ABSTRACT

Desta, Belayneh B. Ph.D., Purdue University, December 2015. Determination of D-Cracking Resistance of Carbonate Concrete Aggregates by the Hydraulic Fracture Test (HFT) Major Professor: Jan Olek.

Concrete pavements containing coarse aggregate derived from certain types of sedimentary rocks, mainly limestone and dolomite, and exposed to a freeze-thaw (FT) environment may develop a series of closely spaced parallel cracks (D-cracks) located near the transverse and longitudinal joints. D-cracking resistance of aggregates is influenced by its microstructural properties and mineralogy. However, it is still not fully understood how each of these factors relates to FT durability of the aggregate.

The main objective of the study was to assess the influence of mineralogy, crystal/grain size, type of porosity, and content of non-carbonate minerals on D-cracking resistance of coarse carbonate aggregates quarried in the state of Indiana. The D-cracking resistance of aggregates was evaluated by two methods: (a) standard Indiana Department of Transportation (INDOT) freeze-thaw test (ITM210) performed on concrete beams containing the aggregate in question and (b) modified Hydraulic Fracture Test (HFT).

Eighteen sets of coarse aggregate samples were collected from fourteen quarries in the state of Indiana. The samples included aggregates from different geological formations, with a range of D-cracking performance characteristics: durable, non-durable and variable (or unknown). In addition to previously mentioned D-cracking resistance evaluation, representative samples from each of the aggregate sources were thoroughly characterized with respect to their mineralogical and porosity characteristics by performing such tests as: specific gravity, absorption, determination of acid insoluble residue, X-Ray powder diffraction (XRPD), thermo-gravimetric analysis (TGA), thin section petrographic analysis, dynamic vapor sorption analysis (DVS), scanning electron microscope (SEM) analysis, and inductively coupled plasma optical emission spectroscopy (ICP) analysis. An attempt was then made to relate the results of these tests to aggregate D-cracking performance, in order to identify how it is influenced by the basic characteristics of the source material. The results of the basic characterization tests revealed

that the aggregates used in the study belonged to one of the three different mineralogical categories: (a) calcite (limestone), (b) dolomite, and (c) dolomitic limestone. The D-cracking resistance (FT durability) of dolomite aggregates is influenced by the type of its porosity (interparticle, intercrystal, channel porosity etc.), the size of crystals and the presence of non-carbonate minerals such as pyrite and microcrystalline quartz. The relative proportions of the carbonate mud matrix and the grains (fossils) influence the FT performance of calcite (limestone) aggregates. Specifically, limestone aggregates containing relatively high (more than 90%) amounts of carbonate mud matrix tend to be not FT durable. Similarly, dolomite aggregates consisting mainly of small (less than 50 microns) crystals tend to have low D-cracking resistance. On the other hand, dolomite aggregates with porous microstructure are FT durable. The test results also showed that aggregates having large (over 25%) percentage of fine (below 80 nm) pores tend to be susceptible to FT problem. Finally, the study also revealed that the presence of clay and microcrystalline quartz in the intercrystalline pores negatively impacts the freeze-thaw resistance of aggregates.

Statistical analyses were performed to develop linear regression models to predict percent dilation and durability factor (DF) of the freeze-thaw test (ITM210) using the variables obtained from the modified HFT results. The models developed in the study predicted the FT performance of the aggregates with high certainty. The use of the modified HFT equipment developed during this study, combined with the test procedures and analysis methods described in this thesis will allow for reduction of the testing time required to assess the D-cracking resistance of carbonate aggregates quarried in Indiana from the current 90-days (as per ITM210 test method) to 8 days.