1st Croatian Conference on Earthquake Engineering
1CroCEE
22-24 March 2021 Zagreb, Croatia

DOI: https://doi.org/10.5592/CO/1CroCEE.2021.254

Modes of of long-span structures subjected to multiple support earthquake excitation

Nina Čeh[1], Han Qin[2], Gordan Jelenić[3], Luyu Li[4]

[1] *Assistant Professor*, University of Rijeka, Faculty of Civil Engineering, Rijeka, Croatia, *nina.ceh@uniri.hr*
[2] *Postdoctor*, Dalian University of Technology, School of Civil Engineering, Dalian, China, *hiker_qh@qq.com*
[3] *Professor*, University of Rijeka, Faculty of Civil Engineering, Rijeka, Croatia, *gordan.jelenic@uniri.hr*
[4] *Professor*, Dalian University of Technology, School of Civil Engineering, Dalian, China, *liluyu@dlut.edu.cn*

Abstract

Long span structures with significant distance between the adjacent supports experience multiple support excitation. The difference in the excitation of the supports occurs due to the change of seismic-wave properties when passing from one medium to another, a delay caused by the distance between the supports, the position of the epicentre relative to the structure etc. The dynamic response of a long-span structure to such excitation usually significantly differs from the dynamic response of the same structure to uniform excitation of the supports. This is most obvious in the contribution of the antisymmetric modes of oscillation to the total shape of the deformed structure, which can increase significantly.

Key words: multiple support excitation, earthquake excitation, long-span structures, antisymmetric modes of oscillation

Long span structures with significant distance between the adjacent supports experience multiple support excitation. The difference in the excitation of the supports occurs due to the change of seismic-wave properties when passing from one medium to another, a delay caused by the distance between the supports, the position of the epicentre relative to the structure etc. The dynamic response of a long-span structure to such excitation usually significantly differs from the dynamic response of the same structure to uniform excitation of the supports. This is most obvious in the contribution of the antisymmetric modes of oscillation to the total shape of the deformed structure, which can increase significantly.
In order to detect this effect and determine some of the critical excitation conditions of the multiple support excitation, a series of experiments on a simply supported beam with added masses subjected to multiple support excitation via two biaxial seismic platforms is designed and conducted. The experimental set-up is designed based on a number of preliminary experiments [3] and shown in Figure 1. The beam is aluminium, as well as the specially designed supports. The supports are fixed to two biaxial shaking tables Quanser STI-III with electromagnetic linear motors run by LabView-based software.

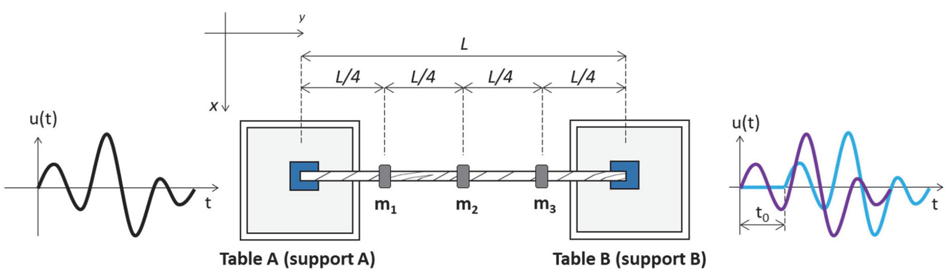

Figure 1. Scheme of laboratory experiments: beam with three added masses and supports attached to two separate shaking tables

