Key Engineering Materials
ISSN: 1662-9795, Vol. 853, pp 193-197
doi:10.4028/www.scientific.net/KEM.853.193

Submitted: 2020-02-17
Accepted: 2020-02-21
Online: 2020-07-15

Effect of Aggregate Max Size on the Rheological Properties of Self Consolidating Concrete

Samer Al Martini[1,a], Ziad Hassan[2,b] and Ahmad Khartabil[3,c]

[1]Corresponding Author, Associate Professor, PhD, P. Eng, College of Engineering, Abu Dhabi University, Abu Dhabi, Chair Technical Committee of FIB UAE Chapter UAE

[2]Master Student at Abu Dhabi University

[3]Master Student at Abu Dhabi University and Technical Manager at TransGulf Ready Mix, Abu Dhabi and Dubai, UAE, Member of Technical Committee of FIB UAE Chapter

[a]samer.almartini@adu.ac.ae, [b]zeiadhassan@hotmail.com, [c]ahmad.khartabil@tgrmcc.com

Keywords: Self Consolidating Concrete, rheology, maximum size aggregate

Abstract. The effects of aggregate size and supplementary cementitious materials (SCMs) on the rheology of self -consolidating concrete (SCC) were studied in this paper. Two main concrete mixtures with different maximum aggregate sizes were prepared and investigated. The first mix had a maximum size aggregate of 5 mm and the second mix was with 20 mm max size aggregates. All mixes incorporated different dosages of Ground granulated blast furnace slag (GGBS). The rheology of all mixes investigated was measured over 2 hour time period. It was found that the size of aggregates and GGBS dosage have influence on the yield stress of studied concrete mixes.

Introduction

The maximum size of coarse aggregates and supplementary cementitious materials (SCMs) have effects on the properties of self-consolidating concrete mixtures. Previous studies concentrated on the effects of coarse aggregate size and SCMs on the rheological, fresh, and hardened properties of self-consolidating concrete incorporating chemical admixtures [1,2,3,4]. Krishna, et. al., [4] reported the effects of aggregate maximum size of coarse aggregates on the fresh properties of self-compacting concrete. In that investigation, eight mixes with various maximum size aggregates (20mm, 16mm, 12.5mm, and 10mm) were studied. The mix was performed as per the guidelines of European Federation of National Associations Representing for Concrete (EFNARC). The study concluded that the fresh properties of SCC improved with reducing the size of coarse aggregates. When the aggregates size decreased, the required amounts of chemical admixtures and viscosity modifying agent increased. It was also noticed that the segregation of the SCC mixtures decreased by increasing the size of aggregates.

Khaleel et al. [5] studied the effects of the properties of coarse aggregates on fresh and hardened properties of Self-Compacting Concrete (SCC). The effect of the size of coarse aggregates was studied, since it has a major influence on the properties of SCC. Uncrushed gravel and crushed gravel, and crushed limestone with a maximum aggregate size of 20 mm were used. Twelve mixes were designed, mixed, tested, and casted based on the method of EFNARC 2002. The study concluded that flow ability and passing ability decreased when the maximum size of coarse aggregates increased.

A research performed by Pandurangan et al. [6] studied the effects of the shape and size of coarse aggregate on the flow and strength properties of self-compacting concrete. The study found that the SCC with high volume fly ash (HVF), 10mm and 16mm coarse aggregates gave higher flow ability and strength than that with low volume fly ash (LVF) and 20mm coarse aggregates.

Manawadu et al., [7] studied the effect of fly ash on the rheology of self-compacting concrete. A binary blends were performed between Fly Ash Class F and Portland cement. The fly ash replacement varied as 0%, 6%, 12%, 18%, 24%, 30%, and 36%. The results showed that adding more fly ash Class F increased the yield shear stress of SCC. Adding more fly ash reduced the heat of hydration, while the increment of yield shear stress made the SCC a high resistance to the initial slump. They concluded that yield shear stress increased with the additional of fly ash content.

