Effect of Asynchronous Earthquake Motion on Complex Bridges. I: Methodology and Input Motion

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Abstract: Based on observed damage patterns from previous earthquakes and a rich history of analytical studies, asynchronous input motion has been identified as a major source of unfavorable response for long-span structures, such as bridges. This study is aimed at quantifying the effect of geometric incoherence and wave arrival delay on complex straight and curved bridges using state-of-the-art methodologies and tools. Using fully parametrized computer codes combining expert geotechnical and earthquake structural engineering knowledge, suites of asynchronous accelerograms are produced for use in inelastic dynamic analysis of the bridge model. Two multi-degree-of-freedom analytical models are analyzed using 2,000 unique synthetic accelerograms with results showing significant response amplification due to asynchronous input motion, demonstrating the importance of considering asynchronous seismic input in complex, irregular bridge design. The paper, Part 1 of a two-paper investigation, presents the development of the input motion sets and the modeling and analysis approach employed, concluding with sample results. Detailed results and implications on seismic assessment are presented in the companion paper: Effect of Asynchronous Motion on Complex Bridges. Part II: Results and Implications on Assessment.

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Introduction

Because curved elevated transportation structures are becoming a common solution to complex transportation problems, it is important that a commensurate breadth and depth of research are invested in understanding these complex structures. Natural disasters of the past few decades have provided numerous examples of bridge damage and collapse for bridges that were designed for seismic forces (Elnashai et al. 1999). To better protect bridges from future earthquakes, researchers must aid bridge designers by utilizing field observations and expanding on past investigations to include representative bridges of all types and alignments, striving to make inelastic dynamic analyses as realistic as possible. With advances in computing power, structural and seismological features previously simplified can be fully included in analysis.

Utilizing advanced analysis tools, this study seeks to include two complicating factors not often considered in seismic analysis: (1) bridge irregularity, including varied pier heights, abutment end conditions, and a curved horizontal alignment; and (2) spatially varied seismic input with a range of incoherence cases. Inclusion of the first factor recognizes that actual bridges must often be irregular due to site limitations or alignment requirements. The second factor is included due to increased understanding of the seismological characteristics of earthquakes and the higher displacement demand possible from asynchronous input, demonstrated in recent studies (Sextos et al. 2004; Lupoi et al. 2005).

To consider the effect of bridge irregularity, equivalent curved and straight concrete bridge models will be subjected to asynchronous earthquake motion and their responses compared in the following companion paper. Because the vast majority of previous analytical studies have been performed on straight bridges, this comparison will determine whether asynchronous response amplification can be expected to be similar for curved versions of previous bridges studied. The effect of various levels of earthquake incoherence will be determined using synthetic accelerograms generated by means of two specifically developed, state-of-the-art asynchronous record generation software programs.

Spatially Asynchronous Earthquake Motion

Sources of Asynchronous Motion

Consideration of spatially varied seismic input motion is challenging due to its complexity. Wave travel speed, reflection and

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