53º CONGRESO ESPAÑOL DE ACÚSTICA
XII CONGRESO IBÉRICO DE ACÚSTICA

Impact of different types of building structures on the efficiency of Building Base Isolation: Real case study

PACS:

Arana, Iñigo
CDM Stravitec SL, Av. Diagonal 131, 08018 Barcelona, Spain, +34 93 626 40 60, i.arana@cdm-stravitec.com)

CARDONA, Joan
AV Enginyers, Sant Cugat Business Park, Via Augusta, 15-25, 08174 Sant Cugat del Vallès, Spain, +34 936 74 31 91, (jcg@avenginyers.com)

NOORI, Beshad
AV Enginyers, Sant Cugat Business Park, Via Augusta, 15-25, 08174 Sant Cugat del Vallès, Spain, +34 936 74 31 91, (beshad.noori@avenginyers.com)

Masoumi, Hamid
CDM Stravitec nv, Reutenbeek 9-11, Overijse 3090, Belgium, +32 2 687 79 07, h.masoumi@cdm-stravitec.com

Aissani, Amina
CDM Stravitec nv, Reutenbeek 9-11, Overijse 3090, Belgium, +32 2 687 79 07, a.aissani@cdm-stravitec.com

Key Words: building base isolation; vibration isolation; structures; concrete; steel.

ABSTRACT.

The aim of the current study is to investigate the impacts of different types of building structure on the acoustic performance of a Building Base Isolation (BBI) solution. Our comparative analysis is based on real case experiences in Spain:

1. Clínica Girona is a reinforced concrete building, bordered by the railway line with a mixed traffic of long-distance and freight trains.
2. The second building is a steel construction, housing high end rental apartments, standing directly on the transition slab that covers the Arc de Triomf metro/train station. Holding-down bolts are used to fix the steel column baseplates to the existing slab.

The applicable regulations, given the intended uses of the buildings, imposes not to exceed 72dB and 75 dB respectively. Based on in-situ vibration measurements, for both projects the acousticians have recommended a BBI system with a natural frequency below 4.5Hz.

At completion of works, inspections of the performance have been conducted on site, showing different performances. In this paper, we will review and discuss the impact of the different structures on the final performance.

1. INTRODUCTION

Buildings, especially near railway or subway networks, can be subjected to ground-borne vibrations resulting in unacceptable level of structure-borne noise and vibration for the occupants of the building.

In order to protect a building from the ground-borne noise and vibration, it is necessary to decouple the building from the surrounding noise and vibration sources, at the foundation level or at the columns or walls in an upper level, by introducing a building base (vibration) isolation solution.

The assessment of real insertion gain requires a comparison of the noise and vibration levels inside the isolated building, to the same building without isolation. However, in practice, the real insertion gain is not measurable, because once the building is isolated, we cannot refer to the non-isolated building.

Today, the required vibration attenuation and the performance of a Building Base Isolation (BBI) system is defined in terms of the resonance frequency of a Single-Degree-Of-Freedom (SDOF) mass-spring system; whereas the dynamic mass is taken as the building self-weight including a portion of the equipment/furnishes (defined as the Acoustic Design Loads). The spring stiffness is equivalent to the dynamic stiffness of the isolation bearings given by bearings manufacturers.

In reality, this simple SDOF model do fully represent the real dynamic behaviour of an isolated building with its flexible elements nor the vibration transmission mechanism from the substructure (non-isolated part) towards the superstructure (the isolated part).

In order to showcase the effect of the superstructure, the performance of two buildings with similar isolation systems (the spring system) but different superstructure systems have been investigated.

