



Methods of Assessment for Vibration Impact on People in Buildings

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Abstract

Various diagnostic and design situations in which the influence of vibration on people in buildings should be taken under consideration, have been analysed. Based on the review requirements of ISO standards and national standards are given criteria for evaluating the impact of vibration on people. Then the requirements for the measurement methods have been summarised. Based on the experience of the authors, the procedure for the analysis of measurement results and obtaining the values used in the evaluation criterion was given. The dependence on the state of the vibration source (to be designed or existing) and object receiving the vibrations (to be designed or existing) five situations are identified.

Keywords: railway vibrations, transport vibrations, influence on people.

1 Introduction

Increasingly, influence of vibrations propagating through the ground onto buildings located in close neighbourhood of transport routes and on people residing in these buildings should be taken into regard. In a number of design and diagnostic situations influence of vibrations on people inside the building may be of decisive value in assessment of compliance with requirements concerning building serviceability.

The paper presents methodology of evaluation of transport vibrations influence on people inside the existing and designed buildings. Basing on analysis of the assessment criteria included in standards (Polish standard PN-88-B-02170 [1], British BS 6472-1 [2], German DIN4150 [3], and international standards ISO [4,5]) and upon the review of respective positions of publications with consideration of the author's experience in this field the most useful assessment criteria were chosen and a measurement – interpretational methodology of such assessment was elaborated. This methodology was described in this paper.

2 Choice of assessment criteria of vibration influence on people in buildings

At present three assessment criteria are in use. In these criteria the following parameters of assessment are applied:

- value of acceleration (or velocity) of vibration corrected in the whole frequency range,
- spectrum (frequency structure) of the effective value (RMS) of acceleration (or velocity) of vibration in $\frac{1}{3}$ octave band,
- vibration dose.

In standards referred to the above assessments are given in frequency range from 1 to 80Hz. The vibrational perception (sensitivity) threshold in these criteria was the reference level. The description of the vibrational perception threshold takes into consideration differences in human sensitivity to vibration in dependence on the direction of their propagation onto man (direction z according to the line foot – head and directions xy perpendicular to direction z) and vibration frequency (f [Hz]). Figure 1 shows (after [1, 4, 5]) lines corresponding to the sensitivity threshold of vibrations transferred onto man in direction z and in directions xy.

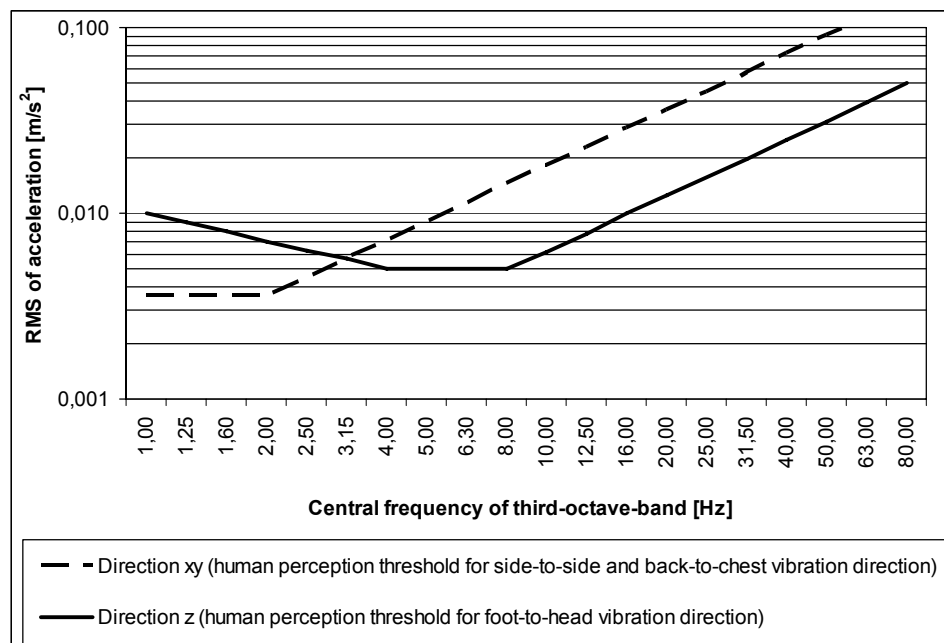


Figure 1: Lines of vibrational sensitivity (perception) threshold by people in direction z and xy

From the three above mentioned criteria of assessment of vibration influence on people most information is obtained by application of the criterion mentioned in point “b”. In particular it is about getting information on the vibration frequency range in which they are violated requirements corresponding to giving people the necessary comfort. Such knowledge permits a more precise designing of technical

means leading to respective vibration reduction. In the following the methodology with application of the assessment criterion mentioned point “b” will be described.

