Influence of drying temperature during production of hydrated cement on mortar strength

K. Miyazaki [1]* and T. Iyoda [2]

[1] Shibaura Institute of Technology, Tokyo, Japan
Email: me19089@shibaura-it.ac.jp
[2] Shibaura Institute of Technology, Tokyo, Japan
Email: iyoda@shibaura-it.ac.jp

ABSTRACT

In recent years, environmental impacts reduction has been regarded as important for all the industries. Every year, a large amount of concrete is discarded by the construction industry. This concrete can be reused in various ways. One of them is using a washing process in which concrete is separated into aggregate and sludge water. The aggregate and sludge water collected at this time can be used for new mixing. However, most of the remaining sludge cake is discarded without being used. Dry sludge powder is a method of recycling sludge cake. The time from water contact to drying is called processing time. The dry sludge powder is made by drying the sludge cake at approximately 130 degrees Celsius. It is expected that this material can be reused as replacement of cement. Previous study shows that it has half the strength of OPC. The factors such as of processing time and drying temperature for making dry sludge powder can affect the strength. In this study, it was investigated the strength developing property of mortar using the dry sludge powder with different processing times and hydrated cement with different processing times and drying temperatures. As a result, when the drying temperature was 500 degrees Celsius, 80% of the strength of OPC was developed and a correlation was confirmed between the amount of CH contained in cement and the strength.

Keywords: Dry sludge powder, drying temperature, processing time

1. INTRODUCTION

In recent years, waste disposal has become a problem. In the Japanese construction industry, a large amount of returned concrete are available. These concretes are reused in various ways.
One of the methods is the washing process. It is a process of washing concrete with water and separating it into aggregate and sludge water. Recovered aggregate and supernatant water can be used again for concrete. But sludge cake generated from sludge water is discarded as industrial waste. Therefore, researches for using sludge cake are in progress. One of the researches is to make cement substitutes from sludge cake, that is called “Dry sludge powder (DSP)”.
In the process, concrete will be cleaned as soon as it is returned and the sludge cake separated, so it is powdered while being dried at approximately 130 degrees. The time from mix of the concrete to drying of the sludge cake are 3 to 24 hours from contact with water, this is called “processing time”.
It is considered that the quality of DSP is affected by processing time and temperature.
The studies have been trying to make the cement, once it hydrated, called hydrated cement. The DSP manufacturing process ~~It~~ was set as reference for the method. Using hydrated cement and DSP, the effects of drying temperature and processing time on the strength of cement after rehydration were evaluated. It was also examined how to evaluate the quality.

2. OUTLINE OF EXPERIMENT

In this study, 9 types of hydrated cement and 7 types of DSP were used as shown on Table.1 and Table.

2. Figure 1 shows the process of making hydrated cement. In this study, W / C 200% cement paste was stirred using Magnetic stirrer. The stirring times were set as 3, 8 and 24 hours. After that, they were dewatered and dried to stop hydration. The drying temperatures were set as 105, 300 and 500 degrees Celsius. The dried sample was grinded using a mill. After that, the sample passed through a 150µm sieve was used as hydrated cement.

Table.1 Hydrated cement production

		processing time		
		3h	8h	24h
drying temperature	105°C	3h105°C	8h105°C	24h105°C
	300°C	3h300°C	8h300°C	24h300°C
	500°C	3h500°C	8h500°C	24h500°C

Table.2 Properties of DSP

	OPC	DSP-A	DSP-B	DSP-C	DSP-D	DSP-E	DSP-F	DSP-G
processing time (h)		8	6	5	9	24	12	24
Density (g/cm^3)	3.16	2.81	2.69	2.81	2.58	2.43	2.46	2.45

