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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 addictive 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 degree mix of the constituents.

Different technology has been developed to monitor such processes including the use of computer aided monitor system for real time monitoring and analysis of the construction process. The use of electrical resistivity has also been engaged to provide instant feedback on the mixing degree between constituents of the cement milk during placement. This is accurately deduced from the change in resistivity of the resulting compound.

During the mixing process of concrete or cement slurry in our previous experiments, it has been established that with regards to the ion concentration of the primary materials, the electrical resistivity of the compound is adequately lower when properly mixed and increase in cases where the compound is incompletely stirred [3].

Aside the aforementioned issues, another factor that relatively affects cement mixture is bleeding. Bleeding is equally important 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.

In structures using cement milk such as piles, ground improvement and cement soil mixture, the occurrence of excessive bleeding results to the formation of a weak hardened cement milk layer and cause problems relative to level control.

Although bleeding plays an important role during concrete setting as it replaces evaporated moisture and thus prevents excessively early hardening. Excessive bleeding leads to strength loss by producing laitance at the surface of the concrete. This also leads to wear resistance and poor bonding between the layers of the concrete.

Aside the cement water ratio, cement type and the corresponding size of the fine aggregate also indicates the bleeding rate to a large extent. In the cases of grouting, factors such as pressure and height also affect the rate and percentage of bleeding.

Although Addition of supplementary binding materials, use of finer cements including the introduction of an air entraining admixture can be effective in controlling bleeding rate however, care must be taken to ensure that the rate of chemical composition of the mix does not end up increasing the bleeding rate.

In this study, we experimentally verified the possibility of controlling bleeding by adding baking soda to cement milk. The purpose is to examine the behavior of baking soda as a catalyst to promote the hydration reaction of cement.

The effect of the addictive on bleeding rate of cement milk including the electrical resistivity was also monitored relatively to the compressive strength.

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

Weight (Kg)				W/C (%)	B/C (%)
Water	Backing soda	Cement	Total		
14	0.2	19	33.2	70	1
14	0.4	19	33.4	70	2
13	0.6	19	32.6	70	3
13	0.8	19	32.8	70	4

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

No.	B/C (%)	Volume			Bleeding (%)	
		Immediate	1day	2days		
1	1	585	560	570	4	3
2	2	590	571	581	3	2
3	3	670	660	660	1	1
4	4	660	650	660	2	0

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 48hours 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.

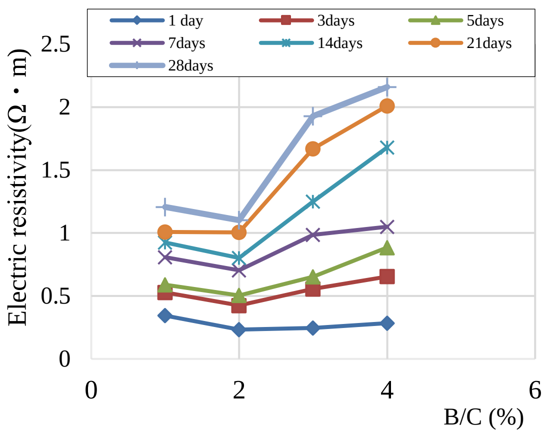

Fig. 1 Relationship between the B/C ratio and the electrical resistivity of the specimens

In this study, the Electrical resistivity of the concrete mix was recorded at day 1, 3, 5, 7, 14, 21and 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

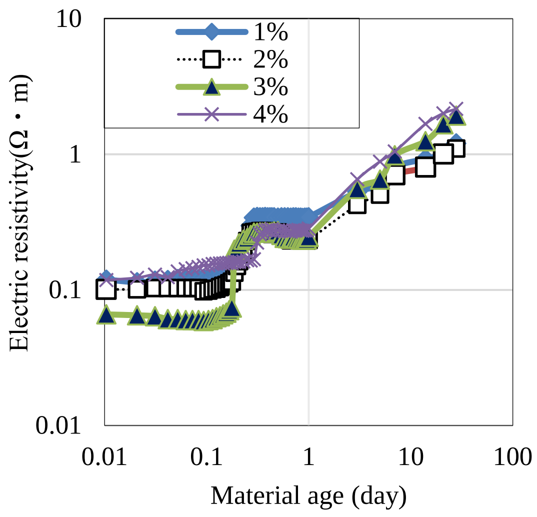

Fig. 2 Relationship between age and the electrical resistivity of the specimens

3% and 4%, there was steady increase in the electrical resistivity values within the first 14days. 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.

