INTERNATIONAL STANDARD

ISO 2017-2

First edition
2007-12-15

Mechanical vibration and shock — Resilient mounting systems —

Part 2:
Technical information to be exchanged for the application of vibration isolation associated with railway systems

Vibrations et chocs mécaniques — Systèmes de montage résilients —

Partie 2: Informations techniques à échanger pour l'application d'isolation vibratoire associée aux chemins de fer

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Reference number
ISO 2017-2:2007(E)

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Published in Switzerland

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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 2017-2 was prepared by Technical Committee ISO/TC 108, *Mechanical vibration, shock and condition monitoring*.

The first edition, together with ISO 2017-1:2005 cancels and replaces ISO 2017:1982 which has been technically revised.

ISO 2017 consists of the following parts, under the general title *Mechanical vibration and shock — Resilient mounting systems*:

— *Part 1: Technical information to be exchanged for the application of isolation systems*

— *Part 2: Technical information to be exchanged for the application of vibration isolation associated with railway systems*

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Introduction

This part of ISO 2017 is limited to consideration of resilient devices.

Some suppliers of shock and vibration isolators (resilient mounts) have experience covering a wide variety of applications. In most instances, they are willing to use their background information for solving the user's isolation problems. However, it is frequently difficult for the supplier to provide this service, because the customer, the user or the producer of vibration source or receiver has not furnished sufficient information regarding the application.

On the other hand, the user is sometimes handicapped in applying isolators properly because sufficient technical information is not furnished by the supplier. Consequently, the user will often conduct his own experimental evaluation of the isolator and may unknowingly duplicate work already carried out by the supplier.

In some cases of vibration source or receiver, the producer provides the isolating system. To do that he needs detailed information from the customer relating to his future application, site and environment.

This part of ISO 2017 is intended to serve as guide for the exchange of technical information regarding the application of isolation elements for vibrations and shocks generated by railway systems, between the customer, supplier of resilient devices and producer of vibration source or receiver as required for their proper application.

For the purposes of this part of ISO 2017, a resilient device is defined as a flexible element or system used between an equipment item and its supporting structure to attenuate the transmission of shock or vibration from the railway systems to the structure.

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Mechanical vibration and shock — Resilient mounting systems —

Part 2: Technical information to be exchanged for the application of vibration isolation associated with railway systems

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1 Scope

This part of ISO 2017 establishes requirements to ensure appropriate exchange of information regarding the application of isolation for vibrations and shocks generated by railway systems.

This part of ISO 2017 is applicable to the construction of new railway systems. It may also be applied to previously installed systems when the user wishes to solve a new vibration problem arising from railroad degradation, when new environmental land use planning requirements are put in place, or when new vibration-sensitive land development occurs in proximity to existing railway systems.

It applies to vibration problems encountered in a railway environment but does not address vibration problems within railway cars (carriages) themselves.

This part of ISO 2017 intends to give appropriate responses to questions highlighted by the producer and users (why, what, when and how to isolate mechanical systems).

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, *Mechanical vibration, shock and condition monitoring — Vocabulary*

ISO 2631-2, *Mechanical vibration and shock — Evaluation of human exposure to whole-body vibration — Part 2: Vibration in buildings (1 Hz to 80 Hz)*

ISO 4866, *Mechanical vibration and shock — Vibration of buildings — Guidelines for the measurement of vibrations and evaluation of their effects on buildings*

ISO 7626-1, *Vibration and shock — Experimental determination of mechanical mobility — Part 1: Basic definitions and transducers*

ISO 8569, *Mechanical vibration and shock — Measurement and evaluation of shock and vibration effects on sensitive equipment in buildings*

ISO 9688, *Mechanical vibration and shock — Analytical methods of assessing shock resistance of mechanical systems — Information exchange between suppliers and users of analyses*

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ISO 10815, *Mechanical vibration — Measurement of vibration generated internally in railway tunnels by the passage of trains*

ISO 10846 (all parts), *Acoustics and vibration — Laboratory measurement of vibro-acoustic transfer properties of resilient elements*

ISO 14837-1, *Mechanical vibration — Ground-borne noise and vibration arising from rail systems — Part 1: General guidance*

ISO 14964, *Mechanical vibration and shock — Vibration of stationary structures — Specific requirements for quality management in measurement and evaluation of vibration*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 2041, ISO 7626-1, ISO 9688, ISO 10846 and ISO 14837-1 and the following apply.

