

DGMS(Tech)/(S&T) Circular No. 7 of 1997 dated 29.8.1997

To
Owners/Agents/Managers of all Mines



Subject : Damage of structures due to blast induced ground vibrations in the mining areas.

1.0 Introduction

In response to increase demand for coal and other minerals, a number of large mechanised opencast mines have come into operation. Some of these opencast workings are located near surface structures like residential buildings, schools, commercial shops, hutments with large number of inhabitants etc. Whenever blasting is done in these opencast mines, ground vibrations are generated outward from the blast area and cause damage to surrounding surface structures. The vibrations radiating from the blast holes while passing through surface structures, induce vibrations on the structures causing resonance. The components of ground motion can affect the structures through compression and tension and also through vertical and horizontal shearing effects. Blast induced ground vibrations create socioeconomic problems for the mine managements as well as the people residing in vicinity of these mines. As only 20-30% of energy of commercial explosives used in the mines is utilised for fragmenting the rock, the rest of energy is transmitted through the earth in the form of ground vibrations resulting in damage to the surrounding structures.

2.0 Damage criteria

The peak particle velocity has so far been considered as the best criterion for evaluating blast vibrations in terms of its potential to cause damage. The extensive studies on the problems have established that the frequency of the waves is also equally important factor to consider the effect of damage.

The blasting damage is generally classified into following four categories :

Sl. No.	Category	Description of damage
(i)	No appreciable damage	No formation of noticeable cracks
(ii)	Threshold damage	Formation of fine cracks, fall of plaster, opening & lengthening of old cracks, loosening of joints, dislodging of loose objects etc.
(iii)	Minor damage	Superficial not affecting the strength of structure(s). Hair line cracks in masonry around openings near partition, broken windows. Fall of loose mortar etc.
(iv)	Major damage	Formation of several large cracks, serious weakening of structures, shifting of foundation, fall of masonry, ruptures of opening vaults etc.

3.0 Natural Frequencies

Elements of building construction such as sprung floors, stud partition walls, ceilings and windows can all react as mass-spring systems, each with its own natural frequencies of about 4-24 Hz. (low frequencies). Ground vibrations at these frequencies amplified by the structures increase the risk of damage. When the low frequency ground vibration coincides with the natural frequency of the structure resonance is originated. The resonance is a state in which the structure absorbs most energy progressively becoming deformed with time, until plastic deformation occurs. Therefore even the low peak particle velocity of ground vibrations at natural frequency of structures is more harmful to the structure. Natural frequencies of brick and concrete structures generally vary from 8-16 Hz.

4.0 Structural response

All structures develop cracks from natural causes like periodic changes in humidity, temperature and wind velocity. Changes in soil moisture cause foundation cracks. The width of old cracks change seasonally and number of cracks increase with the time. This damage is independent of damage caused by blasting.

The cracking location and the wall material have an influence on the particle velocity at which cracking begins. If the entire structure is not inspected thoroughly, there may be chances of biased opinion on the type of cracks. Thus, it is important to place transducer properly for the correct assessment of damage.

In the mud houses, number of cracks develop before blasting and these cracks widened and get extended with the passage of time. These cracks are further widened and get extended due to blast induced ground vibrations. Concrete structures vibrate for longer duration than brick and mud structures. Concrete walls have free top and show no cracks at vibration levels for which mud and brick walls can damage. Cracks develop in concrete walls with large vibration level. Cracks in brick structures can be observed at junction of walls, roof and at window corners. Brick walls with clay mortar and cement - sand mortar behave in same fashion. Steel structures can sustain more vibration level.

The magnitude of vibration on structures is much more than on the ground. Duration of vibration in structure is also longer than that of ground vibration. Multi-storeyed buildings are more sensitive to blast vibration than the single-storeyed buildings.

To predict the extent of damage and to take preventive measures, it is necessary to measure ground vibrations due to blasting. Studies on structural response of ground vibration in the structures of different constructions within the mining areas under Indian condition are limited and therefore such study should be carried out to ascertain the degree of damages for improvement and standardisation of damage criteria under Indian conditions.

5.0 Measurement of blast induced ground vibrations

5.1 Instrumentation

The instrument selected for monitoring blast induced ground vibration shall be simple, light, compact, easily portable, battery operated, digital form output, triggering by geophone, etc. Triaxial transducers for recording blast vibration shall have a linear frequency upto 500 Hz and capable of recording particle velocity upto 100 mm/s.