The measurements are obtained from a series of photos taken by GOM Aramis 4M optical measuring system, which consists of two high-speed cameras. The optical system measures the position of discrete points on the surface of the model, in this case the positions of the two supports (attached to tables A and B) and the three added masses (m_1, m_2 and m_3). The presented model is excited in x direction (Figure 1) by a generated 10 Hz bandlimited white noise signal which is either sent to both tables uniformly (at the same time) or to table B with a delay of 0.5 or 1 s [1, 2].
Displacement histories obtained after post-processing the data from the optical measuring system are translated into the frequency domain. Power spectral density (PSD) of mass m_1 is chosen to present the dynamic response of the midpoint of the system (shown in Figure 2). This illustrates that the displacements of the midpoint corresponding to the excitation frequency similar to the first and third natural frequency of the beam slightly decrease when a delay in excitation of support B is present. Furthermore,

a significant increase in the displacements corresponding to the excitation frequency close to the second natural frequency are noticed. This clearly proves that the antisymmetric mode of oscillation is amplified.

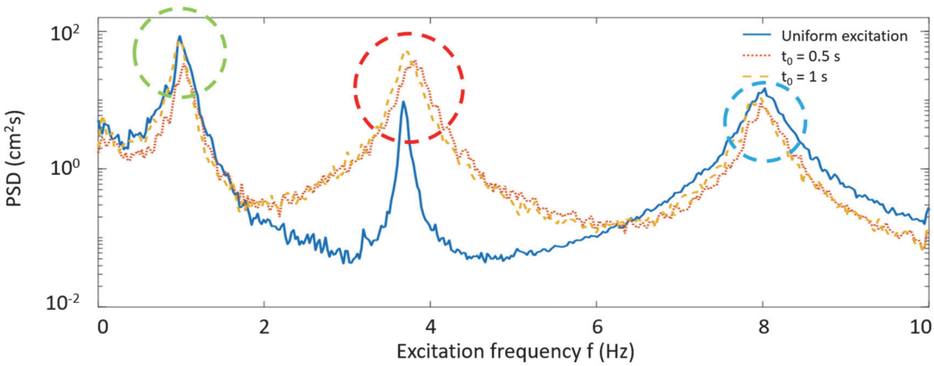

Figure 2. Power spectral density for mass m_1 with respect to the excitation frequency of a white noise excitation that is either uniform or contains a delay between the two supports

The experimental program shows that the displacements corresponding to the antisymmetric modes are significantly increased when a small delay in the excitation of the supports is present, as well as other interesting effects that should be considered during the analysis. Our future plan includes using these phenomenon for bridge design and control. When designing the bridge span the wave passage effect should be considered in order to reduce the prominent modes. Furthermore, control devices such as different dampers can be used to change the properties of the structure.

Acknowledgements

This research is a part of bilateral projects between University of Rijeka, Faculty of Civil Engineering (Croatia) and Dalian University of Technology, School of Civil Engineering (China) "Experimental study of large span structure considering multiple support excitation" (2018-2020) and "Experimental study of bridge structures considering the asymmetric effect under multiple support excitation" (2021-2023). The laboratory equipment used to conduct the experiments is purchased within the project RC.2.2.06-0001 "Research Infrastructure for University of Rijeka Campus (RISK)" founded by the European Fund for Regional Development.

References

[1] R. S. Harichandran and E. H. Vanmarcke, “Stochastic Variation of Earthquake Ground Motion in Space and Time,” *J. Eng. Mech.*, vol. 112, no. 2, pp. 154–174, Feb. 1986, doi: 10.1061/(ASCE)0733-9399(1986)112:2(154).

[2] J. E. Luco and A. Mita, “Response of Circular Foundation to Spatially Random Ground Motion,” *J. Eng. Mech.*, vol. 113, no. 1, pp. 1–15, Jan. 1987, doi: 10.1061/(asce)0733-9399(1987)113:1(1).

[3] S. Dobrilla, N. Čeh, M. Tuhtan, and G. Jelenić, “Eksperimentalna analiza odziva grednog nosača na nejednoliku pobudu oslonacaExperimental Analysis of Structure Response to Non-uniform Support Excitation,” *Zb. Rad.*, vol. 20, no. 1, pp. 175–188, Jul. 2018, doi: 10.32762/zr.20.1.11.