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STRUCTURAL PERFORMANCE OF ASR AFFECTED CONCRETE

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INTRODUCTION

A programme of laboratory testing on the structural effects of ASR is being carried out at the Building Research Station, England. The concrete specimen strength tests described here form the first phase of this programme. They were carried out in order to amplify the laboratory results obtained by Nixon and Bollinghaus on the effect of ASR on concrete strength (1) and to provide a basis for the testing of specially cast prestressed concrete beams subject to ASR which forms the second phase of the programme.

THE CONCRETE MIX AND CONDITIONING

One reactive mix was used throughout. It contained an inert limestone coarse aggregate (20mm to 5mm) and a "pessimum" proportion of reactive Thames Valley sand (5mm down). The cement content was 400 kg/m3 and the free water-cement ratio was 0.45, giving a cube compressive strength of 50 N/mm2 @ 28 days. A high alkali cement was used (0.9% equivalent Na_2O content). In addition, sodium and potassium sulphate was dissolved in the mixing water to raise the total alkali content to 7 kg/m3. All specimens were cured in 20°C water for 28 days. Thereafter they were immersed in 38°C water. All specimens were tested saturated.

THE STRENGTH TESTS

Five strength tests were carried out as detailed in Table 1. Three of these are British Standard tests. The specimens for the tall prism compression tests were cast as beams (the same as for the flexure test) and tested as columns. It was important to include the tall prism compression test because the cube compressive strength is enhanced by end frictional restraint between the concrete and the loading platens.

The gas pressure tension test is a simple method developed at the Building Research Station, England, for the investigation of suspect concrete (2). The specimen is a standard, solid, concrete cylinder and the mode of fracture is the same as if the ends of the cylinder had been pulled apart by direct tension.

All strengths were measured at one monthly intervals from casting up to 5 months. The relationships obtained between strength change and time for all the test methods are shown in Figure 1.

TABLE 1 STRENGTH TEST METHODS USED

Test Method	Test Specimen	Reference
cube compression	100mm cube	B.S.1881 Part 116
cylinder splitting (Brazillian)	100mm dia. x 200mm cylinder	B.S.1881 Part 117
flexure	300mm x 90mm x 90mm prism	B.S.1881 Part 118
tall prism compression	300mm x 90mm x 90mm prism	see text
gas pressure tension	100mm dia. x 200mm cylinder	reference 2

EXPANSION MEASUREMENT

The unrestrained expansion of specimens made from the same mix batches as used for the strength tests was continually monitored up to 5 months. The resulting expansion graph is shown in Figure 2. This graph includes the complete range of specimen expansions measured on the cylinders and prisms made for the strength tests and also on 200mm x 75mm x 75mm prisms.

COMMENTS ON THE RESULTS

Looking, firstly, just at the strength test results (Figure 1), all tests show clearly, as expected, a drop in strength at some stage. The cube compressive strength is the least affected and does not drop below the 28 day value. At the other extreme, the gas pressure tensile strength shows an 80% decrease below the 28 day strength. Part of this severe decrease is attributable to an enhancement of gas pressure tensile strength which occurs for undamaged (28 day) concrete when tested saturated (3). If account is taken of this factor, a tensile strength loss of 60% is found relative to the 28 day value. The flexure test shows a slightly less severe effect than this because of the different direction of the fracture plane in relation to the direction of casting.

As indicated in Figure 1, there is no significant difference between the tall prism compression test and the cylinder splitting (Brazillian) test in relation to ASR. Since both the gas pressure tension test and the flexure test show a greater loss in strength than the cylinder splitting test, it must be concluded that the cylinder splitting test cannot be used to assess the tensile strength of ASR affected concrete.

Proof of the inadequacy of the cylinder splitting test in determining the tensile strength of damaged concrete has been presented by Hannant (4). On the other hand, Figure 1 shows that the cylinder splitting test does give a reliable indication of the effect of ASR on the compressive strength and it is in this light that the test is most usefully viewed. The compressive stress is derived from the cylinder splitting test by simply dividing the load by the bearing area (5).

Looking, now, at the strength test results compared to the measured expansion (Figures 1 & 2), it is clear there is no correlation between one and the other. Strength loss starts before there is significant expansion, whereas strength loss is stable when expansion is increasing at the greatest rate.

The stage on the expansion graph where expansion starts to increase rapidly (at about 1½ months @ 38°C, 2½ months since casting) corresponds to the appearance of macrocracking on the surface. At this stage, the strength of the concrete, as measured by all the tests, reaches its minimum value and, although the concrete continues to expand, there is no further significant change in strength thereafter. Expansion levels off after 4 months at 38°C (5 months since casting).

