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APPLICATION OF POWDER SUPERPLASTICIZERS IN JAPAN AND SOUTHEAST ASIAN COUNTRIES

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ABSTRACT :

In order to confirm the applicability of Packed-Type Powder Superplasticizers to various types of concrete, we verified the use of the superplasticizers to high-strength concrete, and ready-mixed concrete in two Southeast Asian countries (Thailand and Indonesia). Test results in Japan were also given in the paper. It was found that the use of superplasticizers improved the tested fresh properties of the tested concrete by enhancing the workability.

KEYWORDS : Superplasticizer, Slump recovery, Fluidizer, Workability, Fresh concrete

1. Introduction

Infrastructure improvement is rapid in Southeast Asian countries, especially in Thailand and Indonesia, in line with economic growth, and concrete has been extensively used in the infrastructure improvement projects. Furthermore, the demand for high-quality concrete has been increasing, especially since the Great East Japan Earthquake on March 11, 2011.

In this study, we discuss the results of applying superplasticizers to high-strength concrete in an effort to expand the application range of superplasticizers beyond the conventional range in Japan. In addition, we report field confirmation tests to verify the use of superplasticizers to ready-mixed concrete in Thailand and Indonesia.

2. Powder Superplasticizer

Seven types of chemical admixtures are specified in the Japanese Industrial Standards “Chemical admixtures for concrete” (JIS A 6204). One of them is the superplasticizer group. A superplasticizer is defined as a chemical admixture that is added to concrete to increase its fluidity. Superplasticizers are mainly used to improve the workability of ready-mixed concrete that is transported to the application site. We evaluated two powder superplasticizers of which the powder dispersive agent is packed in alkaline-soluble paper (see Table 1). Thus, the on-site weighing and cost estimating of typically expensive superplasticizers is simplified; furthermore, no additional water is added to the concrete. This is an epoch-making chemical admixture because it eliminates any concern about the increase of water content because of chemicals added at later stages.

Table 1 Packed-type powder superplasticizers

Name of superplasticizer (SP)	Type	Main component
SP-G	Set retarding	Polycarboxylix acid ether-based
SP-H		Alkyl alyl sulfonic acid-based

3. Example of Application of The Superlasticizers in Japan

3.1 Concrete mix design and production

Table 2 shows the concrete mix designs and materials used in the tests. We used a 100 L pan-type forced-action mixer for making 40 L of concrete. Figure 1 shows the mixing method. We assume that the LJ-1 mix represents the ordinary strength concrete widely used in Japan and LJ-2 mix represents high-strength concrete.

Cement: ordinary Portland cement (Code: OPC, Sumitomo Cement, specific gravity : 3.16. Portland blast-furnace slag cement, Class B (Code: BB, Sumitomo Cement, specific gravity: 3.05). Mixing water: tap water. Fine aggregate from Kasumigaura (specific gravity: 2.60, FM : 2.54). Coarse aggregate from Kuzuu (specific gravity: 2.71, FM: 6.55). Ad : AE water-reducing agent (NMB Pozzolith No 70).

3.2 Test and methods

To confirm the properties of fresh and hardened concrete, we performed the tests in Table 3.

3.3 Results and discussion

After mixing the reference concrete and confirming its fresh properties, we prepared the plasticizer-containing concrete. We adjusted the fluidity of the plasticized concrete by adjusting the amount of the powder superplasticizer SP-H to obtain a slump of 21 cm. Then, we monitored the changes in the properties of fresh concrete with time. Table 4 shows the test results.

Despite the fluidity of the reference concrete is different in each mix, we were able to obtain the target slump by adding the same amount of superplasticizer. Thus, we can control the concrete fluidity by adding the superplasticizer.