The current paper investigates the effect of the maximum size of aggregates on the rheological properties of self consolidating concrete. It was found that the yield stress influenced by the size of aggregates.

Experimental Program

Type I Portland cement was used throughout this study. The cement was replaced with various types of supplementary cementitious materials (SCMs) including GGBS and Class F fly ash (FA). A concrete mixture with a volume of 0.05 m^3 was prepared to fit the pan mixer capacity of 35 L. Mixing for the fresh SCC was continued for 2 hours.

The ICAR concrete rheometer was used to study the rheology of fresh self-consolidating concrete (SCC) as shown in Fig. 1. The ICAR rheometer is a portable instrument that can be handled and installed easily. The ICAR rheometer consists of a container to be filled with fresh SCC, a driver with and an electrical motor, four vanes to apply a torque and measure the rheology of the fresh SCC, a frame to hold the driver and the vanes, and a computer to operate the electric motor and calculate the torque, while testing the fresh SCC.

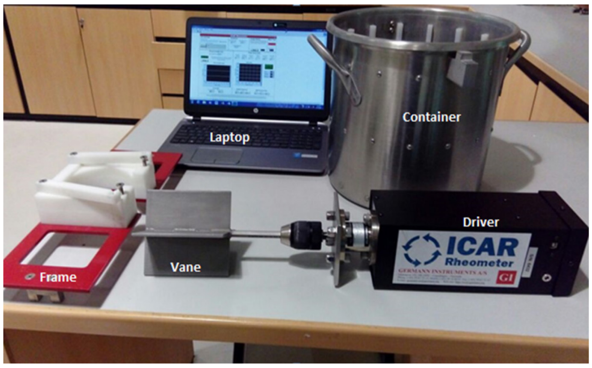


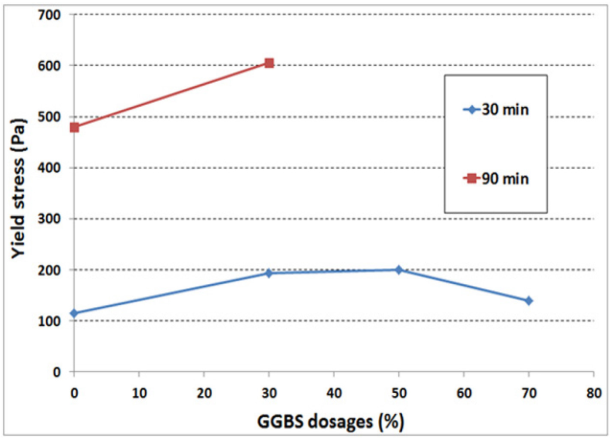
Figure 1. ICAR rheometer

Results and Discussion

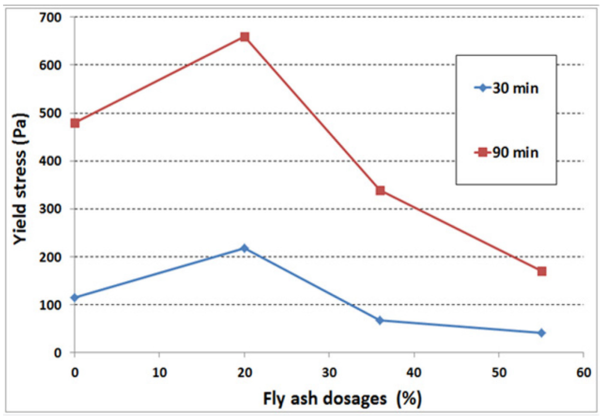
Effect of SCMs in Binary and Ternary Blends on Yield Stress of SCC Mixtures Containing 20 mm Coarse Aggregate Size. Figure 2a shows the effect of various dosages of GGBS (30%, 50%, 70%) in binary blends on yield stress for SCC mixtures at two different mixing time (30 and 90 min). The results show that the longer the mixing time, the higher the yield stress. Results show that incorporating GGBS dosages of 30%, 50%, and 70% increased the yield stress for all SCC mixtures at 30 min, while at 90 min the concrete was stiff for SCC mixtures when incorporating 50% and 70% of GGBS dosages as shown in the slump results. In general, incorporating various GGBS dosages gave higher yield stress compared to the reference mixture (SCC without SCMs). The highest yield stress value was observed at 30% GGBS after long term of continuous mixing (90 min). After 30 min of continuous mixing and at 70% of GGBS dosages the yield stress was lower than that at 30% and 50% of GGBS dosages, however all yield stress values for various dosages of GGBS after 30 min of continuous mixing were higher than reference mixture.

