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Influence of chemical admixture content particle and grade on viscosity of self-leveling mortar

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Abstract: Concrete has to some properties in both the fresh and hardened state. In most cases the properties of fresh concrete directly affect the quality of the hardened concrete and ultimately its durability. One of these properties is its viscosity in fresh state. In this study, effect of natural sand gradation on viscosity of self-consolidating mortar (SCM) has been investigated. In the study mixes were produced in four different water/powder ratios and in ratio of 1, 1.5, 2 and 2.5 % chemical admixture content. Totally 40 series were designed with two types of sand grade as graded and non-graded. The slump-flow test was made on the all series. The apparent viscosity of SCM's has been determined by using of viscometer in different rotational speed. According to experiment results, it was obtained that resistance to flow of self-consolidating mortar was increased by using of graded aggregates, specifically in low water to cement ratios. Moreover, lower water/cement ratio is required with high chemical admixture content for production of self-consolidating mortar desired.

Keywords: Aggregate grade; Self-consolidating mortar; viscosity, chemical admixture.

1. Introduction

The most important one among the properties of concrete is workability. Fresh concrete is deformed when it is mixing, pumping, or placing by effect of self weight or vibration. Protection of desired properties of concrete against these affect is depending on its uniformity as rheological. For a fresh concrete mix is being a self consolidate able concrete, mortar of the concrete should have low yield stress and optimum viscosity [1]. It is known that workability or rheology is effected its component such as cement dosage, water to cement ratio and gaps between the aggregates [2]. Generally, the flow behavior of concrete approximates that of a Bingham fluid. Therefore, at least two parameters, yield stress and viscosity, are necessary to characterize the flow [3]. Viscosity is a measure of the resistance of a fluid which is being deformed by shear stress. Tendency of deformation versus shear stress gives the plastic viscosity of a liquid. However, cementitious suspensions such as cement paste mortar and concrete are more appropriate the Bingham model [4]. The most important factor which affects the viscosity is internal friction which occurs between the aggregates. The increase of friction between the aggregates and escape of mortar from between the aggregates resulted with an increase of yield stress and also in viscosity. Superplasticizer admixtures used in SCC provide homogeny distribution of cement particles in concrete by surround them. These cement particles

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that pasted the aggregate surface can occur lubrication between the aggregates [5]. Thus, internal friction between the aggregates should be decreased significantly by using of chemical admixtures [6]. Hence, the yield stress of self consolidating concrete is low.

The production of Self-consolidating concrete (SCC) that must have lower yield stress than normal concrete involves the appropriate selection and proportioning of the constituents to produce a concrete mainly characterized by its flow-ability, passing-ability, and segregation resistance in fresh condition [7]. SCC quality is controlled by the flow behavior of cement paste, which is related to the dispersion of cement particles [8]. Superplasticizers (SP) provide the possibility of better cement particle dispersion, thereby producing a paste with greater fluidity [9]. However, mineral additives or fillers also have as many beneficial effects as superplasticizers, such as improvement of rheological and durability properties of fresh and hardened concrete, respectively [10].

Some researchers have investigated the effects of different parameters on the rheological properties of self-consolidating mortar (SCM) or SCC. Yau [11] made a study on the rheology of cement pastes incorporated with superplasticizer and pulverized fly ash. Empirical tests such as slump flow test, V-funnel test and flow cone test on different mixes of cement pastes at a water-binder ratio of 0.2 were undertaken. Dosage of superplasticizer and the replacement level of cement by pulverized fly ash were varied. The results indicated that at a fixed water-binder ratio, there is an optimum superplasticizer content for maximum performance which was found to increase with the amount of cement replaced by pulverized fly ash. The rheological properties of cementitious materials were investigated using a Brookfield rheometer with a serrated coaxial cylinder. Laskar and Talukdar [12] performed a study on the effects of mineral admixtures, including rice husk, silica fume, and fly ash, on the rheological properties of high performance concrete. They observed that yield stress decreased when the replacement ratio of rice husk and fly ash increased. Leeman and Winnefeld [13] investigated the influence of different viscosity modifying agents (VMA), such as microsilica and nanosilica slurry, high molecular ethylenoxide derivate, natural polysaccharide, and starch derivate, on the rheological properties of SCM. Mortars were also produced with different water/binder ratios (w/b) and VMA dosages. The authors reported that the addition of VMA causes a decrease in the slump flow of mortar and an increase in the yield stress and plastic viscosity at a constant w/p ratio. Yahia and co-workers [6] investigated the rheological properties of SCM containing limestone filler. The limestone filler content was replaced by cement (0% to 50% by powder volume). The mixes were designed in 0.35, 0.4, and 0.45 water/cement ratios. The admixture dosage was also varied from 0.6% to 2.2%, by cement weight. They observed that an increase in SP dosage caused an increase in the relative slump flow area and relative V-box flow-time. However, with a 0.40 w/c ratio and 1.8 % SP content, the mix exhibited segregation. Mirza and co-workers [14] carried out a study on the rheological and mechanical properties of grouts containing high volume FA. They investigated the effects of SP on the flow time of low-w/p grouts and the stability of high-w/p grouts. The results indicate that the addition of fly ash in cement grouts reduces the flow time and improves the stability of grouts. Bentz and co-workers [15] investigated the particle size distribution on yield stress and viscosity of cement-fly ash pastes. They reported that rheological properties that including the viscosity are strongly dependent on the particle characteristics of the powders employed in preparing a blended cement/fly ash paste with a constant volume fraction of water. Also, it was found that both particle properties such as densities and surface areas are critical parameters influencing rheological behavior.

