EVALUATION OF VIBRATION'S TRANSMISSION IN AN EXISTING BUILDING

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Abstract: The aim of this work is to study the transmission of vibration caused by the operation of electromechanical equipment, in an existing building. In this study the effects of vibration's propagation are evaluated, which is based on international regulations like the ISO 2631, BS 1989 and 6472, 1992 where we can check the suitability of a building to human comfort, regarding the presence of such phenomena vibration.

Keywords: vibrations in structures, criteria of comfort, propagation of vibrations, structural dynamics; FFT.

1. Introduction

In recent years, the great technological evolution in the field of structural engineering has resulted in the use of more resistant materials such as steel structures, and development of advanced construction techniques in order to achieve a faster construction's process.

Despite these advantages, there are disadvantages which are related to the dynamic behavior, mainly due to the high transmissibility of these materials. This occurs because these structures are lighter, more slender, and with lower damping, causing a reduction in structures' natural frequencies. The natural frequencies become closer to its excitation frequencies, leaving the structures more susceptible to dynamic loads. Thus, the dynamic loads can produce high vibrations' levels, which may compromise the structural safety or cause discomfort to the buildings' occupants.

These confort levels can be evaluated based on the British standard BS 6472 [BS, 1992], whose evaluation is based on ISO 2631-2 [ISO, 1989] which contains insufficient information for an efficient evaluation of buildings' vibrations. The ISO 2631-2 [ISO 1989] provides measurement procedures and acceptability criteria for vibration which affects human comfort, providing acceptable limit factors which depend on the type of vibration, the period of the day that it occurs (daytime or night) and in the area of buildings' occupancy. In other words, it is an international standard for the "Assessment of Human Exposure to vibrations in buildings", which defines and provides numerical values of the exposures' limits to the human body's vibration in a range of frequency between 1 and 80Hz for periodic and non-periodic vibrations.

The BS 6472 [BS 1992] complements the information on the confort assessment by introducing a table that identifies the limits of vibration (in the horizontal and vertical direction) based on limit curves depending on the sort of activity (critical working areas, hospital, residential, office, workshops, etc. ..) and the occupation period (day or night) of a building.

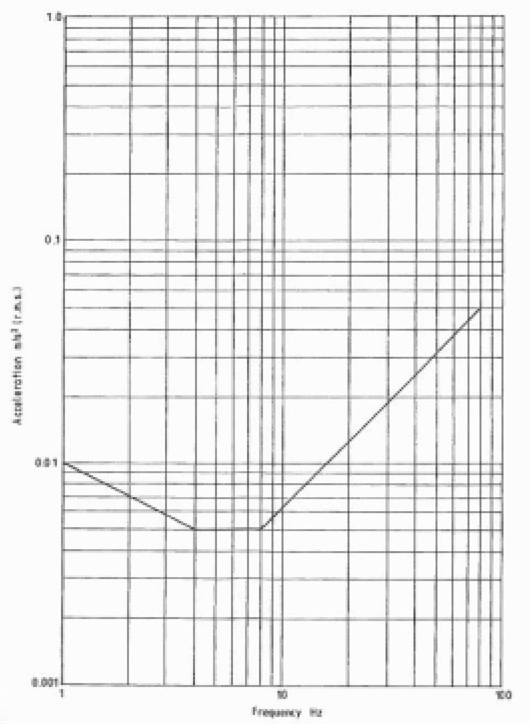


Figure 1 – Base curve for vertical accelerations. Source: ISO 2631-2.1989

The limit curves mentioned are estimated through multiplying factors which are based on a acceleration curve as a function of frequency, depending on the type of activity and the period of building's occupation.

As we can see in figure 1 the base curve doesn't provide much information when used alone to obtain acceptable vibration's levels for a certain time period or for the structure's business use. In this manner a table of multiplying factors was developed to obtain acceptable limits of vibration in relation to human comfort for a variety of situations. The multiplication factors related to the pesent case of study is presented in Table 1.

