Improving The Urban Seismic Resilience Through Vibrating Barriers

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Background:

Recent disasters worldwide manifest the clear need to address the seismic resilience of existing buildings in a different and more affordable way. The construction industry successfully introduced devices such as isolators and dampers to mitigate dynamic vibrations induced by earthquakes but such devices are rarely used for the protection of existing buildings, as they require substantial alteration of the original structure. In the case of heritage buildings, especially in developing countries, those traditional localized solutions might become impractical. The present study focuses on the study of the efficiency of the novel Vibrating Barriers (Cacciola and Tombari 2015) to improve the seismic resilience in urban areas.

Aims:

The research aims to numerically and experimentally evaluate the efficiency of the Vibrating Barriers a in the urban environment.

Objectives:

- Numerical FE models for site-city-interaction study will be determined.
- Reduced scaled physical models will be built to study experimentally the site-city interactions.
- ViBas will be designed and tested numerically and experimentally.

Vibrating Barrier:

Vibrating barriers have been developed at the University of Brighton through the EPRSC grant (EP/K004867/1) led by Dr Cacciola. ViBas are massive structures hosted in the soil and tuned to reduce the vibrations of neighbourhood structures through a structure-soil-structure interaction mechanism (Fig. 1)

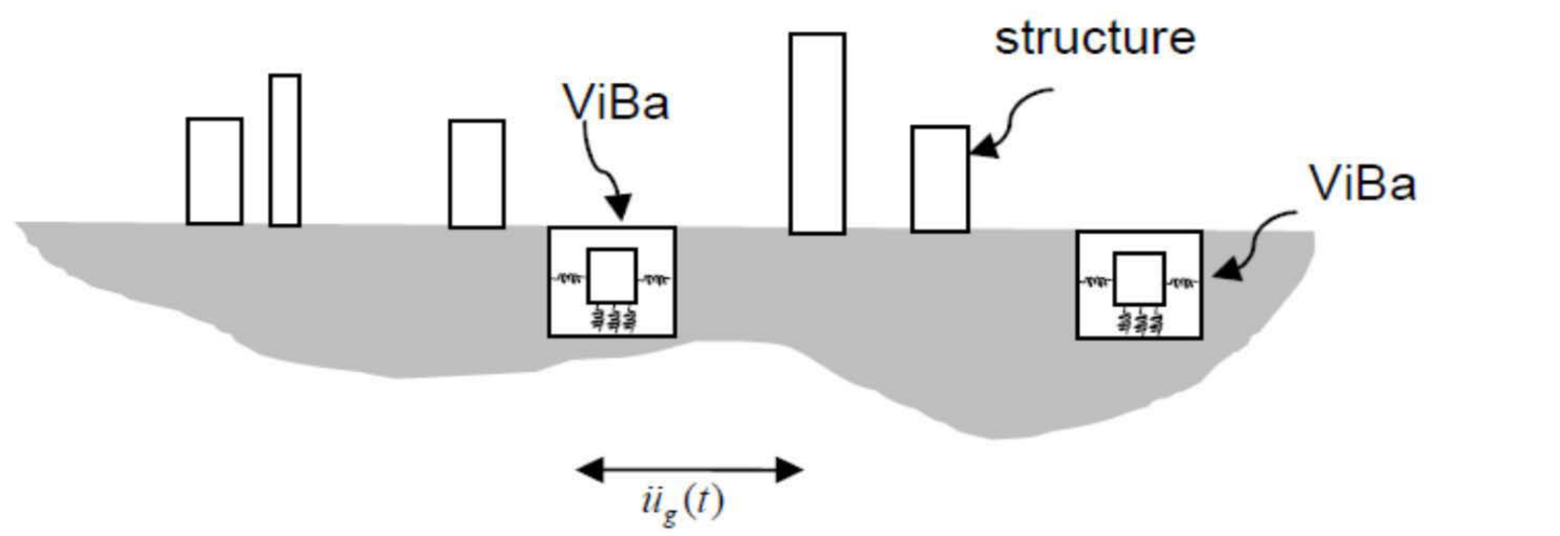

Figure 1: Sketch of the Vibrating Barrier device in the built environment (after Cacciola and Tombari 2015)

References:

Cacciola, P., Tombari, A. (2015). Vibrating barrier: a novel device for the passive control of structures under ground motion. *Royal Society Publishing*. 471 (2179).
Kham M., Semblat J-F., Bard P-Y., Dangla P. (2006). Seismic site-city interaction: main governing phenomena through simplified numerical models, *Bull. Seism. Soc. Am.* 96, no.5, 1934-1951.
Semblat, J.F., Duval, A.M., Dangla P. (2000). Numerical analysis of seismic wave amplification in Nice (France) and comparisons with experiments, *Soil Dynamics and Earthquake Eng.* 19, no.5, p347-362.

