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ASSESSMENT OF THE DETERIORATION OF AN AIRPORT CONCRETE APRON DUE TO AAR

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ABSTRACT

The paper describes the deterioration due to AAR of an airport concrete apron. Techniques used to identify AAR included visual and petrographic examination and semi-quantitative analysis of reaction products by EDAX. The progress of deterioration was semi-quantitatively assessed by static stress-strain tests and ultrasonic pulse velocity (U.P.V.) tests on cores. Indexes comprising ratios of tangent to secant moduli, and percentage reductions in U.P.V. during testing, appeared to be sensitive to internal damage due to AAR.

1. INTRODUCTION

Much work has been done on AAR mechanisms and identification of reactive aggregates. However, there still remains a need to assess the extent of deterioration of actual structures subject to AAR, and to interpret this in terms of structural safety and serviceability.

Some previous work has addressed the question of the properties of AAR-affected concrete [1, 2, 3, 4]. The problem of deciding on the progress of deterioration can be approached from chemical and thermodynamic viewpoints. Other approaches can include measuring the continuing expansion of samples from the structure [5], or assessment and interpretation of mechanical properties in terms of known values for sound concrete. The work reported here is an attempt at this. Further data needs to be gathered from a wide range of structures.

To this end, a 10 year old concrete airport apron subject to AAR was investigated in order to assess the degree of damage. The concrete apron is located in a near-coastal zone in South Africa, and contains coarse and fine aggregate comprising quartzite pebbles or pebble fragments derived from gravel debris of the Ordovician Table Mountain Group of the Cape Supergroup. Although the cement origin in the mix could not be established, the cement was probably derived from sources known to have high alkali contents (e.g. 0,66 to 0,87 Na_2O equiv.). A general cracking survey of the apron was done, and 5 vertically-drilled cores of 100mm diameter were extracted for laboratory examination (see Table 1 for details).

2. VISUAL AND PETROGRAPHIC EXAMINATION OF CORES

Blight et al [6] have used a scoring method for identifying and classifying AAR in concrete, which involves identifying up to 5 different visual characteristics, viz. (a) dark reaction rims around aggregate, (b) white acid-insoluble reaction products, (c) cracks in aggregate particles, (d) cracks in mortar, and (e) bond cracks between mortar and coarse aggregate. A value of 1 is assigned for each characteristic present, and thus a maximum score of 5 is possible. Table 1 shows that at least 4 of the characteristics were present in some cores. In general, aggregate particles were characterised by the presence of internal elongated open fissures or failure planes, and horizontal circumferential cracks occurred near the base of cores 1 and 3.

TABLE 1 - DETAILS OF CONCRETE CORES

CORE	POSITION AND CONDITION OF PANEL CONTAINING CORE	MACROSCOPIC CHARACTERISTICS (a) (b) (c) (d) (e)
1	Aircraft parking area. Moderate cracking, one full-depth crack through slab.	x ✓ ✓ ✓ ✓ Total Score = 4
2	Aircraft parking area. No visible cracking. Slight edge spalling.	No clear characteristics of AAR
3	Area of slab subject to ponding. General cracking.	x ✓ ✓ ✓ ✓ Total Score = 4
4	Ditto 3. General cracking.	No clear characteristics of AAR
5	Ditto 3. General cracking.	x ✓ ✓ ✓ ✓ Total Score = 4 (but less severe than 1 or 3)

x indicates no clear evidence of characteristic present.

Three random thin sections were prepared for stereomicroscopic and petrographic study from core 5. Petrographically the quartzite aggregate ranges from granoblastic relatively unstrained rock to particles characterised by pronounced mortar-textures and marked undulose extinction effects in individual quartz grains, indicating a highly strained material, as shown in Figure 1.

This figure also shows microfractures filled with a colourless optically isotropic substance. Petrographically similar quartzites were also tested by an independent laboratory and found to be alkali reactive [7].

A sample of the white reaction product in an air void was analysed by EDAX. Typical composition spectra are shown in Figure 2. The analysis showed major silicon accompanied by varying proportions of calcium, potassium, chlorine, (possibly due to near-coastal location or an admixture) and minor sodium.

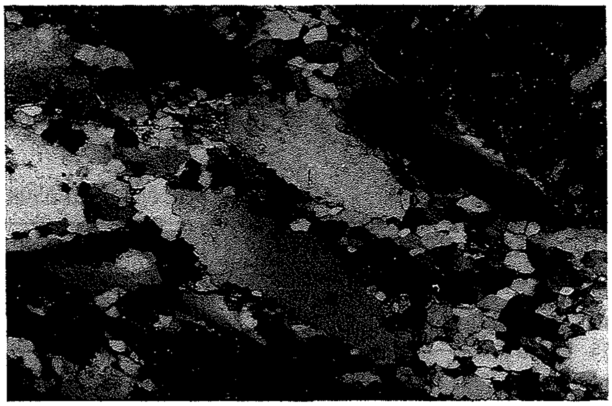

FIGURE 1: HIGHLY STRAINED QUARTZITE PRESENT AS COARSE AGGREGATE PARTICLES (x POLARS, X 30)

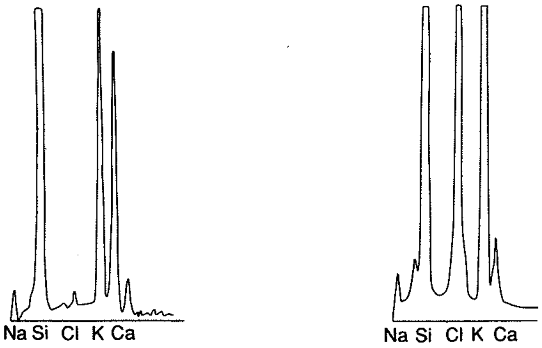

FIGURE 2: TYPICAL COMPOSITION SPECTRA OF 2 SAMPLES OF REACTION PRODUCT

The above examination clearly pointed to the presence of AAR in the concrete apron. What was not clear was how far the resulting deterioration had progressed.