In the experiment of slump flow of fresh concrete, when the flow of concrete stops, it is accepted that yield stress and shear stress are equal. When high yield stress represents that flow ability of fresh concrete is low; low yield stress indicate that flow ability of concrete is high. The yield stress of fresh concrete can be measured by rheometer. However, the cost of these instrument is hardening to making the experiment on the fresh concrete in situ, and the researchers are focused on relationship between slump flow and yield stress.

2. Experimental program

2.1. Materials used

As binder and powder material, CEM I 42.5 R type Ordinary Portland cement (OPC) was used. The properties of the OPC were presented in Table 1. Mortars were produced with two different type of quartz based natural aggregate as graded in size of 0.25/1 mm and non-graded in maximum size of 1 mm. In the production of self-consolidating concrete/mortar, the materials used that under the 125 µ is called as filler or powder material. So, presence of the powder material was 4.6% by weight in the non-graded sand. The physical properties of aggregate were given in Table 2.

Table 1. Cemical properties of OPC

Component	Content (%)
CaO	63.56
SiO_2	19.3
Al_2O_3	5.57
Fe_2O_3	3.46
MgO	0.86
SO_3	2.96
K_2O	0.8
Na_2O	0.13
LOI	1.15
Specific gravity	3.07
Fineness (Blaine) (cm^2/g)	3212

Table 2. Characteristic properties of the aggregate

Property	**Value**	**Standard**
Specific gravity	2.57	EN 1097-6
Loose density, kg/m^3	1260	EN 1097-3
Organic material (Color change in NaOH)	No (Light yellow)	EN 1744-1
Water absorption, %	3.37	EN 1097-6
Fine material content, %	4.60	TS 3527

Chemical admixture used in the production of mortars is polycarboxylate based super plasticizer that it is new generation and is commercially named as Optima 208. Properties of superplasticizer given by firm were presented in Table 3.

Table 3. Properties of chemical admixture

Using ratio (%)	Density kg/m^3	pH	Solid ratio (%)	Chloride (%)	NaO equivalent
0.3 - 3	1090	6.5	20	< % 0.1	< % 0.1

2.2. Preparation of Mixes

Production of mortars was carried out with 500 kg cement per cubic meter. In the mixes, 40 different series were produced by using the two different aggregate grade types; in five different chemical admixture (SP) contents as in ratio of 0%, 1%, 1.5%, 2%, and 2.5%; and in four different water/cement ratios as 0.35, 0.40, 0.45 and 0.50. All of the aggregates were added the mix by saturated and dry surface. A 1500 ml batch was prepared for all mixtures using a mixer with a rotational velocity of 1000 rpm. Production of mixes was carried out according to TS EN 196-1 [16] by using a mixer which has 5 lt volume capacities. In the mixing of mortars, aggregate and OPC mixed for 1 min, then, two to three of mix water was added the mix. The admixture was added the mix after diluted in remaining water for mix, and the mixing process was continued for 3 min, again. The mini slump flow test was made on a smoothness plate for every mix (Fig. 1). Before every test, the frustum was damped, and the internal friction between mortar and metal surface were ignored. In the slump flow test, the slump value or mortar was measured.

