Investigation for Strength and Durability of Mortar Using Dry Sludge Powder

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ABSTRACT

In recent years, reducing environmental impact is required in all industries. Therefore, the dry sludge powder has attracted a great deal of attention in the construction industry. Dry sludge powder is a method to reuse returned concrete. It is hoped that this can be reuse as replace cement. In the previous study, it is reported that specific surface area and density are different in the dry sludge powder according to the processing time at the production. We need to investigate strength and the durability to utilize dry sludge powder effectively because these are necessary for construction materials. In this study, authors inspected the strength developing property and durability of mortar using the dry sludge powder which different processing time. As a result, the strength development property obeys the progress of hydration reaction. The carbonation depth of mortar using the dry sludge powder became larger than mortar using Ordinary Portland Cement. On the other hand, the salt penetration depth become smaller than mortar using the Ordinary Portland Cement.

KEYWORDS: *dry sludge powder, processing time, strength, durability*

1. Introduction

Recently, in the construction industry, the processing of returned concrete is a problem. The returned concrete is cleaned and separated into recovered aggregate and sludge water. Recovered aggregate, supernatant water and sludge water satisfying the criteria of sludge solid fraction of 3% or less are accepted for reuse in JIS. This process not only costs a lot of money but also places a burden on the environment. Therefore, a method of using dry sludge fine powder (hereinafter referred to as DSP) obtained by drying the sludge cake as cement has been studied. In the past research, it is reported that DSP has different density and specific surface area depending on the time from kneading of raw concrete to drying treatment. However, little is known about durability. In this research, we aimed to clear the salt penetration resistance of mortar using only DSP with different curing time. In addition, we investigated mass transfer and pore size distribution affecting salinity penetration resistance.

2. Outline of Experiment

Materials used in this study, 4 types of DSP on processing times (respectively DSP-A, DSP-B, DSP-C, DSP-D) as shown in Table 1. For comparison, Ordinary Portland cement (OPC) was used. Mix proportion was 1: 3 mortar with reference to the cement strength test of JIS R 5201, demolished on the date of injection and sealed curing was carried out for 28 days in a constant temperature and humidity environment (temperature 20 degree Celsius, humidity RH60%).

Table 1. Details of DSP

	DSP-A	DSP-B	DSP-C	DSP-D
Processing Time (h)	8	12	24	24
Specific Surface Area (cm^2/g)	7410	8920	10590	11400
Dencity (g/cm^2)	2.81	2.58	2.46	2.45

2.1 Strength Test

Bending and compressive strength test of mortar after curing period was conducted according to JIS R 5201.

2.2 Pore Measurement Test

A sample of about 40 × 40 × 30 mm was taken from the mortar specimen. Hydration stopped by accetone. After put in a drying oven at temperature 40 degree Celsius, measuring the mass in an absolutely dry state, saturated in a vacuum state, and the saturated water mass and the mass in water were measured. The porosity was calculated by the Archimedes method using these values.

2.3 Accelerated Carbonation test

After 28 days of sealing curing, open the one side except casting side, specimen was placed in accelerated carbonation test equipment (Carbon dioxide concentration 5%, temperature 20 degree Celsius, humidity RH60%). Carbonation depth was measured at by 7,]
14, 28, 42days brown part using phenolphthalein solutions in split area. Then, it was calculated the coefficient of carbonation ratio using these results.

2.4 Salt Water Immersion Test

After 28 days of sealing curing, the specimen coated with epoxy resin except casting side, specimen was put into the NaCl 10% solution. The saltwater dipping period were 7, 14,28,42 days. After each immersion periods, splitting was performed and an aqueous silver nitrate solution was sprayed on the split face. The depth from the surface to the point where it turned white was measured, and the number of points to be measured was set to 4 points. These measured values were averaged and taken as the salt penetration depth.

