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Effect of Time and Speed Mixes on Concrete Properties

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***Abstract*— Mixing process of concrete is dispersing the constituent ingredients, e.g. cement, sand, gravel and other components in water to get homogeneous and solid product. Properties of this product depend on natures of materials and mixing conditions. Ready mixed concrete is subjected to continuous mixing during transportation time. This research discusses the effects of time and speed mixes on fresh and hardened properties of concrete with different dosage of chemical admixtures. Results from this study indicate that increasing mixing time or speed leeds to decreasing of workability (slump value), but on the other hand, compressive strength increases. Results show an inverse relation between slump and compressive strength of mixtures with chemical admixtures when water content is constant for all mixes.**

***Index Terms* — mixing time, mixing speed, retarder, superplastizers.**

I. INTRODUCTION

Concrete is the most widely construction material used over the world. The final body of concrete depends on properties of selected raw materials and mixing process. Selection of raw materials is the main role of engineer based on designed characteristics of concrete. Mixing process is dispersing the constituent ingredients i.e. cement, sand and gravel in water to get homogeneous and solid components. This complex process depends on mixing method, mixing time and speed. Ready Mixed Concrete (RMC) is used all over the world for many building construction. Currently, it is preferred because of high control level and high quality. It is subjected to a continuous mixing time during its transport from concrete mixing station to destination construction site. This time varies according to the distance and traffic conditions. RMC should achieve the required properties at the end of destination time in work site. It should be uniform throughout a given batch to keep its fluidity during transport in order to be easily casted while maintaining the required strength. Long mixing time affects workability and compressive strength of RMC. Selecting appropriate mixing speed and dosage of chemical admixtures depends on long distance and required properties at the end of mixing.

II. RESEARCH OBJECTIVES

This research distinguishes the effects of the mixing time and mixing speed on fresh and hardened properties of concrete mixtures with constant cement, sand, gravel and water contents with various dosage of superplastizers or retarder admixtures.

III. LITERATURE REVIEW

David Trejo and Jiaming Chen [11] approved that mixtures of Portland Cement (PC) pastes reach homogeneous state at some minimum energy input. In addition to exceeding this energy is less useful to mixtures. The author hypothesized that when cement hardens during mixing, the degree of homogeneity decreases. This supports requirement of limitation to the time and drum revolution in many specifications.

David Trejo and Jiaming Chen [12] reported that slump value decrease as a function of increased time and speed for all mixtures. High speed accelerates slump loss rate. In addition, mixtures with high dosage of superplastizers have high slump values. Laboratory mixtures exhibited reduced values in hardened characteristics when mixed at 15-rpm speed. The author assessed that this reduction is related to low workability.

Ravina and Soroka [9] indicated that agitation of concrete is associated with destroying the absorbed layer of retarder existed on cement particles. Hence, retardation mechanism fails to occur. The authors also reported that when retarder fails to operate, it acts as water reducing admixtures. There is positive relation between compressive strength and mixing time. A relationship returns to that prolonged mixing improves homogeneity of mixes and reduces formation of less dense.

Dirk lowke [7] studied the effect of mixing energy on properties of self-compacting concrete (SCC). The author prepared a SCC mixture and measured its flow by j-ring test and found that concrete reaches maximum flow at 720 s with a tool velocity = 1.3 m /s although it reaches maximum flow at 120 s with velocity 8.7 m/s. The author indicated that maximum flowability of mixes decreases with increased tool speed. In addition, prolonged mixing time leads to loss of slump value. The author also assessed that increasing velocity of mixing tool causes an increase of mix temperature and that increases the kinetic energy of particles to second power. The water demand of mixtures prepared with high velocities was higher than other mixtures with low velocities, so the result was low flowability. Concrete subjected to long mixing time has reduction in plant capacity and formation of bottlenecks on work site.

Tarek U.M [13] prepared concrete mixtures at speed 20 rpm for 5 minutes to get homogeneity. The mixing speed was lowered to be 6 rpm as a simulation of RMC. The mixer was stopped every 15 minutes intervals to conduct slump tests. The mixing process was not finished until the final slump reached less than or equal to 2 cm and specimens for compressive strength were extracted. The authors reported that concrete with high dosage of superplastizers is still

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workable for long duration and get higher compressive strength, tensile strength and young modulus compared to mixtures without admixtures. It is better to use dosage of chemical admixtures at two stages than using the same dosage at the beginning of mixing process only as it keeps concrete more workable for longer duration.