Place	**Time**	**Multiplying factors – Exposure to continuous vibration (16h day; 8h night)**	**Multiplying factors – Impulsive vibration excitation with multiple occurrences**
Office	Day	4	128

Table1 – Base curve's multiplying factors. Source: ISO 2631-2,1989

The factors presented in table 1 lead to the limit curves which are presented in figure 2, referring to different times of vibration's exposure:

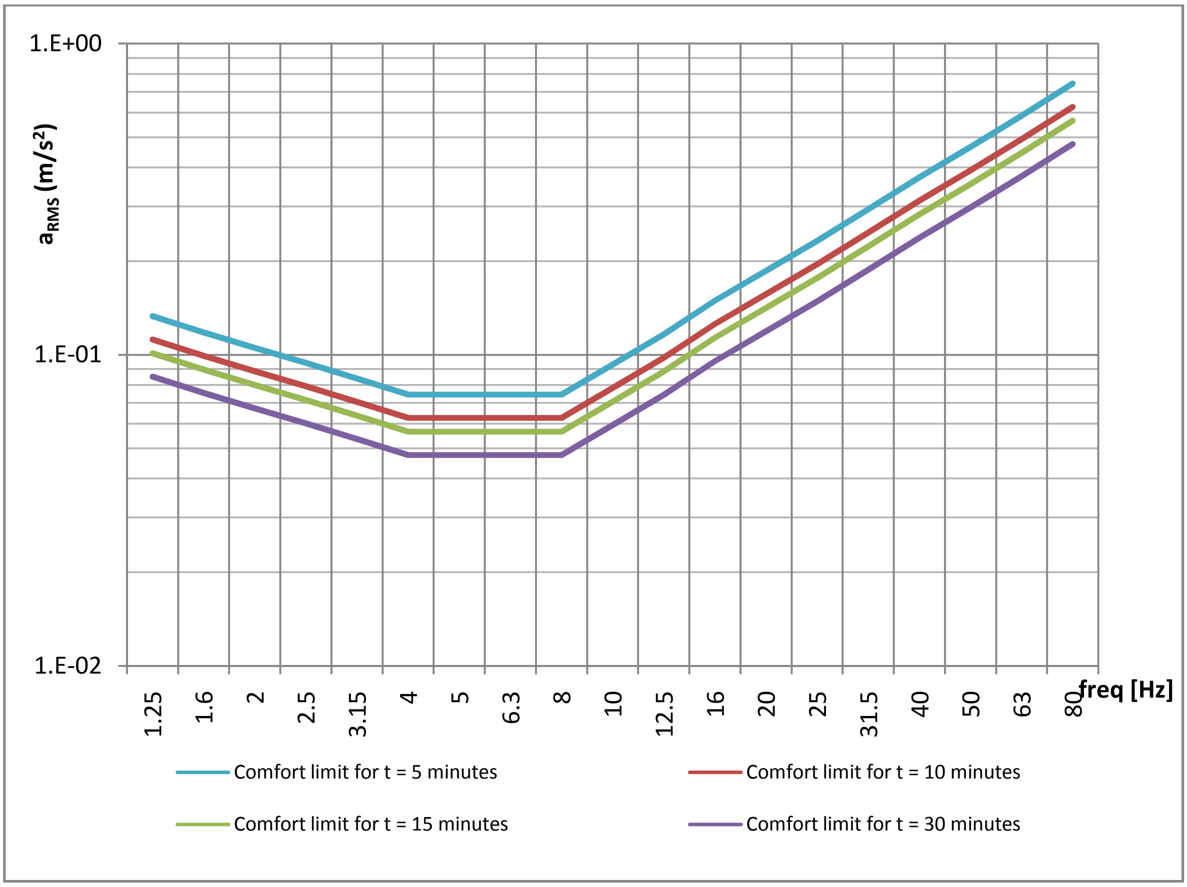


Figure 2 – Base curves for different time exposures of continuous vibrations.

2. Case study

This study is based on measurements in Navy' buildings: active departments in Vila Franca de Xira Navy Technology's School (ETNA), including the Maritime Police Training's Center (PM) and the Directorate of Maritime Authority's School (EAM), and the Electronics and Communications' building (DEC), in Arsenal of Alfeite. The DEC's building, in Alfeite it is planned to be a school with classrooms and technical laboratories. Thus, it becomes relevant to study the vibrations' propagation caused by the equipment present at the laboratories, to estimate the suitability of its operation with classes operating in the classrooms.