2.5 Water Permeability

It specimens using cylindrical specimens φ100 × 50mm, acetone was quenched hydrated, was absolutely dry state in a drying oven at temperature 40 degree Celsius. Put a certain amount of water with stand pipe graduated to calculate the permeated water actually specimen from a height of reduced water under pressure. Incidentally, was measured time measured up to 30 minutes each and then permeability started after 3 hours. The loading pressure was carried out in two patterns of 0. 6 MPa and 0.05 MPa, both outflow side pressure was 0. 1 MPa.

2.6 Mercury Intrusion Test

Since the pore structure greatly affects the substance permeability, mercury penetration test was carried out using a mercury intrusion porosimeter for the purpose of grasping the pore diameter distribution. Using a mortar sample cut to about 5 × 5 × 5 mm, the pore size distribution was measured with a mercury intrusion porosimeter.

3. Results and Discussion

3.1 Strength

A strength test was conducted to confirm the strength development of DSP. Figure 1 shows the bending strengths at 7 and 28 days of curing and Figure 2 shows the compressive strength at 7 and 28 days of curing. In general, DSP does not reach the strength of OPC. Similarly, to the previous studies, DSP with a long processing time has low strength development, and as the processing time becomes shorter, the strength development of DSP becomes higher. Fig. 3 shows the results of the porosity test. Porosity of mortar using DSP became larger than mortar using OPC. Figure 4 shows the relationship between compressive strength and porosity after 28 days of sealing curing. DSP-C and DSP-D showed virtually equal porosity and compressive strength. Also, the higher the porosity, the lower the compressive strength.

