Combined Effect of Heat Stimulation and Delayed Addition of Superplasticizer with Slag on Fresh and Hardened Property of Mortar

Faraidoon Rahmanzai, Mizuki Takigawa, Yu Bomura, Shigeyuki Date

***Abstract*—**To obtain the high quality and essential workability of mortar, different types of superplasticizers are used. The superplasticizers are the chemical admixture used in the mix to improve the fluidity of mortar. Many factors influenced the superplasticizer to disperse the cement particle in the mortar. Nature and amount of replaced cement by slag, mixing procedure, delayed addition time, and heat stimulation technique of superplasticizer cause the varied effect on the fluidity of the cementitious material. In this experiment, the superplasticizers were heated for 1 hour under 60 °C in a thermostatic chamber. Furthermore, the effect of delayed addition time of heat stimulated superplasticizers (SP) was also analyzed. This method was applied to two types of polycarboxylic acid based ether SP (precast type superplasticizer (SP2) and ready-mix type superplasticizer (SP1)) in combination with a partial replacement of normal Portland cement with blast furnace slag (BFS) with 30% w/c ratio. On the other hands, the fluidity, air content, fresh density, and compressive strength for 7 and 28 days were studied. The results indicate that the addition time and heat stimulation technique improved the flow and air content, decreased the density, and slightly decreased the compressive strength of mortar. Moreover, the slag improved the flow of mortar by increasing the amount of slag, and the effect of external temperature of SP on the flow of mortar was decreased. In comparison, the flow of mortar was improved on 5-minute delay for both kinds of SP, but SP1 has improved the flow in all conditions. Most importantly, the transition points in both types of SP appear to be the same, at about 5±1 min. In addition, the optimum addition time of SP to mortar should be in this period.

***Keywords*—**Combined effect, delayed addition, heat stimulation, flow of mortar.

I. Introduction

USAGE of SP increases the workability of mortar and concrete. The SP is mainly using for these two purposes:

1. To control the flow characteristic, which is the most important parameter for the design of self-compacting concrete.
2. To reduce the w/c ratio, in order to obtain durable and high strength concrete. [1], [2], [6].

Faraidoon Rahmanzai is Graduate student of Civil Engineering, Tokai University, 4-1-1 Kitakaname, Hiratsuka, Kanagawa. Japan, 259-1292 (phone: 0463-58-1211(exp 6076), e-mail: frahmanzai@gmail.com).

Mizuki Takigawa, Yu Bomura is with the Civil Engineering Tokai University 4-1-1 Kitakaname, Hiratsuka, kanagawa, Japan, 259-1292 (phone: 0463-58-1211(exp 6076), e-mail: 25concrete.4miz9@gmail.com, yu.bomura.tokai@gmail.com).

Shigeyuki Date is professor in department of civil engineering, Tokai university, 4-1-1 Kitakaname, Hiratsuka, kanagawa, Japan, 259-1292 (phone: 0463-58-1211(exp 6076), e-mail: sdat@tokai-u.jp).

Therefore, they are known as high range water reducer (SP). Heat stimulation technique also improves the fluidity of mortar and slightly decreased the compressive strength [3]-[5]. In this research, different amounts of normal Portland cement (OPC) (30%, 45%, and 60%) were replaced via BFS in combination with two kinds of polycarboxylic acid based SP (precast type (SP2) and ready-mix type (SP1)). By increasing the amount of BFS, the fluidity of mortar increased, and the amount of SP decreased. Moreover, the efficiency of external heating was decreased on the fluidity of mortar. Furthermore, by increasing the amount of BFS the compressive strength of mortar was decreased [7], [8]. On the other hand, the delayed addition time of SP increased the fluidity of mortar. By increasing the amount of BFS, the efficiency of delayed addition time on fluidity also decreased especially for more than 5 minutes [9]-[11]. Therefore, after 5-minute delayed addition of SP, the flow of mortar for heated and non-heated admixture was decreased. Some researchers reported that the delayed addition of SP resulted in decreased slump values for the period from 5 to 50 minutes after the concrete was mixed with water. But, the fluidity of mortar is affected by different factors like amount and type of admixture, type of cement, and chemical composition of SP. By heat stimulation and the delayed addition of SP, the compressive strength was slightly decreased. Furthermore, by using heat stimulation technique and replacement of cement with slag, the cost of concrete was decreased.

