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INFLUENCE OF SUPERPLASTICIZERS IN HEAVY DOSAGE ON HYDRATION OF CEMENT AND STRENGTH OF MORTAR

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Because of low W/C of high strength concrete, heavy dosage of superplasticizer is needed for high workability of concrete. The concentration of superplasticizer is so high that it may effect the hydration and strength of the cement. In this paper three types of superplasticizer in a large range of dosage were used, and the effects of superplasticizer on the hydration and strength of cement were investigated. According to the test's results, it is concluded that the adsorption of superplasticizer on cement and effect of superplasticizer on concentration of Ca^{2+} in solution of paste influence the hydration of cement and strength of the mortar.

Key Words: *adsorption, calcium ion, cement hydration, dosage, strength, superplasticizer, type*

1. INTRODUCTION

Recently, more and more of high performance concrete, which has high workability, high strength and or high durability, has been demanded for construction market. In order to obtain high strength and durability, not only the water to cement ratio (W/C) of the concrete has to be lowered but also the fine mineral admixtures, such as silica fume and blast-furnace slag, has to be admixed in the concrete. Owing to the high specific surface area of silica fume, some of the mix water was adsorbed on the surface of the silica fume and the workability of the concrete, especially when W/C was lower, became bad. Fortunately, this problem could be solved by admixing the superplasticizer in the concrete. In the high performance concrete, as the W/C is very lower and the fine mineral admixture such as the silica fume is often added, heavier dosage of the superplasticizer is needed for obtaining the high workability. Thus, the concentration of the superplasticizer in the mix water is dramatically raised. For example, if the dosage of superplasticizer increases 1% by weight of cement with 0.1 reducution of water cement ratio, the increase of concentration of superplasticizer with the decrease of water cement ratio can be calculated as it is shown in **Fig. 1**. In practice it was found that when some types of the super-plasticizer were admixed in concrete, besides setting time of the concrete was retarded with the increase of dosage, even the strength of the concrete was lowered in presence of the heavy dosage superplasticizer [1)]. However, for other superplasticizers, it did not happen. Why was the strength of the concrete decreased with the increase of the dosage of the superplasticizer? How did the superplasticizer effect the setting time and strength of the concrete? What type of superplasticizer suit to being used in heavy dosage? It is very important to investigate these problems because the results of the investigation can suggest how to use superplasticizer in the high performance concrete. This paper is intended to clarify the questions above mainly mentioned.

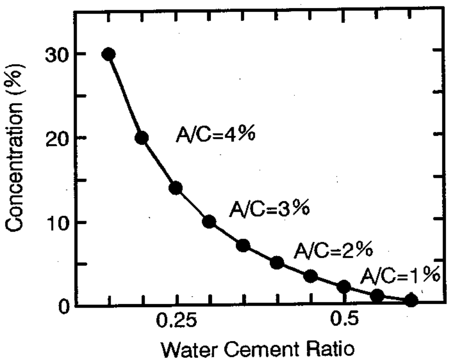

Fig. 1 Relation between concentration of superplasticizer in mix water and W/C

2. SCOPE OF THE INVESTIGATION

In this research, three types of superplasticizer, in which one is a typical superplasticizer of sulfonated naphthalene formaldehyde condensate and others are two new types of air-entraining superplasticizer (naphthalene type and amino-sulfonic acid type), in a large range of dosage were used for investigating the influence of type and dosage of superplasticizer on hydration and strength of portland cement. Although the superplasticizers have different chemical compositions, the principal active components of them are surface-active agents which are concentrated at the interface between the two immiscible phases and alter the physical-chemical forces acting at the interface. In cement- super-plasticizer-water system, the superplasticizer can be adsorbed on the surface of the cement. Generally, it was thought that the adsorption can effect the hydration of cement [2), 3), 4)]. Thus, in order to study the effects of type and dosage of the superplasticizer on the hydration of the cement, firstly, (1) the adsorption characters of the superplasticizers on the surface of the cement particles were investigated. The early hydration of cement is also controlled by the concentration of calcium ion in the solution of fresh paste. The delay of the hydration of the cement is always greater the higher of the concentration of the calcium ion in the solution of the fresh paste [5)]. So, (2) the effect of the superplasticizer on the concentration of calcium ion in the solution of fresh cement paste was investigated, too. According to results of (1) and (2), authors wanted to find the mechanism of the effects of the superplasticizer on the hydration of cement. To evidence the mechanism, (3) the effects of the superplasticizer on the hydration of the cement, which involved the effect of the superplasticizer on the kinetic process and degree of hydration of the cement, were measured directly. Finally, because both of the retarding cement hydration and air entraining of superplasticizer may decrease the strength of the hardened cement mortar, (4) the compressive strengths and air content of the mortar admixed by different types and dosages of the superplasticizers were determined to understand which one is the main reason for decrease of the strength.

