay was collected and then transported to the laboratory. The properties of marine clay are summarized in Table 1.

<table>
<thead>
<tr>
<th>Properties</th>
<th>Marine Clay</th>
</tr>
</thead>
<tbody>
<tr>
<td>Liquid limit, LL (%)</td>
<td>88</td>
</tr>
<tr>
<td>Plastic limit, PL (%)</td>
<td>36</td>
</tr>
<tr>
<td>Plasticity index, PI (%)</td>
<td>52</td>
</tr>
<tr>
<td>Water content, WC (%)</td>
<td>70</td>
</tr>
<tr>
<td>Liquid index, LI</td>
<td>0.65</td>
</tr>
<tr>
<td>Initial void ratio, $e_0$</td>
<td>1.90</td>
</tr>
<tr>
<td>Specific gravity, $G_s$</td>
<td>2.65</td>
</tr>
</tbody>
</table>

In this study, one chemical binder is used to study the effect of stabilizing marine clay. This chemical binder is a type of cementing material originating from the silicate-based chemicals modified by a high-tech powdery polymer. The physical specifications of this chemical binder including fineness, setting time and specific gravity are shown in Table 2. Portland cement supplied by Aalborg Portland Malaysia Sda was also used in this study to estimate the effect of this chemical binder.

<table>
<thead>
<tr>
<th>Properties</th>
<th>Chemical Binder</th>
<th>Portland Cement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fineness(mm)</td>
<td>75</td>
<td>0.074</td>
</tr>
<tr>
<td>Setting Time(hour)</td>
<td>2.5~3.0</td>
<td>4.0</td>
</tr>
<tr>
<td>Specific Gravity</td>
<td>3.15</td>
<td>2.8</td>
</tr>
<tr>
<td>Main Components</td>
<td>Portland cement clinker, Limestone, Furnace slag, Gypsum</td>
<td>Polymer with high-tech powder to modify silicate-based chemicals</td>
</tr>
</tbody>
</table>
3. Specimen Preparation

The specimens used in this study are prepared according to ASTM D5102-96 (ASTM, 2004). Marine clay used in this study was oven-dried overnight in order to obtain its water content. The calculated water content of marine clay was the key for specimens’ preparation and the subsequent testing. All of the specimens were prepared according to the water content and additive quantities. The additive quantities of chemical binder or cement were 10%, 20% and 30% of dry mass of marine clay. The calculated chemical binder or cement was mixed with marine clay until homogenous. Then the mixed marine clay were poured into the mould (76 mm in height and 38 mm in diameter), extruded from it and wrapped in cling film to preserve the water content and to minimize the exposure of chemical binder and cement with specimens. The specimens were then cured in a desiccator at 20℃ and with humidity of more than 90% for 7, 14, and 28 days, respectively.

4. Results and Discussion

4.1 Shear strength behaviour

Unconfined compression test is carried out to determine the maximum compressive strength of treated marine clay. The results of the unconfined compressive tests are obtained and plotted with different curing days in Fig.1. The shear strength of each specimen is determined based on the peak value of stress versus strain curve. The shear strength of pure marine clay is also illustrated in the figure. Compared with treated marine clay, the shear strength of pure marine clay with water content exceeding 40% is very low. At 7 days, the strength of chemical binder treated marine clay is higher than that of cement treated marine clay under the condition of water content exceeding some values. For 14 and 28 days, with the same dosage, the strength of chemical binder treated marine clay is about 1.2-1.4 times of cement treated marine clay. The strength of chemical binder treated marine clay can reach 80% of the maximum value at 14 days curing time. This proves that 14 curing days is enough to make the chemical binder treated marine clay obtain sufficient strength.
4.2 Durability of treated marine clay

In order to investigate the slaking behavior of chemical binder treated marine clay, the durability test of specimens was conducted in the water tank, as shown in Fig.2. The chemical binder and cement treated marine clay with 7 curing days were soaked in the water tank for 7 days and the slaking behavior were being recorded by the webcam during the test. It showed that these two types of treated marine clay had no collapse phenomenon or slaking behavior under the water, except for a layer of bubbles covering the specimens’ surface. It is possible to use chemical binder or cement to treat marine clay in a shallow sea environment.
Figure 2. Chemical binder and cement treated marine clay with 7 days curing time in water tank.

The results of slaking test demonstrate that these two treated marine clay has good durability under water. In order to obtain the shear strength of specimens after soaking, the specimens after 7 days soaking were taken out of the tank and did the unconfined compression test. The relationship between compression strength and water content is shown in Fig. 3. With the water content from 100% to 200%, the chemical binder treated marine clay has a better adhesion behavior than that of cement treated marine clay.

Figure 3. Relationship between compressive strength and water content of treated marine clay after 7 days soaking.

Conclusions
This paper presents a series of laboratory tests on the potential to use a chemical binder to stabilize marine clay. The major conclusions may be summarized as follows:
1) The unconfined compression strength of chemical binder or cement treated marine clay is significantly higher than that of pure marine clay. This indicates that this chemical binder or cement can be used to stabilize the marine clay.

2) With the same dosage, the confined compression strength of this chemical binder treated marine clay is about 1.2-1.4 times of that of cement treated marine clay at the same curing time. At 14 curing days, the shear strength of chemical binder treated marine clay can reach 80% of the maximum value.

3) Slaking test results indicate that chemical binder or cement treated marine clay has good durability under water. With the same dosage, the shear strength of chemical binder treated marine clay is higher than that of cement treated marine clay after 7 days soaking.

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References
