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The Effect of Amount and Type of Mineral Admixtures on the Yield Stress and Plastic Viscosity of Self Consolidating Concretes

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ABSTRACT

The aim of this study was to evaluate the effect of self-consolidating concrete mixture components on yield stress (static and dynamic yield stress) and plastic viscosity. Accordingly, mixtures with different water-cement ratio and the amount of limestone powder (100, 150 and 200 kg/m^3) were made. In addition, cement has been replaced with different percentages of silica fume, slag and metakaolin. Results show that increase in water to cement ratio cause decrease in yield stress and plastic viscosity. On the other hand, increasing in limestone content leads to yield stress reduction. Over time, this yield stress increased while the plastic viscosity of mixtures showed no significant change. By replacing the silica fume, yield stress increased but plastic viscosity unchanged while metakaolin cause increasing in both parameters.

KEYWORDS:

Self-Consolidating Concrete, Yield Stress, Plastic Viscosity, Mineral Admixtures

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1- Introduction

The quality of concrete and concrete structures depends on the rheological properties and fresh concrete properties at the stage of casting. The rheological properties of self-consolidating concrete (SCC) also is effective in the mechanical properties and durability of concrete. Rheology is a science that is associated with the deformation and flow of materials. Fresh SCC can be as suspended particles in cement paste and aggregate with non-Newtonian fluid behavior. Flow behavior of SCC has been shown with the Bingham model as Eq. (1):

$$\tau = \tau_0 + \mu\dot{\gamma} \quad (1)$$

Where τ, τ_0, μ and $\dot{\gamma}$ are yield stress, initial yield stress, plastic viscosity, and shear rate respectively. Generally, changes in the workability tests results of SCC are consistent with the changes of rheological parameters. Many researchers have studied the relationship between the rheological parameters of concrete and workability tests. They have concluded that the correlation between yield stress and slump flow diameter and also correlation between plastic viscosity with the V-funnel test time.

In this study, the effect of limestone powder and mineral admixtures on rheological properties of self-consolidating concrete, especially the yield stress, plastic viscosity using the rheometer and the relationship between the two parameters of fresh concrete and compressive strength tests have been studied. At the end of paper it is tried to show the rheograph as a guide for determining the appropriate range of yield stress and plastic viscosity of mixtures in Iran.

2- Materials and experimental program

In the present study, a locally available ordinary Portland cement type II is conforming the requirements of ASTM C150 was utilized. The mineral admixtures were limestone powder, silica fume, metakaolin and a type of low activity ground granulated blast-furnace slag (GGBFS).Two types of river sand (coarse and fine sand) with a specific gravity of 2550 kg/m^3 was also used as fine aggregate. Crushed limestone with maximum size of 19 mm and specific gravity of 2600 kg/m^3 was used as coarse aggregate.

The workability tests including slump flow, J -ring, T_{50}, V-funnel and visual stability index (VSI) were performed according to PCI methods. For measuring the rheology parameters including yield stress and plastic viscosity, a coaxial rheometer was used. Compressive strength of SCC mixture was tested according to BS1881 and the results reported after 28 days wet curing in standard condition.

3- Results and discussion

3- 1- Workability of SCC mixtures

The results of workability tests show that increasing of limestone powder amount improved workability. For example, reduce the amount of J-ring ratio and increase L-box test value. This is due to the increasing the amount of fine particle and paste of mixture. The results also show that increasing the surface area of the fine aggregate, cause to goes up the workability of mixtures. The fine mineral admixtures such as silica fume and metakaoline made easier through rebar space and increase plastic viscosity and T_{50} test time.

3- 2- Yield stress and plastic viscosity

The results in this section indicate that with increasing in the amount of limestone powder, the yield stress decreases. This could be due to an increase in the amount of super plasticizer percent. From results it can be seen that the increase in the limestone powder, cause increasing of slump flow test results because of having higher super plasticizer admixture. The results of the study are according with the results presented by Mueller and Wallevik. According to research, increasing of metakaoline, added the plastic viscosity. But as it is evident from results, by changes in the amount of GGBFS replacement, there is no significant effect on the viscosity, while according to Koehler and Fowler, expressed that the plastic viscosity has increased up to 20% replacement and then decrease. Maximum yield stress is belonging to the mixture containing 8% silica fume. This is may be due to the high surface area of silica fume grains.

3- 3- Relation between yield stress and plastic viscosity

The yield stress and plastic viscosity at the times zero, 10 and 20 minutes for mixtures was measured. Zero time after the mixture and pouring in the rheometer is intended. As is clear, with the passage of time, dynamic yield stress increases. However it depends to the amount of the composition of the mixture, such as water, cement, fine aggregates and the value modifying viscosity agent.

The results showed that plastic viscosity changing with time is small and irregular. The ICAR results reported similar results in 2007 by Koehler and Fowler. The report stated the amount of plastic viscosity is essentially constant over time.

The rate of increasing in the slope line of static and dynamic stress is plotted in time for the different mixtures of paper. As can be seen, this rate is slightly higher than for static yield stress. This is verified that the dynamic yield stress has a close association with the mixture and not much change.

3- 4- The relationship between stress and plastic viscosity

Generally, changes in fresh concrete properties results are consistent with the changes of rheological parameters. With the increasing of yield stress, slump flow is reduced and concrete moves slowly. Increase in stress could be numerous reasons such as the amount of cement, limestone, super plasticizer, aggregate and water-cement ratio.

3- 5- Rheograph

Rheograph is a tool for tracking the changes in the relationship between the current stress (y-axis) and plastic viscosity (x-axis) which is a function of the nature of matter and time. In fact, the use of Rheograph determines a systematic way to depict the effect of different parameters on the rheological behavior. It is clear from rheograph that increasing of water-cement ratio, cause reducing the plastic viscosity and the yield stress. Also it shows that the suitable combination of limestone powder amount and water cement ratio cause a mixture with low yield stress and medium plastic viscosity.

4- Conclusions

Main conclusions of the paper can be explained as bellow:

• The study was found that by increasing the amount of limestone, the yield stress was reduced. By increase in limestone up to 150 kg/m^3, plastic viscosity decreased and then increased.

• Among mixtures containing mineral admixtures, mixture with 8% silica fume has maximum yield stress while no significant effect was observed on the plastic viscosity.

• The replacement of metakaoline to 8%, showed slight increase in yield stress. While metakaoline higher than 15% decreased the stress.

• The yield stress (static and dynamic) increases with time. While time has shown little impact on the plastic viscosity.

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