Figure 2b shows the effect of various dosages of fly ash (FA) (20%, 36%, and 55%) in binary blends on yield stress for SCC mixtures at two different mixing time (30 and 90 min). The results show that the longer the mixing time, the higher the yield stress. The results show that yield stress values increased in both short and long term with continuous mixing time (30 and 90 min) when incorporating 20% fly ash compared to the reference mixture (SCC without SCMs). After 30 and 90 min, the yield stress of concrete mixtures incorporating 36% and 50% of fly ash dosages was lower than the reference mixture. The yield stress of concrete mixture incorporating 36% fly ash at short and long term mixing times was higher than that with 55% of fly ash. The highest yield stress was observed at 20% fly ash after 90 min of continuous mixing, however the lowest yield stress value was observed at long term mixing time (90 min) at 55% fly ash.

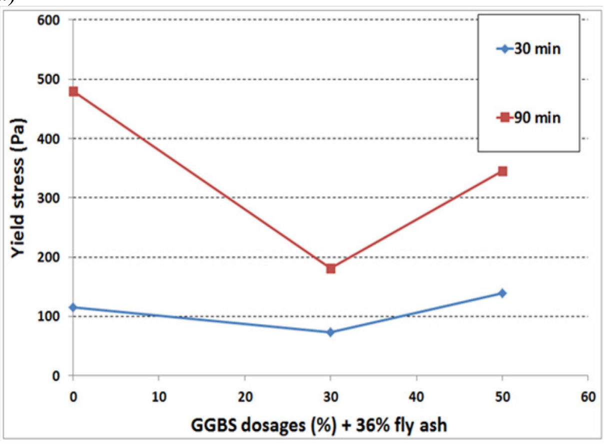
Figure 4 shows the effect of various dosages of GGBS and constant dosage of fly ash (FA) (36% fly ash and 30% GGBS and 36% fly ash and 50% GGBS) in ternary blends on yield stress for SCC mixtures at two different mixing time (30 and 90 min). The results showed that the longer the mixing time, the higher the yield stress. After short time of continuous mixing (30 min) the yield stress was lower than the reference mixture (SCC without SCMs) when incorporating 36% fly ash and 30% GGBS. However, the yield stress when incorporating 36% fly ash and 50% GGBS increased and was higher than that value recorded for the reference mixture. After long term of continuous mixing (90 min) the yield stress when incorporating various dosages of fly ash and GGBS in ternary blends (36% fly ash & 30% GGBS and 36% fly ash & 50% GGBS) was lower than that recorded for the reference mixture. Meanwhile, the yield stress at 36% fly ash & 30% GGBS was lower than that value recorder for SCC mixtures incorporating 36% fly ash & 50% GGBS at 30 and 90 min.



(a)



(b)



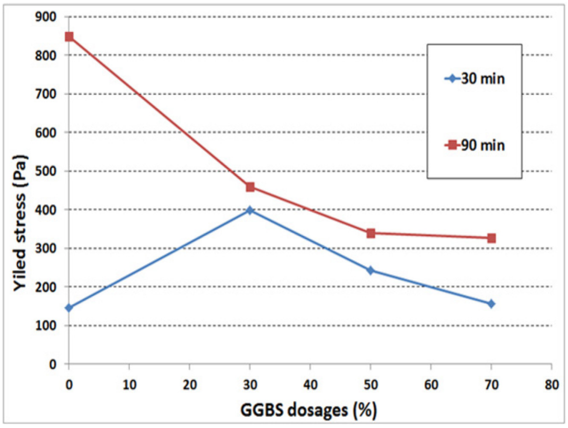
(c)

