Estimation Model for Concrete Slump Recovery by Using Superplasticizer

Chaiyakrit Raoupatham, Ram Hari Dhakal, Chalermchai Wanichlamlert

Abstract—This paper aimed to introduce the solution of concrete slump recovery using chemical admixture type-F (superplasticizer, naphthalene base) to the practice in order to solve unusable concrete problem due to concrete loss its slump, especially for those tropical countries that have faster slump loss rate. In the other hand, randomly adding superplasticizer into concrete can cause concrete to segregate. Therefore, this paper also develops the estimation model used to calculate amount of second dose of superplasticizer need for concrete slump recovery. Fresh properties of ordinary Portland cement concrete with volumetric ratio of paste to void between aggregate (paste content) of 1.1-1.3 with water-cement ratio zone of 0.30 to 0.67 and initial superplasticizer (naphthalene base) of 0.25%-1.6% were tested for initial slump and slump loss for every 30 minutes for one and half hour by slump cone test. Those concretes with slump loss range from 10% to 90% were re-dosed and successfully recovered back to its initial slump. Slump after re-dosed was tested by slump cone test. From the result, it has been concluded that, slump loss was slower for those mix with high initial dose of superplasticizer due to addition of superplasticizer will disturb cement hydration. The required second dose of superplasticizer was affected by two major parameters, which were water-cement ratio and paste content, where lower water-cement ratio and paste content cause an increase in require second dose of superplasticizer. The amount of second dose of superplasticizer is higher as the solid content within the system is increase, solid can be either from cement particles or aggregate. The data was analyzed to form an equation use to estimate the amount of second dosage requirement of superplasticizer to recovery slump to its original.

Keywords—Estimation model, second superplasticizer dosage, slump loss, slump recovery.

I. INTRODUCTION

FRESH stage of concrete will mostly concern on workability of 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 [1]. In practice, concrete is design based on slump-class and strength-class, where slump of concrete is design to compatible with construction methods but slump can be loss through elapse of time [2]. In ready-mix concrete industry, ready-mix concrete suppliers have faced slump loss issue. Slump loss is a phenomenon which cement is hydrating and use up free water cause concrete to loss its fluidity. Hydration reaction is continuously reaction of cement and water, where reaction rate is affected by ambient temperature excluded from chemical composition of cements and mix proportion. In case of Thailand, ambient temperature was typically high due to tropical located. Therefore, this will triggered faster rate of reaction. Moreover, there are unflavored traffic conditions, which cause a delay on concrete delivering. When delayed concrete was delivered to construction site, the slump of concrete is unusable. In practice, there are two solutions for unusable concrete, which are reject or adding water. In case of adding water, concrete will lose its quality such as strength, water tightness, etc. In case of reject, suppliers will loss and waste of materials. Therefore, superplasticizer (naphthalene based type F) was introduced to concrete as second dose to recover slump of concrete to solve unusable concrete slump. By adding superplasticizer into system will disperse the colloid particle (cement) [3]. At this moment, there are only those experienced engineer could do superplasticizer addition, even though the expertise could do the slump recovery using superplasticizer but frequent of success was just a random. Therefore, this estimation model is needed for those with lesser experience and to make a guideline even an expertise can use to ensure that second dose will successfully recover concrete slump.

II. EXPERIMENTAL

A. Materials

Cement: Ordinary Portland cement Type I was used. The physical and chemical compositions of cement are shown in Table I according to ASTM C150.

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TABLE I
CHEMICAL/PHYSICAL PROPERTIES OF CEMENT AND AGGREGATE USED

Chemical/Physical Properties of Powder			
Ingredients	Cement	Ingredients	Cement
CaO (%)	64.28	K_2O (%)	0.48
SiO_2 (%)	20.35	SO_3 (%)	2.92
Al_2O_3 (%)	5.02	Specific Gravity	3.1
Fe_2O_3 (%)	3.18	Blaine Fineness (cm^2/g)	3440
MgO (%)	2.03	Loss of Ignition (%)	1.427
Na_2O (%)	0.20		

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

World Academy of Science, Engineering and Technology
International Journal of Civil and Environmental Engineering
Vol:9, No:12, 2015

Aggregate: The natural river sand passing through sieve no. 4 and Aggregate: The natural river sand passing through sieve no. 4 and naturally found in Thailand was used as the fine aggregate and crushed 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) are shown in the Table I.

