Oil Shale, 2002, Vol. 19, No. 3
pp. 261-266
ISSN 0208-189X

https://doi.org/10.3176/oil.2002.3.02

THE RETROSPECTIVE ASSESSMENT OF BLAST VIBRATION IMPACT ON THE ENVIRONMENT AT OPENCAST MINING

A. TOOMIK

Tallinn University of Educational Sciences,
Institute of Ecology,
North-East Estonian Department
15 Pargi St., Jõhvi, 41537 Estonia

The principle of the method proposed is to assess blast vibration impact on the environment for the cases when the blasting in an opencast mine had been performed long time ago. Restoration of the blasting situation and establishment of the method used studying the properties of vibration medium of the blasting site allow determining vibration intensity at the time and site we are interested in. The method is applicable to assess blast vibration impact in the case of both closed oil shale opencasts and working ones. In the case of working opencast it is necessary when blasting parameters, situation or local regulations have been changed.

Introduction

In Estonia the rock blasting has been used during the whole history of oil shale mining in mines and opencasts. Blast vibration impact on the environment has been studied only during the last decade. After closing the exhausted mining works their postmining environmental impact should be assessed. One of the factors to be studied is the possible impact of blast vibration on the environment during the mining process in previous decades.

For this provisional information about blasting situation of the period under study is needed, i.e. the location of blasting site and potentially endangered objects, blasting parameters and geological conditions of the blasting site. These data enable to carry out the retrospective analysis and to assess the impact of blast vibration on an individual site during a certain period. As a methodical example, the conditions of one oil shale opencast in Estonian oil shale deposit, the *Aidu* opencast, served as a basis for the present analysis.

Geological Conditions

The thickness of productive oil shale bed is approximately 3 m, including limestone interlayers. Oil shale bed lays horizontally maximally in the depth 20 m and is covered by overburden including 14–17 m of Ordovician limestone and 3–4 m of Quaternary sand and moraine. In the frontline of the mining face the soil is removed first, then the "unearthed" limestone is loosed by blasting and removed by excavators to the mined-out area. Thereafter the oil shale bed is blasted and excavated, transporting oil shale mining mass for separation and on to consumers.

Overburden blasting produces the main seismic effect due to greater charges. The impact of oil shale bed blasting is negligible. Explosive impulse starting in limestone basic rocks continues to propagate there and also spreads to the upper layers of rocks and soils. Constructions receive vibration through soil, where the basement is located in soil, and through soil and basic rocks, where the basement is located on basic rocks. Underground constructions, i.e. wells, receive vibrations through basic rocks.

Assessment of Vibration Intensity

Vibration velocity, more precisely the particle peak velocity, is the main criterion at assessing vibration velocity. It depends on the mass of charge used for blasting and on the distance between charges and endangered objects. The greater the mass of charge, the higher the vibration intensity; and the greater the distance between charges and endangered objects, the lower the vibration intensity. Attenuation of vibration intensity depends on the properties of rocks where the blast waves propagate, i.e. on the local conditions. For conditions of the *Aidu* opencast, attenuation equation was established [1], and vibration velocity (V, mm/s) is empirically expressed as

$$V = 11{,}450 \cdot d_s^{-2.03} \qquad (1)$$

where d_s is scaled distance, m·kg$^{-0.5}$;

$$d_s = d/\sqrt{Q}$$

where d is distance between charge and endangered objects, m;

Q is mass of charge, kg.

According to Equation (1) it is possible to assess vibration velocity for the objects whose basements are located in soil, in the heaviest conditions for constructions. Ground vibration velocity attenuates slower in soil than in basic rocks.

Attenuation equation for basic rocks given in [1] may be used to assess the blast impact for wells and other underground objects. For practical use of Equation (1) the graph is proposed in Fig. 1.

In order to guarantee the maximum safety for constructions, the 95-% upper confidence line in this figure should be used.