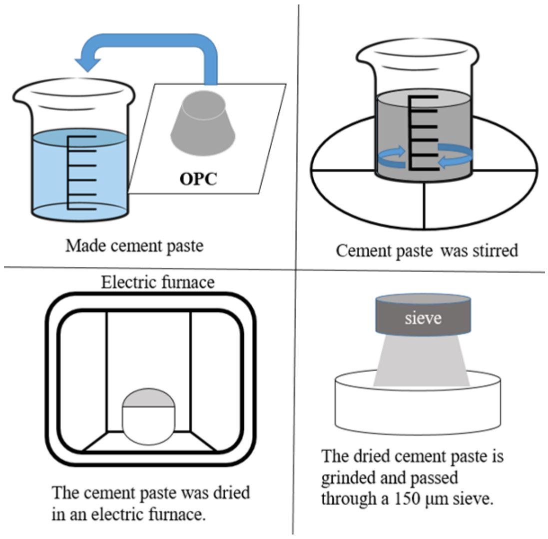

Figure.1 Production procedures of hydrated cement

2.1 X-ray Diffraction (XRD)

XRD was used for qualitative analysis of hydrates in the samples. The components of the samples using hydrated cement were analysed. The measurement conditions were a tube voltage of 250 mA, a scan rate of 0.025deg / min and a scan range of 2θ = 5 to 60 °.

2.2 Thermogravimetric Differential Thermal Analysis (TG-DTA)

TG-DTA was used for quantitative analysis of hydrates in the samples. The amount of CH and $CaCO_3$ were determined from mass change when the sample was heated from 105 to 1,000 degrees Celsius. The amount contained in the hydrated cement and the cement paste aged for 28 days were examined.

2.3 Strength Test

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

3. RESULTS AND DISCUSSION

3.1 XRD

Figure.2 shows the XRD results of the hydrated cement. It was compared hydrated cements with different processing times. The longer the processing time, the larger the CH peak. Wherever there is a peak in hydrated cement XRD (Figure.2), it was the same for the different processing time and temperature. Figure.3 shows the XRD results of OPC, hydrated cement and DSP. First, compare the mineral composition of OPC and hydrated cement. The peaks of mineral composition except CH are almost the same. Second one compares the mineral composition of hydrated cement and DSP. It can be seen that the mineral composition of DSP is different from hydrated cement. From this, it is appropriate to consider DSP and hydrated cement as different materials. It is considered to be the influence of fine particles derived from aggregate.

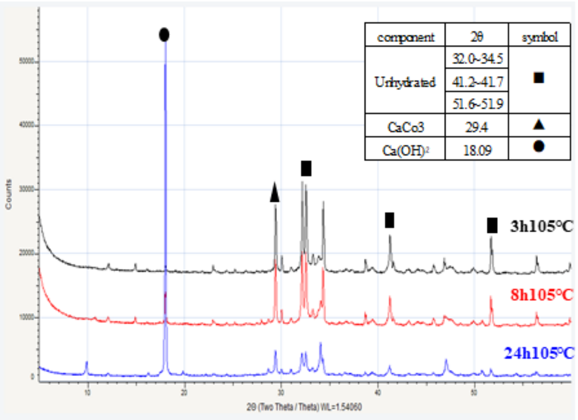

Figure.2 Results on XRD of hydrated cement

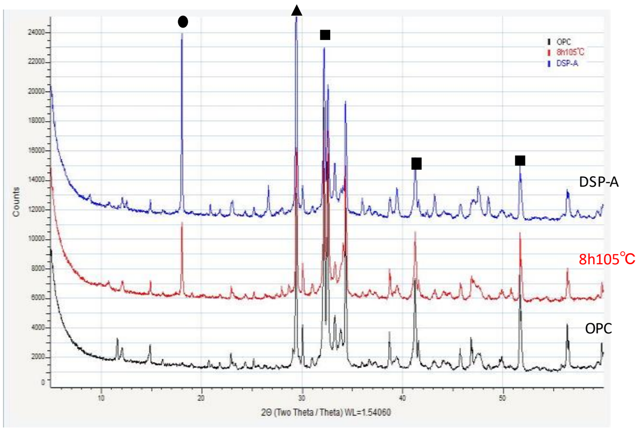

Figure.3 Results on XRD of hydrated cement, OPC and DSP

3.2 TG-DTA

Figure.4 shows amount of CH and $CaCO_3$ contained in DSP and hydrated cement. Figure.5 shows the amounts of CH before and after rehydration. From this result, it can be understood that the longer the processing time, when cement is included, the more CH. For different hydrated cements, the amounts of $CaCO_3$ are almost same. It is assumed that hydrated cement $CaCO_3$ initially was contained in cement. After rehydration the amount of CH was almost the same. From this fact, even if the time to stop the hydration of the cement is different, the amount of CH contained after rehydration is almost the same. However, amount of DSP`s $CaCO_3$ is much more than in hydrated cement. DSP's CH after rehydration is less than in cement. It appears that contained $CaCO_3$ from concrete`s aggregate and CH was carbonated during drying process.

