ICEGE
ISTANBUL 2013
From Case History to Practice | In honour of Prof. Kenji Ishihara

ASYNCHRONOUS EXCITATION OF LONG BRIDGES CONSIDERING SOIL-STRUCTURE INTERACTION: EVIDENCE, ONGOING RESEARCH AND DESIGN IMPLICATIONS

Anastasios SEXTOS[1]

EXTENDED ABSTRACT

Although bridge structures might seem at a first sight as rather linear and simple structural systems, their actual performance under earthquake loading is more complicated than that of ordinary buildings, because bridges have typically an order of magnitude larger overall and cross-sectional dimensions, different energy absorption mechanisms, more significant contribution of higher modes, while they are most commonly crossing non-uniform soil profiles that yield critical the pier-dependent effect of soil-foundation-superstructure interaction. For this reason and despite the significant research progress made to date which has already shed some light on many bridge engineering problems, the development of a “realistic” earthquake motion scenario is still associated with the highest relative uncertainty compared to maybe all other design and construction aspects.

This is even more pronounced in the case of long bridges, where the variation of ground motion among its supports in terms of arrival time, frequency content and amplitude, can strongly affect both the pseudo-static and the dynamic component of the system. One major difficulty in assessing in advance the spatially variable patterns of earthquake ground motion is the complex reflections, refractions and superpositions that take place as seismic waves travel through inhomogeneous soil media. Different analytical formulations have been proposed in the past, but the inherent multi-parametric and coupled nature of wave propagation and soil-structure interaction makes it practically impossible to predict the asynchronous input along the bridge length and the overal seismic response of the system in a deterministic manner (Sextos *et al.* 2003, Burdette *et al.* 2008, Zerva 2009, Cacciola and Deodatis 2011, Soyluk and Sicacik 2011, Konakli and Der Kiureghian 2012).

The objective of this presentation therefore, is to discuss the recent findings on the the impact of asynchronous seismic excitation, based on analytical and numerical evidence as well as on the monitored response of specific bridges recently constructed along the new 780km Egnatia highway in northern Greece (a highway consisting of a total 40km of bridges, most of them located in areas of high seismicity and an unfavorable mountainous topography). Emphasis is also given on the monitored response of the 400m cable-stayed Evripos bridge that connects the Evia island to the Greek mainland, primarily because it has been excited by the 1999 Athens earthquake (Lekidis et al., 2005). It is seen that despite the long distance from the earthquake source, the simultaneous free-field and on-structure recordings reveal interesting patterns of higher mode excitation and subsequent dynamic behaviour that cannot be a-priori predicted using both the conventional analytical methods and the existing design code provisions for asynchronous motion (Karakostas et al., 2011). Overall, having assessed 28 different bridges under spatially variable earthquake motion scenarios, the results are comparatively assessed and important design implications are discussed.

[1] Assistant Professor, Department of Civil Engineering, Aristotle University of Thessaloniki, Greece
asextos@civil.auth.gr

Keywords: Spatial variability of earthquake ground motion, bridges, soil-structure-interaction