Salahaldein AlSadey [1] investigated the effects of superplastizers (SP) and retarder (R) admixtures on concrete properties. The author referred that slump values decrease with time for all mixtures. Retarded concrete has longer setting time than concrete with superplastizers. Setting of concrete leads to reduction of slump value. In addition, using SP and retarder makes concrete in liquid state for long times and hence reduces slump loss during transportation. After 5 hours, results showed that retarded concrete retains slump value more than concrete with SP. The author indicated that using both chemical admixtures enables concrete to have better strength. However, at high dosages cohesiveness reduces.

Ravina [10] compared compressive strength of mixtures with and without Water Reducer Admixtures (WRA) when mixed up to 180 minutes. The author reported that the compressive strength increases linearly with time

Kırca et al. [5] studied the relation between 7 and 28-day compressive strengths and mixing time at a constant mixing speed. The authors reported that there is an increase in compressive strength as a function of mixing time. The authors referred the reason that the loss of water due to evaporation leads to a decrease in water to cement ratio (w/c). In addition, grinding of cement particles due to longer mixing times can result in finer cement grains and more hydration reactions. Prolonged delivery time rises concrete temperature, so water content demand is needed to save slump value.

M. Mazloom, A. Ranjbar [8] indicated that strength of concrete is referred to ability to carry loads. Strength is adversely affected by the voids ratio in compacted concrete. In order to achieve maximum possible density, sufficient workability or virtually full compaction is required. Increased voids ratio reduces density and then reduces strength. The author referred to 5 percent of voids can lower strength by 30 percent. The author also indicated to adverse linear relation between workability of self-compacting concrete and compression strength when mixing proportions were the same for all mixes. The author referred this relation to wider spread of air bubbles because of high range of superplastizers used with mixtures.

IV. MATERIALS AND EXPERIMENTAL PROGRAM

All concrete materials (cement, aggregates, chemical admixtures and water) were locally imported to laboratories at normal temperature. Mixtures had cement type I 42.5 N and complied with requirements of the Egyptian standard specifications and has specific weight = 3.15. Cement was protected from humidity.

Dolomite used as coarse aggregates and has a specific weight = 2.70. Sand passing from sieve No 4 (4.75 mm) and retained on sieve No.200 (75µm) used as fine aggregates and has a specific weight =2.65. Both types of aggregates were clean and washed by water to remove dust. Submersing aggregates before using was essential to remain water content in mixtures as designed.

Sika viscocrete-3425 used as a high performance superplastizers concrete admixtures and it met the requirements of ASTM-C- 494 [2] types G and F and BS EN 934 part 2: 2001, it had a specific weight = 1.08. Addicrete BVS used a high range water reducing, superplastizers and set retarding concrete admixture and it met the requirements of ASTM-C- 494 [2] type G, EN 934 and EN 1899, it had a specific weight = 1.2

This study included seven mixtures of concrete. One mixture was conventional concrete as reference one with no admixtures. Three mixtures had Sika viscocrete-3425 as superplastizers admixture at percentage 0.60 %, 1.0 and 2.0 % by weight of cement. Another three mixtures had Addicrete BVS as Superplastizers and retarder admixture at percentage 0.60 %, 1.0 and 2.0 % by weight of cement. It should be noted that all mixtures had the same content of cement (350 kg/m^3) and water (175 kg/m^3) and had the same dolomite to sand ratio.(D/S=2). Table 1 and 2 shows the mixtures proportions and quantity of each component respectively. Absolute volume method was used to determine quantities of materials.

Experimental program of this research shown in figure 1 included two parts of practice. First part aimed to distinguish the influence of low mixing speeds during long times on workability and strength of mixtures as a simulation of RMC industry. Mixtures were mixed with speed 8 rpm for first three minutes and then speed decreased to be 1 rpm for remaining time. Specimens for slump and compression tests were extracted after zero minutes (3 minutes from start point), 45 minutes (48 minutes from start point) and 90 minutes (93 minutes from start point). End of mixing time depended on degree of workability of concrete. Therefore, only mixtures with 2.0% chemical admixtures could continue to time higher than 90 minutes with suitable flow.

