Evaluation of Concrete Properties for High Strength Steel Applications

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Summary

Utilizing High-Strength Steel Rebars (HSR) as reinforcement in concrete structures has widely increased recently. However, the American Concrete Institute (ACI) in the ACI-318-11 building code requirements for structural concrete specifies the yield strength to be the stress corresponding to a strain of 0.35%, if rebars with yield stresses higher than 420MPa to be used. This limit is to ensure ductile behavior and avoid concrete crushing as a controlling failure mode. Due to the brittle nature and very high strength of most commercially available high-strength steel rebars there is an inherent difficulty in achieving the steel's strength through yielding without the concrete crushing and causing a catastrophic brittle failure. The possible problems that could arise from the use of HSR with its limited ductility are: less frequent yet deeper cracks in the concrete matrix, issues with the bond between steel and concrete, and pre-mature or undetected failure in the tensile planes within the member. In addition, a recent study concluded that for serviceability and cracking control, stresses in steel should be limited to 50% of the yield strength to have similar performance of Grade 60 steel. In this paper, extensive evaluation of concrete mixes with different compressive strengths with and without steel fiber will be presented as solutions to such challenges. Also to emphasis the expected benefits of adding steel fiber to improve post cracking behavior, test results will be discussed and presented.

Keywords: High strength steel; ductile; yield strength; steel fiber; brittle; cracks behavior; failure.

1. Introduction

Coping with the continuously improving construction industry especially in the area of high-rise concrete structures, a particular emphasis has been placed on trying to find alternatives to increase concrete strength in addition to reducing overall cost. HSR, technically known as ASTM-A1035, is one of the latest investigated opportunities in construction that has finally made its way into being used in few projects. It has an obvious advantage over the current conventional steel (420 MPa). At the beginning, HSR was only used for confinement in columns and shear wall boundaries to reduce congestion when conventional steel bars were used. Although its use has recently expanded to increasing the flexural capacity of structural elements, HSR is not fully adopted yet and more efforts are needed to better understand the structural behavior and to benefit from its mechanical properties.

The main limitation in using HSR to increase the flexural capacity of reinforced concrete (RC) structural elements is the possibility of concrete crushing before the steel reaches its yielding point. Several solutions were suggested in previous studies to enhance the concrete properties and to

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investigate opportunities to utilize the additional strength provided by HSR. In this paper, properties of concrete mixtures with and without steel fibers were evaluated. In addition, improvement of high strength concrete properties by the addition of steel fiberes is investigated.

2. Experimental Program

The main objective of the experimental program is to evaluate the structural performance of different types of HSC. Four different concrete mixes were considered in this study; plain concrete (80 MPa) noted as 80NS, plain concrete (50 MPa) noted as 50NS, steel fiber-reinforced concrete (80 MPa) noted as 80SF, and steel fiber-reinforced concrete (50 MPa) noted as 50SF. Compressive strength, splitting tensile, rupture and modulus of elasticity tests were conducted during the evalaution as per the appropriate ASTM standards.

2.1 Test Matrix

Tests, speciemens' sizes, number of samples per test and test dates are summarized in Table 1.

Table 1: Summary of test matrix

Test	Test Specifications	Specimen Size	No. of Specimens per Test	Test Dates Since Casting
Compressive Test	ASTM C 39-12	Cylinder 150* mm x300* mm	2	3, 7, 28
	ASTM C 39-12	Cylinder 100* mm x200* mm		
	BS 1881: Part 116: 1983	Cube 150 mm x 150 mm x 150 mm		3, 7, 14, 21, 28
	BS 1881: Part 116: 1983	Cube 100 mm x 100 mm x 100 mm		
Splitting Tensile Test	ASTM C 496-11	Cylinder 100* mm x200* mm	2	14, 28
Rupture Test	ASTM C 293-10	Prism 500 mm x 100 mm x 100 mm	2	3, 7, 14, 21, 28
Elasticity Test	ASTM C 469-10	Cylinder 150* mm x300* mm	2	14, 28

3. Concluding Remarks

The test results showed that the addition of steel fibers has improved the overall concrete performance by improving the ductile behavior as well as enhancing its mechanical properties. Results at 28-day testing showed considerable improvement in SFRC samples over the RC samples without fibers as per the following ratios; 5-10% in compressive strength, 50-80% in splitting tensile strength and 50-100% in the modulus of rupture. Moreover, the addition of steel fibers has notably enhanced the ductile behavior of the SFRC samples which was reflected on by the 30% reduction in the elastic modulus. Furthermore, the addition of steel fibers has enhanced the overall performance that is required for the use of HSR reinforcement.