DRISI
Caltrans Division of Research, Innovation and System Information

Research Notes

Second Order Effects on the Design of Slender Reinforced Concrete Bridge Columns

Bridge research to improve reinforced concrete slender bridge column design procedure and reduce construction and maintenance costs

Geotechnical/ Structures

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Project Title:
Second Order Effects on the Design of Slender Reinforced Concrete Bridge Columns

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WHAT IS THE NEED?

The current reinforced concrete (RC) slender bridge column design procedure is based on the American Association of State Highway and Transportation Officials (AASHTO) Load and Resistance Factor Design (LRFD) Bridge Design Specification approximate analysis method that was adopted from the building industry, i.e. American Concrete Institute, and has not been readily studied for applicability to bridge.

Due to a lack of bridge focused guidance, designers often make very conservative assumptions when dealing with slender bridge columns. Refined analysis using finite element models (FEM) have consistently resulted in lower second-order effects than would be predicted using the approximate method, yet the refined method is rarely used in design because it requires significantly more effort when compared to the approximate method. There is a clear need to evaluate the accuracy of the approximate method and method formulation.

Moreover, if the refined method is to become more widely used, better guidance and bridge modeling guidelines will need to be developed.

WHAT ARE WE DOING?

Through the PEER-Bridge Program, Caltrans is contracting with Oregon State University (PI) and University of Tennessee, Knoxville (Co-PI) to evaluate AASHTO approximate moment magnification method using second-order analysis including P-Δ effects for deflection on axial loads and moments. Parametric studies will be conducted on common Caltrans bridge types.

Develop bridge modeling guidelines for the use of refined model analysis method. The study will also include recommendations on incorporation of slender column material effective stiffness and effective length factor for design practice based on a comprehensive literature survey and finite element modeling assessment.

WHAT IS OUR GOAL?

The primary goal of this project is to evaluate the performance of the AASHTO moment magnification method on slender bridge columns. Develop bridge modeling guidelines for using FEM.

WHAT IS THE BENEFIT?

Bridges play a critical role in the transportation system in enhancing California's mobility and economy. In the current slender bridge column design of approximate method of analysis, conservative estimates of slender column axial load carrying capacity can lead to unnecessary additional cost in the bridge support system. The current approximate method was adopted mainly from the building industry.

Bridge frames are vastly different from building frames, so the assumptions and parameters that may be appropriate for use in buildings are not necessarily appropriate for bridges. By evaluating the approximate method against refined method, Caltrans can improve the current slender column design methodology, with better estimates of design parameters, a more efficient and cost-effective bridge column design can be achieved to meet the growing traffic demand of users.

WHAT IS THE PROGRESS TO DATE?

Second Order Effects on the Design of Slender Reinforced Concrete Bridge Columns project started on June 01, 2021 and operate for 29 months.

Literature review on experiments, modeling, and the design of slender RC columns has been completed. Review results and column experimental database has been complied for model validations. Experimental data on loaded slender reinforced columns and columns subject to long term loading has been collected and compiled into a database. Literature review and the modeling and design of slender reinforced column has been completed. Development of preliminary list of practical range of column parameters for second order analysis is completed. Development of basic OpenSees model for a single reinforced column using fiber-discretization of circular column section is ongoing.

The code necessary to determine maximum permitted applied loads from second-order inelastic analysis is currently under active development. Several Python classes and functions have been written to automatically build OpenSees models, perform analyses, and post-process results. The general code and short-term loading analysis capabilities were developed and validated at the University of Tennessee. The long-term loading analysis capabilities have been developed at Oregon State University, but validation is still ongoing. OpenSees models of two Caltrans bridges were adapted from previous projects in order to assess the stability of bridge columns accounting for actual cap beam and superstructure stiffness. With simple roller abutment models and linear-elastic column behavior, effective length factors (K) were calculated for longitudinal and transverse response one-column bents.

Developing code to determine flexural rigidity, EI, for the design of column is underway.