In-Place Bond Testing and Surface Preparation of Concrete

by Kal R. Hindo

Concrete rehabilitation commonly includes removing poor concrete and replacing it with patches and overlay materials. Proper surface preparation of the substrate and bonding of the new material are important factors in the success of these repairs, creating a need to accurately and positively determine the quality and strength of concrete bonding.

Indirect tests have been used with a variety of apparatus and applications. Some of these tests include the split-shear test, the shear test, and the direct tensile test (Fig. 1).

The first test uses samples prepared, bonded, cured, and tested under ideal conditions in the laboratory. The other two tests can use core samples from the field or samples prepared in the laboratory, but all specimens require laboratory testing. The results of these tests are used to evaluate the quality and strength of the bond; however, some of them do not represent actual site conditions, nor have they been proven to accurately evaluate in-situ bond strength.

A new method has been devised to determine the strength and quality of bond directly. NTH Consultants, Ltd. of Farmington Hills, Michigan, and Trow, Ltd. of Ontario, Canada, pioneered and developed a successful method in which in-place direct tensile tests of concrete can be performed using the LOK-TEST pullout device. The technique has been very successful in quality control of overlay and patch work during concrete repair programs, providing consistent and reliable results.

The procedure calls for a partial depth core to be drilled in the test area. The depth of the test cut should extend beyond the bonded interface into the original concrete material to adequately evaluate the bond strength (Fig. 2). A circular steel plate with a threaded insert is then bonded with a fast-setting epoxy to the top of the unbroken core.

After the epoxy has cured, an adjustable loading frame is placed and leveled over the test area. Then the test is performed using the pullout instrument to apply a tensile force until failure occurs (Fig. 3 and 4). The force required to cause failure divided by the cross-sectional area of the concrete core is a direct measure of the tensile strength of the material across the failure plane. The core hole left by the test can be filled with a nonshrink concrete mortar.

Since failure occurs along the weakest plane, this test not only provides a quantitative measure of tensile strength but also identifies the location and nature of failure. This often provides valuable insight into specific problems, such as weak bond, poor base or overlay materials, improper surface preparation, or other surface defects.

Using pneumatic hammers for concrete removal has been standard practice; however, in-place bond testing has shown that the pneumatic hammers cause the formation of a "bruised" layer extending from the prepared surface to a depth of approximately ⅜ in. (9 mm). Microscopic examination of this layer reveals microcracking due to the dynamic action of the hammers.

Fig. 5 and 6 illustrate the bond interface, indicated by the black outlined arrows, while the lower solid black arrows identify microcracking of the prepared surface. The number of microcracks and the thickness of the bruised layer depend on the rated capacity of the hammer, concrete quality, and the amount of effort exerted.

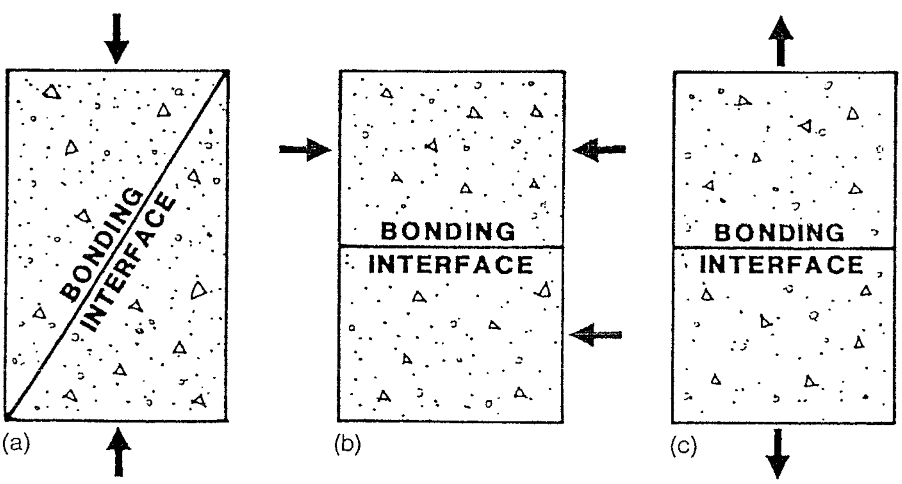

Fig. 1—Schematic diagrams of laboratory bond strength tests: (a) split-shear test; (b) shear test; (c) direct tensile test.