Table1 Chemical analysis and physical properties of cement, slag and silica fume

Chemical Analysis (%)	Cement	BFS	SF
L. O. I.	0.40	1.10	2.71
SiO_2	21.30	34.70	86.50
Al_2O_3	5.00	14.20	1.47
Fe_2O_3	2.60	0.50	0.16
CaO	65.00	41.70	1.48
MgO	2.00	7.00	1.94
SO_3	1.90	0.00	0.61
Na_2O	0.21	0.20	0.61
K_2O	0.67	0.34	1.09
Physiscal Properties			
Specific Gravity	3.17	2.91	2.20
Blaine Fineness(m^2/g)	0.323	0.832	---
Specific Surface Area (m^2/g)	0.806	2.220	32.394

Note: Specific surface area was measured with BET method.

Table2 Main compounds and solid contents of superplasticizers

No.	AESP1	AESP2	SP
Main Compound	Naphthalene	Aminosulfonic Acid	Naphthalene
State	Liquid	Liquid	Liquid
Solid Content (%)	40	30	40

3. TEST MATERIALS

(1) Cement

Ordinary portland cement (OPC) made in Japan was used in this research. Its physical properties and chemical analysis are given in **Table1**.

(2) Superplasticizer

One type of superplasticizer (SP) and two types of air-entraining superplasticizer (AESP1 and AESP2) were used. They were got from the market in Japan. The main compounds and the solid contents of the superplasticizers were given in **Table 2**.

(3) Sand

Three kinds of silica sand made in Japan were used in the mortar. They were standard Toyoura sand and Soma silica sands (special No. 4 and No. 5).

(4) Silica Fume

The silica fume (SF), byproduct in the production of Si-Fe alloy, was got from China. Its physical properties and chemical analysis are given in **Table 1**.

(5) Granulated Blast-Furnace Slag

The granulated blast-furnace slag (BFS) was made in Japan. Its physical properties and chemical analysis are given in **Table 1**.

4. EXPERIMENTAL WORKS

(1) The Measurement of Adsorption of Superplasticizer on Cement Particles

The adsorption of the superplasticizer on the cement was determined on the change of the concentration of the superplasticizer in the mix water of the fresh paste before and after the cement was stirred with the mix water. In this research, firstly, the samples of fresh paste (water/cement = 0.50) were prepared. Then, the solution of the fresh paste was disengaged from the paste by high speed centrifugal equipment at 4000 r.p.m.. Finally, the concentration of the superplasticizer in the solution was analyzed by a spectrophotometer at the wavelength where the superplasticizer has a highest absorption peak.

(2) The Analysis of the Concentration of Calcium Ion in the Solution of the Fresh Paste

The samples of fresh paste were prepared and the solution was disengaged as the section 1 of this chapter. However the concentration of calcium ion in the solution was measured with the ion chromatography method.

(3) The Measurement of Hydration of the Cement

The evolution of hydration heat of the cement at

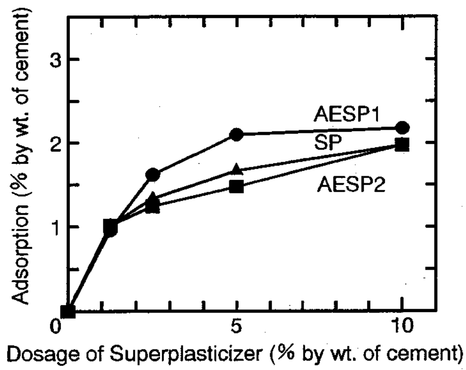

Fig. 2 Isotherm adsorption of superplasticizer on cement

20℃ was measured with a conductive micro-calorimeter, after sample (W/C=0.25) was stirred for 30 seconds. The content of non-evaporable water of the hardened paste was determined on the difference of the weight of the hardened paste sample at 105±5℃ and 950±5℃. The relative content of $Ca(OH)_2$ in hardened paste was measured by a powder X-ray diffraction analyzer.

(4) The test of the Properties of Mortar

a) Air content of fresh mortar

The air content of fresh mortar was determined by way of the volumetric method with an air-meter for mortar. The ratio of water to cement of the mortar was 0.27. The ratio of sand to cement was 1.0, but when the dosage of superplasticizer was equal or over 5% of the weight of cement, the ratio of sand to cement was 1.5. The mixing method is in accordance with JIS R5201.

b) The Compressive Strength of Mortar

The mix proportions of specimen were the same as that in air content test. All the specimens were ϕ50 by 100 mm cylinders which were cured in 20℃ water as soon as they were de-modeled after casting for one day.