3.1
railway system
all train, track and other elements of railway which generate or transmit vibrations, either in open space or in tunnels

3.2
vibration receiver
all structures or elements of structures responding to vibration energy emitted by an internal or external source

3.3
customer
user or purchaser of a product (building, machine, etc.)

3.4
producer
party constructing or manufacturing the product that needs to be isolated from internal or external vibration and which the customer agrees to purchase

3.5
isolation supplier
party who is responsible for providing and installing an isolation system that will meet the requirements to reduce vibration agreed upon with the customer who agrees to purchase

NOTE 1 In certain cases the producer and the supplier may be the same party.

NOTE 2 Every one of the three main actors can mandate subcontractors to execute the work or to purchase elements. From a legal point of view the three stay responsible in case of failure of the project.

3.6
base isolation
item or support arrangements that secure a structure to its supporting ground or equipment to its supporting structure and provide protection from shock and/or vibration

4 Vibration of railway systems

There are distinct mechanisms that give rise to ground vibration from the passage of trains. They are generally associated with train-track interaction.

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The train is represented as a moving load. If the support stiffness did not vary along the track, a static load would then come on during the train passage. At train speeds below wave propagation speeds in the track and soil, this would present essentially a standing load problem to be solved.

However, in practice the rail is supported at intervals via rail track fasteners traditionally fixed to sleepers laid within ballast. The rail therefore provides varying support stiffness to the moving load.

The static load therefore appears and disappears at these discrete supports, the periodicity of which is a function of train speed, spacing between axles, and the spacing between the discrete supports.

This loading is therefore often referred to as quasi-static, or parametric, as it is due to a change in parameter, such as stiffness.

Measurements of wayside vibration indicate peaks in the frequency spectrum that tie in with the sleeper passage and axle passage frequencies.

The ground vibration that results from these discrete supports tends to cause peaks in the frequency spectrum below 80 Hz (train speed dependant), and is partly responsible for vibration that is felt at the wayside.

Another mechanism relates to wheel and rail roughness, arising either from manufacturing tolerances or from in-service wear. On the wheel there are wheel flats that develop due to braking. The rail surface may exhibit corrugation. As the wheel traverses this irregular profile, the unsprung mass (wheel set) is accelerated, which produces forces.

This roughness produces random vibration. There are devices for measuring the irregular rail profiles in the wavelength of 5 mm to 2,5 m. The data on rail roughness is reported as a random function.

Another mechanism involves impacts due to the rail's rail breaks or discontinuities in the rail due to joints, switches (points) and crossings.

These latter mechanisms are dynamic effects and are largely responsible for the higher frequency ground vibration that is responsible for re-radiated structure-borne noise, which is usually the dominant issue with underground train sources.

Other forces arise during acceleration and deceleration, or negotiation of curves in the track due to hunting as the bogie mechanism works. Impacts also excite vehicle dynamics such as bounce frequency, and bending modes of the coach.

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5 Purpose of vibration isolation (why isolate mechanical systems)

The purpose of vibration isolation is to reduce the vibrations and shocks felt by people, structures and other mechanical systems by taking action between the source and the receiver. In the case of railway systems the purpose may include the assurance of:

a) the structural integrity of the buildings surrounding the railway systems;

b) the comfort of people in temporary or permanent structures that may be subject to the vibration excitation;

c) the functionality of sensitive equipment in these structures;

d) the correct operation of any existing isolated equipment;

e) the conformity with legal requirements, if any.

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6 What is to be isolated

6.1 Source isolation

The purpose in this case is the modification of the input at the source level. This involves the train, the track, and track support. The vibrations spread by rail tracks are mainly generated by movement of the train and the contact between wheels and rails.

In the long run, rail corrugation and deformation of wheels are almost unavoidable.

The practicability, limitations, restrictions and costs of isolating at the source may be significant, so a great deal of maintenance may be required to control vibration due to degeneration of the contacting surfaces. The periodic grinding of rails in long track sections within sensitive areas may be expensive as is treatment of the wheels.

Quite a number of vibration attenuation techniques have been developed which differ significantly in efficiency and costs. Rail and base plate pads mainly provide elasticity to the track as especially required in the case of a slab track system rather than reduce noise and vibration radiation. In this aspect, other systems can be expected to be more effective.

