Proceedings of the 9th International Symposium on
LOWLAND TECHNOLOGY

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“Problems and Remedial measures of Lowland”
September 29 - October 1, 2014
Saga, Japan

Organized By:
International Association of Lowland Technology (IALT)
Institute of Lowland and Marine Research (ILMR)
Saga University, Saga, Japan
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IN COLLABORATION WITH:

Lowland Research Association
Department of Civil Engineering and Architecture, Saga University
Western Branch, Japan Society of Civil Engineers
Kyushu-Okinawa Branch, Japan Society on Water Environment
International Symposium on Lowland Technology

ISLT 2014

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ABSTRACT: Indonesia is an archipelagic country which makes many areas doesn’t have qualified water as drinking water. As concrete construction building in the region has possibly minimum or non-existent amount of fresh water, the using of sea water in mixing concrete and curing concrete is unavoidable. The demand of water is getting more and more increasing in both the improvement of infrastructure development and the life need. In the concrete industry, several billion tons of water is used as water mixing, curing and cleaning every year. Therefore the use of seawater is not allowed. In fact, we know that seawater is one of the abundant natural resources. Due to this problem, the research on the use of seawater is very important owing to the saving of freshwater is seriously needed. This study uses seawater by combining effective and efficient concrete technology of Self Compacting Concrete (SCC).

This paper is a part of ongoing research studying about microstructure characteristics and the strength of SCC using seawater. It discusses about the compressive strength, absorption and porosity as microstructure characteristics of SCC until the age of 28 days. The results are: (1) the seawater used as mixing water did not affect the development of the compressive strength of concrete, (2) the difference compressive strength of SCC-SS with SCC-FF at an early age is very high occurred at ages 1 and 3 days and (3). The higher the compressive strength value is, the smaller the absorption and porosity is in concrete.

Keywords: Self compacting concrete (SCC), compressive strength, absorption, porosity, seawater

INTRODUCTION

Water is one of the constituent materials of the concrete mixing which triggers a cement chemical process in cement pasta. In addition, the functions of it can be adhesive and lubricate materials for concrete fresh to be workable. Generally, concrete mixing uses drinking water/fresh water. The quantity and quality of water will affect the strength and durability of concrete.

Indonesia is the world’s largest archipelagic state that consists over 7.9 million square kilometers of seawater and 18,000 islands. It is makes many areas don’t have qualified water as drinking water. In concrete construction, the use of seawater in mixing is always avoided. Whereas, as we know that concrete construction infrastructure in the region has possibly minimum or non-existent amount of fresh water, the using of seawater in mixing concrete and curing concrete is unavoidable. Beside that there are some areas where seawater is used as mixing water with or without intension. The demand of water is getting more and more increasing in both the improvement of infrastructure development and the life need. Therefore, saving fresh water is essential to do by utilizing seawater due to it is an abundant natural resource.

Seawater contains of Sodium Chloride (NaCl), which gives the effect to the concrete. As what had been researched in the previous studies by Pruckner, F and Gjorv, OE, 2003. The addition of NaCl to fresh concrete will form Friedel's salt crystals (3CaO. Al2O3. CaCl2. 10H2O) which can increase pH and alkalinity to be higher, so it will allow the hydration of cement and also provide more solid structure with smaller pores. Besides that, Otsuki, N et al (2011), examined the using seawater as mixing water in the concrete was safe, which it has little influence on the strength and corrosion in concrete. Furthermore, by Tjaronge (2013), seawater can be used as mixing water and concrete curing water which concrete cured in the air has hydration process doing bad than it many pores and cracks. According to Shetty
(1982), seawater or water quality are not the factor that affect corrosion in concrete but rather permeability of concrete and the lack concrete cover.

Self Compacting Concrete (SCC) is an innovative concrete technology concept which is effective and efficient. Furthermore, fresh SCC has high fluidity so that it is able to flow and fill the spaces in the mold with little or no vibration process (Okamura, H and Ouchi, M, 2003).

SCC durability research had been carried out, among others, Al-Tamimi, AK and Sonebi, M (2003), the SCC performed better than the conventional concrete in sulfuric solution but was slightly more vulnerable to hydrochloric acid attack compared to conventional concrete. Persson, B. (2001, 2003), creep, shrinkage and modulus of elasticity of SCC are not different significantly with normal concrete and SCC. Moreover, there are no differences in mass and damage caused by sulfate after doing maintenance on up to 900 days in both sea and fresh water. Dinakar, P. et al (2008) SCC showed higher permeable voids and water absorption than the vibrated normal concretes of the same strength grades. However, in acid attack and chloride diffusion studies the high volume fly ash SCCs had significantly lower weight losses and chloride ion diffusion. Otsuki et al (2011, 2012) confident to safely use seawater as mixing water in normal concrete which is this 20 years’ exposure test, the kind of mixing water has little influence on the strength and corrosion in concrete. Furuya, D et al (2009) the Blast-Furnace Slag (BFS) cement with mixing seawater caused reaction ratio of BFS rose, the products of Friedel’s salt and Ettringite increased, and micro pore total volume decrease and small pore increase - compared with mixing distilled water. The compressive test results that mixing seawater specimens were stronger than mixing distilled water specimens. Heikal, M. et al (2012), the presence super plasticizer in Self Compacting Concrete make the microstructure displayed are dense arrangement structure of microcrystalline CSH as the main hydration products with sheets of Ca(OH)2 as shown in the micrograph.

