Construction of U/G Metro Rail Project in Urban Environment: Role of Controlled Blasting

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***Abstract*:** Bangalore Metro Rail project is a prestigious project in Karnataka, India. It is having six underground stations, which required hard rock excavation. To excavate the hard rock mass, drilling and blasting is the cheapest method. Rock excavation was carried out near important buildings, old and sensitive structures. Conducting blasting operations in such projects is a challenging task, as the operation should not cause any damage to the structures, and cause inconvenience to public in any respect. A case study of the construction of some of the underground stations is presented in this paper. Extensive controlled blasting operations were carried out in this project where underground stations were developed close to important structures, some of which are more than 100 years old.

Keywords: Metro Construction, Ground Vibrations, Fly Rock, Controlled Blasting

I. Introduction

Usage of explosive energy for hard rock excavation is common in various civil engineering projects like tunnels, canals, pipeline projects, hydel power projects, ports, etc. Usage of explosive energy, in addition to fragment and displace the intact rock mass, is always associated with environmental effects like ground vibrations, fly rock and noise. It is essential to carry out a critical analysis taking into account the factors influencing blasting operations, public complaints, statutory regulations, environmental restrictions before the commencement of blasting operations. Sastry and Ramchandar [1] summarized influence of side effects of blasting operations and control measures in blasting operations (Table-1).

Ground vibrations cause damage to structures and annoyance to residents in neighboring areas, in case the intensity is above threshold values, which vary for different types of structures. In many instances the intensity of ground vibrations is much lower than safe limits, but still complaints keep pouring in due to various factors. Noise generated during blasting operations is another major problem having psychological effects. Studies conducted by Sastry and Chandar [2] showed a considerable reduction of 5 to 10 per cent in noise levels with shock tube initiation compared to conventional D-cord system.

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Fly rock is another major problem that may cause damage to structures in the vicinity of excavation works and may also result in serious to fatal accidents if proper care is not taken. In some extreme cases, environmental problems may endanger the operation of project itself. It is, therefore, important to evaluate the impact of these risks / problems in order to design safe control measures.

TABLE I: Influence of Side Effects of Rock Blasting and Control Measures

Parameter	Effect	Control
Ground Vibrations	-Damage to structures -Annoyance to people -Migration of wild life -Rehabilitation of settlements - Litigations	- Proper blast design - Increase delays - Proper initiation system and sequence - Decrease maximum charge per delay - Reduce confinement - Create a spilt/channel between blast site and structure
Fly rock	- Damage to structures/ machinery - Injury to people - Fatal accidents - Frequency	- Blast design - Change explosive - Change initiation system - Reduce confinement - Muffling arrangement
Noise	-Inconvenience to people -Structural damage -Frequency	- Cover the D-cord with soil - Use short delay detonators - Use sequential blasting machine - Change initiation from conventional to shocktube system

II. Case Study

Fig. 1 shows some of the important structures around the rock excavation site of Bangalore Metro Rail Corporation Limited, Bangalore. Construction of underground stations for the metro rail project involved excavation of hard granitic formation, which in some cases is exposed almost to the surface with thin soil layer of about 1-1.5m. Depth of excavation is around 25m. The area of excavation is surrounded by important buildings like Central College, Session Court, Vidhana Soudha, etc., with one of the structures declared as Heritage Structure of more than 100 years old. A Pre-Blast survey was taken up before commencing the blasting operations. All the buildings/structures in the vicinity to excavation site were surveyed carefully to assess the type and condition of structures for assigning threshold ground vibration limits. Different structures were assigned threshold ground vibration limits of 2mm/s, 5mm/s and 10mm/s, depending upon the type and condition of structure, following International Standards.

(a)

(b)

(c)

Fig. 1: Important Structures near the Rock Excavation Site.

III. Methodology

Blastholes of 32mm diameter were drilled using wagon drills, with the depth varying from 0.75m to 3.5m (Fig. 2). After drilling, each blasthole was charged with cartridged emulsion explosives. Shock tube system of initiation was used to initiate each blasthole. Each blasthole was charged with explosive quantity of 0.125kg to 1.3125kg. The maximum charge per delay varied from 0.125kg to 1.0kg. The total explosive charge per blast round varied from 0.875kg to a maximum of 128.125kg in different blasts.

Fig. 2 Drilling of Blastholes in Progress

Fly rock along with ground vibrations is a major concern as a number of important buildings are there in the surroundings and also due to busy public traffic. Heavy muffling arrangement was done using rubber blast mats, each weighing 2.5t to control fly rock (Fig. 3). Each blast was monitored using two units of Minimate Plus Blast Vibration Monitors of Instantel, Canada, for ground vibrations and noise at specific locations on day to day basis (Fig. 4). Controlled blasting methodology was devised, based on the nature of rock mass, condition of the buildings and distance from the buildings to excavation site. Blasting methodology was established based on data generated from 31 stage wise trial blasts, and considering previous experiences in similar ground conditions. Details of trial blasts conducted for establishing the controlled blasting methodology are given in Table-2. Subsequently, blasting operations were carried out in a very safe and efficient manner for completing the excavation at the given site. Post-Blast analysis was conducted periodically after every 10 to 15 blasts, by verifying the sample cracks recorded during Pre-Blast analysis. It was observed that out of 1100 blasts conducted, the peak particle velocity at different structures exceeded the permissible levels only on 17 occasions.