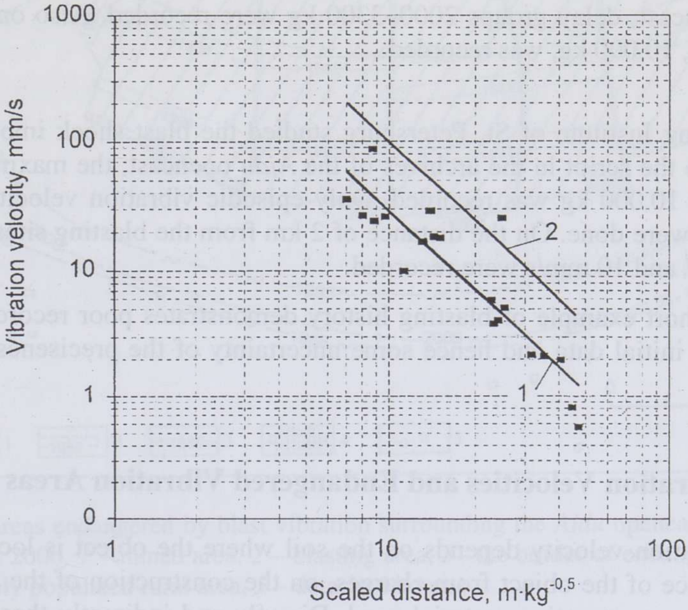

Fig. 1. Maximum vibration velocity versus scaled distance at opencast blasting when the object is located in soil: *1* – statistical average, *2* – 95-% upper confidence line

Rock Blasting in Opencast. Short History

The principal blasting was performed in overburden rocks. Usually the size of simultaneously loosed rock bench was 40 × 60 m and the depth of blastholes – 13 m. Blastholes were located in a 5 × 5 m grid. As a rule, one blasting included five rows of this grid.

2000–2001

The weight of charge used in one blasthole was 120–340 kg. The explosive ANFO (specific consumption 1 kg per 1 m^3 rocks) and nonelectric ignition system Dynaschock were used. The total weight of one delay group, i.e. 2-3 charges together, was 240–1000 kg.

1996

Firing with detonating fuse was still used, hence the delay groups were bigger. According to [1] the biggest delay groups 1036–1950 kg on blasting sites were recorded.

1993
According to the blast vibration impact study made by Ralph Kall, the representative of Canadian organisation CESO in Maidla municipality near the *Aidu* opencast, delay groups 2000–3300 kg were recorded. Also one maximum case, 10,000 kg, was recorded.

1988
The Mining Institute of St. Petersburg studied the blast shock impact. According to the script in the archives of the *Aidu* opencast, the maximum delay group 10,000 kg was recorded. Only episodic vibration velocity measurements were done. On the distance of 2 km from the blasting sites the velocities 27 and 10 mm/s were recorded.

This short example of blasting history demonstrates poor recording and saving of initial data and hence some uncertainty of the preciseness of the results.

Safe Vibration Velocities and Endangered Vibration Areas

Safe vibration velocity depends on the soil where the object is located, on the distance of the object from charges, on the construction of the building and on the construction material used. Directly and indirectly these conditions are included in regulations. According to the regulation [2], the safe vibration velocity for dwelling houses surrounding the opencast is 5–7 mm/s. In order to determine the safe distance one has to proceed from the maximum charge used and then to compute the distance where vibration velocity on the attenuation graph is below the safe value. For computing it is better to use the graph in Fig. 1. Calculated safe distances are given in the Table. In 2000, when charges 500–1000 kg were used, safe distances were 1000–1200 m.

Due to "easier" regulations in the previous decades the safe distances at charges approximately 3500 kg were considered the same. The endangered areas according to this analysis are demonstrated in Fig. 2. One can see that, in spite of easy regulations, the border of endangered area reached the eastern part of the densely populated village in 1993 already. After 2001–2002 the border of the endangered area will reach the detached houses in southern direction, and measures are to be taken to minimise blast impact, e.g. charge weights are to be further reduced.

Safe Distances of Dwelling Houses from Blasting Sites of an Opencast

Year	Maximum charge weight, kg	Safe distances (m) for permissible vibration velocities	
		5 mm/s	30 mm/s*
1988	10 000	–	2000
1993	3500	–	1200
2000	1000	1200	–
2000	500	1000	–

* Regulations until 2000.

