Footbridges and floors comfort, bridges model updating

Dynamic exciter for civil engineering structures

Identification of bridges, footbridges and floors

Key features

- A 320 kg mass is moved using an electromechanical jack controlled by a PC. The resulting acceleration of the structure is measured using accelerometers and used to determine the modal (vibration) properties.
- Dynamic forces up to 3 kN in a very controlled and known way.
- Accurate estimation of the modal parameters between 0.2 and 10 Hz
- Provide information on the stiffness and mass distribution of a structure
- Modal masses of up to 5400 tons have been identified in the past
- Quick: 1 to 2 days for a bridge or floor

Summary

The identification of the vibration properties of civil engineering structures such as bridges, footbridges and floors is becoming increasingly important to cope with the aging European road network and the increasing flexibility of new constructions.

Modern footbridges are often very slender and light and require tuned mass dampers (TMDs) to withstand the excitation of pedestrians and/or of the wind. The design of such dampers requires a very precise knowledge of the modal damping and frequencies of the bridge which can be done using the exciter. The exciter can also be used after the installation of the TMDs to validate their performance.

Similarly, new buildings tend to feature very flexible floors which can cause discomfort for workers and again sometimes require stiffening of the addition of TMDs. Older studies directly used pedestrians for vibration quantification but the bridge exciter provides a much more controlled input force and therefore more accurate results.

The aging European road network will require renovations and extensions in the next decades to withstand the increasing traffic. Renovations and modifications of such structures require mathematical models which are often not available and based on old plans and/or unknown material conditions. Static loading tests can provide a first insight of the stiffness of the structures. The exciter on the other hand can provide additional information about the damping, the modal masses and the boundary conditions of the structure, thus allowing the design office to refine their mathematical models.

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Civil engineering structures identification

Reference case studies

- Mantes-la-Jolie footbridge
- Grognon footbridge (Namur)
- Empalot footbridge (Toulouse)

- Utrecht A27 Highway bridge

- Centre Pompidou Kanal
- Luxembourg arsenal
- Luxembourg firestation
- Nantes parking floor
- Paris University floor
- Porte Maillot glass floor (Paris)

Bridge exciter on the Empalot footbridge (Toulouse)

FROM VIBRATIONS
TO IDENTIFICATION

Methodology

The Dynamic Bridge Exciter is usually used in a three step methodology:

- First, a broadband random signal of several minutes is applied to the structure to provide a first estimation of the natural frequencies of interest.
- Second, a stepped sine test is performed in the vicinity of each natural frequency of interest: sinusoidal excitations are performed with frequency steps as small as 0.01 Hz to accurately capture the shape of the frequency response function. This second stage provides more accurate frequency estimates, modal damping estimates and will be used to compute the modal masses.
- Third, the frequency is set to a natural frequency of interest and an array of wireless sensors is moved on the structure to determine the shape of mode identified and to finalise the computation of the modal mass.

This three steps procedure allows the identification of the first few modal frequencies, dampings and deformations of a structure within one or two days.

Summary

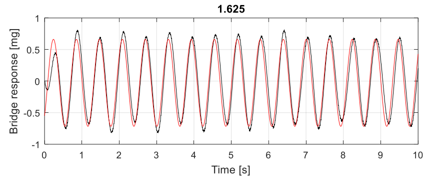
The bridge exciter is tool used to identify the modal properties of a wide range of civil engineering structures, mostly (foot)bridges and floors. The output of the results can be used to enrich or validate mathematical models and to verify the performance of tuned mass dampers.

The exciter can provide dynamic forces up to 3 kN between 0.2 and 10 Hz, which has been sufficient to successfully identify modes with masses of 5 400 tons in the past.

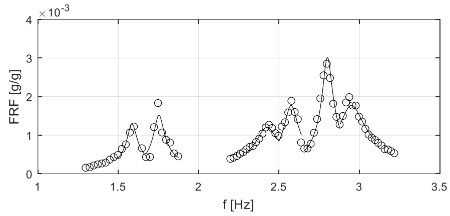
The identification procedure is usually performed within one or two days.

Use case: Utrecht A27 bridge

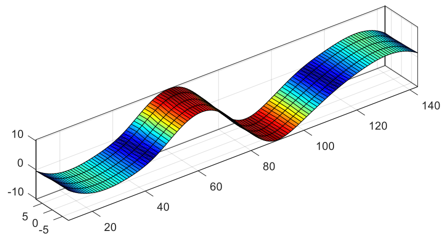
The bridge is excited at various frequencies and its response (in mg) is recorded:



The frequency response function (response amplitude as a function of the frequency) is computed. Six vibration modes are identified.



The modal deformations are computed by setting the exciter at a modal frequency (1.75 Hz here) and moving an array of wireless sensors



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