The first building (Clinica Girona – Figure 1.a) is a concrete structure isolated at ground floor level while the second building (Arc de Triomf – Figure 1.b) has steel structural elements built on top of an existing concrete structure. (Ref Fig.1)

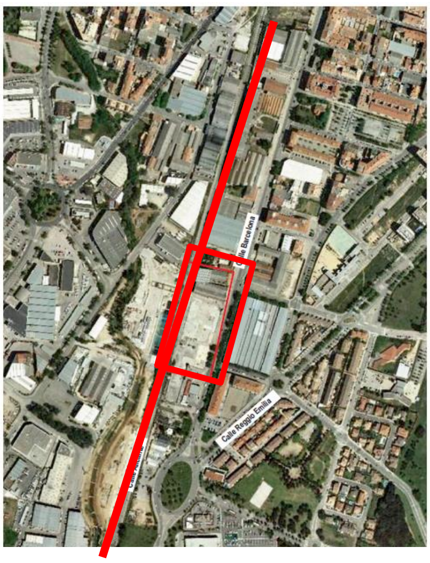


Figure 1.a. Location of the Clinica Girona building and the railway line.

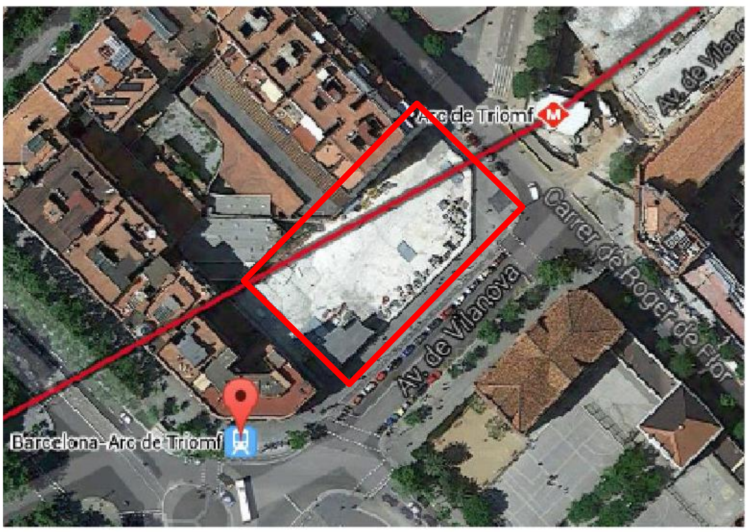


Figure 1.b. Location of the Arc de triomf building and the subway line.

In an early stage, before any construction work, the railway and subway induced ground-borne vibration levels, at the Clinica Girona and Arc de Trimof sites respectively, were assessed. During this experimental measurement campaign, the recordings were made at different locations as shown in Figure 2. for Clinica Girona and Figure 3. for Arc de trimof.

In the case of Clinica Girona, different trains passing by were noticed, including commuter trains, freight trains and high-speed trains. At least 8 trains passages at each location were recorded and it was observed that the vibrations induced by high-speed trains were low, for the main reason that the high speed trains move very slowly in that area due to the presence of a train stop station very close to the clinic. In the other hand, freight trains and commuter trains induced high vibration levels.