Acknowledgment:

The support of Mr David Harker for the development of the physical model of the urban environment and the development of the ViBa device is greatly appreciated

Numerical Analysis:

The numerical model of an urban environment has been developed in agreement to Kham et al. (2006). Figure 2 shows the numerical FE model developed in SAP2000 with Points 1-6 indicated and its validation shown in Figure 3 and Figure 5.

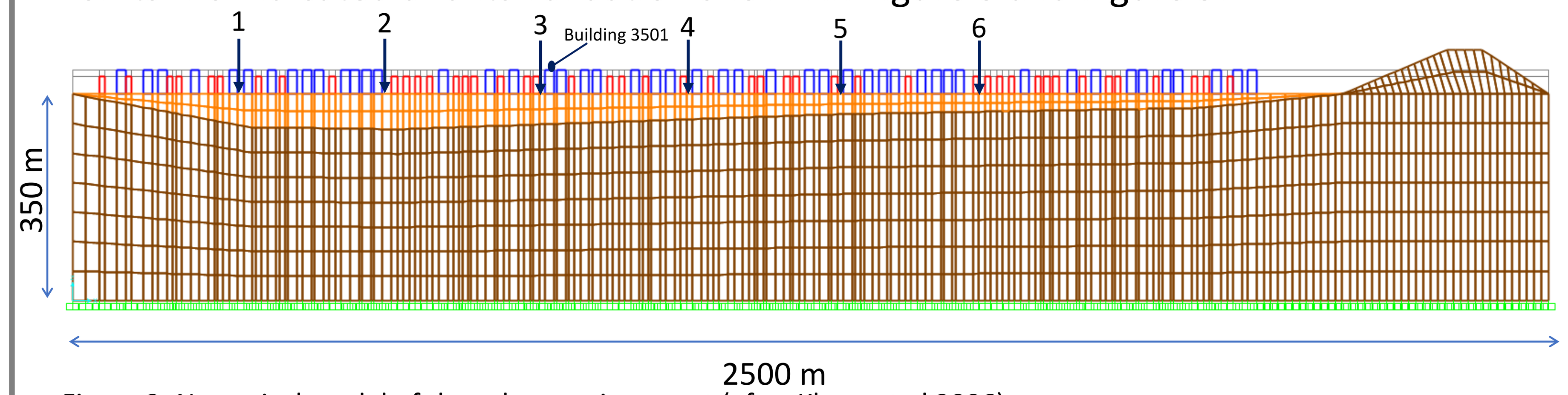

Figure 2: Numerical model of the urban environment (after Kham et al 2006)