Chemical Admixture (Superplasticizer): Naphthalene based Superplasticizer (SP) according to ASTM C494 commercially available and widely used in Thailand was used.

B. Paste Content (γ)

Paste content was parameter used to define minimum paste volume needed to fill up void between aggregate, in order to make concrete dense. Fig. 1 shows the graph obtained from void analysis described on the ASTM C29 (Fig. 1).
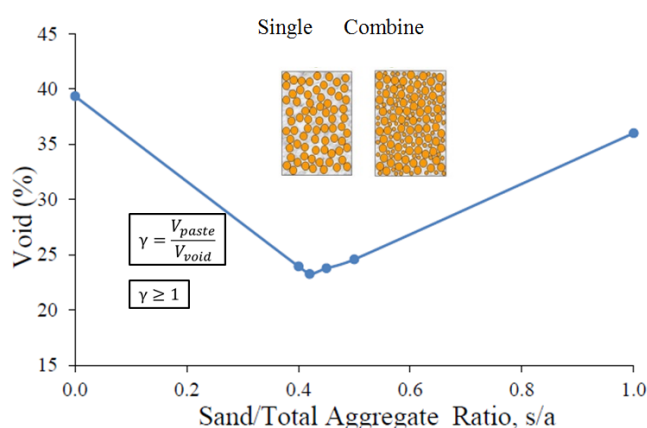

Fig. 1 Minimum void concept

C. Mix Proportion

Mix design of concrete was prepared for water-to-cement ratio (w/c) of 0.3-0.67 respectively. Volumetric of paste to void (γ, Paste content) varying from 1.1 to 1.3. Sand-to-aggregates ratio (S/A) was fixed as 0.42, which give value of void between aggregates equal to 23%. In case of slump-class, concrete was control the slump to be 7 cm. for paste content 1.1 and 10 cm for paste content 1.2 and 1.3 shown in Table II.

TABLE II
MIX PROPORTION

Parameters	Range
Water-binder ratio	0.3-0.67
Paste content (γ)	1.1 : Slump 7 cm 1.2-1.3 : Slump 10 cm
Sand-aggregate ratio	0.42
Void between aggregate	23%

D. Slump Measurement

Mixing procedure was standard mixing procedure. Slump was measured immediately after the mixing procedure was finished and recorded as initial slump. Slump test was described on the ASTM C143-90 (Fig. 2).

E. Re-Dosing of Superplasticizer

Fresh concrete was kept in tray with cover to prevent loss of water by evaporation. Then sample of the concrete was used to measure slump value at 30, 60, and 90 min. The measured slump was recorded as the slump before re-does. Before measuring slump, the sample was mixed for two minutes to make it homogenous. Then weighted amount of superplasticizer 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 re-dose of superplasticizer. The amount of second dose was varied from 0.1 to 1 % by weight of binder.

Fig. 2 Slump test

III. RESULTS AND DISCUSSION

A. Slump Loss

In this research, the slump class was fixed for every water-to-cement ratio but slump class will change respect to change in paste content. Initial slump of concrete is lower for mixes whose have lower paste content, while maintain both initial dose of superplasticizer and water-cement ratio. Due to balance between solid and cement paste, as cement paste decrease will increase solid phase within concrete, therefore slump is loss faster (Fig. 3). While maintain same slump class, those mix design whose have lower water-to-cement ratio needed higher initial dose of superplasticizer. In stipulated elapsed time, the slump loss was slower for those mixes that having higher initial dose of superplasticizer (Fig. 4) because the adsorbed superplasticizer molecules will disturb the cement hydration by coating around calcium particles, which cause slower diffusion of ions. In this case, initial slump, ambient temperature, type of cement and type of superplasticizer were same and the only different were water-to-cement ratio, paste content and initial dose of superplasticizer. The mechanisms responsible for the slump loss were chemical and physical process [1]. Loss of consistency in cement paste during the dormant stage is mainly attributable to the physical coagulation of cement particles rather than the chemical effect [4].