In dependence on the function of room designed to accommodate people the upper level (limit value) of vibrational comfort assurance is determined. It corresponds with the line parallel to the line of the human perception threshold of vibration whose coordinates are n times bigger. The value of the coefficient n depends on many parameters, the most important of which are function of the room, duration of vibration, time of the day. In Table 1 exemplary values of coefficients n are given (after [5]).

Place	Time	Continuous of intermittent vibration	Transient vibration excitation with several occurrences per day
Critical working areas (hospital, operating – theatres, precision laboratories)	Day Night	1	1
Residential	Day	2÷4	30÷90
	Night	1,4	1,4÷20
Office	Day	4	60÷128
	Night		
Workshop	Day	8	90÷128
	Night		

Table 1: Values of the coefficient n (after [5]).

Table 1 shows values of the coefficient n in the range (from – to) and additional information drawn up in standard [5] permit choice a respective value corresponding with real conditions. Application of the adopted criterion of assessment is best to present on a specific example. Measurement of vertical vibration of the floor (measurement direction Z) in place of receipt by people was performed. On the basis of analysis the vibrogram values of acceleration RMS in $\frac{1}{3}$ octave bands were obtained. They were plotted in Figure 2. This figure shows also lines corresponding to sensitivity threshold of vibration transmitted onto man in direction z (the lowest continuous line) and in direction xy (the lowest broken line). Vibrations were qualified as continuous occurring in a precise laboratory (value $n=1,0$). It may be easily noticed that in case the lines of sensitivity threshold of vibration determine the upper limit of providing the necessary vibrational comfort. The line corresponding with the receipt direction z was exceeded in bands of middle part frequencies: 50Hz and 63Hz. So, the measured vibrations infringe the conditions of necessary vibration comfort with respect to people working in rooms designed for laboratory. If, however, vibrations of the same parameters occur in a residential room then the higher placed lines should be taken into consideration and the influence of these vibrations on people both at day time and night should be additionally assessed.