2.1. General procedures adopted in measurements

2.1.1. Recording equipment

In the vibration recording it was used an accelerometer ETNA - Altus Series of Kinemetrics (Strong Motion Accelerograph) with three channels, two of them for registration of the horizontal acceleration in two perpendicular directions and a third channel for recording vertical accelerations. As we intend to evaluate the transmission of vibration in the vertical, the acceleration of interest is along the axis z.The main aim was to evaluate the vertical vibration transmission between the ground floor and the first floor of the DEC building in Alfeite.

2.1.2. Signal recording

The characterization of the excitation sources (in this case, vibration) to be installed in the DEC's building at Arsenal Alfeite was performed on a sample of six equipments which are operating in Navy Technology's School (ETNA) in Vila Franca de Xira, and will be transferred later to the first building's installations. Thus, the vibration's levels measurements was performed near the equipment base foundation in the Vila Franca building. In Figure 3 is presented, as example, the vibration record of Volvo Penta engine. The recorded signal andcits Fourier spectrum of acceleration obtained for the Volvo Penta engine is presented in Figure 4.

Figure 3 - Volvo Penta engine which is placed in MO2’s workshop (360 cv/1800 rpm).

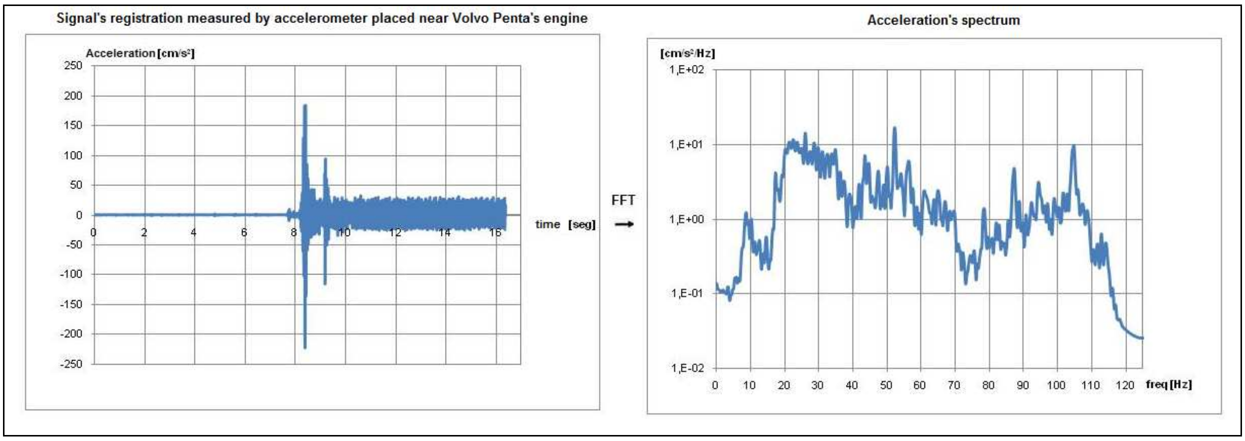
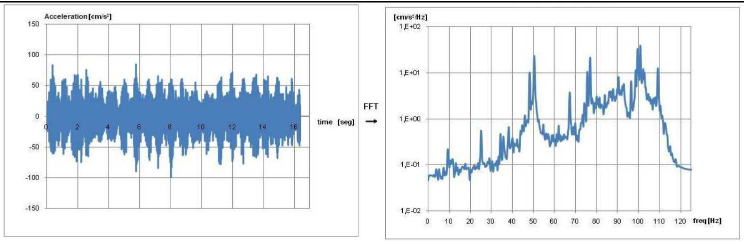


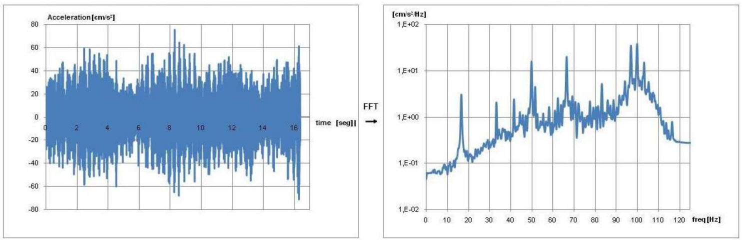
Figure 4 - Recorded signal and Fourier spectrum of acceleration measured Volvo Penta’s engine in MO2’s workshop.