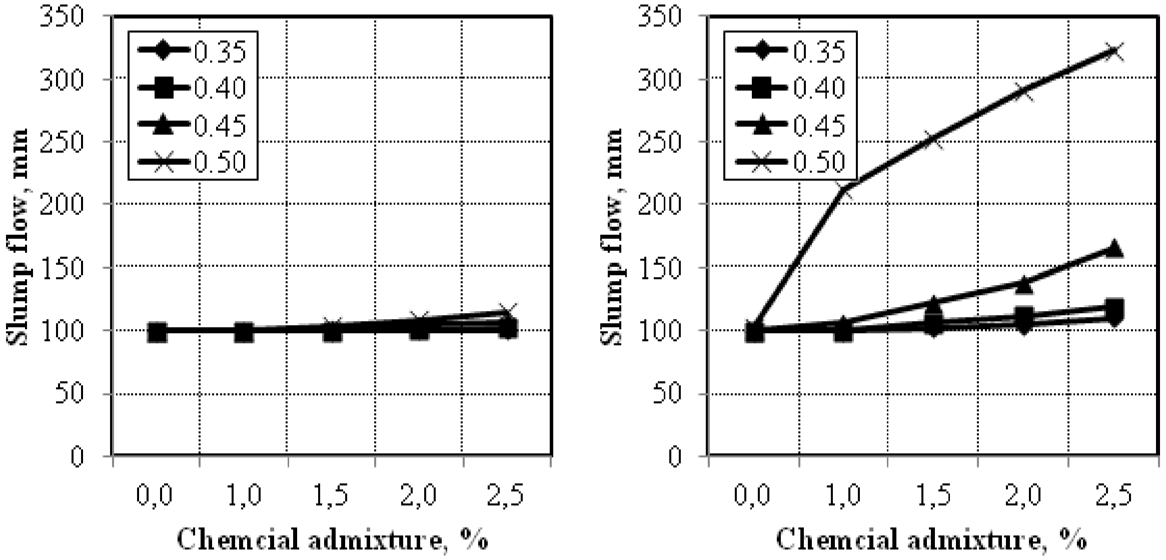
Figure-1. Slump flow test on SCM mortars

Figure-2. Viscometer and its apparatus

A Brookfield DV-II PRO automatic instrument was used to measure the visco-elastic properties of SCM series (Fig. 2). After slump flow test, the cement mortar was introduced into the viscometer which has 600 ml cap. Measurement was taken from 10 to 100 rpm shear rate by increasing 10 rpm at each min. It was carried out by disc shape spindles at room temperature.

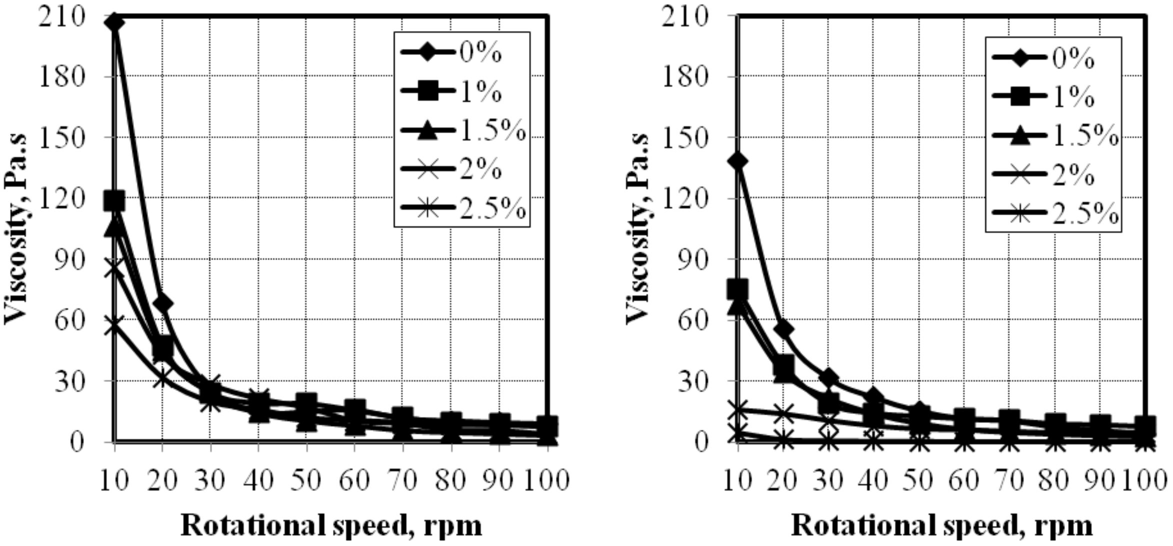
3. Results and Discussions

Production of self-consolidating mortars was designed in two different aggregate grade types, in four different ratios of chemical admixtures and in four different water to cement (w-c) ratios. Slump flow experimental results of SCMs were studied and presented in Fig. 3.a and b, respectively for graded and non-graded aggregate. According to EFNARC committee [17], it was proposed that slump flow values should be found between 240-260 mm for good workability of mortar. When the slump flows of mortars are compared, it can be clearly seen that SCMs that produced with graded sand slumped restrictedly, although they contains chemical admixture in ratio of 2.5%. In some mixes, especially in low water/powder ratio and low admixture content, the slump flow value could not obtained. There is no significant change in mini-slump spread, by changing the percentage of SP from 0%-2.5%.This was due to the high viscosity and yield stress of SCMs because of lack of lubrication between the particles [1].



