Identification of natural frequencies of the spire and pendulum TMD of Samba Tower Riyadh

1 INTRODUCTION

The purpose of the tests was the characterization of the main dynamic parameters of the spire at the top of the building in order to calibrate the Tuned Mass Damper (TMD) used to mitigate vibrations of the steel structure. The measurements took place at the section of the spire at the level of the mass of the TMD, as well as on the TMD mass itself. This allowed to characterize the natural frequencies of the spire and to measure the vibrating frequency of the TMD mass before mounting springs and dampers.

Additionally, measurements at the top of the concrete building were performed. The spectra calculated from that data allowed to check the interference between the dynamics of the building and the spire. That information may be useful to the Structural Engineer in order to verify and calibrate the numerical model of the whole structure.

2 Description of equipment and sensors

Signals were acquired at a frequency of 100kHz and decimated to a frequency of 100Hz after using a low-pass Butterworth filter of 3 poles with a low-cut frequency of 50Hz. The sensors used to acquire signals are force balance seismic accelerometers configured to measure accelerations in the range of ±1g with a sensitivity of 20V/g.

3 Test procedure

In all set-ups, two accelerometers were used to take measurements in two horizontal and orthogonal directions.

In order to estimate the natural frequency of the TMD, additional set-up of measurements was conducted, based on the positioning of one accelerometer at the top of the mass to capture the horizontal motion of the pendulum.

Figure 1 – Measurement directions in the spire


Figure 2 – Photos of the accelerometers

Figure 3 – Measurement on the TMD: a) View of the device (left); b) Accelerometer on top (right)

After the measurements at the spire, other tests were performed at the top concrete floor of the building. This was important to ascertain if the dominant vibrating frequency of the spire corresponds in fact to a local vibration mode, or if it could arise from a vibration mode of the concrete building. One of the measurement points is located at one corner of the building, in order to capture natural frequencies associated with bending and torsion vibration modes. Accelerometer 1 was installed along the direction of the shortest diagonal of the building and the accelerometer 2 was oriented along the longest diagonal. The other selected point is located approximated at the centre of the building.

3 Time signals and Spectra

Figure here-below shows the plot of the Average Normalized Power Spectrum Densities (ANPSD) of the time signals of a set-up. The spectra are useful to identify system natural frequencies associated with the peaks. They were calculated from averaged spectra of segments with 4096 points overlapped by 50% after the application of a Hanning window. Given the adopted frequency acquisition of 100Hz, the achieved resolution for the spectra is 0.0244Hz in the range of 0 to 50Hz. The graphs only represent frequencies up to 12Hz due to the predominance of low natural frequencies in the structure.

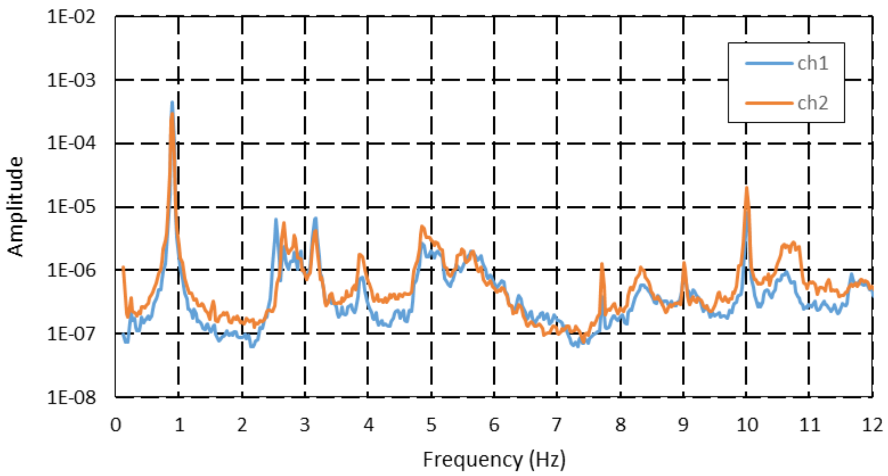

Figure – ANPSD calculated with signals

4 Analysis of the processed data

Spectra calculated from data recorded showed the first natural frequency. The peak can be clearly detected in both directions meaning that the spire has practically the same natural frequency in the main orthogonal directions.

The spectra collected at the top level of the concrete building allowed to confirm that the frequency measured at the top of the spire was due to a local vibration mode and not from the dynamics of the building.

With regard to the dynamics of the building, it was possible to identify some first natural frequencies of the concrete structure.

5 Conclusions

The fundamental vibrating frequency of the spire was identified in both directions of that structure. The identification of the natural frequencies of the concrete structure allowed to conclude that the fundamental frequency of the spire is in fact associated with a local vibration mode, i.e., is not a global vibration mode of the building.