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Reference Values in Evaluating Effects of Vibrations on Buildings and Persons

Buildings can be affected by vibrations if theirs parameters outgrow certain limits. The nature of the damage is given by the value of this parameters (displacement, velocity or acceleration). The paper presents reference values adopted in different countries regarding the maximum admitted level of vibrations.

1. Legal aspects regarding pollution by vibrations

On European level, decreasing and control of every kind of pollution, including vibrations, is an actual issue. Evaluation and management of vibrations produced by industrial sources transferred to the urban habitat are part of this concerning. The aim is the adoption and implementation of solutions to decrease pollution produced by sources which produce vibrations (forge hammers, rolling-mills, cranes, compressors, ventilators, other industrial equipment with components in rotation or alternative translation motion, metallurgical ovens with electrical arc, so.) and its effects on the urban environment and the population. There are norms and standards which indicate the maximum level vibrations for different intensities or exposed time. To reduce the risks of exposure to vibrations is not optionally, but it is a priority in the European policy (ex. Directive 2002/44 CE).

To provide suitable development includes knowing the areas under influence of vibrations, which can affect buildings and people as part of the urban environment. Romania adopted in the year 2005 the Directives 2002/44 CE, promising to align to the European norms, specific for this field, and to develop organisms and accredited systems for monitoring and controlling the evolution of the pollution level generated by noise and vibration, to evaluate the risks and take adequate measures.

The authors perform in this paper some guidelines for evaluation of effects of vibrations on buildings and persons.

2. Reference values

Constructions are usually not sensitive to vibrations. However, vibrations can produce *light damages* like in buildings; just if they reach high level they can produce important damages. What *important damages* are depends from country to country, been linked to the social norms and the concept of private property in that country. Usually the national standards accept lower level of vibration in those countries in which the private property has higher importance. This fact gives to the standards in this field a subjective note, and makes difficult the comparisation between them (from pure technical point of view).

The level of damages in constructions and effects on humans produced by vibrations depends on various factors:

- Magnitude of displacements, velocity and acceleration
- Frequency of vibration
- Exposure time
- Tip of construction

Vibrations of industrial sources consist of a composite or *spectrum* of many frequencies and are generally classified as broadband or random vibrations. The normal frequency range of most ground-borne vibration that can be felt generally starts from a low frequency of less than 1 Hz to a high of about 200 Hz. Vibration levels are usually expressed as single-number measure of vibration magnitude, in terms of displacement, velocity or acceleration, which describes the severity of the vibration without the frequency variable. Vibration energy spreads out as it travels through the ground, causing the vibration level to diminish with distance away from the source. High frequency vibrations reduce much more rapidly than low frequencies, so that low frequencies tend to dominate the spectrum at large distances from the source. Discontinuities in the soil strata can also cause diffractions or channeling effects that affect the propagation of vibration over long distances. When vibration encounters a building, a ground-to-foundation coupling loss will usually reduce the overall vibration level, however, under certain circumstances, the ground-to-foundation coupling may also amplify the vibration level due to structural resonances of the floors and walls.

While people have varying sensitivities to vibrations at different frequencies, in general they are most sensitive to low-frequency vibration. Vibration in buildings caused by industrial activities may be perceived as motion of building surfaces or rattling of windows, items on shelves, and pictures hanging on walls. Vibration of building components can also take the form of an audible low-frequency rumbling noise, which is referred to as ground-borne noise. Ground-borne noise is usually only a problem when the originating vibration spectrum is dominated by frequencies in the upper end of the range (60 to 200 Hz), or when the structure and the industrial activity are connected by foundations or utilities, such as sewer and water pipes.

Researchers like Cieselski offer limits for the allowed vibration magnitude dependent from the height of the buildings and the frequency of the vibration. Figure 1 summarizes the levels of vibration and the usual effect on people, machines and buildings regarding the magnitude of displacement corroborated with their frequency (Swiss Norm SN 640 312 a).

