Experimental Investigations on Upgrading Structures with High Strength Concrete Overlay

Norbert RANDL
Professor
Carinthia Univ. Appl. Sci.
Spittal an der Drau, Austria
n.randl@cuas.at

Norbert Randl, born 1967, received his civil engineering degree from the University of Innsbruck, Austria. He worked for the Hilti Corporation in Germany before becoming Professor at the Carinthia University of Applied Sciences, Austria. His main fields of research are related to strengthening and behaviour of concrete structures as well as post-installed fastenings.

Csaba SIMON
Research Assistant
Carinthia Univ. Appl. Sci.
Spittal an der Drau, Austria
c.simon@cuas.at

Csaba Simon, born 1984, received his civil engineering degree from the Budapest University of Technology and Economics, Hungary. He worked for the Hídépítő Company in Hungary before becoming Research Assistant at the Carinthia University of Applied Sciences, Austria. His main field of research is related to high performance concrete structures.

Summary

In the frame of the research project “HiPerComp” founded by the Austrian Research Foundation (FFG) several tests were performed in order to investigate the bond properties between normal concrete substrates (about C50/60) and high strength concrete (HSC) overlays with a 28 days compressive cube strength of about 120 MPa. Slant shear tests with different joint angles and bending tests with reinforced concrete slabs were carried out. The substrates were treated with high pressure water jetting and sand blasting to increase the surface roughness.

The usage of HSC overlays leads to a more durable and compact top layer due to its decreased porosity and its resistance is higher against mechanical abrasion, while the bond properties are better compared to normal concrete overlays.

Keywords: Concrete overlay, high strength concrete, slant shear test, structural upgrading, high pressure water jetting, sand blasting.

1. Overview of the testing program and test setup

The testing program contained three different phases. In the first phase, the test specimens including small scale slant shear specimens and large scale slab specimens were produced. In the second phase, the slant shear tests were performed. Based on the test results the bond properties between the two different concretes have been determined in order to estimate the resistance of the interface of the large scale specimens, which were tested in the third phase. The slab interfaces were treated by sandblasting (SB) or high pressure water jetting (HPW), thereby reaching a mean roughness depth of about 0,8-1,1 mm (SB) or 2,4-3,6 mm (HPW), measured by the sand patch method. In addition, in case of two slant shear specimens and two slabs a number of powder-actuated studs were applied along the interface. All substrate structures were made out of normal strength concrete (NSC) with a strength class in the upper range. The new concrete parts (overlays) were made out of a specially developed self-compacting high strength concrete (HSC) with a mean 28 days compressive cube strength of 124 MPa. For reference two slant shear specimens and two slabs were prepared with NSC overlays. As reinforcement for the slabs “BSt 550” steel – which is commonly used in Austria – was applied.

The dimensions of the nine **slant shear** specimens were 15 x 15 x 70 cm and the angles of the interfaces were 60°, 70° and 75°, three of each respectively. The surface treatment method and the concrete quality has been varied as well (see Fig. 2).

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For simulating old reinforced concrete slabs which are upgraded and strengthened with a concrete overlay, seven **slab bending tests** have been performed. For the longitudinal reinforcement Ø 10/15 and for the transversal reinforcement Ø 8/25 were applied with a concrete cover of 15 mm. Each slab test specimen had a dimension of 3,5 x 1,5 x 0,15 m, in which the overlay is included as 5 cm of the total thickness (see Fig. 1).

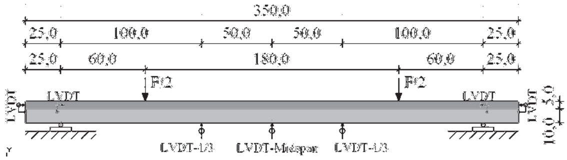

Fig. 1: Slab bending test setup

2. Test results and evaluation

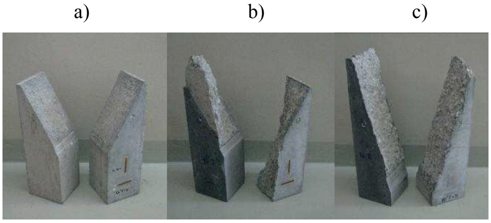

Fig. 2: Slant shear test: failure modes

In case of the slant shear tests the failure occurred in three different modes. The first mode was the shear failure of the interface (see Fig. 2/a), the second one was the compression failure of the NSC part (see Fig. 2/b) and the third one was a shear failure of the NSC parallel to the inclined joint (see Fig. 2/c).

Based on former investigations [1] and friction tests performed subsequently to the slant shear tests a mean friction coefficient μ of 1,1 for sandblasted and 1,5 for water jetted surfaces was determined. Applying these coefficients, from the test results the adhesive bond-strength values of the joints $\tau_{j,ad}$ were calculated.

In case of the slab tests all specimens failed finally due to bending. The load bearing capacities were between 246 to 310 kN. The first cracks appeared approximately at a load level of 50 kN on the bottom side of the slabs. At a load of about 150 kN shear cracks appeared between the supports and the load introductions. On the longitudinal side sometimes crack offsets were observed when cracks crossed the interface. However these crack offsets were observed in both cases with the HSC and the NSC overlays, they were more pronounced in case of the NSC overlay and the same with the crack widths.

The maximum deflection $W_{F,max}$ at failure reached about 55-60 mm with the high strength overlays. In case of the normal strength concrete overlay, the measured deflection at failure was significantly larger, about 74 mm with the sandblasted and 87 mm with the HPW interface.

3. Conclusions

In the slant shear tests, it turned out, that the concrete quality of the overlay influences – especially in case of the sandblasted surfaces – significantly the bond shear strength.

In the slab tests, it was proven, that the stiffness of building elements can increase due to a HSC strengthening. Therefore the deflection under service load can decrease as well as the crack widths compared to NSC overlay. Because of the higher adhesive bond of HSC, failure of the interface can be excluded.

4. References

[1] RANDL N., „Untersuchung zur Kraftübertragung zwischen Alt- und Neubeton bei unterschiedlichen Fugenrauhigkeiten“, *Dissertation*, Institut für Betonbau, Leopold-Franzens-Universität Innsbruck, 1997 (in German)