STUDY ON THE EFFECT OF BAKING SODA ON BLEEDING AND COMpressive STRENGTH OF CEMENT MILk

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ABSTRACT: Cement milk is used for earth retaining structures, pile construction and also for ground improvement through cement deep mixing and other methods. However, it is quite difficult to estimate or evaluate the compressive strength of concrete mix during curing phase of the construction process. Excessive bleeding also remains a pertinent issue. Excessive absorption of moisture eventually leads to expansion, cracks, and causes reduction in concrete strength. This research was focused on reducing bleeding of cement solidified materials by adding baking soda. Baking soda acts as a catalyst and promotes hydration of cement through hydrolysis reaction. An alkali silica reaction occurs within the cement milk to form alkali silica gel. This shortens the setting time, and curtails excess moisture. The Laboratory experiments revealed that addition of about 3% of backing soda was the most effective. Furthermore, from the electrical resistivity and the compressive strength of 24 hours of the cement solidified material to which 1 to 4% of sodium bicarbonate was added, the compressive strength of 28 days of the material was also accurately estimated.

Keywords: Cement milk, Bleeding, Baking soda, Electrical resistivity, Compressive strength

1. INTRODUCTION

Cement milk or slurry is generally considered as liquefied cement. It is a mixed liquid that is composed of cement, water and other relative chemical additives. Cement milk has varied densities depending on the applied degree of mix. Cement milk has unique mechanical properties as it can flow under gravity and are also capable of being pumped. It can also be used in under water projects. In the past few decades, the use of cement milk in relative construction projects has greatly increased.

In Japan, cement milk is used for earth retaining structures, pile construction and also for ground improvement through cement deep mixing. The Cement Deep Mixing (CDM) method is a technique to chemically solidify and strengthen soft ground by in-situ mixing of the soil with cement slurry. This method of ground improvement is environmentally friendly and cost effective.

This method has been repeatedly used in ground improvement applications to prevent embankment instability and settlement, improve ground stability for construction projects, as countermeasures against liquefaction, and as reinforcement of ground to improve earthquake-response of superstructures [5].

The use of cement milk as a construction material is widely acceptable. However, bleeding has been a major constraint to the efficiency of this material in construction projects. Bleeding is an important phenomenon in construction process. This occurs majorly in freshly mixed concrete. Bleeding is widely described as the upward movement of moisture towards the surface as a result of the uneven settlement of heavier particles constituent of the mix.

Although various researches have been conducted on the possibilities of controlling bleeding including the use of slag as addictive, bleeding still remains a concern with regards to quality assurance of the use of cement milk especially in marine.

The purpose of this study is to examine and ascertain the hypothesis that backing soda can be used as additive in cement milk to control the bleeding rate of the material during construction process. It is expected to stabilize the hydration reaction of the cement.

2. LITERATURE REVIEW

Real time monitoring and control of high-quality execution is an important aspect in construction management. Development of techniques and technology with such features has been a growing concern. Ground improvement processes are also not left out of these concerns.

For example, while using cement milk material for in-situ cement deep mixing, it will be important to monitor the flow rate of the cement slurry, penetration and retrieval speed, and the rotation speed of the mixing shaft including the accuracy of
A method of estimating the 28-day compressive strength of cement milk from the initial electrical resistivity and the compressive strength, using a strength prediction based on the electrical resistance of the cement milk was proposed. In this way, we aim to realize a construction management method which is easy to operate with higher precision and quality assurance.

3. MATERIALS

Materials used for this study includes cement, water and baking soda. In the experiment, sodium bicarbonate was mixed with cement milk in four different ratios. The bicarbonate and cement ratio (B / C) was at 1%, 2%, 3% and 4%. These were mixed with 70% water and marked as the W / C ratio. The detail of each of these samples including the total weight of each specimen is as shown on Table 1.

### Table 1 Recipe of the specimens

<table>
<thead>
<tr>
<th>No.</th>
<th>B/C (%)</th>
<th>Water (Kg)</th>
<th>Backing soda (Kg)</th>
<th>Cement (Kg)</th>
<th>Total (Kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>14</td>
<td>0.2</td>
<td>19</td>
<td>33.2</td>
</tr>
<tr>
<td>1</td>
<td>2</td>
<td>14</td>
<td>0.4</td>
<td>19</td>
<td>33.4</td>
</tr>
<tr>
<td>1</td>
<td>3</td>
<td>13</td>
<td>0.6</td>
<td>19</td>
<td>32.6</td>
</tr>
<tr>
<td>1</td>
<td>4</td>
<td>13</td>
<td>0.8</td>
<td>19</td>
<td>32.8</td>
</tr>
</tbody>
</table>

4. EXPERIMENTAL EVALUATIONS

4.1 Bleeding Test

In cases where concrete retains excess moisture, cracks could occur. This results to a decrease in strength of the concrete. In this study, the impact and influence of baking soda through the soda cement ratio was noticed.