PRESTRESSED BEAM TESTS

This is research currently in progress.

The beams are pretensioned, I sectioned and made using the same concrete mix as used for the specimen tests described above. Half the number have shear reinforcement and are 400mm deep by 200mm wide. The others are 240mm deep by 120mm wide and have no shear reinforcement. The conditioning is exactly as described above for the specimens. The following are being measured:

(i) shear strength
(ii) flexural strength
(iii) prestress level
(iv) compressive & tensile strength of cores

These measurements are being made on beams stored for 5 months in 38°C water i.e. when full expansion (of unrestrained concrete) has occurred. In addition, the same measurements are being made on beams stored for just 1½ months in 38°C water, at the stage when macrocracking has started but the expansion (of unrestrained concrete) is still less than 0.5 mm/m. As discussed in the previous section, although the expansion is insignificant at this stage, the concrete strength is already at the minimum. These tests will therefore assess the effect purely of loss in concrete strength, without the complication of expansion. The tests at full expansion will then determine the additional effect of the expansion itself.

Additional beams are currently on an exposure site to compare the effect of natural conditions with storage in water at 38°C.

CONCLUSIONS

The tensile strength of the concrete specimens subjected to accelerated ASR is 60% below the 28 day value. The compressive strength loss, as determined from tall prisms, is 30%.

The cylinder splitting (Brazillian) test cannot be used to assess tensile strength loss due to ASR. It is, however, a good indicator of compressive strength loss.

There is no correlation between concrete strength and expansion. When expansion is about 0.5mm/m and macrocracking has occurred, strength has already reached a minimum and there is no further significant strength change with continued expansion.

In the prestressed beam testing programme currently being carried out, it is essential to test when macrocracking first occurs as well as at ultimate expansion in order to separate out the effect of concrete strength loss from the effect of concrete expansion.

ACKNOWLEDGMENT

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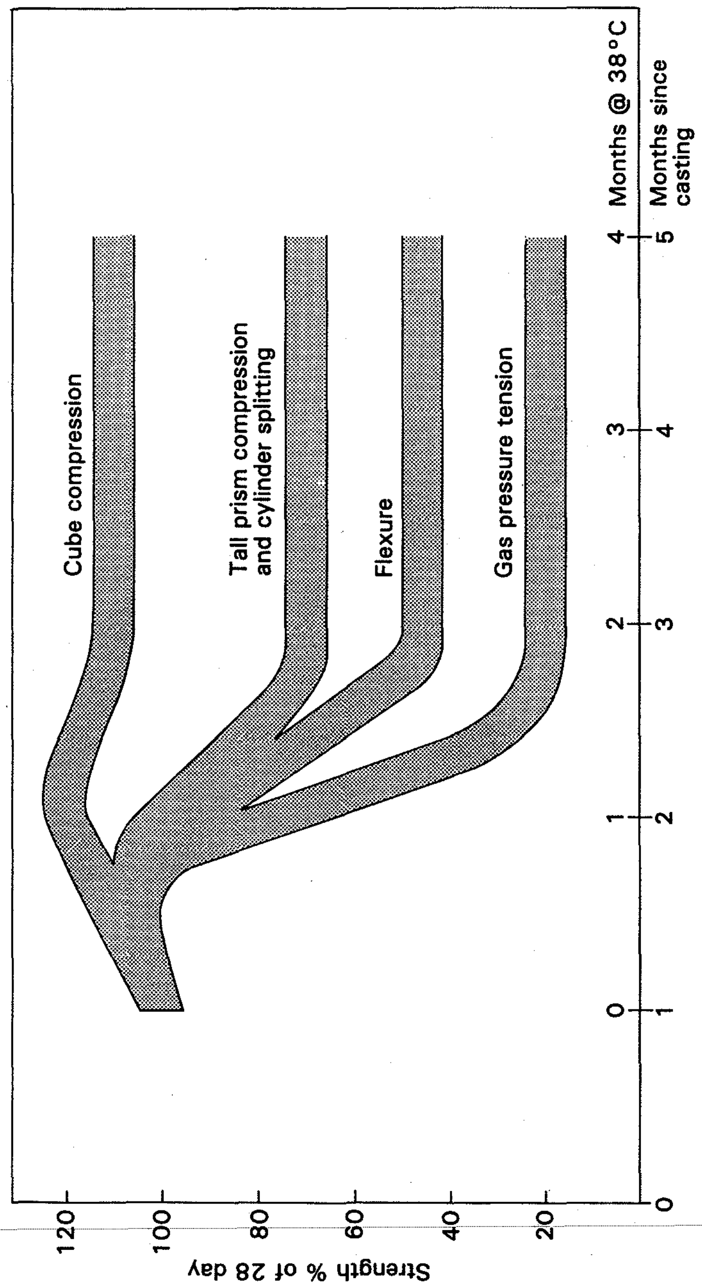

