TAI

Tunnelling Asia' 2023

International Conference on
Climate Change Resilience and Sustainability
in Tunnelling and Underground Space

ASSOCIATION INTERNATIONALE DES TUNNELS ET DE L'ESPACE SOUTERRAIN
AITES | ITA
INTERNATIONAL TUNNELLING AND UNDERGROUND SPACE ASSOCIATION

Design and Planning of Excavation Sequence and Blasting Techniques For Large UG Caverns

by

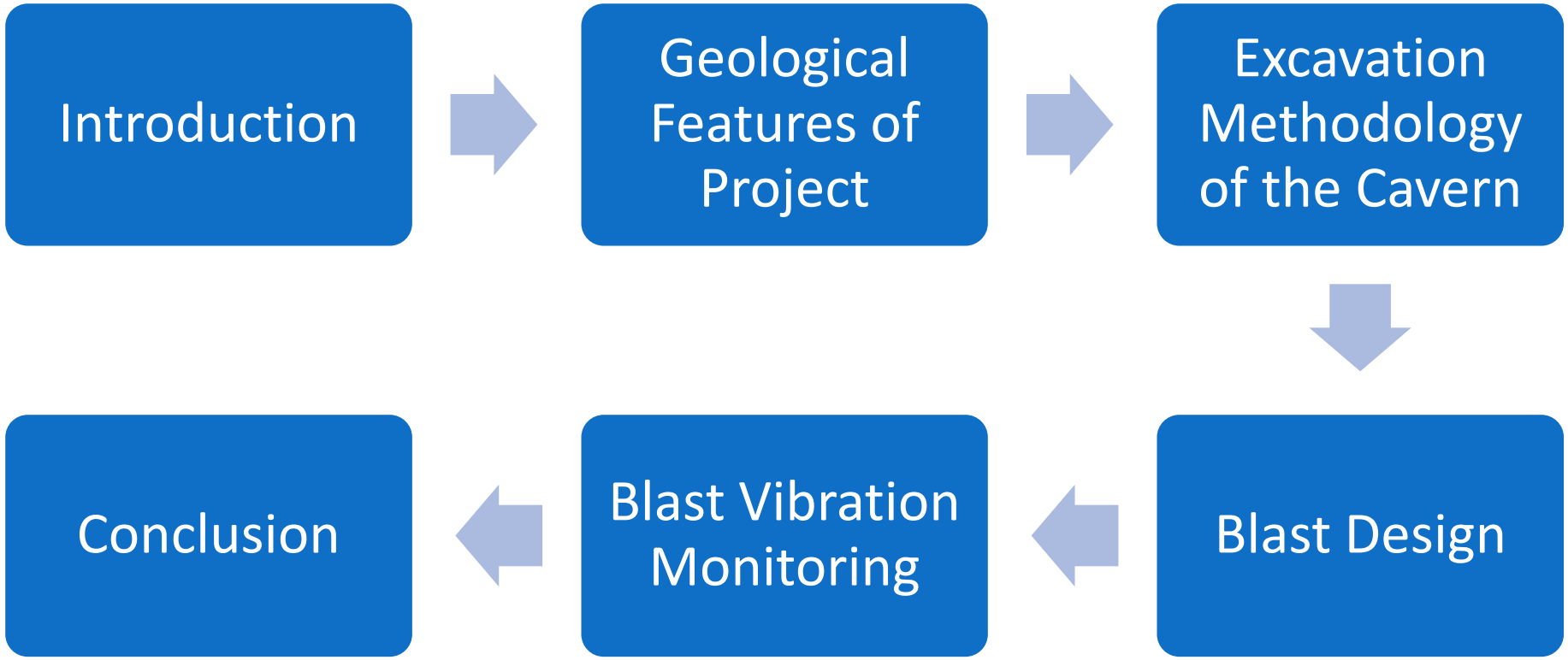
Rakesh Kumar Khali, Vice President-Operations

