Effect of structural parameters on failure probability of piers in seismic isolated concrete bridges

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ABSTRACT

Bridges are a critical part of the urban and suburban transportation network, so they are supposed to be designed to sustain earthquake induced damages to be utilized after earthquake. Various parameters can affect the behavior and probability of failure of a bridge and the present work aims to evaluate the effects of structural parameters on the probability of failure in isolated concrete bridges

OpenSees software is used for simulating and analyzing 16 different bridge models. Incremental dynamic analysis is conducted using this software and IDA and fragility curves of models are derived and presented. The results show that the probability of failure decreases with the increase of the pier diameter, concrete compressive strength, yield strength of longitudinal rebar, and diameter of longitudinal bars. Also increasing the stiffness of elastic isolator and decreasing confined diameter of pier results in increasing the probability of failure. Furthermore, results show that, the probability of failure is more sensitive on the variation of pier confined diameter, yield strength of longitudinal rebar, diameter of longitudinal bars and the stiffness of elastic isolators in comparison with the variation of concrete compressive strength.

KEYWORDS

Concrete bridge, IDA, Fragility curves, Elastomeric seismic isolator

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1. Introduction

As often observed from destructive earthquakes, bridges are one of the most vulnerable components of a highway network system subjected to earthquake ground motion. Seismic behavior of isolated reinforced concrete bridges can be affected by changing geometrical or material properties. The object of this paper is to investigate the effect of structural parameters on failure probability of piers in seismic isolated concrete bridges. For this reason, a group of structural parameters consisting concrete compressive strength; yield strength of longitudinal rebar; pier confined diameter; pier diameter; stiffness of isolators and diameter of longitudinal rebar considered.

2. Methodology

The base model is a regular three-span isolated RC bridge with circular piers which is in a high seismic hazard zone, located on soil type III and has been designed based on AASHTO standards[4]. "Figure 1" shows the main characteristics of the base model.

For bridges, a common idealized for dynamic analysis is using a stick model. OpenSees software is used for simulating and analyzing 16 different bridge models. Incremental dynamic analysis is conducted using this software and IDA and fragility curves of models are derived. Concrete and rebar materials were modeled by using Concrete02 and Steel02 materials respectively. Isolators have been modeled using zeroLenght element and assigning an Elastic uniaxialMaterial to them. Superstructure and columns have been modeled using nonlinear element.

In this study, fragility curves which are developed by conducting incremental dynamic analysis, are used to evaluate the effects of structural parameters on seismic behavior and the probability of failure of isolated RC bridges. "Table 1" shows the assumed structural parameters and their amount [6-8].

Table 1. Assumed structural parameters and their amounts

Assumed amounts	Unit	Parameter
20-25-28-30	MPa	(fc) Concrete compressive strength
300-400-500	MPa	(fy) Yield Strength
1.7-1.73-1.75-1.77	m	Confined diameter
100-200-400-800	Ton/m	(k) Stiffness of isolator
1.5-1.8-2.0	m	Pier diameter
20-26-32	mm	Rebar diameter

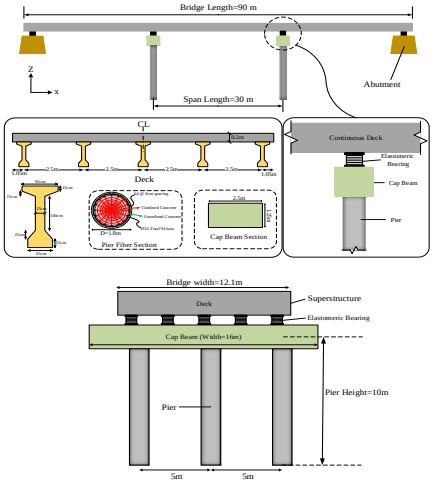


Figure 1. Main characteristics of the base bridge model

A group of 7 near-field earthquake have been chosen for incremental dynamic analysis and Dutta and Mander limit states which are based on piers' drift are considered for developing fragility curves [9].

3. Results and Discussion

In figures 3 to 8, fragility curves of bridge piers based on considered limit states and structural parameters are available.

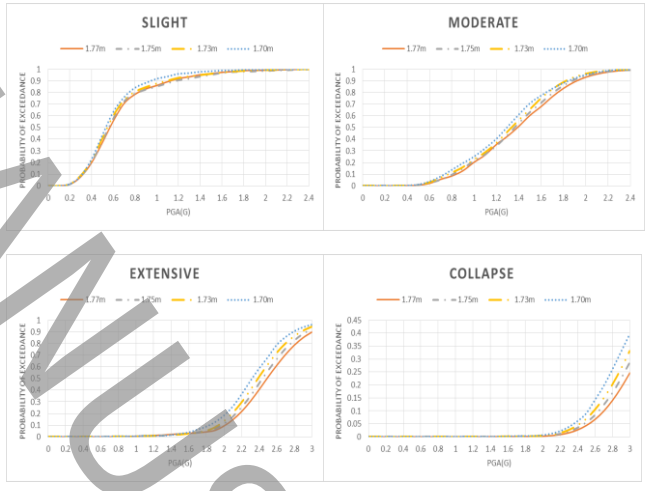
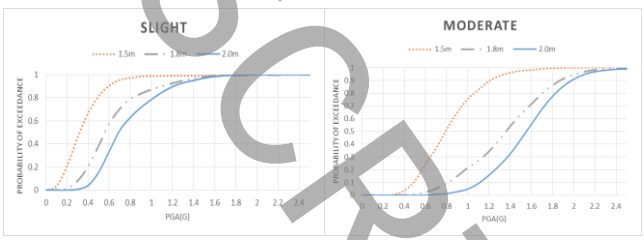


