IMPROVED EFFECT OF CEMENT BENTONITE TYPED FILLING BY MIXING SODIUM CARBONATE

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ABSTRACT

Cement milk is used as a grout to fill holes which are resulted from pile extraction. Although cement milk has an advantage of being able to perform blending and placing according to circumstance of work on site, cement and water cause segregation, so uniform filling is difficult over the entire length of holes. In addition, there is a disadvantage that cement milk can't perform a predetermined strength when diluted by groundwater erosion. Sodium carbonate is a substance expected to suppress the segregation of cement milk and to speed up the development of strength. In this study, we conducted an indoor mixing test on fillers mixed with sodium carbonate into cement milk which is a mixture consisting of water, cement and bentonite, and examined various characteristics from the viewpoint of physical and chemical aspects. (1) By mixing sodium carbonate, bleeding of cement milk is suppressed. This is considered to be due to increased swelling of bentonite by receiving sodium ions. (2) By mixing sodium carbonate, the strength development time of cement milk is advanced and the long-term strength also increases. This is considered that calcium carbonate is generated at the initial stage of reaction from the reaction of bentonite and sodium carbonate.

Keywords: cement, bentonite, sodium carbonate, bleeding, early strength

1. INTRODUCTION

1.1. RESEARCH BACKGROUND

In demolition work, it is necessary to remove existing piles in the ground. If new land use is planned, existing piles must be removed so as not to interfere with pile foundation of newly built-structures. In addition, existing piles remaining in the ground are industrial waste, so troubles often occur in the land sale transaction. Therefore, removal of existing piles is indispensable. In order to remove an existing piles, a drawing out method is generally adopted. In the drawing out method, holes are formed in the ground, which adversely affect the ground environment. In the vicinity of the hole, it may cause problems such as collapse of earth and sand, subduction of the surrounding ground, weakening, so it is necessary to fill the filling and stabilize the ground quickly. Depending on the construction site, the properties required for the filling are different, but there is no regulation on filling presently. From the above, there is a demand for constructing a filler that can reliably fill and secure stable strength.

1.2. PURPOSE

We will aim for the development of a filling that exhibits uniform strength without causing material separation when filling holes generated by pulling out existing piles. We aim at sophistication of cement bentonite typed cavity filling since it is possible to adjust blending filling at the construction site. By mixing sodium carbonate (Na_2CO_3), it is expected that the strength development of the cement bentonite type cavity filling will be promoted and the bleeding will be suppressed. We will examine the improvement and usefulness as cavity filling by conducting an indoor blending test on cement bentonite and sodium carbonate mixed cement bentonite. For examining the improvement and usefulness, a comparative test is conducted in view of strength characteristics, fluidity and material separation.

1.3. OUTLINE OF RESEARCH

In this research, we carried out uniaxial compression test, penetration test, bleeding test and flow test on cement bentonite and cement bentonite mixing sodium carbonate, and examine usefulness of cement bentonite typed filling by mixing sodium carbonate. In addition, we consider the mechanism of the development of various properties exerted by mixing sodium carbonate from the physical and chemical point of view (Fig.1).

2. Method

2.1 Materials and mixing conditions

(1) Cement

The type of cement used in this study is ordinary portland cement, and one is having a density of 3.16g /cm3 and a specific surface of 3200cm^2/g. Cement is a main component which exerts a curing function as a cement bentonite typed cavity filling because it reaction with hydration and develops initial and long-term strength by the formation of ettringite and calcium silicate hydrate(C-S-H).

(2) Bentonite

The chemical components of the bentonite used on our test are shown in Table 1. Bentonite has the effect of suppressing material separation of cement and water by swelling property due to take water into the one [1)]. Bentonite is a smectite clay mineral containing montmorillonite as a main component and has a layered structure in which thin plate crystals are stacked. The crystal is negatively charged and electrical equilibrium is maintained by adsorbing cations between crystal layers. The interlayer cations of montmorillonite are mainly composed of sodium ion (Na^+), calcium ion (Ca^{2+}), potassium ion (K^+), magnesium ion (Mg^{2+}), and the properties of bentonite vary depending on the type of the one. The type is divided into two types, one is called Na type where a large number of monovalent cations such as Na^+ and K^+ are adsorbed, and the other is called Ca type where a large number of divalent cations such as Ca^{2+} and Mg^{2+} are adsorbed [2)]. The bentonite used in this experiment is a Na type bentonite having many Na^+ in interlayer cations.

