DOI: 10.24904/footbridge2017.09363

DYNAMIC CONSIDERATIONS IN CASE OF FOOTBRIDGES WITH ELEVATORS

Miguel A. VICENTE
Associate Professor
University of Burgos
Burgos, Spain
mvicente@ubu.es

Achim LICHTENFELS
Civil Engineer
Ingenieurbüro Lichtenfels
Keltern, Germany
achim.lichtenfels@lichtenfels.li

Dorys C. GONZÁLEZ
Associate Professor
University of Burgos
Burgos, Spain
dgonzalez@ubu.es

Summary

During the last two decades, there has been a significant increase of the number of footbridges including elevators. This is a very interesting solution in case of footbridges located in urban areas. However, it is necessary to take into account the dynamic forces induced by the machinery, in order to achieve an adequate comfort level and to avoid resonance phenomena.

This paper shows the dynamic testing carried out on the "Zarautz Bridge", placed in San Sebastián (Spain). The results show that elevator provokes a vibration in the structure that can be measured by the sensors. During starting and stopping, impact loads appear and provoke and small-in-amplitude free vibration of the footbridge. In this particular case, elevator does not provoke no comfort problems to the pedestrians. However, we should take the interaction footbridge-elevator into account during the design process, in order to prevent malfunctions of the structure.

Keywords: footbridge-elevator interactions; dynamic response; accelerations; vibrations

1. Introduction

Footbridges with elevator is becoming an increasingly common structural solution, especially in urban areas. They offer the advantage that they request less floor space, since ramps are not necessary. From the structural point of view, the elevator has been considered as an external element. The elevator is installed inside the elevator shaft, usually made of reinforced concrete. This elevator shaft also serves to support the catwalk and, eventually, to support the stairs.

However, to date, the fact that the presence of a mechanical element such as the elevator induces vibrations in the structure to be taken into account has not been considered. To date, the elevator is considered as an element outside the footbridge.

There is much research related to the dynamic response of footbridges and their interaction with user comfort [1 to 4]. There is also much research related to machine-structure interaction, but not in particular for the footbridges [5, 6]. This paper shows the experimental results and numerical analysis carried out on a footbridge placed in San Sebastian (Spain), which includes an elevator. The results show that there is a coupling between the natural frequencies of vibration of the footbridge and the excitation frequencies caused by the elevator.

2. Description of the structure

The footbridge shown in this paper is placed in San Sebastian (Spain). It is a composite steel-concrete footbridge composed by two steel box girders and an upper concrete slab. The footbridge has two levels. The lower one has only one span of 18.63 meters. The upper one has two spans of 18.63 and 14.77 meters. The intermediate pile is made of steel and it is 6.70 meters high. In one of the ends, the footbridge is supported in the concrete elevator shaft using two conventional elastic bearings. In addition, the stair runs

helicoidally around the elevator shaft. This document focuses on the dynamic study of the tower in which the elevator is located and on the upper level of the footbridge.

3. Analysis of the dynamic response

Four excitation hypotheses have been carried out to analyze the footbridge response. Hypothesis 1 consider four people placed on the mid-span of the greater span of the footbridge, centrally, and giving a single jump. Hypothesis 2 consider four people walking quickly along the footbridge aligned with a spacing of 1.5 meter between them, along the footbridge axis, starting at the elevator shaft. Hypothesis 3 consider the vertical movement of the elevator, without people, from the bottom to the top, and return. Hypothesis 4 consider the vertical movement of the elevator, with 6 people inside it, from the bottom to the top, and return. Additionally, 6 people waiting for the elevator on the footbridge. In hypothesis 1 and 2, people is used to excite the footbridge. In hypothesis 3 and 4, the elevator is used to excite the footbridge. Additionally, one excitation hypothesis has been carried out to analyze the concrete elevator shaft response. Hypothesis 5 consider the vertical movement of the elevator, with 6 people inside it, from the bottom to the top, and return.

In all cases, two triaxial accelerometers have been used with a range in accelerations of ± 2·g, a range in frequencies between 0 Hz and 100 Hz and an accuracy of 0.001·g.

4. Discussion and conclusions

The data shown in this paper provide some interesting information:

1) The starting and the stopping of the elevator provoke dynamic effects, that they are enough to cause free vibration in the structure. When the elevator starts or stops, it is possible to obtain the natural frequencies of the structure.

2) The own excitation frequency of the elevator, in this case, is quite high (about 40 Hz). However, in analysis of the dynamic response of the elevator shaft it is possible to detect vibration frequencies coincident with those of the footbridge.

3) During the design process of footbridges with elevators, it is important to consider the dynamic effects that the elevator induces to the footbridge. In this particular case, elevator does not provoke no comfort problems to the pedestrians. However, we should take the interaction footbridge-elevator into account during the design process, in order to prevent malfunctions of the structure. Different footbridge designs and different elevator shafts may show resonance phenomena.

5. Acknowledgements

The authors want to especially thank the City of San Sebastian and the Spanish company Landabe for the help shown in the implementation of the measures in the field.

6. References

[1] ZIVANOVIC S., PAVIC A., and REYNOLDS P., “Vibration serviceability of footbridges under human-induced excitation: a literature review”, Journal of Sound and Vibration, Vol. 279, 2005, pp. 1-71.

[2] SHAHABPOOR E., PAVIC, A., RACIC, V., and ZIVANOVIC S., “Effect of group walking traffic on dynamic properties of pedestrian structures”, Journal of Sound and Vibration, Vol. 387, 2017, pp. 207-225.

[3] SKEIVALAS, J., JUREVICIUS M., KILIKEVICIUS A., and TURLA V., “An analysis of footbridge vibration parameters”, Measurement, Vol. 66, 2015, pp. 222-228.

[4] VENUTI F., and BRUNO L., “Crowd-structure interaction in lively footbridges under synchronous lateral excitation: A literature review”, Physics of Life Reviews, Vol. 6, 2009, pp. 176-206.

[5] ZHANG N., TIAN Y., and XIA H., “A train-bride dynamic interaction analysis method and its experimental validation”, Engineering, Vol. 2, 2016, pp. 528-536.

[6] ZAHLE F., SORENSEN N.N., and JOHANSEN J., “Wind turbine rotor-tower interaction using an incompressible overset grid method”, Wind Energy, Vol. 12, 2009, pp. 594-619.