(a) (b)

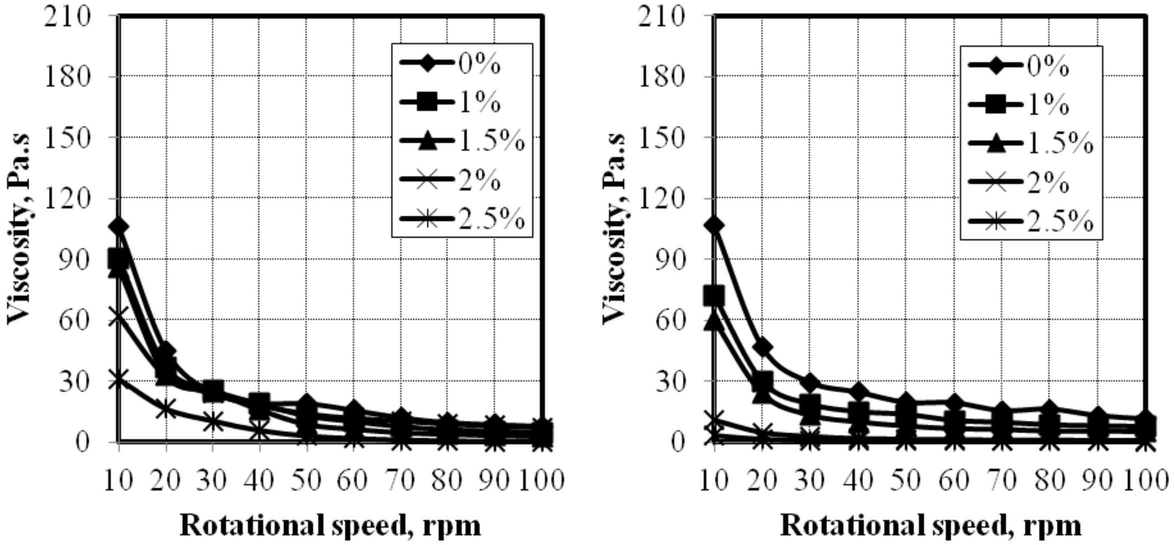
Figure-3. Slump flow of SCM (a: graded; b: non-graded sand)



(a) (b)

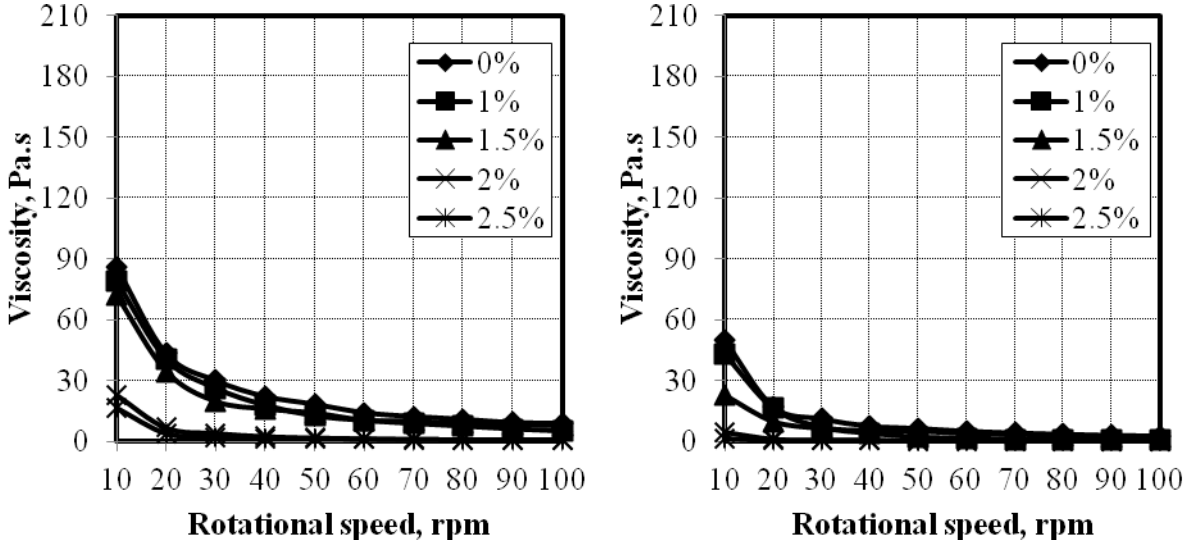
Figure-4. Viscosity measurements of SCM at 0.35 w-c (a: graded; b: non-graded sand)