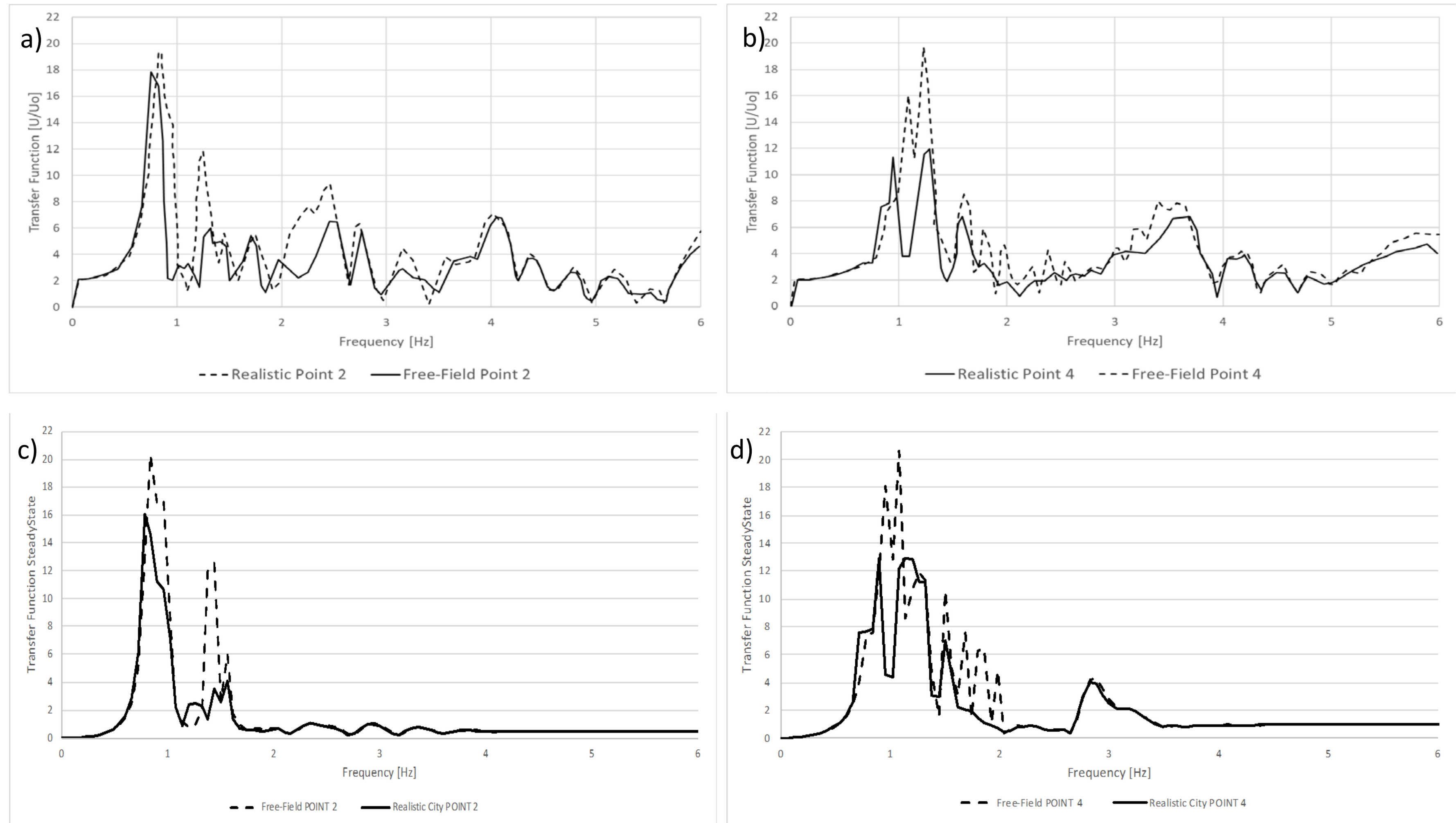

Figure 3: a) & b) Points 1 and 4 Realistic city compared to Free-field city taken from Semblat et al.,(2008). c) & d) Points 2 & 4 taken from our numerical analysis to compare with Semblat et al for further validation of models accuracy.

Scaled model:

The model has been scaled geometrically 1:2500 and selecting materials (foam and silicone rubber) able to mimic the ratio of scaled velocity of shear waves (Figure 4). Specifically, silicone rubber for the soil basin and foam for the bedrock layer.

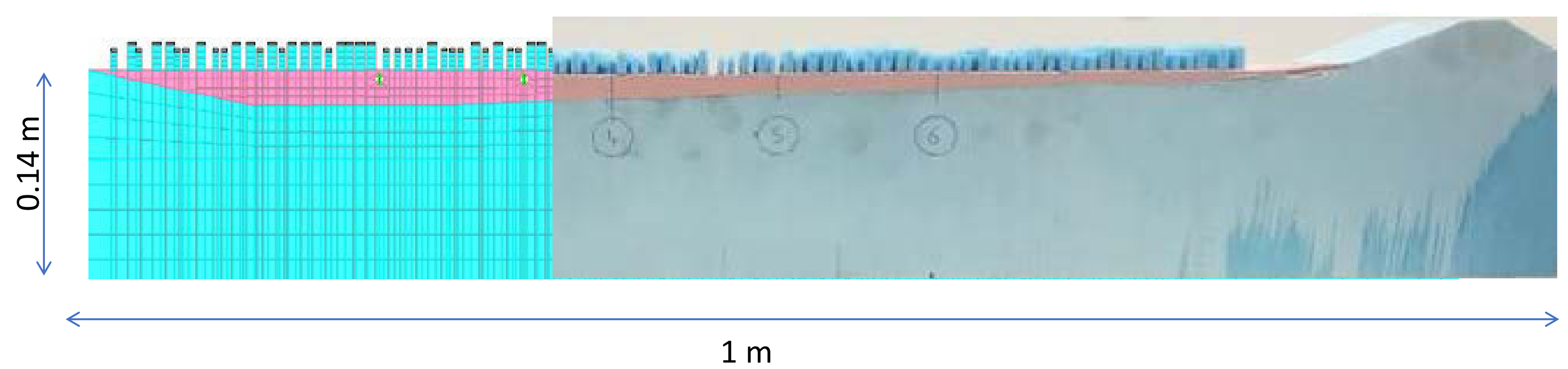

Figure 4: Numerical model to the left and experimental model to the right.