In Figure 5 are presented the results for five other engines considered in the study.

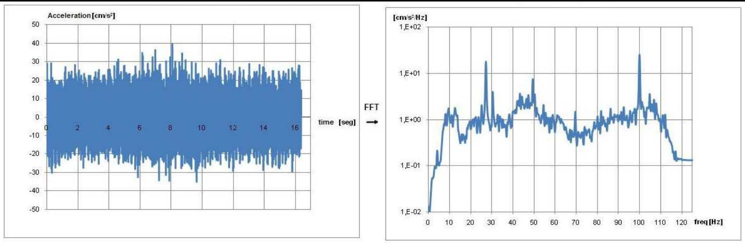
Engine located in AC controllers' lab.



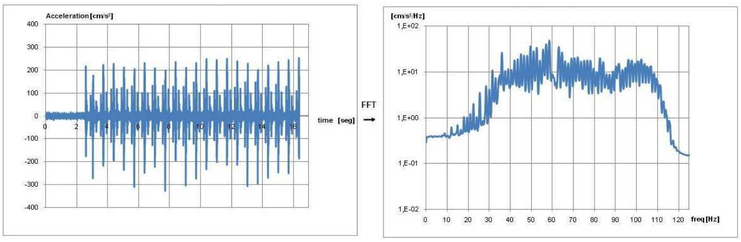
Transformer located in main control room.



Rotating tool located in Machinery and Tools' workshop.



Filer located in Machinery and Tools' workshop.



Generator (Caterpillar) located in Electric station.

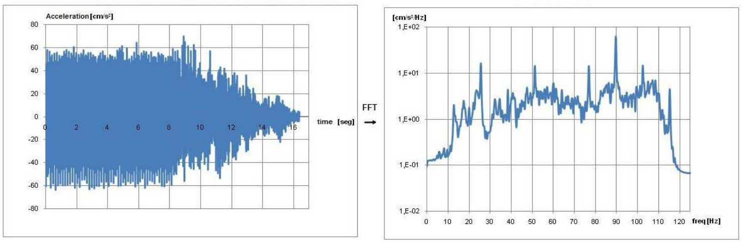


Figure 5 – Recorded signal and Fourier spectrum of acceleration measured at equipments' base.

As can be seen in Figure 5, equipments in general have frequencies 'peaks near 100 Hz.

2.1.3. Vibration’s transmission assessment

The identification of structural vibration’s is based on acceleration’s characterization through transfer functions, H (f) between the accelerations measured at the excitation’s point (s) - Machinery and Tools’ workshop (point 1 of the floor 0) / Locksmiths’ workshop (point 2 of floor 0) - and the accelerations measured in receptors’ points - in the Auditorium (Points 1-6 of the first floor), as indicated on the plans in Figure 6. The location of these points was chosen where the larger slab deformation was expected (at span’s mid) and in locations where acceleration transmission could be higher (at the floor corners). The choice of these last points allows us to identify different discomfort’s situations, because they are greater structural rigidity’s points (floor, walls and colums) – where it will be expected to register greater vibration’s transmission with increasing frequency excitation.

