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STUDIES ON THE EFFECTS OF VIBRATIONS FROM INDUSTRIAL ENVIRONMENTS

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Abstract

Vibrations caused by some industrial sources (forges, presses etc.) are transmitted to the ground, generating different surface waves, with significant effects on building foundations, as well as some effects on buildings and their occupants. The structural dynamic response to this type of vibration also depends on the phenomenon of structure-soil interaction and the phenomenon of attenuation/amplification of vibrations. The principle of the applied method consists in determining the actual values of the characteristic parameters from the recorded vibrations in-situ /in building, in order to verify the fulfilment of the velocity criteria which are correlated with certain degrees of damage. In view of the means of controlling vibrations (at source, by transmission and in remote buildings) with physical or on human perception effects, the made assessments will determine whether the prevailing frequency produced by industrial equipment, within the monitored activities, is finds itself in the area of adjacent buildings' frequencies, with possible effects on the comfort of the inhabitants. The article aims to present comparatively the results obtained from the some instrumented sites.

Key words: *damages, industrial vibrations, velocities.*

INTRODUCTION

Vibrations caused by some industrial sources (forges, presses for forging large and heavy parts, loading/unloading ramps and silos platforms, activities specific to the mineral industry/cement plant/co-incineration of waste in the cement plant etc.) are transmitted to the ground, generating different continuous, impulsive or intermittent waves, with significant effects on building foundations, as well as some effects on buildings and their occupants. The dynamic response of buildings to vibrational forces is an important concern and often involves adopting measures to reduce the level of vibrations transmitted through the soil and to prevent their propagation to adjacent buildings. Determination of the vibration level is generally based on direct measurements and there are some technical codes that make references to structural vibrations (C 125 – 2013, DIN 4150-3/1999, STAS 12025/2-94). These codes set limits for normal use of residential and social-cultural buildings subjected to vibrations produced by equipment located inside or outside buildings (admissible vibration level, admissible values for the internal equivalent vibration level - equally physiological effect curves, curves to appreciate material degradation). The structural dynamic response also depends, in this case, on the phenomenon of soil-structure interaction, the approach being relatively similar to the propagation of seismic waves, not surface type (Dobre, 2012) and the phenomenon of attenuation/amplification of vibrations (from source to the foundations of neighboring buildings, then to the top of the building) (Dragomir, 2011).

MATERIALS AND METHODS

The principle of the applied method is based on the determination of the actual values of the characteristic parameters (displacement, velocity, acceleration) from the vibrations recorded in a site/building, in order to verify the fulfilment of the velocity criteria (in particular). The velocity criteria, as defined in various norms or studies, generally refer to buildings with structures designed in accordance with technical standards. Limits allowed for the normal functioning of residential and social-cultural buildings subjected to vibrations produced by equipment located inside or outside buildings (admissible vibration levels, allowable values for the internal vibration equivalent level - curves of equal physiological effect, curves for appreciate material degradation).

RESULTS AND DISCUSSIONS

In view of the means of controlling vibration (at source, by transmission and in remote buildings) with physical effects or at the level of human perception, the assessments made will determine whether the predominant frequency of industrial equipment or activities generating oscillations in the monitored activities are in the area of adjacent building frequencies, with possible effects on the comfort of the inhabitants. The article aims to present comparatively the results obtained from some instrumented locations.

Case study 1: Determining the level of vibrations produced by an industrial activity (forging press)

Records made to determine the vibration level produced by a 12 000t forging press have been sequential and performed with GMS Plus, GeoSIG multichannel stations. The position of the seismic sensors was the following: a sensor inside the hall, in the same line as the large tonnage press and the outer sensor, and a sensor located outside the hall on the sidewalk (the eastern side) (Figure 1).

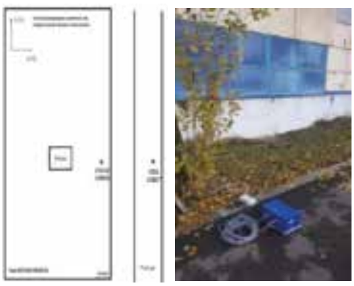

Figure 1. Position of seismic sensors. The outside sensor

The velocity variation on the three directions highlights predominant values in the z-direction at the sensor near the press (Figure 2) and with comparative values in the y and z directions, smaller than the press, in most of the records, to the external sensor (Figure 3).