In constant water/powder ratios, flow-ability of mortars increased by increasing of admixture content. This condition is valid for increasing of water/cement ratio regardless of admixture content. The highest flows were observed in the highest SP content. When the w-c ratio was increased from 0.35 to 0.50, the slump-flow increased in ratio of 13.9% with 2.5% SP content for SCM with graded sand. On the other hand, for the same SP content, the slump-flow of SCM increased in ratio of 194% by increasing the w-c ratios from 0.35 to 0.50 in SCM with non-graded sand. In a fresh cement paste without SP, C_2S and C_3S have a negative zeta-potential while C_3A and C_4AF have a positive zeta-potential [11]. This leads to a faster coagulation of the cement grains. Due to addition of SP, the surface potential of all cement phases becomes negative and they start repelling each other. Thus, repulsive effects occur between the cement particles and increase the workability. Although the SCMs with two different gradation of sand were produced with the same SP content and w-p ratio, slump flow values are fairly different because of importance of fine material in the mortar. So, it decreases the shear stress between the aggregates.



(a) (b)

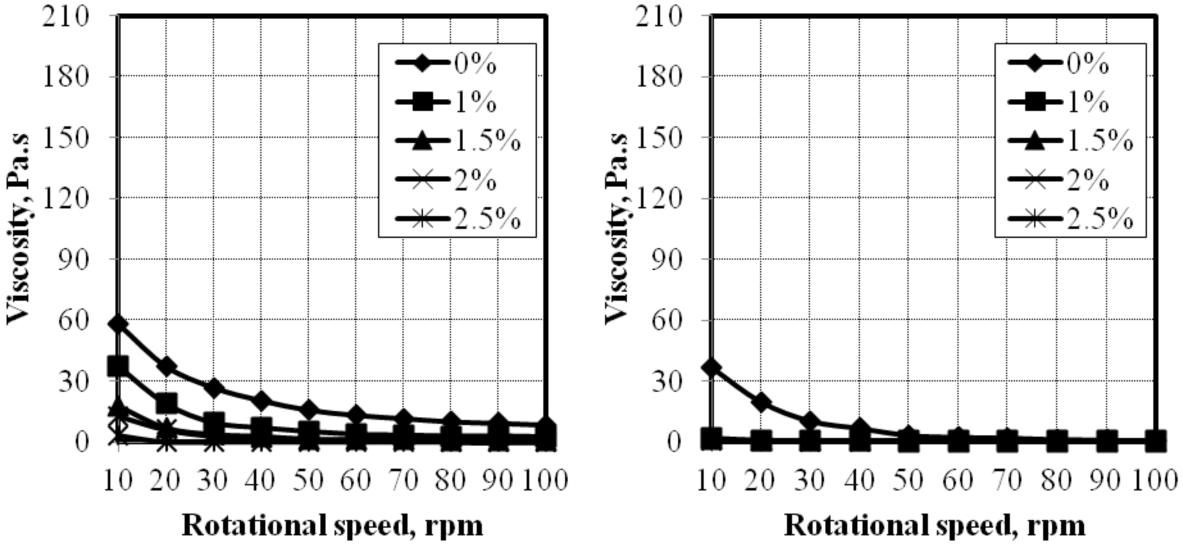
Figure-5. Viscosity measurements of SCM at w-c of 0.40 (a: graded; b: non-graded sand)



(a) (b)