5. RESULTS AND DISCUSSION

(1) Adsorption Characters of Superplasticizer on Cement

a) Isotherm Adsorption of Superplasticizer on Cement

The curves of isotherm adsorption of superplasticizer on the cement are given in **Fig. 2**. From this figure, it can be found that for all the three kinds of the superplasticizers, the quantities of the superplasticizer adsorbed on the surface of

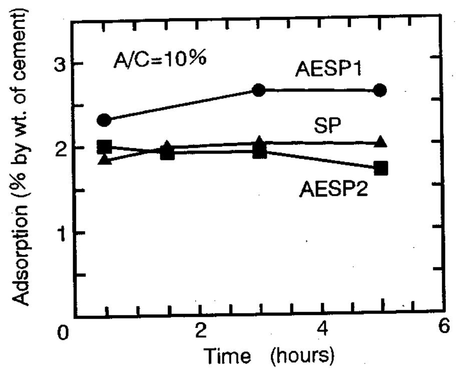

Fig. 3 Change of saturated adsorption of superplasticizer on cement with time

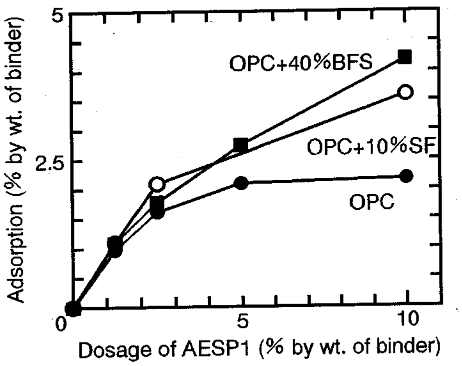

Fig. 4 Effect of fine mineral admixtures on adsorption of superplasticizer on cementitious materials

the cement increased with the increase of its dosage but there was a saturated adsorption for each of the superplasticizers. Although the isotherm adsorption cures of the superplasticizers were the same type cures, the quantities of the superplasticizers adsorbed on the cement were different. When the dosage of the superplasticizer was below 1.25% by the weight of the cement, the quantities of the superplasticizers adsorbed on the cement were almost the same. However, when the dosage of the superplasticizer was above 1.25% by the weight of the cement, the adsorbed quantity of AESP1 was higher than that of AESP2 and SP. When dosage of AESP1 was 5% by the weight of the cement the adsorption of AESP1 on the cement reached saturated condition but in the same dosage the adsorption of AESP2 or SP on the cement was far from saturated.

b) Change of Adsorption of Superplasticizer on cement with Time

In dosage of saturated adsorption (superplasticizer was the 10% by the weight of the

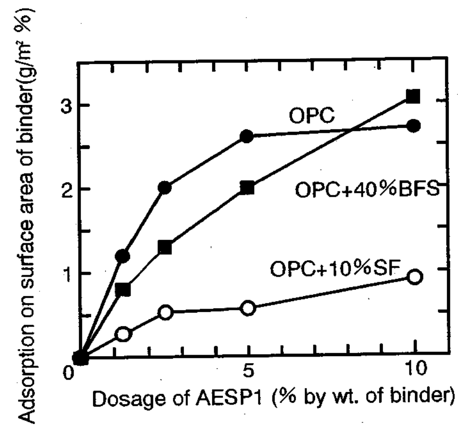

Fig. 5 Effect of fine mineral admixtures on adsorption of superplasticizer on specific surface area of cementitious materials

cement), the change of the quantity of the superplasticizer adsorbed on the cement with time was investigated. The results are shown in **Fig. 3**. From this figure, it can be found that the quantities of AESP1 and SP adsorbed on the cement had a small increase with time but that of AESP2 reduced a little with time. It suggests that when heavy dosage of superplasticizer is added in the cement paste the adsorption of superplasticizer on the surface of the cement can keep steady for a long time.

c) Effect of Fine Mineral Admixture on Adsorption of Superplasticizer on Cement

In order to advance the properties of concrete, the fine mineral admixtures, for instance, silica fume and blast-furnace slag, have often been used with superplasticizer in concrete. Because the fine mineral admixtures have larger specific surface area, they may affect the adsorption of the cement to the superplasticizer. This effect is shown in **Fig 4**. When the fine mineral admixtures admixed in the paste, the quantity of the superplasticizer adsorbed on the cementitious materials was much higher than on the blank cement. However, the quantity of superplasticizer adsorbed on the unit surface area of the cementitious material with silica fume was much lower than those on the control cement or cement added by 40% blast-furnace slag (shown in **Fig. 5**). It is the reason for it that the silica fume had a huge specific surface area (about 40 times as large as that of the cement).