B. Second Dose of Superplasticizer

To stimulate the slump loss concrete situation, the concrete was kept inside the tray for periods (Figs. 3 and 4). In this

World Academy of Science, Engineering and Technology
International Journal of Civil and Environmental Engineering
Vol:9, No:12, 2015

experiment, the selected re-dosing times were 30, 60 and 90 min after mixed. Then slump loss concrete was added with second dose of superplasticizer. The additional superplasticizer will generate force (electrostatic repulsive, naphthalene based) within the system and push cement particles away, which reduce friction force. Therefore, slump is regained back to its original (Fig. 5) [5].
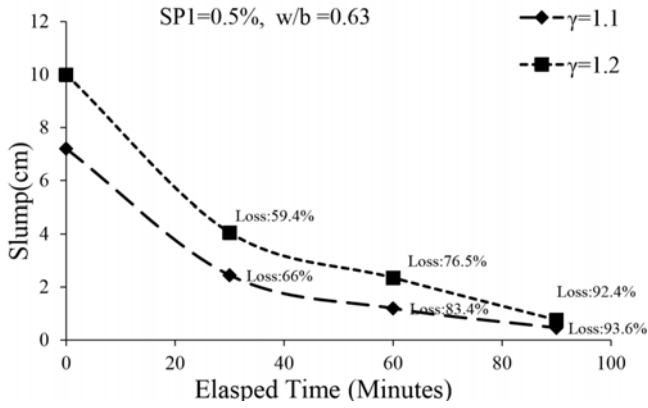
Fig. 3 Slump loss of concrete with same w/c and initial dose of superplasticizer
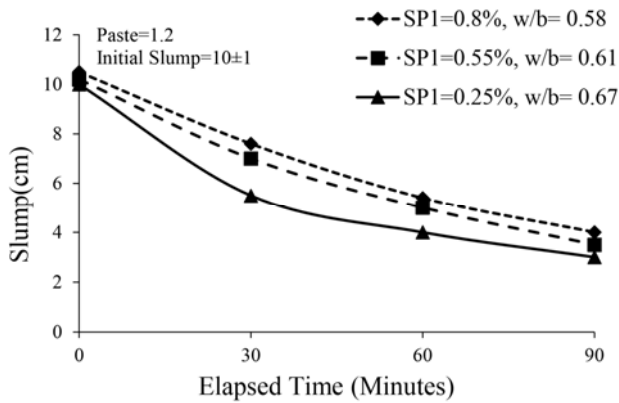
Fig. 4 Slump loss of concrete with same paste content and initial slump with different w/c
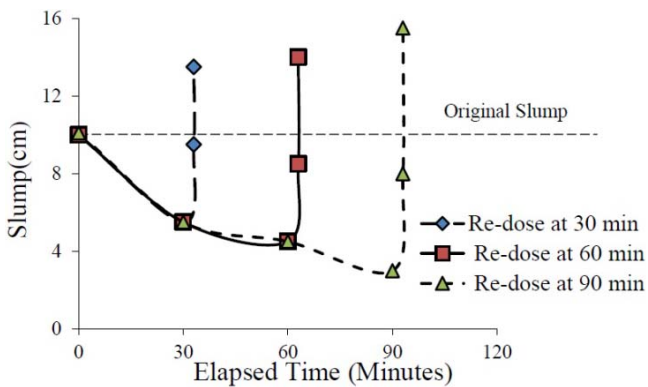
Fig. 5 Concept of Re-Dose