Naveen Bahuguna, General Manager-Design

G R INFRAPROJECT LIMITED, DELHI-INDIA

rakesh.khali@grinfra.com; naveen.bahuguna@grinfra.com

Contents


Introduction
Geological Features of Project
Excavation Methodology of the Cavern
Blast Design
Blast Vibration Monitoring
Conclusion

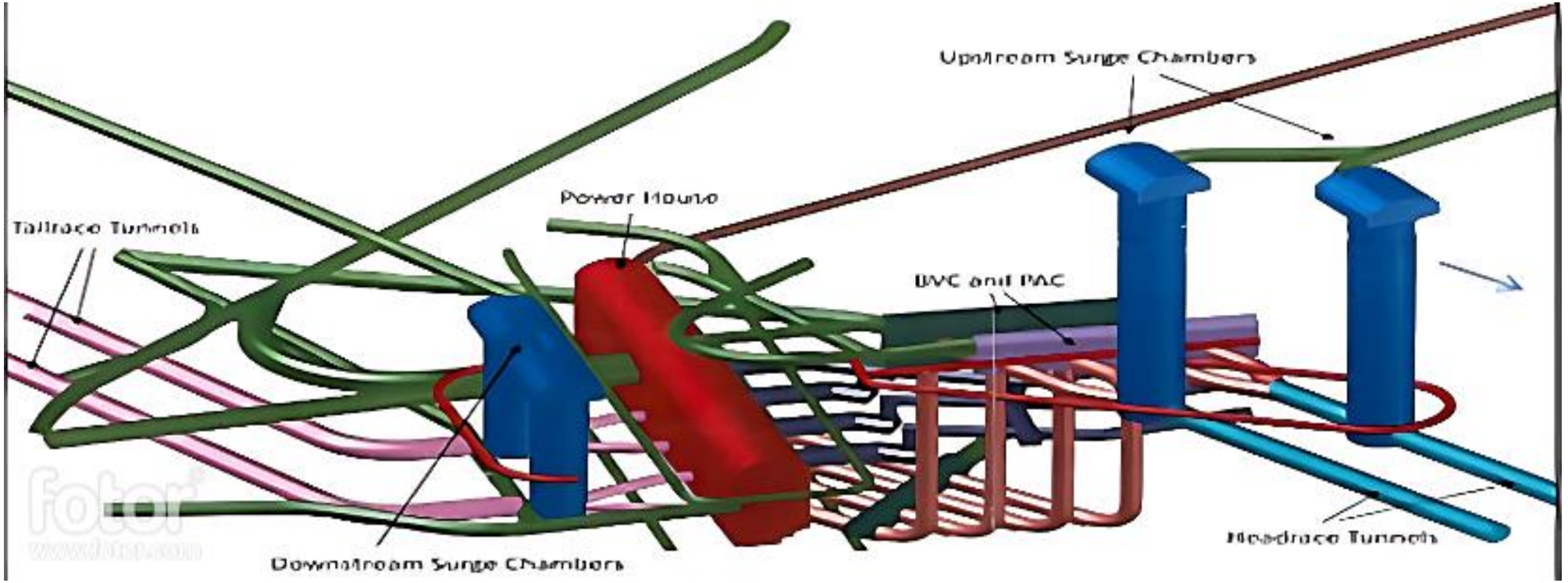
Introduction

The Tehri PSP is currently under construction by THDCIL. It envisions a vast underground machine hall cavern hosting four reversible pump turbine units, each having a capacity of 250 MW. Surprisingly, the subterranean Tehri PSP, which is nearing completion, is located in the same hillocks where the Tehri Hydro Power Project (THPP) is currently operational.

The main project components of the PSP are 26.2m (W) X 57.3m (H) X 202.9m (L) sized machine halls to accommodate four 250 MW turbines, each 22m dia. There are two upstream surge shafts with surge chambers, a 77m (L) X24m (H) X10m (W) sized BVC, an 81m (L) X20m (H) X13m (W) PAC, and two 18m -dia. downstream surge chambers. TRTs of 1081m and 1176m.

