TEST 65 - THE INVESTIGATION OF CRACK DISTRIBUTION

AND CRACK WIDTH FORMED IN UNRESTRAINED

ENCAPSULATION GROUNTS DURING TENDÓN STRESSING

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CRACK WIDTH FORMED IN UNRESTRAINED ENCAPSULATION

GROUTS DURING TENDON STRESSING

1.0 INTRODUCTION

The British Code of Practice for Ground Anchorages (BS 8081) approves the concept of a 5mm thick annulus of grout, bonded around the tendon within the plastic encapsulation duct, constituting a corrosion protective layer. The grout must also provide full bond between the tendon and the encapsulation duct to ensure efficient transfer of anchor load without load loss due to creep behaviour.

In the case of cementitious grouts, which have no tensile strength and are inelastic in relation to the tendon, then it is acknowledged that cracking must occur during stressing. However, should the crack distribution be uniform and frequent such that the crack widths do not exceed 0.1mm, the grout layer will prevent corrosion of the tendon in the appropriate conditions (Beeny 1978). Papers have also been published concluding that the deformations on bar tendons control, in certain conditions, the crack distribution. This can ensure uniform crack distribution and the formation of a high density of cracks each with a width less than 0.1mm.

In the case of resinous grout, it is considered that an "elastic" grout can be produced, which when stressed, will deform with the tendon and thus produce no cracks to allow penetration of corrosive fluids. It is not considered that resinous grouts provide a corrosion resistant barrier when cracked due to the absence of the alkalinity of cement grout and due to their inability to self seal.

In the U.K. the sale of both "crack-controlled cement grout" systems involving the use of deformed bar and "elastic resin" systems involving bar or strand tendons are promoted. Both are purchased and incorporated in permanent anchor works without, to my knowledge, any conclusive evidence to prove that the system satisfies the corrosion protection requirements of BS 8081 in all possible working conditions.

2.0 THE SIMULATED TEST CONDITIONS:

If the systems are to be guaranteed to conform with the corrosion protection requirements in working conditions, then it is likely that the presence of an encapsulated section within an ungrouted bore is the most severe test. The condition could occur due to leakage or leaching of grout from the upper fixed length bore. Similar conditions, of limited or partial restraint, could also be encountered if the upper fixed length around the
encapsulation is within weak ground whilst the lower encapsulation is in the rock or strong material adequate to maintain load. Such conditions would also occur if the corrosion protection system was offered for free length protection.

3.0 THE TEST:

The pre-fabricated encapsulation of 2.5m length for cement grout and 1.5m length for resin grout is constructed with a free tendon protruding from both ends. This is then fitted in a test jig which allows the tendon to be locked off at one end and stressed with a jack from the other end (Figure 1). The 2.8m long tendon is then cyclically loaded in accordance with BS 8081 On-Site Acceptance Test in order to simulate normal anchor loading conditions whilst monitoring tendon extension. When the tendon is locked off at proof load (which was varied from 33 to 79% characteristic strength of the tendon) then the plastic encapsulation duct is stripped off over a 0.75 to 1.5m mid-length of the encapsulation and the exposed grout inspected for the presence of cracks and for crack distribution.

4.0 CRACK OBSERVATION MEASUREMENT AND RECORDS:

In cement grout tests, the 1.5m observed length was split into 5 x 300mm lengths and the crack distribution over each unit length sketched out. In the resin grout tests, four 300mm lengths were inspected in one test and a full 750mm length in the other. Observations were enhanced by use of a magnifying glass and are also recorded by photographing.

5.0 CRACKING AND/OR CRACK WIDTH ACCEPTANCE CRITERION:

The encapsulation duct and the outer cement grout face are unrestrained during tendon loading. Thus the grout must deform uniformly with the stretching tendon. At proof load, the extension of the full tendon length is measured (generally 13 to 17mm). The extension of each 300mm unit length of grout under observation is known (1.37 to 1.79mm).

If, in the case of cementitious grout, the cracking is controlled to ensure the crack width does not exceed 0.1mm, then the number of cracks per 300mm length can be calculated. This number of cracks (or more) must be uniformly distributed to ensure compliance with the crack control requirements.

In the case of "elastic" resinous grout there must be no cracking present.
6.0 THE RESULTS:

6.1 Deformed Bar with Cementitious Grout:

Two tests were carried out on systems promoted as "crack-controlled" double corrosion protection.

a) A 36mm dia bar in a 65mm dia encapsulation duct.

b) A 25mm dia bar in a 50mm dia encapsulation duct.

Tests were carried out 5 days after encapsulation grouting when grout strengths were in excess of 40N/mm².

Details of crack observations and calculated average crack widths are recorded in Tables 1 and 2 and crack distribution recorded in Figures 2 and 3 and portrayed in Photo 1.

Cracks observed in both tests were frequent but not uniformly distributed. Also it was clear that the thickness of the cracks was in fact variable; from barely visible (hairline) to clearly visible; the latter being visibly in excess of 0.1mm.

Calculations from tendon extension values establish average crack widths for Test A at 57% of characteristic bar strength up to 0.23mm, and for Test B up to 0.36mm at 79% of characteristic bar strength.

In all cases, the encapsulation duct itself extended during loading and no duct cracking occurred.

6.2 "Elastic" Non-crack Resinous Grout:

Two tests were carried out using the same resin in different strand encapsulation systems.

c) 5No. 15.2mm dyform strands in an 80mm dia encapsulation duct.

d) 3No. 15.2mm dyform strands in an 80mm dia encapsulation duct.

Tests were carried out 4 days after encapsulation grouting when grout strength according to the Manufacturers data sheet would be in excess of 70N/mm².

Details of crack observations are recorded on Figures 4 and 5 and portrayed in Photos 2 and 3.
Both tests, one at 33% characteristic strength of the tendon and the other at 56%, confirmed that in the unrestrained condition, the resin does not deform elastically with tendon and does crack. Furthermore, as load was increased, the crack widths also increased rather than forming a larger number of narrow cracks. Cracks as wide as 1mm were observed.

7.0 CONCLUSION:

The deformed bar system promoted as a double protection system using "crack-controlled grout" did not provide the appropriate crack-control to restrict crack width to less than 0.1mm when stressed.

The strand system promoted is a double protection system "elastic resin" did not provide a crack-free resin grout when stressed.

In all four tests, the encapsulation duct (50, 65 and 80mm diameters) deformed during testing and provided no indication of cracking.

In the circumstances of the test, where the tendon within the unconfined and unrestrained pre-grouted encapsulation was loaded in tension, the system promoted as double protection did in fact only provide single protection as defined in BS 8081.

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<table>
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<tr>
<th>Cracks over Full Section</th>
<th>Hairline Type</th>
<th>Average Width (mm)</th>
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<td>No.</td>
<td>Cracks including discontinuous</td>
<td>Average Width (mm)</td>
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<tr>
<td>5-6</td>
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Table 1: Crack Distribution in "Crack-Controlled" System A at 57% Characteristic Strength of Tendon
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<th>300mm Observation Length</th>
<th>Cracks including discontinuous Hairline Type</th>
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<tr>
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<tr>
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<td>5-6</td>
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Table 2: Crack Distribution in "Crack-Controlled" System B
at 79% Characteristic Strength of Tendon