Figure.6 shows ignition loss. Before hydration DSP`s ignition loss is bigger than hydrated cements. However, after hydration, DSP`s ignition loss was less than hydrated cements.

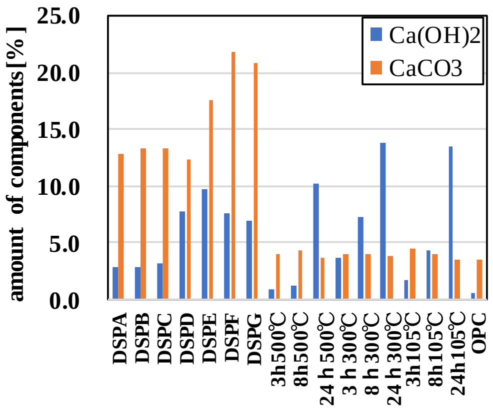

Figure.4 Component amounts in the samples

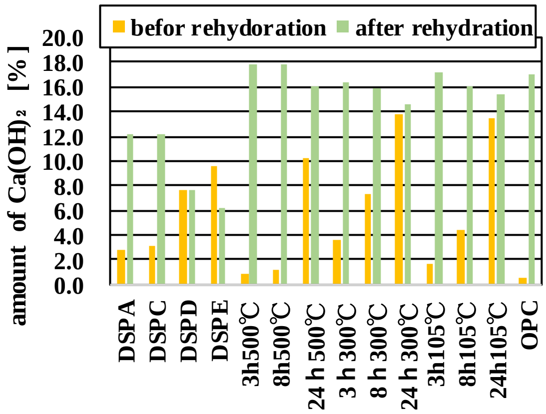

Figure.5 Amount of CH in the samples

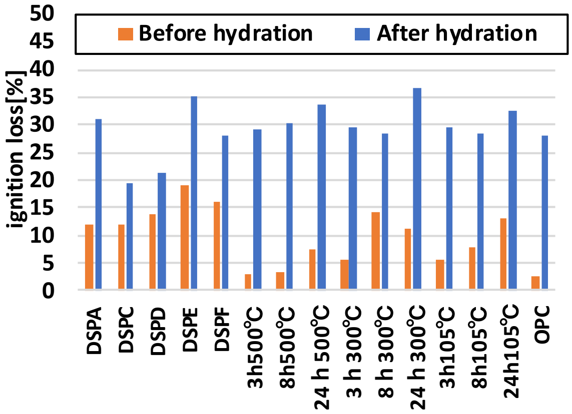

Figure.6 Ignition loss

3.3 Compressive Strength

A strength test was conducted to confirm the strength development of cement. Figure.7 shows the compressive strength and Figure.8 shows the compressive strength and processing time of hydrated cement. The strength of DSP and hydrated cements are lower than OPC. Hydrated cement`s strength becomes lower as processing time is longer. Because unhydrated components contained in cement decreases. The strength at 3h500℃ and 8h500℃ are stronger than other hydrated cements. It is approximately 80% strength of ordinary portland cement. It is thought that the hydrate such as CH was dehydrated at 500 degree and strength was developed at the time of rehydration.

