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The influence of the circular distribution of radial and tangential seismic velocity on the structural safety of residential buildings

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Abstract

The article presents the results of conditions of circular distribution of seismic vibrations generated during rock blasting. The Scales of Dynamic Influences [SWD] of the harmfulness of the vibration velocity on a two-storey building [SWDI] and a five-storey building[SWDII] are given. The value of seismic velocity safe for the construction of the buildings has been determined. They are in Zone II of the Dynamic Influence Scale [SWD] SWD I and SWD II. The magnitude of the components of the vibration velocity at the same distance from the source of vibration depends on the directional angle between the line of blast holes and the line connecting the centre of the surface of the mined rock block and the place of measurement. For the circular distribution of the vibration velocity, a theoretical analysis of the change in the radial value Vx and the tangential Vy of the vibration velocity depending on the change in the directional angle was conducted. Graphs of vibration velocity for circular distribution, measured during mining of rocks and complying with theoretical predictions were presented. For residential buildings, with SWDI and SWDII, the limit value of the safe vibration velocity for the building structures is given.

Keywords: ground vibrations, seismic vibrations, circular distribution of vibrations.

1 Introduction

This paper discusses the effect of the directional angle in the circular distribution of seismic velocity generated by blasting rock on the value of seismic velocity safe for building structures. Compact rocks are mined using blasting materials [BM], which cause vibrations in the mining medium and then in the ground outside the mine. These vibrations are transmitted by seismic waves propagating in all directions and have harmful effects on road and housing infrastructure. So far in Poland and worldwide is believed that seismic vibrations generated during mining rocks using BM propagate along a circular path with equal energy in each direction, like waves on water from a stone thrown into it (Chrzan and Modrzejewski 2014). In Fig.1B the directional angle of measurement "α"=90º between the line of blast holes and the line connecting the measurement point/house/ with the central blast hole is marked and the distance between the vibration source and the object is marked.

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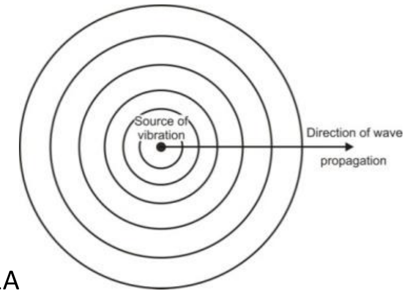
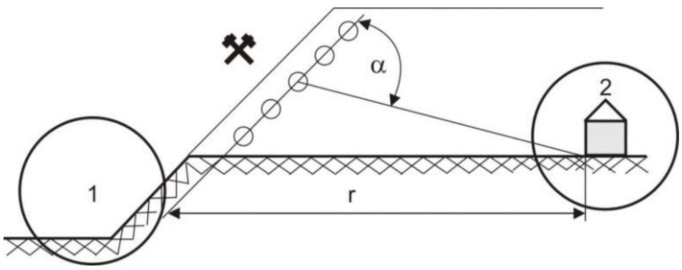


1A



1B

Figure 1A.Circular directional distribution of horizontal velocity Vxy of vibrations (Chrzan2014). Figure.1B. Outline of a place of vibration formation / mine "1', bench blasting / and the distance "r "between the mine and the building '2" which is affected by vibrations and the directional angle "α", /own elaboration/.