According to above results, it suggests that the adsorption of the superplasticizers on cement may retard hydration of the cement. The isotherm

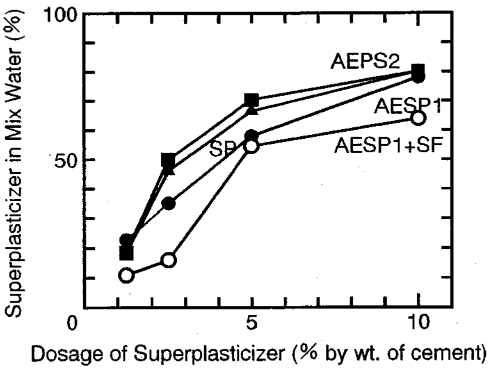

Fig. 6 Percentage of superplasticizer remaining in mix water in different dosage

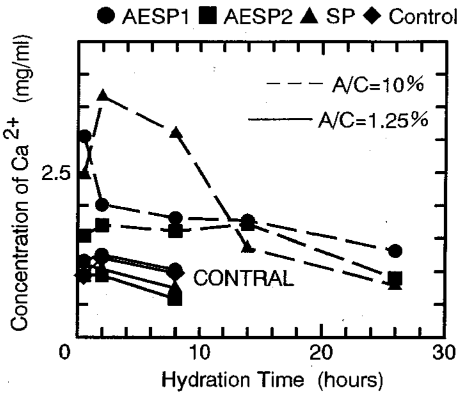

Fig. 7 Influence of superplasticizer on concentration of Ca^{2+} in solution of fresh paste

adsorption of the superplasticizer on the cement was determined by type and dosage of superplasticizer. In the normal dosage of superplasticizer, the superplasticzers adsorbed on the cement were not much and almost the same of the three types of the superplasticizers. It means that in the normal dosage although the chemical compositions of the superplasticizers are different they all have a little effect on the hydration of the cement. However, when the heavy dosage of the superplasticizer was admixed in the cement paste, the adsorptions of the different superplasticizers on the cement were very different. The adsorption of AESP1 on the cement increased much faster than that of AESP2 or SP with the increase of the dosage and the quantity of the saturated adsorption of AESP1 was higher than that of AESP2 or SP. These suggest that in the heavy dosage the retarding effect of AESP1 on the hydration of the cement get much more serious than AESP2 or SP.

Because the saturated adsorption of the superplasticizers on the cement was steady, the retarding effect of the superplasticizers may keep for rather long time.

When silica fume was admixed in cement paste with the superplasticizer simultaneously, the adsorption of the superplasticizer on the cement was reduced because silica fume adsorbed much superplasticizer as its huge specific area. Thus, in this case the retarding effect of superplasticizer on the hydration of the cement could be reduced.

(2) Effect of Superplasticizer on Concentration of Calcium Ion in the Solution of the Fresh Paste

The percentage of the superplasticizers remaining in the mix water, which was not adsorbed by the cement, is shown in **Fig. 6**. According to **Fig. 6**, the superplasticizer remaining in the mix water increased with the increase of its dosage. As a dosage of superplasticizer was 10% of the weight of the cement, there was about 80% of the superplasticizer which was not adsorbed on the cement and remained in the mix water. The superplasticizer remaining in the water may react with the calcium ions releasing from the cement to affect the concentration of calcium ion in the solution of the fresh paste.

a) Change of Concentration of Calcium Ion

The concentration of calcium ion in the solution of the fresh cement paste (W/C = 0.5) is given in **Fig. 7**. From this figure, it can be found that the concentration of calcium ion in the solution of control paste (no superplasticizer being admixed) was about 1.0 mg/ml. When normal dosage of superplasticizer ($\leqq 2.5\%$ by the weight of the cement) was added in the fresh paste, the concentrations of calcium ion were similar to (for AESP1) or lower than (for AESP2 and SP) that in the control paste. But when heavy dosage of superplasticizer ($\geqq 5\%$ by the weight of the cement) was added, the concentration of calcium ion in the solution of the fresh paste was much higher than that in the control paste in the first 8 hours after the paste stirred.

b) Change of the Concentration of Calcium Ion with the Cement Hydration

In **Fig. 7**, it also shows that concentration of calcium ion in the solution of the fresh paste changed with the cement hydration. Although the concentrations of calcium ion in the solution of the pastes admixed by heavy dosage of the superplasticizers were very high, they could decrease with the hydration of the cement. However, the rates of the decrease were different