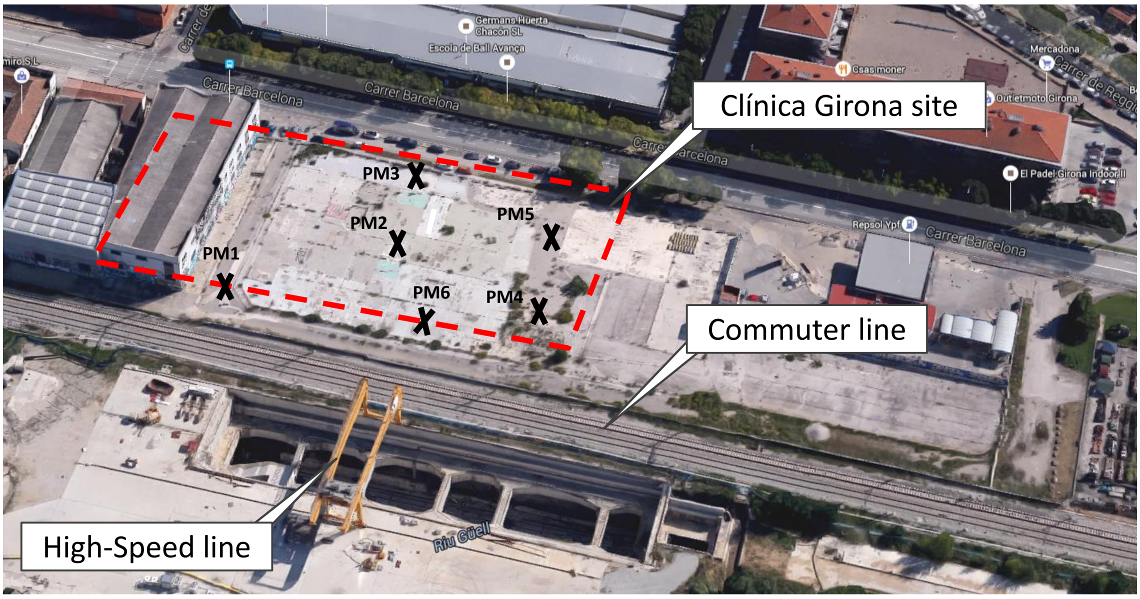


Figure 2. Locations of measurements points in Clinica Girona.

Figure 3. Measurements points considered in Arc de Triomf.

The measurements were taken using a Norsonic Nor133 triaxial vibration measurement device as well as a Siemens LMS Scadas XS 12 channel device, hence 3 orthogonally (x,y,z) highsensitivity seismic accelerometers were used at each measurement point. Acceleration time-signals were post-processed to obtain Maximum Transient Vibration Value, MTTV, according to ISO 2631-2 standard as well as the average spectra and its scattering at each location. Figure 4. and Figure 5. show the devices used at each measurement points in.

Figure 4. View of some of the measurement points considered for the prediction.

Figure 5. View of some of the measurement points considered for the prediction.

Using these spectra and its MTVV, the ground-borne vibration levels induced into the new building to be constructed were predicted, using a statistical building dynamic behaviour model developed by AV Enginyers and calibrated using a huge amount of experimental data.

Prediction results showed that vibration levels to be induced into the future Clinica Girona and Arc de Triomf buildings, due to the trains and subways passing by, will be higher than specified by the acoustic standards for hospitals and hotels. Therefore, vibration mitigation solutions were required.

Due to the low frequency content of the predicted spectra into the buildings, a Building Base Isolation system based on a 3.5 Hz natural frequency metal spring bearing were proposed.

After completion of the building construction, final measurement campaigns were conducted to assess the railway and subway induced ground-borne vibration levels into the buildings and check the performance of the BBI systems installed.

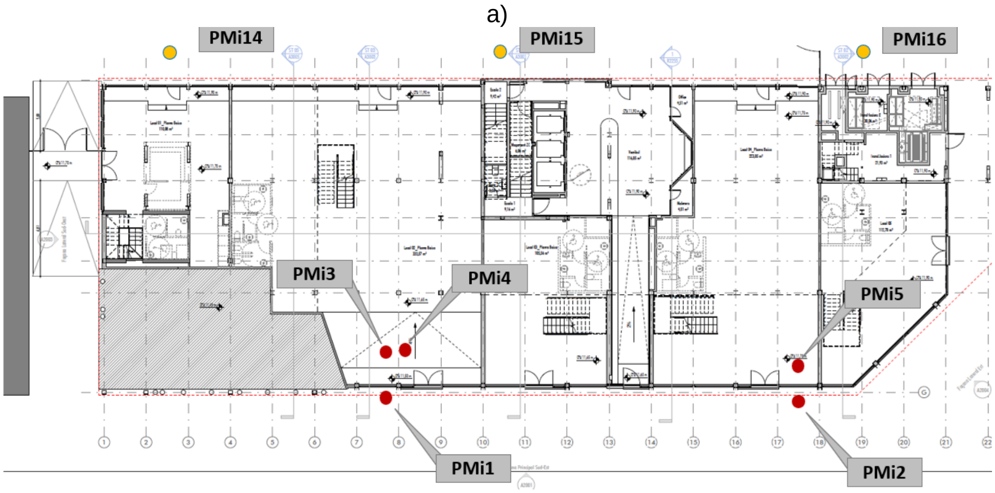
In the case of Clinica Girona, the Spring elements were placed on the top of the first basement columns (Figure 6.b). Therefore, measurements at the first basement (non-isolated floor) and at the ground floor (first isolated floor) were taken during the operation of the railway lines. The measurement devices were used at the same locations as for the initial measurements and all measurement points were located at the mid-floor span as stated by the standards.