C. Factors Affect Required Second Dose of Superplasticizer

The effect of paste content and initial amount of superplasticizer was observed. The result shows that lower paste content need more second dose to regain original slump and vice versa (Fig. 7). The second dose of superplasticizer are higher for mixes that have low paste content because mixes that have lower paste content will have higher solid (aggregate) within the system, which have high interlock and friction between solid, therefore it need more repulsive compared with high paste content. While paste content of 1.1 and 1.2 have similar slump loss, behavior and required second dose of superplasticizer (Fig. 6).
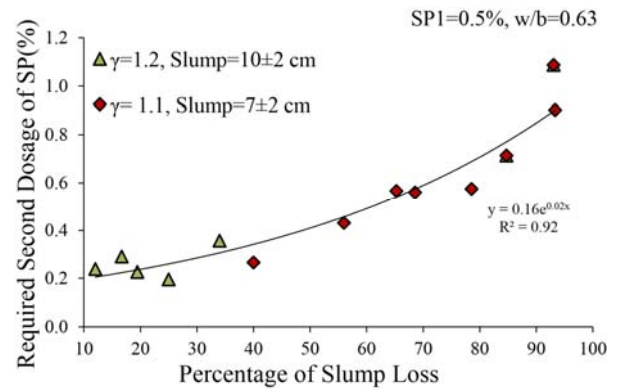

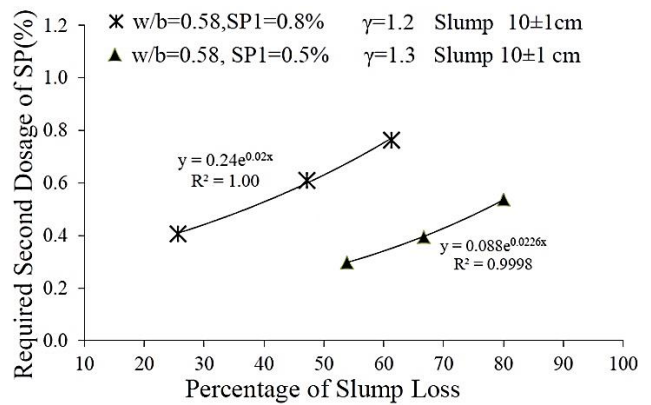Fig. 6 The comparison between paste content of 1.1 and 1.2 on required second dosage

Fig. 7 Effect of combination between paste content and initial superplaticizer of same slump class on required second dosage

The effect of water-to-cement ratio and initial amount of superplasticizer was observed, while re-dosing of superplasticizer. Tendency of graph shows that, lower water-to-cement ratio needed more second dose of superplasticizer to regain original slump and vice versa (Fig. 8). Lower water-cement ratio needed higher second dose of superplasticizer because low water-cement ratio means that there is high cement content in the system, where cement particle size was small. Therefore, the specific surface area within the system will rise. Due to high specific surface area and friction between particles, cause concrete to have higher initial dose of superplasticizer, in order to obtain the same slump compared to high water-cement ratio. Due to high initial superplasticizer content, the concrete reaction was retarded. Therefore, at same slump loss, the cement particle of mixes that have higher initial superplasticizer will be larger because there was longer

World Academy of Science, Engineering and Technology
International Journal of Civil and Environmental Engineering
Vol:9, No:12, 2015

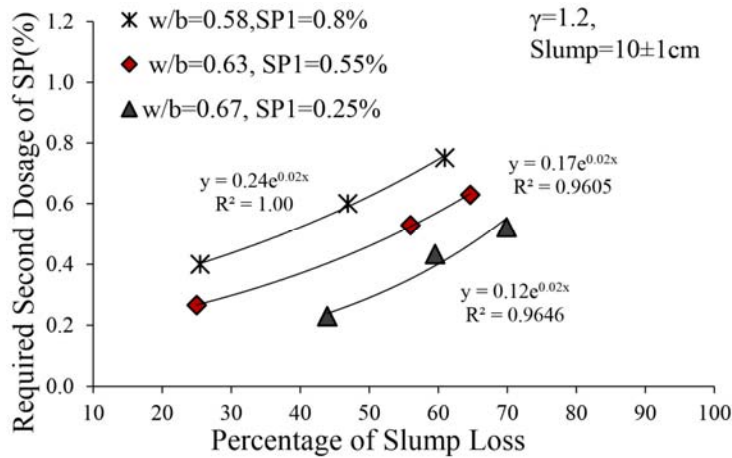reaction time. Therefore, second dose of superplasticizer was increased.

