An improved understanding of frame pier bridge response to temperature and shrinkage effects over time will help Iowa DOT maximize cost-effectiveness and durability in bridge design.

RESEARCH SOLUTIONS

Understanding shrinkage and temperature forces on frame pier bridges

Iowa DOT relies on frame pier bridges as a cost-effective solution for overpasses and short stream crossings. To optimize construction and life cycle efficiency, the agency must design frame piers to withstand environmental stressors that could impact concrete. Using current and historical field data, researchers developed high-fidelity models that simulate the effects of temperature and shrinkage on concrete to fine-tune frame pier bridge design.

THE NEED

Frame piers can be an economical bridge choice for applications such as grade separations where foundations do not need to be placed in water. These piers commonly have multiple columns that are generally smaller, and geometry is simpler than other pier types, requiring fewer resources for construction. Frame piers usually don't need to be tall in grade separation situations, but must be wide to accommodate multilane roads.

Using two shorter cap beams instead of one long cap beam may increase construction time and cost. But environmental factors on a long cap beam with multiple columns can be complicated, and bridge design methodologies must estimate the effects of temperature and shrinkage on the components.

Current design analyses may overestimate these effects, leading to costlier construction. To ensure accurate estimates, Iowa DOT wanted to understand the factors that best predict susceptibility of frame pier bridges to temperature and shrinkage effects.

RESEARCH APPROACH

Researchers visually inspected nine frame pier bridges of varying length and height. They also reviewed inspection reports from additional bridges considered vulnerable to

(continued)

"This research validated our current design approach for ensuring frame pier bridges are not susceptible to temperature and shrinkage."

— MICHAEL NOP,
Iowa DOT Bridge Project Development Engineer

temperature and shrinkage effects. Then they instrumented and monitored two bridges from the beginning of construction in 2019 and 2020 to monitor a frame pier's structural behavior. Sensors in the exterior columns and adjacent areas of the cap beams recorded strain developments during and after construction under different ambient temperatures.

In addition to the field data, a database with over 40 years of experimental data from several hundred concrete shrinkage and creep tests provided the input to accurately model the effects of temperature and shrinkage. A series of finite element (FE) models validated by the field and database data numerically simulated various frame pier configurations. Parameters investigated in the models included the temperature and moisture at the time of pier casting, column stiffness properties, and geometric details. An analysis of various frame pier configurations identified factors that capture frame pier bridge susceptibility to temperature and shrinkage.

WHAT IOWA LEARNED

Visual inspection of frame pier bridges found only minor damage that was not attributed to temperature and shrinkage. Additional bridges were inspected, and reports indicated that most showed no clear damage from temperature and shrinkage. However, two bridges exhibited minor damage that was likely caused or worsened by the effects of temperature and shrinkage.

The FE models validated by the health monitoring data accurately simulated frame pier bridge behavior and revealed the following:

- Frame piers that were most susceptible to temperature and shrinkage were cast on warm summer days in June and July.
- Uniformity of column size did not appear to impact the likelihood of shrinkage-induced damage.
- Individual bay lengths had a negligible effect on temperature and shrinkage effects.
- The lateral stiffness of the columns, length of the frame, and flexural stiffness of the cap beam were the most important design factors.

PUTTING IT TO WORK

An improved understanding of frame pier bridge response to environmental stressors over time will help fine-tune the design process. The models produced in the research supported the development of a 2D linear modeling tool to provide a simplified process that bridge engineers can use to analyze temperature and shrinkage effects.

ABOUT THIS PROJECT

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