How to Specify Durable Concrete

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The Hot Topic at the NYC Spring 2005 American Concrete Institute Convention was How to Specify Durable Concrete. It was my privilege to have chaired this session, held on Sunday, April 17, 2005, at 7:30 pm. Despite the late hour on a Sunday evening, nearly 100 people came to hear the presentations and participate in the discussions.

The great turnout was due in large part to the three outstanding speakers we had for the session. Dr. Celik Ozyildirim from the Virginia Research Council presented the work that the Virginia Department Of Transportation (VDOT) has done in the research and implementation of durable concrete specifications. Dr. Colin Lobo from the National Ready Mix Concrete Association (NRMCA) presented the opinion of the ready mix industry on how durable concrete should be specified. Tom Ruttura, from Ruttura & Sons Concrete Company, presented the contractor's perspective on placing, finishing, and curing durable concrete. Every segment of the industry, the owner (engineer), concrete producer, and contractor had an opportunity to give their opinions on how to specify and obtain durable concrete.

How to specify and obtain durable concrete is indeed a hot topic. There are many opinions on how to specify durable concrete. "What is durable concrete?" is the first question that must be answered. Well, concrete durability has many facets. We can all agree that we want the concrete to provide the desired service for a long time, perhaps 100 years with little maintenance costs. For the New York City metropolitan area, concrete is durable when cracking, the ingress of chlorides in reinforced concrete, and freeze-thaw deterioration are minimized.

The June 2005 issue of Concrete International contained the findings of a survey on the life expectancy of parking structures. Of the owners and professionals who responded, the majority ranked concrete durability as the most important but, unfortunately, 45% expected their concrete parking structures to last less than 25 years. This is a sad statement on the perceived quality of durable concrete in our country.

Currently, The Port Authority of NY & NJ (PA) is studying the possibility of building a replacement bridge to the Goethals Bridge. We had engaged the services of a consultant, HNTB, known for designing bridges worldwide. One of the discussions was whether to have precast or cast-in-place concrete for the bridge deck. HNTB stated that for cast-in-place decks, they would always recommend a wearing course over the cast-in-place concrete, such as asphalt or a polymer. Their experience is that it is nearly impossible to consistently produce a cast-in-place concrete deck with no cracks or with acceptable cracks. Somehow all of this should tell us that many concrete users had less than desirable experiences with concrete. In order to change this perception, we need to specify and deliver a more durable concrete, and place and cure differently from how it is being done, because obviously too many people had poor experiences.

The Port Authority has concluded that to produce a more durable concrete, we need to go back to the basics by paying more attention to the aggregate size and gradation in order to reduce the cementitious and water content. This alone will reduce shrinkage, thermal cracking, and permeability. The substitution of fly ash and/or slag cement for portland cement will greatly reduce concrete permeability. Of course, all must be verified with competent quality acceptance testing and inspection. If we continue to use the same mix design proportions, placement, and curing procedures, we will get the same results.

Dr. Ozyildirim presented the research and conclusions the VDOT had arrived at in specifying durable concrete, which turned out to be very similar to the findings at the PA. To produce a concrete that will have a low permeability and less tendency to crack, three basic elements must be incorporated in the concrete mix proportion: low cementitious content, substituting fly ash and/or slag cement for portland cement, and relatively low water/cementitious ratio, less than or equal to .45.

It was reassuring that the research at the VDOT and the PA confirmed fly ash and slag cement reduce permeability significantly, and the use of silica fume was not required. This was confirmed by making concrete specimens with various combinations of fly ash, slag and silica fume at various water/cement ratios, and ponding a chloride ion solution on this concrete for over a year in accordance with AASHTO T-259 test method.

With water ponded for one year, it can be clearly seen in *Figure 1* (on page 24) that chloride ions did not penetrate deeper than 10 mm in concrete with coulomb numbers less than 1000. This is impressive data that can be used to design concrete mix proportions for decks exposed to chloride ions.

To reduce the potential for shrinkage and

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cracking, VDOT and the PA's experience is to use fly ash and slag cement with about 600 lbs. of total cementitious material at a water/cementitious ratio of about 0.40 to produce 5000 psi concrete, and to perhaps require this strength in 56 days, not the standard 28 days. Silica fume has been found to produce considerably more cracking in structural decks, thereby reducing the durability of the concrete.

The VDOT and the PA use the Rapid Chloride Test for concrete acceptance where chloride ion and water permeability are of primary concern. VDOT requires less than 2000 coulombs at 56 days; the PA requires less than 1000 coulombs in 120 days. Both agencies had good experiences regarding the repeatability of the coulomb test. Of course, this is based on qualified staff performing the tests.

Figure 2 shows data from a PA project where the coulomb and compressive strength tests were performed. Note that the within test coefficient of variation for the coulomb test was 3.1%, whereas for the compressive strength, it was 4.98%. For this project, the coulomb test results had less variability for within batch samples than the compressive strength results.

Dr. Lobo expressed concern in the use of the Rapid Chloride Ion Permeability Test for acceptance because there are few testing laboratories that can perform the test. In fact, he expressed the concrete producer's concern with the general lack of quality testing, but did not disagree with the technical findings of the VDOT and the PA. Dr. Lobo presented the goal of the NRMCA, which is to have the concrete producers eventually go to a performance-based specification, where the purchaser would give end-result requirements such as no cracking or 100-year service life, and the concrete producers would provide the mix proportion. All agreed that this is a good goal to strive for, but we are not at this point today.