Table 2 Concrete mix design

Mix No.	Cement type	w/c (%)	S/a (%)	Unit (kg/m^3)				
				Cement (C)	Water (W)	Aggregate		Admixture (Cx%)
						Fine	Coarse	
LJ-1	OPC	55.0	48.0	320	177	860	992	0.2
LJ-2	BB	35.0	35.0	471	165	660	1033	0.9

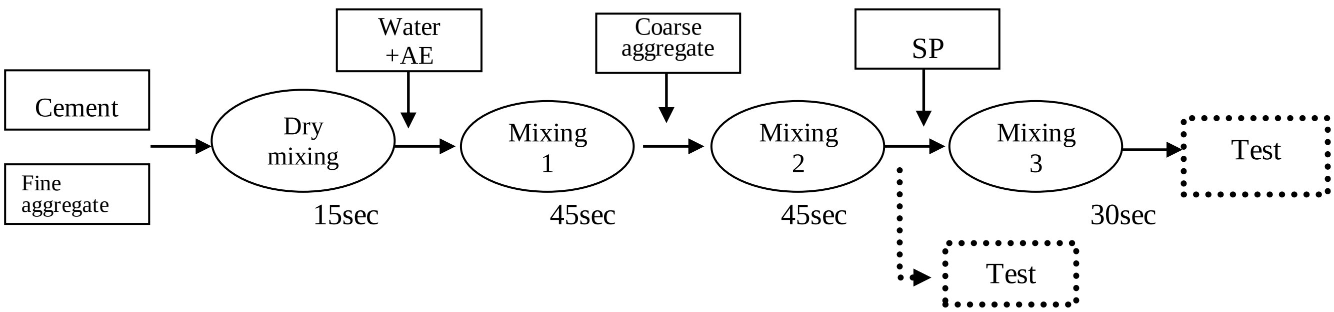

Figure 1 Concrete mixing and in-door testing flowchart

Table 3 Fresh and hardened concrete properties and standard test methods

Test parameter	Standard test method
Slump	JIS A 1101 method of test for slump of concrete.
Air content	JIS A 1128 method of test for air content of fresh concrete by pressure method.
Bleeding	JIS A 1123 method of test for bleeding of concrete.
Setting time	JIS A 6204 Annex 1 Chemical admixtures for concrete.
Compressive strength	JIS A 1108 method of test for compressive strength of concrete.

Table 4 Fresh concrete properties of the plasticized concrete

Mix No.	Reference concrete		Superplasticizer SP-H (C × %)	Plasticized concrete				Change after plasticizing
				Immediately after	20 minutes	40 minutes	60 minutes	
LJ-1	SL (cm)	15.8	0.21	20.7	19.7	19.2	15.5	4.9
	Air (%)	5.2		4.9	3.7	3.1	2.3	-0.3
LJ-2	SL (cm)	6.5	0.22	20.8	19.9	15.8	12.3	14.3
	Air (%)	3.5		2.6	2.4	1.9	1.7	-0.9

SL: Slump

Table 5 Bleeding and compressive strength test results for mix LJ-2

Mix No.	Superplasticizer	Superplasticizer (C×%)	Plasticized concrete				
			Bleeding (cc/ｃｍ²)	Setting (min)		Compressive strength (N/mm²)	
				Start	Finish	7 days	28 days
LJ-2	Base	-	0.015	(+0)	(+0)	29.1 (100%)	45.1 (100%)
	SP-H	0.22	0.017	(+73)	(+75)	32.2 (111%)	48.2 (107%)

The amount of superplasticizer is almost the same in LJ-1 and LJ-2; however, the increase of the slump is different. Although the fluidity of the concrete is affected by shape of the aggregate or concrete mix design, the aggregate used in both mixes is the same. Therefore we paid attention to quantity of cement paste. This may be because the cement paste, influencing concrete fluidity, is known to be affected by the volume of cement paste, which consists of fine particles of cement, water, and aggregates. The volume of cement paste of the LJ-1mix is 278 L/m^3, whereas that of the LJ-2 mix is 319 L/m^3. In addition, the amount of coarse aggregates for LJ-2 is greater than that of LJ-1. Hence, we guessed that LJ-2 is the easier plasticized mix.