### Table 2 Bleeding Test Results

<table>
<thead>
<tr>
<th>No.</th>
<th>B/C (%)</th>
<th>Immediate Volume (Kg)</th>
<th>1day Volume (Kg)</th>
<th>2days Volume (Kg)</th>
<th>Bleeding (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>585</td>
<td>560</td>
<td>570</td>
<td>4</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>590</td>
<td>571</td>
<td>581</td>
<td>3</td>
</tr>
<tr>
<td>3</td>
<td>3</td>
<td>670</td>
<td>660</td>
<td>660</td>
<td>1</td>
</tr>
<tr>
<td>4</td>
<td>4</td>
<td>660</td>
<td>650</td>
<td>660</td>
<td>2</td>
</tr>
</tbody>
</table>

The bleeding rates were noted at the initial age of 0-24 hours including 15 minutes, 30 minutes, and 1 hour. The bleeding rate was also recorded at day 1, 3, 5, 7, 14, 21 and 28.
Table 2 shows the results of bleeding experiments at each baking soda cement ratio (B / C) within the first 48 hours of the experiment. Although there is no much difference in the result recorded from the specimens, the material with more bicarbonate shows the least amount of bleeding.

4.2 Electrical Resistivity

In this experiment, instant feedback on the mixing degree of the cement milk was achieved using electrical resistivity.

Electrical resistivity quantifies the extent of resistance of a material to the flow of current. The sensor is made up of electrodes that measures both current and voltage when inserted into a compound. Using the Ohms law, the resistance to current flow can be calculated.

During the mixing process of constituents of ground improvement bodies, or cement slurry in previous experiment, the relationship between the ion concentration of the primary materials relative to the electrical resistivity of the compound was established by comparing the resulting values when the compound is properly mixed and cases where the compound is incompletely stirred [3]. This has further improved the quality assurance during construction management.

Fig. 1 Relationship between the B/C ratio and the electrical resistivity of the specimens

In this study, the Electrical resistivity of the concrete mix was recorded at day 1, 3, 5, 7, 14, 21 and 28 of curing. Fig. 1 shows the relationship between sodium bicarbonate cement ratio (B / C) and electrical resistivity at each day.

At the age of 1 to 7 days, the specific resistance value increased only moderately regardless of the baking soda cement ratio, but after 14 days, the specific resistance value increased remarkably with the increase of the baking soda cement ratio as shown in Fig. 2. The values at B / C of 1% and 2% showed similar tendency until the 28th day. But at B / C of 3% and 4%, there was steady increase in the electrical resistivity values within the first 14 days. However, there was a sharp increase in values afterwards and through the curing age.

4.3 Uniaxial Compressive Test

In this study, the compressive strength test of each experimental sample with different ratio of baking soda was also conducted.

As shown in Fig. 3 the compressive strength of specimens with B/C of 1%, 2%, and 3%, shows only slight difference in increment between the day 5-21 and rises steadily till the 28th day. However, there was a huge difference with the 1%
B/C specimen. There was a sharp rise in the compressive strength from the first 24 hours to the 7th day. A much higher strength was recorded at the 28th day compared to the other specimens.

4.4 Temperature

The corresponding temperature differences of the specimens were monitored during the course of the experiments.

Fig. 4 Relationship age and temperature of the specimens

As shown in Fig. 4, the temperature peaked at about 75 °C after 10 hours and showed the same tendency in all baking soda ratios. However, the specimen with B/C 4% showed a rise in temperature slightly later than the other samples. Generally, the temperature dropped back at a drastic rate within the following 15 hours after attaining the peak temperature.

Also from Fig. 2, it will be observed that each specimen increased in specific resistance with rapid temperature change 5 hours after the start of the experiment. After 7 hours, the specific resistance value gradually increased.

