LTRC Technical Summary Report 451

LTRC Proj. No. 07-2C ~ State Proj. No. 736-99-1450

December 2011

Louisiana Transportation Research Center

4101 Gourrier Ave., Baton Rouge, LA 70808

# Determination of Coefficient of Thermal Expansion Effects on Louisiana's PCC Pavement Design

## Introduction

The coefficient of thermal expansion (CTE) has been widely considered as a fundamental property of Portland cement concrete (PCC) pavement but has never played an important role in the thickness design procedure for PCC pavement until recently. In the Mechanistic-Empirical Pavement Design Guide (MEPDG), developed through NCHRP 1-37A project, the CTE became a direct input parameter that was closely related to pavement performance. Therefore, it was imperative to measure accurate CTE for PCC pavement to predict critical pavement distresses within the designed years. Research has shown that CTE is related to cracking, joint faulting, and International Roughness Index (IRI) in jointed plain concrete pavements (JPCP).

## Objective

The objectives of this research were to measure typical CTE values of concrete mixtures used for PCC pavement structures to investigate the relationship between CTE and other critical variables such as aggregate types, age of concrete, dimension of specimen, amount of course aggregate in mixture, relative humidity, and concrete mechanical properties, and to assist in the implementation of MEPDG for PCC pavement design in Louisiana. Recommendations for the coarse aggregate type in the mixture and maximum joint spacing in JPCP are provided based on results of the MEPDG analysis. This study also calculates the curling stresses in the PCC pavement due to non-linear temperature and moisture gradient throughout slab thickness.

## Scope

Three aggregates widely used in Louisiana (Kentucky limestone, gravel, and Mexican limestone) were chosen for the coarse aggregate of the concrete mixture, and CTE tests were performed to find aggregate effects. CTE is also measured with various ages (3, 5, 7, 14, 28, 60, and 90 days), various coarse aggregate proportions (20, 64, and 80 percent of coarse aggregate), and various relative humidities of specimen to verify the factor that has the most critical impact on CTE. After finding the relationship between CTE and other critical variables, results of CTE and mechanical property tests were used to run the MEPDG analysis. Results of the MEPDG analysis were PCC pavement distresses such as mean joint faulting, transverse cracking, and terminal IRI. Appropriate coarse aggregate type and joint spacing in JPCP can be recommended by comparing the results of the MEPDG analysis to the specifications.

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*Sponsored jointly by the Louisiana Department of Transportation and Development and Louisiana State University*

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## Methodology

To study the effects of different parameters on CTE, three different mixtures were designed having different coarse aggregates: Kentucky limestone, river gravel, and Mexican limestone. A siliceous sand (A 133 TXI Dennis Mills) was used for fine aggregate for all of the mixtures. The percentile of coarse aggregate and fine aggregate were kept close to 64 percent and 36 percent, respectively. The same amount of type II Portland Cement (Holcim) was used in all blends. A constant water-to-cement (w/c) ratio of 0.451 was used for the mixtures to minimize the effect of cement paste. Daravair 1440 and WRDA 35 were used as admixtures to provide desirable air content and workability.

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Samples were cured for different ages to determine the effect of sample age on CTE and tested at 3, 5, 7, 14, 28, 60, and 90 days. Scale effects on CTE, both cylindrical (4 in. diameter and 8 in. height) and prismatic (3 in. length, 3 in. width, and 8 in. height) were determined. To determine the coarse aggregate fraction effects on CTE, the volume of coarse aggregate was changed to 20 percent and 80 percent while keeping the total volume of aggregates constant. The effect of relative humidity of the samples was also investigated.

Standard lab testing for these mixes included air and concrete temperature (ASTM C 1064), slump (ASTM C 143), pressure air content (ASTM C 231), volumetric air content (ASTM C 173), and unit weight (ASTM C 138).

Upon completion of the CTE testing, MEPDG analyses were conducted to determine the effect of CTE and joint spacing on IRI, percent slabs cracked, and mean joint faulting.

## Conclusions and Recommendations

Aggregate types have a statistically significant impact on CTE, while age of specimens was found to have no significant effect on CTE. The CTE between cylindrical and prismatic specimen has a statistically significant difference, thus 4-in. nominal diameter cylinders should be used for measuring CTE to follow AASHTO TP 60. Statistical analysis (ANOVA) showed that CTE of concrete is significantly influenced by the amount of coarse aggregate. The impact of coarse aggregate percentile on CTE should be evaluated at the mixture design state and construction stage. Representative CTE shows the peak point around 85 percent of humidity, but it did not have statistical significance. However, expansion CTE shows a clear peak point around 60 percent of relative humidity and has a statistical significance. The current maximum transverse joint spacing (20 ft.) in Louisiana should be adjusted by the coarse aggregate types following the results of the MEPDG analysis.

Considering both the MEPDG analysis and the case study of other states, current maximum joint spacing (20 ft.) can be adjusted to 15 or 18 ft. joint spacing when Kentucky limestone is used as a coarse aggregate. A future study should be focused on the nonlinear stress effect on curling and failure in PCC pavement.

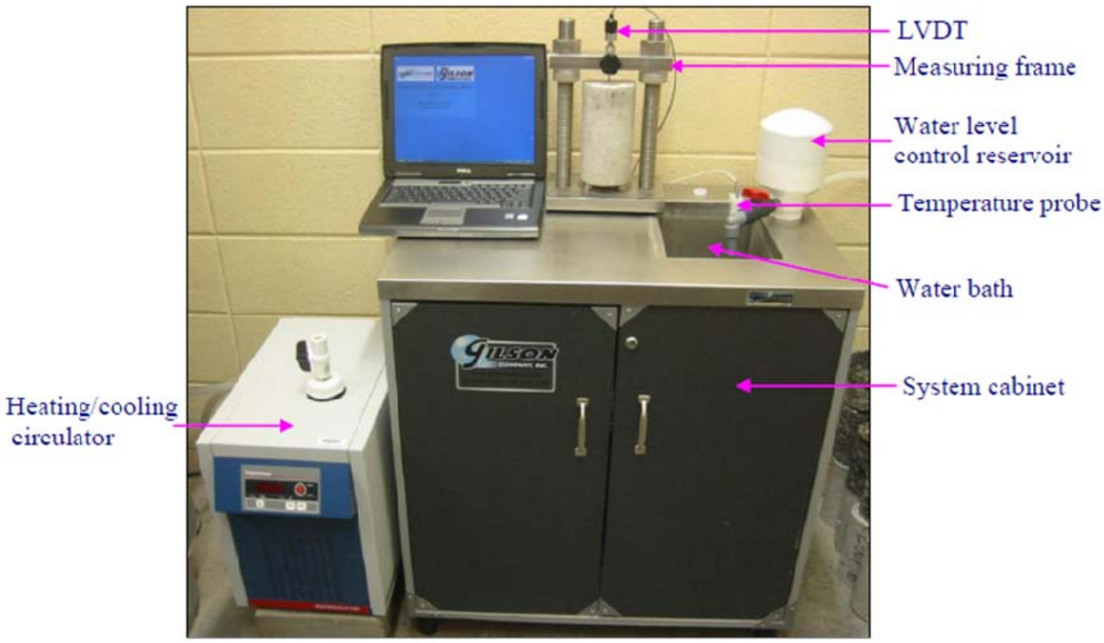


**Figure 1**
**CTE measuring apparatus**

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