6.2 Receiver isolation

If it is impossible to isolate the source, or, if the results of such isolation are not satisfactory, receiver isolation is applied. It may also be appropriate when incompatible land development occurs near existing rail facilities. Sometimes it is an economical compromise. It may concern:

a) sensitive buildings (music halls, laboratories or sensitive installations);

b) new structures (bridges, towers, etc.) or elements of structures in the neighbourhood of a railway or tunnel;

c) support of sensitive equipment (laser tables, computer disks, electronic microscopes, etc.).

7 Applicability of vibration isolation (when to isolate structures or mechanical systems)

A vibration isolation system may be used in addition to other design measures for reducing vibration.

In urban areas, underground, over ground or elevated railways produce vibration and structure-borne noise that reduce quality of life in nearby buildings. Major quality of life concerns include:

— effects of ground-borne vibration on building structures;

— perception of ground-borne vibration by human occupants;

— perception of re-radiated noise (25 Hz to 500 Hz) by occupants;

— effects of vibration on sensitive equipment inside a building.

If vibration isolation can be applied at the source, then the neighbourhood will be less affected.

This can be achieved:

a) when designing and constructing a new railway system near buildings or structures;

b) when traffic conditions (loadings, velocity) are modified;

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c) when the railway structure is modified;

d) when the propagation path between railway structure and the environment is modified;

e) when complaints are received from people working or living in the area of vibration sources;

f) when the limiting values for vibration in legislation are exceeded;

g) when isolation of the receiver is difficult or impossible.

When new structures, buildings or equipment are to be located near existing railways, receiver isolation is generally preferable to source isolation.

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8 Measurement and evaluation of vibration conditions

In order to choose and design an adequate isolation mounting system, it is necessary to analyse the dynamic properties of the railway system and to make prior measurements and evaluation of vibration at the site.

Measurements shall be made under the environmental conditions relevant for the location of the source or receiver. The measurements and analysis shall help in providing an understanding of the origin of the problem and possibly give an indication of the solutions.

These measurements and related analysis may also be used for the estimation of maximum accepted vibration level at receiver when designing a new railway system. Measurements shall be made in accordance with an appropriate International Standard (ISO 2631-2, ISO 4866, ISO 8569 or ISO 10815) and the standard shall be identified.

The measuring position can be defined in a contract. The mounting points of transducers and directions of measurements shall be reported.

These measurements shall include time history monitoring, for a sufficiently long period to cover train passages to be considered as the source of vibration.

For source measurements, analysis of frequency responses for the structures that transmit and receive vibration will help to avoid coincidence between dominant frequencies of the source and the natural frequencies of these structures.

For receiver measurements, the determination of the background vibration shall be carried out in order to know the inherent level below which no solution is normally necessary.

9 Information for the choice of an isolation mounting system

Isolators for use in base isolation applications in railway systems are commonly made from natural/synthetic rubber or other composite, or formed using steel coil springs. The possibility of using other types cannot be excluded.

Rubber bearings are typically formed as discrete blocks. Rubber bearings should be deployed in a manner that will ensure that they are not subjected to tensile loading.

Whilst resilient mats can be used, they generally produce high stiffness compared to steel coil springs which can provide the lowest rigid body natural frequency and can also be supplied with pre-stressing assemblies that can allow easy replacement or fine-tuning. When evaluating different isolators, it should be noted that their dynamic performance depends upon dynamic stiffness and cut-off frequencies which shall be between 5 Hz and 15 Hz, and not on how, specifically, these characteristics are achieved.

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The location chosen for the isolators depends upon many factors such as areas to be isolated, other connection paths, the dynamic characteristics of the isolated building and practicalities of providing access for inspection and replacement, where necessary.

In order to select appropriate isolators and to correctly fit the isolation, exchange of information is needed amongst the producer, the supplier of the isolator, and the railway authority. Clauses 10 to 12 list the information required for an optimized isolation.

The choice of the isolation system shall take into consideration not only the static characteristics of the isolated structure, but also its dynamic characteristics and the dynamic characteristics of its surrounding structure and further sources.

It will often be necessary for the supplier of a vibration isolation system to ask for more detailed information from the user in order to provide the best possible solution.

The information is different depending upon whether source or receiver isolation is needed.

