8th ICAAR 1989 KYOTO
8th Internationl Conference
on Alkali-Aggregate Reaction

NEW TEST FOR DELETERIOUS EXPANSION IN CONCRETE

Ross Duggan and Frank Scott

Canadian National Railways
Technical Research Centre
3950 Hickmore Avenue
St. Laurent, Qué., Canada H4T 1K2

1. ABSTRACT

The blame for the premature cracking of concrete, caused by deleterious expansive reactivity between the cement and the aggregates, has in the past been largely attributed to the aggregate portion of the concrete mix. This paper shows that the cement manufacturers must share an equal part of the blame. Aggregates have been in place for millions of years, and it is more logical and economical to change a cement which constitutes roughly 5% of the total cost of a structure than it is to change the local aggregate. For this reason it is very important to be able to rank the cements along with the local aggregates for their combined potential for deleterious expansion in concrete. The Duggan Expansion Test has the ability to rank concretes, cements, aggregates, and effects of admixtures. It can direct the cement manufacturers to manufacture cements that are compatible with local aggregates, and the concrete producers to select materials that, when combined in job mix designs, will produce concretes that are free of deleterious expansion. It allows the concrete user to verify that he is receiving a durable concrete, and the maintenance engineer to determine if his existing structure has any residual potential for deleterious expansion. Test results can be generated in the laboratory within a six-week time period.

2. INTRODUCTION

This test method of measuring concrete expansion in small drilled cores was first presented at the 7th International Conference, Ottawa, Canada, in 1986 [1]. New data shows that the test can rank cements, aggregates, admixtures, concretes and structures for their potential to produce deleterious physical expansions due to chemical reactions. Current standard preventive practices are to select aggregates that have shown no potential for deleterious expansion, mix in a proven pozzolan when reactivity is expected, or choose a low alkali cement. This essentially places blame on the aggregate source leaving the cement source virtually blameless. Much unexplained expansion in concrete has been attributed to the convenient dumping ground of alkali aggregate reactivity.

Tests using this new method show that portland cements having equal alkali contents but from different sources do not behave equally when mixed with the same aggregate. This implies that the cement alkali content (or alkali burden of the concrete) is not the sole factor in determining whether a concrete will be expansive or non-expansive. Concrete producers must be as selective in choosing a portland cement source as they now are in a selecting a known aggregate source. A portland cement manufacturer may have many plants at many locations and each one must be regarded as a different source. Likewise, each type of cement must be regarded as a new source. This report emphasizes the important role the cement portion of the concrete mix has in producing deleterious expansion.

The concretes shown in Figures 1 and 2 exhibit roughly the same amount of cracking, but they are 30 years old and 1 year old respectively.

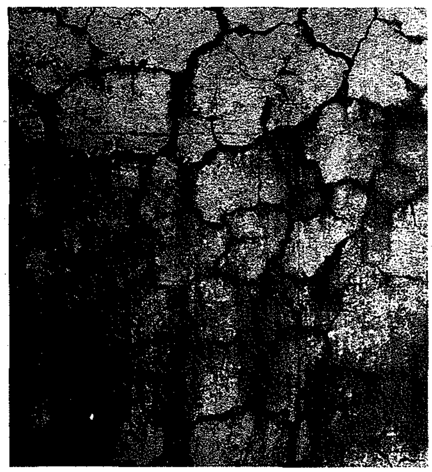

FIGURE 1 Thirty-year Old Concrete

FIGURE 2 One-year Old Concrete

While regional aggregate sources have remained the same over the years, cement manufacturing has changed.

3. SIX WEEK TEST FOR DETECTION OF DELETERIOUS EXPANSION DUE TO CHEMICAL REACTION IN CONCRETE — DUGGAN EXPANSION TEST

Concrete cores 22 mm in diameter are wet drilled from cured laboratory specimens or any existing structures. They are cut with smooth and perpendicular ends to a length of 50 mm. The test procedure involves a cycle of treatment to the concrete cores, the immersion of the cores in distilled water, and the use of a length measurement comparator. Five cores per test are put through the treatment cycle listed in Table 1.

TABLE 1 — DUGGAN CYCLE

Core Treatment	Temperature	Time
Soaking in distilled water	21°C	72 hrs.
Dry heat in oven	82°C	24 hrs.
Air cooled to room temperature	21°C	1 hr.
Soaking in distilled water	21°C	24 hrs.
Dry heat in oven	82°C	24 hrs.
Air cooled to room temperature	21°C	1 hr.
Soaking in distilled water	21°C	24 hrs.
Dry heat in oven	82°C	72 hrs.
Air cooling to room temperature	21°C	1 hr.

After the core samples have been cooled for the last time, a zero reading is taken using a suitable length comparator with an accuracy of .001 mm. The five cores are placed in a plastic jar and submerged in distilled water at 21°C. Prior to each length measurement, cores are allowed to drain on absorbent paper towels until their surface is dry. After measurement the cores are immediately placed back in their respective jar with the same distilled water and topped up with more water if necessary to ensure they remain submerged. Cores are measured at intervals of approximately three days. If the average expansion of the five cores is less than 0.1% at 20 days, the concrete would be considered innocuous or non-expansive.

4. OUTLINE OF THE TESTS

The test program was divided into three parts. In Part 1, Aggregate Ranking, the effect the aggregate portion of the concrete has in the chemical reaction process is examined. Three different aggregate sources were chosen because of their known performance histories. In Part 2, Cement Ranking, the effect the cement portion of the concrete has on the chemical reaction process is examined. Seven different sources of cements are compared to each other. In Part 3, Concrete Ranking, expansions of 21 different concretes made from the aggregates and cements used in Parts 1 and 2 are compared to each other.