II. Methodology

The mixing process was according to the JIS R 5201" Physical testing methods for cement". The OPC cement was replaced with BFS 30%, 45%, and 60%. Initially, the cement, slag and river sand ware mixed on slow speed of mixer for 30 seconds, subsequently, the water was added and mixed on slow speed for 60 seconds and finally, the mortar was mixed on higher speed of mixer for 30 seconds, with premix of cement BFS and sand. The SP was added to the mix directly with water, and 5 minutes and 10 minutes' delay. The same procedure was used to prepare the mortar with non-heated SP. The ambient temperature of the mix was 18± 3 °C.

To confirm the changes in the fluidity of mortar after heat stimulation of admixture, the flow table of "JIS R 5201" Physical testing methods for cement was used. For the measurement of fluidity, the mortar spread was the average of two perpendicularly crossing diameters by millimeter.

III. Material Used

The materials used in this research are shown in Table I. OPC cement was partially replaced with BFS, 30%, 45%, and 60%. The water-cement ratio was 30%, and the sand-cement ratio was 2.0. The quantity of SP1 and SP2 were changed with the various amount of BFS. The dosage of SP was changed rendering the amount of cement.

TABLE I
Material Property

Materials		Description	Density g/cm^3
Cement	OPC	Ordinary Portland Cement	3.16
	BFS	BFS	2.89
Aggregate	Sand	Kanagawa river sand	2.69
SP	Sp1	Polycarboxylic acid-based ether (RMC type)	
	Sp2	Polycarboxylic acid-based ether (PCa type)	

IV. Result and Discussion

A. Combined Effect of Heated SP with BFS Slag on Flow of Mortar

The results showed that the delayed addition time of the heated and non-heated SP was influenced by the amount of BFS. Though on 5-minute delayed addition the flow was varied for the deferent amount of BFS, for more than 5-minute delay, the result was changed. The efficiency of different percentage of BFS on flow is as follows:

- For 30% BFS, on immediate and delayed addition, the heated SP1 improved the flow than SP2. So, on 5-min delay, the fluidity of mortar tends to enhance sharply, with heated SP1, but SP2 increased with a mild slope. Furthermore, on 10-minute delay, the SP1 slightly increased, while the SP2 decreased (Fig. 1).

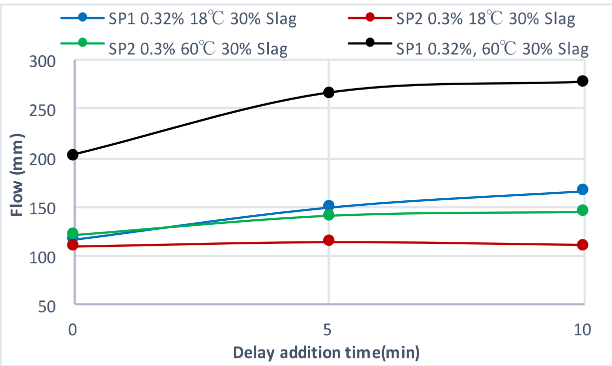

Fig. 1 Effect of heat stimulation and delayed addition of SP with 30% slag on flow of mortar

- For 45% BFS at immediate and 5-minute delayed addition, the flow of both SP was increased. On the other hands, on 10-min delay, the flow of heated SP1 was increased, while the non-heated of SP1 and heated and non-heated of SP2 decreased the flow of mortar (Fig. 2).
- For 60% BFS on immediate and 5-minute delayed addition, the heat stimulation technique caused to improve the flow, but for the non-heated SP1 and heated and non-heated SP2, the flow was decreased (Fig. 3).