Based on the problem, the research on the use of seawater is very important owing to the saving of fresh water is seriously done. This study uses seawater by combining effective and efficient concrete technology, Self Compacting Concrete (SCC).

MATERIALS

Cement

This study has used the type of Portland Composite Cement (PCC). The chemical composition of cement used can be seen in Table 1.

<table>
<thead>
<tr>
<th>SiO₂</th>
<th>Al₂O₃</th>
<th>Fe₂O₃</th>
<th>CaO</th>
<th>MgO</th>
<th>SO₃</th>
<th>LOI</th>
</tr>
</thead>
<tbody>
<tr>
<td>19.53</td>
<td>5.24</td>
<td>3.50</td>
<td>66.77</td>
<td>0.88</td>
<td>2.28</td>
<td>6.84</td>
</tr>
</tbody>
</table>

Seawater

This study used seawater to mix water and to cure. The chemical composition of seawater used can be seen in Table 2.

<table>
<thead>
<tr>
<th>Specific gravity</th>
<th>Chemical composition (mg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.01</td>
<td>Cl</td>
</tr>
<tr>
<td>8</td>
<td>20415.3</td>
</tr>
</tbody>
</table>

Coarse Aggregates

The Coarse aggregate used crushed stone with a maximum size of 20 mm. The specific gravity of coarse aggregate was 2.62.

Fine Aggregate

The fine aggregate used local natural sand with maximum size 4.75 mm. The specific gravity of fine aggregate was 2.57.

Admixtures

A ViscoCrete-3115 is a third generation as superplasticizer for SCC used in this study.

MIXING DESIGN AND EXPERIMENTAL METHODS

The European Federation of Specialist Chemicals and Concrete Constructions Systems (EFNARC) methods are used designing of SCC. The design used the volume ratio between water and cement equals to 1.1. Likewise, water cement factor equals to 0.35. SCC-SS was the name given to the self-compacting concrete using seawater as mixing water and curing. Workability of fresh concrete was observed by using a slump cone, slump flow and T500 which were measured. Compressive strength samples and porosity uses a cylindrical specimen with a size of 10 mm x 20
compressive strength testing was performed at the age of 1.3, 7, and 28. Proportion of mixing design in detail can be seen in Table 3.

Table 3 Mix design (liter/m³)

<table>
<thead>
<tr>
<th></th>
<th>Seawater</th>
<th>Cement</th>
<th>Sand</th>
<th>Crushed Stone</th>
<th>Superplasticizer</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>210</td>
<td>210</td>
<td>290</td>
<td>290</td>
<td>6.36</td>
</tr>
</tbody>
</table>

Compressive strength testing method follows the ASTM test standard 39/C 39M - 99. Equipment of Universal Testing Machine (UTM) is used to test the compressive strength by providing static monotonic uniaxial compressive load at an average speed of 0.14 to 0.34 MPa/Sec. Compressive strength can be calculated by Eq. 1.

\[
f_c = \frac{P}{A}
\]

Where \(f_c\) = compressive strength at the age (t) days (MPa), \(P\) = Maximum Load (N), \(A\) = surface area (mm).

Absorption and porosity test were using ASTM standard C642-13. Initially, the mass of the specimen was determined, and dried in an oven at a temperature of 100 to 110 °C for not less than 24 hours (A). After that, it was immersed in water at about 21°C for not less than 48 hours and up to two consecutive grades mass of dry sample surface at intervals of 24 hours showed an increase in mass of less than 0.5% of the larger value (B). Then, it was boiled for 5 hours and then let it cool by a natural loss of heat for not less than 14 hours until a final temperature of 20 to 25°C. The mass of the specimen that has been boiled (C) is determined, and then it was determined again in the water (D). Absorption and porosity can be calculated by the following Eq. 2 and 3, sequentially.

\[
a\% = \frac{B - A}{A} \times 100
\]

\[
e\% = \frac{C - A}{C - D} \times 100
\]

Where \(a\%\) = absorption (%), \(e\%\) = porosity of the concrete (%), \(A\) = mass of oven-dried sample in air, \(B\) = mass of surface-dry sample in air after oven and immersion, \(C\) = mass of surface-dry sample in air after immersion and boiling (g), \(D\) = mass of sample in water after immersion and boiling (g).

