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## Effect of Blast Induced Ground Vibrations on Green Concrete at Mumbra Tunnel Project, Mumbai, India

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**ABSTRACT:** In mining, civil construction projects drilling and blasting method widely used for rock excavation, as still it is considered one of the cheapest method of rock excavation. Due to rock blasting many problems may occur such as flyrock, blast induced vibrations and etc. In fact, 38-40 % explosive energy utilised to produce vibrations only [2]. These blasts induced ground vibration may cause damage on newly performed bed concreting layers in construction process or shot create process in tunneling. There also arise similar problems in mining, where concrete supporting is required in drivages of weak rock. Therefore, investigation of on Effect of Blast Induced Ground Vibrations on Green Concrete and determining reasonable time gap and distance between blasting work and concreting is of great importance.

This paper presented review on effect of Vibrations on green concrete. The recommendations given by various researchers are broad and general in nature. This research attempted to correlate the strength acquired by the concrete with the threshold maximum vibration level. In this research, experimental blasts carried out during construction of piers concrete works and shot creating in open cut of tunnel of a Mumbra Tunnel and road work in Mumbai. Peak Particle Velocity (PPV) was recorded by using seismographs. Effect of PPV on green concrete strength with respect to time. This paper presented difference in strength of green concrete, which is exposed to blast vibrations with strength of green concrete without exposing vibrations with respect to age of green concrete.

**KEYWORDS:** Green Concentrate, Young Shotcrete, Blasting, Vibration, Peak Particle Velocity(PPV).

### I. INTRODUCTION

Explosive are being used as primary source of energy for rock and concrete breakage in most of the mining and civil engineering applications. The effective utilisation of explosive energy has been reported to be around 15 per cent [2]. Major part of explosive energy, which is not used for rock fragmentation, results in generating undesirable side effects like ground vibrations, air overpressure and flyrock. The vibration energy that travels beyond the zone of rock breakage is wastage and results in structural damage and human annoyance. In a properly designed and executed production blast, in general, only 20-25 % of the total explosive energy is utilised in useful work and remaining 75-80 % of energy is being wasted in generation of ill effects. [10]

Ground vibration is an elastic deformation of ground due to blast-induced forces and air overpressure is a transient increase in air pressure (above or below the atmospheric pressure) arising from the detonation of an explosive. The unproductive explosive energy used for generation of vibrations and air overpressure can travel many kilometers under favorable geological conditions and cause disturbance to the structures and habitats in the vicinity. Surface blasting in general, results in both positive and negative effects with regards to the safety and productivity (Fig 1). Since blasting is the cheapest method of rock breakage, mining and civil construction projects, in general, adopt the method for rock breakage and excavation. Even small scale blasts near structures

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and vital installations may generate dangerous vibration levels. Now-a-days prediction of blast induced ground vibrations is becoming increasingly important because of the fact that mining activity is spreading towards populated areas as well as the urban sprawl near mines and quarries. Therefore, fine-tuning of the causative and control parameters of the vibrations and air overpressure has become a thrust area of investigation in the present day context.

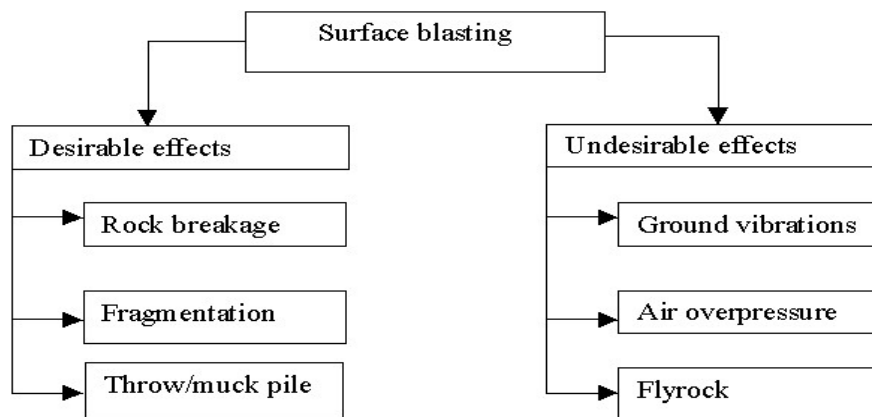


Fig 1: Desirable and Undesirable Effects of Surface Blasting

## II. REVIEW ON EFFECT OF VIBRATIONS ON GREEN CONCRETE

Hulshizer and Desai (1984) [3] use the term “green concrete” to describe conventional concrete having an age of less than 24 hour after completion of placement. Byfors (1980)[1] defines “fresh concrete” as concrete before setting, “early age concrete” as concrete between setting and approximately 1–3 days of age, “almost hardened concrete” as concrete older than 1–3 days, but younger than 28 days which defines a “hardened concrete”. In the following, “young shotcrete” will be used for shotcrete up to one day old.