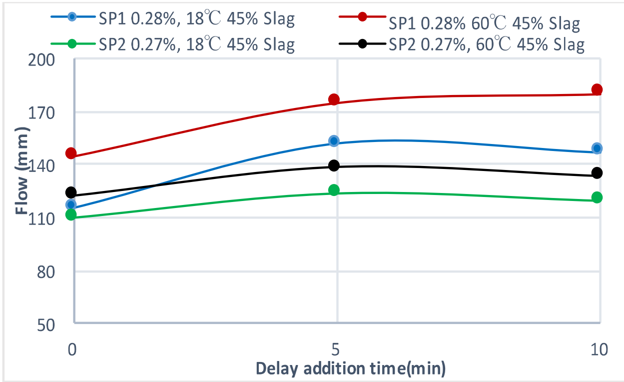

Fig. 2 Effect of heat stimulation and delayed addition of SP with 45% slag on flow of mortar

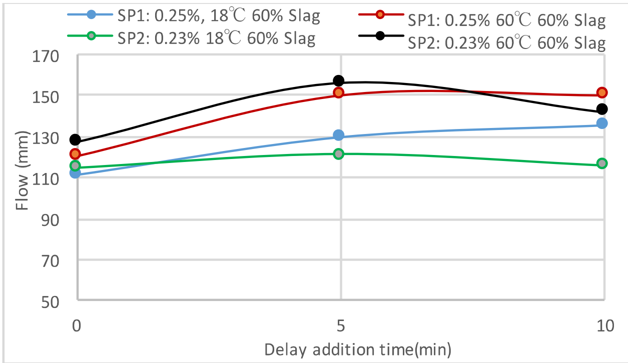

Fig. 3 Effect of heat stimulation and delayed addition of SP with 60% BFS on flow of mortar

B. Combined Effect of Heated SP with BFS on Fresh Density of Mortar

In this research, the fresh density of mortar which contained heated, non-heated SP, and different percentages of BFS, was studied. During the study process, it was revealed that several factors affect the density of mortar, such as external temperature, the amount of slag and delayed addition time. The outputs of slags for different percentages are as follows:

- For 30% replaced BFS, it was indicated that on immediate and 5-minute delayed addition, the density of heated SP1 was decreased in comparison with heated SP2. Consequently, for 10-minute delayed addition, the densities of mortar for both types of heated SP were approximately the same (Fig. 4)
- For 45% of replaced BFS, the density of mortar for heated SP2 was higher in comparison with SP1 at immediate and delayed addition (Fig. 5).
- For 60% replaced BFS, at the immediate addition of the heated and non-heated condition of SP, no significant impact was observed on density. But, on delayed addition of heated SP1 and SP2, the density of mortar was decreased (Fig. 6).

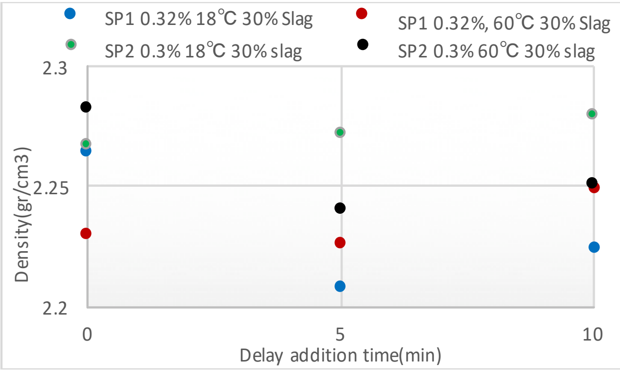

Fig. 4 Effect of heat stimulation and delayed addition of SP with 30% slag on fresh density of mortar

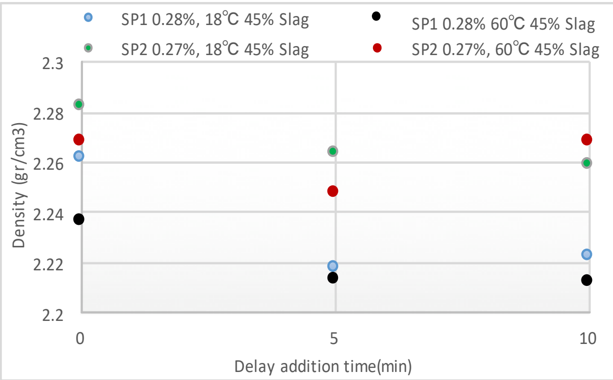

Fig. 5 Effect of heat stimulation and delayed addition of SP with 45% slag on fresh density of mortar