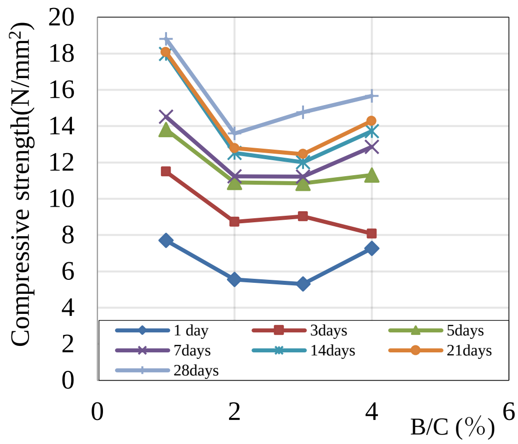

Fig. 3 Relationship between B/C ratio and compressive strength of the specimens

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 24hours 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.

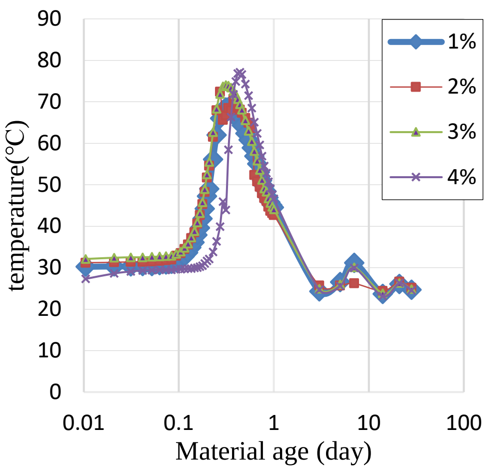

Fig. 4 Relationship age and temperature of the specimens

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.

5.1EXPERIMENTAL CONSIDERATION AND EVALUATION

Formulas (1) and (2) are used with reference to the evaluation method of prior research [1]. From the

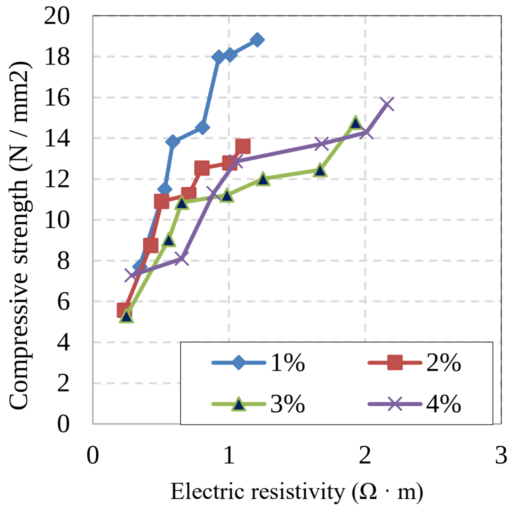

Fig. 5 Relationship compressive strength and electric resistivity

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

$$\rho(X) = aX^b + \{\rho(1) - \rho(1ave)\} \quad (1)$$

ρ(X) : Electric resistivity of the material at age X day(Ω·m)

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

ρ (1AVE) = 0.27675[Ω·m]

ρ (1AVE) : 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 [%]

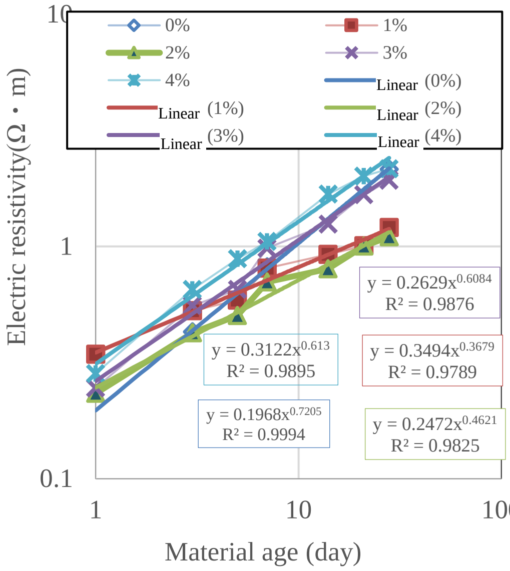

Fig. 6 Evaluation of material age and electrical resistivity

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.