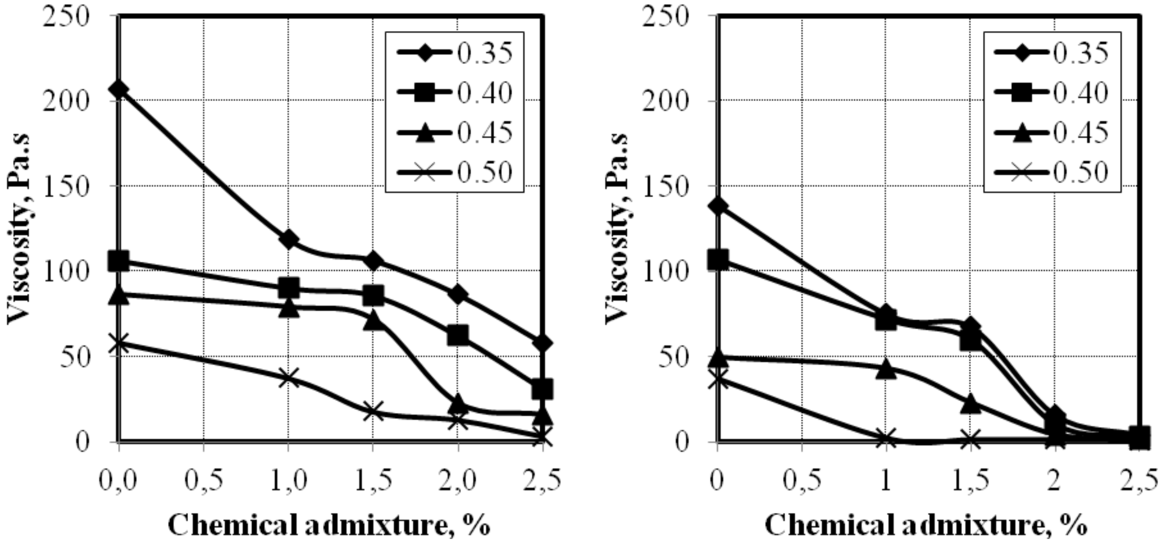
Figure-6. Viscosity measurements of SCM at w-c of 0.45 (a: graded; b: non-graded sand)

Viscosity describes the resistance of a concrete to flow under external stress. Viscosity is caused by internal friction. The speed of flow of concrete is related to its viscosity [18,19]. All the apparent viscosities measured are plotted in Fig. 4, Fig. 5, Fig. 6 and Fig. 7 depending on w-c ratios of 0.35, 0.40, 0.45 and 0.50, respectively. It can be clearly seen that all viscosity values are dramatically decreased by increasing of the rotational speed of spindle, i.e. increasing of the shear rates. Generally, it was observed that viscosity values decreased by increasing of water/cement ratio and admixture content, and they are inversely proportioned with slump-flow. In other words, it was decreased by increasing of slump flow. The chemical admixtures and water content can drastically alter the rheological properties of the pastes, as they typically absorb on the particle surfaces, thus influencing both yield stress and plastic viscosities [15]. The highest viscosity values are obtained in the lowest w-c ratio and admixture content when regardless of rotational speed. For the SCM with graded sand in w-c ratio of 0.35, viscosity values are ranged between 210 and 59 Pa.s, when it was between 140 and 8 Pa.s for SCM with non-graded sand at 10 rpm. Viscosity values of SCM with graded sand are also higher than SCM with non-graded sand in other rpm shear rates and w-c ratios.



(a) (b)

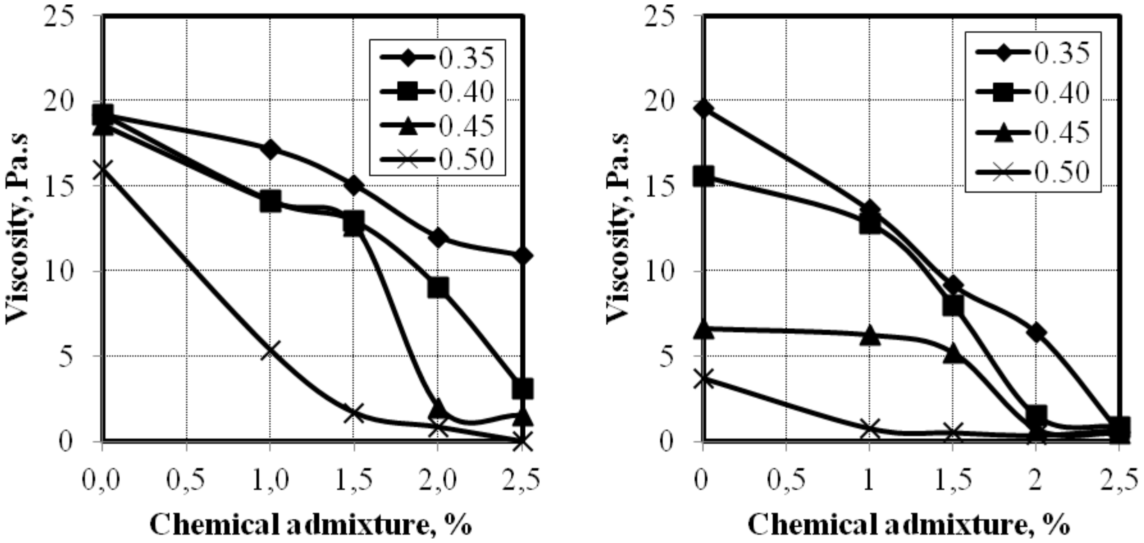
Figure-7. Viscosity measurements of SCM at w-c of 0.50 (a: graded; b: non-graded sand)