a) b)

Figure 6. View of some of the measurement points considered for the verification of the building base isolation systems installed in Clinica Girona, a) ground floor and b) first basement floor.

In the case of Arc de Triomf, in total 16 different measurement points were considered, distributed in the ground floor (GF) and different storeys of the building (ref Figure 7.)

a)



b)

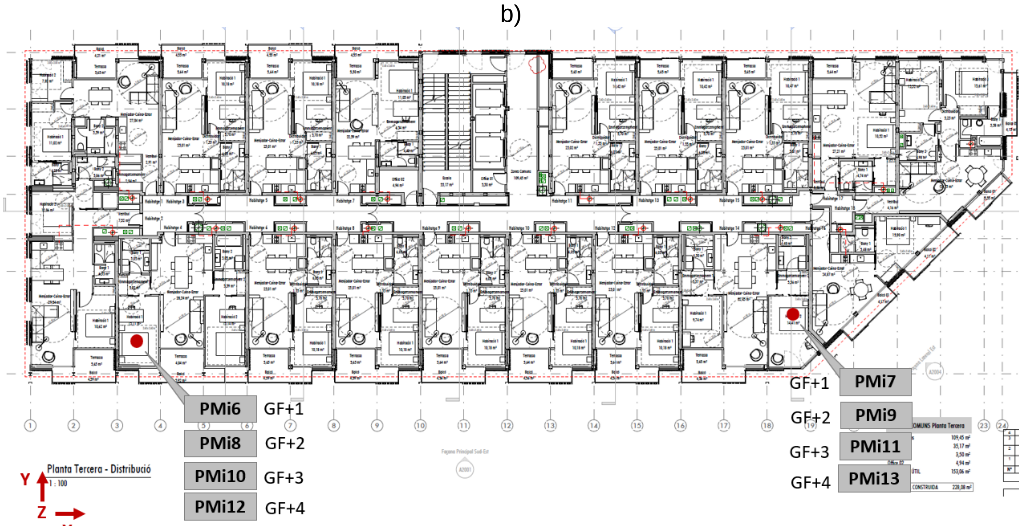


Figure 7. View of the measurement points considered for the verification of the building base isolation system installed in Arc de Triomf.

3. MEASUREMENT RESULTS

3.1. Clinica Girona:

The Figure 8 below shows the spectrum of the average vibration measured on the construction site of Clinica Girona before the construction works.

Reference measurement on the construction site shows a very high energy at low frequencies between 8 to 20 Hz. After analysis of the different train passages, this energy was attributed to the vibration modes of an open-cut tunnel structure adjacent and below the surface of the railway track. Those vibrations modes were not induced by the passing of the high speed trains but rather the commuters and freight trains.

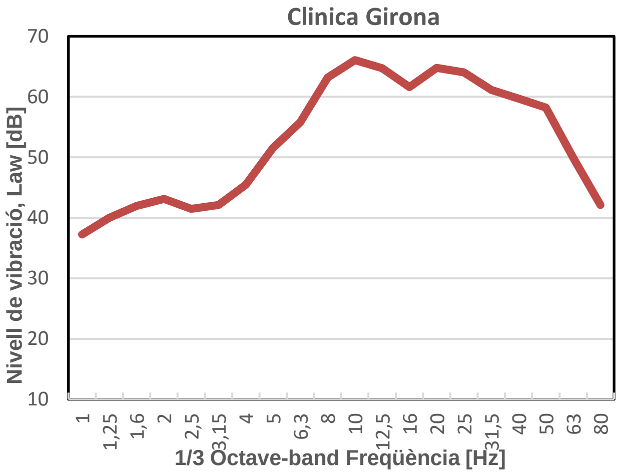


Figure 8. Spectrum of the averaged vibration measured on the construction site before the building construction, 20 m from the railway track.