(3) sodium carbonate

When we mix sodium carbonate as an admixture into a cement bentonite typed cavity filling in this experiment, we use anhydrous salt obtained by heating at a high temperature of 300°C. Table 2 shows the chemical components of the admixture, and it contains Na_2CO_3 of 99.41%. Sodium carbonate is expected to promote the hydration reaction between cement and water and exert the effect of early strength development [3)].

(4) mixing condition

Table 3 shows the mixing conditions of each material used in the series of tests. The target strength is set to 0.5N/mm^2 on the mixing condition. In the precast pile driving method prescribed in the "Public Building Standards Manual"[4)], since the pile circumferential fixing liquid is set to 0.5N/mm^2 at the compression strength after 28 day material age and is considered to be the same as the ground strength, the strength is generally adopted as a standard. In blend A and B, cement bentonite and cement bentonite mixing sodium carbonate whose weight ratios C/B=5, 6 of

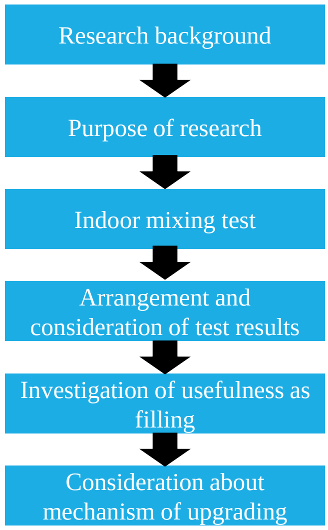


Fig.1 Procedure of study

Table 1 Chemical components of bentonite

Chemical Components	Content (%)
SiO_2	67.1
Al_2O_3	16.8
Fe_2O_3	3.7
MgO	3.3
CaO	2.7
Na_2O	2.2
K_2O	1.3
Ignition loss	2.9

Table 2 Chemical components of the admixture

Chemical Components	Content (%)
Na_2Co_3	99.41
NaCl	0.35
Fe_2O_3	0.003 or less
Insoluble matter	0.001or less
Ignition loss	0.15

Table 3 Mixing conditions of each material

No.	B (kg/m^3)	C (kg/m^3)	S (kg/m^3)	W (kg/m^3)	W/C (%)
A-1	50	240	0	905	377
A-2	50	240	20	897	374
B-1	50	300	0	886	295
B-2	50	300	20	878	293
C	50	180	20	916	509
D	50	200	20	910	455
E	50	220	20	903	410
F	50	250	20	894	358
G	50	260	20	891	343

cement (C) and bentonite (B) were prepared, and we investigate the properties of cement bentonite mixing sodium carbonate perform. In blend C, D, E, F and G, only the amount of cement (C) is changed to prepare cement bentonite mixing sodium carbonate and the correlation between sodium carbonate and cement is examined. In the mixing procedure, water (W) and bentonite (B) were added to a stirrer having a rotation speed of 1,500 rpm/min and stirred for 3 minutes, then ordinary portland cement (C) was added and stir for 3 minutes and sodium carbonate was added and stir for 3 minutes (Fig.2).

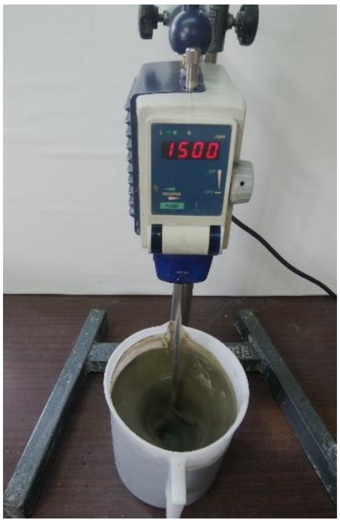


Fig.2 Mixing and stirring of materials

2.2. Strength test

The strength development of cement bentonite mixing sodium carbonate will be examined according to the Japanese Industrial Standard (JIS A 1216) "uniaxial compression test". Each material is mixed according to mixing conditions and it is poured into a mold having a diameter of 50mm and a height of 100mm to prepare a sample. Curing is performed for 7, 14, 28, 60, 90, 120 days in a thermostatic chamber at 20°C, and a uniaxial compression test is performed at each curing day (Fig.3).

