Assessment of AAR Damage to Concrete Structures

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ABSTRACT

The paper deals with the assessment of AAR damage to concrete structures by visual inspection, ultrasonic pulse transmission, core tests, loading tests, and observation of in-service behaviour. The latter three methods appear most suitable, with the other methods providing useful correlations.

ASSESSMENT OF THE EXTENT OF DAMAGE BY AAR TO A STRUCTURE

(i) Ultrasonic Pulse Transmission

Blight et al (1981) showed that ultrasonic pulse transmissions may be used to assess the extent of damage by AAR to a reinforced concrete structure. They showed the results of calibration measurements which demonstrate the usefulness of the technique for exploring the depth to which damage, visible on the surface of the concrete, extends.

An ultrasonic pulse velocity survey conducted on the beam of a reinforced concrete portal frame (Blight et al (1983)) indicated that almost the entire beam had been badly affected by AAR. Nevertheless, a subsequent full-scale load test showed that the structural integrity of the beam had been little affected. It then became apparent that the observed retardation of the ultrasonic pulse velocity was caused by a relatively thin shell of deteriorated concrete that surrounded the almost unaffected heart of the member. A similar experience occurred with a large badly cracked foundation block. Ultrasonic pulse velocity measurements indicated extreme deterioration. However, coring showed that the deterioration extended no more than 300mm below the surface of the block. Ultrasonic pulses transmitted from the bottom of a core hole and received from a similar hole on the opposite side of the block showed that the heart of the block had not deteriorated significantly.

It may be concluded that an ultrasonic pulse velocity survey can be a useful method of exploring the extent of deterioration by AAR. However, the method should not be used without calibration against a more direct physical method such as the examination of cores, or load tests on similar structures.

(ii) Visual Examination of Cores

Blight et al (1981) suggested a "petrographic examination score" which rated the extent of deterioration of concrete on the basis of the presence of various manifestations of AAR attack. This can be a useful technique if it is used to compare the condition of one structure with that of another. A semi-quantitative means of comparison may be necessary, for instance, to decide on priorities for a repair and rehabilitation programme for a structure or a series of structures.

To establish the petrographic examination score, the concrete is examined for the presence and extent of five features that are typical of deterioration by alkali-aggregate reaction. These are :

1. the presence of dark reaction rims around the perimeter of aggregate particles;
2. the presence of white or translucent reaction products in voids or cracks in the concrete;
3. the presence of cracks in the aggregate particles;
4. the presence of cracks in the mortar; and
5. loss of bond between mortar and aggregate.

The scoring system is as follows :

1 = feature present, but occasional
2 = feature occurs fairly frequently
3 = feature present in abundance.

The maximum score, corresponding to the worst state of deterioration, is thus 15.

This approach has been found very useful, but it must be emphasized that the correlation with measured concrete properties is tenuous. Figure 1 for example shows the petrographic examination score for a series of concrete cores, plotted against compressive strength. As the diagram shows, the cores taken from a bridge column show a weak negative correlation, which is to be expected. The cores taken from the foundation pier which supports the column, however, show a positive correlation, if considered in isolation.

(iii) Mechanical Testing of Cores

(a) The selection of core sites will usually bias the results optimistically. For example, a core having a large crack through it will not be taken or tested unless it is to explore the depth of the crack. Although such a core might have zero strength in the laboratory, under field loading the crack may partially close, and the concrete on either side of it carry some stress.

(b) Notwithstanding the benefit of selection, it is recognized that the strength of any specimen depends on its size. (Neville (1956)). Boundary restraints applied by the test machine tend to increase the measured strength of a small specimen. Also, there is a statistically greater chance of including a strength-reducing defect the larger the specimen size.

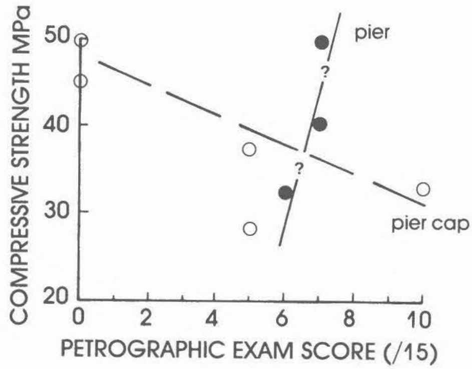

Figure 1: Poor correlation between visual features and strength of concrete

Figure 2 gives some typical results of tests on cores taken from an AAR-deteriorated structure. The data are for the same