Figure 1 Strength of Laboratory ASR Specimens in Water at 38 C

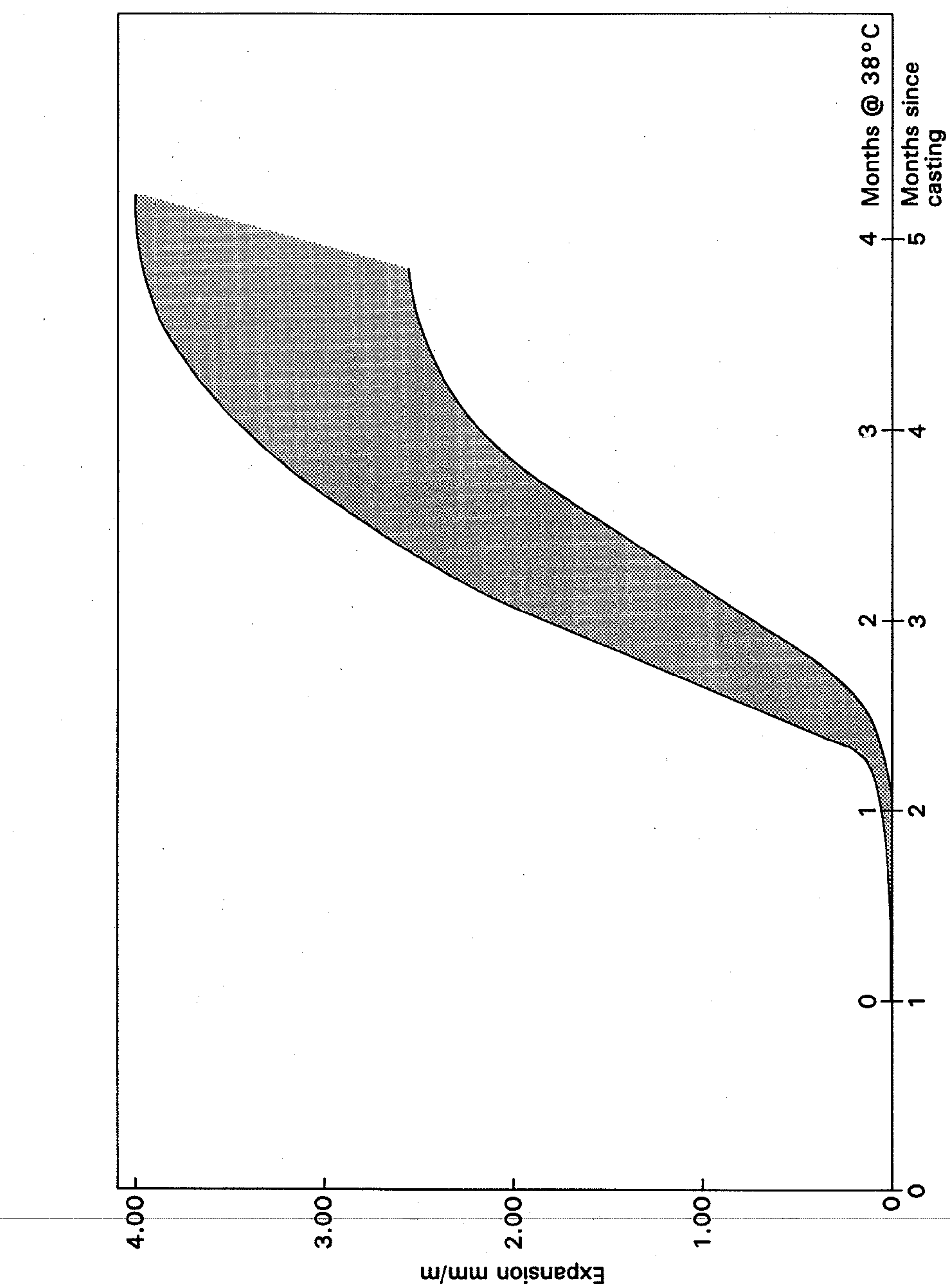

Figure 2 Expansion of Laboratory ASR Specimens in Water at 38 C