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Integral Abutment Bridge for Louisiana's Soft and Stiff Soils

INTRODUCTION

Integral abutment bridges (IABs) have been designed and constructed in some US states over the past few decades. The initial purpose of building such bridges was to eliminate the expansion joints and resolve the joint-induced problems. Although IABs have been widely accepted due to their satisfying performance, they have not been largely applied in practice because of uncertainties on the structural and geotechnical behaviors of such bridges under the temperature variations, shrinkage and creep of materials, traffic loads, etc. Recently, the first two full IABs were constructed on soft and stiff soil conditions in Louisiana by the Louisiana Department of Transportation and Development (DOTD). This report presents the field instrumentation plans and monitoring results for two bridges: Caminada Bay Bridge, constructed on mainly fine sand and silty sand deposit, and Bodcau Bayou Bridge, constructed on a relatively lean and fat clay with low plasticity.

The IAB system is gaining wider acceptability in the US and worldwide mainly because of the reduced initial costs, lower long-term maintenance expenses, and improved riding quality. Louisiana's experience has been limited to the construction of semi-integral abutment bridges in stiff soils only. No full integral abutment bridges have been used in Louisiana so far. Success and effectiveness of the IAB system is dependent on proper understanding of the soil-structure interaction and behavior of components as well as the full system. It is particularly important as soft soils in Louisiana are known for their poor strength quality from the engineering point of view.

Finite element modeling was also conducted to understand and assess the bridges' performances. Based on the available information of the bridges, with the monitoring results, 3D numerical models were implemented and validated in the study, where the pile-soil and abutment-backfill interaction behaviors were considered. The concerning parameters were varied through a parametric study to further investigate their effects on the bridge thermal performances under the other complicated structural and geotechnical conditions.

OBJECTIVE

In this project, field-instrumentation, monitoring, and analyzing the design and construction of full integral abutment bridges for Louisiana's fine sand and silty sand deposit and clay soil conditions were conducted. Comparison of results was submitted to DOTD's Bridge Design and Geotechnical Sections in the form of guidelines to incorporate in future designs.

SCOPE

One of the major goals of this research was to understand the response of IABs at two sites in Louisiana so that the behavior of IAB could be understood under moderately soft and stiff soil conditions. The foundation soil of the Caminada Bay Bridge consists of mainly fine sand and silty sand deposit, and the Bodcau Bayou Bridge piles are driven into lean and fat clay with low plasticity. For the Caminada Bay Bridge, one section of the bridge is monitored. For the Bodcau Bayou Bridge, Bent 1 was instrumented including four piles backwall of the bent, two abutments, backfill, the girders, and the deck.

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The finite element analysis was conducted for the substructure, which is used in conjunction with the superstructure finite analysis. Appropriate constitutive models for the soils was used for the analysis of the substructures.

METHODOLOGY

A literature review is outlined for the IAB. This includes in-service problems, classification and construction, instrumentation/testing, and monitoring of substructure and superstructure of bridges. This is followed by an extensive plan and implementation of the instrumentation and testing plan of the two bridges chosen for this study. A rigorous plan is outlined for the monitoring system for both the substructure and corresponding superstructure of the two bridges chosen for this study.

The finite element analysis was conducted for the substructure, which was used in conjunction with the superstructure finite analysis of the two bridges. Appropriate constitutive models for the soils were used for the analysis of the substructures. Parametric studies were conducted for the modeling and analysis of the bridges.

Finally, field monitoring was conducted for the two bridges, which was used to check on the accuracy of the predictive numerical models. Conclusions and recommendations were drawn from these analyses.

CONCLUSIONS

Based on the observed temperature effects, the design of the piles of Caminada Bay Bridge is very conservative and the piles were driven in a sandy soil deposit. The piles experienced very low bending moments and Bent 1 experienced very small lateral movement, which corresponds to very small pressure on the backfill soil. Correspondingly, the rotation of the abutment is small.

The piles that support Bodcau Bayou Bridge are not as stiff as the piles of Caminada Bay Bridge. The bridge expansion and contraction due to thermal changes is evident and correlates well with field measurements of pile lateral movement and bent-soil interaction. The piles experienced relatively larger bending moments than Caminada Bay Bridge did, but still small moment when compared to yielding moment.

Based on numerical simulations on the Caminada Bay Bridge, the soils behind the abutment affect the behaviors of the integral abutments in terms of their displacements and rotations. These effects are complicated, and the soil restraints to the abutment deformations accumulate with time due to the plastic behaviors of the soil. However, at locations far away from the integral abutments or the expansion joints are provided between slab-abutment, these soil restraining effects become negligible.

Based on numerical simulations on the Caminada Bay Bridge, the soils surrounding the piles show the most obvious effects on the bridge responses. Under the current bridge configuration, if changing the soft soils to stiff ones, it will generate a maximum of 1.5 times smaller bridge displacements and 20% smaller backfill pressures; but at the same time, it will also induce 70% larger pile positive strains and 48% larger slab negative strains. Thus, an optimized structure needs to simultaneously benefit both the superstructure and substructure.

No significant issues are observed at this stage and the designs of details for these two monitored bridges seem to be effective in accommodating the thermal effect.

While the monitored period may be sufficiently long to make exclusive conclusions on the thermal effect, continued monitoring of the bridge field performance is needed for the combined effect, such as live load and scour effect.

RECOMMENDATIONS

A successful implementation of this integral abutment monitoring system will have far reaching benefits for Louisiana and other states. The measured seasonal temperatures and daily gradients of the slabs, during the monitoring period, are either reaching or slightly exceeding the design values are specified by AASHTO LRFD (2007). Therefore, it is recommended to re-examine the DOTD specifications for Louisiana bridges in terms of thermal effects.

No significant issues are observed at this stage and the designs of details for these two monitored bridges seem to be effective in accommodating the thermal effect. Therefore, these details can be used for similar bridges. However, more parametric studies using the calibrated model of the current study, considering longer span and longer bridges etc., are recommended to develop broader applications in Louisiana.

While the monitored period may be sufficiently long to make exclusive conclusions on the thermal effect, continued monitoring of the bridge field performance is needed for the combined effect, such as live load and scour effect. Therefore, continued monitoring of the bridge field performance is recommended.

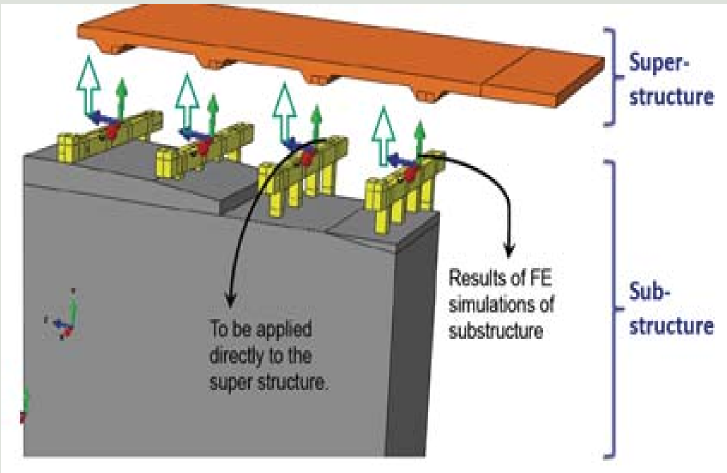

Figure 1
The strategy of conducting the numerical analyses of sub-structure and using the results for super-structure