Figure 2. The effect of SCMS on yield stress of SCC with maximum size of 20 mm: (a) GGBS, (b) fly ash, and (c) ternary blends of GGBS dosages and constant fly ash dosage (36%)

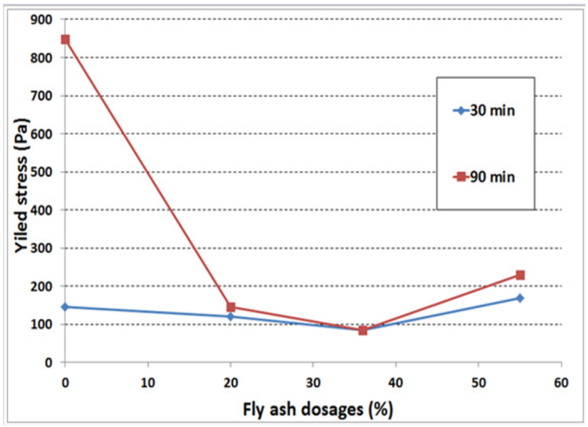
Effect of GGBS dosages in binary blends on the yield stress of SCC mixtures containing 5 mm coarse aggregates. Figure 3a shows the effect of various dosages of GGBS (30%, 50%, 70%) in binary blind on yield stress for SCC mixtures at two different mixing time (30 and 90 min). The results show that the longer the mixing time, the higher the yield stress. Results show that incorporating GGBS dosages of 30%, 50%, and 70% increased the yield stress for all SCC mixtures at 30 min, while at 90 min the concrete was stiff for SCC mixtures when incorporating 30%, 50% and 70% of GGBS dosages as shown in the slump results. The highest yield stress value was observed after 90 minutes of continuous mixing without incorporating GGBS (reference mixture). After 30 and 90 minutes of continuous mixing and at 30% of GGBS dosages the yield stress were recorded to be the highest that SCC mixtures containing 50% and 70% of GGBS dosages. Moreover, it can be observed from Fig. 5, that the loss in yield stress was recorder to be the highest for the reference mixture and the lowest was recorded when incorporating 30% GGBS.

Figure 3b shows the effect of various dosages of fly ash (FA) (20%, 36%, and 55%) in binary blends on yield stress for SCC mixtures at two different mixing time (30 and 90 min). The results show that the longer the mixing time, the higher the yield stress. The results show that yield stress values decreased in both short and long term of continuous mixing (30 and 90 min) when incorporating 20% fly ash compared to the reference mixture (SCC without SCMs). After 30 and 90 min and when incorporating 36% of fly ash dosages the yield stress were lower than the reference mixture and the SCC mixture containing 20% of fly ash dosages. The yield stress at short and long term mixing times at 55% fly ash increased to be higher that the SCC mixtures incorporating 20% and 36% fly ash. The highest yield stress was observed after 90 min of continuous mixing without incorporating any dosage of fly ash, however the lowest yield stress value was observed at long term mixing time (90 min) at 55% fly ash.

