Zeitschrift: IABSE bulletin = Bulletin AIPC = IVBH Bulletin

Band: 9 (1985)

Heft: B-35: IABSE bulletin

Vereinsnachrichten: Discussion of IABSE proceedings

2. Discussion of IABSE PROCEEDINGS

«Dynamic Load Testing of Highway Bridges», Reto Cantieni, P-75/84, published August 1984 in IABSE PERIODICA 3/1984

A discussion by Roberto Giacchetti and Giovanni Menditto, Università degli Studi die Ancona, Italy

The dynamic study of a bridge is carried out by dealing with two aspects of the problem. The first is the valuation of the magnification factor derived from the ratio between the dynamic and static system responses, which concerns the early stage of design.

The dynamic increment Φ is generally referred to as the ratio between the stress caused by the excitation, which changes rapidly in time, and that yielded by the loads applied statically under the same conditions of geometry and constraint. In this way one considers only the time-variation of loads without evaluating the substantial difference between the static and dynamic responses of the system[1]. In fact, besides the above mentioned geometric and constraint conditions and the inherent dynamic properties, the system dynamic response depends on the frequency components of the excitation, in the sense that an increment of stress may be obtained either because the external action attains high levels or because its frequency bandwidth is such that a resonance condition is excited by certain components.

The attempt to relate the dynamic increment to the bridge length – in substance to its natural frequency that may be found as a function of its span – somehow takes into consideration the possibility that the response might be amplified due to the attainment of a resonance condition; nevertheless it seems to be vague because, as seen before, the dynamic increment depends on the ratio between the system natural frequency and the excitation frequency.

Moreover, as the natural frequency is not simply a function of the bridge geometry, the dynamic increment cannot be expressed as a function of mere geometric parameters.

On the basis of what has previously been stated, it would be appropriate to explain how A_{stat}, which forms part of the definition of Φ , is found.

In order to be «homogeneous» with the value of A_{dyn}, A_{stat} should be determined by referring to some «dynamic rigidity» rather than to a static one. This seems to be specified by the Author when he suggests performing the crawl test in order to determine A_{stat}.

Moreover, it should be noted that, as far as some kinds of structure (such as truss bridges or curved bridges) are concerned, the dynamic increment should take the flexural-torsional coupling into account.

The second aspect of the problem is represented by the modal analysis, that is the determination of both the mode shapes and the mode parameters. The modal analysis permits one to characterize the system from a dynamic point of view, especially by making it possible to locate the most stressed sections and to point out any possible behavior oddity including torsional modes in such a way as to ascertain the capacity of resisting any time-variable actions.

Modal analysis proves to be a very effective means either when the structural design is supported by experimental tests on models[2] or when an improvement of the strength and dynamic capacity of in-situ bridges should be obtained[3].

Moreover, unexpected non-symmetries and torsional effects sometimes point out constructive irregularities or secondary effects with consequences which should be carefully considered.

As a matter of discussion and in support of the previous remarks, we believe it worth discussing some of the questions Mr. Cantieni dealt with in his paper:

1) as to the measurement of the damping factor, it shoud be pointed out that the experimental procedure suggested by the author is correct when motion is represented by a pure harmonic. In this case masses move synchronously and the vibration shape repeats itself until it dies out due to damping;
2) it is stated by the Author that the location of the measuring station does not exert any influence on the valuation of Φ, in the case of a box-girder bridge, whereas this is no longer true in the case of a truss-bridge. Undoubtedly it seems right in the case of straight bridges, but it has to be at least verified when curved bridges are dealt with, where torsional and flexural vibrations are coupled, sometimes in a non-negligible manner, especially if the box girder is supported by means of spherical bearings;
3) it should be pointed out that value $\alpha \leq 1$ is subordinated to a standard test recommendation that requires the vehicle running along the longitudinal axis of the bridge, as is shown in fig. 8 of Mr. Cantieni's report;
4) the Author talks about a classification of the deck surface: it would be interesting to know the criteria that led to such a classification;
5) in figures 10 and 13 of Mr. Cantieni's report, a classification of decks is given as a function of their flexural stiffnesses and global damping, respectively: also in this case it would be interesting to have some information.

(1) One needs only consider the difference between the values of concrete moduli of elasticity and of the role played by the inertial mass during the vibration process.