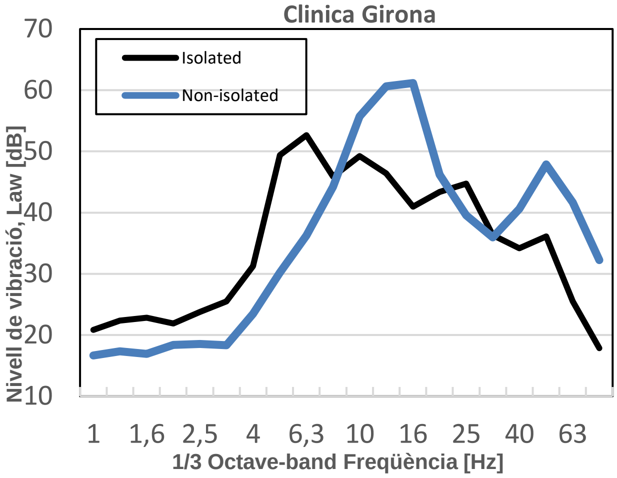


Figure 9. Spectrum of the averaged vibration inside the building below the vibration isolation system (the black line) and above (the blue line) the vibration isolation system.

The peak at 12 -16 Hz on the vibration measured in the non-isolated part refers to both the resonance frequency in the "non-isolated" and the dominant frequency of the ground borne vibration, as well. The peak at around 5 Hz on the isolated part reflects the isolation frequency of the isolation system.

Successfully, a transmission loss of about 5 to 20 dB has been obtained at frequencies above 10 Hz (Figure 10). The applicable regulations[1] requires Hospitals not to exceed 72dB, and thanks to the Building Base Isolation system, the highest measurement indicated a 66dB.

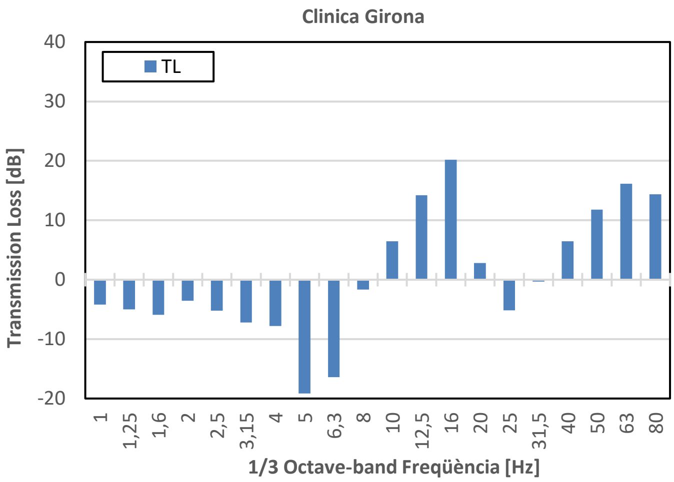


Figure 10. Transmission loss calculated between the measurement points below and above the isolation system.

3.2. Arc de Triomf :

In the case of Arc de Triomf, Figure 11 shows the vibration level measured inside the building. The black line refers to the non-isolated slab, while the orange and blue lines refer to the first and

[1] El Decret 176/2009

second storeys, respectively. The peak observed at 5 Hz on the isolated part, refers to the isolation frequency of the isolation system.