5. Relationship between Compressive Strength and Electric Resistivity

As shown in Fig. 5, the compressive strengths of all the specimens increase with increase in electrical resistivity although the response followed different trends. For instance, specimen with B/C of 1% shows a rapid increment in Compressive strength to attain the peak value compare to others.

5.1 EXPERIMENTAL CONSIDERATION AND EVALUATION

Formulas (1) and (2) are used with reference to the evaluation method of prior research [1]. From the results of these experiments, evaluation equations were proposed by setting the constants $a$ and $b$ of Eq. (1) and the coefficients $K1$ and $K2$ of Eq. (2).

The relationship between material age and electrical resistivity is shown in Fig. 6. Since the material age and the specific resistance value are close to a linear relationship, it can be expressed by the near-form equation of $Y = aX^b$ (X: material age, Y: specific resistance value) based on material age and specific resistance value.

Since the value of $a$ does not have a big difference in B/C, an average value is used this time. Since the value of $b$ varies depending on the amount of baking soda blended, an approximate expression was used from the tendency of the inclination

$$\rho(X) = aX^b + \left\{ \rho(1) - \rho(\text{AVE}) \right\}$$

$\rho(X)$: Electric resistivity of the material at age $X$ (Ω·m)

$\rho(1)$: Measured electrical resistivity of the material at age 1 day (Ω·m)

$\rho(\text{AVE}) = 0.27675$ (Ω·m)

$\rho(1)$: the average value of 1 day of the materials as shown in Table 3

$a = 0.292925$  \quad $b = 0.3656B^{0.3984}

B$: Baking soda cement ratio [%]
The electrical resistivity at 1 day of material age in Fig. 6 shows a somewhat constant value regardless of B / C. As shown in Fig. 7, in the trends of material ages 1 to 28 days, changes in specific resistance value and compressive strength ratio were almost constant at each B / C. As mentioned above, the evaluation formula was proposed with reference to the following coefficients K1 and K2.

\[
\rho_{28} = K_1 \{ \rho(28) - K_2 + \rho(1) \} \quad (2)
\]

\( \rho_{28} \): Compression strength of the material at age 28 day \((\text{N/mm}^2)\)

\( \rho(1) \): Measured compression strength of the material at age 1 day \((\text{N/mm}^2)\)

\( \rho(28) \): Estimated electrical resistivity of the material at 28 days of age \((\Omega \cdot \text{m})\)

\[
Y = 0.3122x^{0.1285} \\
R^2 = 0.9985
\]

This time, using the measured electrical resistivity \((\Omega \cdot \text{m})\) of 1 day of material age of 28 days which was measured and recorded during the course of the experiment was verified according to Eq. (1) and was compared with the estimated value of the compressive strength according to Eq. (2). It was deduced that both are highly similar.

### Table 4  Validity of evaluation formula

<table>
<thead>
<tr>
<th>Experimental value ((\text{N/mm}^2))</th>
<th>Evaluation formula ((\text{N/mm}^2))</th>
</tr>
</thead>
<tbody>
<tr>
<td>1%</td>
<td>18.811</td>
</tr>
<tr>
<td></td>
<td>18.075</td>
</tr>
<tr>
<td>2%</td>
<td>13.593</td>
</tr>
<tr>
<td></td>
<td>13.846</td>
</tr>
<tr>
<td>3%</td>
<td>14.771</td>
</tr>
<tr>
<td></td>
<td>13.624</td>
</tr>
<tr>
<td>4%</td>
<td>15.668</td>
</tr>
<tr>
<td></td>
<td>15.889</td>
</tr>
</tbody>
</table>

Also, the electrical resistivity at 1 day of the specimens was derived using Eq. (1) and used with the measured compression at 1 day of material age in Eq. (2). The strengths were used to correctly estimate the 28-day compressive strength of cement milk mixed with baking soda.

It was finally deduced that baking soda can be used as a catalyst in controlling the bleeding rate of cement milk or a cement soil mixture. Through an alkali silica reaction within the cement milk to form alkali silica gel, backing soda can shorten setting time and reduce bleeding rate while fostering the continuous hydration of the cement milk.
In addition, it has been verified that this method can be used to estimate the 28-day compressive strength of cement milk from the initial electrical resistivity and the compressive strength. This is achieved using strength prediction based on the electrical specific resistance of the cement milk. This method can also be used as a tool in preempting likely behavior of the resulting material from the cement milk mixture towards fostering quality assurance in construction management.

7. REFERENCES


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