Fig. 8 Effect of combination between water-to-cement and initial superplaticizer of same slump class on required second dosage

D. Equations

From Figs. 6-8, general relation between required second dose of superplasticizer and percentage slump loss is given by

$$y = ae^{bx} \qquad (1)$$

where, y is required second dosage of superplasticizer, x is percentage slump loss, b is constant equal to 0.02 for OPC concrete and a_{OPC} is a function of water-cement ratio and paste content.

Fig. 9 gives relation between 'a_{OPC}', γ and water-to-cement ratio. As the paste content increase, the required second dose of superplasticizer will decrease. While paste content of 1.1 and 1.2 have similar percentage slump loss and required second dosage of superplasticizer; therefore, the value of 'a_{OPC}' is nearly equal for paste content 1.1 and 1.2. In case of low water-cement ratio, the required second dose of superplasticizer is because cement content is more. Therefore, yield shear stress of concrete is higher.
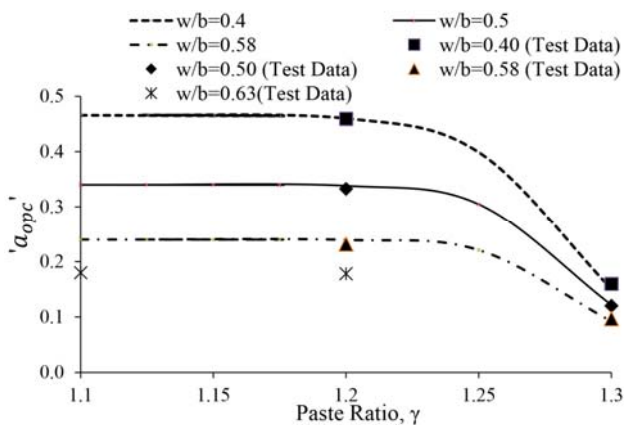

Fig. 9 Effect of γ and water-to-cement on 'a_{OPC}'

From Fig. 5, parameter "a_{OPC}" can be expressed as:

$$a = \left[-1.255 * \left(w/c \right) + 0.968 \right]$$
$$* \, erf \left\{ \left[\gamma - 1.32 \right] * \left[-16.563 * \left(w/c \right) - 8.154 \right] \right\} \qquad (2)$$

IV. VERIFICATION

The accuracy of estimation model was verified by comparing between estimated and tested amount of second dose of superplasticizer used to regain slump.

Figs. 10-12 show the tested and predicted required second dosage of superplasticizer for paste ratio 1.3, 1.2, and 1.1, respectively. Fig. 9 shows that most of the predicted data are slightly lower than tested data for paste ratio of 1.2 and 1.3 and slightly over for paste ratio of 1.1. However, most of predicted and tested required second dosage of superplasticizer was within ±10%.

V. CONCLUSION

From the experiment data, it has been concluded that, slump loss was slower for higher initial superplasticizer dosage because superplasticizer polymer will coated around the cement particles and disturb cement hydration reaction. The required second dose of superplaseticizer was depended on water-to-cement ratio and paste content, where lower water-to-cement ratio and lower paste content need more initial dose of superplaticizer to obtain same slump class as higher water-to-cement ratio and paste content. Even, same percentage loss of slump, the amount of second dose of superplasticizer is more for mixes having higher initial superplasticizer and vice versa for same initial slump because the addition of initial dose of superplasticizer was retarded the reaction. Therefore, at same percentage of slump loss the mix with have higher initial dose of superplasticizer and lower water-cement ratio will eventually have larger cement hydrated particles. The model was verified to be accurate while the tolerance was ±10%.