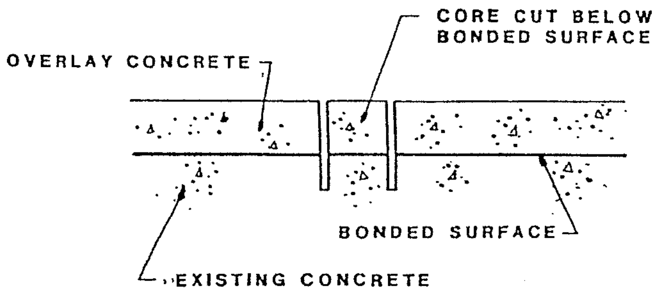

Fig. 2—Schematic representation of in-place bond test preparation.

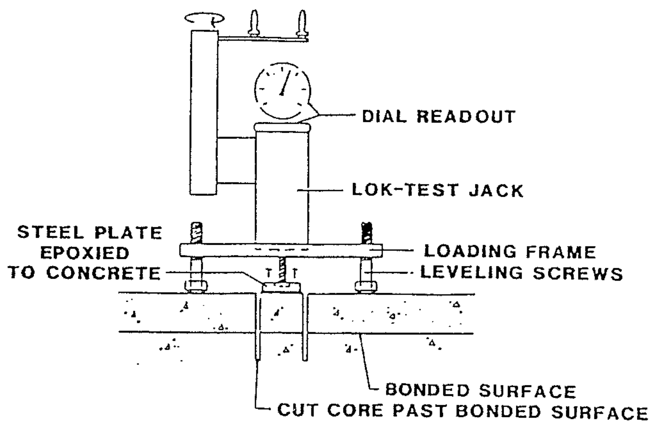

Fig. 3—Schematic representation of test apparatus.

Tests performed on bonded sound concrete with base surfaces prepared using pneumatic hammers have typically shown tensile strengths ranging from 70 to 300 psi (0.48 to 2.07 MPa) (Table 1), but the majority of test results fall in the order of 100 psi (0.69 MPa), with failure occurring within the bruised region. The variations in bond strength values depend on the depth of the bruised layer, the type of bond material, and the quality of the surface preparation and/or concrete materials. ACI Committee 503[1] stipulates that a minimum pullout strength of 100 psi (0.69 MPa) must be developed at the prepared surface to achieve adequate bonding.

The problem of microcracking[2] and resultant weakening at the bond interface has been considerably improved by using hydrodemolition, also called hydroblasting or hydrojetting. The method uses high-pressure water jets to remove concrete by three separate mechanisms: direct impact on the surface, pressurizing the cracks, and cavitation.[3]

Water pressures range from 12,000 to 35,000 psi (82.8 to 241.4 MPa), depending on the type of equipment. The process can achieve selective removal of concrete because it provides the ability to control the amount of energy released. The equipment is designed to remove concrete to a prescribed and controlled depth; when unsound concrete is encountered during hydrodemolition, the poor concrete is removed until sound material is reached.

The surfaces prepared by hydrodemolition do not develop significant microcracking; examination of the interface (Fig. 7 and 8) does not reveal the presence of a bruised layer. Minor microcracks can develop in some cases, but they are negligible in comparison with the surface damage created by the pneumatic hammers. In addition, the surfaces prepared by hydrodemolition provide increased percentages of micropores in the cement paste, as well as greater surface area.

Using hydrodemolition in concrete repair work produces a bond interface superior to the jack hammer method due to the following factors:

- Lack of a bruised layer.
- Irregular wavy surface profile.
- Increased number of micropores.
- Greater surface area.

Experience has shown that when hydrodemolition is used bond strength has generally increased to

Fig. 4—The test apparatus.

Table 1—Comparison of bond strengths using different methods of surface preparation

Type of repair	Jack hammer	Jack hammer	Jack hammer	Jack hammer	Hydrodemolition	Hydrodemolition	Hydrodemolition
Number of breaks below bond interface	6	4	75	10	4	4	10
Bonding agent	Epoxy	Polymer-modified cement slurry	Epoxy	Epoxy	Latex/cement slurry	Latex/cement slurry	Cement slurry
Range of bond strengths, psi	70-125	94-150	45-251	144-245	144-197	103-278	173-257
Mean bond strength, psi	108	124	135	174	175	210	212

