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Vibration och stöt – Riktlinjer för dynamiska provningar och undersökningar på broar och viadukter (ISO 14963:2003, IDT)

Mechanical vibration and shock – Guidelines for dynamic tests and investigations on bridges and viaducts (ISO 14963:2003, IDT)

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 14963 was prepared by Technical Committee ISO/TC 108, *Mechanical vibration and shock*, Subcommittee SC 2, *Measurement and evaluation of mechanical vibration and shock as applied to machines, vehicles and structures*.

Introduction

Dynamic investigations can contribute to the control of structures through the measurement, interpretation and reporting of their response to dynamic excitation. The design of the tests should correspond to the specific purposes of the investigation and the type of structure. The measurements usually lead to a characterization of the dynamic behaviour of the whole bridge, including foundations, or local structural elements in the frequency and/or time domain.

This International Standard is for use with permanent design, temporary works, construction and maintenance of bridges and viaducts as defined. Dynamic tests may be undertaken with the objective of

— evaluating the safety of bridge structures under construction,

— confirming after construction the values used in design,

— evaluating dynamic characteristics to be used in wind and earthquake analysis and for live loading,

— monitoring of real bridges in-service and detecting any damage,

— confirming reinforcement effects on bridges,

— bridge diagnosis under an emergency, and

— diagnostic testing as a basis for condition monitoring.

Dynamic investigation may be used as part of the design process (design by testing) for new construction or for maintenance and rehabilitation management.

Mechanical vibration and shock — Guidelines for dynamic tests and investigations on bridges and viaducts

1 Scope

This International Standard provides guidelines for dynamic tests and investigations on bridges and viaducts. It

— classifies the testing as a function of construction and usage,

— indicates the types of investigation and control for individual structural parts and whole structures,

— lists the equipment required for excitation and measurement, and

— classifies the techniques of investigation with reference to suitable methods for signal processing, data presentation and reporting.

This International Standard provides general criteria for dynamic tests. These can supply information on the dynamic behaviour of a structure that can serve as a basis for condition monitoring or system identification. The dynamic tests detailed in this International Standard do not replace static tests.

The tests may seek to define all of the dynamic characteristics of each mode of vibration examined (i.e. frequency, stiffness, mode shape and damping) and their non-linear variation with amplitude of motion.

This International Standard is applicable to road, rail and pedestrian bridges and viaducts (both during construction and operation) and also to other works (or types of works), provided that their particular structure justifies its application.

The application of this International Standard to special structures (stayed or suspension bridges) requires specific tests which take into account the particular characteristics of the work.

NOTE Hereinafter in this International Standard, the term “bridges” means “bridges and viaducts”.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 2041, *Vibration and shock — Vocabulary*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 2041 apply.

4 Classification

4.1 General

The dynamic behaviour of bridges is highly influenced by the type of superstructure, static design and construction method, deck cross-section, support conditions, foundation type and elevation substructures (piers and abutments). Since these characteristics need to be considered in dynamic tests, a classification of bridges is given in 4.2 to 4.4. This classification aids the proper reporting of measurements.

4.2 Type of superstructure

The main categories of bridge deck with respect to the superstructure material are the following:

a) reinforced concrete bridge decks (either *in situ* or precast);

b) prestressed concrete bridge decks (either *in situ* or precast); pretensioned or post-tensioned, or combined pre- and post-tensioned units are generally used;

c) steel bridge decks (with orthotropic plate or longitudinal stiffeners);

d) composite steel beam and concrete slab bridge decks;

e) masonry bridges;

f) new materials (e.g. fibre reinforced concrete, fibre reinforced plastic).

4.3 Static design, methods of construction and substructure

4.3.1 Static design

The static design and the support conditions influence the dynamic behaviour of the structure and they should be taken into account in programming the tests.

With respect to static design, bridges can be classified as follows:

a) single-span bridges or bridges with simply supported independent spans;

b) viaducts with spans resting with their extremities supported and suitably constrained, yet independent in every span;

c) multi-span continuous bridges, generally with significant variations in the longitudinal flexural rigidity along the span;

d) a statically determinant Gerber-type continuous span; the longitudinal profile can be of constant or variable cross section;

e) framed bridges;

f) arch bridges;

g) truss bridges;

h) prefabricated modular bridges;

i) tubular steel arch bridges.

4.3.2 Methods of construction

Bridges are generally erected using different construction methods that may effect both global dynamic behaviour and the theoretical modelling of the structure. As an example, some common construction methods are the following:

— *in-situ* construction with precast concrete or steel beams and concrete (*in-situ* or precast) slab;

— precast segmental or staging construction.

Furthermore, strengthening or retrofit effects need to be considered in the test design.