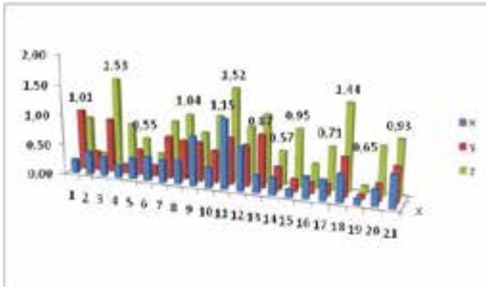

Figure 2. Variation of velocity at the sensor near the press

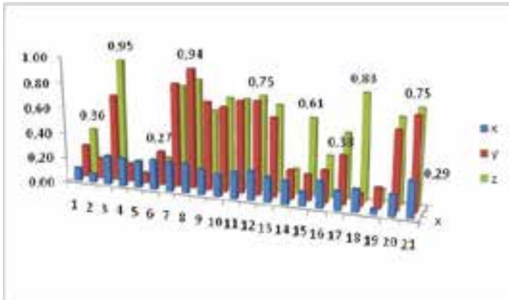

Figure 3. Velocity variation at outer sensor (eastern side)

Also, Tables 1 and 2 show the maximum/minimum values of accelerations and velocities outside the industrial hall (east side), these values being of interest. There is a distribution of the frequency values near the forging press and from the outside sensor, in directions x and y (inside of industrial hall – black; east side/outside of industrial hall - grey) (Figure 4):

- in the direction of x, the predominant field [9.2…10.89] Hz - near the press, [8.79…9.59] Hz - at the eastern side, with point values of 5 Hz and 12 Hz in both locations;
- in the direction of y, the predominant field [8.54…11.50] Hz - near the press, [9.47…11.25] Hz - at the eastern side, with point values of 12 Hz in both locations.

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Table 1. Maximum/minimum acceleration values

Acceleration [mm/s^2] (outside - east side)	Forging press at work/direction			The forging press removed from work/direction		
	x	y	z	x	y	z
Maximum	17.99	56.80	48.44	3.46	6.46	5.66
Minimum	1.45	4.51	4.57	0.20	0.33	0.32

Table 2. Maximum/minimum velocity values

Velocity [mm/s] (outside - east side)	Forging press at work/direction			The forging press removed from work/direction		
	x	y	z	x	y	z
Maximum	0.29	0.94	0.95	0.053	0.095	0.11
Minimum	0.04	0.08	0.11	0.005	0.009	0.02

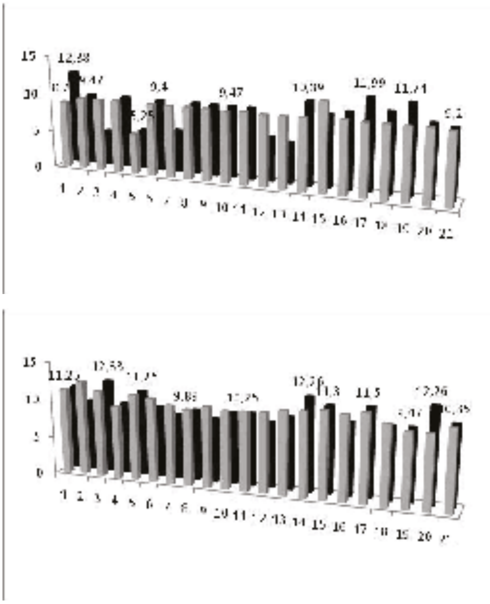

Figure 4. Frequency values, in the direction of x and y (4 ... 13 Hz)

According to the 2014 study, we can compare the recorded velocities with a 12-channel GeoDAS station equipped with four triaxial sensors (placed as follows: on the foundation of 12000 tf; on the slab/at the edge of the hall; outside the hall to the eastern side; outside to the road, at a distance of 1-5 m) and a 3-channel GeoDAS station equipped with 1 triaxial sensor (3 axial sensors, respectively) (located on the ground in the area of blocks with height regime P + 4 and P + 5), which are shown in Figure 5.