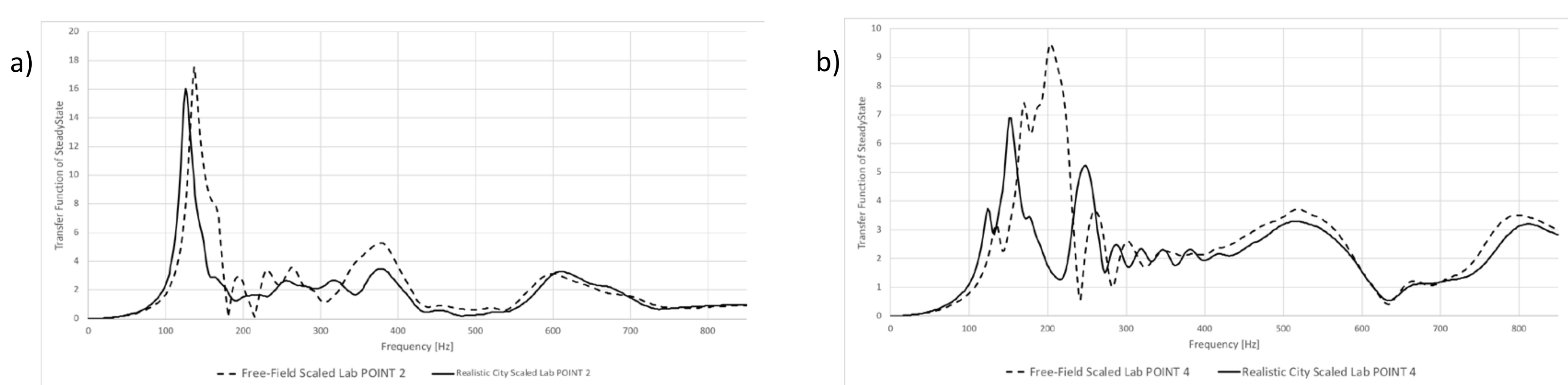

Figure 5: a) & b) Free-field vs Realistic city of scaled experimental lab model for Points 2 & 4.

ViBa Design:

The ViBa has been designed for harmonic excitation to absorb a design frequency (i.e. the peak of the transfer function as in Figure 8).

$$\bar{k}_{\mathrm{ViBa}}^{\mathrm{optimal}}(\omega_0)=\frac{(\omega_0^2 m_{\mathrm{ViBa}})[\bar{k}_{f,\mathrm{ViBa}}+\bar{k}_{\mathrm{SSSI}}(2+\bar{k}_{f,\mathrm{ViBa}}/\bar{k}_f)-\omega_0^2 m_{f,\mathrm{ViBa}}]}{\bar{k}_{f,\mathrm{ViBa}}+\bar{k}_{\mathrm{SSSI}}(2+\bar{k}_{f,\mathrm{ViBa}}/\bar{k}_f)-\omega_0^2(m_{f,\mathrm{ViBa}}+m_{\mathrm{ViBa}})}.$$

The Vibrating Barrier was designed using a mass threaded through a guitar string (Figure 6) able to be tuned at a desired frequency. The mass and springs were incased in an aluminum tube which was poured into the silicone rubber basin, the hole at point 2 in Figure 7 is the casing of one of the ViBa's.

A miniature piezoelectric accelerometer (lightweight 0.2gm ceramic shear ICP) along with the SCADAS LMS mobile acquisition system device was used to measure the time and frequency domains response characteristics (seen in Figure 6).

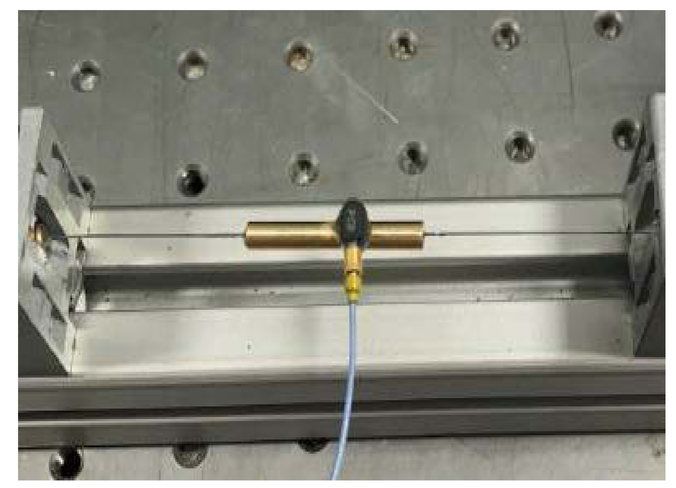

Figure 6: ViBa being designed and tested outside of tube casing to tune to a specific frequency.