Table 5 shows the bleeding test results for the reference and plasticized concrete for the LJ-2 mix, as well as the compressive strength at 7 and 28 days.

We found that the amount of bleeding increases with increasing amount of superplasticizer and the start and finish of setting are delayed about 75 min. This is probably because of the delayed cement hydration owing to the adsorption of the dispersing agent, the main component of the superplasticizer, to cement particles. Compressive strength was not affected as can be seen that the same strength or greater than that of the reference concrete was observed.

Next, we compared the changes in slump and air content of the plasticized concrete with time for LJ-1 and LJ-2. Figure 2 and Figure 3 show the results.

Although the air content tends to decrease with time in LJ-1, slump decrease was not observed up to 40 min after plasticizing, which shows good fluidity. In LJ-2, slump decrease was not observed up to 20 min. However, the LJ-2 slump decreased more seriously than the slump in LJ-1, with the addition of the superplasticizer. This may be owing to the greater amount of cement in LJ-2 and the greater effect of hydration reactions in LJ-2 than in LJ-1. These results confirm that, if concreting takes longer than normal or anticipated, the concrete fluidity can be maintained by adding superplasticizer.

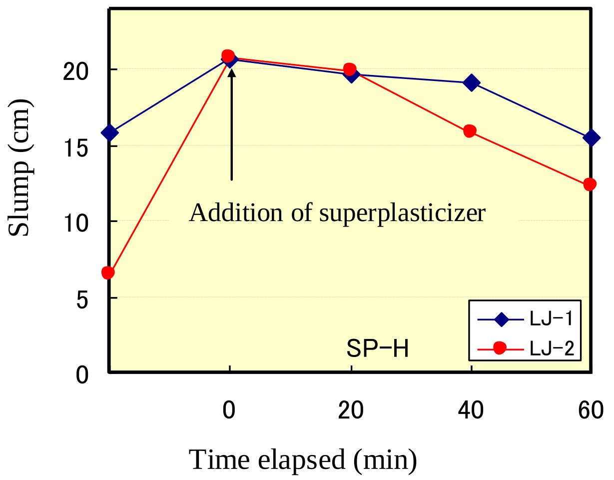

Figure 2 Change in slump of fresh concrete with time

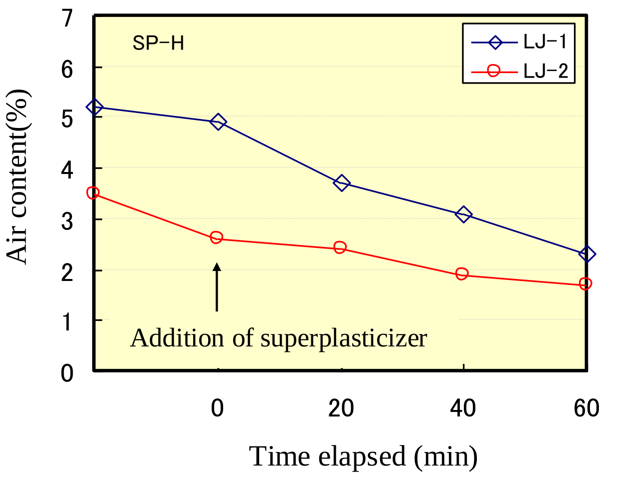

Figure 3 Change in air content of fresh concrete with time

3.4 Examples of application in Japan

The results for the plasticized concrete in Japan are discussed below.

1) Application at site (1)

Table 6 Summary of application

Class of concrete	45-12→18-20N
Element position	1F slab
Concrete volume	240m^3
SP-H average amount	6.0 bags/unit (C×0.127%)

Table 7 Concrete mix design

Cement type	w/c (%)	S/a (%)	Unit (kg/m^3)			
			Cement	Water	Aggregate	
					Fine	Coarse
OPC	38.5	37.6	460	177	618	1066

Figure 4 shows the slump test for the reference and plasticized concrete, as well as the number of bags used. The transport time varied owing to the long distance from the plant to the site; thus, the transportation conditions affected the reference slump. However, the slump after plasticizing was stabilized by adjusting the number of bags used. The amount needed to increase 1cm of slump was C × 0.021%.