Figure 2. Fragility curves for piers



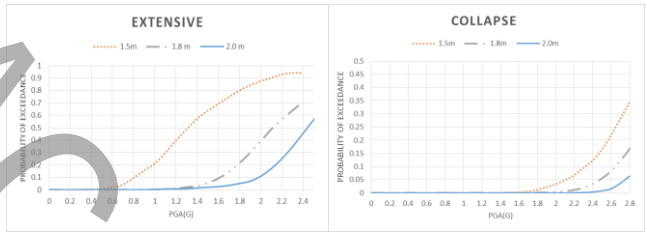


Figure 3. Fragility curves of for pier diameter

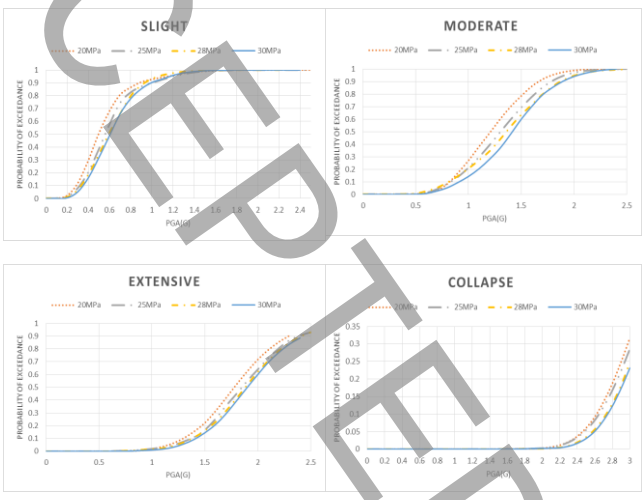


Figure 4. Fragility curves for concrete compressive strength

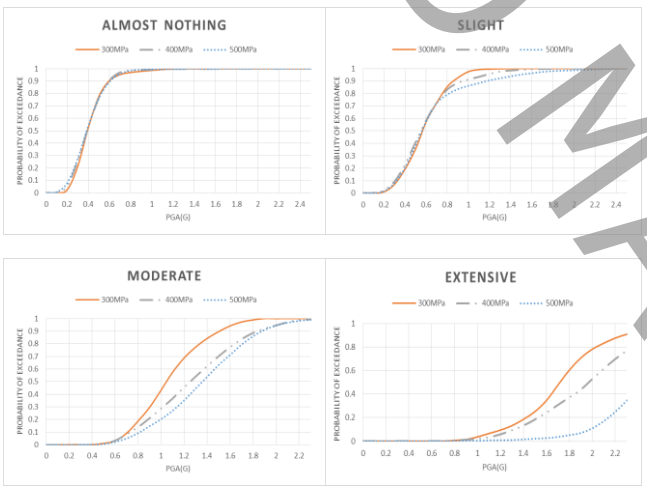


Figure 5. Fragility curves for different rebar yield strength

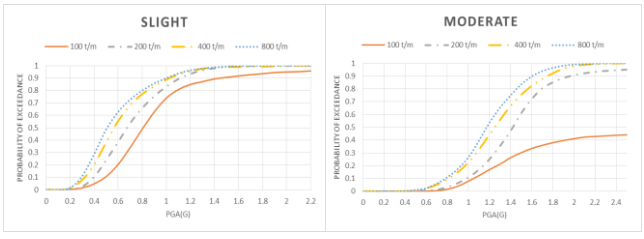


Figure 6. Fragility curves for different isolator stiffness

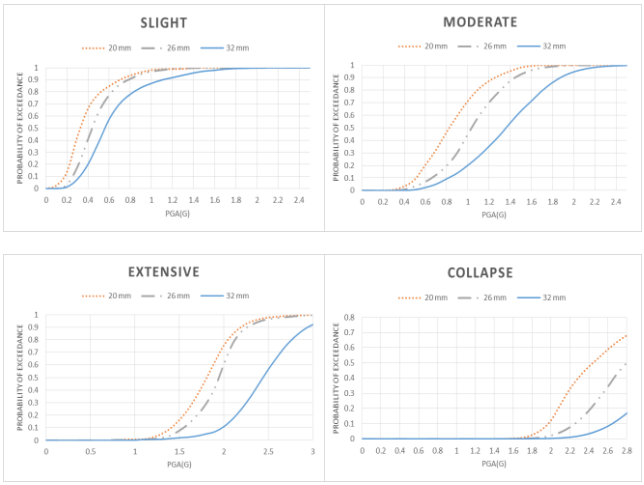


Figure 7. Fragility curves of different longitudinal rebar diameter in all damage states

4. Conclusions

The focus of this study was to investigate the effect of structural parameters on failure probability of piers in seismic isolated RC bridges. Based on developed fragility curves:

1. By decreasing the amount of piers' confined diameter, failure probability increases.

2. Increasing the amounts of pier diameter and rebar yield strength, results in decreasing the probability of failure.

3. Although the concrete compressive strength does not have a substantial effect on the seismic behavior of piers, increasing the amount of this parameter, decreases the probability of failure.

4. Stiffness of isolators is one of the major parameters in seismic behavior of isolated RC bridges. Increasing the amount of this parameter, increases piers' drift and displacement and as a result the probability of failure increases.

5. The last considered parameter is longitudinal rebar diameter that increasing the amount of this parameter results in decreasing the failure probability of seismic isolated RC bridges.

5. References

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