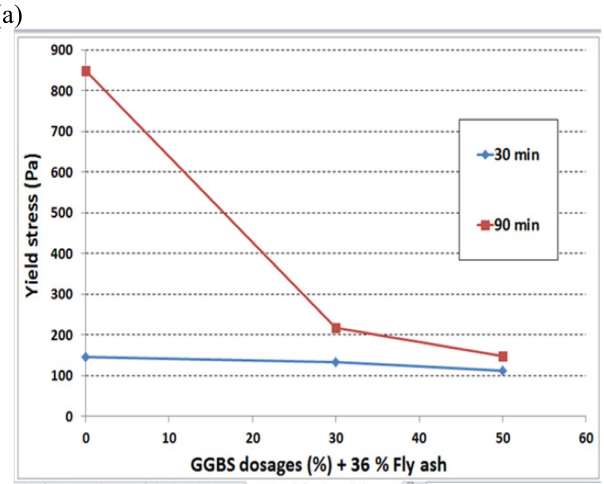
Figure 3c shows the effect of various dosages of GGBS and constant dosage of fly ash (FA) (36% fly ash & 30% GGBS and 36% fly ash & 50% GGBS) in ternary blends on yield stress for SCC mixtures at two different mixing time (30 and 90 min). The results show that the longer the mixing time, the higher the yield stress. After short time of continuous mixing (30 min), the yield stress was lower than the reference mixture (SCC without SCMs) for all studied ternary blend 5 mm mixtures. The same was observed after long term of continuous mixing (90 min), the yield stress when incorporating various dosages of fly ash and GGBS in ternary blends (36% fly ash & 30% GGBS and 36% fly ash & 50% GGBS) was lower than that recorded for the reference mixture. Meanwhile, the yield stress at 36% fly ash & 30% GGBS was lower than that value recorder for SCC mixtures incorporating 36% fly ash & 50% GGBS at 30 and 90 min. It can be observed that the more the GGBS dosages with constant dosage of fly ash (36%), the less the value of yield stress.



(a)



(b)



(c)

Figure 3. The effect of SCMS on yield stress of SCC with maximum size of 5 mm: (a) GGBS, (b) fly ash, and (c) ternary blends of GGBS dosages and constant fly ash dosage (36%)

Conclusions

Based on the above results, the following conclusions can be drawn

- In general, mixes with 20 mm and no SCMs had higher yield stress than mixes with 5 mm max size aggregates.
- In general, the yield stress values of mixes with 5mm max size were lower than those with 20 mm max size after short mixing times (30 min)
- After long mixing time (90 min), mixes with 20 mm had higher yield stress than those with 5 mm max size mixes.

Acknowledgement

The authors would like to acknowledge the financial support of Abu Dhabi University (ADU), Grant received in 2017 from the Centre of Excellence on Sustainable Built Environment at ADU (cost center No. 19300354). The authors would like also to thank Transgulf Readymix Concrete Company in Abu Dhabi and Dubai for donating the necessary raw materials used in this research.

References

[1] Al Martini S , Hassan Z, and Khartabil A. (2019) "Flow Behavior of Self Consolidating Concrete Mixes with Various Maximum Size Aggregates", Key Engineering Materials, Volume 803, pp. 233-238.

[2]Al Martini S., Hassan Z, and Khartabil A., and Al Martini S (2019) "Compressive Strength of Sustainable Concrete Mixes with Different Maximum Size Aggregates" Key Engineering Materials, Volume 803, pp. 228-232..

[3] Biswadeep Bharali. (2015). EXPERIMENTAL STUDY ON SELF COMPACTING CONCRETE (SCC) USING GGBS AND FLY ASH. International Journal Of Core Engineering & Management , 2348-9510.

[4] A.V. Krishna, B. KrishnaRao, and A. Rajagopal. (2010). Effect of different sizes of coarse aggregates on the propertis of NCC and SCC. International Journal of Engineering Science and Technology, 5959-5965.

[5] O. R. Khaleel, S. A. AL- Mishhadani, and H. Abdul Razak. (2011). The Effect of Coarse Aggregate on Fresh and Hardened Properties of Self-Compacting Concrete (SCC). The Twelfth East Asia-Pacific Conference on Structural Engineering and Construction (pp. 805-813). ScienceDirect.

[6] K. Pandurangan, G. Ramakrishna, and S. Kothandaraman. (2012). Effect of Coarse Aggregate Size And Shape on the Strength and Flow Characteristics of Self-compacting Concrete. ICI Journal, 1-7.

[7] A. K. Manawadu, W.M.K.B. Wijesinghe, and H. Abeyruwan. (2015). Rheological Behavior of Cement Paste with Fly Ash in the Formulation of Self-Compacting Concrete (SCC). International Conference on Structural Engineering and Construction Management (pp. 192-199). Kandy: Deparment of Civil Engineering, University of Peradeniya