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Features

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Testing for Durability

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In the past few years our industry has started to specify performance-based mix designs with a focus on durability, rather than the usual practice of targeting strengths.

Before we dig deeper, let's review some of the basic durability concepts. We may often hear that a building has been designed for a life of 50 or 100 years. The concept of "life" in a building can be easily misunderstood. What does this actually mean?

By "life" we mean the Expected Service Life, i.e. the capability of a building to fulfill its intended function without major repairs. We expect that after the expiration of the service life a building might need some major repairs in order to continue operating. In reality service life is always a very conservative estimate and a structure should always exceed it with ease.

In order to ensure the above, we should provide a durable concrete, meaning "a concrete that will be able to withstand the processes of deterioration to which it can be expected to be exposed". Traditionally we ensured durability by increasing strength. Although some relation between higher strength and durability does exist, this is a very expensive way to ensure durability when it works, and in many cases higher strength alone will either be inadequate or impractical to achieve.

These days most international standards organisations have accepted this and have officially introduced the concept of prescribing not only strength but also durability. Both ACI 318-08 (US and other countries, including Saudi Arabia) and EN-206 (replaced both BS and DIN standards, used in the EU and a few other countries) have recognized this and included in their concrete specifications the concept of Exposure Categories and Classes. These categories link the specified concrete with the expected environmental conditions, such as presence of sulfates, contact with water, chlorides and others. Every category/class has specific limitations, usually a limit of maximum water/cement ratio, a strength class, type of cement etc.

The most obvious omission from the Standards is any mention of actual durability testing. Although almost all the tests we use are standardized (either ASTM, EN or BS), there is no mention in any of the above standards of any durability testing or of any test limits on the actual concrete. In the future we might see some limitations but right now this is an indication of how difficult it is to correlate durability testing with real life applications. *

There are different opinions on why the tests are omitted, but I think it is mainly due to a) a lack of clear correlation between service life predictions and test results and b) the accuracy of the tests themselves.

The above two points are the main reason why we haven't seen wider adoption of durability requirements for concrete. There is still not an accepted method for estimating concrete deterioration time (from carbonation, chlorides or

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sulfates just to mention the main 3 forms of attack) related to the mix design used. That is not to say that people haven't tried. There have been some excellent efforts in developing predicting software (google: STADIUM™, DURACON, EUCON™) but they all suffer from similar issues. They require a very large number of scientific input that may or may not be available to the designer, such as the chemical and mineralogical composition of every constituent, or factors connected with cement hydration) and the output is based on theoretical simulations that may not necessarily apply to every structure. In other words, they are very difficult to use and they don't provide answers everyone can agree on.

Still several designers specify concrete for particular projects with a set of durability test requirements. The limits are usually set from previous experience or limited studies and they might differ from designer to designer.

These tests are usually connected with measuring in some way the permeability of the concrete. As most concrete deterioration happens because gas or fluid transport mechanisms are involved, it is always a good idea to limit the permeability of concrete. The Rapid Chloride Penetration Test (RCPT), the DIN (now EN) depth of penetration tests, the BS absorption test by shallow immersion, and the Initial Surface Absorption Test (ISAT) are the main ones used, but many other tests exist as well even if they are employed less frequently. These tests do not test the same transport mechanism and their results have to be taken into account together before we decide on the durability of a specific mix design.

Other tests are concerned with the Heat of Hydration development, freeze-thaw, steel corrosion or carbonation. Although they are not completely disconnected to permeability they should be treated as different aspects of concrete durability.

But how reliable are these tests?

It depends. Needless to say they need to be performed exactly as described in the relevant testing standards, but even then we might have large variations, even between competent certified laboratories.

