Recent developments on the effect of asynchronous earthquake excitation on the dynamic response of soil-foundation-superstructure bridge systems

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Abstract

During strong ground motion, it is expected that bridge structures are subjected to excitation that is non-uniform along their longitudinal axis in terms of amplitude, frequency content and arrival time, a fact primarily attributed to the wave arrival delay, their loss of coherency and the effect of local site conditions. To this end, advanced analytical solutions and enhanced know-how is utilized in order to identify the relative importance of the aforementioned phenomena and investigate potential implications in engineering design. The scope of this paper therefore, is to review the recent developments on the problem by illustrating numerical examples of the dynamic response of characteristic bridge structures under asynchronous excitation scenarios of varying levels of complexity and refinement. It is concluded that the problem is multi-parametric and complex but certain situations can be identified where the assumption of identical excitation between support points strongly underestimates the imposed ductility demand both at the foundation and the superstructure.

INTRODUCTION

From all the parameters that define the non-linear dynamic response of complex structures such as bridges, the input motion has by far the highest level of uncertainty. The last three decades, different approaches, methodologies and tools have been utilized to deal with this uncertainty and put it in a framework that can be quantified and thus uniformly interpreted by the practicing engineers and the scientific community. The extensive use of refined response spectra and the utilization of real records from different soil and seismotechtonic conditions is a precious source of information regarding the potential excitation of bridges, which when combined with the increasingly enhanced capabilities for inelastic dynamic analysis provides a very good estimate of the expected response of bridge structures under earthquake loading. Nevertheless, the uniform application of the selected natural or even artificial motions along the supports is not necessarily valid for extended structures since, as recent research has shown, seismic motion can be not only significantly different at each pier support point but also induce forces and deformations that could not be predicted with the assumption of synchronous excitation.

The sources of spatial and temporal variations of seismic motion are well known (Der Kiureghian & Keshishian) and can be summarized as the effect of a) waves travelling at a finite velocity, so that their arrival at each support point is out of phase b) loss of coherency in terms of statistical dependence, that is, loss of signals ‘similarity’ due to multiple reflections, refractions and superpositioning of the incident seismic waves that occur during propagation and c) local soil conditions especially for cases that the soil profile through which motion propagates varies significantly. Due to the above, both peak ground acceleration and frequency content of the motion may be strongly varied among the foundations of the successive piers. Although often neglected, the potential filtering at the foundation level that results from the relative flexibility of the foundation-soil system components is an additional parameter that contributes to the extent of variability of the motions that are actually imposed at each separate pier.

Another simplification often made is that, bridge structures are commonly considered to