The effect of wire drawing lubricant residues on the bond characteristics of prestressing strand

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ABSTRACT: WJE performed a four-year study of US produced prestressing strand aimed at determining why its bond properties have declined over the past 20 years. This study was funded by the National Cooperative Highway Research Program (NCHRP 10-62). WJE found that only certain manufacturers were making strand with deficient bond as a result of excess residual wire drawing lubricants and other factors. Surface tests were developed by the research that can be used to predict the bond properties of the strand. These tests were compared to transfer length tests and pullout tests of untensioned strand embedded in concrete and mortar. The tests developed by WJE are proposed for use in strand production facilities to qualify the bond properties of strand before it is shipped to customers.

1 BACKGROUND

1.1 7 wire strand

In the USA, 7 wire prestressing strand is typically 12.7 mm, 13.2 mm, or 15.2 mm in diameter, consisting of 6 wires twisted around a straight central wire called the king wire. The individual wires are drawn from 8 mm rod stock, which has been pickled and treated with phosphorous or borax to facilitate the adherence of wire drawing lubricants, typically sodium or calcium stearate based but often containing other compounds. The rod stock is drawn through a series of eight dies to achieve the final wire diameter. The wires are spooled then loaded into a skip strander. The skip strander dispenses the 6 outer wires around the central wire to make the 7-wire strand. The strand then passes through an oven, under tension (to achieve its low-relaxation properties), followed by a water bath, drying, and spooling. Some of the wire drawing lubricant is still adhered to the surface of the wire after drawing. If the residual wire drawing lubricants are excessive, they can interfere with the bond between the strand and the surrounding concrete.

1.2 History of problem

The bond properties of strand used in the USA was studied in the 1950's and 60's. Those studies resulted in the current equations for bond transfer and development lengths. Transfer length is the distance from the end of the member to the point on the strand where the strand pretension is developed. The development length is the distance from the end of the member to the point on the strand where the ultimate strength of the strand is developed. Currently, the American Concrete Institute (ACI) and the American Association of State Highway and Transportation Officials (AASHTO) specify a transfer length of about 50 to 60 strand diameters and a development length about three times the transfer length. The transfer length can be estimated as about 300 times the amount of end slip that occurs after release of prestress. Therefore, for 12.7 mm strand, for example, we would calculate a transfer length of about 700 mm and an end slip of about 2.3 mm. End slips greater than about 2.5 mm are a cause for concern because they could indicate a strand with poor bond properties, i.e. require a greater distance to develop than expected based on the ACI and AASHTO prediction equations.

In the mid-1980's, a major test program was undertaken at the North Carolina State University to compare the bond properties of epoxy coated strand to that of uncoated strand. The researchers found to their surprise that uncoated strand had sometimes twice the expected transfer length. They did not try to understand the source of this unexpected result. But, as a precautionary measure, the Federal Highway Administration instituted a 1.6 multiplier on the calculated transfer length until the problem could be better understood and resolved. Numerous experimental programs took place in the 1990's to study the bond characteristics of prestressing strand in concrete, but none of them
studied the potentially harmful effects of wire drawing lubricants. In 1992, a strand lifting loop pulled out of a member causing the member to be dropped. The ensuing investigation determined that the strand bond properties were less than they should be, based on a simple test where an untensioned strand is pulled out of a concrete block. Seven manufacturer’s products were tested and four of them were found to have deficient bond properties. Autopsies of concrete exhibiting slip problems showed a shiny surface at the bond line (Figure 1).

As a result of these historic events, the National Cooperative Highway Research Program (NCHRP) funded project 10-62 to specifically study the surface characteristics of prestressing strands, determine how those characteristics influence bond, and develop test methods to qualify the strand for bond.

2 TEST PROGRAM

2.1 Surface tests

Twelve different test methods were developed in an attempt to characterize the bond properties of the strand. The test methods and their relative success are as follows:

2.2 Physical tests

Numerous bond tests in the literature were studied. The two most prominent pull-out tests were the NASPA test and the Large Concrete Block test (LCB). The NASPA test is a pullout test of untensioned strand from a cylinder of mortar. The LCB test is a pullout test of untensioned strand from a large concrete block. These tests were compared to standard concrete transfer length tests of prestressed concrete prisms. The LCB test correlated better with transfer length than did the NASPA test. The NASPA test was not as discriminating between the samples of strand available to WJE. Both tests are preferred to the transfer length test because they are easier to run. A comparison of these two methods from one data set is presented in Figure 2.

2.3 Final Results

The best correlation between the pullout tests and the surface tests was achieved using a combined index of Loss on Ignition (LOI), Contact Angle measurement after lime dip (CA) and Corrosion Potential (CP)