

Influence of the Roughness and Moisture of the Substrate Surface on the Bond between Old and New Concrete

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Abstract

This paper describes the experimental results of the interface properties of layered beam which is composed by two types of materials such as old concrete substrate and overlay repair material. The interface substrate surface has two types of roughness (rough and smooth) and three types of moistures (dried, saturated wet and saturated superficially dried). Three types of overlay materials were investigated such as: ordinary concrete OC, self compacting concrete SCC and self compacting concrete with silica fume addition SCCSF.

By preparing carefully the state of the interface substrate surface, the results show that it is possible to ensure a good bond with its overlay material.

Keywords: Interface, overlay, roughness, moisture, bond, repair.

1 Introduction

In the field of maintenance of the existing concrete structures, it is not rare to meet a repair by addition of a new layer containing cementing materials (resin, mortar, mortar modified with latex, ordinary concrete, shotcrete, self compacting concrete SCC, SCC with silica fume, with fibre...etc). This maintenance can be dictated by signs of deterioration or defects on the structures. In addition, maintenance can be carried out by a change of the use or by adapting for new requirements of the structures.

Initially the technique of repair system requires the removing of the deteriorated concrete layer, in order to replace it by a new material. The new composite material obtained (often called the layered beam) behaves, in most cases according to the state of its adherence with the substrate. It is vital to ensure a good interface substrate surface quality in terms of roughness and moisture properties [1].

The fundamental theories that govern the mechanisms of the adherence between the substrate surface and cementing overlay materials are mechanical blocking and the adsorption theories [2-5]:

In the first theory, at the macroscopic level, the roughness of surface creates mechanical blockings [5] between overlay (repair material) and its substrate. At the microscopic level, the surface porosity at the interface substrate, comparable to a micro-roughness, facilitates anchoring by tangle of the hydrates.

In the theory of thermodynamic adsorption: the interatomic or/and the intermolecular forces at the interface (van der waal forces), the hydrogen liaison and the chemical linkage through the interface makes to increase the bond between substrate and new material.

2 Experimental details

The study of the surface quality is quantified by four-point bending test on prismatic layered specimen 10x10x40 cm. A specimen consisted of a layer of overlay material on a substrate simulating the structure to be repaired (Fig. 1).

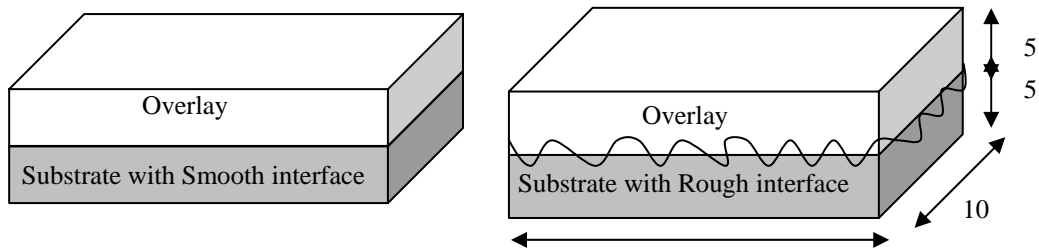


Figure 1 : Type of the interface state (cm)

The substrate material which represents the old concrete was cast with dimensions of 5x10x40 cm. After demoulding and 28-days basic curing in water, the substrates were left during 9 months in room with temperature of 25°C and relative humidity of 75%. The substrate material was made with ordinary concrete having a compressive strength of 26 MPa, whose composition is given in Table 1.

Table 1 Composition of the substrate material

Ordinary Concrete (OC)	Cement CEMII	water	Sand 0-5 mm	Aggregate 5-10mm
Dosage (kg/m ³)	300	150	750	940

The effect of the interface substrate surface quality was carried out through two steps:

- 1- Firstly, two types of roughness have been setup on the first configuration of substrate material (Fig. 2). A part of the substrates have a smooth surface, while the other there surfaces are made rough by using grooving tool on the fresh concrete at 15 to 20 mm depth.



Figure 2 rough substrate surface prepared using grooving tool at fresh

- 2- Secondly and before placing the layer of 5 cm thickness of the overlay material, three different saturation levels have been considered : "dry substrate (SD), saturated with wet surface (SSW) and saturated with dry surface (SSD)".

SD : the substrate was dried for 24 hours at 105°C

SSW : the wet surface of substrate was obtained by their immersion into water for 2 days.

SSD: is the same humidification of the SSW state, but the substrate surface was wiped by sponge.