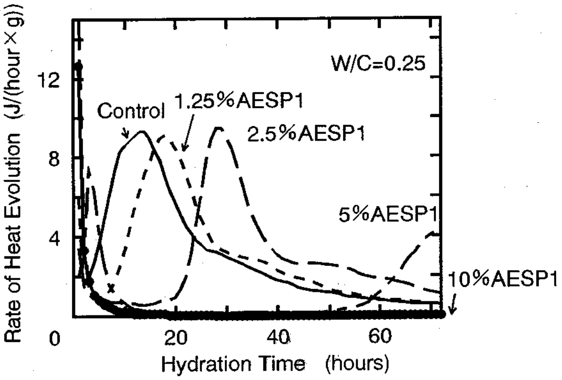

Fig. 8 Evolution of hydration heat of cement admixed by AESP1

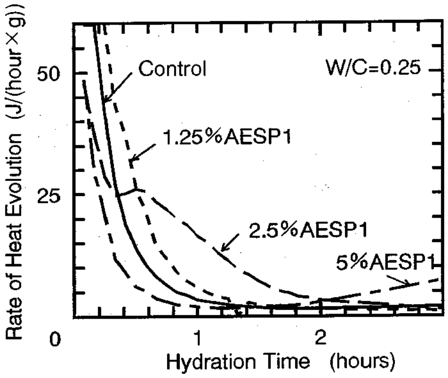

Fig. 9 Effect of AESP1 on evolution of hydration heat of C_3A

for different types of superplasticizer. The rates of AESP2 and SP were higher than that of AESP1. After the cement hydrated for 26 hours, the concentration of calcium ion in the solution of the paste added by AESP2 or SP decreased to almost the same as that in the control paste, but the concentration of calcium ion in that of the paste added by AESP1 maintained a higher level.

According to the results of analysis of the concentration of the calcium ion in the solution of the fresh paste, it can be found that the concentration of calcium ion in the solution was changed due to the admixture of the superplasticizers. Although in the normal dosage all the three type superplasticizers have little effect on the concentration of calcium ion, in the heavy dosage the concentrations of the calcium ion were increased by the superplasticizers to a much higher concentration than that of the control sample. This action of the superplasticizer is very similar to that of some of the retarders [5]. Although it is not exactly known how the superplasticizers reacts with the calcium ions, it is believed that the superplasticizers can react with the calcium ions to form some complex salts to resist the formation of $Ca(OH)_2$ and keep the concentration of calcium ion so high that retard the hydration of the cement. In the heavy dosage range, the concentration of calcium ion in the sample admixed with AESP2 or SP decreased with the hydration, but the concentration of calcium ion in the sample admixed with AESP1 kept high level for longer time. It indicates that the AESP1 in heavy dosage has a serious retarding effect on hydration of the cement.

(3) The Hydration of the Cement Admixed by the Superplasticizer

Because the kinetic process of the cement hydration can be expressed by the evolution curve of the hydration heat, as well as, the hydration degree of the cement can be determined on the quantities of non-evaporable water and relative content of $Ca(OH)_2$ in the hardened paste [6), 7)], these methods were used in determining the effects of superplasticizer on the hydration of the cement.

a) Evolution of Hydration Heat

The evolution curves of hydration heat of the cement admixed by AESP1 in different dosages are given in **Fig. 8**. In the curve of control cement, the first peak was produced by the hydration of C_3A, a little hydration of C_3S and dissolution of free alkali in the cement. The second peak was produced by the hydration of C_3S and C_2S [8)]. From **Fig. 8**, it can be found that the appearance time of the second peak was delayed the higher of the dosage of AESP1 the longer. When the dosage reached 10% by the weight of cement, the second peak even did not appear in three days after the paste was stirred. This evidences that AESP1 has a strong retard action to the hydrations of C_3S and C_2S.

The evolution curves of initial hydration heat of the cement admixed by AESP1 in different dosages are given in **Fig. 9**. It is shown that one part of the first peak was delayed with the increase of the dosage of AESP1. This suggests that AESP1 even can retard C_3A hydration either.

The evolution curves of hydration heat of the cement admixed by AESP2 or SP in different dosages are shown in **Fig. 10** and **Fig. 11**. From the figures, it can be found that in the case of

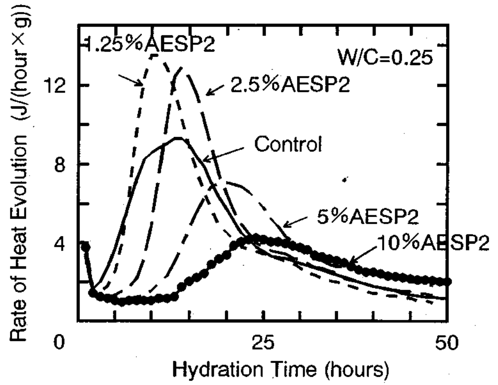

Fig. 10 Evolution of hydration heat of cement admixed by AESP2

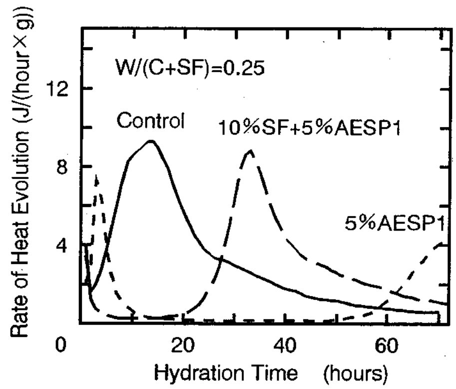

Fig. 12 Effect of silica fume on evolution of hydration heat of cement admixed by AESP1