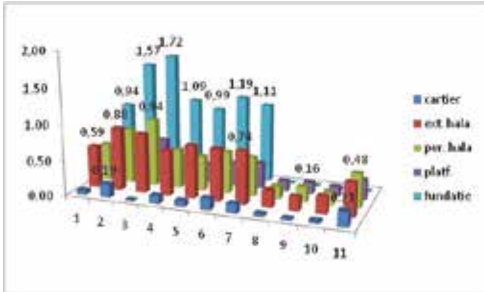

Figure 5. Velocity values recorded in 2014

From the figure above, it can be seen that at a velocity of 0.19 mm/s ... 0.21 mm/s, from the point of view of human comfort, vibrations are not perceived, or are easily perceived, according to the technical codes mentioned at the beginning, or, for example, BS 5228-2: 2009, where the following vibration levels (velocities) are associated with the corresponding effects on human comfort, as follows:

- 0.14 mm/s at low frequencies, vibrations are not perceived;
- 0.3 mm/s vibrations can be easily perceived;
- 1 mm/s sensations appear, but vibrations are tolerated if they are explained to those who feel them;
- 10 mm/s the vibrations are intolerable.

Conclusion 1: After processing all data, the degree of attenuation of the vibration level from the press to the eastern side is obtained; the recorded velocities are not exceeding the permissible value and the recorded values in the outside are lower. Regarding admissible values, the admissible velocity was considered 8 mm/s.

Case study 2: Determining the level of vibrations produced by industrial activity (loading/unloading ramps and silo platforms) within the Monsanto Sinesti agricultural complex

In the program of micro vibration measurements in the ramp hall, four series of records were made using the GMS Plus stations (4 x 1 internal triaxial sensor – 4 x 3 channels) (Figure 6).

The recordings were made with auto-trigger at a pre-set date for synchronization of records from all sensors.

Measurements have been made in several different situations, as follows:

- I: corresponds to the situation where the ramps and the download zone are not loaded (static regime);
- II: corresponds to the situation where the ramps and the download area are not loaded, but the two unloading equipment are in operation (dynamic regime);
- III: corresponds to the situation where the ramps and the download zone are loaded at maximum capacity, but the unloading equipment is not in operation (static regime);
- IV: corresponds to the situation when the ramps and the download zone are loaded and operate at maximum capacity (dynamic regime).

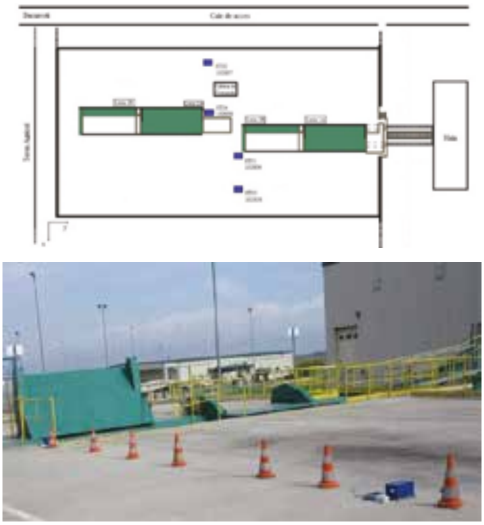

Figure 6. Location of GeoSIG acquisition system consisting of 4 GMSPlus stations. Line 1B

In Figure 7, the velocity variation on the two directions reveals predominant values in the direction x, in situation II (dynamic regime), and predominant in the y direction in the situation IV (dynamic regime), and in Tables 3 and 4 the max/min values of accelerations and velocities are presented.

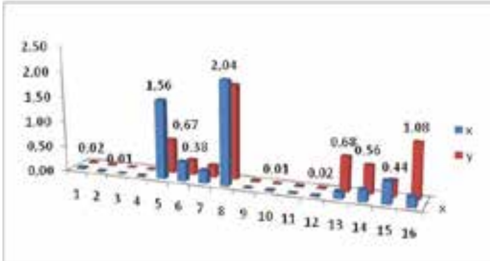

Figure 7. Predominant velocity values in the dynamic regime

A distribution of the frequency values is presented in both directions, with the predominant values: in situation I (static regime) - 13.5 Hz; in situation II (dynamic regime) - 8 Hz; in situation III (static regime) -19.7 Hz; in situation IV (dynamic regime) - 7.9 Hz (Figure 8).