4.3.3 Type of deck cross-section

The main categories of bridge deck cross-section are as follows:

— slab on girder cross-sections with steel or concrete girder (usually connected by means of transverse beams);

— single-cell or multi-cell box girder;

— solid or hollow slab cross-sections.

4.3.4 Type of foundation

The main categories of foundations are the following:

— strip, slab or mass concrete foundations on competent soils or directly on rock;

— pile or sheet-pile foundations;

— caisson foundations.

The behaviour of such foundations on the ground may influence the degree of constraint of the structures (piers and abutments) and it is suggested that, whenever possible, investigation of their behaviour is undertaken during construction.

4.3.5 Piers, abutments and parapets

4.3.5.1 Piers

Most pier systems consist of the following:

— wall-type piers;

— single-column (hollow or solid, straight or tapered) piers;

— multiple-column (hollow or solid, straight or tapered) bents;

— framed piers.

Other types of pier may be classified as a combination of the above main categories.

4.3.5.2 Abutments

Abutment systems generally consist of the following:

— reinforced concrete cast-in-place abutments (solid or with counterforts);

— hollow reinforced concrete cast-in-place abutments;

— precast reinforced concrete abutments;

— mechanical stabilized earth abutments, e.g. soil reinforcements.

4.3.5.3 Parapets

Parapet constructions are generally made of the following:

— concrete;

— masonry.

4.3.6 Special bridges

Special bridges such as the following require special attention:

— skew bridges (with angle of skew > 15°);

— curved bridges ($R/L < 10$);

— inclined bridges (with slope angle > 5 %);

— cable-stayed bridges;

— suspended bridges;

— mobile bridges (e.g. swing and lifting bridges);

— floating bridges.

4.4 Function classification

With respect to function, bridges may be classified as

a) road bridges,

b) railway bridges,

c) pedestrian bridges,

d) product and services bridges, or

e) a combination of the above.

5 General criteria for testing

5.1 General

It is advisable for investigations to be preceded by theoretical models and/or by numerical analysis to obtain the order of magnitude of values to be measured. If similar works have already been investigated, it is reasonable to anticipate a similar order of values. This could concern a whole bridge, or elements, or structural parts. This initial analysis should supply the likely values of displacements, deformations, natural frequencies, mode shapes and damping as guidelines in the choice of the following:

— investigation technique;

— excitation method (type, duration of excitation, spectral distribution);

— choice of measuring instruments;

— location of transducers and/or exciters.

5.2 Choice of test techniques

The choice of the test techniques depends on many factors such as the frequency range, damping and level of excitation necessary for a correct evaluation of the response having regard to the accuracy of the transducers and the environmental noise.

If the signal-to-noise ratio is less than 3, measurements should be processed with particular care and the test report should indicate the corrections adopted and the estimated errors.

5.3 Choice of excitation methods

5.3.1 General

In choosing the excitation methods, two types of structural motion should be considered: free and forced motion. In both cases investigations may be performed in the time, or in the frequency, or in the time-frequency domains.

The free motion may be excited by sudden application of a static load or of imposed displacement, or as tail-response to transient excitation (including the effect of running or braking vehicles). The excitation may be “environmental forced” or “artificial forced”. The first is due to the wind, road traffic, micro-earthquake, and has a random-characteristic wide spectrum. The second is through controlled excitation and may be particularly suitable for concentrating forcing energy around different natural frequencies. It requires the use of one or more exciters which can apply a controlled load of known amplitude and frequency. This type of excitation may be used to evaluate the dynamic characteristics and possible non-linearities of the system.

For pedestrian bridges, consideration should be given to footfall excitation and stochastic interactions.

5.3.2 Equipment type

For the choice of equipment for use with artificial vibration, see 6.1. To select the type of excitation, it is necessary to evaluate both the frequency range and required vibration levels.

5.3.3 Sites of excitation

The number and location of the excitation points should be chosen in relation to vibration modes to be investigated. These sites, zones of maximum modal amplitude, should be selected taking account of the progress of the construction phase and the stiffness of the resistant section. It might be necessary to verify that the structure can bear the anticipated dynamic load.

5.4 Choice of response measuring system

5.4.1 General

The method of monitoring the response should be scheduled in advance in relation to the specific information to be obtained from the tests. Such information may come from the measurement of acceleration, velocity, displacement, inclination, strain or deformation. Particular care should be taken in the detection of the physical parameters that concern fatigue in order to find the deformation and stress ranges for specific points of the structure. This information is of particular importance for evaluating possible local and overall damage.

The global response is the direct detection of the vibration modes of a pier or abutment or of the structure in one or more spans. Often it might be sufficient to detect selected vibration modes, either vertical, horizontal, torsional or combined. The measurement of the global response requires the deployment of measuring instruments along the whole structure or of its elements, with different configurations for each test. This should