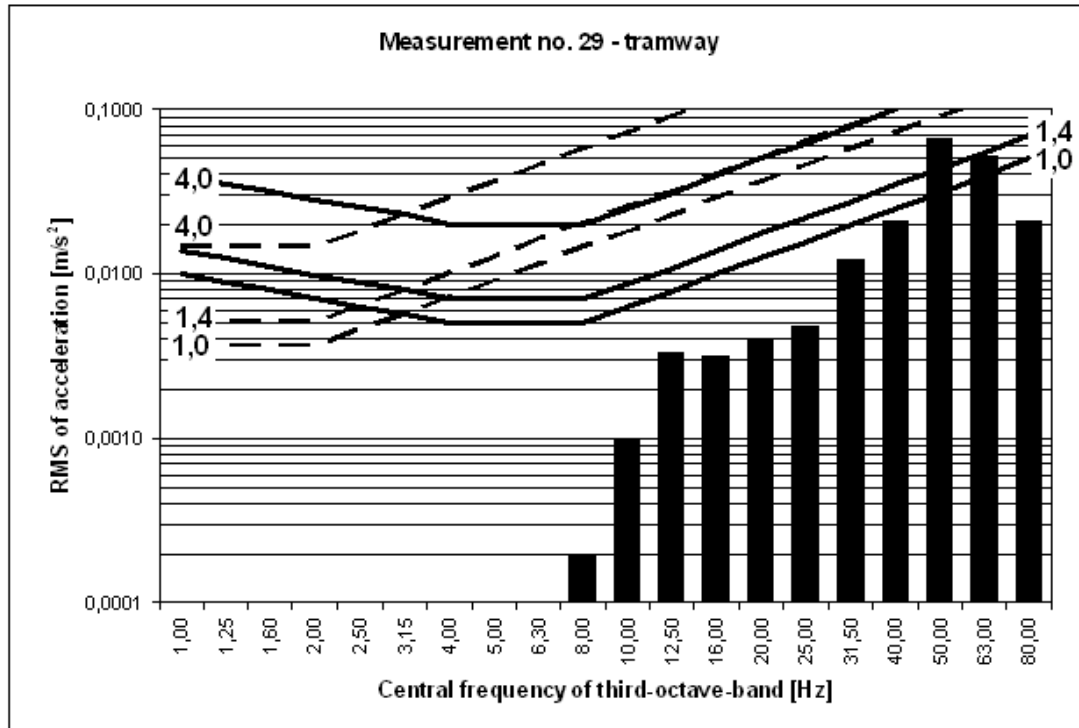


Figure 2: Example of vertical floor vibration influence on people at day and night

3 Diagnostic and designing situations

For a more detailed description of the proposed methodology of assessment of vibration influence first of all basic diagnostic and designing situations to which this methodology may be applied were characterized. In dependence on the state of the vibration source and object receiving the vibrations five situations are distinguished. The description presented in this paper will be linked to this classification reminded in Table 2.

Marking of the situation	Vibration source	Object receiving of vibrations	Determination of the situation
A	operated	existing	diagnosis
B	designed	existing	diagnosis with prognosis
C	operated	designed	designing
D	designed	designed	designing with prognosis
E	occurred previously (repeated occurrence impossible)	existing (at present in damaged state)	diagnosis with a posteriori prognosis

Table 2: Diagnostic and designing situations

Mostly dynamic diagnosis concerns situation “A”. In diagnostic assessment use is made of the results obtained during direct vibration measurements and assessment criteria are applied. Situation “B” and “E” are also treated as diagnoses but in assessments of dynamic influences forecasted vibration parameters are taken into consideration.

Situations “C” and “D” are included as designing tasks but procedures of determination of parameters characterizing vibration sources and their influence on object receiving these vibrations are similar to those applied on situation “B”.

Man residing in the building and passively subject to these vibrations is the “Object” in the above descriptions.

4 Methodology of assessment of vibration influence on people

Basing upon the recognized respective review and on the author’s own experience gained during realization of diagnostic and designing tasks procedures occurring in assessment methodology are described below.

4.1 Procedures referring to diagnostic activates executed on existing buildings

In the case of people residing in existing building two situations may occur:

- the vibration source is operated (then a diagnosis of vibration influence is performed) and
- the vibration source is designed (then a diagnosis with prognosis is elaborated).

Dynamic diagnosis concerning assessment of vibration influence on people residing in the existing building who passively receive vibrations generated by the operated vibration source encloses following activities:

- collection of data on destination of the room people reside in,
- collection of data on vibration sources of which the effect on people may be considerable and on the way of propagation of these vibrations from the source to the place of receipt by people,
- adoption of the assessment criterion,
- determination – on the basis of measurement of values of parameters characterizing the vibrations in place of their receipt by man,
- assessment of vibration influence on people according to the adopted criterion,
- proposed technical means leading at reduction of vibrations in the case infringement of the required vibration comfort was stated.

The above given diagnostic procedure is subject to modification if the vibration source is in state of designing. Then determination of predicted parameters of kinematic forcing of the building and adoption of a computational model of the building under realization is an important stage of diagnosis. Creation of a

computational model of the building proceeds mostly by application of MES. It must be, however, emphasized that there is a necessity of verifications of the model by measurement of building vibrations caused by another vibration source that may be used. Such a model may be verified making use of measurements of the so called dynamic background [comp 6, 7].

4.2 Procedures referring to assessment of people exposure to vibration in designed buildings.

In the case of people who will reside in designed buildings two designing situations may occur:

- Vibration source is operated (than the buildings designed knowing the parameters characterizing its kinematic forcing) and
- Vibration source is also designed (then the building is designed for forecasted vibration parameters).

In both mentioned cases parameters of kinematic forcing of the building is calculated making use of the data from the measurement data base. In the first case there is still needed information on the reduction degrees of vibrations at their transmittance from the ground (on which vibrations may be measured) onto the foundation of the designed building, and in the other case full information on parameters of the forecasted forcing of vibrations is obtained from the measurement data base.

The building should be designed in such a way so that its vibration should not infringe the conditions of necessary comfort of people residing inside.

The most essential elements of procedure of building designing considering vibration influence on people who will reside in it are given below.