The effect of vibrations on green concrete has not been fully investigated by researchers in the past. Except few researchers [6], no published material on the effect of vibrations on young shotcrete has been found. There are, however, a number of interesting reports on *in-situ* tests conducted in tunnels and mines where fully cured shotcrete on rock have been subjected to blast induced vibrations. Some research attempts were made in the area of influence of vibrations on young shotcreting, which is similar to the effect of green concrete. [8]

Kendorski et al. (1973) [5] carried out *in-situ* tests to determine how a concrete lining was affected by standard drift blasts at various distances from the lining. A standard blast that consisted of 409 kg premixed ammonium and fuel oil (ANFO) showed that there was no bond failure at the shotcrete–rock interface. The tests revealed that cracks started to appear in the shotcrete when the detonations occurred at a distance of 16.5 m and that the function of the lining was considerably reduced when detonating from 12.2 m.

In civil construction projects, the strive for a more time-efficient construction process naturally focuses on the possibilities of reducing the time periods of waiting between stages of construction. As an example, the rock excavation in open cut excavations in metro rail projects requires coordination between the bed concreting and adjacent rock blasting so that blast induced vibrations would not affect the green concrete which is hardly at a distance of 5-10m.[8] There also arise similar problems in mining. To be able to excavate as much ore volume as possible, the grid of drifts in a modern mine is dense. This means that supporting systems in one drift are likely to be affected by vibrations in a neighboring drift. A criterion for how close, in time and distance, to the young concrete, blasting can take place would be an important tool in planning for safe and economical mining projects. [7] Another example is the foundation excavation of thermal power projects, where the

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concreting and rock excavation go simultaneously, adjacent to each other, to crash the time.

In actual practice, numerous occasions arise when it is necessary to build concrete structures at the same time when excavations by blasting are being carried out. For example, lining during tunnel driving, foundation for the primary crushing buildings near open pits, etc. [9] Table-1 gives prevention criteria given by Oriard (1980) [6] depending upon curing or hardening time of the concretes, although such recommendations cannot be made extensive to all types of concrete.

As can be observed, during the hardening period of 0 to 4 hours, the concrete is still not hard and the admissible levels are relatively high. From 4 to 24 hours, it begins to harden slowly, and after 7 days it reaches the strength that is approximately 2/3 of the final product (28 days), allowing a progressive intensification of the vibrations. Other factors to take into account are the characteristic frequencies of the vibrations, external hardening conditions, area of rock-concrete contact, etc. On the other hand, Issac & Bubb (1981), [4] summed up all their experiences and those of Scandinavian investigators in a graph where, according to strength acquired by the concrete, the maximum vibration level is determined.

Setting Time	Admissible level of PPV	
	STRUCTURAL CONCRETE	FILL AND MASS CONCRETE
0 – 4 hrs	50 mm/s	100 mm/s
4 – 24 hrs	5 mm/s	25 mm/s
24 – 72 hrs (1-3 days)	25 mm/s	30 mm/s
72 – 168 hrs (3-7 days)	50 mm/s	75 mm/s
168 – 240 hrs (7-10 days)	125 mm/s	200 mm/s
>240 hrs (>10 days)	250 mm/s	375 mm/s

Table 1: Setting Time of Concrete *versus* Admissible Levels of Particle Velocities

The guidelines given by the previous research findings are broad and general in nature. Therefore, it requires further experimentation to correlate the strength acquired by the concrete with the threshold maximum vibration level. Therefore, it is very essential to know the exact effect of vibrations on green concrete to avoid possible damage and deterioration to the structure in long run

### III.FIELD EXPERIMENTATION

Blasting of hard rock was carried out as part of the excavation works in connection with proposed tunnel at Mumbra for Mumbai Metropolitan Regional Development Authority(MMRDA), at locations Mumbra in Mumbai city, India. Controlled blasting operations were carried out keeping in view of the adverse effects like ground vibration, air overpressure and flyrock. Blasting and concrete works used to go hand in hand to meet the time schedules and targets of the project. Therefore, freshly poured concrete was exposed to blast induced ground vibrations as shown in Fig 2. In such situations it was imperative to know the exact levels of ground vibrations, which cannot cause any internal and external damage to the green concrete.

