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Research paper

Control and documentation studies of the impact of blasting on buildings in the surroundings of open pit mines

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ABSTRACT

Environmental Protection Law together with Geological and Mining Law impose on a mining plant a duty to protect its surroundings against the effects of mining operations. It also refers to the impact of vibrations on people and buildings induced by blasting works. Effective protection is possible only if the actual level of the impact is known, hence it has to be recorded. It was and still is the keynote idea of the research conducted at the AGH Laboratory of Blasting and Environmental Protection. The effect of many years of research is the development of an original and, in particular, an effective procedure to record the impact of blasting works with periodical measurements of vibration intensity or monitoring the vibrations' impact on buildings in the surrounding area. These assumptions form part of preventive actions taken by open pit mines, which are aimed at minimizing the impact of blast workings on the surroundings and are often recommended by experts. This article presents the course of action concerning control tests of vibration intensity in the surroundings of a mine. It also shows it is necessary to monitor vibrations in buildings as it is a source of knowledge for the mining plant management personnel and engineers who conduct blasting works, thus contributing to an increase in awareness of the responsible management of a mining plant. The Vibration Monitoring Station (KSMD) developed by a research group, after several upgrades, has become a fully automated system for monitoring and recording the impact of blast workings on the surroundings. Moreover, it should be emphasised that without the mine management personnel's cooperation, it would be impossible to work and achieve the common goal, i.e. conducting blasting works in a way that is safe for the surroundings.

1. Introduction

Detonating explosives in long boreholes is a commonly applied technique for quarrying rocks, hence the problems associated with the method are such an important issue for the surface mining industry. Only 20–30% of the energy of detonated explosives actually quarries rocks. The rest is lost, and as a result, may cause fly-rock debris, airblast and seismic waves. The latter are a source of many problems, because ground vibrations can affect different buildings located in the vicinity of mines. In this case, determining a permissible explosive limit which takes into consideration the protection of such structures is crucial. From the point of view of operation effectiveness and economic reasons, as many charges as possible should be detonated in one series (bench blasting), which may contribute to enhancing the impact.

Thanks to many years of research (financed also by the mines) conducted at the AGH Department of Surface Mining and actions aimed at disseminating the idea of such preventive actions in mining companies, specific research procedures were developed and the mining plant management personnel reached a certain level of awareness of the problem. The effects of this are consultations, control measurements and even the full monitoring of the impact of blasting works on the surroundings. It has significantly improved the psychological comfort of both the mining plant management personnel and those involved in research and analyses. Such actions are also well-received by the local communities and the general public.

A determination of a permissible explosive limit for blasting works is the first step in the preventive actions of open pit mines. More and more mines initiate extensive actions aimed at safe blasting works with simultaneous, periodic or constant documentation of the impact on the buildings in the surrounding area. Such

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actions are slowly becoming routine and young engineers treat them as obvious, associated with the responsible management of a mining plant.

Knowledge of the applied blasting technology, together with an analysis of the intensity of vibrations propagating around a mine, considering the structures in the surrounding area, is an important element of preventive actions. The buildings within the range of vibrations, which propagate as a result of detonating explosive charges, are treated as protected structures. The use of proper, i.e. effective, preventive measures has to result from identifying the issue as cause and effect. It is necessary to explain whether there is cause and effect between damage to a given building (or several buildings) and mining the deposit with explosives, and whether, sometimes, the building vibrations are annoying for people.

It presents the general course of action in a dynamic diagnosis (Winzer, Sołtys, & Pyra, 2016) where the following stages are necessary:

- recognition of building types in the surroundings of a mine,
- recognition of vibration sources, considering mining conditions and the route of vibration propagation from the sources to the buildings,
- assessment of the impact of blasting works on buildings (and assessment of their level of nuisance for people),
- correct diagnosis stating whether there is a cause and effect connection between the actual technical condition of given buildings and vibrations induced in a mine.

The choice of preventive actions in a mine, aimed at minimizing the impact of blasting works, mostly depends on (Winzer et al., 2016):

- the threat level for structures located in the surroundings, their number and purpose (industrial building, residential and utility buildings, protected buildings),
- the frequency of blasting works,
- the technique of blasting works.

Generally, preventive actions are divided into two groups of issues: basic research and documenting the impact of vibrations on the surroundings (Fig. 1).

The aim of basic research is to determine conditions for conducting safe blasting works, considering local geological and mining conditions, and the type, quality and technical condition of buildings in the surrounding area. The final effect of basic research is the determination of the dependences which enable calculations of a permissible explosive limit for the forecast production in a specified time period, together with the description of the technique and technology of conducting the blasting works.

By documenting the impact of blasting works whether the dependences determined in basic research are up-to-date is verified, in other words, if the level of the intensity of vibrations induced in the surroundings complies with the predicted values together with the assessment of the impact of recorded vibrations on buildings. The actions can be realised as periodic control measurements or, in a wider scope, as monitoring vibrations in selected buildings in the surroundings of an excavation.

Therefore, preventive actions ought to involve (Fig. 1):

- an inventory of the technical condition of structures in the surrounding area,
- recognizing directions of vibration propagation and the level of the intensity in the surroundings of a mine working. On this basis, the range of the adverse influence of vibrations and permissible explosive limit are determined,
- conducting periodic control measurements,
- in special cases, monitoring vibration levels in protected structures.

The last two points are often recommended by appraisers. Recently these points have also been required by the licence-granting authorities. These are regulations imposed by Environmental Protection Law and Geological and Mining Law, applied to enterprises which may significantly impact the environment. Most mines which use explosives fall into this category.

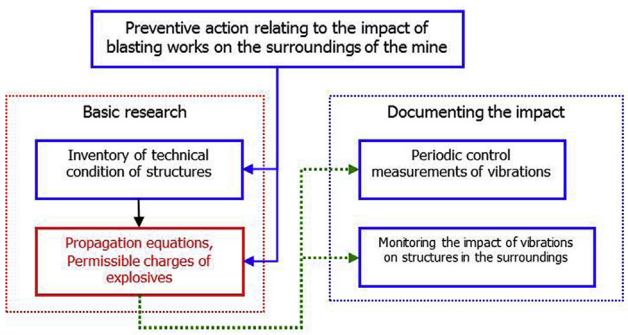

Fig. 1. Preventive actions in open pit mines concerning the impact of blasting works on the surroundings.

2. Material and methods

An important element in preventive actions conducted by surface mines is documenting the level of impact which vibrations induced by blasting works have on structures in their surroundings. It can be realised through periodic control measurements or continuous monitoring of the impact (Fig. 1).

2.1. Research procedure

The aim of periodic tests is to monitor the level of vibration intensity and its compatibility with the previously obtained dependences (vibration propagation equation), i.e. indicate if:

- blasting works are conducted following the assumed limitations (permissible explosive limit),
- the intensity of vibrations does not exceed the predicted level, resulting from applied parameters of blasting works and the distance from protected structures (ground vibration measurements),
- induced vibrations do not have an adverse influence on structures in the surroundings (measurement of vibrations in the foundation of a structure or structures).

Such analysis can be conducted with the following parameters ρ (Fish, 1951; Lopez Jimeno, Lopez Jimeno, & Ayala Carcedo, 1995), which are calculated with the general propagation equation (1):

$$u = k \cdot \rho^{\beta} \quad (1)$$

where:

u – velocity of vibrations, mm/s,
k – coefficient characterising geological and mining conditions, experimentally determined,
ρ – relative explosive charge expressed with equation: (2)

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