If the vibration source exists (is operated) then:

- measurement of ground (foundation ground) in place of future location of the building are made,
- parameters of kinematic forcing of the building (vibrogram) are determined making use of information on measurement results exciting in the measurement data base corresponding to similar situations considering vibration reduction on the contact: ground – building foundation,
- after constructing a computational model of the building vibrations are determined in places of their receipt by man,
- with reference to the analytically determined vibrograms respective criteria of assessment of vibration influence on people are applied,
- when particular requirements are not satisfied changes in the structure are introduced in such a way as to obtain proper condition concerning provision of required vibration comfort to people.

If the vibration source is designed then:

- on the basis of analysis of the set of information given in the measurement data base a most likely description of forcing of building vibration is given and this description is set against the model of the designed building,
- building vibrations in place of receipt by man are determined,

- the determined parameters are applied in assessment of vibration influence on man according to the adopted criterion of assessment (corrected value, value RMS in $\frac{1}{3}$ octave bands or value VDV),
- when respective requirements are not satisfied changes in the building structure are introduced and calculations are repeated until the goal is obtained i.e. by the structure of the designed building satisfies the requirements referring to vibration influence on people.

4.3 Procedures referring to situations connected with creation of transport routes in the surrounding of the existing and designed buildings

In some practical situations a necessity of recognizing the influence of vibrations generated by a new vibration source arose in consequence of a change of conditions of the assisting vibration source. This may e.g. concern change of conditions of passage of along the existing but modernized road, railway or underground metro line. Global assessment of influence of the new vibration source on the existing buildings and people in these buildings may need elaboration of a map of dynamic influences.

Carrying out casual investigations in chosen characteristic sections of the existing vibration source and diagnosing data accumulated in the measurement data base a map of predicted dynamic vibrations in consequence of a change of characteristics of the existing vibration source may be elaborated.

These maps can be used in designing new building objects located in the vicinity of designed transport vibration sources taking into consideration the planned new traffic-road conditions. After introduction of a new vibration source performance of casual dynamic investigations in chosen places is advisable in order to verify the value of predicted (from prognosis) dynamic influences given on the map.

In the procedure of this kind of designing two evident measurement stages occur and between them the calculation stage. These stages may be described with following tasks.

- Stage I (measurement of dynamic back ground) contains such tasks as:
 - ✓ recognition of the territory under the influence of the designed vibration source,
 - ✓ choice of building object which with regard to their location in relation to the vibration source technical condition, and designation should to individual dynamic analysis carrying out measurements of the so called dynamic background i.e. on chosen objects performance of measurements of vibrations generated by the actually occurring sources or application of a specially modelled vibration source.
- Stage II (calculations concerning of prognosis) includes such tasks as:
 - ✓ on the basis of measurements performed in stage I verification of the adopted computational models of the building,
 - ✓ choosing from the data base vibrograms best corresponding with action of the vibration source covered by prognosis,

- ✓ application of forecasted vibrograms as kinematic forcing of computational models,
- ✓ elaboration of assessment of influence of forecasted vibrations on people residing in the designed building,
- ✓ in case exceeding the level of the necessary comfort (or safer: human perception threshold of vibration) introduction of possible structural changes of the building aiming at reduction of dynamic influences or taking into consideration in calculations application of other technical means of vibration reduction.
- Stage III (measurement verification of the realized building compliance with assessment criteria of vibration influence on people inside) includes such tasks:
 - ✓ carrying out (after modernization of the vibration source) measurements on the object earlier subject to analysis,
 - ✓ assessment of influence of recorded vibrations on people,
 - ✓ in the case of infringement of assessment criteria application of additional technical means aiming at reduction of vibrations.

Additionally in all the three stages influence of construction vibrations generated during building (or rebuilding) of the designed vibration source should be also considered. Especially important is here consideration in these analysis works of vibration road rollers, vibro-hammers and other similar tools.

5 Conclusions

Various diagnostic and design situations in which the influence of vibration on people in buildings should be taken under consideration, have been analysed. Based on the review requirements of ISO standards and national standards criteria are given for evaluating the impact of vibration on people. Then the requirements for the measurement methods have been summarized. Based on the experience of the authors, the procedure for the analysis of measurement results obtaining values used in the evaluation criterion was given.

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