General recommendation for vibration test
in long term observation of concrete bridge structures (1)

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1. INTRODUCTION

1.1. All structures vibrate in accordance with the type of
the structure and have several natural frequencies, specific
damping and dynamic factor. Significant changes in these
parameters indicate a modification in the mechanical or
physical conditions of the bridge structures (caused by
damage, repair or changes in prestressing).

1.2. A uniforme loss of flexural rigidity produces an
increase in displacements. The pattern of change in these
displacements gives an indication of the loss of stiffness.

1.3. The dynamic test method can solve some of the
problems in all kinds of long-term observation of structu-
res. This method is not expensive and can be applied in a
very short interval of time.

1.4. Natural frequency is the most convenient parameter
in the dynamic test of long-term observation of structures.
Modification of the natural frequency of a bridge structure
can be caused by: cracking in the concrete; change of
temperature; change of the condition of the supports;
change of prestressing (in some cases only).

1.5. The damping factor is a more complex parameter
than the natural frequency. There is no direct relation
between the natural frequency and damping when the
dynamic characteristics start changing, but in general, the
higher the natural frequency the lower the damping of the
bridge.

1.6. The dynamic factor is a very complex parameter and
it is unfavourable for long-term bridge observation. In
general, the higher the natural frequency the higher the
dynamic factor.

2. PURPOSE, OBJECTIVE AND SCOPE

2.1. The purpose of this test is to measure dynamic prop-
ties of structures in order to give an indication of the
damage that may be occurring.

2.2. The objective of dynamic test in long-term observa-
tion of bridge structures is to back-up the visual inspection
of the bridges, to complement but not replace visual inspec-
tion.

2.3. The scope of the test is a non-destructive testing
 technique in the field of testing bridges in situ.

3. DEFINITIONS

In this test the terms have the following meanings:

Amplitude is the maximum value of the displacement of
any particle, measured from its equilibrium position.

Antinode is the point which has the maximum distur-
bance of a mode of vibration. Antinodes are half a wave-
length apart.

Coherence is the phenomenon observed when the parti-
cles vibrate independently, start and stop in order and
pass through zero at the same time. Coherence is the
phenomenon observed when a constant phase difference
exists. Two frequency components which have the same
amplitude ratio and phase difference in all frames have a
coherence 1. A zero coherence indicates no correlation at
that frequency.

Damping is used to explain the dissipation of energy in
a vibrating structure.

Displacement is the vector measured from the equili-
brum position at any time.

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**Dynamic characteristics** in long-term observation of bridge structure cover: natural frequency, damping and dynamic factor.

**Dynamic factor** is the quotient between the dynamic increase of amplitude and amplitude under corresponding static load.

**Frequency** is the number of vibrations per unit of time and is reciprocal of the period.

**Free vibration** is the motion taking place with the applied force set equal to zero (this motion is the free vibration response of the examined structural system).

**Fundamental tone** (or fundamental frequency) is the lowest natural frequency.

**Harmonic** is the overtone frequency when this frequency is the integral multiple of fundamental frequency. It is so called because musical scales and harmony are based upon integral ratios of frequency.

**Logarithmic decrement** is an expression for the appreciation of damping.

**Mode of vibration** is the form of vibration depending on the natural frequency (fundamental or overtones).

**Natural frequency** of vibration body is the frequency which is the characteristic of the body, only.

**Node** is the point which never moves from its normal position of a mode of vibration. Nodes are half a wavelength apart.

**Overtone** is each natural frequency except fundamental frequency.

**Periodic motion** is the sum of the simple harmonic motion components.

**Phase (of the vibration)** is a measure of the position of the particle in its motion.

**Phase angle** (angle of lag) is the time interval between two components of motion. One response lags behind the other. Two vibrations are in phase with each other if two particles pass through their equilibrium position at the same time, going in the same direction, with the same velocity.

**Resonance** is the condition when the frequency ratio is a unity, i.e. when the frequency of the applied load equals one of the natural frequencies of vibration body.

**Simple harmonic motion** is undamped vibrating motion for which the restoring force is directly proportional to the displacement away from the equilibrium position.

**Sum of series of sine wave** is the sum of several motion curves.

4. **DYNAMIC TEST PREPARATIONS**

The dynamic test preparation includes:

4.1. Theoretical analyses of dynamic characteristics.
4.2. Loading diagram—categories of test load, way of use.
4.3. Testing procedure.
4.4. Diagram of preparatory work.
4.5. Description of measurements.
4.6. Schedule of loading and traffic interpretation.
4.7. Safety protection.

5. **LOADING TEST PROCEDURE**

5.1. Ambient load test

Excitation is produced by vehicles on the ambient circulation occurring over the bridge. The vehicles on the bridge are driven without any schedule of loading or in advance determined traffic.

For this load test the natural frequency is mostly accompanied by some harmonic due to the moving of a great number of vehicles on the bridge. In this case the natural frequency in principal cannot be registrated separately.

5.2. Impact load test

This excitation test and other mechanical excitation tests necessitate the closing of a bridge, and the Highway Authorities are often opposed to it. At best, the work has to be done at night when conditions are generally unsatisfactory.

The excitation is produced by the downfall of the rear vehicle axle from the unevenness. The unevenness should be so high as to easily obtain the response of the bridge. The vehicle in the case of long span bridges, remains on the spot beside the unevenness to avoid vibrations due to its displacement. The vehicle on the short span bridges, should leave the bridge to obtain the dynamic characteristics of the bridge without the influence of the vehicle.

The first two bending modes and the first torsional mode are defined by repositioning the vehicle and unevenness in the corresponding antinode places along the bridge. The devices for measuring deflection are disposed in such a way as to define the mode shape of the corresponding natural frequencies.

At the beginning, after downfall had been completed or during the leaving of the vehicle, the natural frequency is accompanied by some harmonics due to spring oscillation or displacement of the vehicle. These additional vibrations are present only for a very short period of time.

5.3. Vehicle running test

The excitation is produced by vehicles running over the bridge according to loading test diagram. The vehicle on the structure has to be driven at a constant speed along the central line or one side of the deck to excite symmetric bending response or torsional response. The speed of the vehicle is changed from zero to the maximum possible speed. In that way one or several modes can be defined. For this load test the natural frequency is always accompanied by some harmonics due to the moving of the vehicle on the bridge.

After the vehicle has left the bridge the natural frequency can be registered.

5.4. Pedestrian walking test

The vibrations of the structure are produced by means of people jumping or walking in step.

5.5. Excitation load test (resonance test)

The internal excitation system is used to apply a sinusoidal force to the bridge structure. In the bridge inspection for resonance test, the excitation system is used in a stationary position.