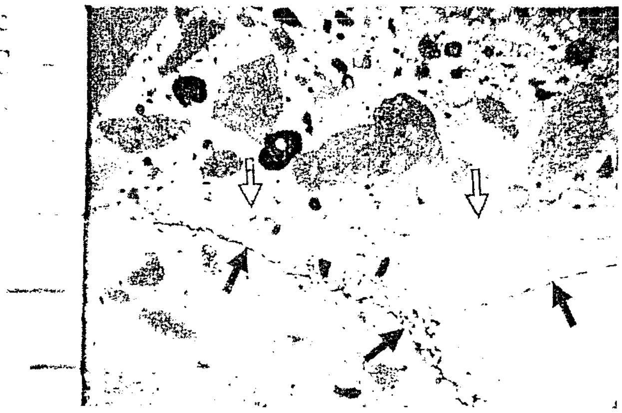

Fig. 5—Typical microcracking below interface using jackhammer.

Fig. 6—Typical microcracking below interface using jackhammer.

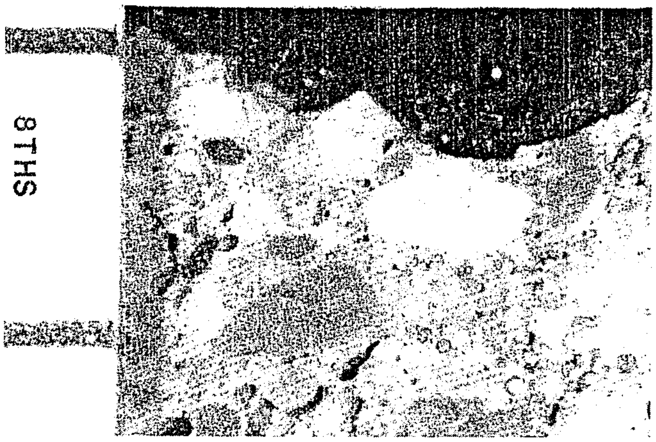

Fig. 7—No cracking at interface using hydrodemolition.

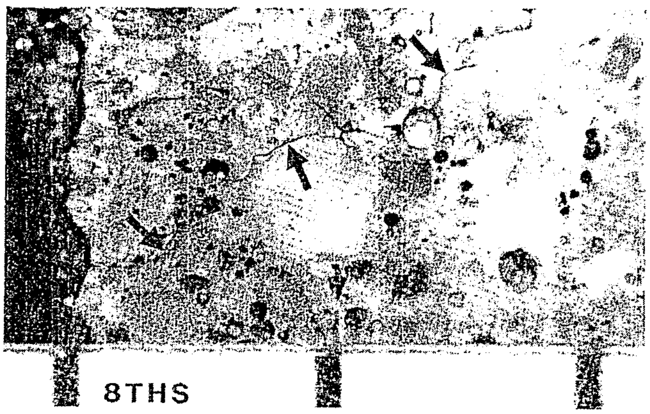

Fig. 8—Minor microcracking at interface using hydrodemolition.

almost twice the strength achieved when surfaces are prepared by pneumatic hammers. Table 1 presents comparative results using both methods of removal and the in-place bond test method. The tabulated data represents projects in North America using various materials and methods of surface preparation.

Conclusions and recommendations

The in-place bond test is a valuable tool to determine directly the bond strength and the quality of the prepared surface. Two important advantages are that the test is performed in-situ and represents actual field conditions and it is a useful tool for quality control during construction repairs. Using pneumatic hammers in concrete causes a bruised surface layer and creates a zone of weakness below the interface.

Hydrodemolition has demonstrated the ability to remove concrete without damage below the prepared surface. The technique minimizes microcracking and provides a superior surface for bonding. Bond strength can be double that of a surface prepared by a pneumatic hammer.

In view of the accurate and reliable nature of the in-place bond test and its representation of actual field conditions, it is recommended that ACI consider adoption of the procedure as a standard for general use. Additionally, the use of pneumatic hammers for concrete removal and surface preparation should be discouraged and replaced where applicable with the hydrodemolition method.

Acknowledgments

The author would like to express his special thanks to John Bickley of John Bickley Associates, Ltd.; Boris Dragunsky of Chicago Concrete Consultants, Ltd.; Ken Lozen of Tracy Materials Consultants; and Thomas Kline of NTH Consultants, Ltd., for contributing data used in developing this article.

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Received and reviewed under Institute publication policies.

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