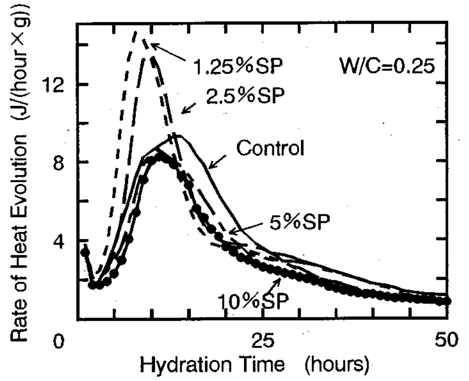

Fig. 11 Evolution of hydration heat of cement admixed by SP

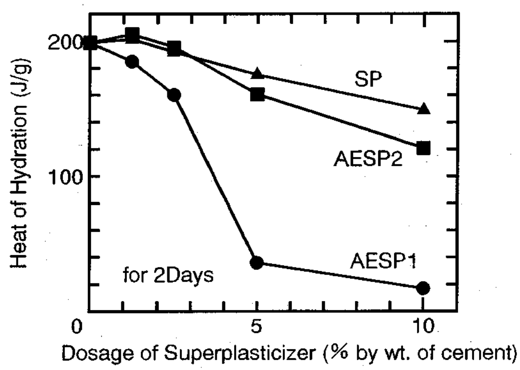

Fig. 13 Hydration heat of cement admixed by superplasticizer for 2 days

normal dosage ($\leqq 2.5\%$), the second peaks almost appeared at the same time as that of the control sample but the heights of the peaks were higher than that of the control sample. These mean that AESP2 and SP in normal dosage can accelerate the hydration of the cement. While in the case of heavy dosage ($\geqq 5\%$), the second peaks appeared at the same time of the control sample (for SP) or a little delay (for AESP2), however, the heights of the peaks were lower than that of the control sample. These suggest that AESP2 and SP in heavy dosage can retard the hydration of the cement only a little.

It is obvious that tendency of the evolution of hydration heat was in accordance with the tendency of the decrease of the concentration of calcium ion in the solution of the fresh paste.

It has been known that as the silica fume could adsorb more of superplasticizer, the superplasticizer adsorbed on the cement and retaining in the solution was less than that of the cement not being admixed with silica fume (**Fig. 5** and **Fig. 6**). This action of silica fume can affect the hydration of the cement admixed with the superplasticizer. In **Fig. 12**, it can be seen that the second peak of evolution of hydration heat of the cement admixed with 5% AESP1 and 10% silica fume appeared earlier than that of the cement admixed with the same superplasticizer but non silica fume.

b) Hydration Heat

The influence of type and dosage of the superplasticizer on the quantity of hydration heat of 2 days is given in **Fig. 13**. When AESP1 was admixed, the hydration heat of the cement was reduced dramatically with the increase of the dosage, i. e., the hydration of the cement was retarded strongly with the increase of the dosage. When AESP2 or SP was admixed, in case of the normal dosage the hydration heat was increased, while, in case of the heavy dosage the hydration heat was reduced with the increase of the dosage gradually, i. e., the hydration of the cement was retarded a little with the increase of the dosage. As the main compositions of AESP1 and SP are same, it is thought that the retarding action of

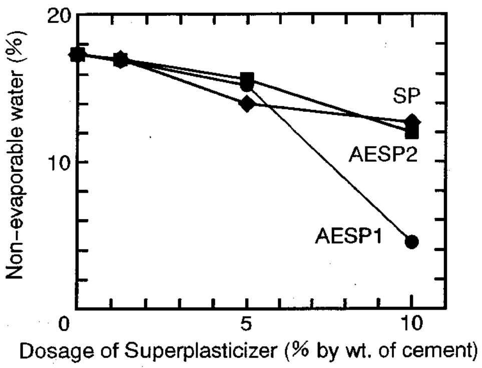

Fig. 14 Non-evaporable water in hardened cement paste admixed by superplasticizer curing 91 days

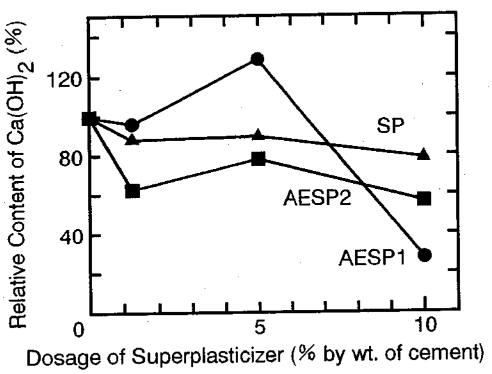

Fig. 15 $Ca(OH)_2$ content in hardened cement paste admixed by superplasticizer curing for 91 days

