CHOICE OF DESIGN PARAMETERS OF AN UNDERGROUND SHOCK WAVE ABSORBER

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Abstract:

The development of a reliable and effective system for thermodynamic blast suppression in underground facilities requires an appropriate selection of an absorber activation device, properties and discharge rates of an absorption agent and its discharge mechanism. These features are directly related to the expected detonation and the geometry of the facility. An underground shock wave absorber parameters and a plan of their location in a tunnel shall be selected so as to ensure minimization of an adverse blast impact at any location and at any time. This paper outlines the methodological aspects that relate the design of a blast energy absorber with the localization of blast energy in underground openings. It contains findings from several experiments aimed at the selection of rational design parameters for such an absorber. Finally, the paper presents structural specifications and the preliminary results of bench testing of a blast energy absorber that was based on such parameters.

Assessment of Blast Threats in Underground Openings

The destructive effects of shock waves on people exposed to an explosion of a bare charge in a tunnel can be divided into two categories: i) direct impact of overpressure; ii) secondary effect of a blast wave related to the impact of a human body propelled by the blast. There are standards for assessing impact on humans at various levels of overpressure, but these do not address the secondary impacts. Table 1 shows that the limit lethality level is between 190 and 400 kPa, while an effective protective system is obtained, when the overpressure can be reduced to 13-16 kPa.

Table 1: Assessment of threat to humans under various blast overpressure levels

Source	Excess Pressure, kPa					
	190	69…76	55	24	16	8,3…5,9
DOD 5154.45	Lethal outcome	Lethal outcome or serious injury	Lethal outcome or serious injury of ears and lungs	10% probability of injury of ears and lungs	Lethal outcome or serious injuries are less likely	No lethal outcome or serious injury
According to the estimates of Russian specialists	400	120	65	35	13	10
	Probability of injury – 100%	Probability of injury – 75%	Probability of injury – 50%	Probability of injury – 35%	Probability of injury – 5%	Probability of injury – 0%

Considering the upper and lower limits of blast overpressure values in underground openings, Figure 2 shows three zones that define the consequences on people in the vicinity of an explosion.

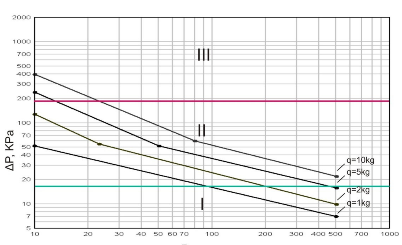
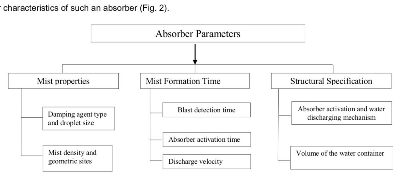


Fig. 1. Overpressure dependence on the distance from blast site in an underground opening with a cross section of 16 m^2, and different charge weights. I - safe zone, II - zone of injuries of different levels, III - zone of lethal outcome.

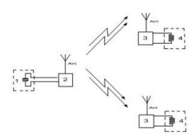
Main Design Parameters of a Blast Energy Absorber

The blast energy absorber effectiveness is defined by the damping properties of the mist and its quick action. The main tasks to be tackled when producing a design is to select mist properties, determine mist formation time, and the properties of an absorber activation device, discharge mechanism and other characteristics of such an absorber (Fig. 2).



Structural Specification of the Proposed Absorber

The Mining Institute of Georgia and the Center for Infrastructure Protection and Physical Security, University of Florida, have developed a new blast energy absorber concept for underground openings. The proposed absorber contains:



1. **wireless system for the detection of explosions, and activation of an absorber without external power supply;**
2. **a new design of a pyrotechnic system for quick discharge of water;**
3. **water container with integrated nozzles for dispersed water mist formation.**

The results of testing of blast detection methods (e.g., seismic, EMP, optical, on overpressure, combined) showed that a constant monitoring of overpressure, in terms of its reliability and response speed, was best to meet the requirements [6]. This method resulted in a wireless system of activation that consists of a detector block with a transmitter and an absorber control block with a receiver (Fig. 3).