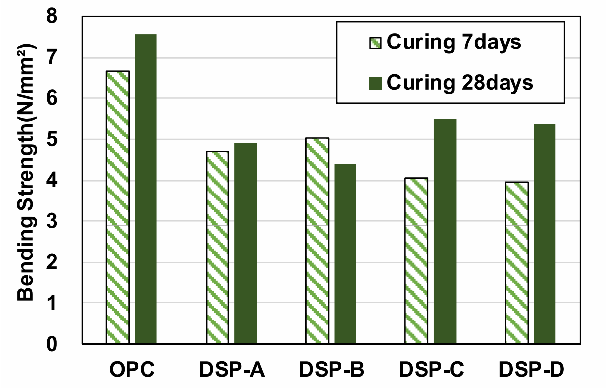

Figure 1. Bending Strength

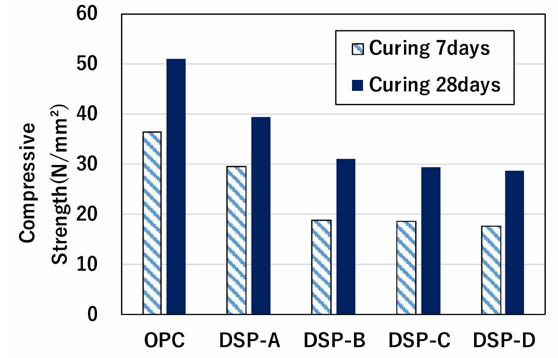

Figure 2. Compressive Strength

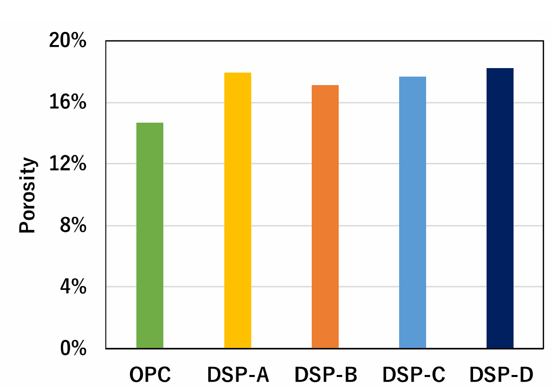

Figure 3. Porosity

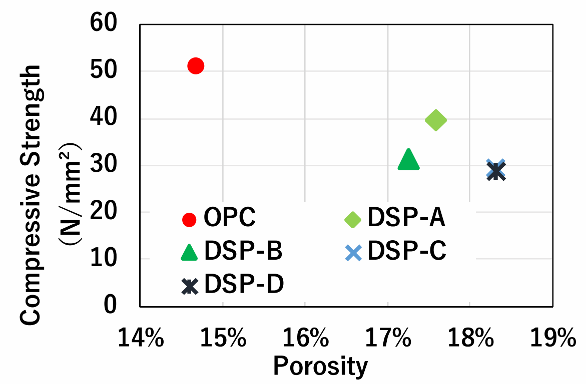

Figure 4. Relationship between compressive strength and porosity

3.2 Accelerated Carbonation test

Figure 5 shows accelerated carbonation test. DSP had a large carbonation depth, despite the fact that carbonation hardly progressed in OPC. Furthermore, the neutralization depths of DSP-A and DSP-B and DSP-C and DSP-D show almost equal values at any age. Figure 6 shows the relationship between the porosity and the carbonation depth at 28 days. From this, as the porosity increases, there is a correlation that the carbonation depth increases. Since the porosity increased and the substance permeability of the gas increased, the carbonation resistance decreased.

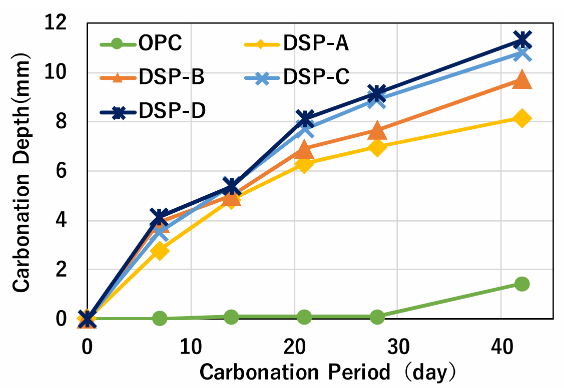

Figure 5. Carbonation Depth

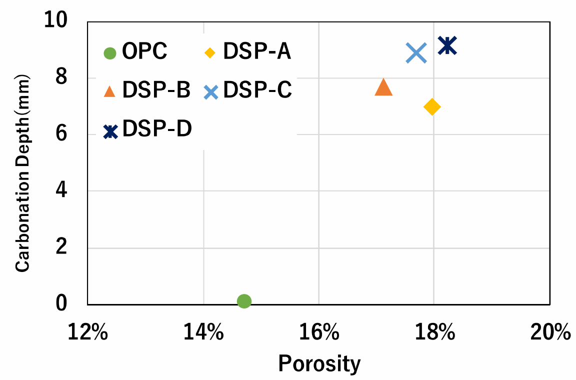

Figure 6. Relationship between Carbonation depth and porosity

3.3 Chloride ion Penetration

Figure 6 shows the results of the salt water immersion test. Salt penetration depth of DSP-A and DSP-B became smaller than OPC at any age. On the other hand, DSP-C and DSP-D showed the same value as OPC. Figure 7 shows the relationship between the porosity and the salt penetration depth at the salt water immersion period of 28 days. Compared with OPC, the DSP has a low salt penetration depth despite the high porosity in general. From this, there was no relationship between porosity and salt penetration depth.

