Structural vibration

Part 1: Predicting vibration parameters

DIN 4150-1

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Supersedes September 1975 edition.

Erschütterungen im Bauwesen – Teil 1: Vorermittlung von Schwingungsgrößen

In keeping with current practice in standards published by the International Organization for Standardization (ISO), a comma has been used throughout as the decimal marker.

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Translation by DIN-Sprachendienst.
In case of doubt, the German-language original should be consulted as the authoritative text.

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Foreword

This standard has been prepared by Technical Committee 00.04.00 *Schwingungsfragen im Bauwesen; Ermittlung der Schwingungsgrößen* of the *Normenausschuss Bauwesen* (Building and Civil Engineering Standards Committee).

The information given in this standard combines the scientific knowledge and practical experience gained since the publication of the previous edition of this standard in 1975. Taking into account that, at present, it is not possible to specify a generally applicable method of vibration prediction, general procedures are given here to ensure the reliability of such predictions, and – in a more practically oriented section – various vibration sources and their effects are described. Furthermore, examples of measurements of vibration from such sources using currently used test methods are given in the Annex.

The subject dealt with here is extremely varied, in some cases extraordinarily complex, and normally influenced by local conditions. Not everyone involved in vibration prediction will be able to draw an accurate picture of expected vibration and make an appropriate and accurate prognosis based on this information. The examples given Annex A should help in this.

Amendments

This standard differs from the September 1975 edition as follows:

a) the standard has been revised in form and content;
b) only clause 3 of the previous edition is dealt with here, in greater detail;
c) damping is now taken into consideration;
d) examples of measurements of vibration generated by different sources are given.

Previous editions

DIN 4150: 1939-07; DIN 4150-1: 1975-09.

1 Scope

This standard gives guidelines for predicting vibration, including the prediction of values for specific parameters. These values can be used to evaluate the effects of vibration on humans (as in DIN 4150-2) or on buildings (as in DIN 4150-3).

NOTE: There are many possible sources of vibration, and the influence of vibration propagation, as well as the effect of the vibration on structures can only be approximated. For this reason, a specialist with sufficient knowledge and experience should be involved in making vibration predictions.

2 Normative references

This standard incorporates, by dated or undated reference, provisions from other publications. These normative references are cited at the appropriate places in the text, and the titles of the publications are listed below. For dated references, subsequent amendments to or revisions of any of these publications apply to this standard only when incorporated in it by amendment or revision. For undated references, the latest edition of the publication referred to applies.

DIN 1311 series Vibration and vibration systems
DIN 4150-2 Structural vibration – Human exposure to vibration in buildings
DIN 4150-3 Structural vibration – Effects of vibration on structures
DIN 45669-1 Mechanical vibration and shock measurement – Measuring equipment
DIN 45669-2 Mechanical vibration and shock measurement – Measurement procedure

[1] Melke, J. *Durchführung von Immissionsprognosen für Schwingungs- und Körperschalleinwirkungen* (Predicting the effects of vibration and structure-borne noise), issued by *Landesamt für Immissionsschutz Nordrhein-Westfalen*, *LIS-Bericht*, 1992: **107**.

[2] Haupt, W. *Bodendynamik – Grundlagen und Anwendung* (Soil dynamics – Principles and applications), 1986: *Vieweg-Verlag*.

[3] Rücker, W. *Schwingungsausbreitung im Untergrund* (Vibration propagation in soil), *Bautechnik*, 1989: **66** (10), 343–350.

[4] *Empfehlungen des Arbeitskreises 9 „Baugrunddynamik“ der Deutschen Gesellschaft für Erd- und Grundbau e. V.* (Recommendations of Technical Committee ‚Subsoil dynamics‘ of the *Deutsche Gesellschaft für Erd- und Grundbau e. V.* (German Society for Earthworks and Foundation Engineering), *Bautechnik*, 1992: **9**.

[5] Lüdeling, R. and Hinzen, K.-G. *Erschütterungsprognose und Erschütterungskataster – Forschungsarbeiten auf dem Gebiet der Sprengerschütterungen* (Vibration prediction and list of sites exposed to vibration – Research in the field of blast-induced vibration), Essen, NOBEL-Hefte, 1986: **52**.(2/3), 105–123.

[6] Schomann, A. *Erschütterungen durch umstürzende Bauwerke bei Abbruchsprengungen*, *NOBEL-Hefte*, Essen, 1983: **49** (3/4), 79–88.