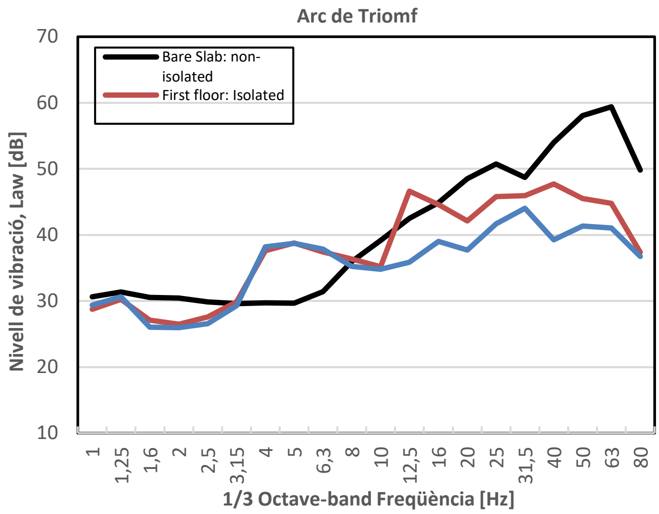


Figure 11. Spectrum of the averaged vibration measured inside of the building below (the black line) and above (the orange and blue lines) the vibration isolation system.

In terms of transmission loss, Figure 12, shows a transmission loss of about 5 to 18 dB at frequencies above 16 Hz and an improvement of about 5 dB between the first and second floors.

These results, show how a buffer zone (floor) just above the vibration cut can guarantee the isolation performance of the isolation system.

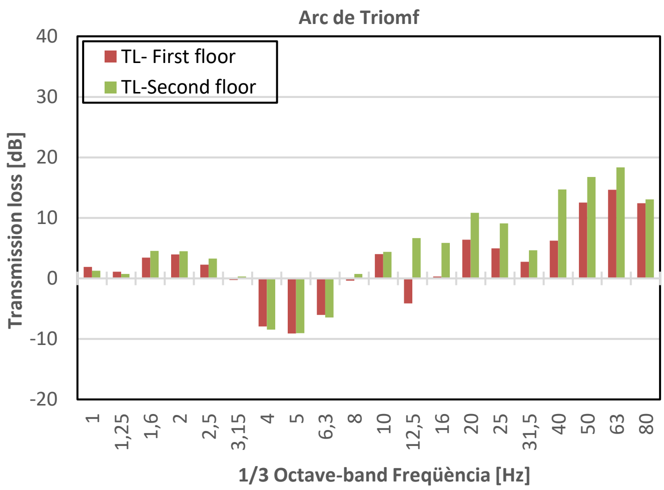


Figure 12. Transmission loss calculated between the measurement points below and above the vibration isolation system.

The applicable regulations[2] in Spain, requires Hotels not to exceed 75dB, and thanks to the Building Base Isolation system, the highest level of vibration measured indicated a 72,1 dB, which was respecting the legal requirements imposed by the country.

[2] El Decret 176/2009

4. DISCUSSION AND CONCLUSION

The verification measurements have shown that both buildings respect the legal requirements imposed by the Spanish regulations. However, the isolation in Clinica Girona has performed better than with Arc de Triomf, despite the same treatment in terms of vibration isolation.

To be able to analyze the results, the authors have analyzed the construction elements of both buildings and the different constructive details to explain the difference in performance.

Figure 13.a. show the vibration isolation installed in Clinica Girona sitting on heavy concrete elements, while Figure 13. b .show the lightweight structure of Arc de triomf. The fact is, in the case of Clinica Girona, the springboxes were sitting simply on the heavy substructure in concrete, without involving specific constructive details. While, a lightweight structure very often requires fixations and uplift restraints, which need specific attention. The reduced performance in Arc de triomf indicated the presence of acoustic bridges which prevent the isolators to move freely and create connections between the substructure and superstructure.

Figure 13. Installation of the Spring isolation in Clinica Girona and Arc de Triomf, respectively.

In conclusion, a specific attention to the installation of a BBI system is very important from both a structural and acoustical point of view. An increased attention is required in the case of lightweight structures, where the presence of fixations and uplift restraints is more important.