Drum batch mixer used in first part as reversing type mixer. It has two directions of rotation, one direction for mixing concrete and another one for discharging it. There are two groups of blades existed inside the drum. One group drops materials upward and downward for mixing and another group pushes the concrete product into the opening for discharging

The second part of practice used high mixing speeds during short times. Each mixture mixed with speed 8 rpm, 15 rpm and 25 rpm and each speed used for mixing times 5, 15 and 30 minutes. Slump test and 28-days compression test established at the end of mixing. In this part, the pan mixer used for mixing. It had a fixed pan where materials could be mixed well with moving blades. The blades were lifted in order to discharge the concrete product. The motor was connected to an electric power invertor to change mixing speed as desired

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Table 1 –Mixtures proportions

Mix No.	Cement content %	W/C	Aggregates		chemical Admixtures	
			Dolomite%	Sand %	SP %	SP + R %
M 1					0	
M 2					0.6	0
M 3					1	0
M 4					2	0
M 5					0	0.6
M 6					0	1
M 7	100	0.5	66.67	33.33	0	2

Table 2 –Quantities of each component by weight

Mix No.	Cement content kg/m^3	water(kg/m^3	Aggregates (kg/m^3)		chemical Admixtures	
			Dolomite	Sand	SP kg/m^3	SP+ R kg/m^3
M 1			1278	639	0	
M 2			1274	637	2.1	0
M 3			1272	636	3.5	0
M 4			1266	633	7	0
M 5			1274	637	0	2.1
M 6			1272	636	0	3.5
M 7	350	175	1266	633	0	7

V. ANALYSIS AND DISCUSSION OF RESULTS

A. First part of practice: low mixing speed

Mixing times reached 90 min for all mixtures with variation of slump values according to the quantity of superplastizers and retarder. Reference mix with no SP reached 90 min with slump = 20 mm i.e. not suitable for casted. Mixing time increased to 130 min for mixture with 2 % superplastizers or 2 % retarder with slump 70 mm and 80 mm respectively

Ravina and Soroka [9] reported that low mixing speeds allows water to be free in voids between constituents long times. The author added that free water decreases friction between cement and aggregates particles. Lobo and Gaynor [6], reported that limits of time were established long ago when mixers had only low mixing speed

Slump of mixtures decreases with time as a result of cement hydration and mixing water reduction. This reduction returned to evaporation and in some cases absorption of water by the aggregates particles. Consequently, the friction between the solid particles (cement and aggregates) increased and the fluidity of the mix thereby minimized, i.e. stiffening occurred .Results showed that slump loss rate was rapid at long periods of mixing compared to short times.

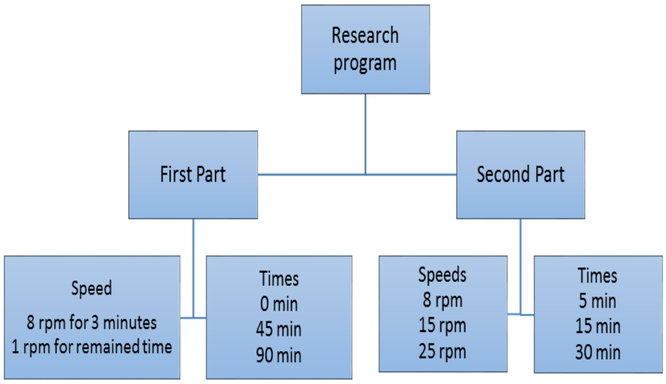

Fig.1-Experimental program of research

Slump of mixtures depended on dosage of chemical admixtures. Mixture with 2 % of SP or R continued workable for long mixing time compared to other poor mixtures. Figure 2(a) and (b) shows effect of mixing time and dosage of SP or SP+R on slump of mixtures.

