Repair of Concrete Structures with SCC

F. Kharchi, M. Benhadji, and O. Bouksani

***Abstract*—**The objective of this work is to study the influence of the properties of the substrate on the retrofit (thin repair) of damaged concrete elements, with the SCC. Fluidity, principal characteristic of the SCC, would enable it to cover and adhere to the concrete to be repaired. Two aspects of repair are considered, the bond (Adhesion) and the tensile strength and the cracking. The investigation is experimental; It was conducted over test specimens made up of ordinary concrete prepared and hardened in advance (the material to be repaired) over which a self compacting concrete layer is cast. Three alternatives of SC concrete and one ordinary concrete (comparison) were tested. It appears that the self-compacting concrete constitutes a good material for repairing. It follows perfectly the surfaces' forms to be repaired and allows a perfect bond. Fracture tests made on specimens of self-compacting concrete show a brittle behaviour. However when a small percentage of fibres is added, the resistance to cracking is very much improve.

***Keywords*—**Adhesion; Concrete; Experimental; Repair; Self compacting

I. INTRODUCTION

SELF-COMPACTING concrete SCC is a material known in fresh state for its workability and stability and it can be set up without any vibration. This characteristic is distinguished in order to use the SCC as a material of repair. The investigation is experimental; tests are carried out in order to repair a concrete beam by a coating of SCC put over the surface of the concrete beam to be repaired, without using any reinforcement. This type of repairing is named retrofit. The work was conducted over test specimens made up of ordinary concrete prepared and hardened in advance (substrate = the material to be repaired) over which a self compacting concrete layer is cast.

II. EXPERIMENTAL PROCEDURE

A. Materials and Specimens

Specimens were made in two phases. At first the substrates were manufactured with ordinary concrete OC (concrete to be repaired). Later, the repair material (SCC) was cast on the substrate [1]. Substrates were streamed 5 months before the test. The concrete substrate composition is presented in table 1 and the repair materials in Table II. The compressive strength of the substrate material is 20Mpa. For the repair material, three alternatives of SCC were considered in addition to an ordinary concrete for comparison [2] [3].

Therefore, the following variations are investigated:
SCC
SCC+SF,
SCC with silica fume,
SCC+ Fibre: SCC with synthetic fibres,
OC: ordinary concrete.

TABLE I
SUBSTRATE COMPOSITION

Constituents	OC
Cement (kg/m3)	392
Water (l/m3)	159
Sand 0-5 mm (kg/m3)	752
Gravels (kg/m3)	938

TABLE II
REPAIR CONCRETE COMPOSITIONS

	OC Weight (kg)	SCC weight (kg)	SCC+10%SF weight (kg)	SCC+10%SF + synthetic fibber weight (kg)
Sand 0/3	630	831.6	831.6	831.6
Gravel 3/8	261	410.4	410.4	410.4
Gravel 8/15	851	399.6	399.6	399.6
Cement	350	540	540	540
Water	200	216	216	216
Superplastizer	/	7.56	7.56	7.56
Silica fume	/	40	40	40
Synthetic fibber	/	/	/	60
W/C	0.5	/	/	/
G/S		0.891	0.891	0.891
W/L		0.4	0.4	0.4
Flow (mm)		690	690	650
Time flow (s)		4.5	4.5	7.7

The compressive and tensile strength for the repair materials are shown in figures 1 and 2. The results are not surprising, the SCC, in general, was more resilient because the cement mix exceeds that of the OC. By comparing the various SCC, we note the positive result of the silica fume, and fibres.

F. Kharchi is with the University of Sciences an Technology Houari Boumediene USTHB, Research lab LBE, Algeria (phone: +213 555 416043; fax:-+213 21 247224, e-mail: kharchifcong@ yahoo.fr).
O. Bouksani, is with the University of Médéa, Algeria (e-mail: omarbouksani@ yahoo.fr).
M.Benhadji was with the University of Médéa, Algeria (e-mail: mlbenhadji@ yahoo.fr).

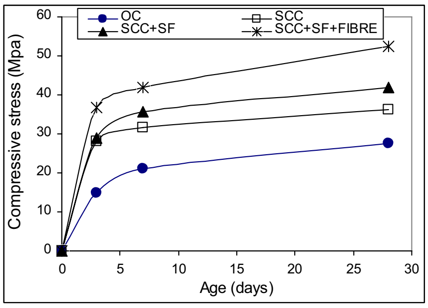


Fig. 1 Compressive stress

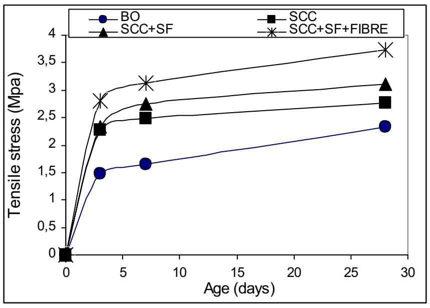


Fig. 2 Tensile stress

B. Studied parameters

– *Optimization of the surface state*

The objective of this study is to investigate the influence of the roughness and the moisture of the surface of the old concrete substrate on the bonding strength with four types of repair materials such as: OC, SCC, SCC with silica fume and SCC with fiber were used.