The following sets of experiments carried out for assessing the effect of blast induced ground vibrations on green concrete:

1. Close field ground vibration monitoring at freshly poured concrete by triaxial geophones
2. Measurement of curing characteristics like strength and temperature release of freshly poured concrete/green concrete by a device called Zone-cure at vibration free zone.

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- Measurement of curing characteristics like strength and temperature release of freshly poured concrete/green concrete at vibration exposed zone.



Fig 2: Freshly Poured Concrete near Blasting Sites at Mumbai Mumbra- Airoli Tunnel road work.

Experiments were carried out during pier bed concrete work of a flyover construction works in India to find out the vibration criteria for freshly poured concrete of age 0 to 4 hours. From the temperature history graphs, it was found that the temperature of concrete starts increasing after 2 hours, which is the indication of curing process. At the experimental site the structural concrete was exposed to a blast induced vibration with peak particle velocity (PPV) level of 48.5 mm/s, which was still less than the threshold limit suggested by Oriard (1980).[6] The vibration monitoring was carried out by engineering seismograph of Instantel make (Canada), which contains triaxial geophones as shown in Figure 3. The vibration level was exposed at 3 hour 15 minutes from concreting. The vibration exposure took place in twice with a gap of 5 minute. There was another site with same structural concrete kept without any exposure of vibrations. After 15 days of curing, samples of both the sites were tested for strength. The in-situ strength was tested by a Concrete Maturity Testing Systems called Zone Cure. The concrete samples were also tested in laboratory for strength measurement as shown in Fig.3. Very interestingly the strength of vibration free concrete sample measured was 41.2 MPa and that of vibration exposed samples was 33.0 MPa. This indicates the vibration exposure resulted in strength reduction of 20 %, which is very substantial one.

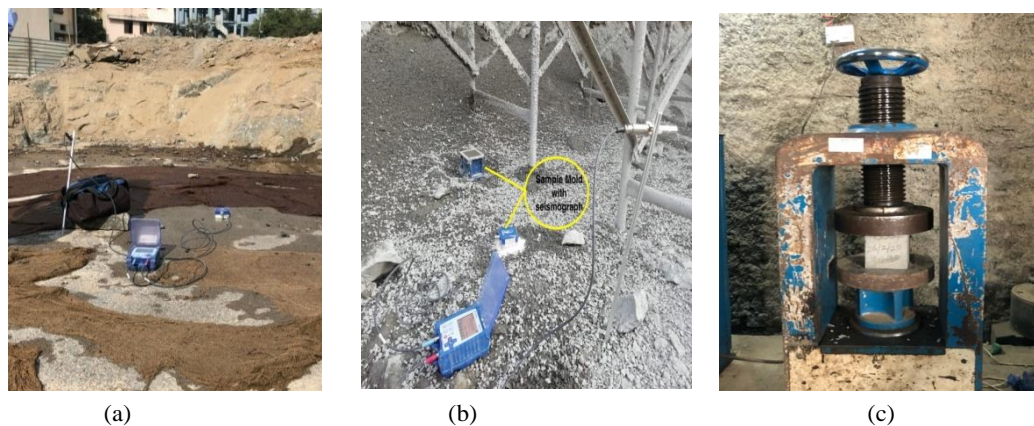


Fig 3: Vibration Monitoring by Engineering Seismograph near the Green Concrete & Concrete Testing Machine(CTM)(a) Mass concrete for pier bed concrete. (b) Sample mold and monitoring near fresh shot concrete. (c) Cube testing by CTM at project laboratory.

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Another experiment was conducted on samples of 3 hours age and with exposure of PPV 24.4 mm/s and observed no reduction in strength of concrete. Similar experiments were conducted on samples of 3-hour age with PPV exposure to 48.5 mm/s and observed 23.5 % reduction in strength. This indicates that no chance of exposure of vibrations should be taken for the freshly poured concrete of age 2 to 4 hour, although the existing global vibration criteria is liberal for concrete up to 4-hour age. Therefore, the paper recommends that the green concrete up to 4-hour age is also vulnerable for vibrations above 40mm/s and stresses for need of more research and experiments in this direction.