Tehri PSP's Powerhouse Cavern excavation was done using Dill & Blast techniques (DBM). The blasting operation was optimised by considering the vicinity of Cavern close to under operation Powerhouse and multiple opening connecting to Cavern, the current rock mass conditions, and the design rock mass support system.

Arrangement of Powerhouse Cavern



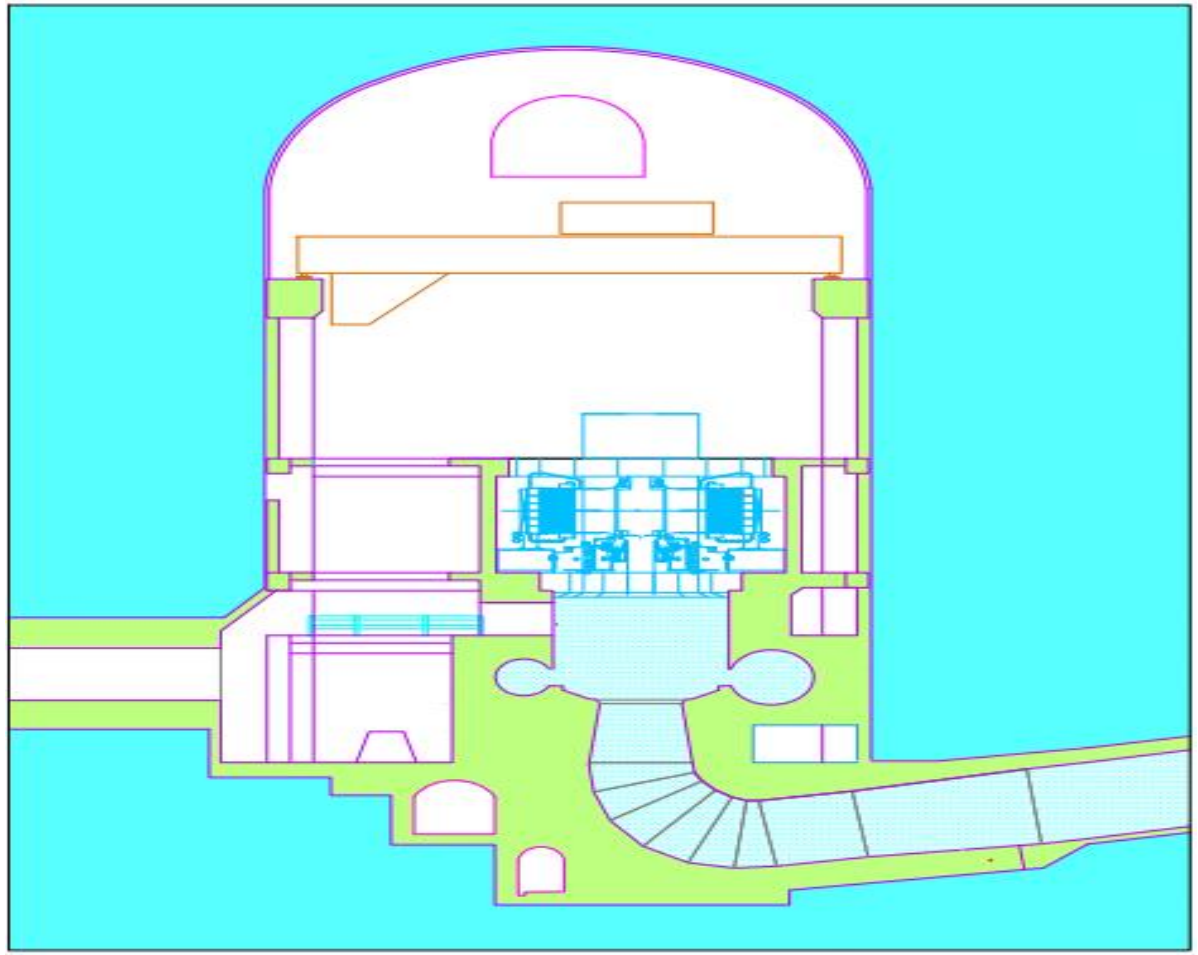
Geological Features

The project location is situated in the Lesser Himalaya, which is tectonically located between the Main Central Thrust (MCT) and the Main Boundary Thrust (MBT). The former separates the Meta Sedimentary sequence of the Lesser Himalaya in the north from the Crystalline rocks of the Higher Himalaya, while the latter separates the Lesser Himalayan sequence from the Frontal Fold Belt (FFB) molasses sediments in the south.