5.2 Methodology

The transducers shall be placed near the structure on the solid undisturbed ground and should be placed well in contact with the ground. For structural response, the transducers shall be placed horizontally over the wall, floors and ceilings. A minimum of 15 points of observations corresponding to a minimum of 10 blasts shall be made for better prediction with a high index of determination.

5.3 Predictor Equation

The least means square method of regression analysis shall be used to interpret the data. The square root scale distance shall be used for analysis and interpretation of data when blasting is done on surface and measurements are taken on the surface; or the blasting is done underground and measurements are taken underground. On the other hand, if blasting is done on the surface and the measurements taken underground the cube root scaled distance shall be used.

6.0 Guidelines on experimental blasting

6.1 Factors

Major factors affecting particle velocity of ground vibration are type and amount of explosive charge used, distance from the charge to the point of observation (surface structures), geological, structural and physical properties of the rock that transmits the vibrations, height of structures and blast geometry. Use of safe charge/delay, in hole delays with non-electric initiation systems, proper burden, inclined holes in conformity with slope of bench, deck charge, airdeck, sequential blasting, clearing off loose pieces of rocks from the blast site and proper stemming of holes bring reduction in blast induced ground vibrations. Controlled blasting methods in conjunction with effective muffling of holes will control ground vibrations and also arrest fly rock.

6.2 Plan

A plan showing structures belonging to the owner and not belonging to the owner in different prominent shades should be prepared. The plan shall incorporate details of construction of the structures in a tabular form. Plan should also show 50 m, 100 m, 200 m and 300 m zones from the structures, the place of experimental study and the limit upto to which blasting is proposed to continue.

6.3 *Study/observations*

In a particular mining area with built-up structures where deep hole blasting is to be introduced for the first time, experimental blasting shall be carried out by any research/academic institute much before the structures fall within the blasting danger zone. The type of instruments, the methodology and predictor norm as recommended in para 5.0 shall be followed in measurement of blast induced vibrations. Based on the study, the safe charges for different zones shall be determined and recommendations made in the report. In a cluster of buildings of different types existing close to each other, the safe charge for the buildings/structures requiring greater protection against damage shall be assessed and recommended.

6.4 *Structural response*

During the study the response of the structures assuming different natural frequencies should be calculated and plotted on a figure. Softwares with the different programmes are available now for the said plot and should be used for convenience.

6.5 *Monitoring*

In order to ensure effective control over the vibration and related damages there is a need of regular inhouse monitoring and the managements should train the blasting personnel during the experimental study and start observations on their own during the regular blasting operations.

7.0 Recommended permissible standards of blast induced ground vibrations

7.1 *Technical considerations*

Permissible standards for different type of structures have been arrived at considering the importance of buildings and structures. The buildings of historical importance and multi-storeyed structures are likely to get damaged with low level of vibration and therefore permissible standards are to be lowest. Similarly buildings not belonging to the owner but with mud/brick in cement construction and others with good construction (RCC and framed structures) should also be protected but higher permissible standards than that of the level fixed for first category has been allowed.

Depending on the type of structures and the dominant excitation frequency, the peak particle velocity (ppv) on the ground adjacent to the structures shall not exceed the values given below in the table.

Table : Permissible Peak Particle Velocity (ppv) at the foundation level of structures in Mining Areas in mm/s

Type of structure	Dominant excitation Frequency, Hz		
	<8 Hz	8-25 Hz	>25 Hz
(A) Buildings/structures not belong to the owner			
(i) Domestic houses/structures (Kuchha, Brick & cement)	5	10	15
(ii) Industrial Buildings (RCC & Framed structures)	10	20	25
(iii) Objects of historical importance & sensitive structures	2	5	10
(B) Buildings belonging to owner with limited span of life			
(i) Domestic houses/structures (Kuchha, brick & cement)	10	15	25
(ii) Industrial buildings (RCC & framed structures)	15	25	50

In view of complexities of the problems I hope you all would take adequate measures as recommended above to ensure that the blasts made near surface structures are carried out with utmost care and precautions. The blast induced ground vibration should be within the permissible limits as specified above.

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