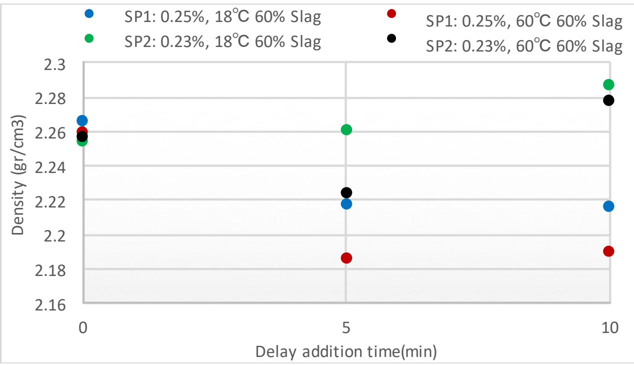

Fig. 6 Effect of delayed addition and heat stimulation of SP with 60% slag on fresh density of mortar

C. Combined Effect of Heated SP with BFS on Air Content of Mortar

In this experiment, it was observed that different factors such as the amount of BFS, external temperature, and addition time of SP can also affect the air content of mortar. The efficiency of heat stimulation technique, delayed addition time, and the amount of BFS are illustrated as follows:

- For 30% BFS, the air content of heated SP1 on immediate addition increased, but on delayed addition, the air content was decreased; on the other hand, for heated SP2 on immediate addition, the air content was decreased, but on delayed addition, the air content was increased (Fig. 7).

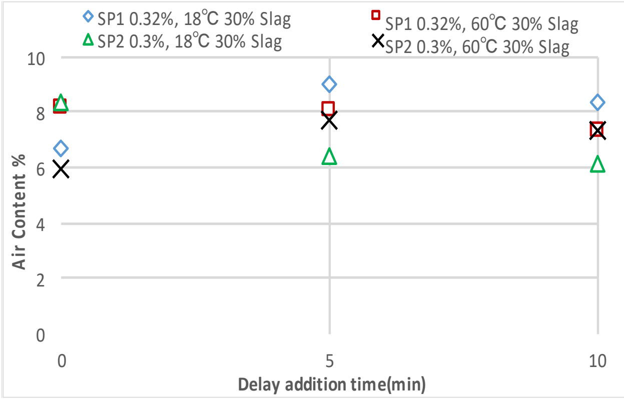

Fig. 7 Effect of delayed addition and heat stimulation of SP with 30% slag on air content of mortar

- For 45% BFS, the air content for heated SP1 was increased on immediate and delayed addition. However, for SP2 type admixture on immediate and delayed addition, the air content was slightly reduced. Lastly, the heated SP1 caused more air in the mortar than SP2 (Fig. 8).

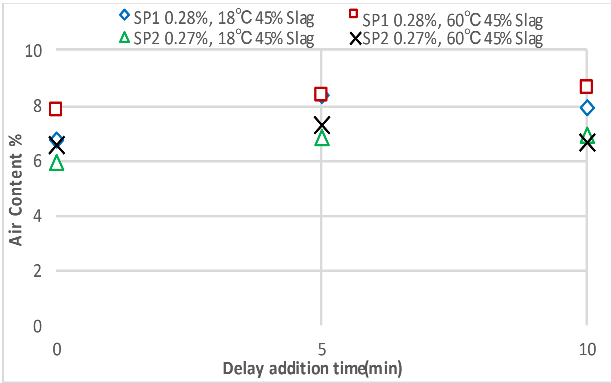

Fig. 8 Effect of heat stimulation and delayed addition of SP with 45% slag on air content of mortar

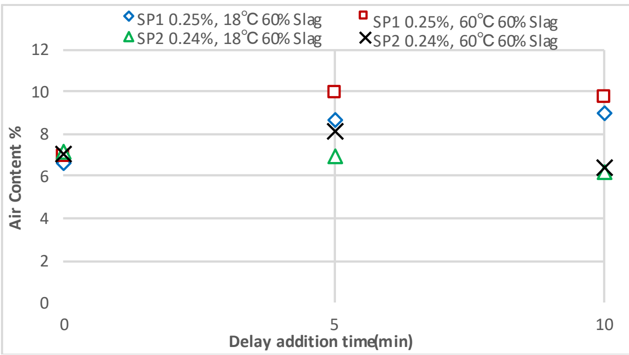

Fig. 9 Effect of delayed addition and heat stimulation of SP with 60% slag on air content of mortar

- For 60% BFS, on immediate addition time of heated SP, there were not any considerable changes, but on delayed addition, the heated condition of both SP1 and SP2 affected more air in the mortar than the non-heated ones. The air content of SP1 was higher than SP2 (Fig. 9).