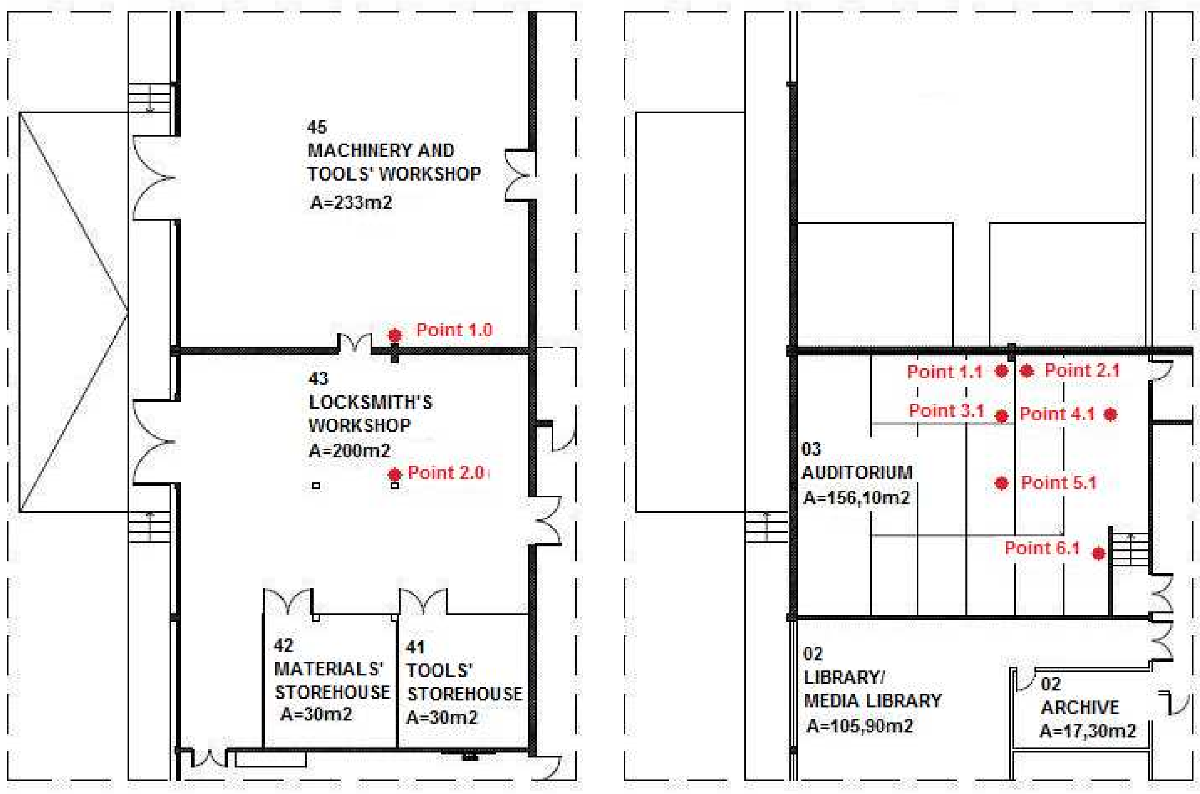


Figure 6 – Measurement’s points of acceleration’s transfer. (a) Floor 0; (b) Floor 1.

With the percussion equipment operating at point (2,0), on the ground floor in DEC’s building , we install the accelerometer at the same point, in order to calculate the absolute acceleration magnitude that will allow us later to estimate the comfort’s levels for equipments’ exhibitions already submitted. The transfer function used to evaluate the vibration’s propagation from the Volvo Penta’s engine was the H(2,0-6,1) function, shown in Figure 7.

Transfer Function					Most amplified mode (Hz)
Nomenclature	**Action Point**	**Local**	**Response Point**	**Local**	
H(2,0-6,1)	Point 2, Floor 0	Locksmith's workshop	Point 6, Floor 1	Auditorium	18,4

Table 2 – Measurement point's designation and its maximum amplification frequency.

