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FRAGILITY CURVES FOR RC BRIDGES USING GENERALIZED PUSHOVER ANALYSIS

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ABSTRACT

Fragility functions have become in recent years a powerful and useful tool for the assessment of seismic losses in populations of structures and therefore the evaluation of the reliability of the different available procedures for their computation is an important task for the development of realistic risk assessment within a particular region. Furthermore, it has been recognised during past seismic events and in previous studies that the vulnerability assessment of bridges can be adequately carried out based on fragility curves. Static and dynamic nonlinear analyses can be implemented for the calculation of analytical fragility curves and, depending on the specific method employed, there are different possibilities for their application, as well as different sources of uncertainty. In this study, the Generalized Pushover Analysis (GPA) is implemented for developing analytical fragility functions of reinforced concrete (RC) bridges. The relative accuracy of the GPA algorithm, when applied to a population of existing bridges, is compared with results from Nonlinear Time History Analysis (NTHA), considered as the "exact" prediction.

Keywords: bridges, multi-mode pushover, seismic response, fragility assessment.

INTRODUCTION

Fragility functions play a critically significant role in the assessment of seismic loss thus the development of reliable procedures for their calculation has become increasingly popular. The existence of different analytical methodologies, as well as structure modelling approaches, has an important influence in the results of fragility functions. In addition, it has been recognized that bridges are one of the most vulnerable structural types during past seismic events. Depending on the seismic conditions of local site, seismic vulnerability assessment of bridges can be carried out based on fragility curves. Many tools are currently available for calculating fragility curves, especially based on analytical approaches, which have become widely used in earthquake engineering community due to its scientific soundness and because they overcome the lack of data in empirical approaches. Both static and dynamic nonlinear analysis can be employed for deriving fragility curves within an analytical approach and both of them feature numerous different possibilities of application as well as many sources of uncertainty. In this study, a recent, theoretically sound, nonlinear static procedure (NSP), the Generalized Pushover Analysis (GPA), is considered to develop analytical fragility functions of RC bridges. The performance of GPA, which is computationally faster than nonlinear time-history analysis (NTHA), is assessed when applied to a large number of existing bridge configurations, through comparison with the results of an extensive number of nonlinear dynamic analyses, considered as benchmark, in order to understand its level of accuracy in calculating seismic fragility functions.

In specific, 3D analytical RC bridge models are generated by OpenSees based on different material and geometric parameters so to take structural variability in consideration. Nonlinear analyses were conducted for each bridge model under different ground motion records, selected according to the local seismic hazard characterizing the exact location of the bridge, so as to duly incorporate the epistemic/aleatory uncertainty. Curvature ductility was employed as the reference parameter in determining the bridge damage limit states in terms of structural capacity and both static and dynamic procedures are used to derive fragility functions for each simulated bridge.

RESULTS AND CONCLUSIONS

The presentation of results is divided in two main parts: one corresponds to the validation of the nonlinear static procedure, through direct comparison of estimated response, by means of a parameter defined as Bridge Index (BI) calculated as the median of the ratios between the response parameter quantities, at different bridge locations, estimated for the performance point of the structure, and the maximum response parameter quantities estimated with nonlinear time-history analysis. The second part of the results regards the performance of the GPA in terms of fragility curves for different damage states.

Figure 1 illustrates the preliminary results regarding the first part of the comparison (validation of GPA with respect to NTHA) for one of the case-study configurations, in which it is seen that there is a very good match between the nonlinear static and dynamic response estimates, with a tendency for the static to overestimate the dynamic counterpart.

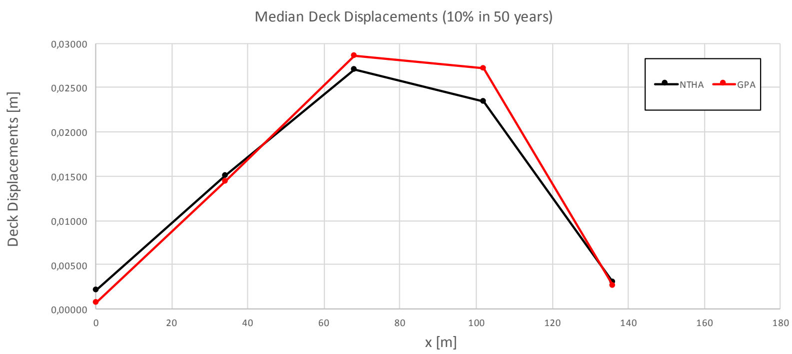

Fig. 1 - Deck displacement shape for static and dynamic approaches

In terms of fragility curves, the results have also demonstrated that the GPA algorithm is able to successfully capture the seismic response of the case study bridges, for all hazard levels considered, for both regular and irregular layout configurations that were considered in this study. These results have been consistently verified for seismic events of low intensity level (low return periods and higher probability of exceedance) and with high return periods i.e. low probability of exceedance.

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