[7] Melke, J. *Erschütterungen und Körperschall des landgebundenen Verkehrs – Prognose und Schutzmaßnahmen* (Vibration induced by land traffic – Prediction and safety measures), issued by *Landesamt für Immissionsschutz Nordrhein-Westfalen, Materialien*, Essen, 1995: **22.**

3 Concepts

For the purposes of this standard, the concepts defined in the DIN 1311 series of standards apply, as well as the following.

3.1 Vibration

Mechanical vibration of solid bodies, which may cause damage or discomfort (from DIN 4150-3).

3.2 Free field (vibration)

The regions of the ground surface not influenced by man-made structures.

4 Prediction principles

4.1 Method

This standard describes methods of estimating the effects of vibration

- from a known source on a planned neighbouring structure, or
- from a planned neighbouring source on an existing structure.

The propagation of vibration and its transmission to a structure can be determined taking values obtained in measurements or on the basis of experience, using the information given here and equations (1) to (4). The predicted vibration parameters can then be used to evaluate the possible effects of vibration (e.g. acceptability in terms of human exposure, or the probability of structural damage) in accordance with DIN 4150-2 and DIN 4150-3.

The vibration parameters to be determined are influenced by the vibration source, the properties of the soil along the propagation path, the conditions of the structure or site receiving the vibration, as well as the subsoil upon which such a structure is built [1].

In clause 5, the different types of vibration source are characterized according to

- source geometry (see subclause 4.2 and figure 1),
- vibration type (see subclause 4.2 and figure 1),
- how often the vibration occurs,
- frequency distribution,
- exposure area,
- source presence (permanent or temporary),
- duration of the effects.

Sources not covered by clause 5 are to be dealt with by analogy.

Examples of each source type and its possible effects are given in Annex A, including:

- source geometry and effects over time,
- classification (vibration type, frequency range, amplitudes),
- excitation mechanisms,
- amplitude-distance curves.

4.2 Propagation of vibration

The energy transmitted to the ground by a vibration source propagates in the form of two different types of wave: body waves (e.g. compression waves, shear waves) and surface waves (e.g. Rayleigh waves). Depending on the source type and nature of energy transmission to the soil, waves are produced at different levels of excitation.

To distinguish between the free wave propagation region (far field) and the region near the vibration source in which complex processes take place (near field), a reference distance from the source centre, R_1, is drawn, defining the transition from the near field to the far field [2]. For all vibration sources which can be idealized as a point or a line, the reference distance to the far field is defined by

$$R_1 = \frac{a}{2} + \lambda_R \quad (1)$$

where

a is the source dimension which is parallel to the direction of propagation;

λ_R is the wavelength of the surface wave.

Sources near the ground surface produce vibration which propagates primarily at the surface (Rayleigh waves).

The magnitude of vibration transmitted via the soil decreases with increasing distance from the source, largely as a function of geometrical damping and material damping.

In the far field (where $R > R_1$), the decrease in vibration velocity amplitude can be approximated by

$$\bar{v} = \bar{v}_1 \left(\frac{R}{R_1} \right)^{-n} \exp[-\alpha(R - R_1)] \quad (2)$$

where

$\bar{v}$ is the vibration velocity amplitude, in mm/s;

$\bar{v}_1$ is the vibration velocity amplitude at R_1, in mm/s;

R_1 is the reference distance, in m;

R is the actual distance from the source, in m;

n is an exponent;

α is the coefficient of attenuation, in m^{-1}, with $\alpha \approx 2\pi D/\lambda$,

where

D is the damping factor;

λ is the relevant wavelength, in m.

λ is given by c/f

where

c is the wave propagation velocity, in m/s;

f is the frequency, in Hz.

The geometrical amplitude attenuation for $(R/R_1)^{-n}$ is a result of the decrease in energy density with increasing distance from the source. The exponent n is a function of the following factors (see also figure 1):

1) source geometry: point (PQ) or linear (LQ);
2) vibration type: harmonic/stationary (HS) or impulsive (I);
3) wave type: body wave (R) or surface wave (O).

For a linear source of limited extension (e.g. a long foundation slab), the exponent will relate to a linear source in the immediate vicinity of the vibration source, but with increasing distance it will relate more to a point source. A foundation with longitudinal dimensions equalling more than half a wavelength cannot be seen as a point source. Trains can be deemed a chain of point sources (i.e. an extended source with out-of-phase excitation), for which the exponent in the far-field will be between 0,3 and 0,5, except at fixed locations (e.g. switches), where it is an impulsive point source which produces surface waves.