D. Effect of Heat Stimulation and Delayed Addition of SP on Compressive Strength of Mortar

The analysis result indicates that the compressive strength of mortar can also be affected by the different factors like external temperature, the amount of slag and delayed addition time of SP. The efficiency of these factors is as follows:

- For 30% BFS on immediate addition for heated SP1 type admixture, the 7-day compressive strength slightly increased, but SP2 was slightly decreased. On the other hand, 28 days compressive strength of both type heated SPs was slightly increased. But, on delayed addition, the 28-days compressive strength of both heated SPs was decreased (Fig. 10).

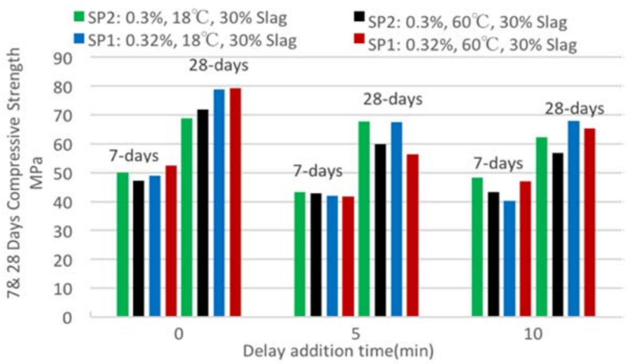

Fig. 10 Effect of delay addition and heat stimulation of SP with 30% BFS on compressive strength of mortar

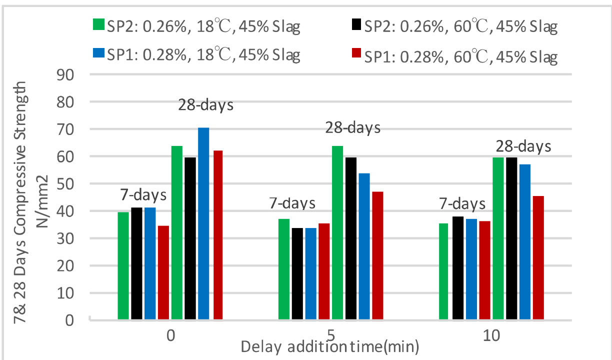

Fig. 11 Effect of delay addition and heat stimulation of SP with 45% BFS on compressive strength of mortar

- For 45% BFS on the immediate addition of heated SP1, the 7-day compressive strength was decreased, but for SP2 the strength was the same, and for 28-days, the compressive strength of heated condition and delayed addition time was decreased (Fig. 11).
- For 60% BFS on immediate and delayed addition, the 7-day compressive strength was the same, but on delayed addition, the compressive strength on heated condition of SP was decreased (Fig. 12).

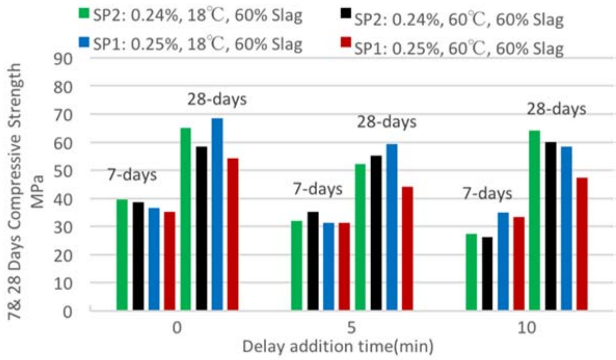

Fig. 12 Effect of delayed addition and heat stimulation of SP with 60% slag on compressive strength of mortar

V. Conclusion

The following conclusions have been derived from the experimental study of heat stimulation and delayed addition of SP with BFS.

- Heat stimulation techniques and delayed addition of SP improved fluidity of mortar.
- SP1 which is a ready-mix type product, showed more fluidity on delaying addition times than precast type in both heated and non-heated conditions.
- By increasing the amount of BFS, the efficiency external temperature on delayed addition was decreased especially for SP2.
- By increasing the amount of slag, the amount of SP decreased.
- While the flow was increased, the air content was also increased.

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