Thomas Ruttura spoke about the problems the contractors have with responding to a variety of different concrete mix requirements. But, he had no real problem working with concrete specifications that used the Rapid Chloride Permeability Test as acceptance criteria. He said contractors want to produce a product that will give the owners the desired performance and service life.

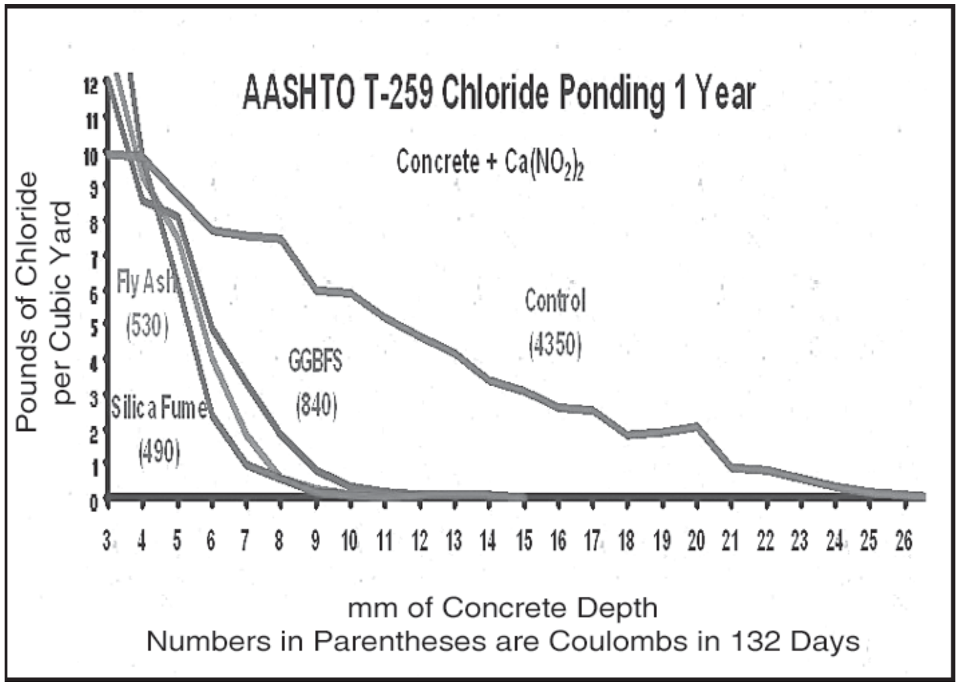

Figure 1.

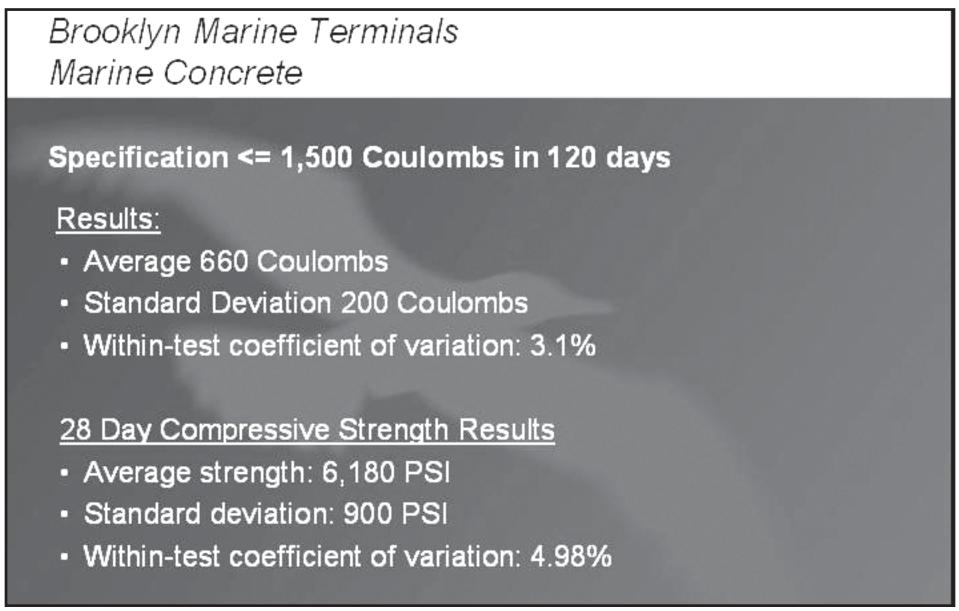

Figure 2.

In summary, durable concrete can be specified to reduce the concrete permeability and cracking potential by:

Reducing the total cementitious content.

Increasing the coarse and total aggregate content by being more attentive to aggregate gradations.

Maintaining aggregate content between 65% - 70% by volume of total mix design.

Reducing water total cementitious ratio to less than 0.45.

Incorporating fly ash and/or slag cement in concrete mix proportions.

These mix design requirements add little, if any, dollars to the cost of concrete. If we are to increase the service life of concrete, our mix design proportions and placement of concrete must change. We can do better!