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Seismic Vulnerability of Interaction Soil-Pile-pier Bridges Under Mainshock-Aftershock Sequences Using the Fragility Methodology

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Abstract

Pile foundations strongly influence the performance of supported structures and bridges during a earthquake, only mainshock actions are considered without incorporating the effect of mainshock-aftershock (MA) sequences. This study primarily investigates the seismic fragility of mainshock-aftershock (MA) sequences damaged of bridge with consideration the effect of interaction soil-pile-structure, type of soil and masse effect. Analytical fragility curves are developed for the bridge components based on the outputs of an Incremental Dynamic Analysis (IDA) using 19 synthetic ground motion records. The results indicate that these parameters are significantly influenced on lateral capacity, ductility and seismic fragility on the ISPS. The increasing in the axial load exhibit high probabilities of exceeding the damage state.

Keywords: Seismic; Interaction Soil-Pile-Structure; Incremental Dynamic Analysis; Fragility Curves; Bridge.

1. Introduction

Some structures are stable during the main shock, with potential for collapse or severe damage from aftershocks. A well-known example of such devastating aftershocks is the 1997 Marche Umbria earthquake in central Italy, which del Preti et al. I have detailed the damage. [1] As evidence for other cases of the 1999 Kocaeli earthquake in Turkey (Mw 7.4) which was rotated by the USGS [2] Severe aftershock damage after the main shock at about 1 month. Theoretically, the inelastic behavior of the structure under the previous main shock results in deformations and residual plastic stiffness. In most studies on the effects of main shocks only ignoring seismic aftershocks, there has been little research on the effects of post-traumatic stress on structures. Bridges are considered one of the most important strategic structures that are characterized by the high costs of their construction. Whereas Ehsan Al-Omranian (2018) study finds fragility curves of RC deviated bridges exposed to major tremors and seismic aftershocks and fragility assessment is performed using cloud analysis method subject to a wide range of recorded sequences.You Dong (2015) also evaluated the probabilistic seismic performance of exposed highway bridges For main- shocks and aftershocks Seismic ground motion intensities, microphone sensitivity analysis for bridges, and assessment of results in the 2021 Seismic Structures Analysis Framework by Mohammad Mehdi Tourve Nejad Design four SSMF models with 4-20 stories numerically in OpenSees and subject to dynamic analysis (IDA) These aims Analyzes to observe the state of structural collapse under aftershock events that were preceded by different levels of major shocks.) from the collapse state in the presence of successive shocks that are then evaluated.] Seismic behavior of bridge structures (PSSI). et al. 2016); Specifically, their superstructures have been modeled as structural components simplified into linear, nonlinear, static or dynamic components (Moehle 2003). Ghazi et al (2018) and Rocky et al. (2020) investigated the interaction between the soil-stack-substrate (ISPS) system and the soil-to-soil interaction system.

(ISP) under lateral loads. The nonlinear static analysis takes into account the lateral load amplitude of the ISPS and the ISP under lateral loading using easy analysis, with the parametric study.

The linear steel ratio, pile length and soil type on the lateral response of the piles were studied with Nisreen Qaitavi on the amplitude curves for each variable to illustrate the fragility curves.

After comparing the embrittlement curves for these parameters; Wahid Choucair (2021) worked on developing a comprehensive and accurate analytical model for the seismic assessment of bridges, by studying the effects of soil-soil interaction (SPSI)

This research study aims to identify the structural and soil parameters (types of the sand, pile diameter, longitudinal steel ratio, and axial force level) that have the most and least sensitive effects on the seismic fragility of bridges. This is achieved by Transportation Infrastructure Geotechnology considering the effect of the interaction of the soil-pile-structure (ISPS) system. To reach this objective, a soil-pile-structure finite element (FE) model and a pushover analysis are used to determine the curve of capacity of the ISPS, define the damage condition criteria, and finally generate the fragility curves.

