DETERMINATION OF ACCEPTANCE PERMEABILITY CHARACTERISTICS FOR PERFORMANCE-RELATED SPECIFICATIONS FOR PORTLAND CEMENT CONCRETE

PROBLEM STATEMENT

The Florida Department of Transportation (FDOT) wishes to make the transition from prescriptive specifications to more flexible performance specifications. A necessary step in developing a performance-related specification for Portland cement concrete is in the selection of the acceptance quality characteristics. For structural concrete, performance is usually defined in terms of strength and durability. Strength is measured by testing cylinders in accordance with AASHTO T 22. This test is considered to be a representative indicator of strength in the field. Durability, however, is a more difficult issue and its measurement more complicated.

OBJECTIVES

The primary objective of this research project is to test concrete samples from FDOT projects around the state of Florida using a procedure designed to indicate a particular concrete permeability to the chloride ion. This test is known as the Rapid Chloride Permeability (RCP) and has been required by FDOT for Class V special concrete. Results of this testing will be compiled for all classes of concrete and statistically analyzed in order to make recommendations to the FDOT for maximum allowable test values for each class of concrete. This will guide the FDOT to determine threshold values for each class of concrete for the purposes of acceptance and payment. The second objective of this research was to determine if a correlation exits between RCP and Surface Resistivity test for the possible future replacement of the RCP test by the Surface Resistivity test. Finally, taking into account that the RCP test is slow and laborious and that its replacement by the Surface Resistivity test remains a possible alternative for the future, the third objective of this research was to make recommendations to improve the current procedures of the RCP test.

FINDINGS AND CONCLUSIONS

Permeability of concrete is believed to be the most important characteristic of concrete that affects its durability. The principal result of the intrusion of chloride (i.e., salt-water) into concrete is the corrosion of the reinforcing steel. Once this occurs, the structure will no longer maintain its structural integrity; the lifespan is reduced, and the general safety of the public is severely degraded. It is increasingly apparent that for many concrete members, the ability of the concrete to resist chloride penetration is an essential factor in determining its successful performance over an extended period.

More than 500 sets of samples were collected from concrete being placed on FDOT projects in all eight FDOT geographic districts. Each set consisted of three 4-inch by 8-inch cylinders, which were trucked to the State Materials Office (SMO) in Gainesville for testing. AASHTO T 277 (ASTM C1202), “Standard Test Method for Electrical Indication of Concrete’s Ability to Resist Chloride Ion Penetration,” was used to determine the relative permeability of the concrete samples. At the end of the six-hour rapid permeability test, coulomb values representing the total current passed through the concrete slices over the testing period were obtained. The total charge passed in coulombs correlates with the resistance of the specimen to chloride ion penetration. These values have been shown to be representative of the chloride ion permeability, which is an indirect indication of the permeability of concrete.

An alternative nondestructive test to the RCP test is the Surface Electrical Resistivity test, which uses a Wenner 4-probe array and a small alternating current to produce instantaneous readings. The readings are returned by a data acquisition unit as an indication of the concrete's ability to conduct current. This test was also applied to the samples in order to reveal a relationship between the two tests (i.e. RCP and Surface Resistivity tests).

Pozzolanic content determined by both observation and statistical analysis proved to have the single greatest effect on the sample performance. In a comparison of Fly Ash and Blast Furnace Slag, as pozzolanic materials, Blast Furnace Slag concrete performed better during the duration of this project. However, Silica Fume concrete outperformed all other categories. These findings were established by the results of the RCP test and supported by the results of the Surface Resistivity test.

No other characteristic seemed to have a consistent effect on RCP or Surface Resistivity results. The two most commonly quoted factors in the literature were the water / cementitious materials ratio of the mix and the mix's type of coarse aggregate. However, neither of these factors affected the results consistently or in any other way served as a basis on which to make a claim, positive or negative.

Several different statistical tools (confidence level, coefficient of variation, and Student's t-value) were employed in the determination of the recommended maximum allowable values for the RCP test for the basis of acceptance and pay by FDOT. Tables were provided that show recommended values for the different concrete classes. Maximum allowable values were identified by their pozzolanic identity and were provided at several different levels of confidence.

Correlation between the RCP test and the Surface Resistivity test was presented by individual concrete class as well as by the entire sample population for the two testing dates (28- and 91-day). The two tests showed a strong relationship, with the 28-day test correlating more closely than the 91-day test. The 28-day test for the entire sample population demonstrated an R^2 value of 0.9481 (correlation coefficient of -0.974), and the 91-day test showed an R^2 value of 0.9321 (correlation coefficient of -0.965); thus, both are significant at the 95% level of confidence. The Surface Resistivity test value ranges equivalent to those provided in the AASHTO T 277 standard for the interpretation of RCP test results were determined using the conversion equations revealed by power trendlines.

Two alternatives were tested to replace the epoxy step in the sample preparation. One was to use ordinary duct tape and the other was to use a Permatex® product intended for stopping leaks on automobile engines (available at NAPA Auto Parts stores). The spray sealant Permatex® outperformed the tape as an alternative. It also outperformed the epoxy in terms of saving time, which is important with regard to cost but even moreso with samples that need to be run immediately. The significantly reduced set time of the spray (less than one hour) is quite an asset over the epoxy, which takes approximately 8 hours to cure (depending on ambient conditions), enough so as not to be affected during desiccation. The spray alternative showed no signs of difficulty during the testing procedure (i.e. leaking), and it has great workability. The spray seemed to be a more desirable choice in all categories.

BENEFITS

This research provided maximum allowable RCP test values for each class of concrete, which is needed for FDOT to develop a performance related specifications for Portland cement concrete. The results will guide the FDOT in the development of threshold permeability values for each class of concrete for the purposes of acceptance and payment. The research also yielded a refined test procedure that would reduce expense and turn-around time for the AASHTO T 277 permeability test. In addition, a good correlation between RCP and Surface Resistivity test results, found in this research, can provide the confidence to accept the Surface Resistivity readings as a measure of in-place durability.

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