Evaluating the influence of temperature and fiber type on the mechanical properties of self-compacting lightweight concrete

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ABSTRACT

The advantages of self-compacting lightweight concrete have led to its increasing use in the construction industry. The use of different fibers in this type of concrete causes problems such as reduced flowability and sensitivity to temperature, which challenges the type and method of using fibers. In present study, the effects of glass and basalt fibers (GF and BF) and temperature on the properties of self-compacting lightweight concrete (SCLC) have been investigated. For this aim, the fresh and hardened properties of 12 SCLC mixes have been investigated that contained monotype and hybrid fibers. The self-compacting properties of SCLC were assessed using slump flow, T500, V-funnel, and J-ring. After 28 days of curing, the compressive, splitting tensile and flexural strengths tests were performed to characterize the mechanical properties of SCLC at room temperature of 20 °C and high temperatures of 100 and 300 °C. The test results of fresh concrete showed that all the mixes could be defined as SCLC with good flowability, viscosity, and passing ability. Hardened test results indicated that the addition of the fibers reduced the compressive strength and increased the tensile strength, flexural strength, and fracture energy. Moreover, compared to monotype fibers, the hybrid ones effectively enhanced the mechanical behaviors of SCLC.

KEYWORDS

Self-compacting lightweight concrete, fiber-reinforced concrete, glass fiber, basalt fiber, high temperature

1. Introduction

Self-compacting lightweight concrete (SCLC) is recognized as a high-performance concrete that combines the desirable properties of self-compacting concrete (SCC) and lightweight concrete (LWC) [1]. In the last decade, the special effects of different admixtures on the properties of SCLC have been investigated to improve its workability, strength, and mix-design procedure [2,3]. Many researchers have concentrated on the use of fibers too. They have reported that the mechanical properties of concrete have been upgraded by the addition of fibers to it [4].

However, there is a few research about the utilization of fibers in SCLC. Mazaheripour et al. [5] released that polypropylene fibers did not influence the compressive strength and elastic modulus of SCLC. Their results represented splitting tensile and flexural strengths enhancements due to the presence of polypropylene fibers.

Grabois et al. [6] showed steel fiber reinforcement could improve the SCLC behavior over tensile strength, tensile Young's modulus, and strain at tensile peak stress. Their mixes presented that using lightweight aggregate enabled an internal curing process, which resulted in low autogenously shrinkage results. This process was more accentuated at early ages.

In recent years, scientists have done a lot of research on the effect of temperature on the properties of concrete. They reported that temperature could have a negative effect on concrete strength. Mazloom and Mirzamohammadi [7] reported that the highest effect of high temperature in fiber reinforced cementitious composites was on its flexural strength.

In this article, Basalt (BF) and glass (GF) fibers are used in SCLC. The primary aim of this paper is to study, analyze and compare the effects of these fibers on the workability, mechanical properties, and fracture behavior of SCLC. The secondary goal of this paper is to investigate the properties of the specimens exposed to different high temperatures.

2. Methodology

This experimental research is conducted to study the changes in properties of SCLC with the addition of basalt and glass fibers. Then, the specimens are exposed to 100 °C and 300 °C temperatures to present a comprehensive study about thermal effects on them. Fresh concrete tests have been performed to prove their self-compacting properties. It is worth noting that 324 specimens have been constructed. In fact, finding the compressive, tensile, and flexural strengths as well as fracture energy after expose to the temperatures of 20, 100 and 300 °C were the main goals here.

Fresh properties of the mixes were tested with slump flow, T500, J-ring, V-funnel and fresh state density. The hardened properties included compressive strength, splitting tensile strength and flexural strength. For each compressive and splitting tensile strength in each temperature, three cylinders with the dimensions of 100 mm in diameter and 200 mm in height were casted. Moreover, for testing of flexural strength in each temperature, three prisms dimensioning 10 ×10 × 350 mm were casted for each type of concrete. Demolding was performed after 24 h of casting; then, the cylinders and prisms were transferred to water tank for moist curing till the testing time.

3. Results and discussion

3.1. Fresh properties

The presence of glass and basalt fibers was very effective in the results of fresh concrete. As the amount of basalt and glass fibers increased, the flowability of concrete decreased. Furthermore, by using basalt fibers, the decrease in flowability was more compared to using glass fibers. The use of basalt fiber content above 1% by volume of concrete could eliminate the self-compacting behavior of concrete. The flowability of the hybrid group had a significant reduction too.

3.2. Hardened properties

3.2.1. Compressive strength

The 28-day compressive strength of all the mixes have been reduced by adding the fibers. This reduction varied with different volumetric percentages of the fibers as well as the various temperatures. The highest reduction in compressive strength was related to the specimens containing 1% basalt fibers, which was 6.28%. The reason for this reduction can be the fact that in the high percentages of fibers, empty spaces increased; therefore, the compressive strength reduced.

