Slump Retention of Concrete by Time Splitting of Superplasticizer Dose

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Abstract: This is preliminary research made to compare the slump retention behavior of concrete with high initial superplasticizer (SP), with high initial slump, and splitting its dosage in two times. Typical concrete mix with water to binder ratio 0.3, paste ratio (ratio of volume of cement to the volume of void in the aggregate) 1.3, initial dosage of SP 1.6% and 2.6% by weight of binder was prepared. It was found that separation of total SP into two can maintain slump for longer period as compared to the case of high initial slump (with high initial SP). The effect of second dosing of SP on compressive strength and setting time was also tested. It was found that there was not adverse effect of second dose on compressive strength and setting time of concrete up to the tested dosage of SP.

Keywords: Re-dosing, Superplasticizer, Ready-mixed, Concrete

1. Introduction

Concrete is a composite construction material primarily composed of aggregates, binding materials and water. Properties of concrete depend upon its age. Plastic property is important in its fresh state where as mechanical properties are important in hardened state. However, each property is interrelated and cannot be considered separately. Due to the plastic property in its fresh state, concrete can be molded into desirable shape.

Sufficient compaction without segregation and bleeding is one of the requirements for durable concrete structures. The concrete having sufficient workability in its fresh state can be made homogeneous and compacted concrete. The workability of fresh concrete can be defined in many ways such as deformability, transportability, consolidation, ability to finish surface, resistance to segregation. The workability also includes flowability, moldability, cohesiveness and compatibility of fresh concrete. (Tangtermsirikul S., et al 2001) Workability of concrete is defined as the amount of useful internal work necessary to produce full compaction (Glanville W. H., et al 1947). ASTM C 125-00 defines workability of the concrete as “that property determines the effort required to manipulate a freshly mixed quantity of concrete with minimum loss of homogeneity.

In a practical term, workability can be defined as, after consistent concrete is poured, the worker will wait until the concrete just start to harden, what is known as the "workable" state of the concrete, where it can be trowelled, shaped, or smoothed. Timing is critical. If trowelled too early, it is in highly plastic state and won't keep the shape, and segregation, especially bleeding, may still take place, resulting in a poor finish. If trowelled too late, it would be too hard and cannot be shaped or smoothed. How well it behaves during the critical time is also included in the "workability of concrete", which depends on factors such as water content, additives and ambient temperature.

Workability represents diverse characteristics of freshly mixed concrete which are difficult to measure collectively and quantitatively. It is the relative property and one of the most popular test methods is slump test. Minimum slump for placement (desired value of slump at site) is determined on the basis of conditions like the type and shape of member, the amount of reinforcing steel and its spacing, method of concrete pouring, method of compaction, etc. Due to the relatively short setting time of concrete at the initial stage, efficient methods for mix proportion are essential to make concrete have relatively longer period of initial setting time to maintain workability during the casting period and make it easy for compaction without bleeding and segregation. Ready-mixed concrete, which is mixed at plant, using a well-designed concrete mix, should arrive at its destination with sufficient workability to enable it to be properly placed and fully compacted.

In such circumstances, where there is a significantly long period of time, due to long transportation distance or traffic jam or any unexpected delay, between mixing and placing sites of the concrete, there will be a noticeable reduction in the workability of fresh concrete. If for any reason, the placement of the concrete is unduly delayed, then it may stiffen to an unacceptable degree. Normally, site staff will insist on the rejection of that concrete batch or the person who has insufficient concrete knowledge mostly adds water in the fresh concrete to improve workability. The addition of water will have an adverse effect on concrete strength at hardened state. If not rejected, excessive vibration will be needed to attempt full compaction of the concrete with the risk of incomplete compaction, expensive repair, or, at worst, removal of the hardened concrete. If the abnormal slump loss is anticipated, the use of a superplasticizer with splitting in timing of its dose may give good results.

2. Methodology

2.1 Materials

The mix design depends on the type of structure being built, how the concrete is mixed and delivered, and how it is placed to form the structure. Properties (physical and chemical) of each material used in this research are described below individually.

