Bridges are essential infrastructure constituents that have been studied for centuries. Typically, bridge design and assessment utilize simplified modeling and analysis techniques based on one-dimensional spine elements and zero-length springs/hinges. The geometry of the elements and calibration of parameters are based on assumptions for the load path and failure modes, e.g., sacrificial backwall and shear keys, neglecting wing walls, and strength based on backfill alone. These assumptions have led to observations of underestimated resistance, overestimated displacement demands, and unpredicted damage and failure mode. Such aftereffect necessitates further identification to the correct load path and failure modes assumptions and its consequences on the modeling and analysis outcome. The focus of the study is on ordinary standard bridges with continuous reinforced concrete box girder superstructure and seated type abutments.

A bridge component calibration study was conducted first using simplified (spine models with 1D elements and springs) and three-dimensional nonlinear continuum finite element models (FEM). Model responses were compared with experimental results to identify the drawbacks in the simplified models and verify the adequacy of the material nonlinearities and analysis procedures. Results show the simplified models do not capture damage propagation and failure mode in the shear key case, nonlinear behaviors in beams with high aspect ratios (or deep beam action), and underestimate the strength and overestimate the stiffness for the backfill case.

The component models (both simplified and continuum) were then used in studying the nonlinear static behaviors of key bridge lateral-load resisting substructures, namely abutments and bents. For the abutment subsystem, cases with and without backfill for the longitudinal direction, with monolithic shear key and shear key with construction joint for the transverse direction, and boundary conditions in the transverse direction were considered. Abutment subsystem results showed simplified models underestimate the resistance by 40-60%, neglect back wall and wing wall structural contributions, and localize damage in the back fill relative to the continuum models. For the bent subsystem, a full bridge system that considers material nonlinearity and damage in the bent segment only was adopted to determine the effect of the finite bent cap or superstructure-to-column connection. Bent subsystem results showed simplified models overestimate the stiffness and resistance, induce excessive flexibility and deformation in the cap beam, and underestimate columns' deformations.

Due to the differences observed in the abutment subsystem, and the potential impact of the abutment behavior on the seismic response of the whole bridge system, dynamic studies on the bridge system were conducted using four abutment parameters: abutment stiffness and strength in each of the longitudinal and transverse directions. Two models were developed to conduct nonlinear time history analysis: an equivalent single-degree-of-freedom (SDOF) model for each of the longitudinal and transverse directions, and a 3D spine bridge model. Results revealed that, besides the columns yielding, the abutment has an early and significant contribution to the behavior. The SDOF system results showed that increasing the abutment stiffness or strength reduces the system displacement demand and increases the system forces, considerably. The consequence of such increase in the forces, as observed, is mobilizing significant amount of force to the abutment causing inelastic response. The full bridge study also confirmed the SDOF results and showed that the abutment forces is more than 200% of the columns forces. This excessive abutments' forces shift the load path and failure mode leading to abutment yielding and undesirable response.

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The public is welcome to attend.