Rock units are part of the low-grade Metamorphic rock that has been thrusted, folded, and deformed.

The Krol Super Group and the Gharwal Group are the two primary tectono-stratigraphic units (R. Shankar et.al.1989). The Jaunsar Group and the Krol Group are subsets of the old Super Group. The Jaunsar Group is found in the Tehri site and consists of diverse amounts of quartzites and phyllites that have undergone various periods of deformation, resulting in the production of many tectonic dislocations, sheared zones, seams, and joints of various scales and types.

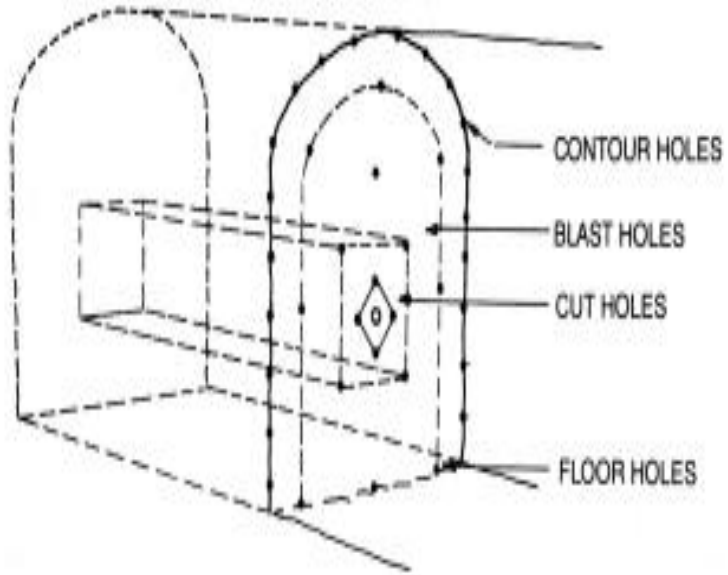
Power-House Cavern(26.2m(Width) X57.3m(Height)X202.9m (Length)

