Dispersion of Silica Fume at Cellular Sprayed concrete for Simple and Economic Two-Lift concrete Pavement

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ABSTRACT

The purpose of this paper is to produce high-strength concrete by dispersing silica fume of high fineness using ball bearing effect of foam by spraying and to evaluate and confirm dispersibility of silica fume by EDS. Dispersibility is measured using EDS test by comparing Si content of silica fume pre-blended cement concrete and cellular sprayed concrete. It was confirmed that Si content increase when silica fume is added. Foam has effect on dispersion of silica fume, because after adding foam the coefficient of variation gets lower due to the remixed effect when sprayed. And dispersibility will be very good. Since the unit volume of foam in the control mix has similar value with the foam which disappear after sprayed, the Si average value is also similar.

Keywords: Cellular Sprayed concrete, Dispersibility, EDS

INTRODUCTION

According to the gradually improved consciousness level of the society, currently road has a multi-dimensional purpose in human activity. But in reality Korean concrete pavement is backward due to application of uniform and simple pavement types, an inadequate development of pavement materials, application of pavement which did not consider functionality, and design which considers only stability and strength-centered. Most of the national highways are asphalt pavement and expressways are being constructed by plain concrete pavement. To address this by solving problems of plain concrete pavement, a continuously reinforced concrete pavement method was applied on Joongbu expressway and some other roads to improve the national budget and level of skill. Plain concrete pavement is disregarded because of the cracks appearing on the surface of most of the pavements.

Therefore, in order to compensate problems of the existing concrete pavement, recently two-lift concrete pavement (2LCP) is emerging which is widely used in developed countries like Europe and United states. But in Korea we still don't have a sample constructed in this method

Two-lift concrete paving (2LCP) involves placing two layers of concrete “wet-on-wet” rather than the traditional method of using a single, homogeneous layer of concrete. The bottom layer is 17~25cm thick and consists of lower quality concrete mixtures or aggregate, in many cases recycled aggregate or local aggregates that are not suitable to use in surface courses. The top layer is thin, 5~12cm, and consists of high-quality concrete and aggregate, that provides better durability, reduced noise, and improved skid resistance. Two-lift concrete pavement can reduce the overall cost of construction. But, since the mix of upper and lower layer is different, two groups of batch plant is required to produce and supply at a constant rate. If the concrete supply is not smooth, the entire process will stop. In addition, quality control and construction

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management is more complicated than the regular concrete pavement, and the construction cost might increase due to the need for the two pavers or the integral 2-lift concrete paver.

However, by using a cellular sprayed concrete for the high performance concrete used in the top layer, OPC can be immediately mixed in the high performance concrete at the site and it is possible to freely adjust the workability. By using ready mixed concrete which has the cheapest material cost and purchasing the required amount of pozzolan materials to be mixed, it can be applied directly at the site by using the ball bearing effect of foam. This can minimize the construction cost since it is easier to produce than the high performance concrete. Being able to apply directly at site, makes the quality control easier.

However, there is insufficient proof of quantitative dispersion effect of silica fume as the increased use of silica fume in high performance concrete, and since there is a lack of domestic studies on dispersion of silica fume it is difficult to find a research to refer to. In this study, it is intended to develop a high performance concrete with high strength and quality by using a predetermined amount of silica fume, adding silica fume and foam in the ready mixed concrete to compare and analyze dispersion of silica fume using EDS due to the surface-active property of the foam.[2][4] Since Si content of silica fume is about 90% EDS component analysis is possible. Therefore, through EDS Si component is measured, coefficient of variation is calculated and finally dispersibility is evaluated.

EXPERIMENTAL PROCEDURES

Materials

First class port land cement with 3300 cm²/g fineness and density of 3.15g/cm^3. A 25mm coarse aggregate with density of 2.77 which can be used in pavement and river sand with density of 2.61 was used. Korean ordinary Portland cement and powder type silica fume is used. Amount of silica fume added is taken as 7% of cement weight. Foam used is Korean H Company product. If the mixing time is greater than the pressure of constant intensity, or if the intensity of the pressure is over the constant mixing time, the amount of foam will reduce. Therefore, during mixing, a proper mixing time at a constant pressure and a proper intensity of pressure in a constant mixing time is required.