Given the ease to achieving the bending test, the optimization of the state of the substrate surface (by terms of roughness and moisture) was conducted by four point bending test.In this case, the old concrete substrate was cast with dimension of 5x10x40 cm and cured for 5 months. Then the repair material was cast on the top of the substrate by a layer of 5cm thickness (figure 3).

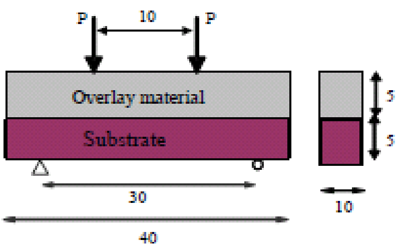


Fig. 3 Specimens for optimization of the surface

Two types of roughness were considered, smooth and rough surface. The rough surface of the old concrete substrate was obtained in fresh state by using a chisel to remove slurry cement from external surface of coarse aggregate.Three states of moisture were also adopted: DS, SDS and SWS.DS: dry surface (substrate was dried for 24 hours at 105°C) SWS: wet and saturated surface, (substrate was saturated with water until the time of the casting of the new material)

SDS: saturated and dry surface, (substrate was saturated with water then, just before the casting, the surface was superficially dried)

– *Adhesion test*

Through the bending test, the repair with SCC on the rough and SDS substrate surface has shown a positive attitude to the repairing (Figure 7). However, it is necessary to justify this behavior by an adhesion test.This test was performed by adapting standards NFP 18858 and EN1542

The test concerns the adhesion between two blocks. The old concrete substrate (15x15x7.5cm) and the SCC repair material which was casted on with layer 5cm. Thus, the total height of the specimen is 12.5 cm.

Fig. 4 Specimens for adhesion test

The test consists to apply a tensile force on a limited area of the bloc [4]. This area is circular form diameter 5 cm. A core of 5cm diameter is drilled into the repair material until the substrate is reached and extending 0.5cm beyond the interface into the substrate layer [5]. A steel disc is glued on the core, with epoxy resin, and the tensile force applied across this disc. The test gives the value of adhesion (in MPa) of the new layer to its support, if the rupture occurs along the contact.

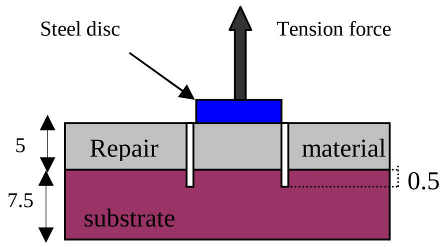


Fig. 5 Adhesion test

Fig. 6 Apparatus test

– *Fracture by cracking test*

In this study the four point bending test was used. The notched layered beam was used, in order to simulate a possible evolution of crack which can result from restrained shrinkage between the substrate and the overlay material. The crack is simulated by artificial notch which is on the substrate and stops at the interface between the repair material and the old concrete.

The crack in bottom of the beam was obtained by a substrate composed by junction end to end of two substrates materials with dimension of 5x10x20cm (Fig. (7).

Than, the overlay material made of each of the OC, SCC and SCCSF was cast on the top of the substrate with 5cm thickness.

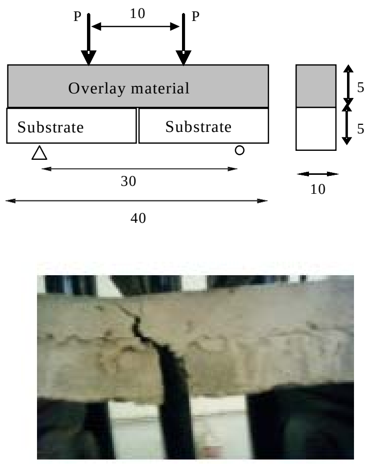


Fig. 7 Bending test on notched specimen

III. Results

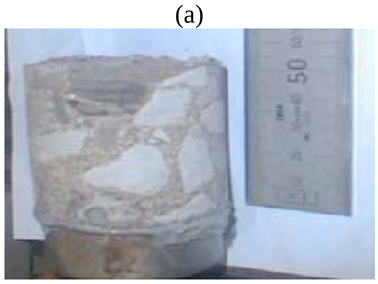
A. Bending test: Optimizing moisture and surface roughness

Bending test was used to optimize the surface state. The results are presented in figure 9 .The use of SCC (single) allows good bond; it can be improved by addition such as silica fume or fibre.

B. *Adhesion* test

The Adhesion in tension or cohesion threshold repairs can be evaluated by two criteria: depth detachment values and cohesion in tension or tensile stress. The figure 8 illustrates the adhesion test.

(a)



(b)

Fig. 8 Depth detachment measure

The cohesion stress [MPa] and the depth of detachment are shown in table III.