The overlay material was cast on the upper of the substrate material with 5cm thickness (Fig. 3). Three different overlay materials were used (ordinary concrete OC, self compacting concrete SCC and SCC with silica fume). The composition and the mechanical characteristics of the different overlay materials are given in Table 2.



Figure 3 overlaying concrete

The layered specimens obtained were left in air drying for 28 days the time of the testing.

Table 2 Composition and main properties of the overlay materials

Overlay Material	OC	SCC	SCCSF
Sand 0/3(kg/m ³)	630	770	800
aggregate 3/8(kg/m ³)	300	380	400
aggregate 8/15(kg/m ³)	750	400	450
Cement CEM II(kg/m ³)	400	500	550
Water (kg/m ³)	200	200	240
Superplastifiant(kg/m ³)	/	7	7.7
Silica fume(kg/m ³)	/	/	55
W/L	0.5	0.4	0.4
Slump flow (mm)	/	710	690
Compressive strength MPa)	36	42	45
Tensile strength (MPa)	3.4	4	4.8
Young's modulus (MPa)	24850	35000	38000
Poisson's ratio	0.2		

4 Results and Discussions

4.1.1 Effect of the roughness of interface surface

The following results correspond to a saturated substrate, where its interface surface was dry (SSD) and its roughness has been varied. Overlaying with OC, SCC or SCCSF, have been applied separately on the top of the smooth interface substrate and then on rough interface.

According to Fig. 4, the overlaying with OC, SCC or SCCSF, on the smooth interface, offers respectively 4.65, 7.64, 8.7kN in the flexural load of layered specimen. However, these flexural load values on the rough interface are respectively improved by 31.6, 51.8, 50.6 % compared to those of the smooth interface.

In the case of the ordinary concrete overlay (OC), this result is confirmed by [7, 8] who found that the addition of the ordinary concrete on rough interface gives better resistance. These results are in agreement with those of many authors [6, 9]. The latters found that the rough interface offers very good bond strength.

However, the self compacting concrete (SCC) overlay is very sensitive to gluing with the smooth interface. The clear progress of 50% is due mainly to the significant volume of the SCC paste and its high viscosity, which can create accrue porosity between smooth interface of substrate (or old concrete) and SCC overlay.

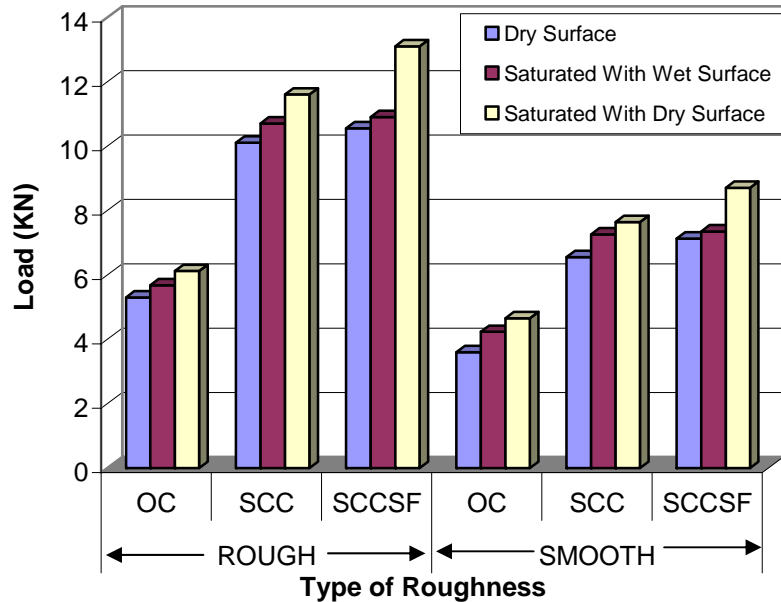


Fig. 4. Effect of the roughness and the moisture surface of the substrate

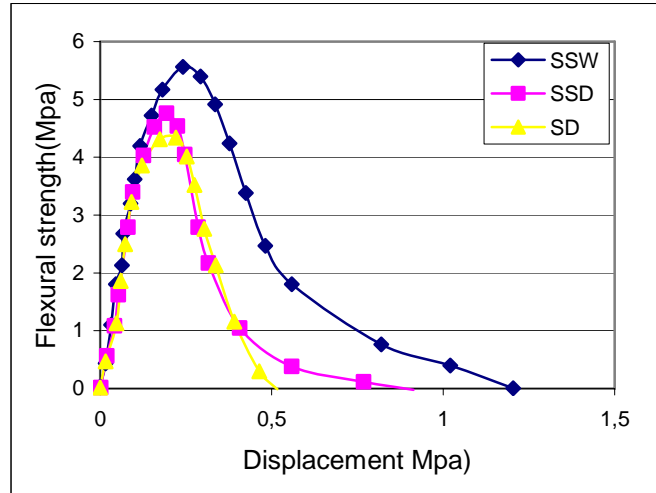
4.1.2 Effect of the moisture of interface surface

The following results correspond to a substrate, where its interface surface was rough and its moisture has been varied.

