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CALTRANS DIVISION OF RESEARCH, INNOVATION AND SYSTEM INFORMATION

TRANSFORMING IDEAS INTO SOLUTIONS

Research Notes

Statistical Variation of Seismic Damage Index (DI) of California Bridges

Bridge research to improve the California Department of Transportation's (Caltrans) performance-based bridge design procedure to enhance transportation network reliability and reduce overall costs.

Geotechnical /Structures

May 2025

Project Title:

Statistical Variation of Seismic Damage Index (DI) of California Bridges

Task Number: 3677

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Completion Date: February 28, 2024

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WHAT IS THE NEED?

A long-term goal of Caltrans is the adoption of performance based seismic bridge design concepts. The primary benefit of this approach is the creation of a uniform level of seismic performance throughout California. This uniformity will enhance transportation network reliability and reduce costs through more efficient seismic design.

In support of this effort, Caltrans bridge engineers have developed a prototype performance-based design procedure called Probabilistic Damage Control Assessment (PDCA). Currently, the PDCA procedure requires laborious Nonlinear Time History Analysis (NTHA) and earthquake input record selection is not well defined. In order to deploy this method, it needs to be made easier and more repeatable in application.

WHAT ARE WE DOING?

Through the PEER-Bridge Program, Caltrans is contracting with UC Irvine to investigate ways to simplify PDCA. Focus areas will include developing estimates of dispersion in structural response that can be used statewide instead of calculated individually for each bridge. These dispersion estimates may include adjustments for regional hazard or bridge geometry.

Another focus area will be the development of earthquake record selection procedures for Nonlinear Time History Analysis (NTHA). Two objectives of these procedures are simplicity and reducing variation in results when performed by different engineers. To speed bridge design, procedures for initial column sizing will be developed that will reduce the number of design iterations required. Finally, incorporation of directivity effects that impact near-fault locations will be investigated.

WHAT IS OUR GOAL?

The primary goal of the project is to refine PDCA design procedures so that they are accurate, repeatable, and efficient for implementation on the design floor.

WHAT IS THE BENEFIT?

Bridges play a critical role in our transportation system in enhancing California mobility and economy. For most bridges (approximately 80%) seismic loading is their dominant load case. Transitioning to a performance-based design framework will result in equal risk of bridge damage and closure statewide. The benefit of this uniform performance will be increased network reliability and cost efficiency. The quantification of performance has the added benefit of providing Caltrans and stakeholders critical information for decision making and future planning of California's transportation network.

WHAT IS THE PROGRESS TO DATE?

This project is completed on February 28, 2024.

Procedures for preparing input information for nonlinear time-history analysis have been developed. Single column models are developed based on the various column parameters. The parameters under consideration are column diameter, column height, axial force, longitudinal reinforcement ratio, transverse hoop size, and hoop spacing. Push over analysis has been conducted to determine column yield displacements, capacity displacements, and demand displacements. Hazard curves and selected ground motions for five (5) give testbed locations are generated for Eureka, Sacramento, Oakland, Los Angeles, and San Diego. Time-history analysis results has been extracted on selected columns. Column Damage Index (DI) values and coefficient of variations (COV) has been calculated per Caltrans PDCA procedure.

Extensive studies and peer-reviewed models has been done to validate the sensitivity of secondary intensity measures, IMs (PGA, CAV, AI, PGV, D5-75, D5-95) in ground motion generation to response parameters (DI, Log(Drift Ratio)). It was found that the sensitivity of response parameter to PGV is significant. As a result, simulation of large set of ground motions with proper PGV distribution is used, where the mean PGV for the set falls between 25% to 75% confidence interval of the mean distribution from peer-reviewed models, and all PGV value falls between 5% to 95% confidence interval. Studies has also been done to investigate the difference between ground motion point scaling and range scaling method. It was found that for point scaling, the COV is lower, and the mean DI is higher than range scaling. Range scaling is chosen as the method to use for the rest of the project.

A contour mapping divided into grids is established for the state of California for location specific time-history analysis for DI and COV calculations. Ground motion near-fault factor and impact on DI statistical parameters has been assessed resulting in the use of USGS 2018 Hazard Model. Ground motion basin amplification factor and impact to DI statistical parameters has been assessed resulting in the use of USGS 2018 Hazard Model. Distribution of COVs and probability of exceeding DS3 and DS5 assessment has been done. CA COV map has been produced with mean and standard deviation distribution for 225, 975, and 2475 year return period.