Use of Fiber-Reinforced Self-Consolidating Concrete to Enhance Serviceability Performance of Damaged Beams

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Introduction and Background

The efficiency of a given repair depends on both the repair material quality and the ability of the material to fill the section to be repaired, especially in congested areas.

Fiber-reinforced self consolidating concrete (FR-SCC) can be placed easily in comparison with conventional FRC. In addition, (FR-SCC) can improve tensile and flexural strengths while reducing cracking density and crack opening.

In this project, the Rutgers University team, with support from and collaboration with RECAST, is utilizing FR-SCC as repair material for structural elements affected by corrosion.

Objectives

1-To investigate key engineering and structural properties of FR-SCC for infrastructure repair and construction.

2-To evaluate the structural behavior of full-scale repaired beams with simulated bar sections reflection corrosion reduction of the steel and concrete cover lost.

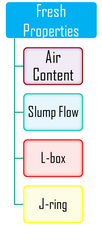
3-To verify ACI 544 code equation for predicting the cracking load with the experimental results.

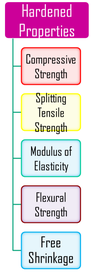
Experimental Program

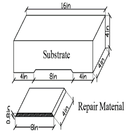
1- Design Mixtures and Test the Mechanical Properties

Mixture	Identification
Class A	Class A
35SL	35% SL
35SL25S	35% SL+0.25%STF
35SL50S	35% SL+0.50%STF
35SL15P	35% SL+0.15%PPF
35SL20P	35% SL+0.20%PPF
10SF	10% SF
10SF25S	10% SF+0.25% STF
10SF50S	10% SF+0.50% STF
10SF10P	10% SF+0.10% PPF
10SF15P	10% SF+0.15% PPF

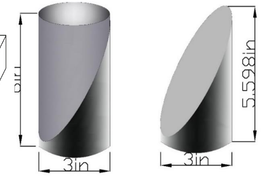
Note: SL=Slag; SF= Silica Fume; STF= Steel Fiber; PPF Polypropylene Fiber







Third-Point Loading Composite Prism Test (Compatibility)



Bond Strength Test Setup and Specimen Dimensions

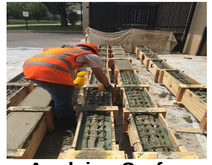
3- Full-Sale Beams for Flexural Strength Test

1

Reinforcment Cages

Installing Strain Gauges

Casting Substrate



Applying Surface Retarder

2

Applying Stream Water

Curing Substrate

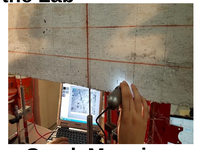
Continue Curing Substrate in the Lab

3

Repairing

Testing Setup

Beam Tests



Crack Mapping

Results

- Failure at the center was observed which refer to a good compatibility. This is mainly due to the low drying shrinkage of developed FR-SCC.

- The recorded failure was in both substrate and repair which means a good bond result.

- A maximum percentage increase of 29 % in the cracking load was achieved for the beam repaired with 10SF50S compared with the Control beams.
- ACI 544 (*2011*) underestimates the cracking load for both control and beams repaired with FR-SCC mixtures.

Beam	Main rebar #	Cracking load, lbs	Increase in Cracking Load, %	Ultimate load, lbs	$Pcr_{exp}/Pcr_{Pred.(ACI\ 544)}$	Mean	Mean
Control 1	5	4700	-	32000	1.40	1.38	1.12
Control 2	5	4600	-	30000	1.37		
35SL25S	4	5500	18.3	24000	1.36	1.05	
35SL15P	4	4900	5.4	22700	0.88		
10SF25S	4	5500	18.3	26200	1.11		
10SF10P	4	5500	18.3	23000	0.94		
35SL50S	3	5700	22.6	16000	1.30		
35SL20P	3	5100	9.7	15492	0.83		
10SF50S	3	6000	29.0	19000	1.13		
10SF15P	3	5700	22.6	15500	0.88		

Conclusions

1. The incorporation of PPF fibers can largely affect SCC workability and placing ability in comparison with STF fibers. Therefore, the maximum fiber percent for the designed mixtures should not exceed 0.5% and 0.2% for STF and PPF, respectively.
2. The use of fiber in FR-SCC has improved all of the strength properties compared with the SCC mixtures.
3. A reduction of 37% in free drying shrinkage at 56 days was obtained when using 0.5% of steel fiber in the 35SL50S mixture compared to the 35SL mixture which is considered as the control mixture without fibers. Mixtures made with 35% SL exhibited lower shrinkage than those with 10% SF. By reducing the shrinkage crack size and distribution, the repaired structural element can be more durable.
4. Most of the FR-SCC mixtures showed good compatibility and bond with the substrate, which is an important factor for a successful repair.
5. The repair with FR-SCC could be an efficient and viable option to repair the damaged beam, protect it from further loss, and to increase its cracking capacity.
6. The ACI 544 code first-crack composite strength provides safe prediction for both control and FR-SCC repaired beams.

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