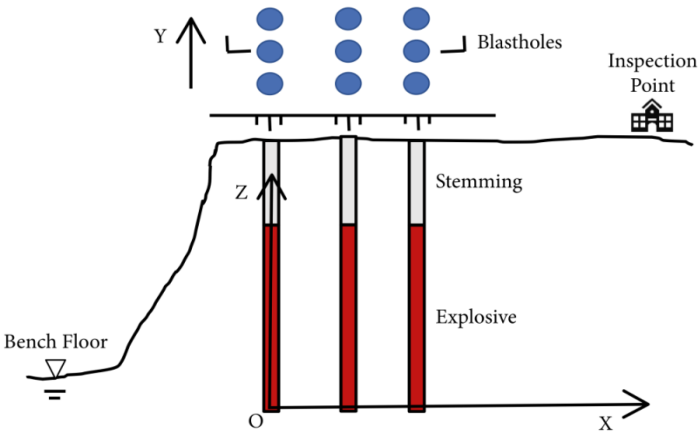
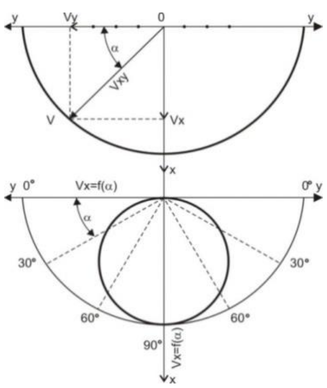


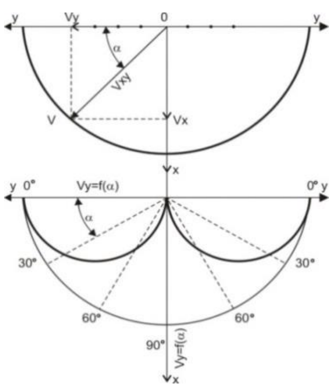
Figure.2 Measuring directions X and Y of the vibration velocities Vx and Vy in relation to the position of the blast holes in the mined BM rock block are shown/own archives/.

2 Theoretical analysis and measurement results

From the analysis of the unit circular distribution of the radial component Vx of the vibration velocity as a function of the directional angle "α" Fig.1A it follows that the radial component Vx of the vibration velocity for the directional angle in the range from "α" = 0-90º has the shape of a semicircle in each quarter of a circle a variable value in the direction of the X-axis, for α =0º, Vx =0, for α =90º, Vx=Vx max. From the analysis of the unit circular distribution of the tangential Vy of the vibration velocity as a function of the directional angle "α" Fig.1B it follows that the tangential component Vy of the vibration velocity for the directional angle in the range from "α" = 0-90º has the shape of a semicircle in each quarter of a circle a variable value in the direction of the Y-axis, for α =0º, Vy=Vy max., for α =90º, Vy=0.



3 A



3 B

Figure 3A. Graphical representation of the shape and value of the unit vector of the resultant vibration velocity Vxy and radial Vx of the vibration velocity of the seismic wave as a function of the directional angle "α" /circular distribution/(Chrzan and Modrzejewski 2014).

Figure 3B. Graphical representation of the shape and value of the unit vector of the resultant vibration velocity Vxy and tangential Vy of the vibration velocity of the seismic wave as a function of the directional angle "α" /circular distribution(Chrzan and Modrzejewski 2014).

Figure.3A and 3B shows that the radial vibration velocity Vx and the tangential vibration velocity Vy have different values depending on the directional angle of the measurements "α". The Y-direction coincides with the line of blast holes and the speed Vx is perpendicular to the Y direction. In the X and Y directions, the horizontal components of the radial Vx and tangential Vy of the vibration velocity on the tested object are measured. The unit value of the resultant velocity vector for a circular distribution can be written as the sum of the component vectors, $Vxy^2 = Vx^2 + Vy^2$, $Vxy^2 = R^2 = 1$. (1.0)

From Figure 2A it follows that $Vx = Vxy * \sin\alpha = 1 * \sin\alpha$, $Vx = Vy * tg\alpha$ (2.0)

From Figure 2B it follows that $Vy = Vxy * \cos\alpha = 1 * \cos\alpha$, $Vy = Vx / tg\alpha$ (3.0)

The actual distribution of radial velocity Vx and the tangential vibration velocity Vy measured during excavation of BM of n non-homogeneous overburden in Adamów lignite deposit (Onderka 1971), Fig.4) is similar to theoretical Fig.3A and 3B. In Figure 4, α=55⁰ is the angle of non-homogeneous of the medium with the highest value of the horizontal radial velocity Vx and the tangential vibration velocity Vy of the vibration. The dashed line is the theoretical circular distribution for Vx, as in Fig.4, -marked values of measurement points-Vx, x-marked values of measurement points-Vy. The non-uniformity is geological in nature and is related to the structure of the ground between the vibration source and the measurement point/house/. It may be an unconsolidated sand layer in glacial till.