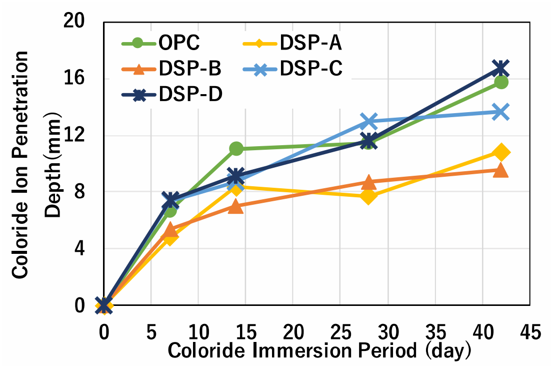

Figure 6. Chloride ion Penetration

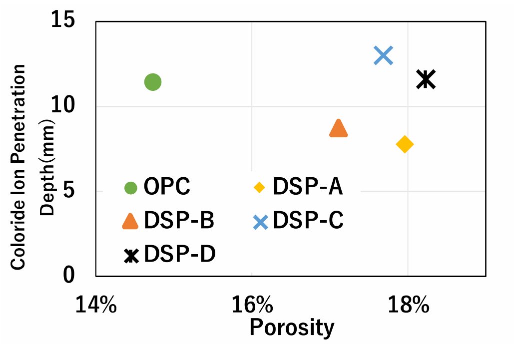

Figure 7. Relationship between Chloride ion Penetration and porosity

3.4 Amount of Permeated Water

Figure 8 shows the results of permeability tests conducted loading pressure in 0.05 MPa and Figure 9 shows the results of loading pressure in 0.6 MPa. When a pressure of 0.05 MPa was applied, the amount of permeated water of OPC and DSP was almost same amount. When applying a pressure of 0.6 MPa, the amount of permeated water was much lower than mortar using OPC for mortar using DSP. Furthermore, mortar using OPC significantly exceeded the amount of permeated water of 0.05 MPa when applying a pressure of 0.6 MPa, but the mortar using DSP did not change in the amount of osmotic water of 0.6 MPa and the amount of permeated water of 0.05 MPa. From this result, DSP has lower moisture permeability than OPC. In addition, the mortar using DSP did not change the amount of permeated water due to pressure change, it can be inferred that mortar using DSP has constructed a pore structure different from mortar using OPC.

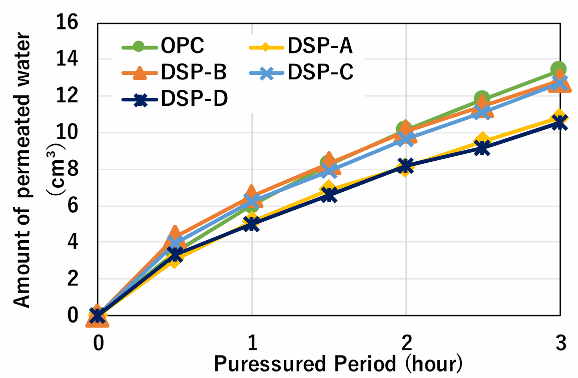

Figure 8. Amount of permeated water when a pressure of 0.05 MPa is applied

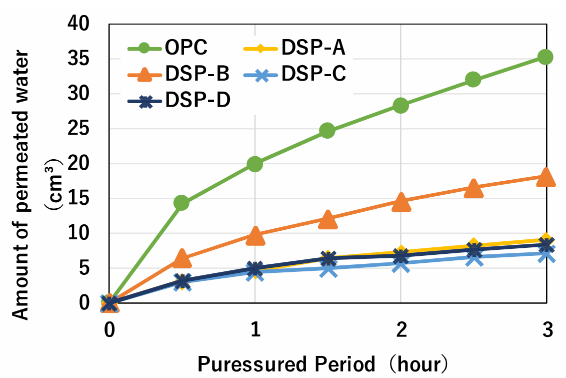

Figure 9. Amount of permeated water when a pressure of 0.6 MPa is applied

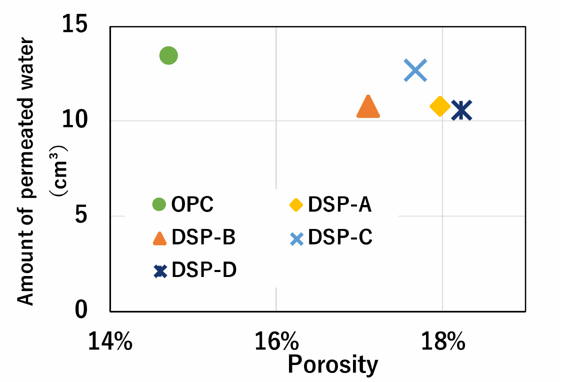

Figure 10. Relationship between amount of permeated water when a pressure of 0.05 MPa and porosity

