Reliability-based Method for Seismic Assessment of Sub-standard Bridge Columns

Probabilistic seismic damage assessment method can help prioritize retrofitting and repairing process of sub-standard bridge columns

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WHAT WAS THE NEED?

The condition of many old bridge columns constructed prior to 1970's (sub-standard bridge columns) is a cause of major concern. Sub-standard bridge columns are susceptible to brittle failure due to inadequate lateral reinforcement and/or slippage of column longitudinal bars spliced at the connection to footing. As a result, these columns need to be assessed urgently to identify their deficiencies and to prioritize a retrofitting program. However, most of the research on sub-standard bridge columns have been on methods to upgrade the structural characteristics of the existing sub-standard columns through effective retrofitting measures and to improve analytical methods. The present study addresses the need for methods to assess the sub-standard columns.

WHAT WAS OUR GOAL?

The main goal of the study was to develop an effective probabilistic method for seismic damage assessment of sub-standard bridge columns. Specifically, the study was aimed at developing load distribution curves and reliability charts for different types of piers taking into account uncertainties in seismic damage and earthquake. The results of the study can be utilized in prioritizing seismic retrofit and repair of sub-standard bridge columns.

WHAT DID WE DO?

A practical method for reliability-based seismic assessment of sub-standard bridge bents that are yet to be retrofitted was developed. The study consisted of development of a capacity (resistance) and a demand (load) model for sub-standard bridge bents and reliability analysis to determine the extent of the bents seismic vulnerability. To develop the capacity model, detailed data from previous experimental studies of 25 bridge column models was reviewed and analyzed, four distinct apparent seismic damage states (SubDSs) were identified, and a response parameter was defined in terms of displacement (damage index). The damage index was correlated to the damage states using a probabilistic approach of “fragility function.” The demand model was developed through extensive
analytical modeling of selected single- and multi-column bents including a practical range of
the number of columns per bent, support conditions, aspect ratios, longitudinal steel ratios,
lap-spayce lengths, ground motion types, site classes, and earthquake return periods. The
demand model was established using load distribution curves developed based on fragility
relationships of demand damage indices. Utilizing the distribution of the capacity and
demand models, reliability against failure and other damage states was determined
incorporating the probability of earthquake exceedance during the lifetime of bridges
(combined reliabilities).

WHAT WAS THE OUTCOME?
In addition to all the steps of the study and methodologies, the final report presented: (1)
combined reliability and reliability charts for use in probabilistic seismic damage
assessment of sub-standard bridge columns, (2) a relatively simple analytical approach to
capture the effect of lap-spliced bars on the response of the sub-standard columns through
modifying the stress-strain relationship of steel (3), and a four-part illustrative example to
help facilitate the application of combined reliability charts in identifying vulnerable
bridges.

WHAT IS THE BENEFIT?
The research outcome assist Caltrans engineers to (1) identify sub-standard bridge piers
that are more susceptible to damage prior to occurrence of earthquakes to prioritize the
retrofitting program using a probabilistic approach specific to the bridge and (2) assess the
level of expected damage to existing sub-standard bridge piers in the aftermath of
earthquakes to prioritize the repairing program. The proposed probabilistic approach will
be more effective than the commonly used retrofitting approach of “all or nothing”, which
may be unnecessary and costly.

LEARN MORE
To view the completed report:
http://wolfweb.unr.edu/homepage/saiidi/caltrans/ProbablisticII/PDFs/FinalreportCaltra
ns%20PSDA-1-18-2017.pdf
Damage states for sub-standard bridge columns

Capacity distribution curves
Sample of demand distribution curves

Sample of combined reliability charts