Monitoring earth pressure on culverts from construction through operation illustrates pressure changes over time in Iowa soil conditions.

RESEARCH SOLUTIONS

Understanding earth pressure on concrete box culverts

Road projects may require constructing culverts to divert water under or alongside a road. Earth pressure on buried concrete culverts varies depending on the depth of the culvert and the amount of fill dirt placed on top of it. As soil characteristics and properties vary across states, national design values may not reflect Iowa conditions. Iowa DOT monitored two culverts from construction through operation to learn how earth pressure changes over time. The results support the agency's interest in surveying other culverts in the state.

THE NEED

Concrete box culverts serve the dual purpose of conveying water under a highway while carrying traffic over ditches or streams. Culverts need to be designed to withstand the weight of the earth that is placed over them. While AASHTO provides earth pressure design values for buried structures like culverts, soil weight and conditions vary from state to state. Additionally, AASHTO guidelines have been updated over the years in response to evolving understandings of seismic earth pressures and ground motion. Older culverts may not meet current ratings.

In Iowa, culverts are typically buried 5 to 10 feet under roadways. Some road projects, however, require burying culverts 20 to 35 feet beneath the surface to divert water. Iowa DOT wanted to understand what load pressures are most realistic for the state's soil conditions and construction methods.

RESEARCH APPROACH

To understand the complexities in determining earth pressure on a culvert, researchers first reviewed

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"Analyzing earth pressure on culverts can be complex due to soil variability and soil arching action. This work, along with federal inspection processes, will help confirm culverts continue to safely perform for their expected service life."

— **JAMES HAUBER,**
Iowa DOT Chief Structural Engineer

the literature to identify the factors related to the vertical and lateral earth pressures on buried structures. For example, measuring earth pressure can be complicated by the arching effect of soil, which refers to soil movement above or adjacent to the structure and the resulting change in pressure created on the culvert.

After successfully testing strain gauges and earth pressure cells against pressures up to 8,500 pounds and 50-degree temperature fluctuations in the laboratory, researchers attached six strain gauges and five pressure cells to a culvert being constructed under U.S. 20 in Ida County. The maximum depth of the soil on top of the 487-foot-long, 10-foot-high culvert was about 37 feet. The instrumentation monitored the earth pressure on the culvert for over 2.5 years.

Following the comparison of the Ida County culvert monitored data with design loading values, researchers conducted a second monitoring effort involving a culvert constructed under U.S. 59 in Crawford County. The 277-foot-long, 9-foot-high culvert supported an earth fill from 21 to 25 feet. More extensive instrumentation included 11 pressure cells and 10 strain gauges on each of three culvert sections supporting different fill heights. Monitoring occurred over 14 months.

For both culverts, data collection began during construction to understand earth pressures and accompanying fill heights during compaction and ongoing pressure, strain, and temperature data during operation. Investigators inspected the culverts for cracking before, during, and after construction.

WHAT IOWA LEARNED

In both culverts, earth pressure gradually increased as soil was added during placement. Following construction, the culverts tended to expand as temperatures increased, which increased the pressure between the soil and the exterior surface. At temperatures below freezing, however, the monitored pressure varied.

Monitored pressures were two to six times greater than current design values. The Crawford County culvert data indicated that vertical pressure increased 1 to 2 psi with every additional foot of fill over the top slab. The maximum earth pressure on the Ida County culvert measured 47 psi below 35 feet of fill. The culverts were not designed to be crack-free, and significant longitudinal cracks formed on the bottom surface of the top slab on both culverts due to vertical soil pressure.

PUTTING IT TO WORK

While pressures monitored on the two culverts exceeded design values, the culverts continue to safely function and perform as designed. Research methods used in this project will support Iowa DOT in continuing to survey other culverts for any condition changes or changes in expected service life performance. The agency will consider new design standards if any changes in performance or service life are observed.

ABOUT THIS PROJECT

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