Sample preparation

Silica fume dispersion was determined in accordance with cellular mixing by applying silica fume and foam. Comparing the properties and dispersion before and after the spray, dispersion is evaluated through the value of coefficient of variation and also foam parameters. Samples are prepared by casting a cylindrical mold of 100×100×200mm for each parameter and measured by EDS after five days of curing. Figure 1 shows the EDS machine.

Because there is no accredited test method for evaluating dispersion using EDS, this study was performed by a method invented by ourselves. By taking a five day sample of 1*1cm, the value of coefficient of variation is calculated by obtaining mean and standard deviation of the Si content for each sample, then dispersion is verified and evaluated for these data. Coefficient of variation was selected because it can figure out the tendency of each value dividing the standard deviation by the average and multiplying by 100.
First paste consistency is checked by slump test immediately after discharging concrete. The 28days compressive strength test is based on Korean standard KS F 2405, the resistance to

chloride ion penetration test (RCPT) at 28 days is based on Korean standard KS F 2711, and the 28 days image analysis test is based on ASTM 457.

Equipment
In this study, a spraying machine produced in the laboratory was used. This machine is made in cone shape having a nozzle at the end, this nozzle is connected to another nozzle and it is designed to spray using the compressor by applying air pressure on the material fed through the nozzle. Unlike large machines that fed the material under pressure by applying pressure on the material using piston, this machine sprays the material without piston using flow of the material and gravity. Figure 2 shows the spraying machine used in this test

EDS Test
EDS is Energy Dispersive X-ray Spectrometer. In general, it is attached to SEM device, it detect the fluorescent x-ray generated while measuring the sample and analyze the element in the sample. It analyze distribution of the elements according to the line or in the particular area.

Samples are prepared by casting a cylindrical mold of 100×100×200mm for each parameter and measured by EDS after five days of curing. If it is over five days the samples are soaked in acetone to prevent further hydration. This is to avoid Si component reduction, since Si component reduces the more the hydration occurs. Figure 3 shows preparation of sample.

Figure 1 EDS Machine

Figure 2 Spraying machine

Figure 1 Sample preparation

Table 1 Mix Design

<table>
<tr><th rowspan="2">Sample</th><th rowspan="2">SF (kg/cm³)</th><th rowspan="2">Cellular (%)</th><th rowspan="2">Gmax (mm)</th><th rowspan="2">W/C (%)</th><th rowspan="2">S/a (%)</th><th colspan="4">Unit Weight(kg/cm³)</th><th rowspan="2">Sp (%)</th></tr>
<tr><th>W</th><th>C</th><th>S</th><th>G</th></tr>
<tr><td>OPC</td><td>0</td><td>-</td><td rowspan="11">25</td><td rowspan="11">42</td><td rowspan="11">40</td><td rowspan="11">155.4</td><td rowspan="11">370</td><td rowspan="11">728</td><td rowspan="11">1167</td><td rowspan="11">0.5</td></tr>
<tr><td>*HPC 7</td><td>28(7%)</td><td>-</td></tr>
<tr><td>*CSC-M 7</td><td>28(7%)</td><td>10</td></tr>
<tr><td>CSC-M 7</td><td rowspan="2">28(7%)</td><td rowspan="2">15</td></tr>
<tr><td>*CSC-S 7</td></tr>
<tr><td>CSC–M 7</td><td>28(7%)</td><td>20</td></tr>
<tr><td>HPC 14</td><td>56(14%)</td><td>-</td></tr>
<tr><td>CSC-M 14</td><td>56(14%)</td><td>15</td></tr>
<tr><td>CSC-M 14</td><td>56(14%)</td><td>20</td></tr>
<tr><td>CSC-M 14</td><td rowspan="2">56(14%)</td><td rowspan="2">25</td></tr>
<tr><td>CSC-S 14</td></tr>
</table>

*HPC: High Performance Concrete (OPC+SF → Mixed)
*CSC-M: Cellular Sprayed Concrete (OPC+SF+Cellular → Mixed)
*CSC-S: Cellular Sprayed Concrete (OPC+SF+Cellular → Sprayed)

EXPERIMENTAL RESULS AND DISCUSSION

Slump and air content

For 7% silica fume, when 14L of foam was added the slump became 50mm, it was so low that it cannot be sprayed, and since segregation occurs when we add 28L of foam, we should spray using 21L foam which gives the most appropriate slump. This time air content was measured about 15%. For 14% silica fume, when 21L of foam was added the slump became 30mm and adding 28L of foam the slump became 80mm, since the slump is too low in both cases, we should spray using 35L foam which gives the most appropriate slump. If the foam exceeds this amount segregation will occur and the test cannot be performed. This time air content was measured as 25%. The air content after spraying satisfied all the proper air content less than 5%. [6][7]