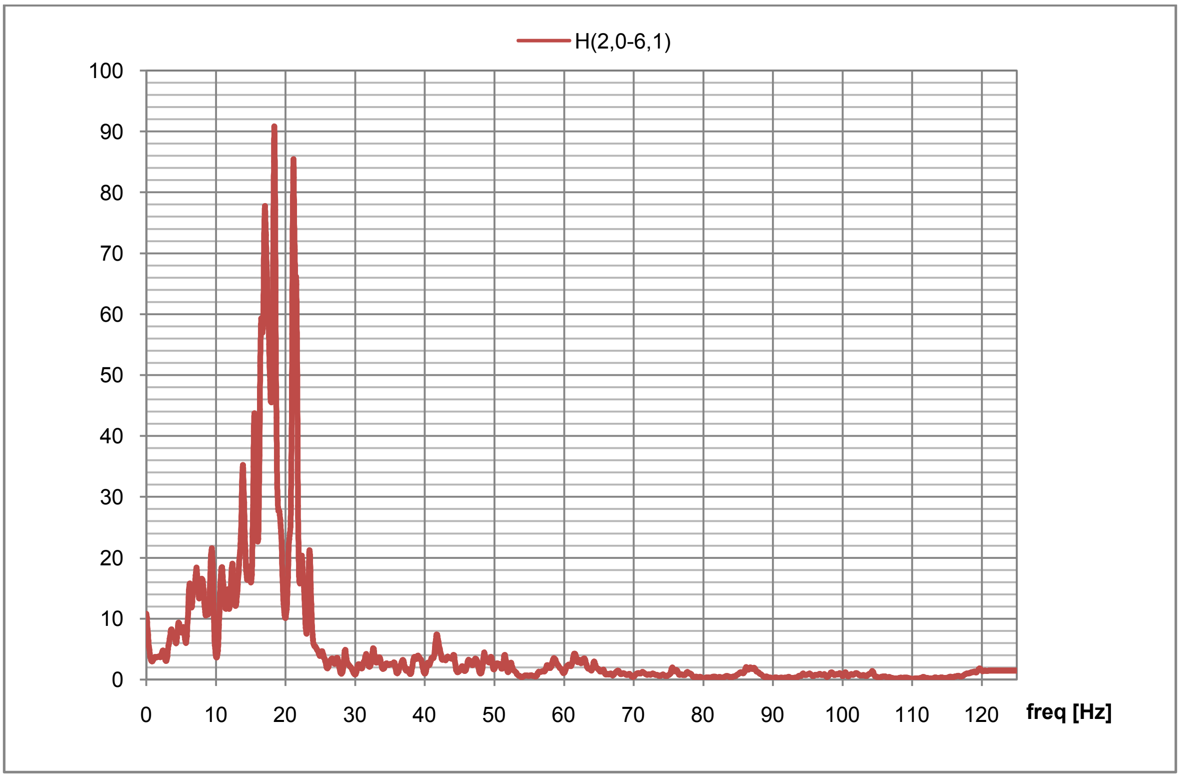


Figure 7 – Transfer functions between the acceleration at point (2,0) on the ground floor and the acceleration at the point (6,1) on first floor.

As it can be observed in figure 7, there is a significant amplification of frequencies between 15 and 21Hz, with particular emphasis around 17Hz. As can also be observed in the figure 7, there is no record of frequencies above 25Hz.

3. Discomfort vibration levels' prediction

As specified in BS 6472 [BS 1992] the vibration limits are presented in graphs that relate the velocity or acceleration with frequencies for each movement's direction, measured in a representative operation's period of excitation source.

As explained in chapter 2, the references' curves for the exposure's periods to continuous vibration above were calculated based on an estimate of their "vibration dose values." Noted that all the assessments which will be presented below were based on the comfort's curves from the unfavorable measurement response points.

In the Volvo Penta's isolated operation, which is presented in figure 8, the limits of perception's curve are based on unfavorable transfer function - H (2,0-6,1) to estimate the discomfort caused by this equipment in the future, in MO2's workshop, in first floor.