2. Numerical Tool and Modeling Strategies

The numerical analyses developed and described in this paper with different nonlinear modeling strategies were studied using the computer program SeismoStruct v7 (SeismoSoft and 2015). The program includes models for the representation of the behavior of spatial frames and soil under static and/or dynamic loading, considering both material and geometric nonlinearities. With this software, seven types of analyses can be performed, namely: dynamic and static timehistory analysis, conventional and adaptive pushover, incremental dynamic analysis, modal analysis, and static analysis (possibly nonlinear) under quasi-permanent loading.

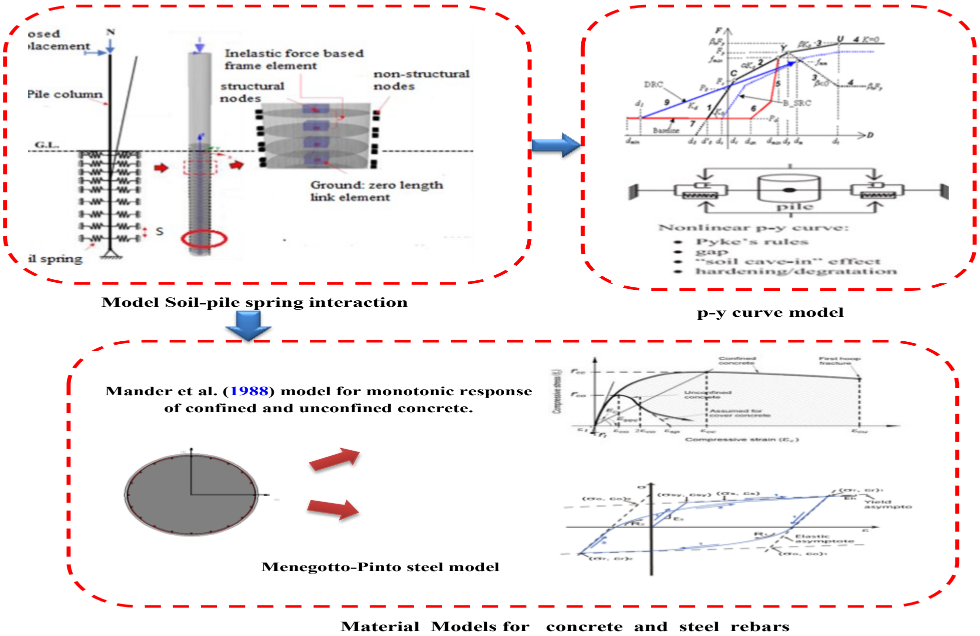
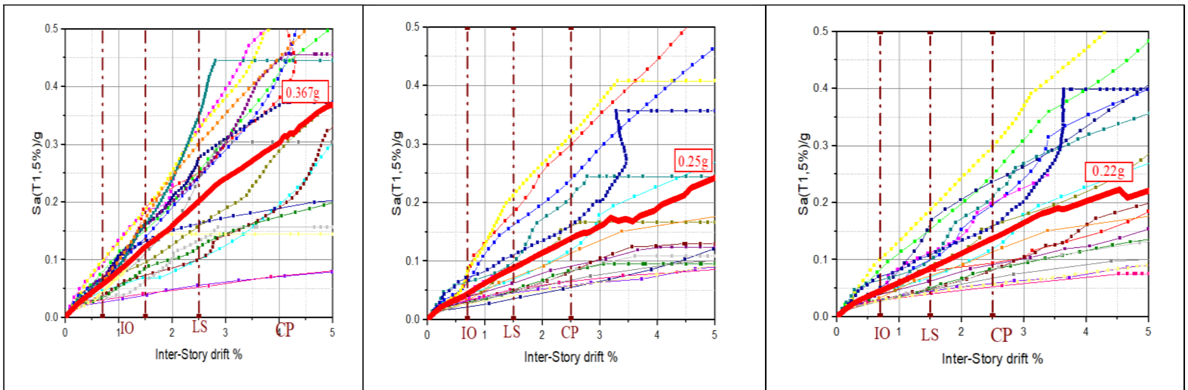


Figure 1. Structure of the Study (Developed by Author).

3. Results and Discussions

3.1 Incremental Dynamic Analysis

The IDA results the ISPS system in (loose) soils were obtained respectively under the influence of mass (150 tons, 350 tons) in the figures2.3. IDA curves were presented for only the three extreme cases, ie, mainshock only (MS), aftershock only (AS) and main shock -aftershock (MS-As). ISPS mean IDA curves are compared.

