Dynamic identification of lightweight civil engineering structures using a portable shaker

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Lightweight civil engineering structures are prone to vibrations induced by ambient forces such as pedestrian or wind loads. These structures can therefore be subject to human comfort issues. In some instances they may require the use of tuned mass dampers (TMDs), or even suffer from structural instabilities . As a result, identifying the modal parameters of such structures is essential to better assess their comfort and decide whether TMDs are necessary and, if they are, to determine how they need to be tuned.

This article presents a three-step methodology relying on a portable shaker developed at the University of Liège and operated by V2i which consists in a mobile mass of up to 230 kg attached to a linear actuator capable of imposing sinusoidal and random excitations of frequencies from DC to 12 Hz. First, the shaker is used to excite the structure over a large frequency band using a broadband random excitation. A control accelerometer is placed on the moving mass of the shaker to know exactly the force imposed on the structure. A second accelerometer measures the response of the structure at the point of excitation. The frequency response function (FRF) is then computed to provide a first estimate of the natural frequencies of the structure that are identifiable from the location of the shaker. The second step of the methodology consists in performing stepped sine tests in the vicinity of each resonance peak identified during the random test. These stepped sine tests provide better estimates of the natural frequencies,damping ratios of the vibration modes as well as a combined information about the modal mass and the modal amplitude at the location of the shaker. The last step of the methodology accurately determines the mode shapes and modal masses, by means of an appropriate forcing. The shaker is used to continuously excite the structure at one of the identified resonance frequencies at a time. A reference accelerometer measures the vibrations at the shaker position. Several wireless accelerometers are moved over the structure. These accelerations and their correlation with the reference acceleration are then used to calculate the mode shapes and the corresponding modal masses. Up to 100 measurement points can be covered with a limited number of accelerometers and within a short period of time.

The methodology will be demonstrated on the “La belle Liégeoise”, a footbridge crossing the Meuse river in the center of Liège. We will illustrate the natural frequencies, damping ratios, modal masses and mode shapes of the footbridge modes which are likely to be excited by pedestrians or cyclists. Some of these mode shape are significantly damped by a set of 7 TMDs; it is demonstrated that the method is accurate enough to not only identify low damping modes. With this respect it is a very accurate approach to quantify the efficiency of TMDs.