Table III
Tensile stress [MPa] and failure depth

Repair material		OC		SCC	
Roughness	Moisture	TS	FD	TS	FS
Rough	SD	1.5	5.1	1.7	5.2
	SDS	2.1	5.4	2.5	6
	SWS	1.9	5.2	2.1	5.4
Smooth	SD	1.2	4.8	1.4	4.9
	SDS	1.8	5.3	2	5.5
	SWS	1.5	5.1	1.8	5.3

Repair material		OC		SCC	
Roughness	Moisture	TS	FS	TS	FS
Rough	SD	1.75	5.2	1.6	5.1
	SDS	2.6	5.7	2.4	5.5
	SWS	2.2	5.4	1.9	5.3
Smooth	SD	1.3	4.7	1.3	4.7
	SDS	2.1	5.4	1.9	5.2
	SWS	1.9	5.2	1.7	5.2

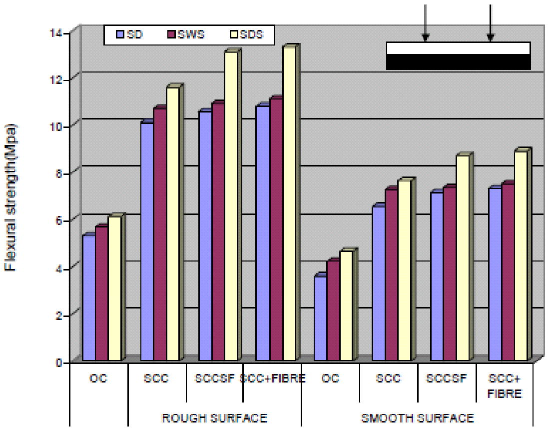


Fig. 9 Surface state influence

Legend:

- *TS: Tensile stress.*
- FD: *failure depth*

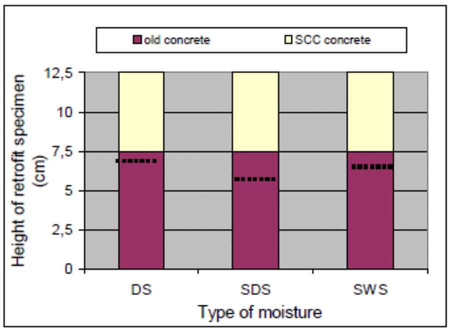


Fig. 10 Depth detachment for rough support with SCC

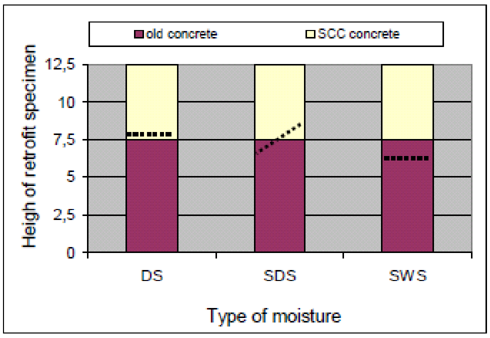


Fig. 11 Depth detachment for smooth support with SCC

Except the case of smooth and completely dry surface (smooth/DS) the separation occurs inside the old concrete, it's particularly clear in case of rough and dry saturated surface (rough/SDS). SCC shows the best behavior, followed by SCC + FS for the case of SDS surfaces. The addition of fibers does not improve the adherence. The detachment between the old and SCC was two types: cohesive (completely fracture in the SCC or in the old concrete) or adhesive (fracture through the interface). In our case the fracture was cohesive.

C. Cracking behaviour

The results of bending tests on notched specimens are presented on the figure 11. It is clear that the best response as cracking is the SCC + FS + fibber. This is certainly due to the presence of fibbers which prevent the propagation of cracks. The SCC alone shows almost fragile behaviour. Therefore, a thin repair with SCC cannot stop cracks propagation. We need in this case a repair with reinforcements (fibbers or steel bar).

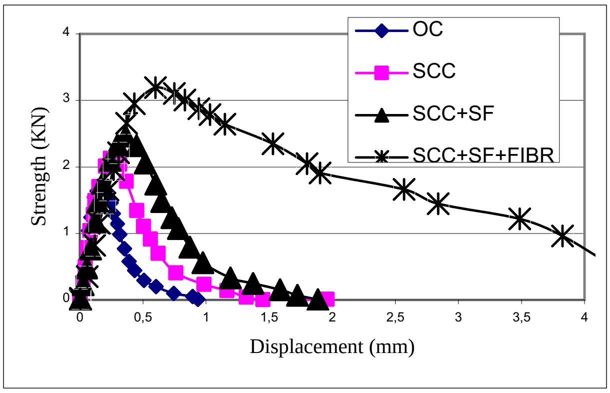


Fig. 12 Notched beam fracture behaviour

IV. Conclusion

Through this study, it appears that the SCC is a good material for repairing. The qualities of stability, uniformity and deformability at the fresh state allow it good adhesion. The surface preparation has a direct impact on the behaviour of double layer elements. Roughness and moisture influence on the adhesion between the two materials. The state of ideal moisture from the surface of the support to receive a new concrete is not to be saturated, but rather to be dry saturated. A surface preparation allows rough enough surface in a comparable manner to a monolithic.

The addition of silica fume improves results of the strength and the shrinkage. The use of synthetic fibres improves strength and increases especially ductility and resistance to crack propagation.

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