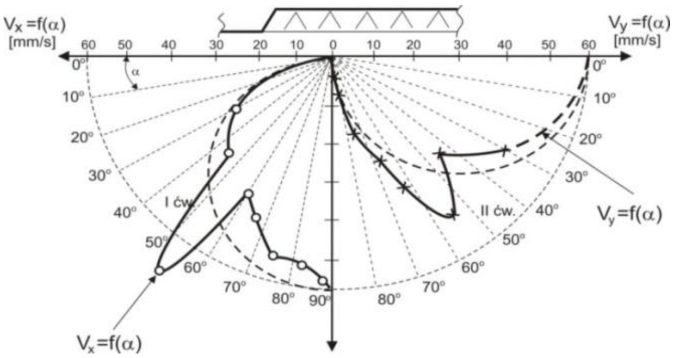


Figure.4 Circular directional distribution of horizontal radial velocity Vx and the tangential of vibrations as a function of directional angle α-I quadrant. Source, Compilation of measurement data (Onderka 1971).

The seismic wave on its direction has a higher velocity and causes a higher vibration velocity of the medium particles than on the neighbouring directions built only of clay. This is confirmed by the measurement results presented in Fig.4.

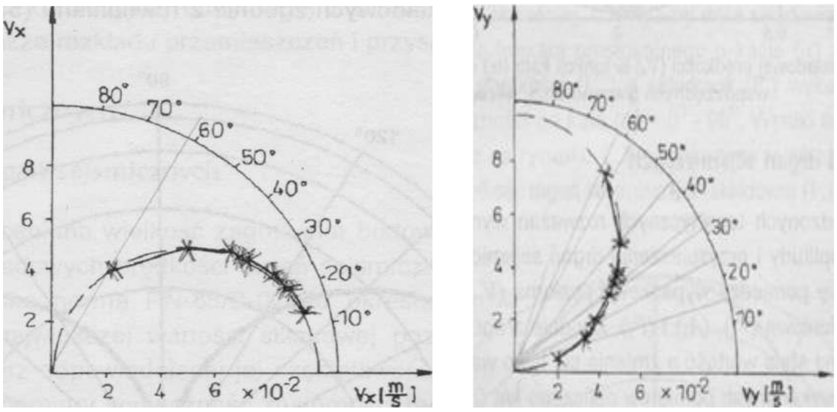


Figure.5 The results of measurements of vibration velocity component the tangential Vx and the radial Vy in the deposits of gypsum (Chrzan and Gliński 1995) as a function of angle α. The dashed line theoretical distribution, the value of x-marked points.

The figure Fig.5 shows, that the measurement points of the horizontal radial velocity components marked as Vy and the tangential component marked as Vx for gypsum(Chrzan and Gliński 1995) slightly deviate from the semicircle drawn with the dashed line, i.e. the theoretical circular distribution. A small number of holes-4- and measurements in the Near Field cause circular directivity of seismic vibrations to occur.

3 Harmfulness scale of vibration velocity, Polish Standard (Norma 2016).

The scale of dynamic effects [SWD] of SWD I and SWD II on buildings was developed as a Polish Standard and has been in force since 1985. The scale is a drawing with lines drawn to define the individual damage zones of vibration speeds. In figure 6, the magnitude of the highest horizontal component of the vibration velocity is measured on the building at ground level and the corresponding frequency is plotted. The intersection point of these data defines the number of the zone and describes the damage to the building in this zone: -Zone I - vibrations not perceptible by the building - boundary A - the lower limit of vibrations' sensibility for the building -Zone II - vibrations perceptible by the building and harmless for the building structure.