Conclusion 2: For the present study, the permissible velocity was considered 12 mm/s, not exceeding, and from the point of view of human comfort it is not taken into account, the area of the agricultural complex being quite far from the inhabited area.

Table 3. Maximum/minimum acceleration values

A m/s²	Situation I		Situation II		Situation III		Situation IV	
	x	y	x	x	y	y	x	y
max	0.584	0.346	28.94	20.14	0.245	0.322	8.43	20.73
min	0.203	0.240	3.99	7.89	0.172	0.202	3.59	7.87

Table 4. Maximum/minimum velocity values

V mm/s	Situation I		Situation II		Situation III		Situation IV	
	x	y	x	x	y	y	x	y
max	0.0390	0.020	2.039	1.860	0.010	0.019	0.443	1.077
min	0.0053	0.0047	0.258	0.228	0.0049	0.0064	0.142	0.324

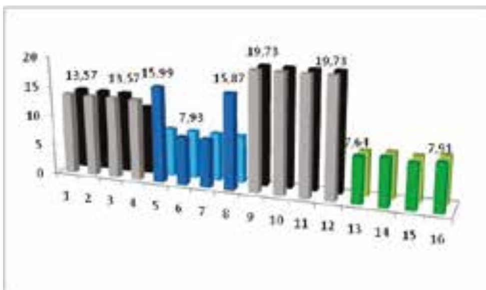

Figure 8. Predominant frequency value in dynamic regime: 8 Hz

Case study 3: Determining the level of vibrations produced by industrial activity (activities specific to the mineral industry/cement plant/co-incineration of waste in the cement plant etc.) within the CRH Cyclone Building, located in Hoghiz, Brasov

The vibrations were determined in four distinct points (established in agreement with the designer), in three directions (two horizontal and one vertical), in the state of technological operation of the cyclone tower building, which will allow the designer to identify the real level of vibrations, amplitudes and frequencies to correlate with the potential damage to some floors and/or other structural elements (at each measuring point, a sequence of 5 records of about 90 seconds). The four triaxial sensors of the GeoSIG, Kinemetrics multi-channel acquisition system were placed vertically on the building (1st floor, 3rd floor, 5th floor, 6th floor terrace) (Figure 9). The orientation of the sensors placed on the vertical of the building was done as follows: the direction x - the direction of the rotating furnace; direction y - direction perpendicular to x direction; direction z - vertical direction of the building.

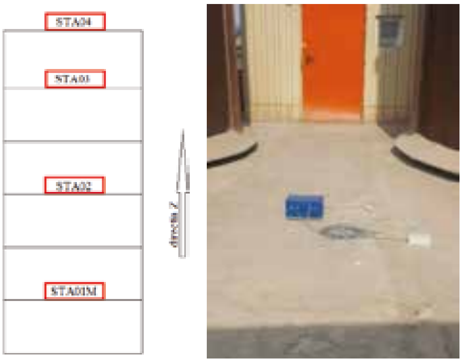

Figure 9. Location of the GeoSIG acquisition system consisting of 4 GMSPlus stations. Sensor on the 6th floor

In Figures 10-13, the velocity variation on the three directions reveals predominant values in the z direction at the lower level and increasing in direction x to the last level (6th floor).