Confirmation of silica fume dispersion in accordance with foam mixing

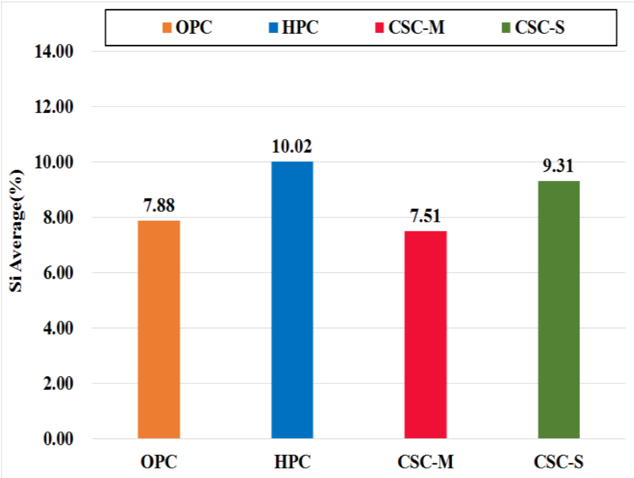
Figure 4 shows the Si average and standard deviation, and coefficient of variation in accordance with mixing foam for 7% silica fume. Figure 5 shows the Si average and standard deviation, and coefficient of variation in accordance with the foam generating for 14% silica fume. It can be confirmed that Si content increases when silica fume is added to OPC and it decrease when foam is added, which shows that an increase in the unit volume of the foam in the sample reduce the Si content. When we compare the coefficient of variation, the value after the spray is very low but it shows that dispersion is very good. Even though the value of coefficient of variation when foam is added and after the spray looks similar, when we calculate the total variation we can see that there is a difference and the dispersion also gets better.

Comparison and analysis of dispersibility before and after sprayed

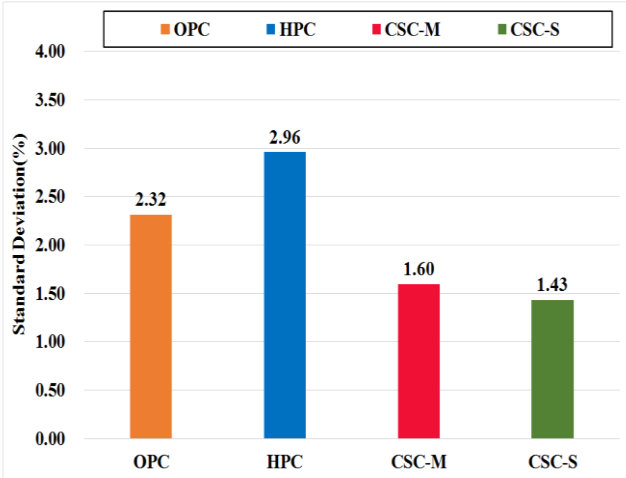
Figure 6 is a comparison of 7% and 14% silica fume before and after spray. The rapid reduction of coefficient of variation after the spray shows that there is a remix effect during spray, and we can see that the dispersion gets better after spray. Si average shows a similar pattern in the control mix [OPC+SF] and after spray because the foam disappears after spray and the unit volume of foam in the sample becomes similar with the control mix. It can be confirmed that the dispersion after the spray is quantitatively quite good.

Dispersibility confirmation in accordance with foam content

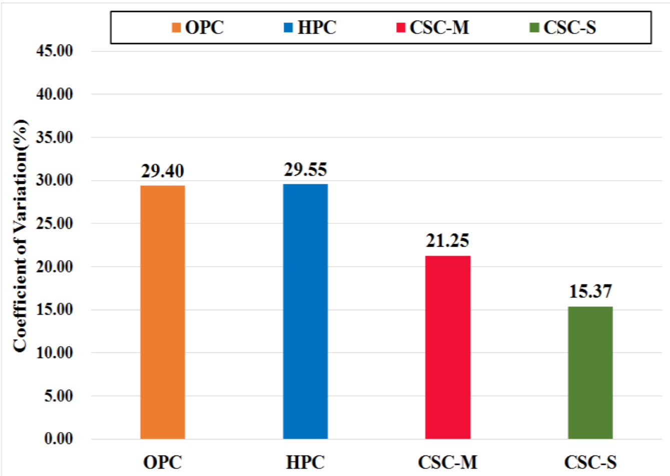
Figure 7 and figure 8 show the value of Si average, standard deviation and coefficient of variation for 7% silica fume and 14% silica fume respectively. The experiment is carried out first stating the accurate mixing time, by measuring the time that we think the foam is well mixed, before the foam starts dissipating through the forced mix. Test results suggest that 100 second is the best time for mixing and 2 minutes for dry mixing, the experiment is carried out adjusting 100 seconds after adding foam. As the amount of foam increase the coefficient of variation decrease and it can been seen that dispersibility is great. It is also confirmed that the Si average increases as the unit volume quantity decreases