Fig. 3. Circuit plan of activation of an absorber. 1 - pressure sensor, 2 – detector block with transmitter, 3 – absorber control block with receiver, 4 – initiator of pyrotechnic device

The detector block contains a sensor, a microprocessor equipped with blast detection software, and a transceiver that transmits an encoded signal at the frequency of 868.35 MHz. The absorber control block has a transceiver that receives the signal at the same frequency of 868.35 MHz, a microprocessor, and a fail safe decoder that produces the activation signal for the operation of the blast absorber .

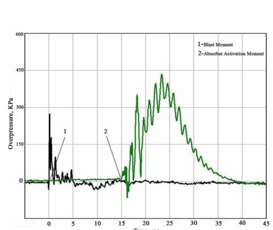
Tests of the wireless system were performed in the laboratory and under explosion conditions in the underground experimental base of the Mining Institute. Over 60 cycles of testing, including 17 experimental blasts, were conducted.

The tests have yielded the following results:

- The time span between the moment of receiving a signal by the sensor and the moment of activation of a start signal was 640 microsecond;

- The minimum overpressure for signal generation was 12 kPa;

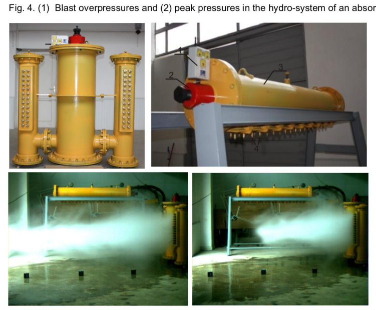
The distance between a transmitter and a receiver in a direct tunnel was at least 150m, or 50m in a tunnel with a 90^0 bend.



Facility the findings of the research conducted by Bemet and Schimmel were applied for the pyrotechnic discharge system design. This system contains a gas generating cartridge and an electrical initiator connected to the absorber control block. The gas pressure is transferred to the water by means of a special channel and an airbag. Bench testing of the pyrotechnic system models showed that the time for blast detection and absorber activation do not exceed 15 ms (Fig. 4)

Hydro-cylinders of the water containers are designed for maximum water pressure up to 30 MPa. Two kinds of containers with integrated spray nozzles have been produced: i) for horizontal dispersal being 220 liters of water and 52 nozzles; ii) for vertical dispersal of 65 liters of water and 36 nozzles (Fig. 5).The proposed absorber design allows to regulate the pressure in the hydro-system as well as to change the type and number of nozzles, which enables to vary flow rates, water discharge velocity and droplet size at different stages of testing. Preliminary tests of an absorber was conducted with nozzles of P120 design producing water droplets ranging in size from 25 to 400 microns.

Fig. 4. (1) Blast overpressures and (2) peak pressures in the hydro-system of an absorber while testing a pyrotechnical system model



At the water pressure in a container under 2,5 MPa, the volume of water discharge produced 90 liters, the distance of water discharge was up to 4,6m, and the velocity of discharge at 0,5m was 5 m/s.

CONCLUSIONS

1. Methodological challenges of designing a shock wave absorber for underground openings by taking into account parameters of an expected explosion and a site to be protected have been considered. The analysis has shown that the development of an automated absorber, containing a wireless system for the detection of explosions and a pyrotechnic system for discharge of a damping agent enabled to increase its effectiveness and response speed.

2. The wireless system for the detection of explosions and activation of an absorber has the following advantages:

- **Time between blast detection and start signal generation does not exceed 640 microseconds;**
- **High reliability of detection when reaching the threshold of 12 kPa;**
- **Possibility of controlling the working capacity of the system in the test mode; no need for an external power source;**
- **Use of wireless transmission will rule out the threat of cable damage from mechanical impact or during blasts.**

3. The pyrotechnic facility for discharge of a damping agent has the following advantages:

- **high speed of absorber activation upon receiving a trigger signal,**
- **the ability to regulate water pressure in a hydro-system and varying of flow rates and speed of the discharge to account for the parameters of an expected explosion and geometrical characteristics of a site.**

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