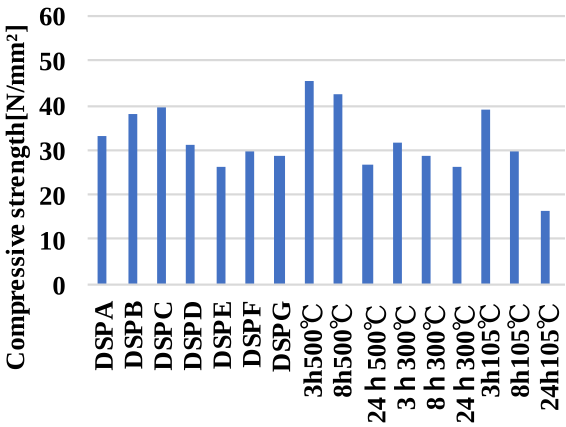

Figure.7 Compressive strength

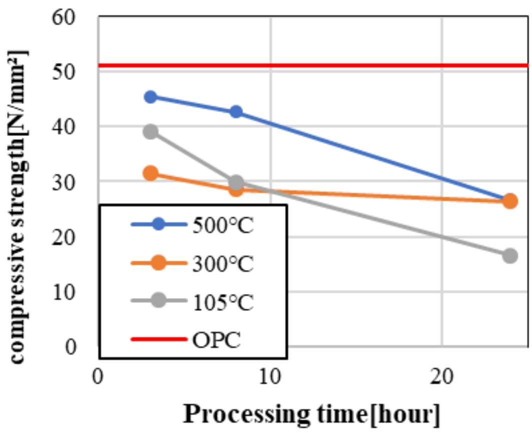

Figure.8 Compressive strength and processing time

4. QUALITY EVALUATION

It is important to dear the hydration ability quantitatively. Previous studies have been conducted on the evaluation of DSP's hydration ability. For this, it can be used the method of ignition loss. The equation for the DSP`s hydration ability is described in (1).

$$A = \frac{B-C}{B} \qquad (1)$$

A: Hydration ability
B: Ignition loss of after hydration
C: Ignition loss of before hydration

This method has some problems. The first one, about ignition loss. It measures hydrates and carbonates. But carbonates have nothing to do with hydration. DSP contains more $CaCO_3$ than hydrated cement so hydration ability will be small. Second one, it is necessary a sample that has been hydrated for 28 days. This method is time consuming and impractical. It is more sustainable a way to predict quality from samples before rehydration. Focusing on CH that can be analyzed quantitatively. The less CH before rehydration the higher hydration ability. Figure.10 shows the compressive strength and amount of CH before rehydration. The compressive strength and CH ratio before rehydration has a correlation. From the results, the rehydration ability of cement can be evaluated by the amount of CH.
In the future, it is necessary to consider whether the quality can be controlled by the amount of CH, even in cement that is weathered by moisture in the air.

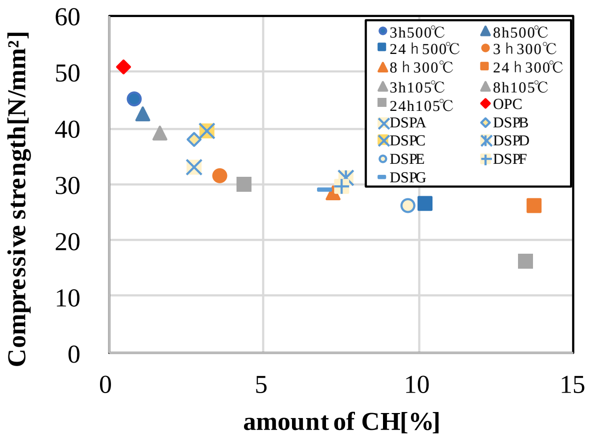

Figure.10 Compressive strength and CH

5. CONCLUSIONS

The following was found after carrying out the compressive strength test and chemical analysis.

1. The longer the processing time, the lower the strength.
2. At drying temperatures of 105 and 300 degrees Celsius, the effect on the hydrate is small, but at 500 degrees Celsius, dehydration occurs and the hydrates decreases.
3. 3h500°C and 8h500°C are stronger than other hydrated cements. It is considered that the hydrate such as CH was dehydrated at 500 degrees Celsius and strength was developed at the time of rehydration.
4. The hydrated cement was made using DSP method. However, the samples contained different amounts of $CaCO_3$. DSP contains fine particles derived from aggregate, it is inferred that there is a large amount of $CaCO_3$.

5. The lower the amount of CH contained in hydrated cement and DSP before hydration, the higher the strength. The strength can be predicted from the amount of CH.
6. As future prospects, it is necessary to consider whether quality can be controlled by the amount of CH even in cement that is weathered by moisture in the air.
7. In order to put the prediction of expression strength by the amount of CH into practical use, it is necessary to develop a method to easily check the amount of CH.

ACKNOWLEDGEMENTS

This study is financially supported by SANWA SEKISAN.

REFERENCES

OHKAWA, K., AOKI, S., KANDA, T., MOMOSE, H., and KASAI, T. (2017) "Study On Durability of Clinker-Free Concreate with a Binder Combining Dehydrated Sludge Powder With Other Industrial By-Products Admixture", Journal of japan Society of Civil Engineers, ser. E2 (materials and Concrete Structures),Vol.73(1):107-117

M. Araki, K. Ohkawa and T. Iyoda, (2018) "Investigation for Strength and Durability of Mortar Using Dry Sludge Powder", The 8th International Conference of Asian Concrete Federation November 4-7, 2018, Fuzhou, China 187-191