(a) Si Average

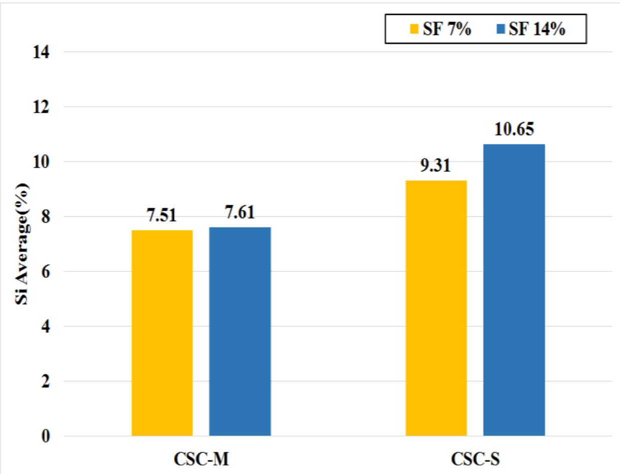


(b) Standard Deviation

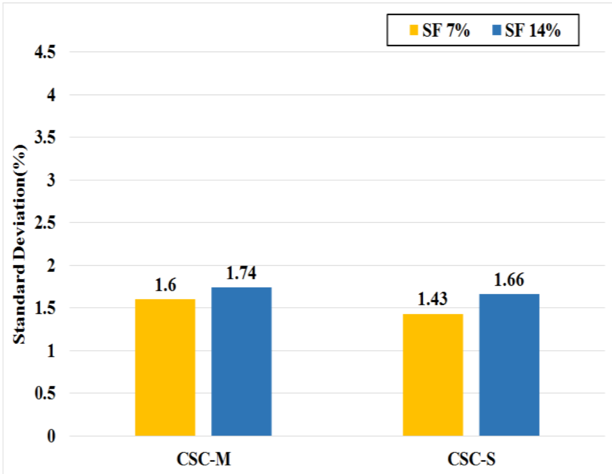


(c) Coefficient of Variation

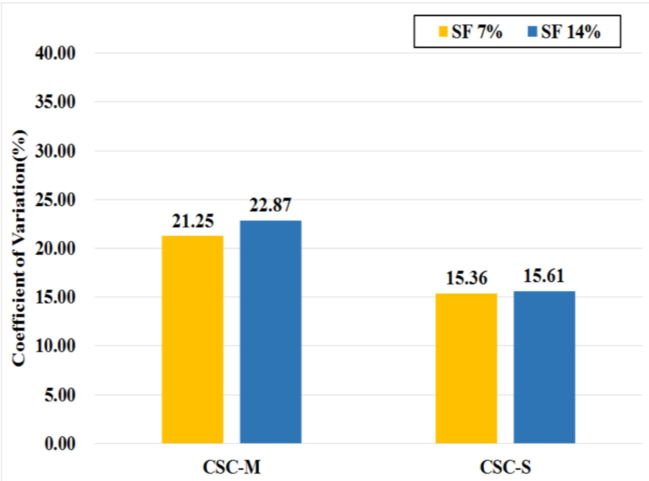
Figure 4 EDS test of results according to foam mixing for 7% silica fume