Cement

Ordinary Portland cement Type I was used. The physical and chemical compositions of cement are shown in the Table 1

Table 1: Chemical and physical properties of binder (Provided by supplier)

Ingredients:	Cement
CaO (%)	64.28
SiO_2 (%)	20.35
Al_2O_3 (%)	5.02
Fe_2O_3 (%)	3.18
MgO (%)	2.03
Na_2O (%)	0.20
K_2O (%)	0.48
SO_3 (%)	2.92
Specific Gravity	3.1
Blaine Finesse (cm^2/gm)	3440
Loss of Ignition (%)	1.427

Table 2: Physical properties of aggregate (Tested in own lab)

Physical Properties	Value	
	Gravel	Sand
Specific gravity	2.71	2.6
Fineness modulus	7.98	2.45
Water absorption (%)	0.7	1.06

Aggregate

The natural river sand passing through sieve no. 4 and naturally found in Thailand was used as the fine aggregate and crushed stone (especially limestone) with the maximum size of 25mm conformed to ASTM C 33 was used as the coarse aggregate. The physical properties of coarse and fine aggregates (gravel and sand) were as shown in the table 2.

Chemical Admixture

Naphthalene (NP) based SP type-F commercially available and widely used in Thailand was used.

2.2 Mix Proportion

Typical concrete mix with water to binder ratio 0.3, paste ratio 1.3, initial dosage of SP 1.6% and 2.6% was prepared for this test.

2.3 Mixing Procedure

The drum type concrete mixture was used to mix concrete. Initially, binder, course aggregate and fine aggregate were weighted and put in the mixture and dry mixed for one minute. Then approximately eighty percentage of weighted water was added and mixed for one minute. Finally, the remaining water and weighted amount of SP was added and mixed for two minutes. The total mixing time was around four minutes.

2.4 Slump Measurement and Re-dosing of SP

The slump was measured immediately after the mixing procedure was finished and recorded as initial slump. Then the concrete was kept in the tray with the plastic cover to prevent loss of water by evaporation. Then the sample of concrete was used to measure the slump value at the stipulated time of 30, 60 and 90 minutes respectively. The measured slump was recorded as the slump before re-does. Before measuring the slump, the sample was mixed for two minutes to make it homogenous. Then the weighted amount of SP was added to the concrete as a second dose and mixed for two minutes to make it homogenous. Again slump was measured and recorded as slump after the second dose of SP. The slump was tested as per the test method described on the ASTM C143-90.

2.5 Measurement of Compressive Strength

Cylindrical specimens of size 100mm diameter and 200mm length were used to find the compressive strength developed at the age of one, seven and twenty eight days respectively. The test specimens were sealed with a plastic wrap after casting and removing mold after one day. Specimens were cured in water at 28±20C till the time of testing.

2.6 Measurement of Setting Time

The test method described on the ASTM C403M was used to find the setting time of concrete. Initial setting time and the hardness development of mortar (final setting time) taken by sieving concrete and is discharged to a 15 x 15 cm cubic mold and stored at room temperature (26±4oC). A spring reaction type probe known as Proctor probe was used to find the penetration resistance of mortar by a standard needle. A graph was plotted between of penetration resistance versus elapsed time. The penetration resistance 3.5 MPa (500psi) and 27.6 MPa (4000psi) was taken as initial and final setting time respectively. From the graph initial and final setting time was determined through interpolation.

3. Results and Discussion

3.1 *Comparison Between and Re-dosing and without Re-dosing*

Conventionally, the target slump at placement and design slump of ready-mixed concrete at factory is fixed as shown in Figures 1 and 2. Minimum slump for placement is fixed according to recommended values provided based on working condition like type of member, the amount of reinforcing steel and its spacing. Slump upon completion of mixing is usually specified at the value obtained by adding the expected slump loss due to transportation from ready-mixed concrete plant to the target slump for unloading.

