Successful Innovations in Construction Technology for Hydro Power Projects - Excavation in High Temperature Zone at Karcham-Wangtoo Project

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Abstract

High temperatures (60°-98°C) were measured in head race tunnel of Karcham-Wangtoo hydroelectric project in Himachal Pradesh, India. A safe method of blasting the tunnel face is presented. The nonel detonators are recommended after cooling the blast holes below 80 °C by throwing chilled water manually.

Introduction

An article "Chemical variations in thermal discharges from Satluj and Spiti Valleys, Himachal Pradesh (India) – A conceptual geochemical model" by Absar *et al.* (1996) in "Geothermal Energy in India" of Geological Survey of India, special publication No.45, 1996, pp 169-182, has mentioned several hot springs in Satluj valley. Hot springs are also present in the project area. On the basis of this article there has been recent findings at Karcham Wangtoo Hydroelectric Project being executed in high temperature zone by Jaiprakash Associates Ltd. on BOO basis. These findings have been reproduced below.

The Karcham-Wangtoo Hydroelectric Project in Himachal Pradesh is a run of the river project and is located on river Satluj in district Kinnaur about 200 km from Shimla. It consists of construction of 98m high concrete gravity dam, 17.2 km long and 10.48 m dia head race tunnel and a 1000 MW (4x250MW) capacity underground power house. General layouts of underground power house and HRT are given at Figures 1 and 2. All the works of the project are in advanced stage of completion and it is expected to be commissioned in the year 2011.

During the advancement of HRT (Adit-4 upstream), a high temperature zone within the tunnel (at RD 1063 m) appeared suddenly. The temperatures measured by the management reported to vary between 60°C and 98°C were felt as "alarming", specifically when tunnel excavation has been proposed to be advanced using drilling & blasting method (DBM). Due to unexpected high temperature within the tunnel, the work was temporarily suspended considering the safety of man and machinery deployed at the site.

Fig. 2To overcome the problem of temperature, an emergency visit of the officials of blasting division of Central Institute of Mining & Fuel Research (CIMFR), Dhanbad, was made between 22 February and 1 March 2009 to assess the problem and evolve a site specific blasting procedure. To continue the work at the site, several temperature sensitivity tests of explosive and detonators being used at the site were carried out near the existing tunnel-face to observe their response under the influence of temperature. This report describes the results of the tests and a site specific blasting procedure based on the results suitable for concerned site under high impact of temperature.

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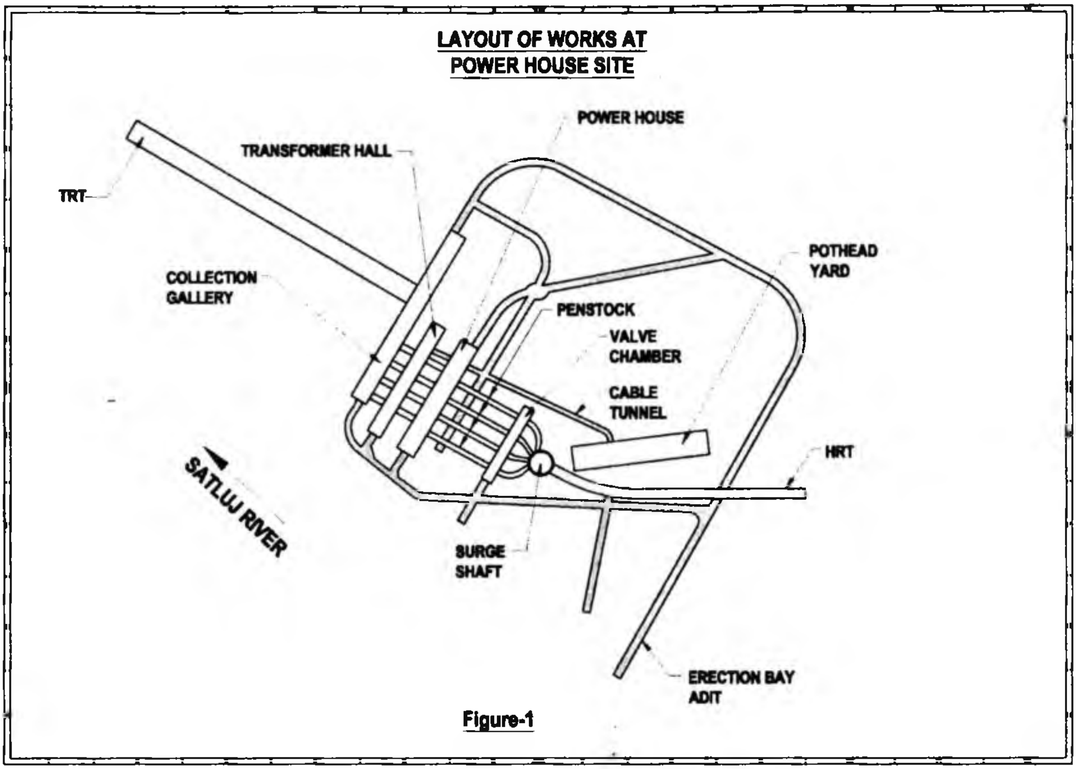
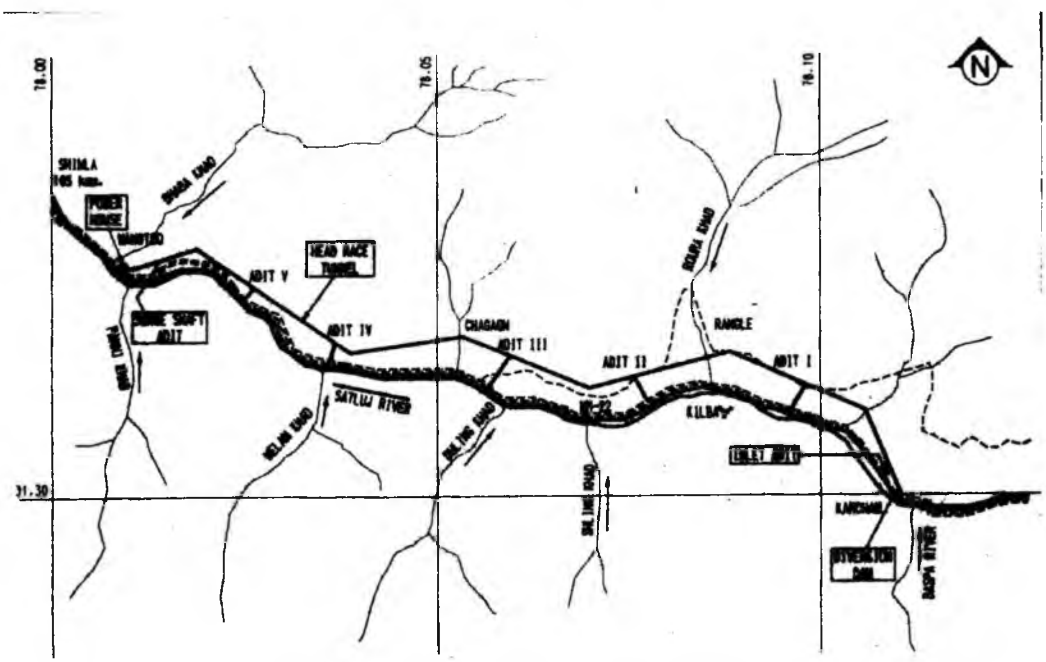


