Florida Department of Transportation Research

Pilot Project for Maximum Heat of Mass Concrete

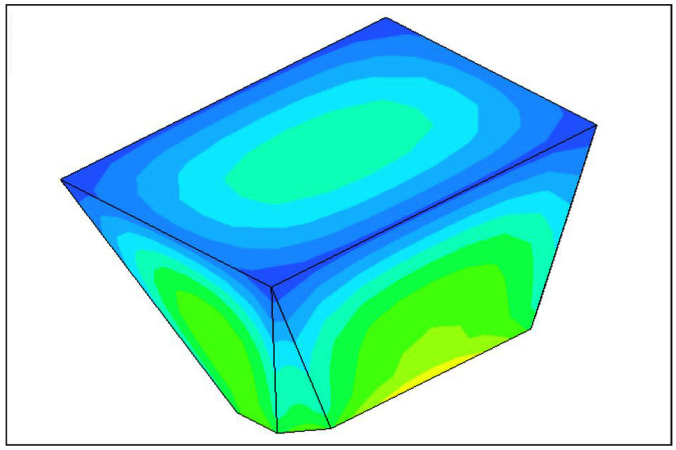
BDK75 977-47

Hardening cement releases heat, and because concrete is a thermal insulator, heat near the surface dissipates into its surroundings more quickly than heat deeper in the mass. Because concrete contracts as it cools, tension can build between surface and interior regions of the mass. The larger the mass, the greater this tension can be, sometimes causing cracking and spalling in the concrete surface. Cracking can reduce the design strength of concrete and weaken concrete structures by creating access for moisture or salt water to attack steel reinforcement.

The Florida Department of Transportation (FDOT) requires analysis of anticipated thermal developments in mass concrete elements for all expected temperature ranges using the selected mix design, casting procedures, and materials. The specification prohibits concrete pours from exceeding 180°F or a core-surface temperature differential of 35°F. In a previous project (FDOT Project BD545-60), University of Florida researchers showed that finite element (FE) modeling could predict thermal behavior of mass concrete. In this project, they extended that work to field applications, such as columns, pier caps, and footings, in three phases: development of the FE model; field measurement of thermal behavior of concrete pours; and refinement of the model. The researchers also developed support tools that significantly facilitate use of the model.

The researchers applied the FE method to predict the early age thermal behavior of a mass concrete footing placed on a soil layer. They chose commercial software, TNO DIANA, because it offered a wide range of material models for analysis of non-linear concrete behavior, including that of young, hardening concrete. The model analyzed two domains: thermal and structural. Formwork, such as plywood and polystyrene foam, was explicitly modeled in the thermal analysis.

Field studies were conducted on four mass concrete bridge structures built in Florida:



Surface temperature distribution on the seventh day as predicted by finite element modeling of a pier cap. Blues represent cooler areas; yellow warmer.

three footings and one pier cap. Continuous temperature measurements were taken for seven days by sensors placed according to FDOT specifications. Temperatures tended to rise rapidly after a few hours to a maximum at roughly 40 to 60 hours after pouring and to decline steadily thereafter. Ambient temperature and wind conditions, which affect convective heat loss, were monitored.

The field structures had different boundary conditions, providing four tests of the model. Predicted and observed temperatures agreed well. Thermal behavior of concrete footings on a variety of soil types was also tested. Three soil types — sand, clay, sand/clay mix — and three moisture levels — dry, moist, and saturated — were tested in all combinations for their effect on thermal behavior concrete in direct contact with different soil types at early age. This showed that the soil on which a footing is placed can have a significant effect on predicted thermal behavior.

Research that provides designers with more comprehensive and precise modeling tools yields better and more durable structures for Florida's transportation infrastructure.

Project Manager: Michael Bergin, FDOT Materials Office
Principal Investigator: Mang Tia, University of Florida
For more information, visit http://www.dot.state.fl.us/research-center