3. MECHANICAL TESTING OF CORES

Static stress-strain tests and ultrasonic pulse velocity (U.P.V.) tests were conducted on cores 1 to 4, to assist in determining the degree of internal damage of the concrete. It has been found that elastic modulus, and to a lesser extent U.P.V., are far more sensitive indicators of damage than compressive strength [1,3]. The cores, which for the stress-strain tests had ground end-faces and aspect ratios of 2:1, were subjected to three loading cycles at a rate of 15MPa/min, and had strain measured on the central 50% of core height using a compressometer rig. The test output was autographically recorded on an X-Y recorder. The same cores were used for U.P.V. testing (40kHz) which was conducted before and after stress-strain testing. Results are shown in Table 2, together with some selected results from cores extracted from a separate bridge structure affected by AAR. Figure 3 shows stress-strain records for cores 2 and 4.

TABLE 2 - RESULTS OF STATIC STRESS-STRAIN AND ULTRASONIC TESTS

CORE		STATIC STRESS-STRAIN TEST				ULTRASONIC TEST		
		Nominal Max Stress (MPa)	Elastic Modulus (E) Values (GPa)			Pulse Velocity (mm/μs)		
			3rd Cycle					
			Initial Tangent (A)	Secant (B)	Index 1 $\frac{(A)}{(B)}$	"Before"	"After"	Index 2 (% Diff.)
1	Apron	12,6	22,9	25,5	0,90	4,250	4,192	1,4
2		10,3	13,4	23,4	0,57	-	4,099	-
3		12,5	17,0	20,9	0,81	4,068	3,899	4,3
4		10,3	24,4	27,2	0,90	4,440	4,434	1,5
a	Bridge	10,3	29,0	32,1	0,90	4,224	4,152	1,7
b		10,3	22,6	27,6	0,82	4,018	3,917	2,5
c		10,4	17,5	19,7	0,89	3,829	3,759	1,8
d		10,4	13,0	16,4	0,79	3,838	3,778	1,6

- Test not conducted.

Core 2 (and to a lesser extent core 3), displayed considerable non-linearity on the second and third cycles of load. Core 3 also exhibited a significant difference between the U.P.V. values before and after static testing, which was not true for cores 1 and 4. The E values and indexes defined in Table 2 are simple measures of material behaviour, and reflect the degree of internal cracking due to AAR. Figure 3 shows that the incipient AAR cracks are "activated" by mechanical stressing during the first load cycle. The same features were noted for the bridge cores.

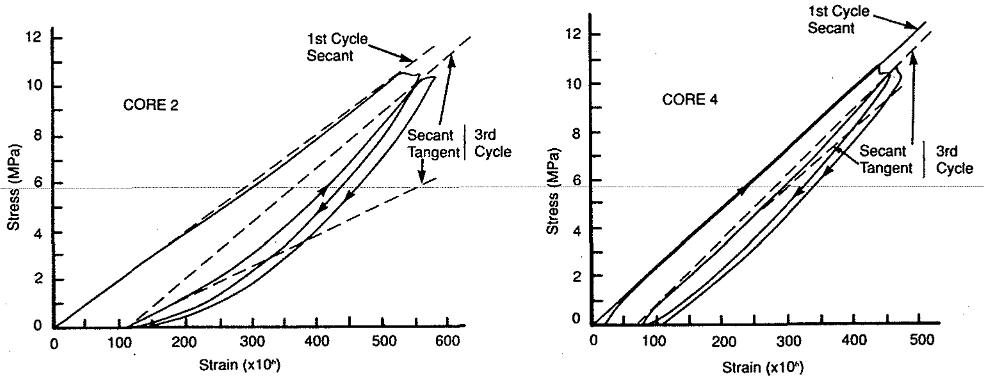

FIGURE 3: STRESS-STRAIN RECORDS FOR CORES 2 AND 4

4. ASSESSMENT AND CONCLUSIONS

The progress of deterioration due to AAR is variable judging from the condition and behaviour of the cores and from the cracking survey. Deterioration is worst in those areas where ponding occurs. This is consistent with the importance of moisture in the progress of AAR.

The data appear to show that deterioration in most parts of the apron is at a relatively early stage. In particular, the mechanical testing of the cores shows very different stress-strain behaviour for different cores, and between the first and subsequent load cycles for a given core. This is also reflected in the U.P.V. values which change most markedly before and after stressing where stress-strain behaviour is more non-linear. The simple indexes defined in Table 2, coupled with the E values, give a quantitative indication of deterioration.

To conclude:

(a) Macroscopic and petrographic examination of AAR-affected concrete does not always provide conclusive answers as to the degree of deterioration.

(b) Mechanical testing of cores (and of full-scale structures) provides a more accurate estimate of the degree of deterioration. E values and indexes comprising ratios of tangent to secant moduli, and percentage reductions in U.P.V. appear to be sensitive to internal damage due to AAR. Further development of these techniques holds promise for assessment of damage due to AAR in concrete.

5. REFERENCES

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