## IV.METHODOLOGY

The primary objectives of this research work are as follows:

1. To investigate the effect of blast vibration intensity on green concrete.
2. To develop guidelines on threshold peak particle velocity of vibration exposed to green concrete which can deteriorate the strength of cured concert in due course of time

In order to achieve the above objective, it is proposed to carry out experimentation in control condition in the field. Concrete blocks are used for small scale model study and exposed to blasting forces. Blocks of different ages are exposed with similar vibration intensity by keeping charge weight, vibration proportion medium and distance from source constant. Vibration intensity versus age of green concrete data is generated with various concrete block model of different ages. The ages are marked on each block for identification. The influence of vibration on the green concrete is determined by testing of the strength of model after curing. Similar round of experiments are conducted with different blocks of different ages and data like temperature and strength are measured. This gives the strength deterioration due to vibration exposure in some models of certain age and no influence of vibration on some model. Hence by conducting many rounds of experiment, it can be found out by particular levels of vibration causing internal deterioration of strength of green concrete.

## V. EXPERIMENTAL RESULTS

Both strength and temperatures were monitored by fixing concrete curing measurement system Zone-cure at the site. The strength was measured for every 12 hours for a period of 15 days and temperature was measured for every 2 hours for a period of 24 hour. The experiment of strength and temperatures was carried out for a green concrete, which was exposed to a vibration level of 24.4-48.5.mm/s. The same experiment was carried out for a green concrete, which was not exposed to any vibration level. The experimental results of strength and temperatures are given in Table 2 and 3 respectively. The temperature monitoring indicate that curing process i.e. cement bonding starts between 2 to 4 hours as the raise in temperature is evident. The fall in strength after 15 days to the vibration exposed concrete indicate that there is substantial influence of vibration even at the levels below 48.5mm/s as shown in Fig.4.

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Sl No.	No. of hours	Strength of green concrete without exposing vibrations	Strength of green concrete with exposing vibrations (24.4-48.5 mm/s)
1	12	8.5	5.5
2	24	16.7	12.5
3	36	19.2	15.75
4	48	26.1	20.15
5	60	27.6	21.7
6	72	31.4	25.5
7	84	34.6	28.5
8	96	37.1	28.6
9	108	36.7	30.5
10	120	36.1	32.0
11	132	39.2	32.15
12	144	39.6	32.3
13	156	37.2	31.1
14	168	40.0	32.0
15	360	41.2	33.2

Table 2: Experimental Results of Strength *versus* Time in Green Concrete.

Sl No.	No. of hours	Strength of green concrete without exposing vibrations	Strength of green concrete with exposing vibrations (24.4-48.5mm/s)
1	0	27	27
2	2	25	25
3	4	28	28
4	6	32	32
5	8	40	40
6	10	51	50
7	12	60	61
8	14	57	58
9	16	54	55
10	18	46	46
11	20	43	44
12	22	40	41
13	24	37	36

Table 3: Experimental Results of Temperature *versus* Time in Green Concrete.

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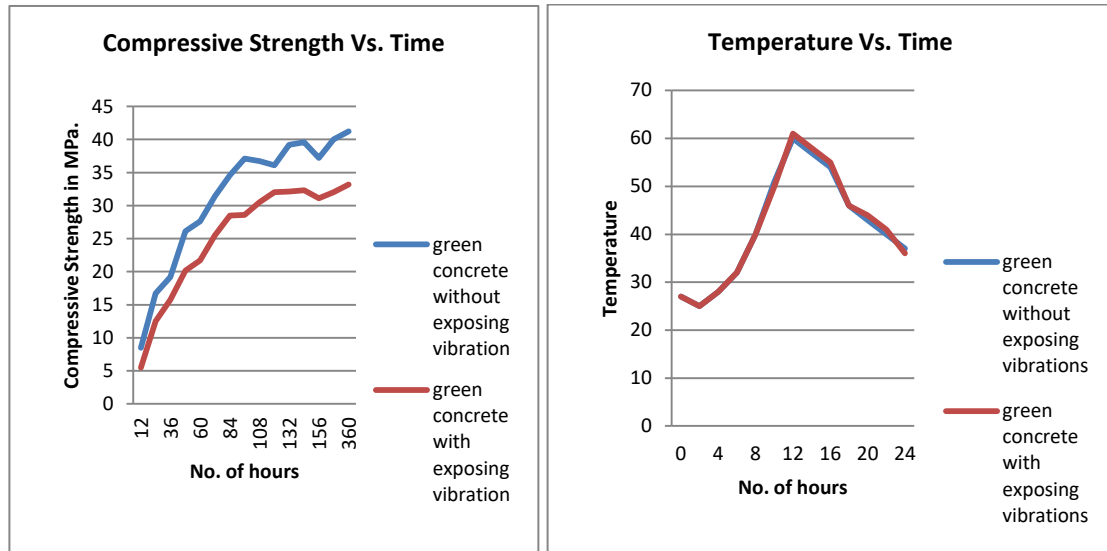


