Chloride content of hardened concrete – a flaw in the maritime code BS 6349-1-4

Chris Clear of MPA–BRMCA and chairman of the British Standards Committees for Concrete (B/517) and Concrete – production and testing (B/517/1) and Mike Taylor of the Mineral Products Association discuss the new British Standard for maritime works.

Recent articles in *Concrete*[1] demonstrate that the chemical analysis of hardened concrete, and particularly the determination of chloride content, is a procedure that requires great care to ensure sensible results are obtained.

Round-robin test results

For laboratory-prepared specimens with a target chloride content below 0.05% by mass of cement, the measured values were between 0 and 0.6%. Similarly, for target chloride contents of 0.50 and 0.65%, measured values between 0.4 and 1.4% were recorded, as shown in Figure 1.

Inspection of Figure 1 shows that around 95% of the measured chloride contents exceed the actual values.

Such a disparity between actual and measured values would draw into question any specification that relied on conformity of chloride content of delivered concrete to be based on determinations carried out on the concrete in its hardened state. 'False positives' appear to be the most common results rather than the exception. In practice, such results could lead to a 'fail' for all the concrete in a structure. Unfortunately this potential route to conformity is the recommendation in the British Standard for maritime works, BS 6439-1-4[2].

Maritime code recommendations

BS 6349-1-1-4 Clause 4.4.7 entitled 'Hardened concrete' includes the recommendation that the chloride content be calculated by the procedure given in the British Standard for concrete, BS 8500-2[3]. This procedure is based on summing the chloride content contributions from each of the constituents using the appropriate standard methods: BS EN 196-2[4] for cementitious materials, BS EN 1744-1[5] for aggregates and BS EN 480-10[6] for admixtures. The determination of the chloride content of concrete is part of the production control procedure for concrete conforming to the European and British Standards for concrete, BS EN

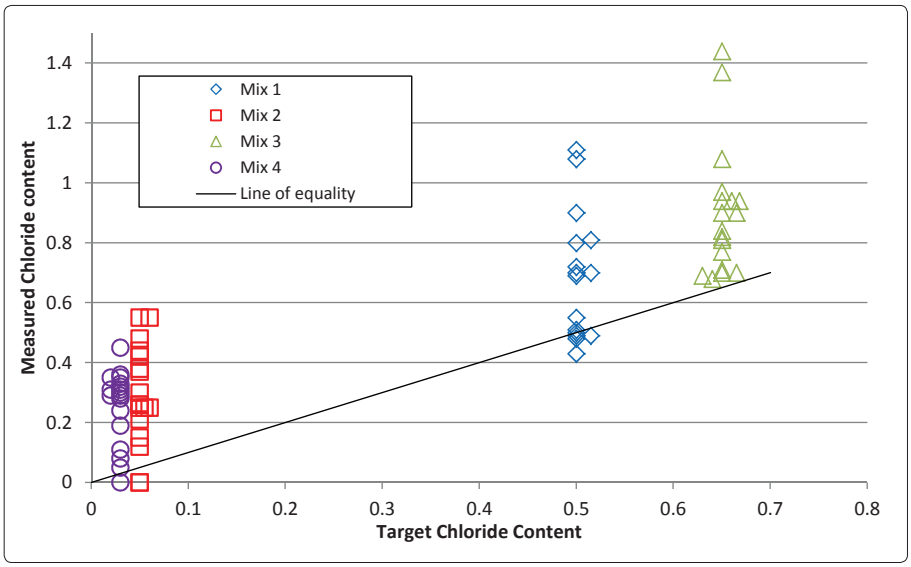

Figure 1: Comparison of actual and measured chloride content, after Barnes and Ingham[1] (see Table 1 for concrete constituents).

Table 1 – Concrete constituents (after Barnes and Ingham[1])

	CEM I	GGBS	Fly ash	Sodium chloride	Aggregates	
					Marine	Limestone
Concrete 1	✓		✓	✓	✓	
Concrete 2	✓	✓			✓	
Concrete 3	✓			✓	✓	
Concrete 4	✓					✓

206-1[7] and BS 8500 respectively. On this basis the BS 6349-1-4 recommendation is that the chloride level should not exceed particular limits, where the limit is 0.20% chloride ion by mass of cement for concrete containing reinforcement or other embedded metal. The determination of chloride content in concrete by summation of any contribution from each constituent has been part of the British Standard for concrete since 1990[8]. These requirements have served the industry well and include the period that has seen the successful and greatly increased use of marine aggregates to meet market demand, particularly in the south and east of the UK.

In addition to the setting of chloride limits in the normal way, and quite inexplicably, BS 6349-1-4 Clause 4.4.7 also recommends that the maximum chloride content of concrete be measured by BS 1881: 124[9] tests on hardened concrete. The limits quoted are: no more than 0.25% chloride by mass of cement and with 95% of all test results less than 0.20%. These limits are difficult to justify because:

- there is no reliably established correlation between the BS 1881 and BS 8500 procedures
- the output from the BS 1881 test method is shown by Barnes and Ingham[1] to be extremely unreliable.

Recommendation

BS 6349-1-4 gives no guidance as to how sampling and testing should be conducted for particular structures, and this means that an unwitting specification may condemn an entire structure based on the results of one or two tests. It is probably safe to assume that the carefully designed round-robin tests as reported in *Concrete*[1] are indicative, which means that if the actual chloride content is 0.20% then 95% of the measured values will exceed this value. Indeed, it appears that if the actual value is 0.05% then over 70% of the measured values will exceed 0.20%. In consequence, specifying the maximum chloride content of concrete on the basis of the chemical analysis of the hardened material is not supportable and the recommendation within BS 6349-1-4 should be withdrawn as quickly as possible. ●

References

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