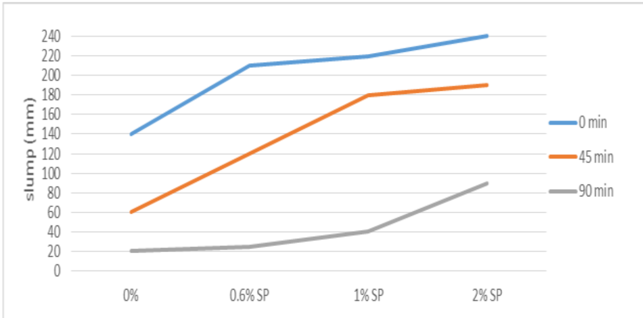

Fig.2 (a) Effect of SP admixtures on slump values of mixtures mixed at speed 1 rpm at different mixing times

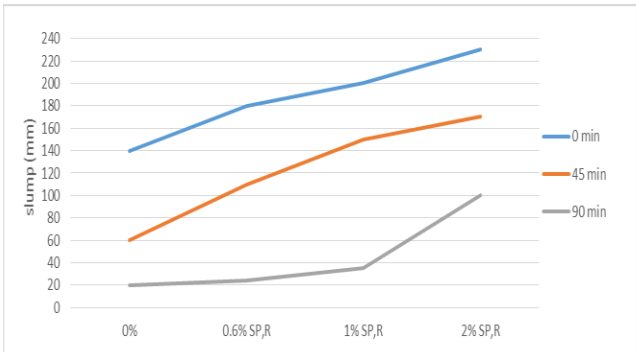

Fig.2 (b) Effect of SP+ R admixtures on slump values of mixtures mixed at speed 1 rpm at different mixing times

Results showed that compressive strength increased with mixing time. This development of strength was a result of grinding effect of cement particles. This leads to get finer cement and hydration reactions establish rapidly. Reduction of water content leads to minimization of water to cement ratio, so more strength obtained

Results assessed that using high dosage of superplastizers performed high values of slump but had an adverse effect on compression strength. Mixture 1 with no SP had maximum strength compared to other concretes but it had the least slump value (not workable). Mixture 3 with high dosage of SP (2%) had the least strength of mixtures but it was suitable to be

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used. The main function of superplastizers is to disperse cement and other components particles from each other and let water be free, thus hydration reactions delay

Tarek U.M [13] reported that compressive strength of concrete increases with the increase of admixture dosage in case of constant final slump value. The author preferred using dosage of admixture recommended by the manufacturer.

The main purpose of using such admixtures is to increase the fluidity (slump) of the mix rather than to reduce the amount of mixing water especially for continuous agitated mixed concrete. Figure 3(a) and (b) indicated the influence of SP or SP+ R admixtures respectively on both slump and compressive strength of mixtures at different times.

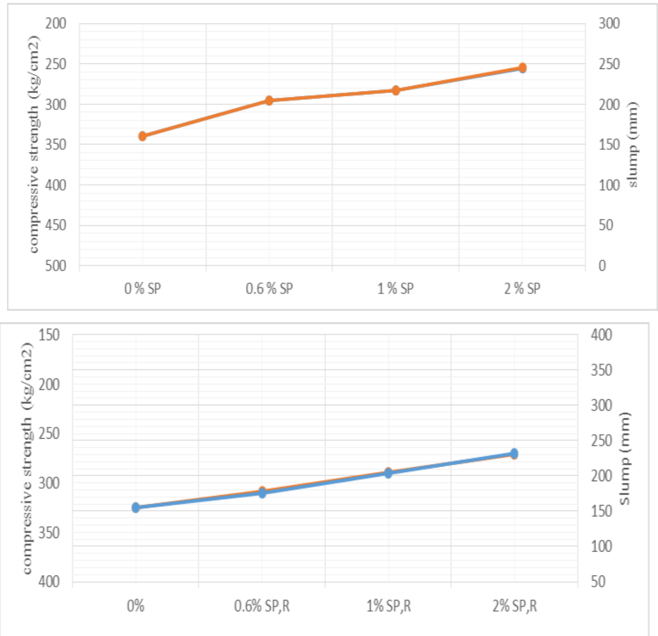

Fig.3 (a) Effect of admixtures on both slump and 28- day strength at speed 1 rpm and time 0 min