Fig.3 Uniaxial compression test

In order to investigate the change about the action of cement bentonite due to mix sodium carbonate, we conduct a simple penetration test on samples of A and B. Penetration resistance values in immediately after sample mixing and 30 minutes, 1, 2, 3, 4, 5, 6, 7, 8, 12, 24 hours are measured using a simple measuring instrument (Fig.4).

Fig.4 Simple penetration test

2.3. Bleeding test

A test is carried out according to the JSCE Standards (JSCE-F522) "Bleeding Rate and Expansion Rate Test Method of grouting Mortar of Prepacked concreat (Polyethylene Bag Method)" in order to evaluate material separation of water and cement (Fig.5). The Sample mixing each material put to a height of 200mm in a polyethylene bag with a diameter of 50mm and the amount of bleeding water after 1, 3, 24 hours is measured, and the bleeding rate is obtained using the following formula.

$$\mathbf{Br} = \left(\frac{\boldsymbol{Wb}}{\boldsymbol{V}}\right) \times \mathbf{100}$$

Br (%) is the bleeding rate, Wb (ml) is the amount of bleeding water at each elapsed time, and V (ml) is the volume of the whole sample.

2.4. Fluidity test

The fluidity of cement bentonite mixing sodium carbonate is evaluated according to JSCE-F521 "Fluidity Test Method of grouting Mortar of Prepacked concreat (Method of P Funnel)". The Sample mixing each material is filled in a P-funnel tester having an outflow pipe inner diameter of 13mm, an outflow pipe length of 38mm and a funnel portion height of 192mm. The sample is allowed to flow by releasing a finger from the flow pipe, and we measure the time until the flow of sample is interrupted for the first time with a stopwatch (Fig.6).

Fig.5 Bleeding test

Fig.6 fluidity test

3. Consideration

3.1. Consideration on strength test

(1) Initial strength development

From the uniaxial compression test results in Fig.8 (a), compare the initial strength of cement bentonite and cement bentonite mixing sodium carbonate. A-1 has the 7th day strength of 0.09N/mm^2, and A-2 has a seven-day strength of 0.30N/mm^2, so A-2 is stronger than A-1. Similarly in the comparison between B-1 and B-2, the 7th day strength of B-1 is 0.37N/mm^2 and the 7th day strength of B-2 is 0.59 N/mm^2, so mixing sodium carbonate makes cement bentonite stronger than when it does not mix. Therefore, it can be said that the initial strength of cement bentonite increases by mixing sodium carbonate. In addition, since no significant difference is observed in the strength development behavior up to the 28th day of age, it is thought that sodium carbonate influence the strength development before the 7th day of age.

In Fig.7, the results of the penetration test showed that the resistance values of cement bentonite of A-1 and B-1 rise about 8 hours after mixing and stirring of each material, but the values of cement bentonite mixing sodium carbonate of A-2 and B-2 rise about 1 hour after mixing and stirring. Since the setting initiation time of cement bentonite is accelerating, it can be said that mixing sodium carbonate affects the solidification performance at the one-day of age. Exercising solidification performance in 1 hour after filling prevents the invasion of groundwater in the ground and helps developing stable strength cement bentonite type cavity filling.

From the above, mixing sodium carbonate into cement bentonite promotes the solidification performance immediately after mixing and stirring of each material, and exerts a useful effect as a filling.

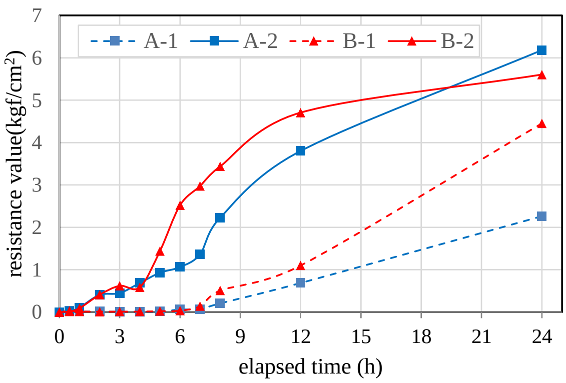


Fig.7 Result of penetration test

(2) long-term strength

From the uniaxial compression test results in Fig. 8(a), compare the long-term strength of cement bentonite and cement bentonite mixing sodium carbonate. In comparing A-1 and A-2, B-1 and B-2, the strength of mixing sodium carbonate is stronger than not mixing at any age. However, as for the tendency of strength development, there is a tendency that the strength increases up to about the 28th day of age in any samples, and the strength hardly increase after that. In addition, Fig.9 shows the values normalized by the strength of 28th day of age (hereinafter referred to as compression strength ratio). Comparison of each sample from Fig.9(a) showed no significant difference in long-term strength development behavior after 28th day of age, and the compressive strength ratio is around 1.0, except for B-

1. There is not effect on the long-term strength development due to mix sodium carbonate, so the reason why the strength is larger on each age at the time mixing sodium carbonate is considered that the increase of the initial strength affects the long-term strength development.

