The Proposed Dotted-Edge Model of Interfacial Transition Zone in Concrete

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BACKGROUND

Concrete is the most commonly used material for construction. Engineers have been looking for concrete which is ever stronger and more durable against aggressive environment, in response to the call for taller buildings, longer span bridges and more elegant structures. Concrete basically consists of cement paste and aggregates. There is ample evidence that the strength and permeability of the concrete against ingress of harmful agents are significantly influenced by the nature of the interface between the cement paste and the aggregates. This interface has unique properties which unfortunately are inferior in nature when compared with the bulk cement paste. As such this interfacial transition zone is widely accepted as a weak link in concrete, and as the third component of concrete besides aggregate and paste.

Since the early eighties, there has been intensified effort to understand this weak link in concrete. A number of models have been proposed to describe this interface. The scanning electron microscope (SEM) was used by many researchers to formulate their models of this very thin interface layer, which has been found to be of the order of 50 to 75 microns thick. The specimens used by many researchers consist of cement paste cast against a flat block of polished aggregate. There has been little attempt to model the interfacial transition zone to take care of the real influence of aggregates. In real concrete, aggregates are of different sizes, usually have very rough surfaces, and often very close to or touching each other. It has been estimated that the mean spacing between aggregate particles in concrete is only 75 – 100 microns. It can thus be argued that all paste in concrete is essentially in transition zones, if the interfacial transition zone exist on all aggregates. This would contradict the concept of the interfacial transition zone as the third component of concrete. It is apparent that there remains questions to be answered, and much to be researched and understood about the nature of the interfacial transition zone in real concrete.

If improvement in the performance of concrete in strength and durability can be made through improvements to the interfacial transition zone, then a better understanding of the interfacial transition zone is something to be desired.

OBJECTIVES AND SCOPE

This thesis deals with a study of the interfacial transition zone. The work in this thesis attempts to address some of the questions mentioned above. The author is aware of the difficulty in precisely characterizing the interfacial transition zone in real concrete. No attempt is made to characterize this zone in terms of precise thickness or porosity. Rather, the main objective of this study is to

1. construct a generic model, based on SEM observations, to best describe the interfacial transition zone in real concrete with well-packed and well-graded aggregates,
2. conduct comparative engineering tests on concrete and mortar produced by removing large aggregates from the concrete, to establish support for the proposed model in respect of the possible difference in nature between the interfacial transition zones of large aggregates and those of fine aggregate particles,
3. study the influence of mix proportion, age and curing temperature on the interfacial transition zone, and
4. relate the test results with the SEM observations to provide a microstructure explanation for the engineering properties.

The scanning electron microscope was used as the primary tool to study the nature and characteristics of the interfacial transition, by analyzing over 300 images on concrete specimens of different strength grades, cement replacement levels of pulverized fuel ash, curing regimes and test ages. Strength tests, mercury intrusion porosimetry tests and chloride permeability tests were used to match the engineering properties with the SEM observations, and to establish support for the proposed model. These tests were aimed to establish the significance of the interfacial transition zone of aggregates larger than 5mm. Variables of the tests included the water to total cementitious content (or binder) ratio, from 0.44 to 0.55, replacement level of pulverized fuel ash (PFA), from zero to 25%, initial curing temperature, from 27°C to 95°C, and age, from 28 days to 2 years.

RESULTS AND THE PROPOSED MODEL

Results of the SEM image analysis on over 300 images show that the interfacial transition zone is not a uniform and continuous layer over the aggregate. There are numerous local microstructure flaws in the form of local zones of high porosity and cracks on the aggregate surface. Around two thirds of these flaws are in local confinements. About half of these confined flaws occur in local depressions of zones of trapped air and local initial high porosity, which is normal in the concrete making process. The other one third are local bands of flaws on the aggregate surface. Based on these observations, the author proposes that a Dotted-edge Model would best describe the interfacial transition zone. The model proposes that numerous local microstructure flaws in the form of local zones of high porosity and cracks on the surface of the aggregate constitute the weak interfacial transition zone. These flaws can be classified into 4 types, namely the ‘cornered-zone’, ‘sandwiched-gap’, ‘pocket-gap’, and ‘local-band’ type. The first occurs within a local zone cornered by more than 2 aggregates including the larger aggregate. The second occurs within the narrow gap between the larger aggregate and a small aggregate within 100µm away. The third occurs in local depressions of up to 100µm depth on the aggregate surface. The last type is simply a local band of flaw on the aggregate surface. These flaws might be the consequence of local insufficient compaction to zones of trapped air and local initial high porosity, which is normal in the concrete making process. By nature, these types of flaws might not exist on very small aggregates. Also by nature they would affect concrete properties. The test results in this study are consistent with these propositions.