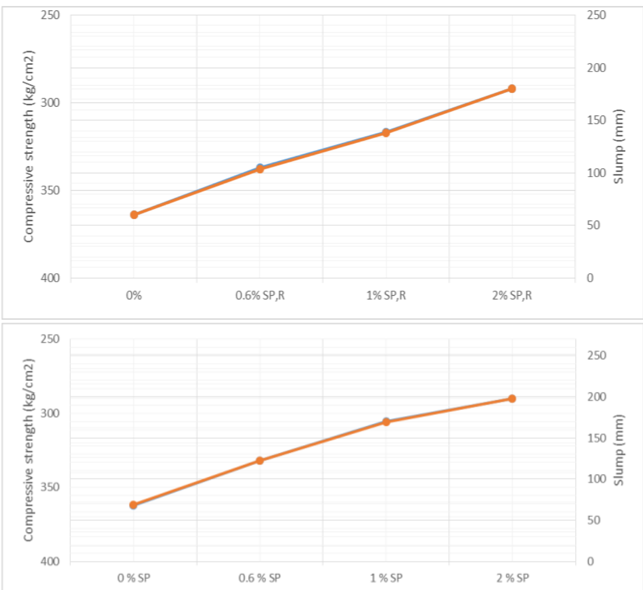

Fig.3 (b) Effect of admixtures on both slump and 28- day strength at speed 1 rpm and time 45 min

B. Second part of practice: High mixing speeds

Slump of mixtures affected by mixing speed, mixing time and dosage of chemical admixtures. Results showed increasing in resistance to flow with increasing of mixing speeds and mixing times. This varied according to dosages of chemical admixtures.

Dongyeop Han [3] reported that concrete mixed at higher mixing speeds have accelerated slump loss. When sample preparation mixed with high mixing speed, cement hydration had accelerated and the overall heat of reactions during this time had increased. This phenomenon happened regardless of whether the mixture contained super plasticizer or not. Therefore, it had considered that the high mixing intensity protocol could hinder the dispersing action of the SP. Figure 4 showed effects of mixing speed on slump values at certain mixing time.

Slump values decreased with exceeding mixing time at high speeds as well as low speeds. High mixing speeds for long time led to high rate of water evaporation and reduction of free water. Consequently, stiffening took place and specimens got less slump. It should be noted that mixtures with retarders achieved small values of slump when subjected to long mixing times as compared to mixtures with superplastizers.

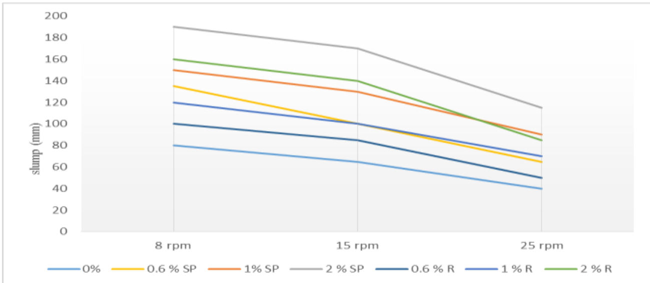

Fig. 4- Effect of mixing speed at time = 15 min on slump results of mixes

Results showed that Strength development rates increased with increasing mixing speed. Strength of mixtures with retarders was higher than mixtures with superplastizers because of poor consolidation, honey combining and less fluidity of mixtures.

Similar to using low speeds, results indicated that growth rates of strength of all mixtures increased with increasing mixing times because of removal of hydration products from the surface of cement particles. This enabled a greater amount of cement to expose to water. Therefor, hydration enhanced and the resulting strength had obtained.

Results referred to an inverse relation between slump and compression strength because of different final water to cement ratio of mixture at the end of mixing. Mixture with high slump had more water content, so it got less strength. Contrarily, mixture with low slump had low water content and got high strength. Concrete with low slump flow and a higher strength was not suitable to be casted. Dongyeop Han [4] indicated that yield stress is inversely related to slump.

Results showed that compressive strength increased linearly with exceeding mixing time as a result of hardening

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and stiffening Figure 5 (a) and (b) showed effect of SP and R on both slump and 28- day strength at speed 8 rpm and time 5 min and 15 min respectively.