This is the way to fix the slump at the time of completion of mixing. But there are some parameters, like the rate of slump loss, exact time of transit, unexpected waiting at the site, temperature change etc., which cannot be predicted precisely. In many occasions slump of concrete just before placement become smaller than the desired slump. This causes problem for placement, also affects quality of concrete or then concrete may have to be rejected. So it is necessary to have some solutions to regain slump in such cases of any accidental delay of placement of concrete.

Planned Re-dosing

Figure 3 shows a comparison between the conventional method of making high initial slump and the proposed method of re-dosing at site.

Case-I: Conventional Method

The concrete with water to binder ratio 0.3 and paste ratio of 1.3 was prepared with an initial dosage of SP (SP1) 2.6%, slump value 21±1 cm and checked value of slump at every 30 minutes until 120 minutes. Concrete with initial SP of 2.6% has a slump of about 4 cm at 90 minutes (Case-I as shown in Figure 3).

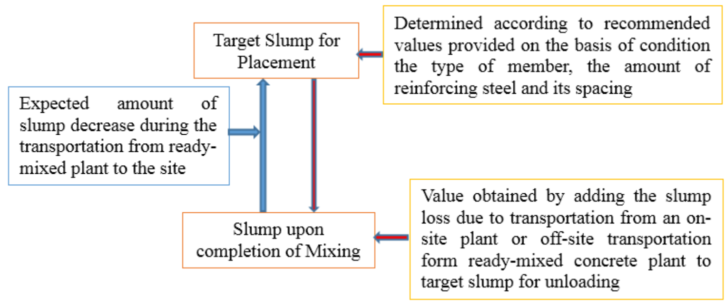

Figure1 Flow chart for slump determination at different stage

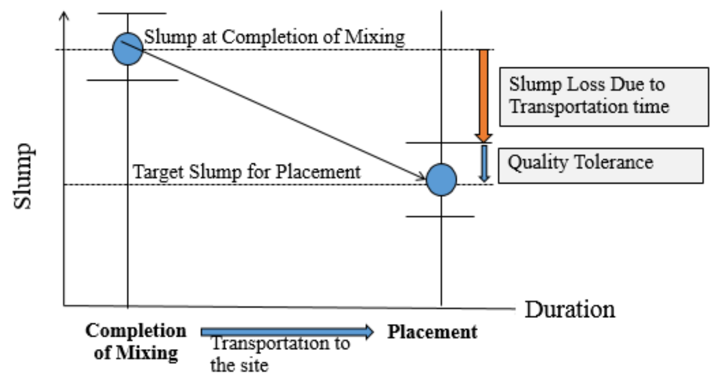

Figure 2 Slump determination at different stage

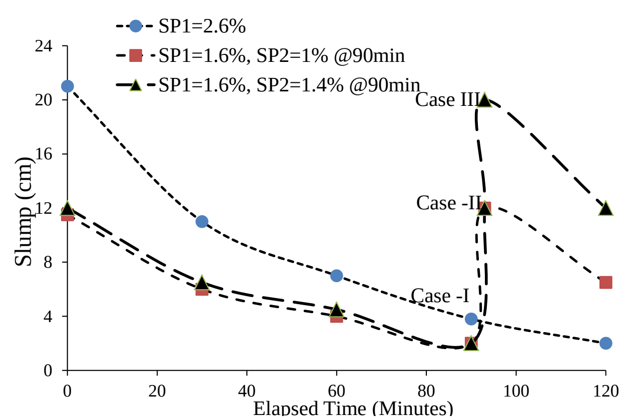

Figure 3 High SP1 and low SP1 with re-dosed

Case-II: Re-dosing Method

Concrete was mixed with water to binder ratio 0.3, paste ratio 1.3, initial dosage of SP 1.6%, slump value 11±1cm and re-dosed at 90 minutes. The concrete with initial SP of 1.6% and re-dosed by 1% at 90 minutes has a slump of 11cm at 90 minutes. For equal superplasticizer, the slump of concrete at 90 minutes in case II is higher than that of case I. Case-III shows slump can be regained up to the value of 21cm at 90 minutes with total SP of 3% (1.6% of SP1+ 1.4% of SP2, Second Dosage of SP). It seems that separation of total SP into two can maintain more slump as compared to the case of high initial slump. The planned re-dosing by separating SP dose not only helps to make higher slump at 90 minutes, but also is beneficial to prevent the concrete from segregation which may occur at very high slump initially.