(3) **Increase Mechanism of Initial and Long-term Strength**

The amount of cement is changed in C, D, E, F, and G of cement bentonite mixing sodium carbonate. From Fig.8(b), there is a trend that the smaller the water-cement ratio is, the stronger the strength is at each age. In addition, from Fig.9(b), there is no clear difference in the tendency of strength development in any samples except for C, and the compressive strength ratio at 90th day of age is about 1.15. There is no difference in behavior of initial and long-term strength development of cement bentonite mixing sodium carbonate by difference in cement amount, so it can be said that sodium carbonate has no effect on cement. Therefore, the initial strength increase of cement bentonite by mixing sodium carbonate does not promote the hydration reaction between cement and water, and it is considered that forms a cured body different from cement hydrate.

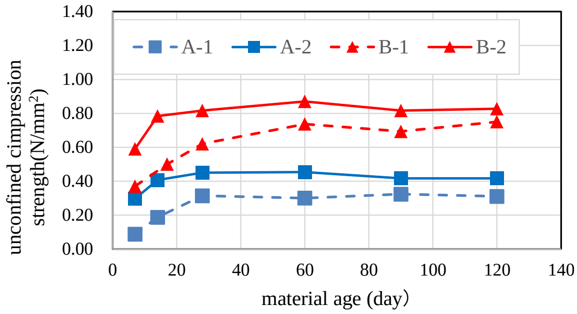
Here, attention is paid to sodium carbonate and bentonite. Bentonite has different properties depending on the type of interlayer cation of montmorillonite, but bentonite easily changes its properties by ion exchange with other types of cations since it has ion exchange properties. The interlayer cation exchangeability increases in the following order[5).

$$\boldsymbol{N^+ < K^+ < Ca^{2+} < Mg^{2+}}$$

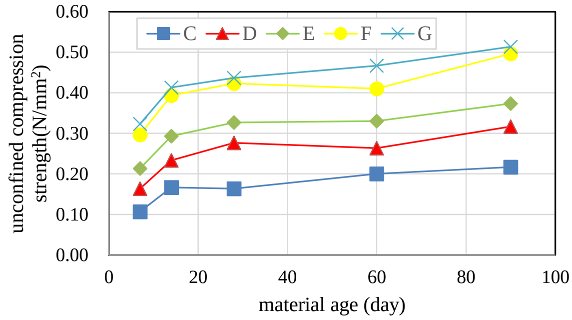
When sodium carbonate (Na_2CO_3) dissolve in water, it ionizes to sodium ion ($2Na^+$) and carbonate ion (CO_3^{2-}).Therefore, Ca^{2+} contained in the interlayer cations in the bentonite and Na^+ ionized from the sodium carbonate perform ion-exchange, and Ca^{2+} and CO_3^{2-} are bonded to form calcium carbonate ($CaCO_3$). Calcium carbonate is a water-insoluble substance, and forms a cured body by binding molecules with each other. The early strength development of cement bentonite by mixing sodium carbonate and the increase in long-term strength are attributed to the formation of a cured body of calcium carbonate immediately after mixing of materials.

3.2. Consideration on breathing test

Table 4 shows the results of the bleeding test. In Cement bentonite of A-1 and B-1, the bleeding rate increase with the passage of time, but in cement bentonite mixing sodium carbonate of A-2 and B-2, about 0.5% bleeding is only confirmed after 1 hour, and there is no moisture on the surface of the specimen. Similarly, in C, D, E, F, and G, it can be confirmed that the bleeding rate becomes 0% within 24 hours from the mixing of the materials. The decrease in the bleeding rate of cement bentonite due to the mixing sodium carbonate is attributed to the increase in the