3.2.2 Splitting tensile strength

In the fiber reinforced specimens with 0.25%, 0.5%, 0.75% and 1% of volumetric basalt fibers at 20 °C, the increases in tensile strengths were 5.84%, 10.81%. , 20.76%, 28.94% respectively. These increases in strengths of glass fibers were 7%, 14.61%, 25.43% and 35.96%, respectively. In the case of hybrid fibers, the highest growth of tensile strength was 38.3%, which was related to the combination of 0.25% of basalt fibers and 0.75% of glass fibers.

3.2.3 Flexural properties

The flexural strength of the specimens that reinforced with glass fibers were more than the ones reinforced with basalt fibers. As shown in Fig. 1, when the temperature increased, the flexural strength of the specimens decreased. The lowest reduction in flexural strength, which was 43.42% in hybrid fibers at 300 ºC, was for the mix containing 0.25% of basalt fibers and 0.75% of glass fibers.

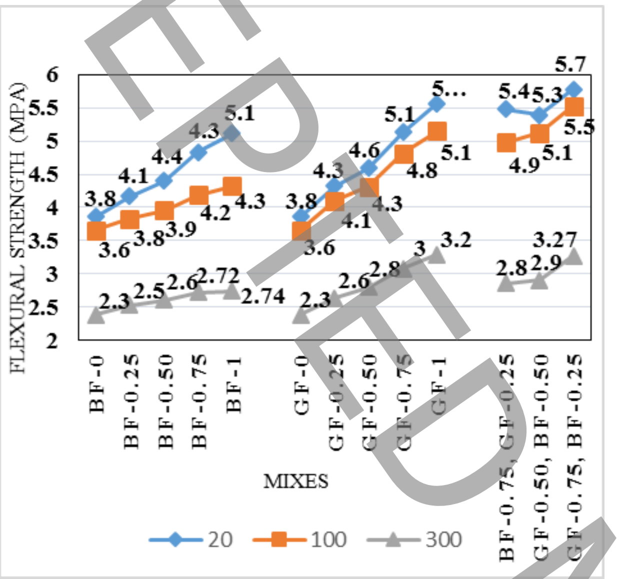

figure 1: Effect of fiber volume fraction on flexural strength

4. Conclusions

Based on the test results obtained from this experimental study, it can be concluded that:

1- The usage of glass and basalt fibers up to 1% volumetric content in self-compacting lightweight concrete covers the criteria of EFNARC, and the use of more than this amount is not recommended.

2- At a temperature of 20 °C, the compressive strength decreased with increasing the fiber content, but the tensile and flexural strengths increased in this situation.

3- Increasing the temperature of the specimens reduced the compressive, tensile, and flexural strengths. The highest reduction was related to the one having 1% of basalt fibers at the temperature of 300 °C.

4- In the monotype usage of fibers in high temperatures, glass fibers had better performance than basalt fibers, and with increasing the temperature, basalt fibers showed less resistance.

5- In the hybrid usage of fibers, the best results were related to the combination of 0.75% GF and 0.25% BF fibers.

5. References

[1] Kaffetzakis, M., and Papanicolaou, C. C. "Lightweight aggregate self-compacting concrete (LWASCC) semi-automated mix design methodology." Construction and Building Materials, 123 (2016): 254-260. Author, A., 1986. *Book Name*. Publisher Name, Address.

[2] Salehi, H., and Mazloom, M. "Opposite effects of ground granulated blast-furnace slag and silica fume on the fracture behavior of self-compacting lightweight concrete." Construction and Building Materials, 222 (2019): 622-632.

[3] Wu, Z., Zhang, Y., Zheng, J., & Ding, Y. "An experimental study on the workability of self-compacting lightweight concrete." Construction and Building Materials, 23(5) (2009): 2087-2092

[4] Kizilkanat, A. B., Kabay, N., Akyüncü, V., Chowdhury, S., and Akça, A. H. "Mechanical properties and fracture behavior of basalt and glass fiber reinforced concrete: An experimental study." Construction and Building Materials, 100 (2015): 218-224.

[5] Mazaheripour, H., Ghanbarpour, S., Mirmoradi, S. H., and Hosseinpour, I. "The effect of polypropylene fibers on the properties of fresh and hardened lightweight self-compacting concrete." Construction and Building Materials, 25.1 (2011): 351-358.

[6] Grabois, T. M., Cordeiro, G. C., and Toledo Filho, R. D. "Fresh and hardened-state properties of self-compacting lightweight concrete reinforced with steel fibers." Construction and Building Materials, 104 (2016): 284-292.

[7] Mazloom, M. and Mirzamohammadi, S. "Fracture of fiber-reinforced cementitious composites after exposure to elevated temperatures". Magazine of Concrete Research, (2019): 1-36.