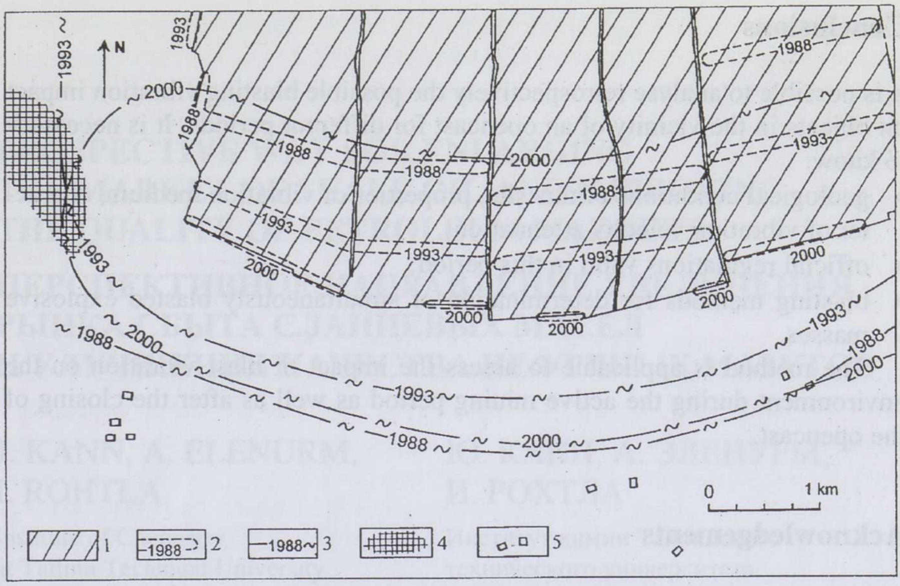

Fig. 2. Areas endangered by blast vibration surrounding the *Aidu* opencast in 1988, 1993 and 2000. *1* – mined area, *2* – blasting area, *3*– the border of endangered area, *4* – densely populated rural area, *5* – detached houses

Confidence of Analysis

It seems that the most problematic data concern the weight of simultaneously blasted charges or delay groups. The further we return to the past, the greater is the possibility to miss the maximum charge probably used in some extraordinary case. Discussions with the engineers of the *Aidu* opencast about blasting methods used in the past revealed that just 10 tons was the maximum in 1993 and even in 1988 in some sites of the opencast. These charges were used in sites far from dwelling houses and another constructions, but some uncertainty still remains as for charge weight.

Geological conditions, i.e. the properties of vibration medium, do not change during mining. Also the attenuative function of vibration velocity is stable for the same site. Studying Fig. 1 once more, one can see that using the 95-% upper confidence line to assess vibration velocity, we increase the mean velocity value 3-4 times. The graph is given in the log/log field. This conservative approach diminishes the probability to miss some extreme cases in charge weights.

An exact restoration of blasting situation and distances between charges and endangered objects for any moment of the past using archival data of mining plans is possible.

Conclusions

It is possible to analyse retrospectively the possible blasting vibration impact on objects in the vicinity of an opencast for different periods. It is necessary to know:

- geological conditions of this site, properties of vibration medium, character of vibration velocity attenuation;
- official regulations valid in this period;
- blasting methods for determination of simultaneously blasted explosive masses.

The method is applicable to assess the impact of blast vibration on the environment during the active mining period as well as after the closing of the opencast.

Acknowledgements

The research was supported by the Estonian Ministry of Education (theme No. 0282119s02). Author is grateful to the Estonian Oil Shale Mining Company for permitting to use archival material.

REFERENCES

1. *Toomik, A., Tomberg, T.* Blast vibrations in oil shale surface mining // Oil Shale. 1997. Vol. 14, No. 2. P. 155–162.
2. The regulations for producing, preserving and using the explosives. Ministry of Economic Affairs of the Republic of Estonia, No. 60, Nov. 30, 1999. RTL 1999, 165, 2391 [in Estonian].

Presented by E. Reinsalu
Received February 13, 2002