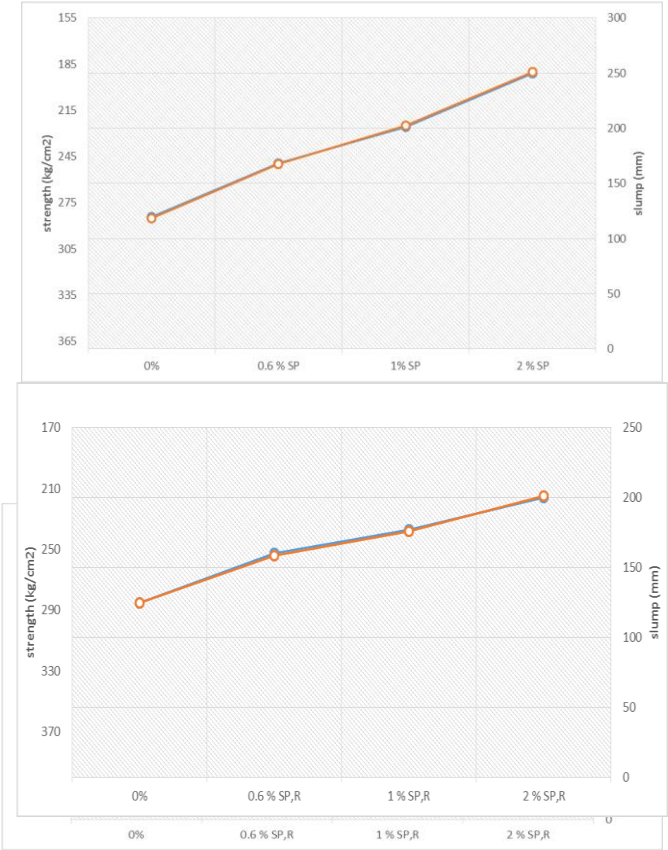

Fig. 5(a) Effect of admixtures on both slump and 28- day strength at speed 8 rpm and time 5 min results of mixes

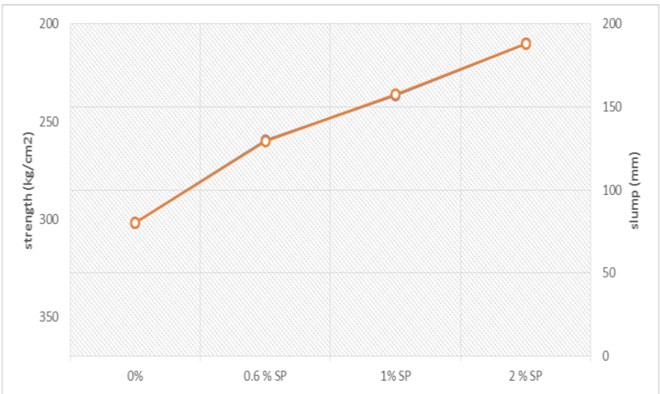

Fig. 5(b) Effect of admixtures on both slump and 28- day strength at speed 8 rpm and time 15 min results of mixes

VI. CONCLUSION

Fresh and hardened properties of concrete are affected properties of used materials and mixing process. Mixing process parameters include mixing tool, mixing speed and mixing time. This study discussed the effects of mixing time, mixing speed and chemical admixtures on fresh and hardened properties of concrete mixes with constant quantities of other solid components.

From this study, the main conclusions are:

1. Low mixing speeds get mixtures still workable until long times, so it is suitable for transferring RMC for long distances.
2. Shortening the mixing time can be achieved by increasing mixing tool speed.
3. High mixing speeds affects adversely slump flow of mixtures especially for long times.
4. Using chemical admixtures improves workability of mixtures according to the used dosage. Using high dosage of SP or R+ SP gives high slump flow of mixes at long times compared to other mixes especially with low speed 1 rpm.
5. Superplastizers make mixes more flow than retarder mixes. On other hand, mixes with retarder loose slump at smaller rates compared to other mixes with Superplastizers.
6. Retardation effect on setting time of cement can't take place when concrete exposed to high mixing speed especially for long times.
7. If there is no target slump of mixtures, chemical admixtures have not a good effect on compressive strength of mixtures. Therefore, conventional concrete with no admixtures has the highest strength. On the other hand, conventional concrete has zero slump and not be useful for casting.
8. In case of using chemical admixtures to decrease w/c ratio, final strength will develop. In addition, slump flow will suitable to use.
9. In RMC industry, selecting dosage of chemical admixture and mixing speed depends on both required mixing time (delivery time) and required flow at work site to give required strength.

VII. RECOMMENDATIONS

The following points are suggested to be studied for the future work:

1. The effect of high dosage of SP or R up to 2 % of cement weight on concrete properties when mixed with low speed for long times up to 180 minutes.
2. The effect of silica fume and fly ash with mixes with various mixing speed.
3. The effect of time and speed mixes on properties of Ultra High Performance Concrete (UHPC).
4. The effect of retempering concrete with superplastizers when mixed with high speeds for long times.

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