Florida Department of Transportation Research

Validation of Stresses Caused by Thermal Gradients in Segmental Concrete Construction
BD545-10

Changes in the weather both seasonally and during the course of a day create varying temperatures throughout the cross-section of bridge superstructures. For example, direct sunlight causes the temperature of the bridge deck to rise. Since concrete is a poor conductor of heat, the lower portion of the bridge's cross-section experiences less temperature rise. These variations in temperature cause thermal stresses.

Bridges built in short segments – one piece at a time – are comprised of deep box-girder sections that not only experience uniform heating and cooling but also varying temperature distribution, known as nonlinear thermal gradients. The stresses that occur from uniform changes in temperature can be accounted for in design by providing sliding joints and flexible piers, among other methods, to allow for movement. However, stresses generated by nonlinear thermal gradients cannot be relieved through support movement alone.

Engineers analytically determine the stresses due to thermal gradients and use the American Association of State Highway and Transportation Officials (AASHTO) specifications to provide allowable limitations. The magnitudes of thermal stresses calculated in this manner can be extremely high and localized, which may lead to an overly conservative design and result in a more costly structure. Little data are available to confirm whether these stresses are actually as high as those predicted analytically, mainly due to the difficulty of measuring stress in concrete.

Researchers from the University of Florida focused on two objectives for this study: (1) determining whether stresses produced by nonlinear thermal gradients are as high as predicted, and (2) evaluating the effect thermal stresses have on cracking. For the first part of the study, researchers used the Santa Rosa Bay bridge, located near Milton, Fla., as a prototype for design of the laboratory segmental beam. The study aimed to quantify stresses due to experimentally imposed thermal gradients. On average, the stresses measured were less than the stresses predicted using the AASHTO method.

Construction of concrete bridge segments from the John Ringling Causeway, Sarasota, Fla.

In the second part of the study, researchers tested the beam used for the first part of the study as well as concrete segments that replicated the top 8 inches of a bridge deck. They loaded the specimens until a crack formed, with a thermal gradient applied to some of the samples and no thermal gradient applied to the rest. Researchers then compared the results and found the thermal gradient appeared to have no significant effect on cracking behavior.

The results of these tests and the lack of anecdotal evidence or experimental research indicating serviceability or durability problems demonstrate that the stresses caused by the nonlinear portion of the thermal gradient can be ignored in design. Stresses generated by structural redundancy in combination with the uniform and linear portions of the thermal gradient, however, must be considered.

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