Fig. 3 Muffling Arrangement for controlling Fly Rock

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Fig. 4 Ground Vibrations Monitoring near the Structures

TABLE II: DETAILS OF THE TRIAL BLASTS CONDUCTED (SASTRY [3])

Sl. No.	MCD (kg)	Distance (m)	PPV (mm/s)
1	0.38	27.73	4.70
2	0.25	28.18	2.60
3	0.31	31.99	2.35
4	0.13	31.30	1.52
5	0.25	28.65	1.65
6	1.00	26.63	8.89
7	0.25	29.15	2.29
8	0.25	29.15	2.79
9	0.31	32.25	2.60
10	0.25	32.50	2.10
11	1.00	32.76	5.46
12	0.38	30.23	2.86
13	0.38	38.91	1.46
14	0.25	31.51	1.46
15	0.25	48.47	1.00
16	0.38	31.16	2.60
17	0.25	31.16	3.49
18	0.38	30.61	2.67
19	0.38	27.72	3.11
20	0.38	30.73	2.48
21	0.75	31.64	5.02
22	0.38	32.20	3.56
23	0.13	35.00	1.00
24	0.75	43.51	4.25
25	0.25	49.87	1.14
26	0.25	36.40	2.03
27	0.25	34.38	1.65
28	0.31	41.10	1.71
29	0.25	34.52	2.60
30	0.25	34.66	2.54
31	0.31	43.30	1.65

PPV: Peak particle velocity
MCD: Maximum charge per delay
SD: Scaled distance

The vibrations data generated during entire project execution clearly indicated the implementation of safe controlled blasting methodology by the Bangalore Metro Rail Corporation. Brief summary of blasts conducted at different u/g stations is given below. Similar methodology was followed at five other underground stations. Summary of the blasts conducted for three u/g stations is given below (Fig. 5):

A. Chikpet Station

Total number of blasts	-	681
Total explosive used	-	5.24t
Total number of blastholes	-	21,186

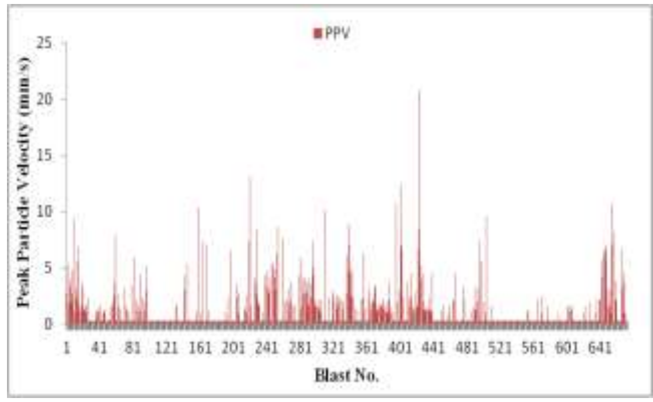

Fig. 5a. Summary of Peak Particle Velocity in Chikpet Station

B. Central College Station

Total number of blasts	-	1,278
Total explosive used	-	28.74t
Total number of blastholes	-	597

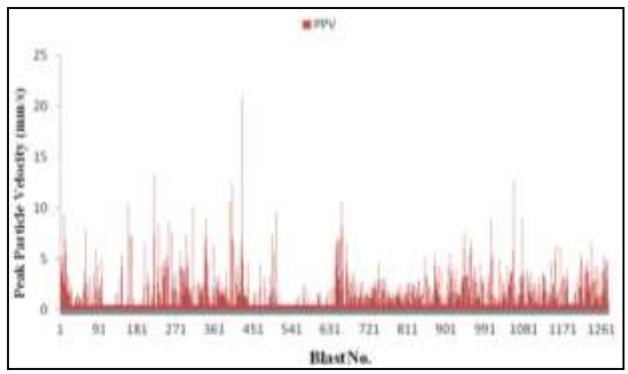

Fig. 5b. Summary of Peak Particle Velocity in Central College Station

C. Cricket Stadium

Total number of blasts	-	539
Total explosive used	-	1.97t
Total number of blastholes	-	4,920

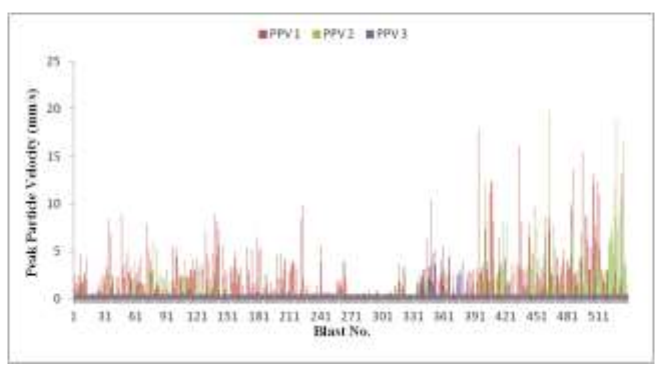

Fig. 5c. Summary of Peak Particle Velocity in Cricket Stadium

IV. CONCLUSIONS

Blasting is an essential activity in rock excavation projects. Usage of explosive energy is always associated with side environmental effects like ground vibrations, fly rock ad noise. These aspects assume special significance while conducting blasting operations in urban environment. Blast rounds should be designed keeping in view the rock mass characteristics and safety of surrounding structures and the people. Pre-blast and post-blast surveys along with risk assessment forms the basis of blast design in such conditions. Ground vibrations , fly rock and noise could be controlled by resorting to modern system of initiation and controlling the delay system in the blast rounds coupled with appropriate muffling arrangement. Such planning and execution of blasting operations can lead to successful completion of any infrastructural project involving huge rock excavation activity operating under restricted environment.

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