(a) Si Average

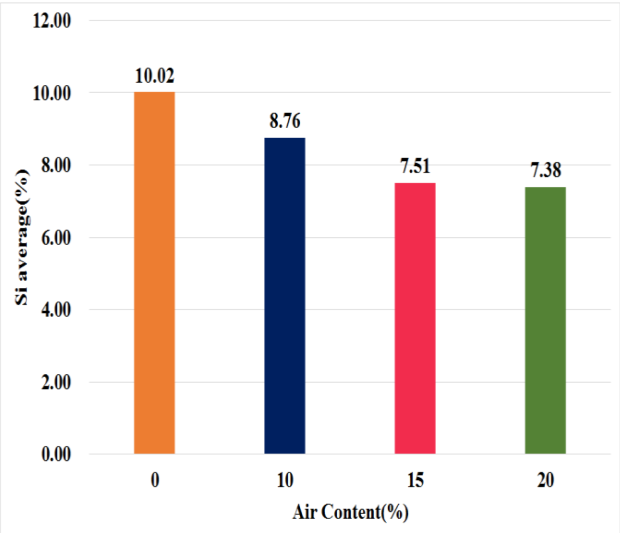


(b) Standard Deviation

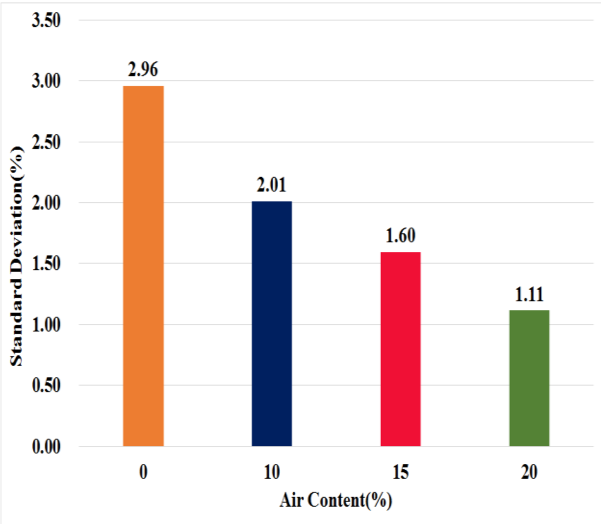


(c) Coefficient of Variation

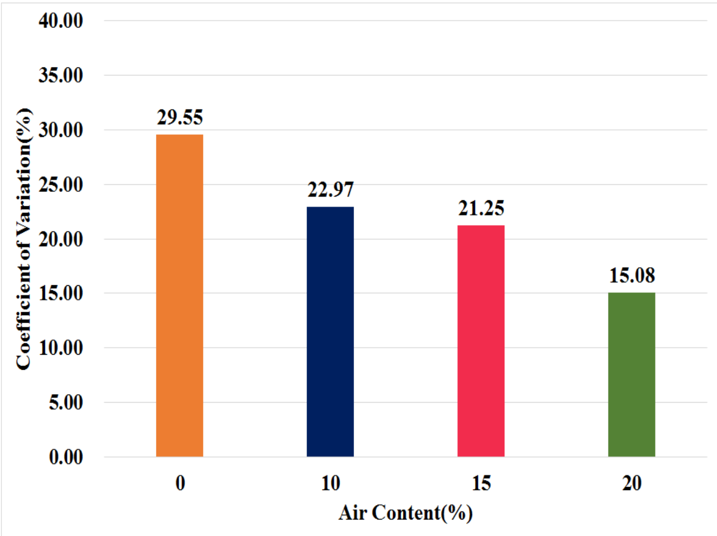
Figure 6 EDS measured value of before and after sprayed