(2) Tests on models permit one to appropriately modify the dynamic characteristics of the actual bridge (stiffness, mass and system damping).

(3) For example by varying the depth of the roadbed or using stays etc.

Reply of the author to the discussion of Messrs. R. Giacchetti and G. Menditto

The remarks of Messrs. Giacchetti und Menditto are very much appreciated. First of all, it can be noted that the contributors agree with one of the most important conclusions drawn from the EMPA test results: The dynamic response of a highway bridge under the passage of a heavy vehicle is strongly influenced by the relationship between the natural frequencies of vehicle and bridge. It is therefore more reasonable to relate the dynamic increment (DI) to the bridge's fundamental frequency than (as is done in many loading codes) to relate it to the length of the bridge's maximum span or to an average spanlength.

On the other hand, the statement that high excitation levels will lead at any rate to high DI's seems to be questionable. If the frequency ranges of excitation and structure do not coincide at all, the dynamic energy offered by the vehicle at any level will not be accepted by the bridge.

The contributors then propose to «homogenize» the DI by relating A_{stat} and A_{dyn} to the same value of (dynamic) bridge stiffness. Indeed, establishing the DI according to EMPA methods implies that A_{stat} reflects the static and A_{dyn} the dynamic bridge stiffness. As the bridge vibrations excited during a crawl test are negligibly small, this also applies if A_{stat} is derived from such a test.

Homogenizing the DI is very attractive from the theoretical point of view: Calculation on the bridge response can then be based on a simple linear model holding for both, the static and the dynamic part of the structural response. Nevertheless, the problem of defining a time function of excitation which suitably reflects reality will still be difficult to solve.

From the practical point of view, homogenization of the DI has two consequences: a) extracting of the difference between the static and dynamic bridge stiffnesses from its formula alters the meaning of the DI, and b) determination of a reliable value for the dynamic bridge stiffness requires performance of experimental modal analysis.

In the author's opinion, the DI value should take into account that (traffic) loads not only induce a static bridge response but that they also excite bridge vibrations. Since the stiffness of a bridge actually is not the same whether a load is applied statically or dynamically, changing the definition of the DI and hence hiding this fact does **not** seem to be very reasonable.

As described in the paper under discussion, experimental modal analysis requires performance of tests which are different in nature from the dynamic load tests according to EMPA standard. Modal analysis is a very powerful tool in investigating the dynamic properties of a structure but it is simply too expensive and too time consuming to be (additionally) used in routine load tests.

Finally, Messrs. Giacchetti and Menditto pose five problems for discussion:

1) As described in the paper, the logarithmic decrement can be determined manually only if the bridge vibrations decay simply harmonically after the passage of the vehicle. Additionally, it can be pointed out that the damping values of all modes contributing to a «disturbed» decay process can be determined with the help of advanced methods of digital signal processing as for example curve-fit methods.

2) It is correct that the location of the measurement point in the bridge cross section influences the measured DI if torsional (or transverse flexural) vibrations are excited additionally and coupled to vibrations of longitudinal flexure. Nevertheless, coupling of various types of vibrations will only occur if their frequencies are rather close together. Considering bridges with a stiff, box-shaped cross section, excitation of coupled vibrations is not probable even for curved bridges. The natural frequencies of torsional and transverse flexural vibrations are then relatively high compared with the bridge's fundamental frequency. The Ponte di Campagna Nova discussed in the paper can be taken as an example of such a bridge (100 m radius of curvature of the bridge axis). Being aware of the fact that choosing the longitudinal bridge axis as the drive axis may artificially suppress the possible excitation of torsional vibrations (above all for straight bridges), the EMPA standard has been changed in the last two years: The vehicle is now being driven in the traffic lane which presumably is mostly used by heavy commercial vehicles. The DI is then established as the average of the values determined for all main longitudinal bridge elements where $\alpha \leq 1.0$ is fulfilled.

3) This also answers the remark 3): The requirement $\alpha \leq 1.0$ is not only valid if the vehicle is driven along the bridge axis.

4), 5) Concerning these remarks the requested details can be found in Reference [5], cited in the paper.

Note from the Editor:
The discussion and reply had been published in the Bulletin B-34/85 but with some printing mistakes for which we present our apologies to the authors.