Influence of Structural Modeling on Seismic Vulnerability Assessment of a RC Viaduct using Fragility Curves

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Summary

The fragility curve is a tool to estimate the probabilities that the structural damage exceeds specific damage state under various levels of seismic excitation. The main objective of this paper is to develop the fragility curves for a typical viaduct by analytical approach. In this study, a sample three span, two lane viaduct, situated in a highly seismic region in the country, is considered for development of fragility curve for seismic vulnerability assessment. Capacity of the bridge has been determined by static nonlinear analysis (Pushover analysis). The seismic demand parameters of the bridge were obtained by performing nonlinear time history analysis for different prescribed ground motion histories recorded in the past earthquakes. The fragility curves for the overbridge piers have been constructed assuming a lognormal distribution. The influence of modeling aspects of the viaduct structure on fragility curves has been investigated by considering two different structural models for the response analysis. It is observed that that the fragility curves are more sensitive to the structural modeling for higher damage level.

Keywords: Seismic vulnerability; fragility curve; modelling; reinforced concrete; viaduct

1. Introduction

Viaducts, like other types of bridges, are the life-line structures and are the critical components of the transportation systems. About 500 bridges have been damaged on 26th January 2001 Bhuj earthquake alone. Most of the bridges suffered severe damage or collapse due to failure of their piers, although the bridge decks were undamaged due to high in-plane stiffness. Therefore, it is important to develop measures to quantify the associated seismic risk and to predict the possible damages that can be experienced by the viaduct structure under seismic events. With this risk quantified, rational decisions can be made as to whether the viaduct / bridge should be retrofitted or replaced, or to accept the risk and leave the bridge in the existing state.

2. Methodology

The likelihood of structural damage due to different levels of seismic ground motion is usually expressed by the fragility curves. A fragility curve describes the cumulative probability of getting damaged to a specific damage level for various levels of ground excitation. In this study, fragility curves are developed analytically with respect to peak ground acceleration (PGA) for seismic damage assessment of the sample viaduct. Ten strong motion data are selected for this analysis

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based on their characteristics. The selected ground motions are further normalized into different PGA levels from 0.1g to 1.5g to get wide ranges of ground motion records.

Fragility curves are constructed with respect to PGA. The damage ratio for each damage level in each excitation level is obtained by calibrating the damage index. Based on these data, fragility curves for the viaduct piers are constructed assuming a lognormal distribution. The cumulative probability $P(\geq R)$ of occurrence of the damage equal or higher than level R is given as

$$P(\geq R) = \phi\left[\frac{\ln X - \lambda_x}{\xi_x}\right] \tag{2}$$

where, ϕ is the standard normal probability distribution, λ_x and ξ_x are the mean and standard deviation respectively of $\ln X$ and X is the peak ground acceleration.

3. Results and discussions

The analytical fragility curves for all the damage levels have been developed using the parameters obtained from the linear regression analysis of damage data. The analytical fragility curve for the sample viaduct obtained from lumped mass model and distributed mass model respectively. It is observed that the slopes of the fragility curves with lower damage level are steeper compared to the same for fragility curve for higher damage levels for any level of PGA. This indicates that the cumulative probability of exceeding lower damage levels is very high within a small span of PGA, while the cumulative probability of exceeding higher damage levels increases gradually with the increase in PGA levels. It is also observed that the probability of meeting or exceeding limiting damage levels of the viaduct – *No Damage* and *Complete Damage* for PGA level 0.36g, prescribed for seismic zone –V as per IS 1893 (I): 2002, are 0.9 and 0.1 respectively.

Comparison of analytical fragility curves obtained using the lumped mass model and distributed mass model have been made to investigate the influence of structural modeling. It is evident that cumulative probability of exceeding damage level – II to V estimated on the basis of lumped mass idealization is on the higher side compared to that obtained on the basis of distributed mass idealization for any PGA level. Thus, the influence of structural modeling on fragility curves has been observed to be significant for higher damage levels.

4. Conclusion

The influence of structural modeling on the fragility curves have also been investigated by considering two different analytical models. Comparison of analytical fragility curves obtained from lumped mass model and distributed mass model reveals that the influence of structural modeling is significant for higher damage levels.