Fig.4: Strength of Concrete versus Time. (b) Relationship between Temperature versus Time.

## VI. CONCLUSION

In this work, blasting vibration parameter peak particle velocity (PPV) monitoring was during the blast excavation of Mumbai metro construction works. The effect of vibration on freshly poured concrete of age 0 to 4 hours investigated. The reasonable time gap between blasting and shotcrete proposed to ensure the security of shotcrete. The main conclusions were drawn as follows:

1. The strength of green concrete samples which is not exposed to blast vibrations was 41.2 MPa and that of vibration exposed samples was 33.2 Mpa. This indicates the vibration exposure resulted in strength reduction of 20 %

2. The samples of 3 hours15 minutes age and with exposure of PPV 48.5 mm/s and observed 23.5% reduction in strength. This indicates that no chance of exposure of vibrations should be taken for the freshly poured concrete of age 2 to 4 hour, although the existing global vibration criteria is liberal for concrete up to 4-hour age.

Therefore, the paper recommends that the green concrete up to 4-hour age is also vulnerable for vibrations above 40mm/s and stresses for need of more research and experiments in this direction. The lower time limit of 0 – 4 hrs. should be kept of 0 – 2 hrs. hours as the cement starts curing after three hours and the vibration threshold of 50 mm/s should be changed as 40 for structural concrete for the first 3 hours exposure to ground vibrations.

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## REFERENCES

- [1] Byfors, J., 1980. Plain concrete at early ages, Research Fo 3:80. Swedish Cement and Concrete Research Institute, Stockholm.p. 345.
- [2] Hagan, T. N. and Just, J. D., 1974, Rock breakage by explosives-theory optimisation, Proc. 3rd Cong. Rock Mech., 2, pp.1349-1358.
- [3] Hulshizer, A.J., Desai, A.J., 1984. Shock vibration effects on freshly placed concrete. J. Constr. Eng. Manage. 110, 266–285.
- [4] Yassin M. Y. Hasan and Lina J. Karam, “Morphological Text Extraction from Images”, IEEE Transactions On Image Processing, vol. 9, No. 11, 2000
- [5] Berta,G.,1990. Explosives: An Engineering Tools.Milano.Italesplosivi.
- [6] Kendorski, F.S., Jude, C.V., Duncan, W.M., 1973. Effect of blasting on shotcrete drift linings. Min. Eng. 25, 38–4.
- [7] Oriard, L. L. and Coulson, J. H., 1980, "TVA Blast Vibration Criteria For Mass Concrete", Proc. Conf. of ASCE, Portland, OR, Preprint 80-175.
- [8] Ramulu, M. & Raina, A.K., P.B. Choudhury, Sinha, A., 2010, Special tunnel blasting techniques- CIMFR contributions, November, 2010, Workshop on Tunnelling Quo Vadis? Kolkata.pp. 1-18.Books & Journals Private Ltd.,
- [9] Ramulu, M., 2013, Controlled blast design, review and monitoring of ground vibrations, air overpressure and flyrock at BMRC project, Phase1, UG1, Bangalore, CIMFR Report.
- [10] Ramulu, M., Sitharam, T.G, 2010, Blast induced damage due to repeated vibrations in jointed gneiss rock formation, Int. Journal of Geotechnical Earthquake Engineering, IGI publications, USA, Vol. No.5, Sept. pp.31 - 39.
- [11] Rollins, 1980, Energy partitioning, Rock mechanics and explosive research center, University of Missori-Rolla.