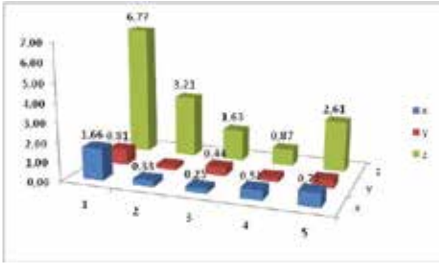

Figure 10. Velocities at the level 1

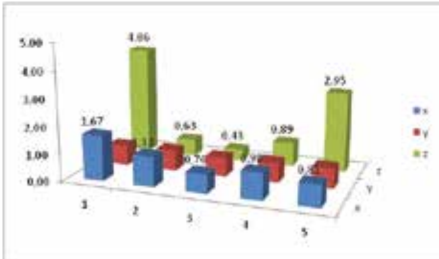

Figure 11. Velocities at the level 3

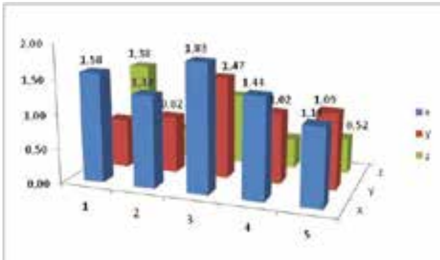

Figure 12. Velocities at the level 5

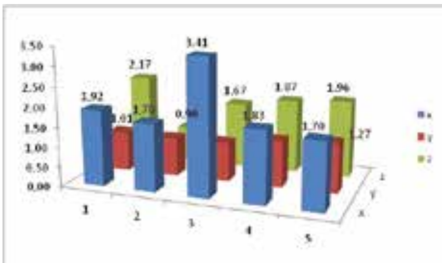

Figure 13. Velocities at the level 6

In Tables 5 and 6 the maximum/minimum values of accelerations and velocities are shown.

Table 5. Maximum/minimum acceleration values

Acceleration [mm/s^2]	dir x	dir y	dir z
maximum	92	78.1	570
minimum	13.45	11.54	32.21

Table 6. Maximum / minimum velocity values

Velocity [mm/s]	dir x	dir y	dir z
maximum	3.412	1.466	6.77
minimum	0.2541	0.222	0.4255

On the upper floor, the frequency values: 1.1 Hz- x direction; 1.4 Hz- y direction; 5 Hz- z direction (Figure 14).

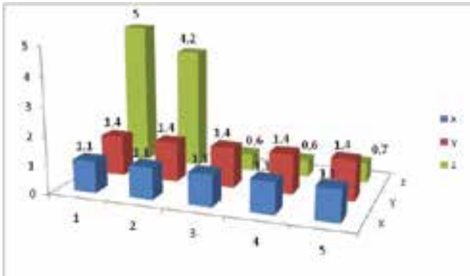

Figure 14. Frequency values on the upper floor
(0.6 ...5 Hz)

Conclusion 3: The recorded velocity values, at the level of the four floors, are below the lower limit of 12 mm/s and from the point of view of human comfort it is not taken into account, the area of the industrial complex being quite far from the inhabited area.

CONCLUSIONS

The normative provisions quite generally specify some admissible limits for vibrations produced in industrial activities. However, the level of vibrations recorded, the nature of the possible vibration source and the specificity of measured vibrations (correlated with the study of Fourier spectra), their secondary effects, with a great variability of the combinations between them, and the impossibility of establishing a general cause and effect relationship applicable, etc. have not been the subject of advanced long-term studies. This paper seeks to clarify some theoretical and practical aspects that improve the level of understanding and the degree of involvement in taking measures to mitigate the effects on adjacent buildings and neighboring people. Excessive vibrations generally create discomfort (sometimes with health damage) rather than effects on structural safety, and tolerance to these vibrations decreases as exposure time increases.
In the first presented case study, the comfort limits were not exceeded, but at a careful analysis it can be determined to what extent the applied criteria could be overcome as a result of the industrial activities carried out.

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REFERENCES

C 125 (2013). Acoustics code in constructions and urban areas (Part IV and Chapter 4.2).

DIN 4150-3 (1999). Vibration in buildings - Effects of vibrations on structures.

STAS 12025/2-94. Acoustics in constructions- Effects of vibrations on buildings or on building parts.

Dobre, D. (2012). The soil-structure interaction in the seismic conditions of Vrancea, Romania, Proceedings 15th World Civil Earthquake Engineeering in Lisbon, Portugal.

Dragomir, C. S. (2011). *Raspunsul seismic al cladirilor civile iregulare*. Ed. Noua.