(a) Si Average

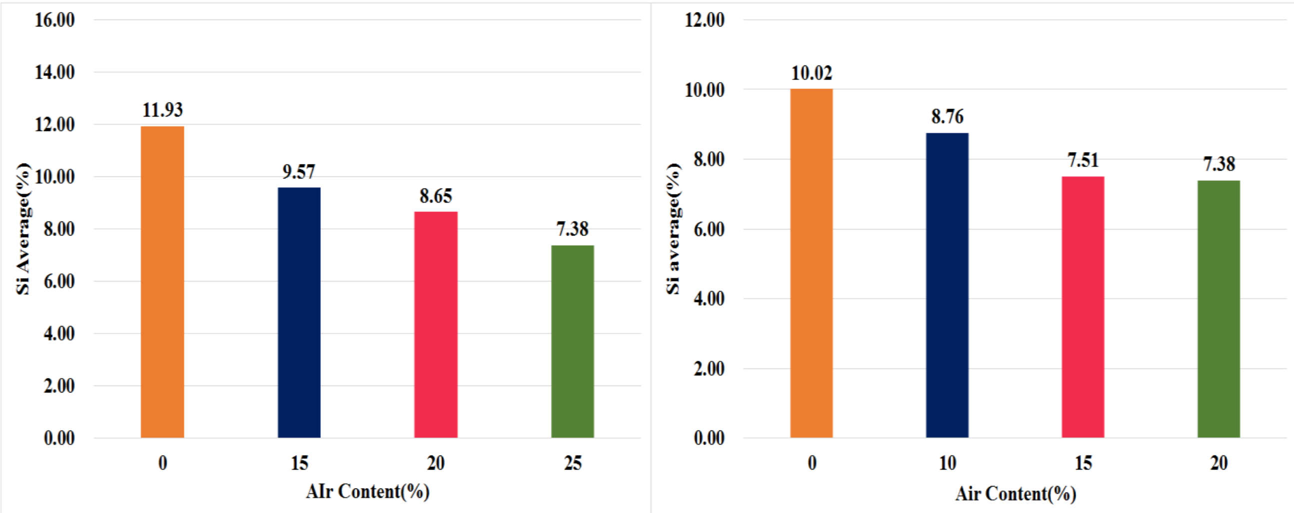


(b) Standard Deviation

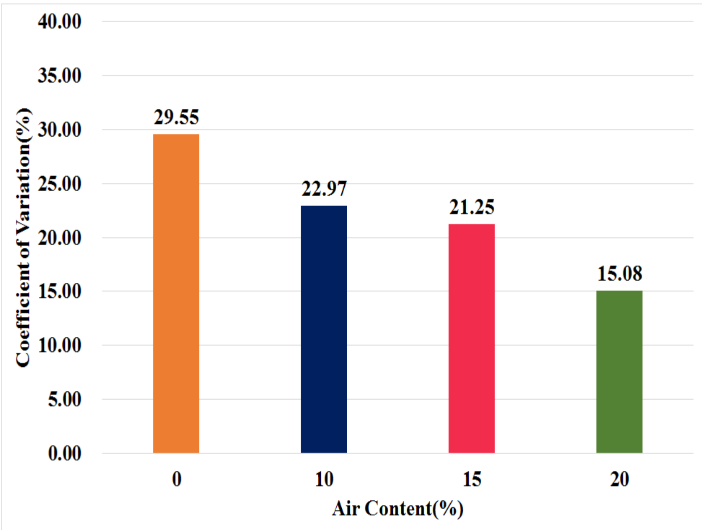


(c) Coefficient of Variation

Figure 7 EDS test results of silica fume 7% according to the amount of foam



(a) Si Average **(b) Standard Deviation**



(c) Coefficient of Variation

Figure 8 EDS test results of silica fume 14% according to the amount of foam

CONCLUSIONS

In this study, evaluation of dispersion was conducted using EDS to check the quantitative value of dispersion after securing liquidity through surface active property by mixing foam in the high performance concrete where silica fume was added in the field. Dispersion in accordance with the amount of foam can be confirmed substantially by calculating the coefficient of variation, comparing and analyzing before and after spray according to the cellular formation. A high strength concrete can be ensured easily through cellular sprayed concrete which has silica fume and foam. Also, construction cost is decreased and quality control of concrete is comfortable.

The overall conclusions of this experiment are shown as follows.

1) Both slump and air content tests meet the target before the spray, having a result of 120~150mm slump, 15% air content for 7% silica fume and 25% air content for 14% silica fume. After sprayed, the air content was less than 5%, 3.7% and 4.4% respectively.

2) Dispersibility test result in accordance with mixing of foam shows that Si content increase when silica fume is added in OPC and decrease when foam is added. This shows that addition of foam increase unit volume of foam in the sample and the Si content become smaller. Spraying by adding foam, we can see that the standard deviation gradually gets smaller. Comparing the coefficient of variation it was found that the coefficient of variation after sprayed is very small and the dispersion is very good.

3) When comparing before and after sprayed, the average Si was found to be similar for both before sprayed HPC and after sprayed. This shows that the foam dissipates while spraying and it can be said that there was a remix effect during spray. Therefore Si average shows a similar pattern in HPC and after spray since the foam disappears after spray and the unit volume of foam in the sample becomes similar with HPC. However, since standard deviation and coefficient of variation are quite low the dispersion was confirmed to be great.

4) Dispersibility test results according to foam content shows that the more we add the amount of foam the lower standard deviation and coefficient of variation will be, and it is confirmed that dispersibility will be very good. But appropriate amount of foam should be used since excess amount can cause segregation.

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