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A torsion test to evaluate the deterioration of concrete due to alkali-aggregate reaction

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Contribution by N. Clayton

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For investigatory work into concrete structures, it is essential that as wide a range of strength tests as is practical is used. The development of a torsion test for practical use by Norris *et al.* is therefore to be warmly

welcomed, as it will extend the available range. Reliance on one particular test, whether it is nominally a compression test, a tension test or indeed a torsion test, would be prejudicial and potentially misleading since

Table 1. Effect of ASR on strength—comparison of the torsion test with five other test methods using cast specimens

Test	Strength relative to the 28 day pre-reaction value		Comments
	Mean	90% confidence limits	
Cube compression test*	109%	107%–112%	The apparent strength increase is because of the compensating effect of cement hydration Height-to-width ratio = 3:3
Tall prism compression test*	70%	63%–77%	
Cylinder splitting (Brazilian) test*	70%	63%–76%	
Flexure test*	47%	40%–55%	A more severe strength loss is indicated by this test if the specimens are saturated Carried out by Dr B. Barr at the University of Wales on BRE specimens
Gas pressure tension test†	41%	35%–47%	
Torsion test†	66%	63%–70%	

*Specimens saturated at test.

†Specimens dried in laboratory air for one week prior to test.

the behaviour of concrete in a structural context cannot be predicted by reference simply to the direction of stresses.

With this philosophy in mind, the BRE carried out five different strength tests on specimens during the recent laboratory investigation into the structural effects of ASR in order to provide a 'spectrum' of behaviour with which to compare the results from tests on structural elements. In addition, we more recently asked Dr Barr to carry out torsion tests, using the method described in the paper, on concrete specimens prepared by the BRE to provide a direct comparison with the other five strength test results. All the tests were carried out on cast specimens, using the same mix and conditioning which assured that ASR would develop in a few months. The results from tests carried out when the reaction was complete (expansion about 4 mm/m) are summarized in the Table 1, as compared with the 28 day pre-reaction value in each case.

In view of the losses in strength indicated by the flexure test and the gas pressure tension test, the torsional strength loss is not as severe as expected. In fact, the strength loss found was barely different from that measured by compression tests on tall prisms (the reason why the cylinder splitting test shows the same loss in strength as the tall prism compression test is fully explained elsewhere¹).

This does not agree with the conclusion by the Authors, therefore, that 'torsional resistance is related to the tensile properties of the concrete'. On the other hand, it may well be the case that the loss in strength indicated by the torsion test reflects the loss in performance of a structural beam in shear (the contribution from the interaction of the ASR expansion with reinforcement apart) more closely than some of the other test methods.

Reference

1. CLAYTON N. The cylinder splitting test as a method for determining the compressive strength of concrete. *Mag. Concr. Res.* 1990, **42**, Mar., 51–55.

Reply by the Authors

The authors would like to thank Mr Clayton for his contribution to the discussion of their Paper. His interest in this subject is well known to the authors, and some tests have been carried out at Cardiff on specimens prepared at the BRE, as stated above.

The first point made by Mr Clayton is that 'as wide a range of strength tests as is practical' should be used in investigatory work into structures. The authors are fully in agreement with this point. In fact, Mott MacDonald has collaborated with three UK universities in the quest for the maximum information on specimens taken from existing structures. Other tests

which have been used include expansion tests, damage index tests and compression tests. The authors agree fully with this first point and regret that their Paper did not draw attention to other parallel studies.

The information presented by Mr Clayton in the above Table 1, showing the results from six different strength tests, is very interesting. The similarity between the results for the tall prism compression test, cylinder splitting test and the torsion test is very significant. It can be assumed that the basic mode of failure in the tall prism compression test would be by the development of vertical cracks, i.e. the actual mode of failure is due to the tensile strains developed in the test specimen. Similarly the basic mode of failure in the cylinder splitting test is due to tensile strain. Further consideration by the authors has led them to conclude that the torsion test is yet another form of indirect tensile test. The basic mode of failure is due to tensile strain developed at approximately 45° to the longitudinal axis. Hence, it is not surprising that these three test geometries show similar results. Therefore, the authors are still of the opinion that the 'torsional resistance is related to the tensile properties of the concrete'.

In the above three tests the greatest reduction in strength is observed in the torsion test—probably due to the fact that a plane of weakness is more readily found in such a testing arrangement. It is also of interest to note that the least spread in the results is observed in the torsion tests (of all the tests reported by Mr Clayton).

The main objective of the Paper by the authors was the development of a strength test on concrete cores taken from real structures. Cores are generally not prepared with smooth surfaces, and both tall compression tests and cylinder splitting tests would be difficult to perform on cores. On the other hand, the torsion test has proved to be a most suitable method of testing cores. The practical advantages of testing cores in torsion is clear.

The last sentence in Mr Clayton's contribution is of some interest to one of the authors who has spent a considerable amount of time (unsuccessfully) trying to develop shear-type test specimen geometries. One such test specimen geometry was circumferentially notched cylinders subjected to torsion! All the evidence which has been gathered by a significant group of people working on the application of fracture mechanics to concrete would suggest that all shear fractures are in fact due to tensile cracks. Some have gone so far as to suggest that 'shear cracks are sheer nonsense'. A finite-element study of the circumferentially notched cylinders showed that fracture was probably initiated by a series of tensile cracks merging together to form a global shear-type fracture. Furthermore, there was experimental evidence of the formation of tensile cracks at the base of the notch at approximately 45° to the longitudinal axis.

The most interesting results presented by Mr Clayton are those for the flexure test and the gas pressure tension test. However, a discussion of these results is beyond the scope of our reply. A great deal of further work is necessary in this important area of developing test methods for assessing accurately the deterioration of strength in concrete structures.

Finally, the authors would like to point out that the original Paper reported on work carried out some two years before its publication. Since then a number of changes have taken place in the experimental arrange-

ments, the two most important being

- (a) the introduction of additional instrumentation so that the rotation over a 120 mm gauge length can be determined directly from the specimen itself
- (b) the torsion test now includes a Damage Index Test as part of the experimental procedure.

The above developments give even more information from the cores subjected to torsion, and the results of these studies will be reported later.