5. TEST RESULTS

In Table 2, expansions of concrete cores made from three aggregates and seven cements are shown. These expansions were recorded at the twentieth day after treatment.

TABLE 2 — CONCRETE CORE TEST EXPANSIONS

CEMENT			Percent Expansion at 20 days AGGREGATES				Cement Percent Difference
No. and Ranking	Type	Percent Alkali	A	B	C	Avg.	
1	10	1.17	.042	.065	.204	.104	Ref.*
2	10	1.07	.050	.084	.264	.133	+28
3	10	0.95	.090	.140	.230	.153	+47
4	30	1.00	.093	.160	.382	.211	+103
5	30	1.00	.188	.240	.555	.328	+215
6	30	1.10	.217	.310	.720	.416	+300
7	30	0.95	.480	.530	.780	.597	+474
Average			.166	.218	.448		
Aggregate Percent Difference			Ref.*	+31	+170		

* The least expansive of the Aggregates and Cements were used as references or benchmarks.

Expansions below 0.10% are considered acceptable under this test method.

It can be clearly seen that the expansions of concretes do not correlate with the alkali contents of cements. It can also be seen that differences in aggregates accounted for average differences of concrete expansion of up to 170%, while differences in cements accounted for average differences of up to 474%.

6. AGGREGATE RANKING

In the bar graph of Figure 3, the average expansion for each of the aggregates A, B and C is plotted (results using seven different cements). Aggregate A produced the least amount of expansion and would be ranked as the best or least expansive of the three aggregates. The expansions in Table 1, however, show that this aggregate should be used with only four of the seven cements. While the aggregate is "good", it would be unsafe to label it as "non-reactive". Aggregate B could be mixed with two of the seven cements while aggregate C should not be used with any of these cements. Current petrographic analysis methods would reject aggregates B and C because they are reactive with some cements. Once an aggregate has shown some reactivity in structures, it has historically been labelled as "reactive" and unsuitable for use in concrete.

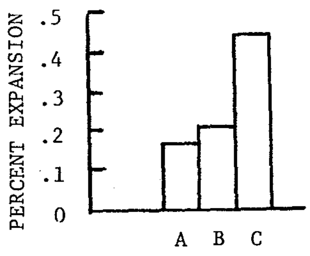

FIGURE 3 RANKING OF AGGREGATES

7. CEMENT RANKING

In the bar graph of Figure 4, the average expansion for each of the seven cements is plotted (results using 3 different aggregates). Cement No. 1 is ranked as the best because it produced the least amount of expansion. From Table 1, cements ranked No. 1 and 2 could be mixed quite safely with Aggregates A and B without causing deleterious expansion. Cements ranked No. 3 and 4 could only be mixed with aggregate A. Cements ranked No. 5, 6 and 7 should not be mixed with these three aggregates (A, B and C).

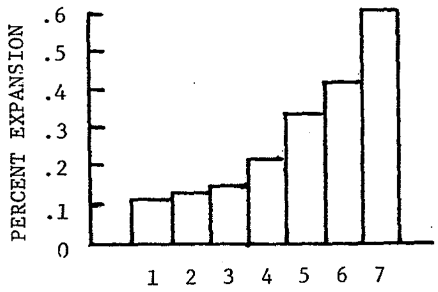

FIGURE 4 RANKING OF CEMENTS

8. CONCRETE RANKING

The ranking of concretes by expansion is shown in the bar graph of Figure 5. Of the 21 concretes made with these seven cements and three aggregates, only six mix designs would be acceptable. The other 15 concretes produced expansions greater than 0.1% at 20 days (the recommended limit for this test method). Two of the three aggregates (B and C) have been deemed reactive by concrete experts using current standard evaluation methods and their opinion is supported by the large number of concrete structures that show expansion. Two mixes, however, made with aggregate A, which they have labelled "non-reactive", show expansion. Also, two mixes made with aggregate B, which they have labelled "reactive", show acceptable expansions.

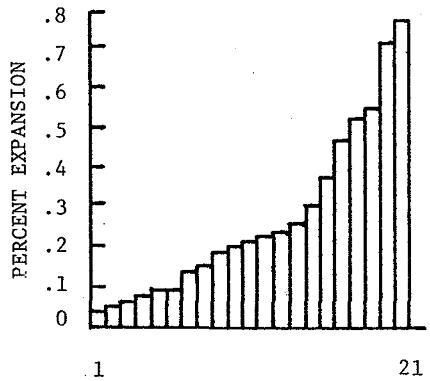

FIGURE 5 RANKING OF CONCRETES

9. CONCLUSIONS

- Aggregates can be ranked using this test method, but they should not be accepted or rejected in isolation.
- Cements can be ranked using this test method, but they should not be accepted or rejected in isolation.
- Concretes can be ranked, and it is only concrete that should be accepted or rejected.
- Complete concrete mix designs, including effects of admixtures, water/cement ratios, and curing procedures, can be evaluated.
- Existing structures can be tested for residual expansion potential.
- Relative expansions of concretes are not governed solely by the alkali content of cements.

10. RECOMMENDATIONS

- The testing emphasis currently placed upon acceptance or rejection of aggregates should be shifted to acceptance or rejection of concrete.
- If incorporated into standards and specifications, this test could be used to prequalify mix designs before concrete is ever poured in a structure.

REFERENCES

[1] Scott, J.F. and Duggan, C.R., Potential New Test for Alkali-Aggregate Reactivity, p. 319, Proceedings of the 7th International Conference, 1986, Ottawa, Canada. Noyes Publications, New Jersey, 1987.