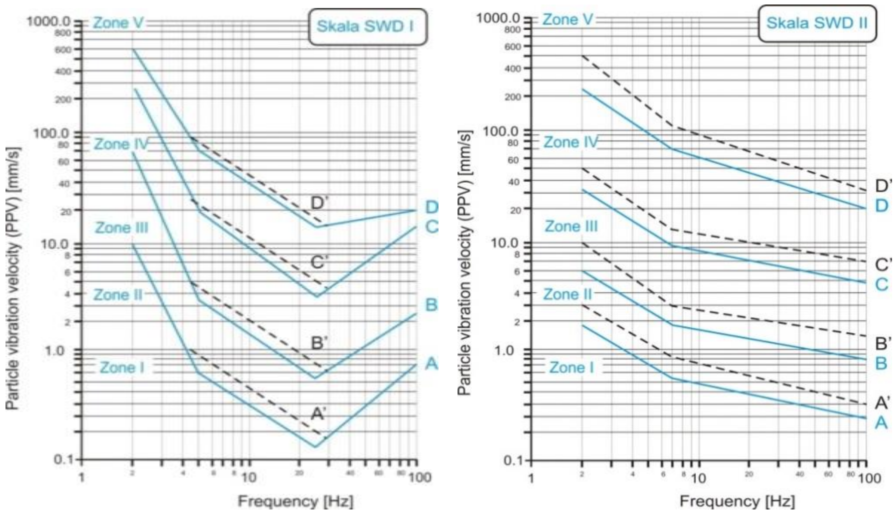


Figure 6. The Scale of dynamic influence, SWD I, for buildings up to two storeys snd scale SWD II, for buildings up to 5 storeys [8].

Zone II - vibrations perceptible by the building and harmless to the building structure, accelerated wear and tear of the building takes place, which is expressed by cracks in the lining, plaster, etc. - B-limit - lower limit for the occurrence of cracks and fractures in structural elements. Zone B - the upper limit of technical safety of the building - Zone III - vibrations harmful to the building, causing local scratches and cracks, possible loss of plasterwork and plastering - Zone C - lower limit of heavy construction damage - limit of resistance of individual elements of the building - Zone IV - vibrations hazardous to people, causing numerous cracks, local destruction of walls and falling of individual elements - Zone V - the collapse of walls. The value of permissible vibration velocity acting on the building without visible damage to structural elements and ensuring technical safety of the building is Limit B, Fig.6. Other speeds cause strictly defined damage to buildings (Norma 2016). The vibration velocity in Zone III is harmful for the building, causing local scratching and cracking of structural elements.On this basis, the author assumed that the technical safety of the building within the range of seismic vibrations can be determined by the vibration velocity marked by line B contained in Zone II of the Dynamic Influence Scale[SWD] , Fig. 6 .The damage limits of each zone are given in two variants A, B, C, D solid line and A′, B′,C′,D′ dashed line. The conditions for the application of these zone boundaries are given in Table 1.

Table 1 Conditions of application of the zone boundaries for SWD(Norma 2016).

Evaluation	Features enabling the use of a border	
According to	Lower - continuous line A,B,C,D	Higher - dashed line A′, B′,C′,D′
Condition of the building	Old, damaged, converted or reinforced buildings	Undamaged buildings, without structural alterations
Materials and construction of the building	Buildings of masonry, cinder-block, stone elements, no foundations, rims vaulted ceilings, large openings or irregular in walls, not carefully constructed	Solid brick walls, reinforced concrete foundations, solid ceilings binding the walls with a ceiling rim, carefully constructed
Type of foundation and foundation method	Subsoil with low stiffness (silty or loose sands), discontinuous foundation various heights	Rigid ground - clay and hard-plastic clay, flat foundation