Unplanned Re-dosing

Designer designed initial slump of concrete considering certain loss of it during transportation (based on certain situation). Sometime, it encountered the unexpected delay on pouring the concrete, the situation which concrete will loss more slump than expected. Figures 4 and 5 show that if the slump of the concrete drops lower than the expected value it can be re-gained to its original value.

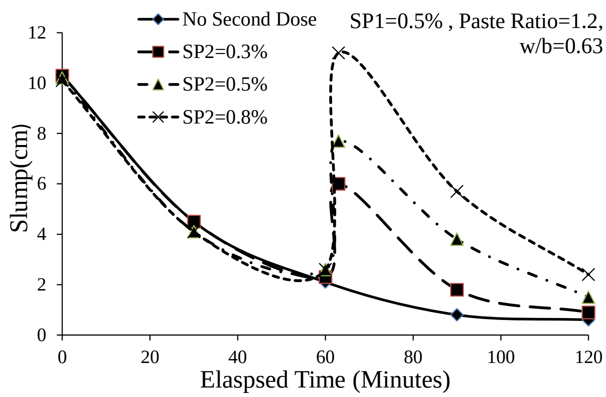

Figure 4: Slump before and after re-dosing at 60 minutes with different dosage

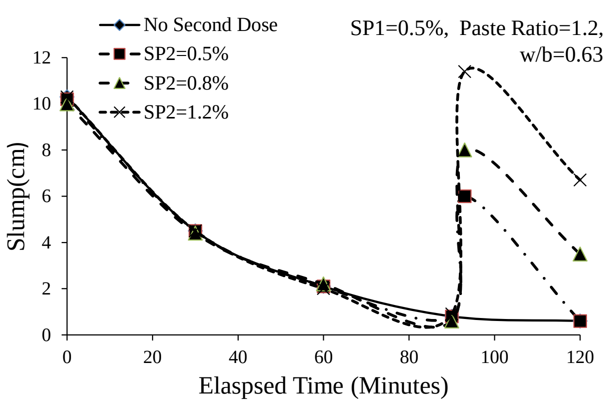

Figure 5: Slump before and after re-dosing at 90 minutes with different dosage

3.2 Effect of Re-dosing on Setting time and Compressive Strength

The effect on setting time due to high initial dosage of SP and separation of dosing into two was compared. Figure 6 shows comparison of setting times between mixes with initial SP 1.6 % and re-dosed at 90 minutes with 1% SP, and mix with SP 2.6% without re-dosing. The setting time of the mix with initial SP 2.6% was quite long as compared to mix with initial SP 1.6 % and another 1% re-dosed at 90 minutes. But the both initial and final setting times of mix with 1.4 % second dosage at 90 minutes, are almost 50% longer than those of control mix (Table 3 mix (1)), but still shorter than the mix with 2.6 % initial SP without SP2. This might be due to the total dosage of SP in the mix and a chance of cement to get contact with water. If there is higher dosage of SP from the beginning chance of cement to get contact with cement will be low as compared to the small dosage at initial and make re-dosed. In the lap time between initial and second dosing of SP, cement may get the chance to get contact with water to continue the hydration.