**RESULTS and DISCUSSIONS**

Slump Flow and \(T_{500}\)

Slump flow is defined as the average diameter of the spread of fresh concrete using slump cone. Both workability of SCC-FF and SCC-SS are qualified as SCC in accordance with the EFNARC standards of the Slump flow entry ranged 60-75 mm and \(T_{500}\) and 2-5 second. From the observation, fresh concrete looks homogeneous and there is no segregation and bleeding.

Compressive Strength

Compressive strength of concrete is the magnitude of the load per unit area, which causes the specimen was destroyed when it is burdened with a certain compression force generated by a machine press. Concrete compressive strength is the most important trait in concrete quality compared with other properties. Compressive strength of concrete is determined by the setting of the cement ratio, coarse and fine aggregates, water and various types of mixtures. Water-cement ratio is a major factor in determining the strength of the concrete. The lower the water-cement ratio is, the higher the compressive strength is. However, the excess of water easily improves the workability of concrete construction but lowers the strength. By utilizing SCC concrete technology, the small water-cement factor will obtain a high compressive strength with good workability.

Seawater used as mixing water and curing in the concrete SCC does not affect the achievement of high quality concrete that is planned \(\geq 50\) MPa. Compressive strength increases with the age growth of the concrete as shown in Fig. 1. Thus, the use seawater as mixing water does not hinder the hydration process of concrete and concrete strength. Figure 1 shows the relationship between concrete compressive strength and the age of each age of 1, 3, 7, until 28 days.
are 0.18, 0.51, 0.7, and 1, respectively. While the concrete used seawater as mixing water (SCC-SS), the ratio of compressive strength at the same range of ages to compressive strength 28 days are 0.29, 0.60, 0.73 and 1, respectively. More details can be seen in Fig. 2.

Figure 2 shows that the ratio of compressive strength of SCC at the age of 1 and 3 has a high difference of the ratio of the compressive strength of normal concrete (fresh water) at 37.58% and 16.10%, respectively. In addition, at the age of 7 days, the compressive strength of SCC ratio is almost the same at 4.92%.

The difference in compressive strength of SCC-SS as compared with SCC-FF at an early age is very high occurred at ages 1 and 3 days. The result agreed with the previous conducted by Falah M. W (2010), the compressive strength of normal concrete were shown to increase for specimens mixed and cured in seawater at early ages up to 14 days. Also, Aburawy, MM and Swamy, RN (2008), the presence of chlorides accelerated the early age strength development of concrete using slag up to about 7–14 days. Beyond this age, there was a distinct loss of strength of the concrete with chlorides but the reduction in strength was not significant. Erniati et al (2013) examined the use of seawater and distilled water in mortar as mixing water, with the result that seawater does not affect the hydration process in mortar and the compressive strength meets the standard specification.

The presence of super plasticizer makes denser microstructure. This result meets the previous studies of Heikal, M., et al (2012), the presence of super plasticizer in SCC gives the settings of denser microstructure and Calcium Silicate Hydrates micro crystals (CSH) as the main products of hydration and calcium hydroxide (CH) as the optional product.

Absorption and Porosity

Absorption (a) is the amount of water absorption into the concrete toward the volume total expressed in percent (%). Porosity (e) is the amount of voids in the concrete toward the volume total stated in percent (%).

The relations between absorption and porosity of concrete with the age can be seen in Figs. 3 and 4. It shows porosity value of SCC-SS is higher absorption value in the ages 3 days, 7 days, and 28 days. The difference between porosity and absorption in concrete SCC-SS is an average of 38.30%.

Figure 3 shows that the higher the compressive strength of concrete, absorption and porosity are getting smaller. Thus, the microstructure of it was denser. Seawater did not reduce the function of super plasticizer in it. As Heikal, M. et al researched (2012), the presence of super plasticizer in SCC gave the settings of denser microstructure and Calcium Silicate Hydrates micro crystals (CSH) as the main products of hydration and calcium hydroxide (CH) as the optional product.
Microstructure characteristic and compressive strength of SCC using sea water

CONCLUSIONS

1) The seawater did not affect workability of fresh SCC-SS.
2) The use of seawater did not interfere with the process of hydration and strength development of SCC-SS up to 28 days.
3) The difference compressive strength of SCC-SS with SCC-FF at an early age is very high occurred at ages 1 and 3 days.
4) The seawater used as mixing water and curing has accelerated the strength development of concrete at early age.
5) The difference between porosity and absorption in concrete SCC-SS is an average of 38.30%
6) The higher the compressive strength value is, the smaller the absorption and porosity is in SCC-SS.

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