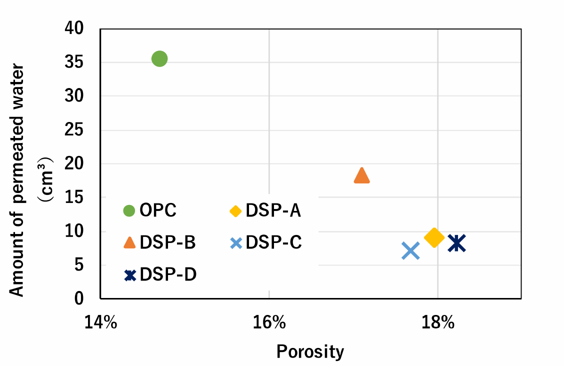

Figure 11. Relationship between amount of permeated water when a pressure of 0.6 MPa and porosity

3.5 Mercury Intrusion Test

Figure 12 and Figure 13 shows that similar pore size distribution can be confirmed in DSP-A and DSP-D. It can be seen that mortar using DSP has many smaller diameter pore compared with mortar using OPC. In particular, the difference in the fine pore size of 0.1 μm or less is remarkable. From this result, complicated pore network is constructed because mortar using DSP has many micro pore. Furthermore, since a large number of minute pore were measured, it was suggested that a pore having an ink bottle effect was present.
It is thought that mortar using DSP has a structure that liquid hardly intrudes into mortar and therefore greatly reduces moisture permeability.

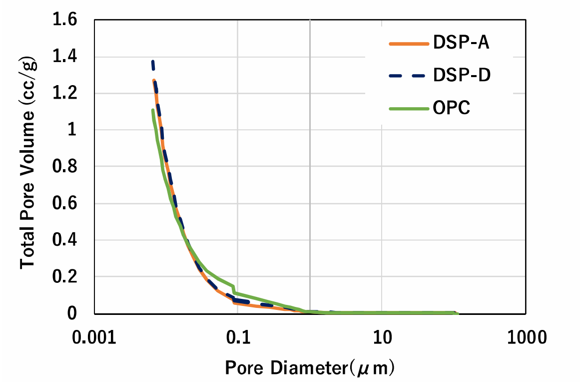

Figure 12. Total pore volume

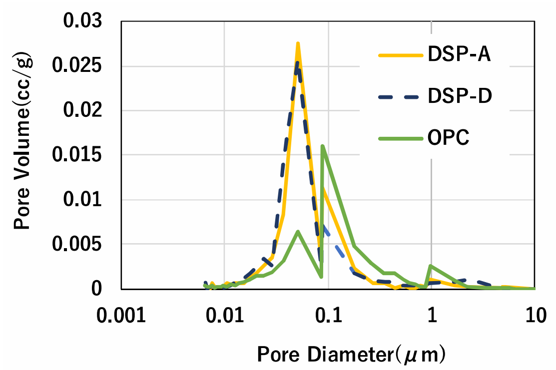

Figure 13. Pore Volume

4. Conclusions

(1) In the mortar using DSP, the depth of penetration was smaller than that of OPC, and there was no correlation with porosity.
(2) As a result of carrying out the permeability test, mortar using DSP was lower in moisture permeability than mortar using OPC.
(3) Since mortar using DSP has more minute pore than mortar using OPC, it can be predicted that the pore network in mortar becomes complicated. Also, since a large number of minute pore were measured, it is possible to suggest the possibility of the existence of a pore having an ink bottle effect which has a structure in which liquid hardly intrudes into the mortar.
(4) It is considered that the mortar using DSP has a structure in which the liquid hardly intrudes into the mortar, so that the moisture permeability is greatly reduced and the depth of penetration of the salt has decreased.

References

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