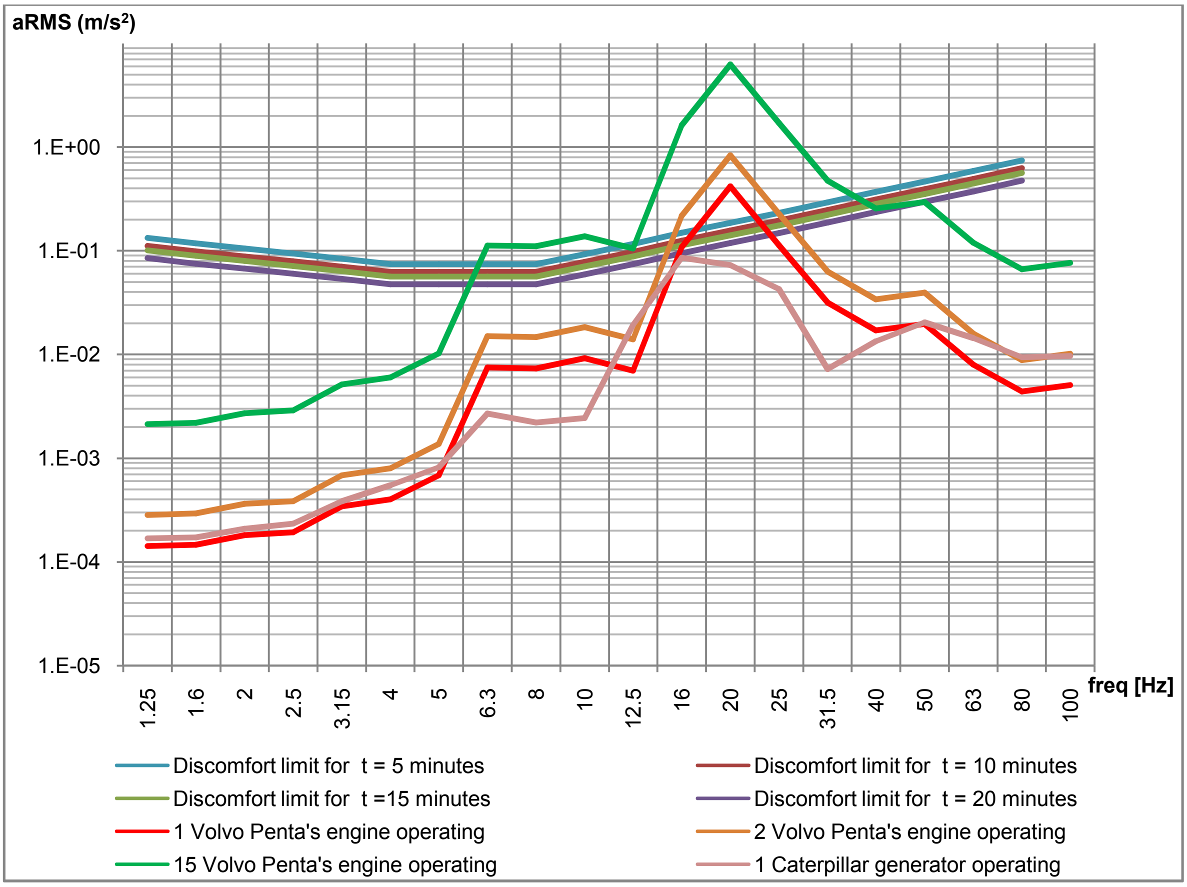


Figure 8 – Discomfort from vibration generated in the classroom 10 by Volvo Penta's engine and a Caterpillar generator operating in MO1 and MO2 workshops based on the transfer function H (2,0-6,1).

If the engine's foundation, in DEC, is similar to one existing in Vila Franca Xira's building, it can be expected significant peak's acceleration for the range of 16 to 25Hz, whose users will feel discomfort when one or more Volvo Penta's engines are operating.

4. Conclusions

In order to make a vibrations' propagation assessment in concrete structures, this work consisted of an evaluation of vibration transmission in an existing building, specifically in the Division of Electronics and Communications' building (DEC), in Arsenal Alfeite. Thus, the main aim was to analyze the acceleration generated in building elements by a mechanical vibration source located on the ground floor of the cited building. With this objective along the present experimental work, there were done a frequencies' characterization of the acceleration produced by equipment's operation, since this equipment will be installed in Alfeite's building, the vibration transmission´s evaluation from the floor ground floor to an upper floor was evaluate. Finally based on earlier studies, limit curves of perception and human comfort to vertical vibrations were generated, verifying the adequacy of the vibrations generated. It was concluded that, in some situations, the comfort limit were not verified.

As a final conclusion of this study, based on the evaluations performed we can conclude that there aren’t currently guaranteed comfort conditions for students who will attend the school activities on the first floor.

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