(a) (b)

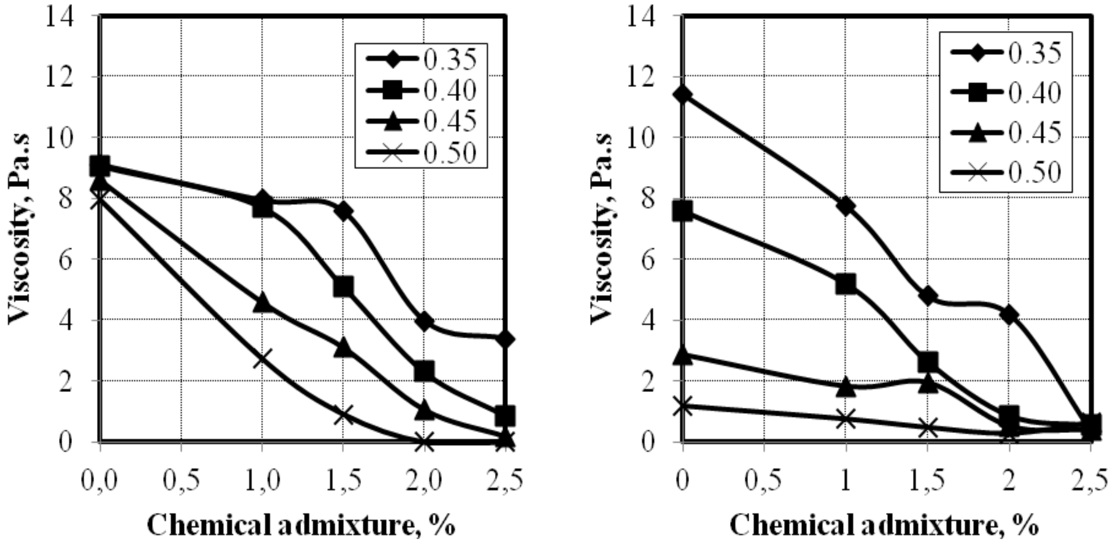
Figure-8. Comparison of viscosity measurements of SCM for 10 rpm (a: graded; b: non-graded sand)

When the water content is increased from 0.35 to 0.50, the viscosity of the SCM with grade sand is reduced to 60 Pa.s for SP content of 0%, and is reduced to about 5 Pa.s for SP content of 2.5%. The water content was decreased the internal friction between aggregate particles and thus, it reduces the viscosity of mixtures. On the other hand, the viscosity values are decreased to 33 Pa.s and 0 Pa.s, respectively, for SCM with non-graded sand mixtures in SP content of from 0% to 2.5%. When SP is added to mixing water, it is promote dispersion of silicate phases and to lower the viscosity of the SCM. In high SP content, mixtures have viscosity as “0”. This is undesirable value for good stability and resistance to segregation and also for bleeding of mixtures. It must be balanced by either using to low the w-c ratio or lower SP content. If the aggregates have powder material, i.e. they are not non-grade, and then effect of SP content would appear at the lower w-c ratios. This phenomenon also would influence the hardened properties of mixtures.



(a) (b)

Figure-9. Comparison of viscosity measurements of SCM for 50 rpm (a: graded; b: non-graded sand)



(a) (b)

Figure-10. Comparison of viscosity measurements of SCM for 100 rpm (a: graded; b: non-graded sand)

In Fig. 8, the viscosity measurement of the SCMs with graded and non-graded sand was compared for 10 rpm rotational speed depending on SP content. It can be clearly seen that the resistance to flow of SCMs are decreased sharply by increasing of the SP content. Again, influence of grading on sand can be seen clearly for each SP value. Similar results are observed at 50 and 100 rpm (Fig.9 and Fig. 10). But, in the lowest w-c ratio, viscosity of SCM with graded becomes more than of

SCM with non-graded sand. This was due to water demand is higher in mixtures with non-graded sand because of fine particles in aggregate. However, after the surface of particles covered with a water film, then they increased the flow-ability and speed of the flow of mixtures [20]. This statement explains the why SCM mixtures with graded sand has higher viscosity values by increasing the w-c ratios at 50 and 100 rpm.

