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PERFORMANCE STUDIES OF SYNTHETIC AGGREGATE CONCRETE

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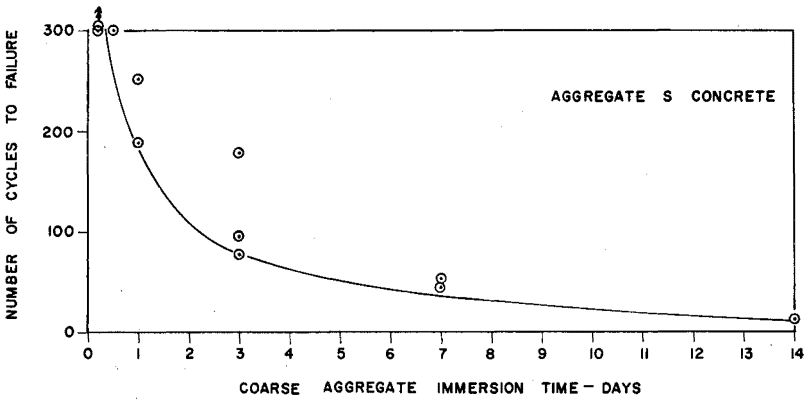

Effect of Aggregate Prewetting on Concrete Durability

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Performance Studies of Synthetic Aggregate Concrete

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The overall objective of this phase of the study is the development of a recommended synthetic aggregate classification system and performance standards for synthetic aggregate portland cement concrete. Essentially, what this objective entails is the answer to the following question: What acceptance criteria and quality control measures must be taken to insure that synthetic aggregate concrete, when used in a highway pavement or structure system, will perform satisfactorily throughout the system's service life?

This research study included three separate experiments—physical durability, chemical durability, and mechanical durability. Five selected commercially produced and eight TTI kiln-produced lightweight aggregates were used in the physical durability experiment. Absorption characteristics and porosity values were determined for each of the aggregates. A total of 69 batches of concrete using these coarse aggregates and natural sand were mixed and tested in accordance with ASTM C290. Various degrees of saturation of the coarse aggregates at the time of mixing were obtained by immersing them in water for periods ranging from 6 hours to 180 days.

The following specific conclusions have been drawn from the data presented:

1. The rates at which the lightweight coarse aggregates studied in this investigation became saturated when given free access to water were greatly different for different aggregates.

2. The resistance of structural lightweight concrete to freezing and thawing as measured by ASTM C290 was greatly influenced by the degree of saturation of the coarse aggregate at the time of mixing.

3. For the concretes investigated, the critical degree of saturation of the coarse aggregate (i.e., the degree of saturation beyond which the resistance of the concrete to freezing and thawing decreased rapidly) at the time of mixing was found to be about 0.25.

4. The length of immersion time required to produce a degree of saturation of 0.25 ranged from about 30 minutes for aggregate D to about 3 days for aggregate R.

Experiments on chemical durability centered upon the detection and possible effects of deleterious substances likely to be present in synthetic aggregates made from clay or shale. Among these are "underburned" clay minerals, lumps of lime and of anhydrite, decomposable sulfides, and organic matter.

Clay minerals incompletely converted in the rotary kiln into more resistant silicates can again take up water, with accompanying expansion and disintegration of the aggregate particle and probable cracking of the adjacent concrete. Such "underburned" clay can be detected by study of thin sections of individual aggregate particles under the petrographic microscope. It can also be revealed by the X-ray diffraction pattern of the powdered aggregate after suitable preparation of the sample. Simpler tests, such as the boiling of the aggregate in a pressure cooker reported in Research Report 81-5, are being further studied.

Lumps of lime (CaO) and of anhydrite ($CaSO_4$) may be formed in the rotary kiln from segregations of calcium carbonate or gypsum in the raw clay. They react with water with considerable expansion. It was found that lumps of lime reacted so rapidly that they disintegrated during the mixing of the concrete, but that lumps of anhydrite hydrated more slowly and caused swelling and distortion of concrete test bars. It seems probable that many of the "popouts" attributed to lime are actually caused by anhydrite.

All raw clays containing pyrite or marcasite burned in the rotary kiln were found to yield aggregates giving positive tests for sulfides decomposable by dilute acids, although none of the aggregates analyzed contained as much as 1% sulfide sulfur. Such sulfides (principally FeS) are known to oxidize on wetting and drying in air with the formation of sulfuric acid, which attacks concrete.

In order to magnify the effects of these slow reactions for purposes of study, aggregates containing artificially high (39%) concentrations of FeS were prepared in a laboratory furnace. Samples of these aggregates were placed in solutions of various pH, some with and some without pieces of steel, and subjected to several cycles of wetting and drying over periods of one to three months. Oxidation, and corrosion of the steel, took place even if the solution was originally alkaline, and these effects were much more pronounced in calcium hydroxide than in sodium hydroxide.

On the other hand, samples of these same high-sulfide aggregates were cast in blocks of concrete and steamed daily for several weeks. No appreciable disintegration of the surrounding concrete was found.

It seems probable that oxidation of the sulfide may do no harm as long as the surrounding concrete remains sufficiently alkaline to neutralize the acid formed. However, the long-term effects are still undetermined, and testing of synthetic aggregates

for sulfide is recommended, so that the engineer may be aware of the possibility of harmful reactions in concrete exposed to the weather.

Considerable organic matter is present in some dark clays and shales. Strong exotherms in the differential-thermal-analysis curves obtained on some black commercial aggregates suggest that under some operating conditions the organic matter is not completely burned off in the rotary kiln. However, this condition was not encountered in the TTI experimental kiln, and no particular study of organic matter was made in this investigation.

The mechanical durability program was designed as a pilot study of the abrasion resistance characteristics of synthetic aggregates. The test used in the investigation was ASTM C418-67T, "Method of Test for Abrasion Resistance of Concrete (Tentative)." This test measures abrasion in terms of the volume of material eroded by a stream of standard size sand particles, blasted onto a specified surface area. Laboratory tests were performed on specimens made with four commercially produced synthetic aggregates and one commercial natural gravel aggregate. All laboratory tests were performed on sawn surfaces to expose the aggregate and therefore amplify the effects on the aggregate. Reproducibility of the method in terms of coefficient of variation was found to vary with moisture content of the specimens. The results obtained on specimens soaked 24 hr. prior to testing (as specified in ASTM C418-67T) were more consistent than those obtained on air dry specimens. There was no significant difference in the performance of the synthetic aggregate concretes tested. However, they all exhibited higher losses than the natural gravel concrete. The cement factor of the concrete did not significantly affect the results obtained.

Core specimens were obtained from three locations on limestone aggregate concrete pavements which exhibited satisfactory and unsatisfactory in-service performance. At each location cores were taken in the wheel path and at the pavement edge where the surfaces at the edge were undisturbed by traffic. Results indicate significantly more wear on specimens from the pavement edge at location 1 (an area exhibiting excessive wear in the wheel path), than on all other cored specimens. These results indicate that the test is capable of distinguishing between a concrete surface that will perform well under traffic and one that will not.

Loss measured on the original surface of the unsatisfactory pavement was of the same order of magnitude as the loss measured on the synthetic aggregate concrete. It follows from these results that if synthetic aggregate is exposed in a concrete pavement surface (as it was in these laboratory tests) it may abrade under traffic wear. The test results indicate that the test could be useful in evaluating surface quality in terms of wear under traffic.