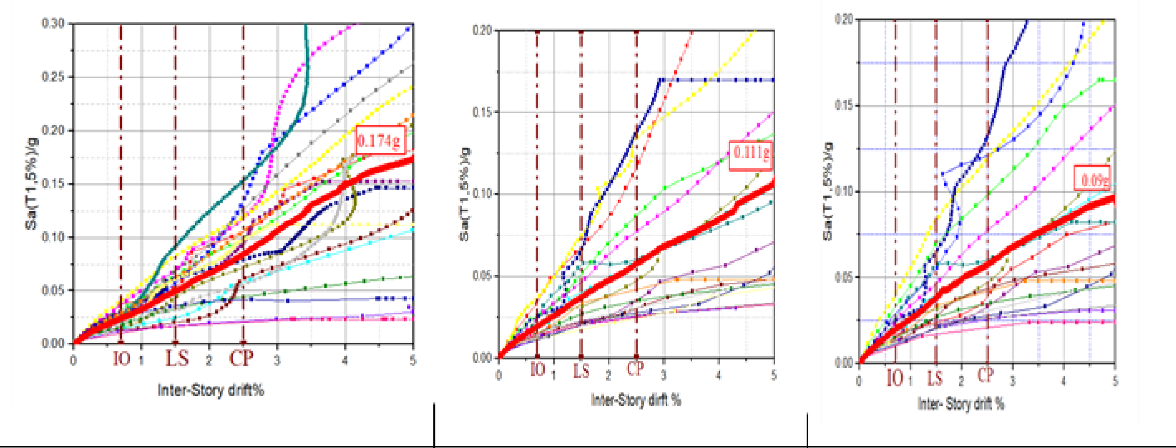


(a) (b) (c)

Figure 2. IDA results for ISPS system under the influence of mass (150t): (a) the aftershock-only (AS); (b) the mainshock-only (MS); (c) the mainshock-after shock (MS-AS).

Comparing the response of the ISPS system under the influence of mass (150 tons) subjected to the main shock only PGAs =0.25g, while the ISPS system under the mainshock- aftershock PGAs=0.22g has a lower capacity of 12%

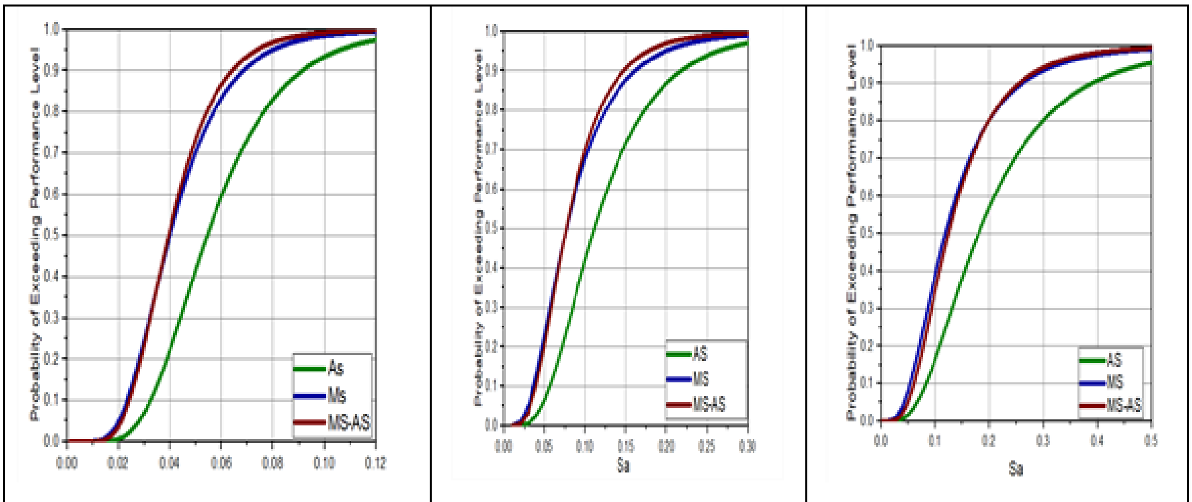
Comparing the response of the ISPS system under the influence of mass (350 tons) subjected to the main shock only PGAs=0.111g, while the ISPS system under the mainshock- aftershock PGAs=0.09g has a lower capacity of 18%.



