Engineers research effects of heat expansion on economically efficient bridge design (w/ Video)

June 26 2009

Kansas State University researchers are studying the effects of integral bridge expansion resulting from heat to make these types of bridges a more viable alternative.

Dunja Peric, associate professor of civil engineering and faculty member with the University Transportation Center at K-State, is studying the effects of different soil conditions and temperature change ranges on thermally induced expansion on integral bridges. Unlike conventional bridges, integral bridges lack expansion joints and have a continuous deck that creates an interconnected piece, which has performance and economic benefits. Integral bridges are more economically efficient than conventional bridges, according to Peric, but their design remains experiential and involves intuition, experimentation and observations.

"Kansas bridges have small spans, which are typical for rural environments," Peric said. "They are mostly highway overpasses. However, Kansas has the fourth largest number of bridges in the nation. The bridges have to be maintained and that costs money."

Peric worked with K-State's Asad Esmaeily, associate professor of civil engineering and faculty member with the University Transportation Center, and Bhavik Shah, a structural engineer and a 2007 K-State master's graduate in civil engineering, on the study that was funded by the Kansas Department of Transportation's K-TRAN program.

The study has been presented in Greece at the International Symposium on Numerical Models in Geomechanics, and in St. Louis at the Artificial Neural Networks in Engineering Conference. The study shows that the response of integral bridges to increased temperature depends on the compaction level of the adjacent soil and the temperature change range.

"The research was driven by the need to further improve the performance of integral bridges and extend their use," Peric said. "Integral bridges have structural advantages that stem from their continuity and reliance on the soil, the most abundant material on earth, in the load transfer process."

Kansas has more than 25,000 bridges, according to data from the Federal Highway Administration. Peric said 1,000 of these bridges are integral bridges.

Peric said conventional bridges have several disadvantages that result from the presence of expansion joints and bearings. The expansion bearings are expensive to buy, install, repair and maintain, she said, and they cause water leakage through their joints, which corrodes the reinforcement in the concrete. This, in effect, decreases the lifecycle of the bridge. The joints in conventional bridges also increase vehicular impact loads, which could damage bridges and vehicles.

Integral bridges are a promising alternative, Peric said. Their design and construction is more sustainable because of labor costs and energy, including the construction and maintenance for the bridge's lifecycle.

Conventional bridges use expansion joints to accommodate temperature change, such as when bridges expand in the summer heat, Peric said. With a lack of joints, integral bridges have more soil-bridge interaction than other types of bridges. Combined with their structural continuity, this provides redundancy and resilience and improves their ability to sustain illegal overloads. The researchers wanted to know what happens when integral bridges experience heat, because the soil doesn't allow for free expansion like expansion joints do.

"The heating up in the summer and cooling down in the winter, even a daily temperature fluctuation, induces some stresses in the bridge superstructure and substructure, and we wanted to make sure these bridges can sustain them," Peric said.

The researchers also wanted to find the limiting effects of these stresses on the maximum lengths of integral bridges. They used a 3-D computational model of an actual integral bridge, which had a superstructure with a concrete slab and seven steel girders, to examine combined effects of different thermal and soil conditions.

"The level of compaction of the soil adjacent to the bridge will affect the safe expansion range of the bridge," Peric said. "The ambient temperature change range depends on the location of the bridge, and Kansas, of course, has a different climate than other states."

The researchers also looked at the effects of the material properties of the soil. The thermal loads on the bridge were simulated by heating the bridge from 0 degrees Fahrenheit to 60, 80 and 100 degrees Fahrenheit. Peric said the researchers observed the thermally induced stresses in the bridge and effects on the bridge's performance, including an extending and bending of the bridge deck and bending of the piles.

"Although the advantages of integral bridges outweigh their disadvantages, there is a need for the knowledge discovery, which will further reduce the disadvantages," Peric said. "The study is a steppingstone. It provides insight into the mechanisms of the bridge response. Now, based on this study that provided a scientific base, we can extend the existing computational model to include other loads, such as traffic and seismic loads."

Source: Kansas State University (news : web)