3. Conclusion

In this study, the influence of powder material in the sand was investigated on viscosity and slum flow of SCM. The experimental results showed that SCM can flow easily when non-graded sand used. It prevent to segregation and blocking of mortar. The using of aggregate with fine material is fairly important for good rheological properties of self-consolidating mortar and concrete. In the production of SCMs the Portland cement was used as fine material. So, the selection of a typical powder is largely based on required qualities of concrete in both fresh and hardened state. The role of filler is to improve packing and hence reduce the water demand of the system. They also replace a part of cement in mortars and concretes resulting in economy, less heat of hydration and hence lower shrinkage.

References

[1] Topçu, İ.B., Uygunoğlu, T., 2010, Influence of mineral additive type on slump-flow and yield stress of self-consolidating mortar, Sci Res Essays,. 5 (12), 1492-1500.

[2] Ferraris, C.F., 1999, Measurement of the rheological properties of cement paste: a new approach, Role of admixtures in High Performance Concrete, Rilem International Symposium, March 21-26, Monterry, Mexico, pp. 333-342.

[3] Bouras, R., Kaci, A., Chaouche, M., 2012, Influence of viscosity modifying admixtures on the rheological behavior of cement and mortar pastes, Korea-Australia Rheol J, 24(1), 35-44.

[4] Roussel, N., Stefani, C., Leroy, R., 2005, From mini-cone test to Abrams cone test: measurement of cement-based materials yield stress using slump tests, Cem Concr Res, 35, 817-822.

[5] Schwartzentruber, L.D., Roy, R.L., Cordin, J., 2006, Rheological behaviour of fresh cement pastes formulated from a Self Compacting Concrete (SCC), Cement and Concrete Research 36, 1203-1213.

[6] Yahia, A., Tanimura, M., Shimoyama, Y., 2005, Rheological properties of highly flowable mortar containing limestone filler-effect of powder content and w/c ratio. Cem Concr Res, 35(3), 532– 539.

[7] Topçu İB, Ünal O, Uygunoğlu T., 2007, Investigation of effect of mineral additives on fresh concrete properties in Self-consolidating concrete. 2nd Chemical Admixtures in Constructions Symposium, Ankara/Turkey, 12-13 April, pp.181-193.

[8] Coussot P., Piau J.M., 1995, A large-scale field coaxial cylinder rheometer to study the rheology of natural coarse suspensions. J Rheol, 39(1), 105–124.

[9] Chandra S., Björnström J., 2002, Influence of cement and superplasticizers type and dosage on the fluidity of cement mortars-Part I. Cem Concr Res, 32(10), 1605-1611.

[10] Petit J.Y., Wirquin E., Vanhove Y., Khayat K., 2007, Yield stress and viscosity equations for mortars and self-consolidating concrete. Cem Concr Res, 37 (5), 655–670.

[11] Yau, K.L., 2007, The influence of mineral admixture and superplasticizer on the rheological behavior of cement paste, City University of Hong Kong, Department of Building and Construction, Master of Philosophy Thesis, 109 pages.

[12] Laskar, A.I., Talukdar, S., 2008, Rheological behavior of high performance concrete with mineral admixtures and their blending. Constr Build Mater, 22(12), 2345-2354.

[13] Leemann, A., Winnefeld, F., 2007, The effect of viscosity modifying agents on mortar and concrete. Cem Concr Comp, 29 (5), 341–349.

[14] Mirza, J., Mirza, M.S., Roy, V., Saleh, K., 2002, Basic rheological and mechanical properties of high-volume fly ash grouts. Constr Build Mater, 16(6), 353–363.

[15] Bentz, D.P., Ferraris, C.F., Galler, M.A., 2012, Influence of Particle Size Distributions on Yield Stress and Viscosity of Cement-Fly Ash Pastes, Cem Concr Res, 42 (2), 404-409.

[16] TS EN 196-1, 2009, Methods of testing cement - Part 1: Determination of strength, Turkish Standard Institute, Ankara [in Turkish].

[17] EFNARC, 2002, "Specification and Guidelines for Self-Compacting Concrete", Association House, 99 West Street, Farnham, Surrey GU9 7EN, UK, February, pp. 8-18.

[18] EFNARC, 2006, Guidelines for Viscosity Modifying Admixtures For Concrete, Association House, 99 West Street, Farnham, Surrey GU9 7EN, UK, September, 11 pages.

[19] Schatzmann, M., Fischer, P., Bezzola, G.R., 2003, Rheological behavior of fine and large particle suspensions. J Hydraul Eng-ASCE, 129(10), 796–803.

[20] Brouwers, H.J.H., Radix, H.J., 2005, Self-compacting concrete: the role of the particle size distribution, First International Symposium on Design, Performance and Use of Self-Consolidating Concrete SCC'2005 - China, 26-28 May, Changsha, Hunan, China.