NEBRASKA
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DEPARTMENT OF TRANSPORTATION

Nebraska Department of Transportation
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Executive Summary, Research Readiness Level Assessment, and Technology Transfer

Field Monitoring of Joint-less Curved Integral Abutment Bridge in Nebraska

Research Objectives

The research objective of this project is to monitor the integral and semi-integral abutment bridges in Nebraska to: 1) obtain data for future design and construction practices for wider applications (longer spans, increased skew angles, improve design details in connections), 2) thoroughly understand the complex long-term behavior of soil-structure interactions (interaction between deck/abutment connection, soil/pile behavior both in integral and semi-integral bridges, backfill/abutment), and 3) better maintain existing structures (repair and strengthen if needed). Our multidisciplinary team of structural and geotechnical engineers will carefully investigate the loads produced in abutments over the Nebraska integral abutment bridges, measure the load-displacement of piles with fiber optic sensing, examine ratcheting effects and voids or settlement under approach span of these structures.

Research Benefits

1) It is anticipated that the long-term response of changes in rotational behavior, stress-strain relations, lateral earth pressures, and the load-displacement behavior of piles in Nebraska integral and semi-integral abutment bridges will be identified through proper implementation of monitoring systems.
2) Extensive and efficient field monitoring data and simulation results from parametric studies will provide us a rich database that can be used for providing background information for the effort of optimizing the design and providing guidelines that cannot be found in other state agencies for the unique specification of Nebraska bridges. The current design that is based on limited empirical data can be revisited and certain limitations can be alleviated within current practices.
3) It is also anticipated that rational design and construction specifications/guidelines tailored to Nebraska soil conditions will be provided including the unique details of Nebraska integral abutment bridges.

Background

There are more than 9,000 integral abutment bridges and 4,000 semi-integral abutment bridges in the U.S., which increased dramatically in the past two decades (White 2nd, 2007). Nebraska is no exception – there are hundreds of integral and semi-integral abutment bridges in the state of Nebraska, and thus guidelines and specifications for these structures listed on the Bridge Office Policies and Procedures (BOPP, 2016). The obvious advantage of using integral abutment bridges is their reduced construction and maintenance costs by eliminating bearings and expansion joints that make the bridge “joint-less”. This also fits well with Nebraska's "well-timed" bridge preservation practice of eliminating problems before they occur. Despite the wide acceptance in usage and the advantage listed above, integral and semi-integral abutment bridges are often built with specific limitations under each State’s bridge design manuals; and the design primarily relies on limited empirical data. Noticeably, small numbers of problems were reported because these bridges were built within limitations of specific skew angles, pile types, span lengths, and construction practices to name a few.

Conclusion

The research objective of this project is to study the behavior of the curved full integral abutment bridge designed in Nebraska through field monitoring and numerical simulation to 1) understand and model the complex short-term and long-term behavior of curved integral abutment bridges, 2) evaluate if the details provided in Nebraska (pile embedment over 4 ft into the abutment) can be expanded for wider design and construction practices (longer spans and larger curvature for curved bridges), and 3) better maintain existing full curved integral bridges in Nebraska based on the findings of this study (revise and optimize design, if needed). The research team carefully instrumented a curved full-integral abutment bridge following the construction schedules of the bridge starting from Jan. 2020 to Aug. 2021, and measured the abutment backfill pressure, abutment tilts, and pile movement profiles. This study documents the measurements completed between April 2021 to July 2022, including a full annual cycle since the bridge has been fully integral. A three-dimensional finite element model was developed for numerical simulation, and the backfill pressure, tilt, and pile top displacement calculated through the model and measured at the field were compared. The results demonstrate that the backfill pressure and the pile top displacement are within 5% difference, and comparable while the tilt has 20% difference between the model and field measurements. However, the change in tilt due to the annual temperature change (ambient) and the shape of the change (trend) is similar between the simulation and monitoring results. A parametric study was conducted additional to these annual cyclic measurements to study the limits of the curved full integral abutment bridge and recommendations are provided based on the findings. Continuous measurements of the backfill pressure, tilt, and pile movement is recommended until the entire bridge movements level out in several years.

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Interested in finding out more?
Final report is available at:
NDOT Research Website

NDOT Recommendations Based Off Research Project

This research did not meet all its goals because of a faulty sensor, resulting in being unable to engage in continuous monitoring of measurements. This ultimately resulted in failure to achieve research benefit Task # 3: tailoring construction specifications and guidelines to Nebraska soil conditions for integral abutment bridges. Because much of this project has already been installed on Big Springs bridge, a retrofit has been proposed replacing the fiber-optic distributed strain system (DSS) with multiple backups. This will allow for continuous measurements of the backfill pressure, tilt, and pile movement until the entire bridge movements level out in several years. However, this retrofit has yet to be installed for this research.

- *As provided by Fouad Jaber and Emilie Hudson, Lead TAC Members*

Research Readiness Level (RRL) Assessment

RRL 2

Level 2: Applied Research

Retrofit will need to followed up on for this research.

Technology Transfer

Principal Investigator did not have any technology transfer for this research project.

This brief summarizes Project SPR-P1 (19) M087
"Design Optimization and Monitoring of Joint-less Integral and Semi-Integral Abutment Bridges in Nebraska"
Nebraska Department of Transportation Research Program