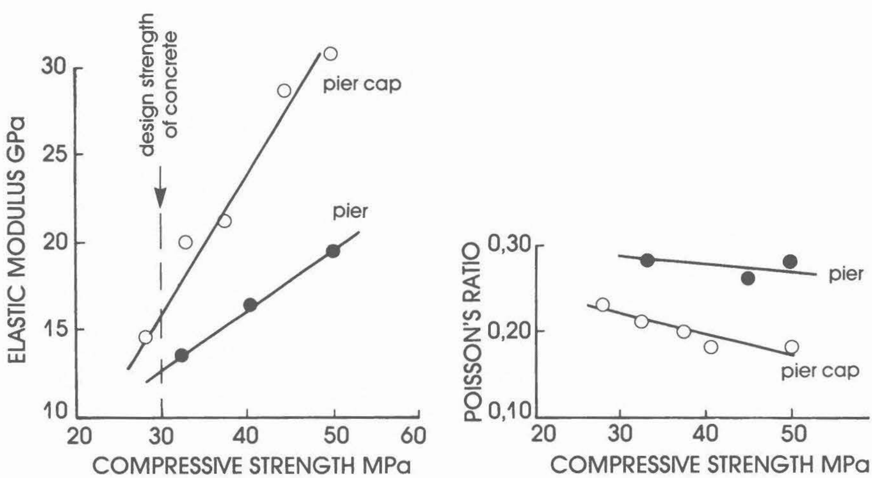

Figure 2: Relationship between Elastic Modulus, Poisson's Ratio and strength for AAR-Affected Concrete.

cores that were described in Figure 1. The results show very clear relationships between compressive strength and elastic modulus and between compressive strength and Poisson's ratio. It will also be noted that the design strength of the concrete was 30MPa, and that only one of the cores tested was below this strength. It is seldom appreciated just how little the compressive strength of concrete is affected by physical disruption. (See also Blight et al (1981 and 1985)).

The applicability of properties measured on realistically selected cores to the performance of a full-scale structure was demonstrated in the only full-scale field loading test on an AAR-deteriorated structure yet to be published (Blight et al (1983)). In this test, the behaviour of the structure under load was correctly predicted before the load test was carried out, on the basis of elastic moduli measured on core samples.

(iv) Load Testing and Observation of In-service Behaviour

Full-scale load testing must be regarded as the ultimate criterion of the safety and serviceability of an AAR-deteriorated structure. If the structure behaves predictably and in accordance with the design requirements, and if strains and deformations are of reasonable magnitude and recoverability, there can be little doubt that structural adequacy has been preserved. Such testing is, however, extremely expensive. In many cases it may be sufficient to instrument the structure, or part of the structure, and observe its behaviour in service, rather than mount a special test to full design load. For example, in the case of the bridge column and its supporting pier referred to in Figures 1 and 2, strain gauges affixed to the pier showed that in normal service, the live load stresses in the pier amounted to a maximum of only 0,4MPa. This is illustrated in Figure 3, which refers to measurements taken during a normal peak traffic period. This information, together with the reassuringly large core strengths was sufficient to demonstrate that the structure remained adequately strong even in its deteriorated condition. Note that the stresses are based on a value of elastic modulus of 30GPa, which according to the data of Figure 2 is a conservatively high value for the pier.

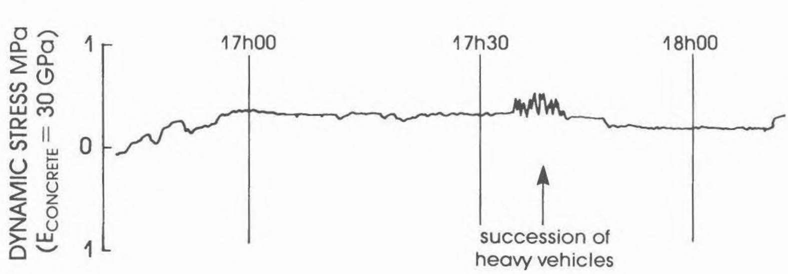

Figure 3: Dynamic strains recorded on pier below pile cap.

To give the reader some idea of the appearance of the concrete described in the three figures above, Figure 4 shows portion of the pier cap with a crack typical of many others present in the structure.

CONCLUSIONS

(i) Ultrasonic pulse transmission is a useful method of assessing the condition of concrete affected by AAR. However, the results of such measurements should be calibrated with reference to a direct physical method such as the examina-

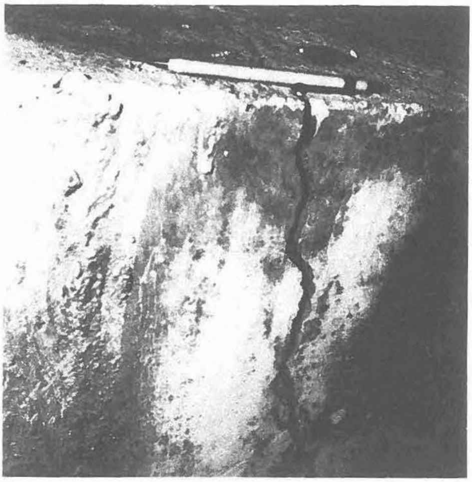

Figure 4: Typical crack in ARR-affected pier cap.

tion of cores.

(ii) The visual condition of cores, quantified by the petrographic examination score, provides a useful means of comparing the state of damage of one structure with another. However, the correlation between the examination score and the strength of the concrete is poor.

(iii) Mechanical strength and stress-strain testing of carefully sited cores provides a good means of assessing the degree of damage to concrete caused by AAR.

(iv) The best means of assessing the extent of AAR damage to a concrete structure is to test-load the instrumented structure, or to measure the strains and deformations suffered by the structure under working load conditions.

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