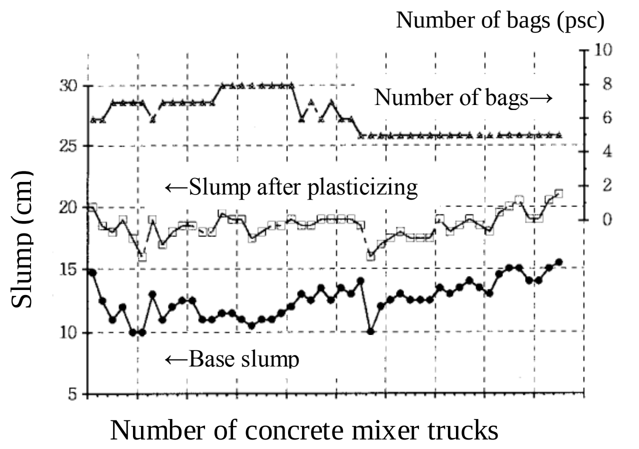

Figure 4 Slump result

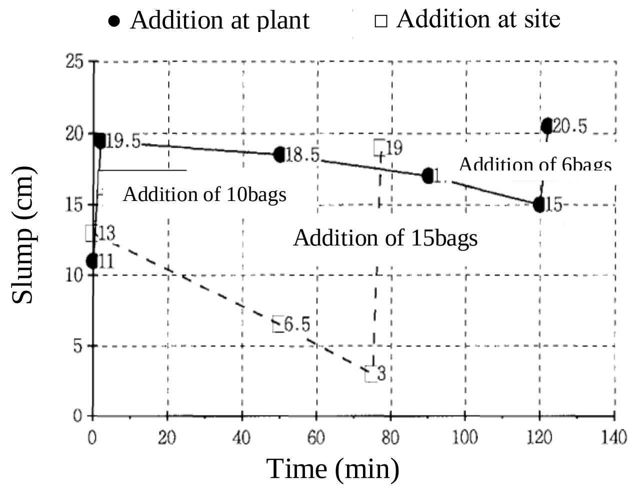

Figure 5 Comparison of the addition at the plant and addition at the site

2) Application at site (2)

In this case, we compared the amount of superplasticizer SP-H added at the ready-mixed concrete plant (addition at the plant) and after the transportation immediately before application (addition at the site). The concrete used was of the class 40-12→18-20N with a cement content of 448 kg/m^3. In the case of addition at the plant, 10bags (C ×0.216%) were needed to increase 8.5 cm of slump. To assure fluidity of the concrete, we added the superplasticizer, aiming to recover the slump 120 min after finishing the mixing at the ready-mixed concrete plant. The amount of superplasticizer needed to increase 1cm of slump in the case of the addition at the plant was C × 0.025%.

4. Application in Thailand and Indonesia

4.1 Concrete mix design and production

Table 6 and Table 7 show the concrete mix designs. After the concrete was mixed at the local ready-mixed concrete plant, the concrete was transported to the site by a concrete agitator truck. After the concrete was transported, we added the powder superplasticizer in the form of bags. Then, it was mixed for 120 s to make the plasticized concrete.

Cement: ordinary Portland cement by Siam Cement Public Company Ltd. (Type 1). Fly ash: BLCP power station, Rayong province. Water: tap water. Fine aggregate: fine sand and mountain sand from the Chonburi Province. Coarse aggregate: crushed stone from Chonburi province. Chemical admixture: CPAC4040/CPAC20403.