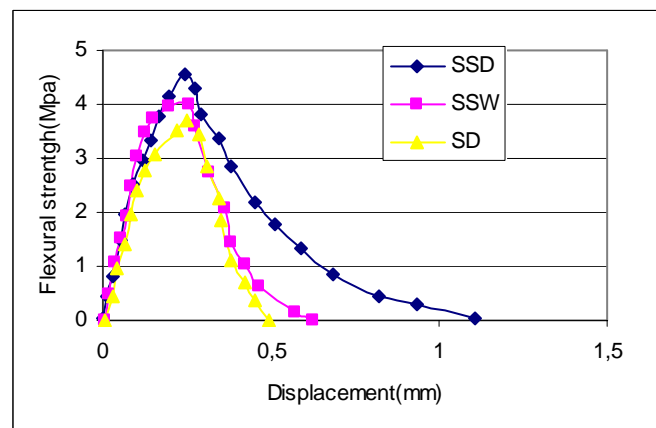
In Figure 5, the added separately of a layer of the OC, SCC or SCCSF on the saturated substrate with wet interface surface (SSW) reduce respectively the flexural strength to 7.2, 7.76 and 16.8 % compared to those of the saturated with dry interface surface (SSD). This is the result of the quantity of water which plays a role of screen in the interfacial zone, and prevents the interpenetration of the hydrates in the porosity of the interface. Similar results exhibited this phenomenon well on surfaces with stagnated water [10-12].

For the dry substrate (SD), the overlaying with each of the OC, SCC or SCCSF reduce respectively the flexural strength by 13.4, 12.93 and 19.46% compared to those of the saturated with dry interface surface (SSD). These results show that a too dry interface absorb a part of water of the overlay material. This effect reduces the W/C ratio, and consequently the cement hydration will be incomplete.

a repair with SCC+SF



b repair with SCC



c repair with OC

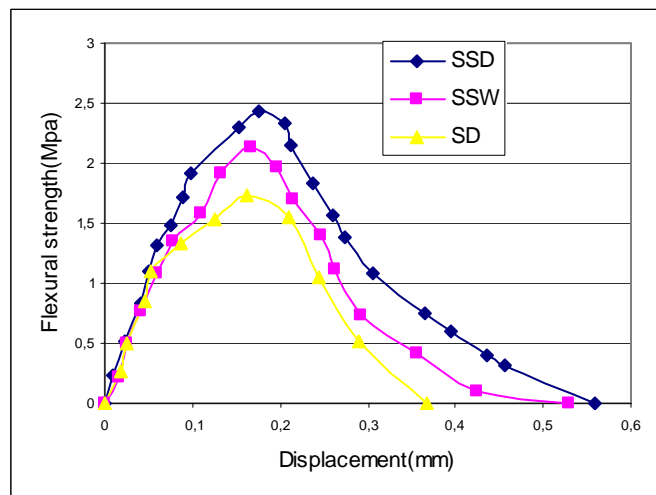


Fig. 5 : Influence of the type of moisture on the flexural strength for different overlay material (a- SCCSF. b-SCC. c- OC)

6. Conclusion

In repairing structures with concrete overlaying, a good bond of the overlay material to the substrate is mainly ensured by the preparation of substrate surface quality. In this paper, following conclusions have been reached:

* In order to ensure a good thermodynamic adsorption and a micro-roughness, the substrate surface must be saturated with dry surface (SSD) (without stagnation of water in surface). Since, while the substrate surface is saturated and wet (SSW) with stagnant water; the latter can clog the pores and prevent absorption of the overlay material. This stagnant water plays a role of screen in the interfacial zone, which reduces the adherence with the substrate. In addition, if the surface is too dry, the interface absorbs too much water from overlay material, which results in an incomplete hydration of cement and reduces the adherence with the overlay material.

* In order to ensure a macro- roughness which creates a mechanical blocking, it was found that a rough substrate surface is necessary to improve the adherence with the overlay material. Also, the SCC overlay is very sensitive to the smooth substrate interface.

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