Let us see a very instructive example:

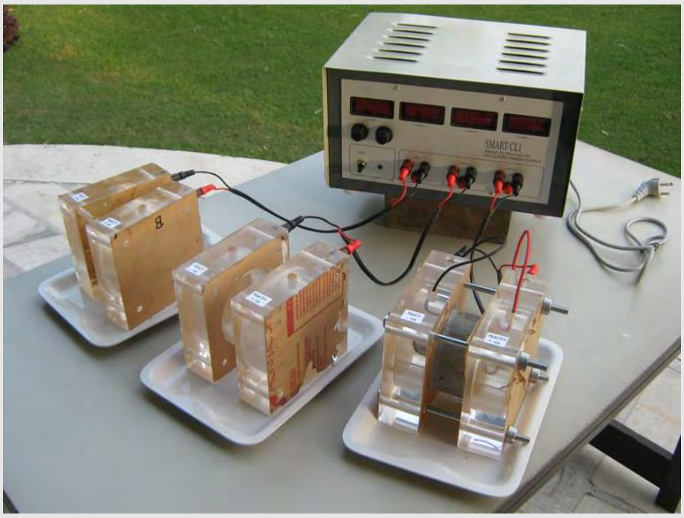
An in-depth study was done in the UAE on a single concrete mix–design to check the variability of durability results.

Test	Standard	Number of results	Mean Value	Standard Deviation	Min-Max Range
Rapid Chloride Penetration (C)	AASHTO T-277	308	437	195	125 - 1325
Water Penetration (mm)	DIN 1048	399	34	22	2.5 - 117.5
Water Absorption (%)	BS1881:122	110	2.2	0.35	1.35 - 3.25

If you look at these numbers, there are significant variations that in the real world would cause a large number of "failures" of concrete. A specifier might put the limit of the water absorption test at 2.5%. From the above data that would mean that around 15% of the test results would fail, *even though we are testing exactly the same samples*. The situation is similar for the RCPT test and worse for the water penetration.

This is not something new. A 1999 paper, written by our very own Willfried Krieg, delivered the most severe criticism of the RCPT test and it is still widely mentioned in international literature.

Similar tests in many different laboratories have come to the same conclusion. Although durability testing is important in today's construction, the actual tests at our disposal produce unacceptably high variations and many false "failures". Sometimes detailed studies end up with conclusions such as these "...the variability shown severely limits the suitability of these tests for commercial projects"



So what to do?

The inclusion of durability testing is the way forward for our industry, despite their accepted issues. Saudi Readymix should be at the forefront of this change, as it will give us a competitive advantage in the market by using our superior know-how and experience and by utilizing our sizable resources.

On the other hand, we might have to deal with less-than-perfect testing methods and unrealistic contractual obligations. Let's see a few ideas of what we can actually do from our side:

- Review carefully the project durability requirements for each concrete class and discuss with the customers before reaching agreement. Are the requirements realistic? Do they really require those limits for the specific project or are they copy-pasted from a previous contract? Real life examples: a requirement for a chloride content limit, which is impossible to reach with local aggregates even in theory. Or a requirement for a very low water absorption value that is only needed for water-tight structures and will only be reached with very expensive admixtures.

- Review the testing methods prescribed in the projects specifications. Inform the customer on the variability of the methods. Water absorption test is usually ok, but on RCPT test we should insist on including a margin of error. According to ASTM C1202 which standardizes the method; it is acceptable for two different laboratories to have a difference of up to 42%! This will be difficult for any customer to accept but we should insist on the inclusion of a margin for low permeability concretes of at least ±300 coulombs. At the other extreme we should fight against tight limits on the water penetration test, as the test is notoriously inaccurate.

- Inspect and supervise the third-party laboratories. We should make certain that the people verifying the quality of our concrete are working to the highest standards. Do they follow the latest version of the relevant standard, without any change or omission? Are their instruments properly maintained and calibrated? Are their technicians proficient enough? Any discrepancies should be recorded, shared and hopefully rectified.

- Check the durability performance of our concrete frequently, as the project is under way. Soon our R&D department will be able to perform these tests internally.

- Use alternative methods of testing. Promote them to customers. The R&D department is successfully using the electrical resistivity test, as an alternative to RCPT. It has a good correlation with RCPT and it allows us to test very early ages and get quick feedback. The IQ-drum can be used instead of full scale hydration testing and can also allow quicker results

- Above all, never consider any test result in isolation. The concrete should be subjected to at least 2 or 3 different tests, repeated several times. Regardless of the inconsistencies of each individual test, the sum of all different tests evaluated together, gives us a fairly good picture of the expected durability of concrete.

Notable exception: The UAE-Roads Dpt-Specification for Roads and Bridge Works does provide limits.