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CALTRANS DIVISION OF RESEARCH, INNOVATION AND SYSTEM INFORMATION

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Research Notes

Damage to Ends of Precast, Prestressed Concrete Bridge Girders (California Bulb-Tee) from Seismic Impact

Assessing Multi-Directional Seismic Impact on Bulb-Tee Girder Ends Through Nonlinear Dynamic Analysis and Testing

Geotechnical/ Structures

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Project Title: Damage to Ends of Precast, Prestressed Concrete Bridge Girders (California Bulb-Tee) from Seismic Impact

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WHAT IS THE NEED?

The 2023 7.8 magnitude earthquake in Turkey dramatically demonstrated that the ends of precast concrete Bulb-Tee girders can be severely damaged from impacts loads under strong seismic shaking, with impacts in the vertical direction from the girders lifting off their reaction points (one end and then the other) and slamming back down again, repeatedly, concrete against concrete, after the rubber bearing pads had slipped off and fallen to the ground, as well as impacts in the transverse direction due to hitting the shear keys, again concrete to concrete, and, finally, impacts in the longitudinal direction with the girders hitting the other girders or the abutment backwalls, concrete to concrete.

Since the damaged girders at the Asi Bridge over the Asi River had Bulb-Tee girders that are almost identical to California Bulb-Tee girders, and because Turkey closely follows the California Department of Transportations (Caltrans) seismic design specifications/practices, there is much interest in California and Caltrans to understand the extensive girder-end-damage to the Asi Bridge, and to ensure this does not happen to California bridges in a future earthquake of similar magnitude/size as the one in Turkey.

WHAT ARE WE DOING?

The first part of this research is analysis, from global modeling of the Asi Bridge to very detailed local modeling of the girder ends. Global bridge modeling is being conducted using nonlinear time-history analyses with SAP 2000, including nonlinear column plastic hinge elements at the base of the piers in their longitudinal/weak direction, and plasticity

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elements to capture hysteretic behavior of internal and external shear keys. The purpose of the global model is to develop end-of-girder impact loads in longitudinal, transverse and vertical directions versus time, which will then be used as applied loads versus time for the local girder models and for physical testing in the laboratory of the girder ends.

The local model will be developed in ABAQUS using solid brick (8-node, 3D) elements for the concrete, and beam or truss elements for all prestressing steel and rebar. This models the girder end region and will be identical in loading and boundary conditions to the physical tests of the girder ends, with both local model and physical tests loaded at their ends by the impact forces found from the global model discussed above. For the structural tests that will be conducted after all analyses are completed, the impact loads will be applied dynamically in all three principal directions by three different dynamic hydraulic actuators, while the other end of this partial-length girder will be fixed in all directions. Hence, it is a cantilever girder with loads applied where the reaction points are in the real bridge.

WHAT IS OUR GOAL?

It is expected that new seismic design specifications and seismic design details will be developed. This will ensure that Bulb-Tee precast girder ends for future California bridge structures will not be severely damaged during a large earthquake.

WHAT IS THE BENEFIT?

The benefit to California is safer bridge structures for the traveling public and more economical designs, benefiting all California citizens. Bridge structures should not collapse under major earthquake loading, and the on-going research contributes significantly to this philosophy, preventing girder ends from spalling and losing their capacity to transfer shear loads to the reactions at the girder ends. Such girder-end-loss could result in complete collapse of a bridge span, or multiple spans. Results from this research will also directly impact Turkey as they intend to adopt the findings from this research into their bridge design.

WHAT IS THE PROGRESS TO DATE?

A detailed global model of the Asi Bridge has been developed using a combination of beam, shell and nonlinear elements. Beam elements represent the Bulb-Tee girders and bent caps, as well as the piers, while shell elements model the cast-in-place concrete deck. Nonlinear elements represent the hysteretic plastic hinge behavior of the base of the piers in their longitudinal/weak direction using the PI's Pivot Model, which is available in SAP2000, as well as the hysteretic behavior of all shear keys, internal and external, using plasticity elements. Additional elements represent the piles below the footings and soil springs along the pile lengths. Currently the global model is being exercised with earthquake loading to verify that all the nonlinear elements and boundary conditions are working as intended. This global bridge model is the key to the remainder of the research project as it will provide impact forces at the girder ends (in all three principal directions) to be used for local girder testing and local detailed analysis models in ABAQUS.

Once the global model is fully verified to be working correctly, a detailed local model will be developed using ABAQUS. This model allows observed end-of-girder concrete spalling and loss of prestressing at the Asi Bridge to be captured analytically using the most advanced computational tools available to structural engineers, with each prestressing strand and rebar included as individual elements, and the concrete modeled as 3D bricks (8 node solid elements).