AESP1 may be caused by the components for retarding or air-entraining.

c) Non-evaporable Water and $Ca(OH)_2$ in Hardened Paste

The effect of type and dosage of the superplasticizer on hydration of the cement in a longer term can be determined quantitatively on the contents of the non-evaporable water and $Ca(OH)_2$ in the hardened paste. The contents of non-evaporable water in the hardened paste admixed with different types and dosages curing 91 days are shown in **Fig. 14**. The relative contents of $Ca(OH)_2$ in the same hardened pastes are shown in **Fig. 15**. From these figures, it can be found that quantity of non-evaporable water and $Ca(OH)_2$ in the hardened paste were decreased with the increase of the dosage of the superplasticizers, but the degrees of the decrease were different. In the hardened paste admixed with AESP1, the contents of non-evaporable water and $Ca(OH)_2$ decreased dramatically with the increase of dosage of the superplasticizer. However, in the hardened pastes

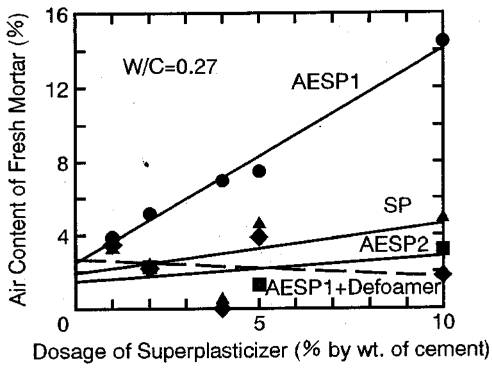

Fig. 16 Air content of fresh mortar

admixed with AESP2 or SP, the contents of non-evaporable water and $Ca(OH)_2$ decreased with the dosage of the superplasticizer a little.

From above discussion, it is suggested that the retarding effect of the superplasticizers on the hydration of the cement may depend on their adsorption on the cement and reaction with the calcium ions in the solution of fresh paste. This suggestion has been evidenced by the results of the tests of evolution of hydration heat, non-evaporable water and $Ca(OH)_2$ in the hardened paste.

According to evolution of the hydration heat, with the dosage increase AESP1 had a strong retarding effect on the early hydration of the cement, but AESP2 or SP did not. From the non-evaporable water and $Ca(OH)_2$ in the hardened paste cured for 91 days, with the dosage increase, AESP1 even can retard the hydration of the cement for a quite long time, but AESP2 or SP has a little retarding effect on the hydration of the cement.

(4) Properties of the Mortar Admixed by the Superplasticizer

a) Air Content of Fresh Mortar

Because of the different types and dosages of the superplasticizers, the air contents entrained in the concrete may be different. As well as, it has been well known that air content of concrete can affect the strength of the concrete. So it is important to investigate the influence of type and dosage of superplasticizer on the air content of concrete. The air contents of the fresh mortar added with the different types and dosages of superplasticizer are given in **Fig. 16**. The air content of the fresh mortar admixed by AESP1 increased with increase

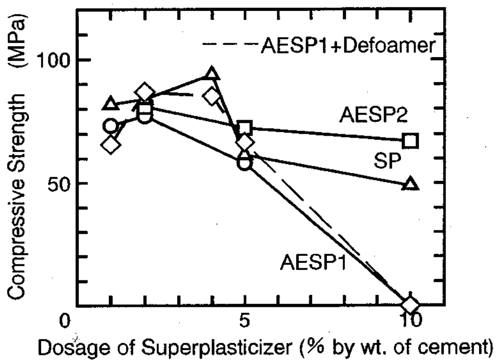

Fig. 17 Compressive strength of hardened mortar at age of 28 days

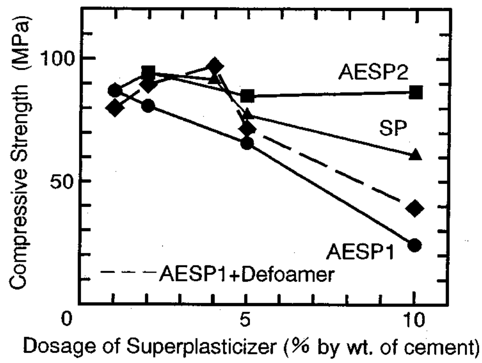

Fig. 18 Compressive strength of hardened mortar at age of 91 days

of its dosage dramatically, but the air content of the fresh mortar admixed by AESP2 or SP almost did not change with the increase of the dosage and kept in low content. This fact indicates that so much of air was entrained in the mortar with the increase of the dosage of AESP1 that the strength of the mortar may be decreased however there were not such problem for AESP2 and SP.