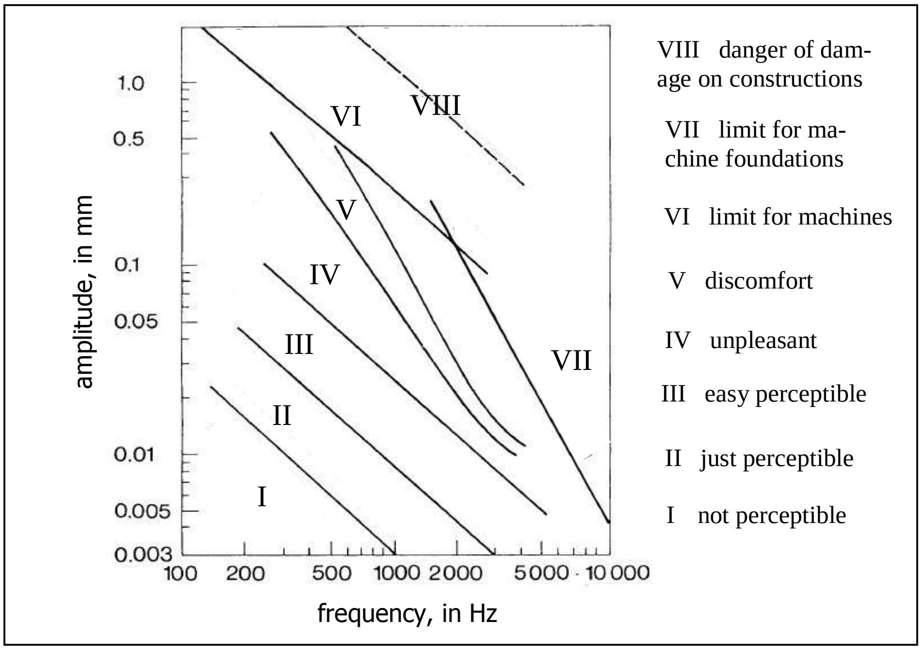

Figure 1. Limits after the Swiss Norm SN 640 312 a

Table 1 summarizes the results obtained by researches made in the US, which recommend that the maximum peak-particle-velocity levels remain below 1.3 mm per second at the nearest structures. Vibration levels above 12,5 mm per second have the potential to cause architectural damage to normal dwellings. The researches also states that vibration levels above 0,4 mm per second are sometimes perceptible to people, and the level at which vibration becomes annoying to people is 20 mm per second.

Tables and diagrams containing information regarding the reference values for the magnitudes of the acceleration are available. One example is presented in Table 2. There are a lot of other norms which indicates the reference values for the presented vibration parameters, available in the materials presented as reference.

Table 1.

Peak Particle Velocity (mm/s)	Effects on Humans	Effects on Buildings
<0,1	Imperceptible	No effect on buildings
0,1 to 0,3	Barely perceptible	No effect on buildings
0,5 to 1,3	Level at which continuous vibrations begin to annoy in buildings	No effect on buildings
2,5 to 12,5	Vibrations considered unacceptable for people exposed to continuous or long-term vibration	Minimal potential for damage to weak or sensitive structures
12,5 to 25	Vibrations considered bothersome by most people, however tolerable if short-term in length	Threshold at which there is a risk of architectural damage to buildings with plastered ceilings and walls. Some risk to ancient monuments and ruins.
25 to 50	Vibrations considered unpleasant by most people	U.S. Bureau of Mines data indicates that blasting vibration in this range will not harm most buildings. Most construction vibration limits are in this range.
>75	Vibration is unpleasant	Potential for architectural damage and possible minor structural damage

The periodicity of the appearance of vibrations and the exposure time influence also the effects on persons and buildings. The Swiss Norm SN 640 312-a classify the periodicity of events when vibrations appear in:

- Rare, for less than 1000 events per year
- Often
- Permanent, for more than 100.000 events per year

and present some typical sources of vibration from this point of view. As event was considered each overlapping of 0,7 of the admitted value.

Two other important factors are: the sensitivity of the construction and its destination. For the first factor the above mentioned norm have foreseen four degrees (from *not sensitive* like tunnels to *very sensitive* like historical monuments with wood structure), while the German norm DIN 4150-3 have foreseen three degrees (industrial and commercial buildings, houses and equivalent and other buildings).

The destination of the buildings and the activities evolved in it conduct to different reference values. For instance for buildings where operation with laser are done, or where electronic microscopes are installed the values are much smaller like these for constructions in the metallurgy.

Exposure time is also an important factor, DIN 4150-3 give the reference values of the velocity for short-time exposure of industrial and commercial buildings 40 mm/s, while for long-term exposure the value is 10 mm/s.

Table 2.

f [Hz]	Buildings with h/b ≤ 1		Buildings with 1 < h/b ≤ 2	
	A	B	A	B
2	60	750	8	300
3	23	450	8	300
4	15	300	8	300
5	10	250	8	300
6	10	250	8	300
8	10	250	9	320
10	10	250	12	360
20	10	250	18	480
30	15	300	21	580
40	25	300	28	650
50	35	500	32	700
70	70	700	40	820
100	150	1000	52	1100

4. Conclusion

Standards and norms present different reference values for the vibration's parameters, as single measures or corroborated with other characteristics. A comparisation between different norms is not opportune, because the criteria which fix these values are mostly subjective, more linked to mentalities and lifestyle than to rigorous technical approach. However, overlapping these values doesn't conduct automatically to damages in constructions or health problems for the persons. Important issues for polluters with vibration are: the monitoring of sources and receptors and mitigation of the vibrations. An important aspect reflected in a lot of researches and also in norms, is that the diminution of the impact of vibrations is possible not just trough technical measures but trough information and organizing measures too.

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