Cement: ordinary Portland cement by PT Indocement (bulk type I). Fly ash: Suraraja thermal power plant ASTM Type F. Water: Cikampek tap water. Fine aggregate: sand from Tsimalakha. Coarse aggregate: crushed stones from BCA stone pit. Chemical admixture: Normet Indonesia TamCem6R (Type D） and PT Normet Indonesia TamCem12R (Type F).

4.2 Tests and methods

We measured the slump (JIS A 1101/ASTM C143), air content (JIS A 1128/ASTM C231), and compressive strength (JIS A 1108/ASTM C39, ϕ 150 × 300 mm, 28 days) for the concrete transported to the site by a concrete agitator truck (5 m^3 loaded), hereafter referred to as the reference concrete, and the concrete after plasticizing, hereafter referred to as the plasticized concrete. As for the K-300 mix (slump 8 cm), we established the properties of fresh concrete after plasticizing and then added more superplasticizer to replasticize the concrete.

4.3 Results and discussion

Table 8 shows the properties of fresh plasticized concrete with SP-G and SP-H (see Table 1). Plasticizing was possible in all concrete mixtures by adjusting the number of superplasticizer bags.

Table 6 Concrete mix design (Thailand)

Mix	Slump (cm)	W/C (%)	S/a (%)	Unit (kg/m^3)				
				Fly ash Cement	Cement (C)	Water (W)	Aggregate	
							Fine	Coarse
A000	5-10	58	40.5	336	-	195	770	1130
B000	5-10	63	42.6	-	310	195	830	1120

Table 7 Concrete mix design (Indonesia)

Blending	Slump(cm)	W/C (%)	S/a (%)	Unit (kg/m^3)				
				Fly ash	Cement	Water	Aggregate	
							Fine aggregate	Coarse aggregate
K-300	8	52	55	80	239	166	1027	848
K-300NFA	8	56	55	-	305	171	1032	851

Table 8 Test results for fresh concrete

Test No.	Mix	Reference concrete			Plasticized concrete (-1)					Replasticized concrete (-2)			
		Before plasticizing		Volume	SP	Added amount		After plasticizing		Added amount		After replasticizing	
		SL (cm)	Air (%)	m^3	Type	bags	C×%	SL (cm)	Air (%)	bags	C×%	SL (cm)	Air (%)
1	A000	7.3	1.1	5	G	4	0.056	12.0	0.9	-	-	-	-
2		7.5	1.1	5	H	4	0.115	12.5	0.5	-	-	-	-
3	B000	7.7	1.2	5	H	4	0.125	12.0	1.4	-	-	-	-
4	K300(8)	8.0	1.0	5	H	3	0.091	12.4	1.3	2	0.061	19.0	0.9
5		8.7	1.2	5	G	3	0.044	12.5	1.1	2	0.029	16.5	1.8
6	K300NFA	9.0	1.9	5	H	3	0.095	12.0	1.9	-	-	-	-

Figure 6 shows the amount of superplasticizer needed to increase 1 cm of slump in each mix. Although there is some difference in the amount among the concrete mixtures, the average required dosage for increasing 1cm of slump are the same as in Japan. Clearly, the fluidity of the concrete used in Thailand and Indonesia can be controlled by adding the superplasticizers to the mix. In No.4-2 and No.5-2 where re-superplasticizing was applied, we did not observe separation of aggregates although we added 2 bags additionally into the plasticized concrete. From these, concrete fluidity can be easily controlled by increasing or decreasing the amount of superplasticizer, and the slump of the concrete can be managed by the number of added bags at the site, making superplasticized concrete.

Figure 7 shows the change in air content before and after plasticizing. The possibility of increasing the air content owing to air entrapment by high-speed mixing at the concrete agitator truck is of concern. Nonetheless, there was little increase in the air content of the mixtures regardless of the superplasticizer. The air content was unchanged and was almost the same as that of the reference concrete. This suggests that SP-G and SP-H have low air-entraining properties.