Table 3: Summary of setting time for high SP1 and low SP1 with re-dosed

Setting Time	Initial SP=1.6%, No SP2 (1)	Initial SP=1.6% & SP2=1% @ 90min (2)	Initial SP=1.6% & SP2=1.4% @ 90min (3)	Initial SP=2.6 %, No SP2 (4)
Initial(Hr)	2.78	3.53	4.28	4.40
Final (Hr)	3.74	4.22	4.99	5.19

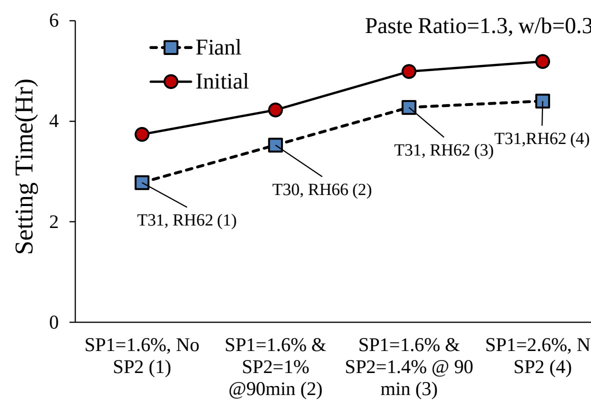

Figure 6: Setting time of mixtures one time dosing and re-dosing

The results of compressive strength of concrete collected without re-dosing of SP, was considered as the control mix. Each strength value published in this report is the average value from three tested specimens. Figure 7 shows the effect on compressive strength between mix with initial SP 1.6 %, re-dosed at 90 min with 1% SP and mix with initial SP of

2.6% without re-dosing. The compressive strength at 1, 7 and 28 days of age of all mixes was within 90% of each other.

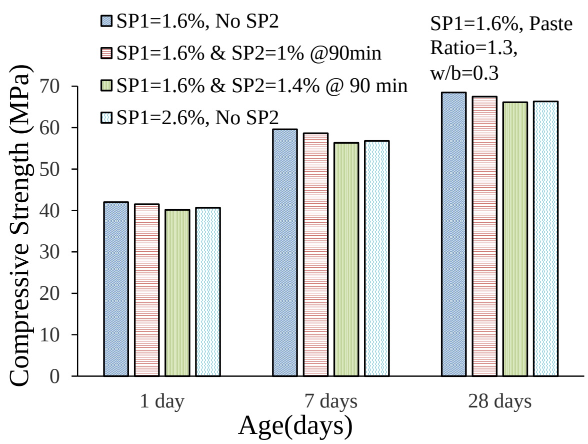

Figure 7: Compressive strength of one time dosing and re-dosing mixtures

Figures 8 show compressive strength of concrete without and with different second dosage of SP. Specimens were prepared from concrete sample, which was re-dosed with different dosages of SP at 60, 90 and 120 minutes. The compressive strength was measured at 1, 7 and 28 days of age. From test data, it is observed that effect of second dosage of SP (up to 1.4% is tested) does not have adverse impact on compressive strength.

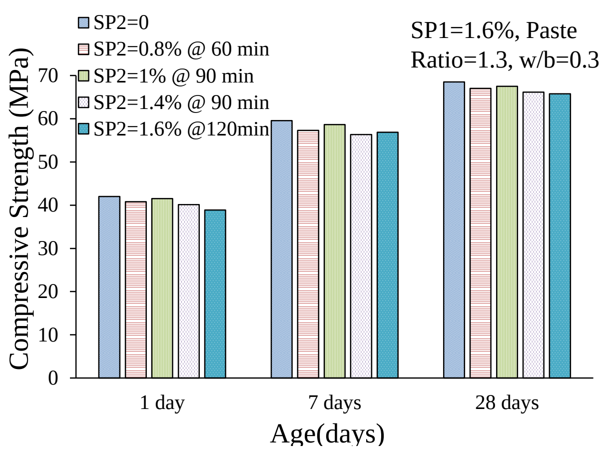

Figure 8: Compressive strength of one time dosing and re-dosing mixtures

5. Conclusion

Comparison is made between concrete with high initial SP (initial slump) and splitting of SP in two dosages at different time with planning (planned re-dosing). It is found that separation of total SP into two can maintain the slump longer period as compared to the case of high initial slump. It is also found that there is not significant effect on compressive strength and setting time by re-dosing of SP (by splitting of initial dosage).

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