Qualified professional acoustical and structural consultants/engineers should be used to obtain the necessary information. Close coordination is required amongst the:

a) railway authority;

b) supplier of the isolation;

c) owners of surrounding structures and sensitive equipment;

d) regulatory authority;

e) project construction contractor;

f) acoustical and structural consultants/engineers.

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10 Information to be supplied by the railway system authority

When possible the following information shall be provided by the railway system authority:

a) site investigation reports that provide geology of the site (ground conditions, soil properties, position of water table);

b) for a new railway system, details of the proposed railway structure (tunnel, etc.) including anticipated or preferred options for foundation and structure frame;

c) moving loads (quasi-static) excitation: the deflection of the track due to the train load moving with the train;

d) excitation caused by roughness, including frequency ranges; random irregularities of the contact surfaces, rail and wheel cause forced excitations of the system (vehicle/track):

— for railway tracks with sleepers, the wheel “sees” a variation of stiffness depending upon its position along the rail; the moving dynamic forces excite the vehicle and track;

— the speed of the vehicle and sleeper spacing affect the sleeper passage frequency;

— the natural frequency of the vehicle and vehicle on track system;

e) details on any policy with regard to noise and vibration for development in the area;

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f) number of tracks, joined or welded;

g) nature of track sub-base;

h) current usage (freight, high speed, etc.) and expected or planned changes to intensity, type of traffic or the track type;

i) static and dynamic characteristics of track, including setting of track, vertical and horizontal slant of rails.

Rail system vibration and isolation design is a highly specialized field requiring considerable technical expertise. In the case of new development adjacent to existing rail facilities, the more technical vibration details listed above may be determined by a professional, qualified consultant retained by the project proponent.

11 Information to be supplied by the receiver producer and user

11.1 Buildings

Existing buildings are the main receivers of vibration. Since it is technically impractical to isolate existing buildings, isolation of the railway system is a solution.

When the railway system is not isolated, receiver isolation is used mainly for new buildings and sensitive equipment. The isolation system is designed by the producer or by a supplier of isolation according to user's demand.

A brief description required for a complete understanding of technical details of the proposed system shall be provided. It includes:

a) a drawing of the structure, detailing the nature, the dimensions and the position of the bearing elements (steel, concrete, combined);

b) the category of the expected foundation (shallow, deep);

c) the position of the foundation in relation to the position of tunnels or traffic roads;

d) the position of underground water table;

e) function of the future building (offices, laboratories, habitation, manufacturing of particular equipment);

f) maximum admissible vibration level for people, structural elements and equipment;

g) a site plan indicating the applicable structures or buildings;

h) details of the proposed isolation system;

i) description of vibration measurements, including transducer locations, equipment used, description of trains measured and results of measurements.

11.2 Sensitive equipment

When sensitive equipment is located in the building the following information shall be provided:

a) the type of equipment to be isolated;

b) the type of structure in which the equipment is mounted;

c) the location of the equipment in the structure;

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d) data on the supporting structure (natural frequencies, etc.);

e) criteria for acceptance of isolation efficiency;

f) description of vibration condition in the surrounding structure with respect to the three orthogonal axes by magnitude, frequencies and duration;

g) environmental condition (temperature, humidity, etc.).

The producer of sensitive equipment shall supply the following information to help the user to choose the best location to set up the equipment:

— the overall dimensions;

— the total mass and the position of the centre of gravity;

— feasible structure attachment points (three points frequently determine the isolation system);

— acceptable vibration level measured at the base of the equipment;

— particular natural frequency to be avoided at the equipment base.

12 Information to be provided by the supplier of the isolation system

12.1 Performance of isolation system

The contract established between the supplier and user of the isolation system shall include the performance of the isolation system and the engagement for the output level measured after reduction of vibration by the isolation system. This will be validated according to Clause 13.

12.2 Physical data of the isolation system

The supplier of the isolation system shall provide detailed information on characteristics of the isolation system:

a) type of isolation system;

b) materials of the isolation system;

c) mass of the isolation system;

d) levelling features;

e) static and dynamic stiffness of isolators;

f) maximum and minimum weight forces under operation conditions;

g) dimensions, structure, mass, location and orientation of the isolation system (e.g. drawing), including any intermediate structure;

h) creep of isolators relative to load and time;

i) special requirements for air mounted systems;

j) fire behaviour, flammability and risk of dangerous gas generation.

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