4 The Term Technical Safety

The term technical safety is relatively new, having been introduced with the emergence of the Safety Engineering course. To date, the authors (Nizinski 2002,Niziński &. Michalski 2002) consider technical safety to be the observance of Polish Standards, Operating Instructions and Technical Operating Regulations. In the monograph, (Pihowicz 2008) "Engineering Technical Safety", the author with reference to analogies to reliability theory gives definitions of technical safety for an object in two aspects, as qualitative and quantitative action on the environment. In the analysed literature there is no definition of technical safety, which would include the interaction of man, environment and technical object. According to the author (Pihowicz 2008) giving after the authors (Peters & Meyna 1985 and Meyna 1982) the qualitative definition of "technical safety" is as follows. It is the ability of a given technical creation operating under specified conditions to ensure, within the prescribed limits and within a specified time, the non-existence of danger to people and the environment. According to the above authors (Peters & Meyna 1985 and

Meyna 1982), the quantitative definition of technical safety states the following. Technical safety is defined as the probability that no danger to people and the environment is caused by a technical device operating under specified conditions within a specified period of time and within specified limits. These definitions define safety as the absence of risk to people and the environment from a technical product, but disregard environmental risks to people and the technical product. On the basis of the research results discussed in the publication(Chrzan 2014,Chrzan 2017) and the resulting conclusions, a modernised definition of technical safety was developed.Technical safety is the normal compliant state of operation of a technical object that does not endanger the life and health of people and the environment. In turn, environmental factors do not endanger people and the object in the form of sudden interruption of its operation, sudden destruction of the object or sudden weakening of its structure throughout its lifetime. The technical safety of an object is also the behaviour of human beings towards the technical object and the environment in accordance or not with the regulations for its operation. This definition contains clearly defined content. The definition contains the possibility of the object acting on people and the environment, and the environment acting on people and the object, and people acting on the environment and the object over a certain period of time. These three factors interacting with each other constitute the technical safety of the facility. Environmental factors include the risk of water, air , fire, ground vibration, ground subsidence, mud and snow avalanches, low and high temperatures. The normal operating condition of a facility is the operation in accordance with the operating instructions, Technical Operation Regulations, Polish Standards and Ministerial Decrees. Long-term destructive processes of technical facilities caused by environmental factors are monitored. Their destructive effects are removed by repairs and worn-out components are replaced with new ones. This is the case when vibration velocities from Zone II of the SWD scale,Fig.6 (Norma 2016) are acting on houses. When the environmental factors acting on the houses in the form of vibration velocity above the line B, Fig.6 (Norma 2016), their technical safety is endangered, in the form of sudden destruction of the object or sudden weakening of its structure.

5 Summary and conclusions

Currently, radial and tangential vibration velocity measurements on a house are carried out at any directional angle and the technical safety of the building is determined on this basis. The effect of the directional angle of measurement on the value of the measured radial and tangential vibration velocity is presented. The relation for calculating the highest values of radial and tangential vibration velocity is given. Angles for measuring the largest values of radial and tangential vibration velocity are given. For the largest values of radial and tangential vibration velocity from SWD I and SWD II, the type of house damage caused should be determined. To ensure the technical safety of engineering structures situated close to an opencast mine, it is possible to plan the front of the mining works in such a way that the engineering structures will be located in the safe zone of the directional angle/ areas with the lowest values of vibrations. With the circular distribution of the vibration velocity, to ensure the technical safety of buildings, the velocity of vibrations acting on them should not the value exceed Limit line B, Fig. 6. The value of the vibration velocity depends on the directional angle α and should be taken into account during measurements.

1) The assessment of the technical safety of the building with the circular distribution of the vibration velocity, should be performed at the maximum measured or calculated ground vibration velocity. For the radial velocity, this is the directional angle $\alpha=90^o$. For the tangential velocity, this is the directional angle $\alpha=0^o$.

2) When assessing the technical safety of a building located at a directional angle α equal to the angle of non-uniformity of the medium, the value of the vibration velocity for the angle of non-uniformity of the medium should be taken into account.

3) With the circular distribution of the vibration velocity the smallest vibrations, should be directed toward the built-up area; the built-up area should be located between 0° and 45° or 60°and 90°degrees of the directional angle - Fig. 4.

Declaration of competing interest

The author declare that has no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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