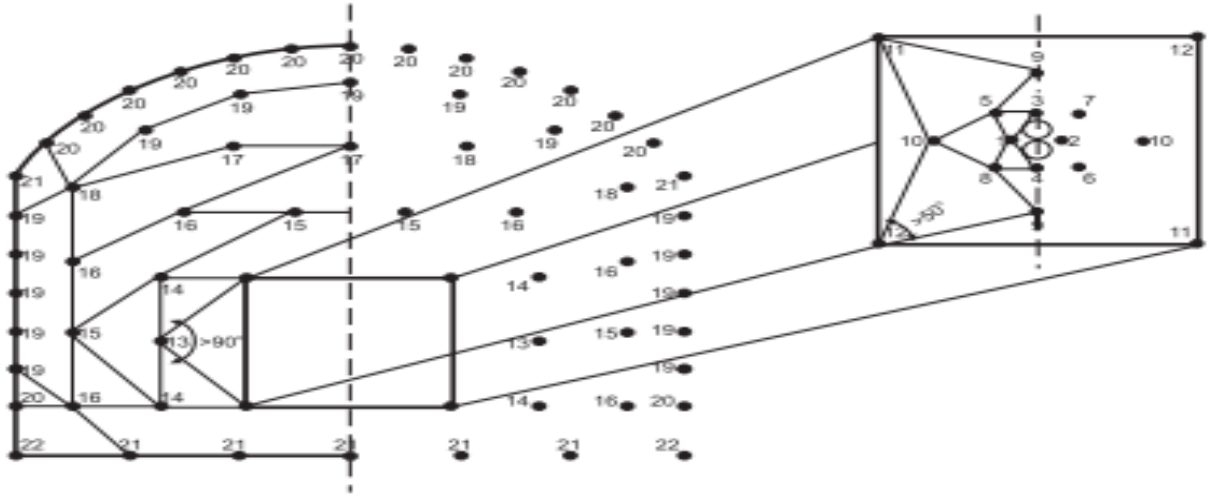


EXCAVATION METHODOLOGY OF THE CAVERN

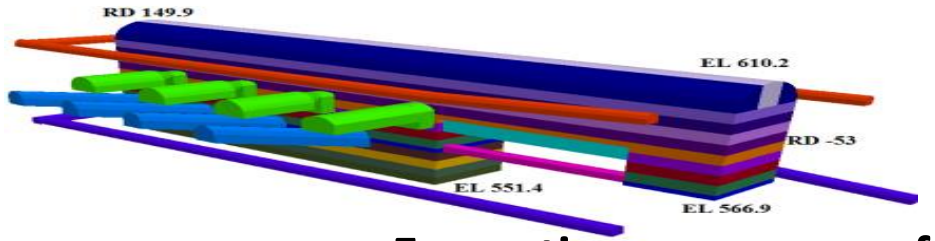
- The excavation of the Powerhouse cavern was planned, along with the construction of a Pilot tunnel (central gullet) at the cavern's summit, as well as side cutting and various phases of benching.
- Tunnelling procedures were intended as the top heading together with the pilot tunnel.
- This allowed for simple access to the cavern roof for the installation of the support works.
- The supporting roof provided safe working conditions for the excavation of the cavern's lowest floors.
- Benching procedures were used to excavate the lowest levels.
- Many concomitant elements were considered when determining the size of the top heading, which was divided into three portions, including the pilot tunnel, left-side and right-side slashing.
- These are top-level sections were chosen based on the following criteria:
  a) Drilling jumbo reach
  b) Rock quality
  c) The presence of a weak rock zone that, due to instability, limits the area of unsupported excavation face.
  d) The amount of explosive released in one round is limited by blast vibration acceptance standards.
  e) The practical depth of blast holes, which ranges between 3 and 4 metres depending on the cross-sectional area of the top heading.

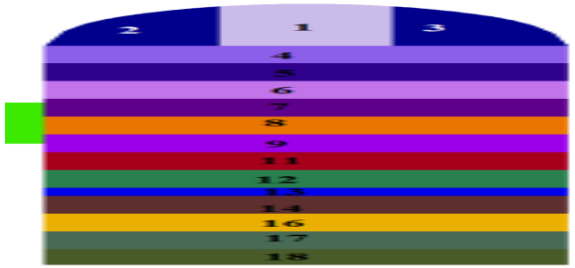
Considering all the above listed factors, 5m diameter pilot tunnels (central gullet) with 3m pull length and two parts of side slashing, with 3m pull length adopted for top heading of cavern. Burn cut drilling pattern is designed for central gullet.





Benching excavation was generally carried out with vertical drill-holes as in a quarrying operation, or with horizontal drillholes. The holes were made with crawler mounted drilling rigs. The cavern excavation was divided into two parts and in benches of suitable height.





Excavation sequences of Cavern Benching

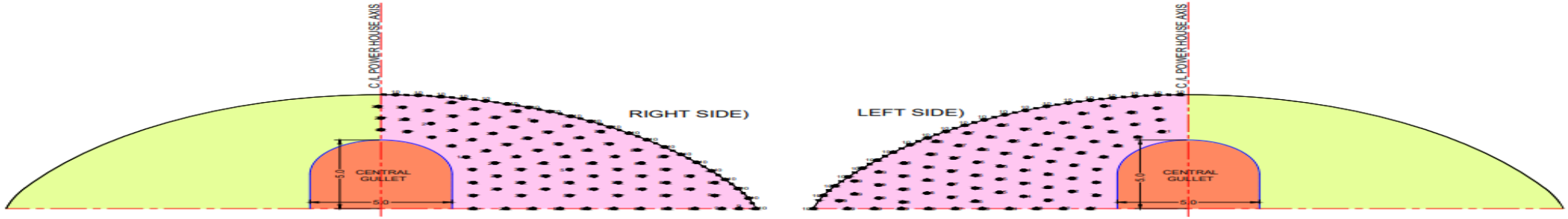
The height of the benches was decided based on the following factors:

- Tunnels placed at appropriate levels provide access and mucking.
- The longer the hole, the higher the possibility of deviation.
- If the cavern wall is too high, it may become unstable, necessitating further bench excavation and support.
- Construction at a low cost, with excavation cycles optimised.
- Restriction on the amount of explosive fired in a round, as specified in the blast vibration acceptability criteria

BLAST DESIGN

- The amount of vibration that can be tolerated may limit the magnitude of the blast or need vibration mitigation blast design.
- If the design or execution is inadequate, the rock that forms the ultimate surface of the excavation may be damaged. Because the PSP Cavern is next to the existing operational Tehri HEP powerhouse cavern, it was critical to design an economical and safe blasting without disrupting the operational powerhouse.

Vibrations are measured in operational powerhouse -cavern using vibrographs for the "designed peak- particle-velocity". Accordingly, the size of each blast was designed on the accepted "peak-particle-velocity- criteria".



Blast design of Side Slashing of Top Heading

(a)	Hole Dia (D)	45mm	4	Drilling Length	2m
(b)	Excavation Area	68.331m2	5	Cartridge length	30cm
(c)	Wight of Cartridge	0.39 kg	6	Cartridge Dia	40mm
S.no	Delay Series	Hole nos.	Car-tridge nos	Cartage Used (No.)	Explosive used (Kg.)
1	I	9	3	27	10.530
2	II	10	3	30	11.700
3	III	12	3	36	14.040
4	IV	9	3	27	10.530
5	V	9	3	27	10.530
6	VI	7	3	21	8.190
7	VII	7	3	21	8.190
8	VIII	10	3	30	11.700
9	IX	7	3	21	8.190
10	X	21	3	63	24.570
	Total	101	3	303	118.170
Burden=		0.75 to 0.85 m			
Distance between Charged Hole= 0.95 to 1.0 m					
Expected volume of blasted muck = 136.662Cum					
Total explosive Consumption (E)=118.17Kg					
Nos. of Detonators (N)=101nos					
Powder Factor (PF)=0.865kg/cum					

