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16. Abstract

In Texas, rigid (or portland cement concrete) pavements and flexible (or asphaltic concrete) pavements are most often constructed using crushed limestone and/or siliceous river gravel as the coarse aggregate. Project 1244, sponsored by the Texas Department of Transportation (TxDOT), evaluated the performance of rigid pavements and flexible pavements made with siliceous river gravel and with crushed limestone as coarse aggregates, in order to develop specifications that obtain equal and adequate performance from the different aggregates.

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EFFECT OF AGGREGATES ON PAVEMENT PERFORMANCE

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Research Report Number 1244-13F

Research Project 0-1244
Evaluation of the Performance of Texas Pavements Made with Different Aggregates

conducted for the
Texas Department of Transportation
in cooperation with the
U.S. Department of Transportation
Federal Highway Administration
by the

CENTER FOR TRANSPORTATION RESEARCH
Bureau of Engineering Research
THE UNIVERSITY OF TEXAS AT AUSTIN

February 1995

IMPLEMENTATION STATEMENT

This report investigates and implements improvements to the analysis of jointed concrete pavement using research undertaken for Projects 1244 and 1169. A rigorous analysis of early-age reaction of the pavement to the environment has been combined with a simple vehicular loading analysis to predict critical distresses in an analysis procedure presented in program JRCP-6. Applications for the program include the analysis of jointed concrete pavement for a site-specific or individual case, or evaluation of the effect of input variables (such as coarse aggregate type) on the performance of jointed concrete pavement in general. While the report includes limited calibration and analysis logic checks, a more intensive investigation is recommended. Finally, the analysis procedure developed in this report may be used for future development of a design program or design procedure for jointed concrete pavement. An example of a design problem is presented for future development.

Prepared in cooperation with the Texas Department of Transportation and the U.S. Department of Transportation, Federal Highway Administration.

DISCLAIMERS

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Research Supervisor

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SUMMARY

In Texas, rigid (or portland cement concrete) pavements and flexible (or asphaltic concrete) pavements are most often constructed using crushed limestone and/or siliceous river gravel as the coarse aggregate. Project 1244, sponsored by the Texas Department of Transportation (TxDOT), evaluated the performance of rigid pavements and flexible pavements made with siliceous river gravel and with crushed limestone as coarse aggregates, in order to develop specifications that obtain equal and adequate performance from the different aggregates.

CHAPTER 1. EXECUTIVE SUMMARY

BACKGROUND

Since 1974, visual condition survey data have been collected on rigid pavements across Texas. Analyses of these data, supplemented with field experience, have shown that pavements constructed with siliceous river gravel (SRG) perform differently from those constructed with limestone (LS) coarse aggregates. For example, given similar designs, pavements constructed with SRG show crack spacing patterns that are closer and more random than pavements built with LS aggregates (primarily owing to the higher thermal expansion of SRG). Consequently, pavements constructed with SRG aggregates experience more spalling and a greater number of punchouts than those constructed with LS aggregates.

In 1986, Project 422 was initiated to study aggregate-induced performance differences. This project, which tested concrete using eight different coarse aggregates commonly used in Texas pavements, specifically sought to determine elastic modulus, tensile strength, compressive strength, drying shrinkage, and thermal coefficient of expansion. Using data from lab testing, a mechanistic computer model (CRCP) was applied to determine the amount of steel reinforcement needed to obtain equal and adequate performance from the different aggregate types in any area of the state during any placement season. These steel designs were later verified in a field study.

In 1989, Project 1244, the successor of Project 422, investigated field sections built in Houston, Cypress, and Texarkana to verify and improve the performance models and reinforcement designs. Test sections were placed using various steel designs, aggregates, and aggregate blends; they were also cured with various techniques. These sections were then monitored for the duration of the project. Throughout the project, meetings were held with an advisory committee that included industry professionals.

This document summarizes the findings and recommendations of Texas Department of Transportation (TxDOT) Research Projects 422 and 1244. Project 422, "Coarse Aggregate for PCC — Pilot Study Evaluation," which began in September 1986 and which produced two reports, was conducted by the Center for Transportation Research (CTR). In 1989, the project, renumbered Project 422/1244, became a joint effort of CTR and the Texas Transportation Institute (TTI). Project 1244, "Evaluation of Performance of Texas Pavements Made with Different Coarse Aggregates," ended in August 1994; the study findings are expected to produce a total of 16 reports, 12 of which have already been submitted to TxDOT as preliminary or final reports at the time of this writing.