Figure 8 shows the compressive strength after plasticizing for each mix and strength ratio of the plasticized to the reference concrete. For every concrete mix and type of superplasticizer, the compressive strength after plasticizing was equal to or greater than that of the reference concrete. There are cases where the compressive strength ratio increased (Tests No. 4 and No. 5). We attribute this to the higher dispersion of the cement particles owing to the superplasticizer and lower air content.

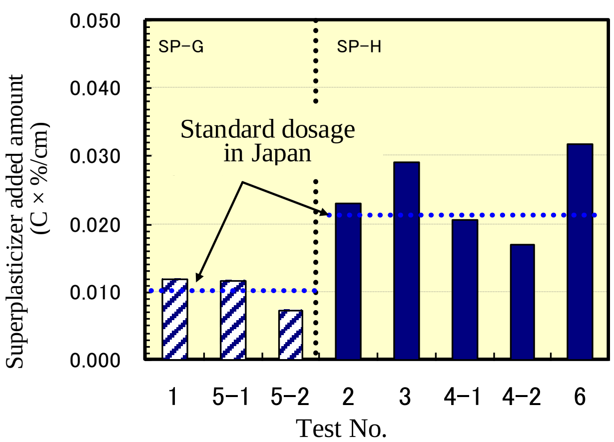

Figure 6 Added amount of superplasticizer

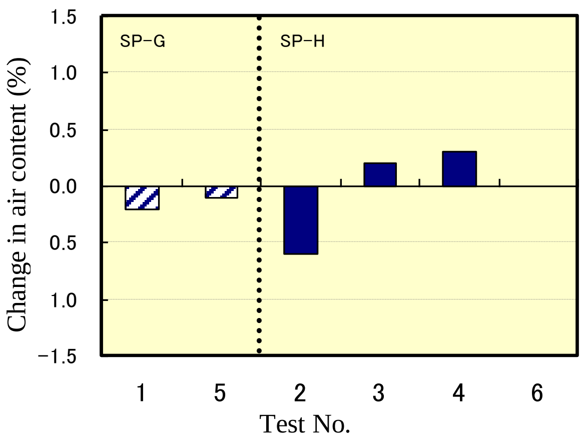

Figure 7 Change in air content before and after plasticzing

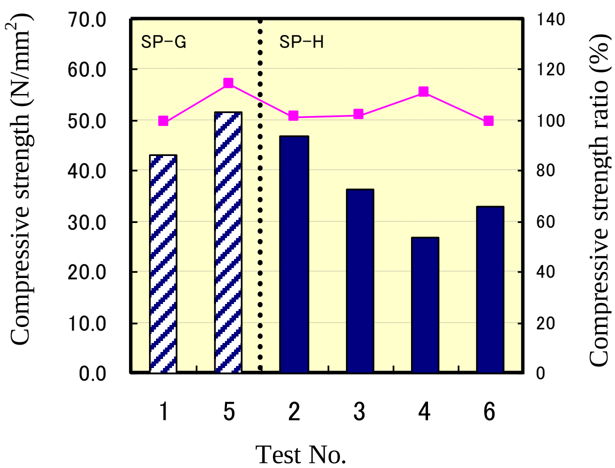

Figure 8 Compressive strength and compressive strength ratio

On the basis of the above results, we conclude that fluidity of the concrete can be controlled by adjusting the amount (number of bags) of superplasticizers SP-G and SP-H on-site in Thailand and Indonesia.

5. Summary

We considered two superplasticizers, which have been used successfully in Japan, for ready-mixed concrete in Thailand and Indonesia. We found that the use of superplasticizers improved the properties of the fresh concrete by enhancing the workability. The followings are the findings of our study:

1. We could adjust the slump by using the superplasticizers SP-G and SP-H as percentage of the mass of the cementitious materials. The required dosage for plasticizing was the same as in Japan.

2. The air content was almost unchanged.
3. The compressive strength after plasticizing was equal or greater than that of the reference concrete. Thus, the compressive strength was not affected.

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