BLAST VIBRATION MONITORING

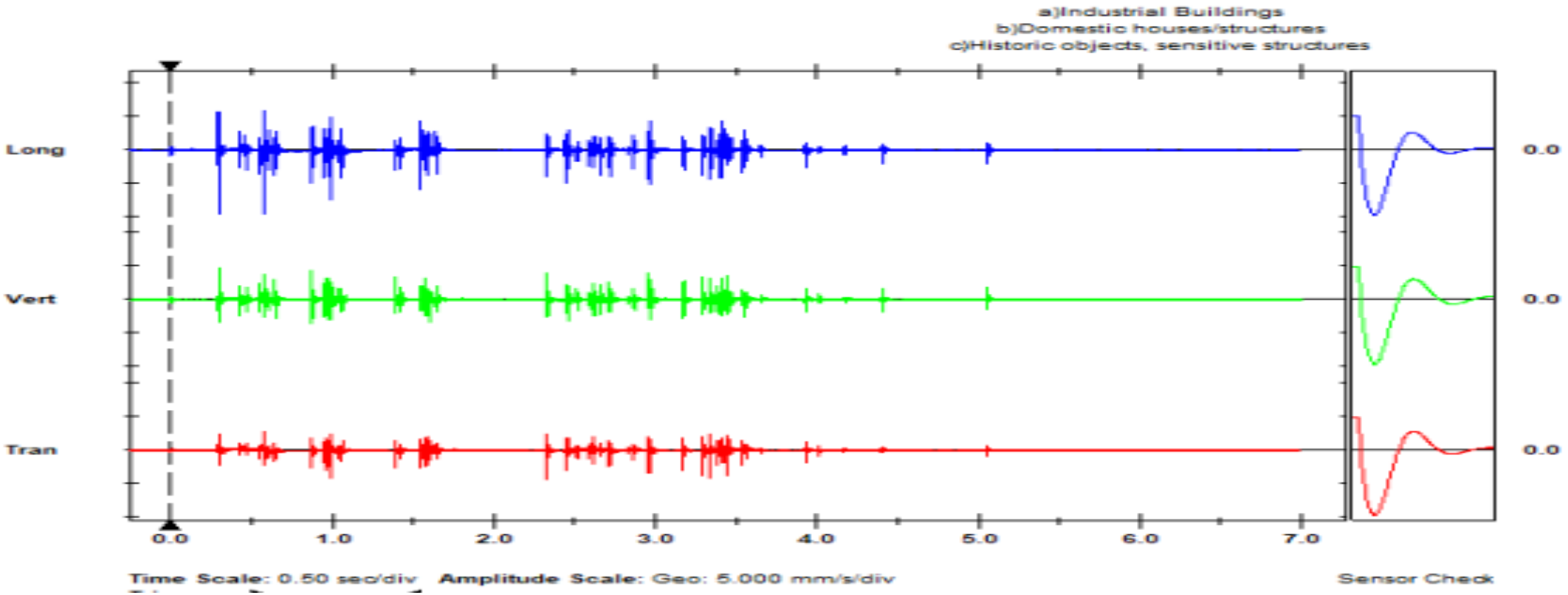
CIMFR Roorkee dispatched a dedicated blast-monitoring crew to the site to independently monitor various blasting operations and record blast-induced ground vibrations at various sites using advanced seismographs supplied by CIMFR Roorkee.

The CIMFR used one Mini Mate Plus seismograph, which is a more advanced type of a seismograph that is sensitive enough to record ripples from the lowest trigger level (0.125-254mm/s) to the maximum level.

More than 100 blast events have been supervised and monitored for blast-induced ground vibration at various key places. During this reporting period, major rock excavations were carried out in the powerhouse Cavern.

In light of the foregoing, all blasting processes have been tuned to ensure that the "peak particle velocity level" is less than 20 mm/s.

The measured vibration data shows that the minimum and greatest values of Peak Particle Velocity observed during this period are 0.648 and 19.98 mm/s, respectively. The majority of the measured vibration data remained below 5.0 mm/s.



Blast event monitoring

CONCLUSION

The excavation of the massive subterranean -cavern of the Tehri Pumped Storage Project (PSP) was critical, given the nearby operational cavern of the Tehri HEP. The effective completion of cavern excavation was due to the excellent execution and design of controlled blasting.

The following precautions were implemented at the site to ensure the cavern's effective excavation:

- Due to the complex geology of the powerhouse cavern, many openings at different levels, and the proximity of the cavern to the operational powerhouse, the ramp was divided in two halves of the cavern's width. The turbine pits were likewise excavated in phases and in a regulated manner.
- Controlled blasting alone was not an effective option for the stability of the enormous underground apertures. It was also critical to implement the required support system around the excavation face on time in order to keep the rock mass from degrading.
- The line- drilling and smooth blasting applied to maintain the specified excavation- line of cavern walls, prevented the overbreak in the walls. The overbreak in some parts, however, was caused by unfavourable geology and tiny planar and wedge failures.

CONCLUSION

- In addition to vibration monitoring, the instrumentation method assessed the impact of explosions on the roofs and walls of the massive underground holes. According to the instrument monitoring data, the measured ground vibration was within safe limits, and no harmful impacts were observed in the powerhouse walls or roof. Data from multipoint bore-hole extensimeters revealed minimal movement in the cavern walls.
- The charge concentrations in the drill hole near the cavern wall were adjusted so that the damage zone from each hole coincided with the projected excavation limit.

THANK YOU FOR YOUR ATTENTION