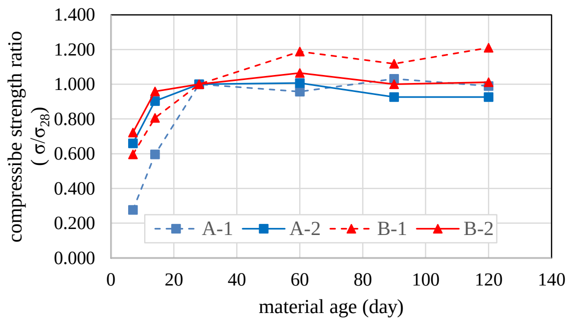


(a) Comparison by mixing sodium carbonate

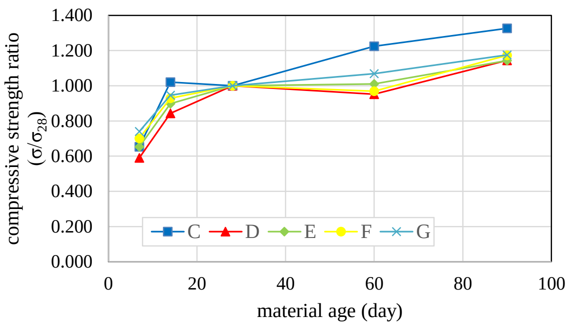


(b) Comparison by changing cement amount

Fig.8 Result of uniaxial compression test



(a) Comparison by mixing sodium carbonate



(b) Comparison by changing cement amount

Fig.9 Compressive strength ratio

Table 4 Results of bleeding and fluidity test

No.	flowing down time (s)	bleeding rate (%)		
		1hour	3hour	24hour
A-1	7.7	3.6	9.3	9.5
A-2	7.6	0.5	0.0	0.0
B-1	7.8	4.0	9.5	9.8
B-2	7.6	0.4	0.0	0.0
C	7.7	0.9	0.8	0.0
D	7.7	0.7	0.5	0.0
E	7.7	0.5	0.0	0.0
F	7.7	0.5	0.0	0.0
G	7.7	0.5	0.0	0.0

swellability of bentonite and the initial strength development of cement bentonite. Bentonite exerts swellability by interlayer cations of montmorillonite adsorbing water molecules. As compared with Ca type bentonite, the Na type bentonite has a weak electrical attraction between the unit layers, and so it is likely to swell when adsorbing water molecules. As described above, sodium carbonate in water is ionized to generate Na^+, which is exchanged with Ca^{2+} contained in interlayer cations in bentonite. It is considered that the swelling property of bentonite is improved, because the interlayer cations become more inclusive of Na^+. In addition, a hardened body is formed quickly since calcium carbonate is produced, and movement of water molecules in cement bentonite is inhibited. There is also a decrease of the amount of water due to the hydration reaction with cement. Therefore, it is considered that various phenomena such as increase of swellability with bentonite due to mixing of sodium carbonate, early strength development of cement bentonite, and hydration reaction of cement and water are involved, and the bleeding does not occur after several hours from mixing.

3.3. Consideration on fluidity test

Table 4 shows the results of the fluidity test. In each sample, the flowing down time is about 7.7s, and no decrease in fluidity of cement bentonite due to mixing sodium carbonate is observed. As described above, since curing started in about one hour after mixing the materials, the early strength development performance does not affect the fluidity at the time of filling. Although there is a possibility that material separation may occur due to flowing down, since bleeding hardly occurs, it can be said that the samples are having moderate fluidity. Therefore, it is able to say that the cement bentonite mixing sodium carbonate has ensured workability as a cavity filling.

4. CONCLUSIONS

In this study, the usefulness of the cement bentonite typed cavity filling mixing sodium carbonate was examined from the viewpoint of strength characteristics, material separation and fluidity. The obtained results are shown below.

(1) From the uniaxial compression test, mixing sodium carbonate increases the initial and long-term strength of cement bentonite. The early strength development helps stabilizing the ground as soon as possible.

(2) From the penetration test, by mixing sodium carbonate, cement bentonite exerts curing performance from about 1 hour after mixing materials. The rapid gelation prevents invasion of groundwater into the filling in the ground, and the filling can stably exhibit the predetermined strength.

(3) From the bleeding test, bleeding of cement bentonite is suppressed by mixing sodium carbonate. When it fills into the hole made by pulling out piles in the ground, the materials is kept homogeneous and the strength is not differ depending on the depth direction.

(4) From the fluidity test, the fluidity of cement bentonite is not lost by mixing sodium carbonate. Workability is assured in filling holes in the ground.

In the future, it is necessary to clarify the mechanism of various characteristics development by verifying from a physicochemical point of view.

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