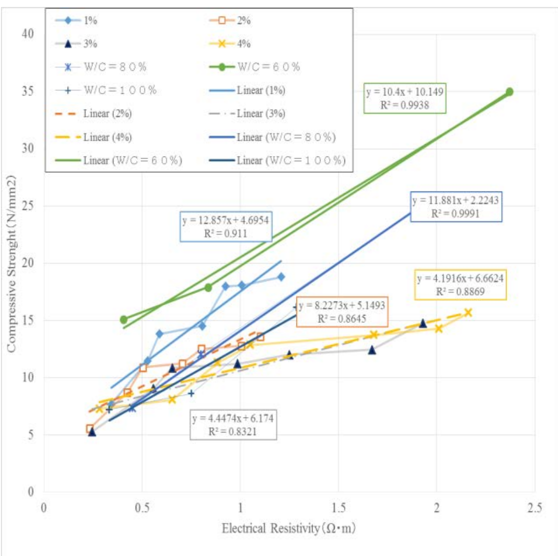

Fig. 7 Evaluation of electrical resistivity and compressive strength

$$qu(28) = K1 \cdot \{\rho(28) - K2 + qu(1)\} \qquad (2)$$

qu(28): Compression strength of the material at age 28 day (N/mm²)

qu(1): Measured compression strength of the material at age 1 day (N/mm²)

ρ (28): Estimated electrical resistivity of the material at 28 days of age (Ω·m)

$$K1 = 13.578B^{(-0.898)}\{N/mm^2 \cdot (\Omega \cdot m)\} \qquad (3)$$

K2: ρ(1)

※ This time, using the measured electrical resistivity (Ω・m) of 1 day of material age

6. SUMMARY AND CONCLUSION

As shown in Fig. 7 and Fig 8, the electrical resistivity of the specimens within the material age

Table 3 Electric resistivity and average value for 1-day material

	1%	2%	3%	4%	Average value
1day	0.344	0.233	0.246	0.284	0.27675

of 28days 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

	Experimental value (N/mm²)	Evaluation formula (N/mm²)
1%	18.811	18.075
2%	13.593	13.846
3%	14.771	13.624
4%	15.668	15.889

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.

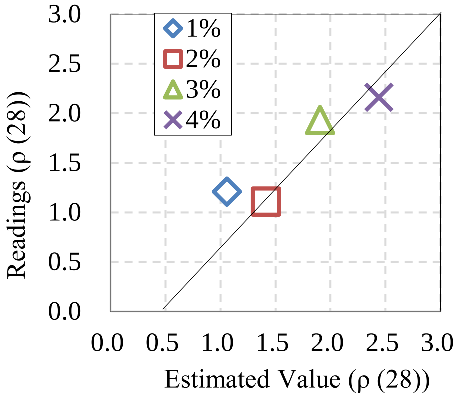

Fig. 8 Relationship between estimated values and measured electrical resistivity values

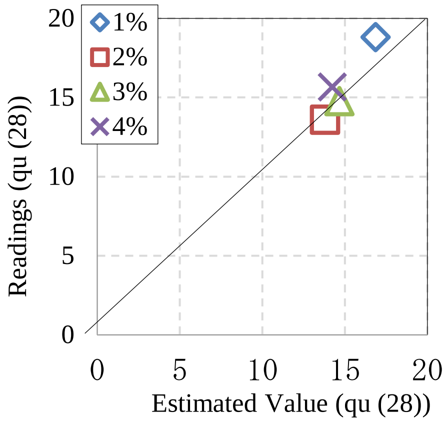

Fig. 9 Relationship between estimated values and measured compressive strength values

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.

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