The air content of the fresh mortar admixed with AESP1 can be decreased by adding the defoamer admixture that is used for reducing excessive entraining air.

b) Compressive Strength of Hardened Mortar

The compressive strengths of the hardened mortars admixed by the superplasticizers curing for 28 days or 91 days are shown in **Fig. 17** and **Fig. 18** respectively.

The compressive strength of the specimen admixed by AESP1 was reduced with the increase of the dosage so dramatically that the specimen admixed by 10% of AESP1 had not any compressive strength after standard curing for 28 days. However, with the increase of the dosage of AESP2 or SP, the compressive strength of the specimen increased in the range of normal dosage as well as reduced gradually in the range of the heavy dosage. These tendencies are in accordance with those in hydration of the cement admixed by the superplasticizers.

Although air content of the fresh mortar can influence the strength, the decrease of the strength was mainly due to the superplasticizer retarding the hydration of cement. From **Fig. 17** and **Fig. 18**, it is shown that the strength of the specimen admixed with AESP1 where the air content was reduced to about 2.5% by the defoamer (shown in Fig. 16) was raised a little higher than that of the specimen admixed by AESP1 only. However the tendency of decrease of strength of the hardened mortar with the increase of dosage of AESP1 did not change as the air content was reduced to a low level by the defoamer.

With the increase of the dosage, the compressive strength of the hardened mortar admixed by AESP1 decreased dramatically but the strength of the hardened mortar admixed by AESP2 or SP decreased only a little. The tendencies of the decrease of the strength with the increase of the dosage of the superplasticizers are in accordance with those in hydration completely. It indicates that the reason for decrease of the strength with the increase of the dosage is the retarding effect of the superplasticizers on the hydration of the cement.

6. CONCLUSIONS

The physical and chemical actions of three types of superplasticizer in a large range of dosage on the cement have been researched. According to the results of the research, the following conclusions can be given:

(1) In the normal dosage of the superplasticizer, the quantity of the superplasticizer adsorbed on the cement was almost the same of the three superplasticizers. However, in the heavy dosage, the adsorption of AESP1 on the cement was much higher than that of AESP2 or SP.

(2) The superplasticizer remaining in the solution of fresh paste can react with the calcium ions releasing from the cement to result in the change of the concentration of the calcium ion. Although

in the normal dosage the concentration of calcium ion was not altered a lot, in the heavy dosage the concentration of calcium ion was increased to much higher level by the superplasticizer. The high concentration of calcium ion can decrease with the hydration of the cement but the speed of the decrease in the paste admixed by AESP2 or SP is faster than in the paste admixed by AESP1.

(3) According to the evolution of hydration heat and the content of non-evaporable water and $Ca(OH)_2$ in hardened paste, the effect of superplasticizer on the hydration was determined on type and dosage of the superplasticizer. And the effects on the hydration of the cement accorded with the adsorption of the superplasticizer on the cement and the increase of calcium ion in the solution of the fresh paste due to the superplasticizer. In the heavy dosage the superplasticizer, because the adsorption of AESP1 on the cement is higher than that of AESP2 or SP and the high concentration of calcium ion caused by AESP1 keeps much longer than that caused by AESP2 or SP, AESP1 has much more strongly retarding effect on the hydration of the cement than AESP2 or SP.

(4) Because tendencies of effect of dosage and type of superplasticizer on the strength of the hardened mortar accorded with that of effects on the hydration of the cement, the effects of type and dosage of superplasticizer on the hydration of the cement determined the influences of them on the strength of the hardened mortar. In the normal dosage, three of the superplasticizers had little effect on the strength of the mortar as they had little effect on the hydration of the cement. However, in the heavy dosage, AESP1 decreased the strength much more than AESP2 or SP because of its stronger retarding effect.

(5) The air entraining actions of the superplasticizers were very different. Although in the heavy dosage, AESP1 entrained too much of air into mortar but the air entrained in the mortar was not main reason for decrease of strength of the hardened mortar.

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高性能(AE)減水剤の多量添加がセメントの水和と強度に及ぼす影響

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高強度コンクリートにおいては，水結合材比が小さい状態で十分な流動性を得るために，高性能(AE)減水剤を大量に添加する必要がある．しかし，高濃度の高性能(AE)減水剤はセメントの水和や強度に影響を与える可能性がある．本研究においては，三種類の高性能(AE)減水剤を使い，添加量の広い範囲で，セメントの水和と強度に及ぼす影響を検討した．その結果，高性能(AE)減水剤がセメントの表面に吸着し，さらには高性能(AE)減水剤がフレッシュセメントペーストの溶液中の Ca^{2+} と反応し，このことがセメントの水和反応を遅延させており，さらには硬化体の強度を低下させることが明らかとなった．