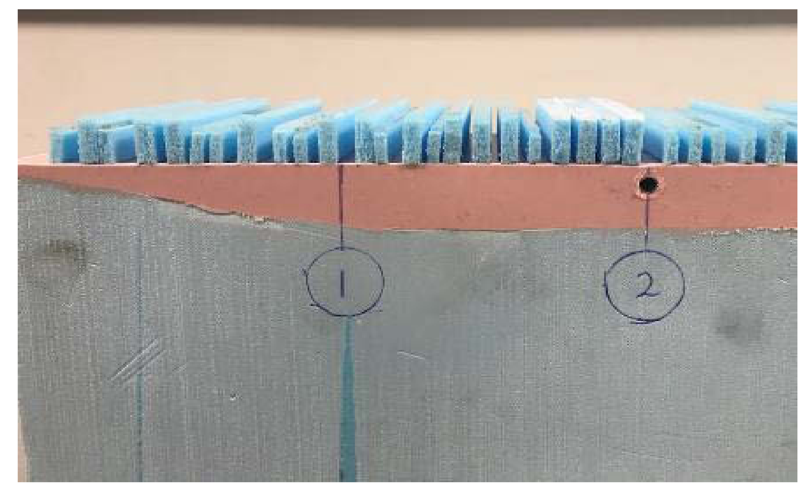

Figure 7: Experimental model, showing foam buildings glued to silicone surface and ViBa cavity hole at point 2.

Experimental results:

As Figure 8 shows the ViBa device showed to produce a clear reduction in the peak relative displacement at of a test building when the ViBa was introduced into the model, the ViBa is seen to absorb the energy at the tuned frequency of the building. The graph in Figure 8 shows that the best results were achieved when the 2 ViBas were introduced into the model. Similar results have also been observed in other buildings.

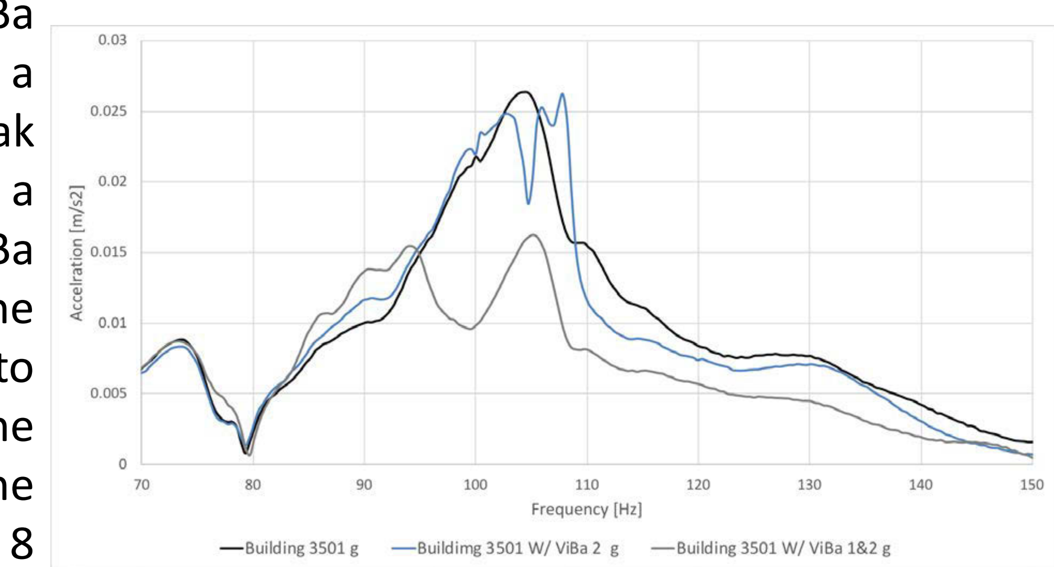

Figure 8: Acceleration Frequency response function of building 3501 showing a reduction in the peak acceleration when the ViBa was introduced into the model.

Conclusion:

This research yields promising results in the use of the Vibrating Barriers as seismic protection for multiple structures in the urban environment. The device can been seen to provide a reduction of relative displacement on multiple structures simultaneously within the same urban environment.
Future work can be utlised to real life application and testing at a larger scale.