OBJECTIVES

The objectives of Project 1244 were as follows:

(1) Study and Design Objectives

- (a) Quantify performance of different coarse aggregate types
- (b) Develop performance models considering aggregate type
- (c) Develop pavement design and analysis tools using the new models

(2) Quality Control Objectives

- (a) Develop an aggregate classification system
- (b) Develop specification information

(3) Interact with industry to recommend improvement in construction materials and practice

(4) Implement findings in cooperation with TxDOT

SUMMARY

Findings to date from the two projects may be summarized as follows:

(1) Pavements constructed with SRG perform differently from those constructed with LS aggregates, particularly with respect to early-age crack spacing, rate of failure development, and spalling.

(2) Using the rigid pavement database, models were developed to predict the rate of failure development with cumulative traffic loading for different reliabilities and construction conditions.

(3) Pavements placed early in the day develop more longitudinal cracks owing to peak heat of hydration coinciding with peak ambient air temperature.

(4) Concrete properties for blended aggregates vary in weighted proportion to the properties of the two aggregates used.

(5) Models were developed to predict concrete properties from the chemical constituents of the coarse aggregate. These have been incorporated in the design program "CHEM2."

(6) Using information from the monitored test sections and from the 20-year database, we developed and calibrated improved failure curves. These improved curves have been included in the analysis tools "CRCP8" and "JRCP6."

(7) A comprehensive design program, CRCPAV, was prepared using output from a factorial analysis run with the analysis programs.

(8) Early-age saw cutting can successfully control crack patterns.

(9) Cotton mats provided the best water retention, followed by plastic sheeting, single membrane, and double membrane. However, cotton mats were the most expensive and time-consuming option.

(10) PCC pavements fail in tension (i.e., although the tensile and compressive stresses are approximately the same magnitude, the compressive strength is much greater than the tensile strength).

(11) No relationship was found between the flexural and compressive strength of the tested aggregates.

(12) A useful relationship was found between the flexural and tensile strength of the tested aggregates.

(13) Subbase type plays an important role in pavement performance. A cement-treated base had the highest friction, followed by flexible base, asphalt stabilized base, lime-treated clay, and untreated clay.

RECOMMENDATIONS

Based on the findings of the combined studies, we recommend that a new construction specification be established for rigid pavements. The specifications should include the following:

(1) Rather than primarily method based, the specifications should be primarily performance based.

(2) The aggregate classification system should be used to develop aggregate categories, based on the engineering properties of the aggregates used in the concrete mixture. The proposed categories are as follows:

a. Coefficient of thermal expansion < 4.0 $\mu\varepsilon$ and a fracture toughness at 1 day > 900 psi $in^{1/2}$

b. Coefficient of thermal expansion > 4.0 but < 6.0 $\mu\varepsilon$ and a fracture toughness at 1 day < 900 but > 700 psi $in^{1/2}$

c. Coefficient of thermal expansion > 6.0 but < 8.0 $\mu\varepsilon$ and a fracture toughness at 1 day < 700 but > 500 psi $in^{1/2}$

d. Coefficient of thermal expansion > 8.0 $\mu\varepsilon$ and a fracture toughness at 1 day < 500 psi in $^{1/2}$

(3) Aggregates in a concrete mixture may be blended to improve the engineering properties of the mixture.

(4) Summer vs winter placement:

Summertime Placement (air temp. < 90° F)

- Random crack control can be enhanced by skewing the transverse reinforcement (at a 60° angle) to minimize the incidence of transverse cracking at the location of the transverse bar for sections using LS coarse aggregates.

- Positively control the crack spacing in pavement sections consisting of SRG coarse aggregates (including blends of 50 percent or more of SRG coarse aggregate) with swallow, transverse saw cut notches (made with early-aged saw cut method) placed at specified intervals in the pavement surface. Also, use the transverse steel (in an unskewed configuration) to supplement induction of the crack at the surface notches. Reduce the percent of steel to at least the 1989 standards to take advantage of the reduced fracture toughness by mixtures containing 50 percent or more of SRG coarse aggregates.

- Use as a minimum a combination of any two of the following curing methods:

  a. One coat of Type I curing compound
  b. One coat of Type II curing compound or
  c. Polyethylene sheeting

Summertime Placement (air temp. > 90° F)

- Same as above, but use two coats of Type II compound for LS placements, and polyeythlene sheeting (with a coat of Type I compound) for SRG placements.

Winter Placement

- Use one coat of Type I and Type II curing compound, but adjust the percent of fly ash to prevent long delays in initial set times.

- Use early-aged transverse saw cutting to minimize the incidence of delamination in SRG placements in combination with mid-depth crack inducers (i.e., alignment of double layer transverse steel with the saw cut notches). SRG placements should use inducers (along with the 1989 CRCP steel standard) placed at mid-depth, since crack initiation is much greater at this location in the slab under winter placing conditions.

(5) The indirect tensile test should be used for the quality control test (instead of the compressive strength test).

(6) Contractor payment should be performance based, using the new specifications.

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