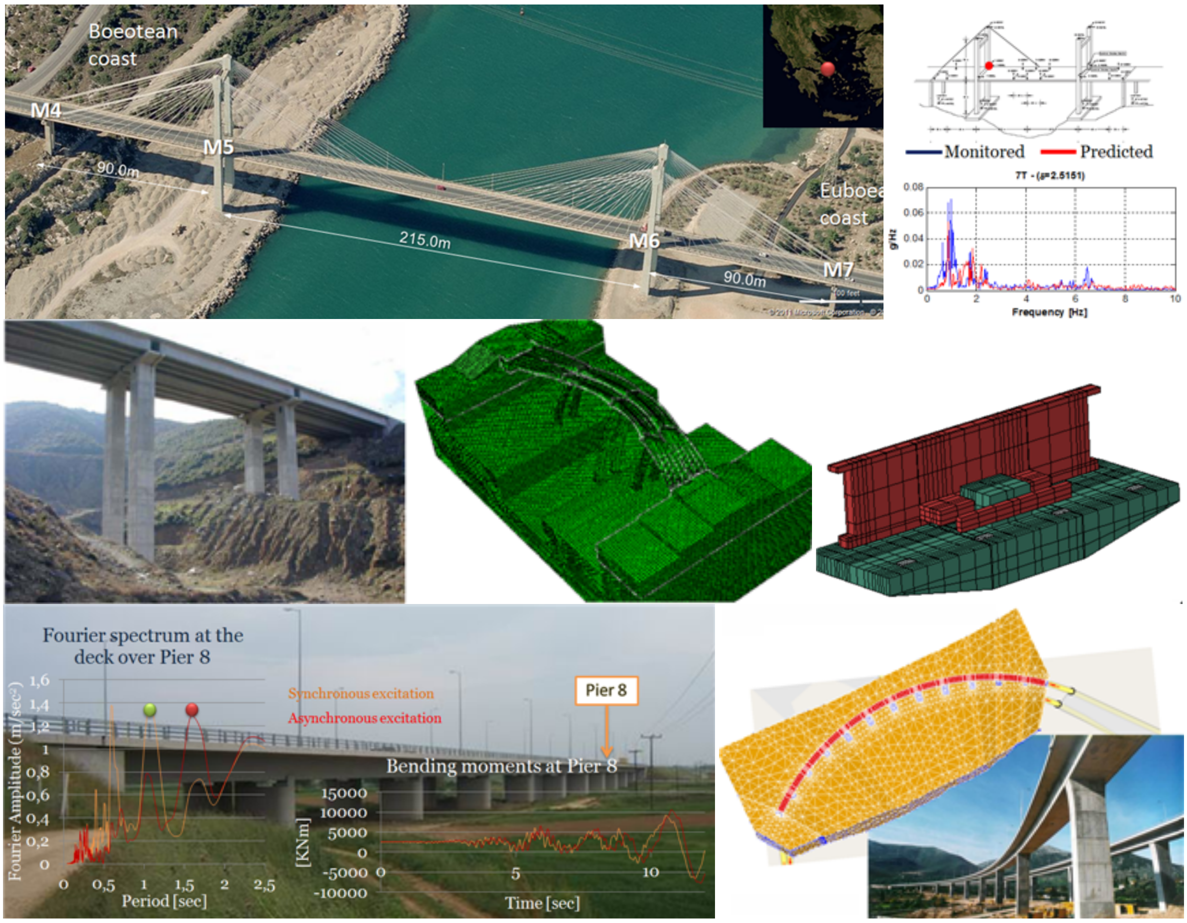

Fig. 1. Overview of Evripos (top), Kavala (middle), Lissos (bottom, left) and Krystallopigi (bottom, right) bridges studied under synchronous and asynchronous earthquake excitation scenarios

REFERENCES

Burdette, N.J., Elnashai, A.S., Lupoi, A., and Sextos, A.G. (2008) "Effect of Asynchronous Earthquake Motion on Complex Bridges. I: Methodology and Input Motion", *Journal of Bridge Engineering*, 13 (2), 158–165.

Cacciola, P. and Deodatis, G. (2011) "A method for generating fully non-stationary and spectrum-compatible ground motion vector processes", *Soil Dynamics and Earthquake Engineering*, 31 (3), 351–360.

Konakli, K. and Der Kiureghian, A. (2012) "Simulation of spatially varying ground motions including incoherence, wave passage and differential site response effects", *Earthquake Engineering & Structural Dynamics*, 41 (3), 495–513.

Lekidis, V., Tsakiri, M., Makra, K., Karakostas, C., Klimis, N., and Sous, I. (2005) "Evaluation of dynamic response and local soil effects of the Evripos cable-stayed bridge using multi-sensor monitoring systems". *Engineering Geology*, 79 (1-2), 43–59.

Karakostas, C., Sextos, A. G., Lekidis, V. & Papadopoulos, S. (2011) "Investigation of the dynamic response of the Evripos cable-stayed bridge in Greece, under asynchronous ground motion records" *3rd ECCOMAS Thematic Conference on Computational Methods in Structural Dynamics and Earthq. Eng.*, Corfu, Greece.

Sextos, A.G. and Kappos, A.J. (2009) "Evaluation of seismic response of bridges under asynchronous excitation and comparisons with Eurocode 8-2 provisions", *Bulletin of Earthquake Engineering*, 7 (2), 519–545.

Sextos, A.G., Pitilakis, K.D., and Kappos, A.J. (2003) "Inelastic dynamic analysis of RC bridges accounting for spatial variability of ground motion, site effects and soil-structure interaction phenomena. Part 1: Methodology and analytical tools", *Earthquake Engineering & Structural Dynamics*, 32 (4), 607–627.

Soyluk, K. and Sicacik, E.A. (2011) "Soil–structure interaction analysis of cable-stayed bridges for spatially varying ground motion components". *Soil Dynamics and Earthquake Engineering*, 35, 80–90.

Zerva, A., 2009. *Spatial Variation of Seismic Ground Motions: Modeling and Engineering Applications (Advances in Engineering Series)*. CRC Press, Taylor & Francis Group, FL.