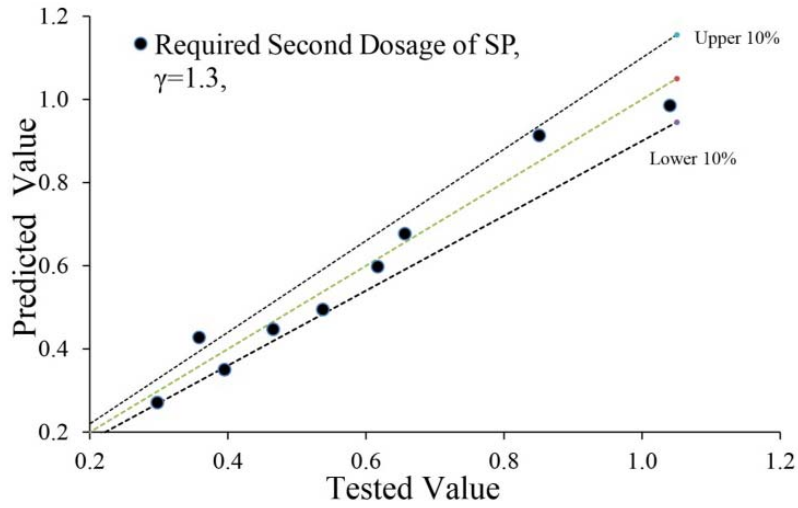World Academy of Science, Engineering and Technology
International Journal of Civil and Environmental Engineering
Vol:9, No:12, 2015

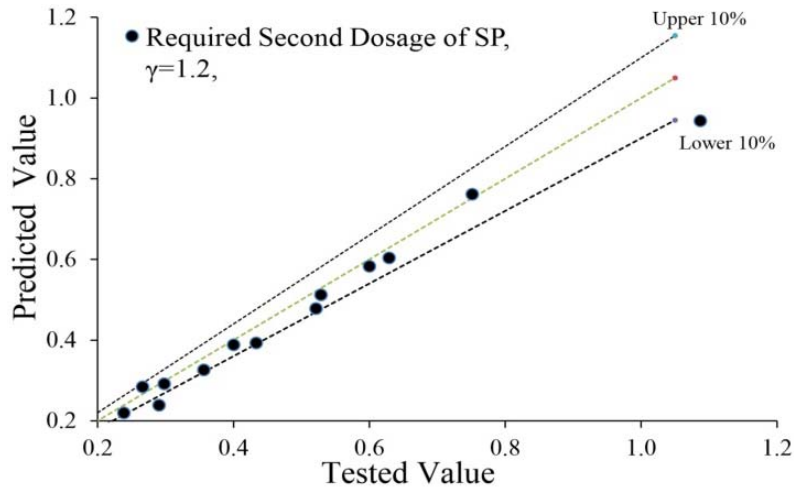Fig. 10 Accuracy of prediction for cement only concrete, γ=1.3

Fig. 11 Accuracy of prediction for cement only concrete, γ=1.2

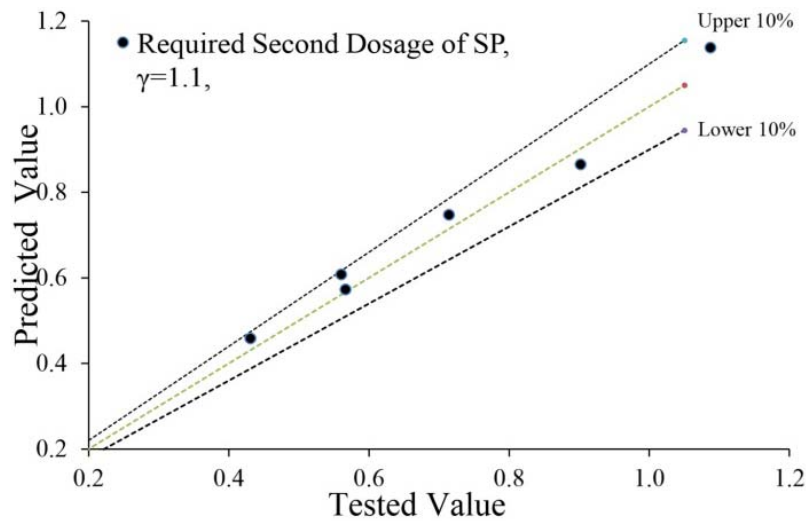Fig. 12 Accuracy of prediction for cement only concrete, γ=1.1

ACKNOWLEDGMENT

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