(a)	(b)	(c)

Figure 3. IDA results for ISPS system under the influence of mass (350t): (a) the aftershock-only (AS); (b) the mainshock-only (MS); (c) the mainshock-after shock (MS-AS).

3.2 Fragility Curves



IO	LS	CP

Figure 4. Fragility curves for ISPS system under the influence of mass(150t):(AS;MS and AS-MS)

The decrease of the value of that the probability of exceedance for each damage state is increased and is affected by different damage states. for ISPS in (loose) soils were obtained respectively under the influence of mass (150 tons) under the influence of main shock-aftershock more vulnerable than under the influence of main shockunder the influence of main shok only and aftershock onlyThe values of Sa (15%) of probability of damage of the ISPS system with for different damage states (IO, LS, CP).

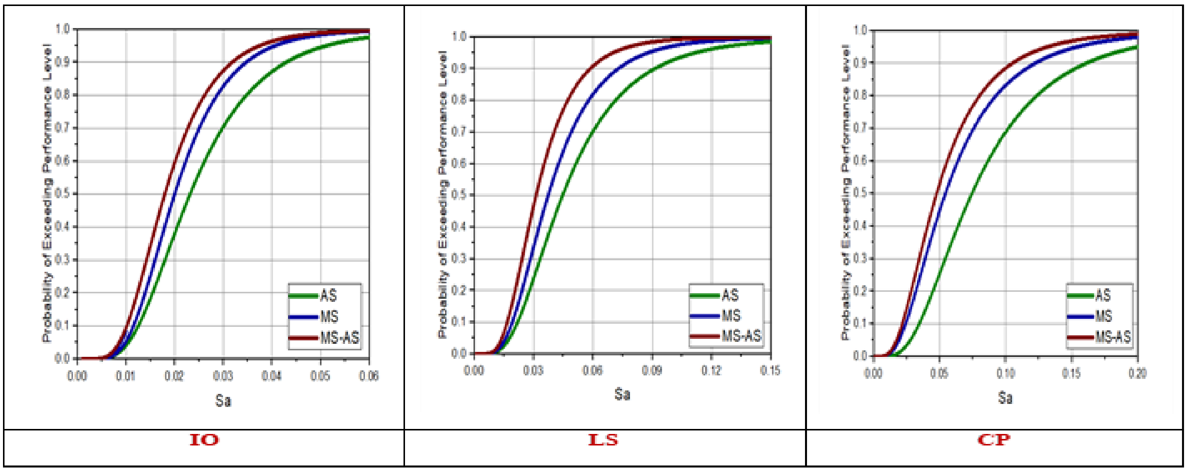


Figure 5. Fragility curves for ISPS system under the influence of mass (150t): (AS; MS and AS-MS)

The decrease of the value of that the probability of exceedance for each damage state is increased and is affected by different damage states. for ISPS in (loose) soils were obtained respectively under the influence of mass (350 t) under the influence of main shock-aftershock more vulnerable than under the influence of main shock under the influence of main shok only and aftershock only The values of Sa (30%) of probability of damage of the ISPS system with for different damage states (IO, LS, CP).

4. Conclusions

this study, the ISPS system in (loose) soils were investigated under earthquake loading capacity, were investigated under earthquake loading. the incremental dynamic analyses were carried for the three ISPS system (mainshock only (MS), aftershock only (AS) and main shock -aftershock (MS-As) for developed the fragility curves were compared, and the important
findings inferred from the study are enumerated as follows:
* The axial load influence the lateral capacity in ISPS system more IDA results (4,5)
*Mainshock–aftershock seismic sequences lead to an increase in the accumulated damage of theISPS system. Strong aftershocks will cause greater damage demands to the undamaged ISPS system than to the mainshock-damaged ISPS system.

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