Figure-1



KARCHAM-WANGTOO HYDROELECTRIC PROJECT
CONCEPTUAL PROJECT LAYOUT

Fig. 2

Geology of the Face and State of Temperature

The rock type at the site was observed to be hard and massive granite gneiss with appearance of a band of biotite schist. As per the geotechnical classification, the rock has been categorized into "fair" class and the rock structure is dominated mainly by the foliation joint, striking N20°W – S20° E with a gentle dip towards northeasterly direction. Surprisingly, water seepage from the face could not be observed during the stay and was completely dry. A number of probing holes of different depth (depth varying between 4 & 35 m) at different locations on the face were already drilled by the management to observe the level of temperature inside the hole. The temperature log of the tunnel between RD 1068 and 1072 Adit-4 (u/s), as provided to us (Fig. 3), did not indicate any precise trend of temperature increase so as to propose diversion of the tunnel. From few of the holes, extremely high temperature vapour was continuously coming out, without any water outflow. Systematic prescribed support system was being implemented without any delay. Injection of cold water into the blast holes as well as on the face was a round the clock practice, which was able to drop down the temperature of the face and holes below 80°C to make the face ready for blasting. A plan showing tunnel length from Adit-3 to Adit-4 is given in Fig. 4 (Plan of HRT) and Fig. 5 (L-section of HRT).

Experimental Tests

The tunnel excavation work of Adit-4 (u/s) was stopped during the visit, so it was decided to perform temperature sensitivity test of the explosive and detonators which were being used at the site in routine blasting work. The procedure of the testing is detailed in Table 1.

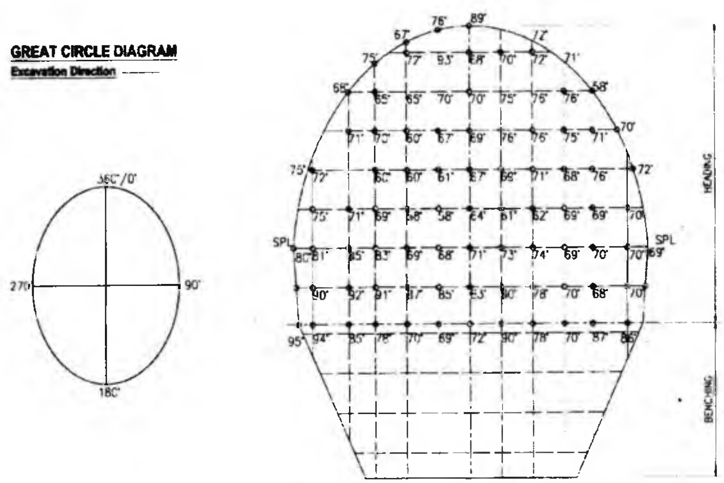


FIG.3: TEMPERATURE LOG OF THE FACE, ADIT-4 (UPSTREAM), KWHEP, H.P

Fig. 3

Fig. 4

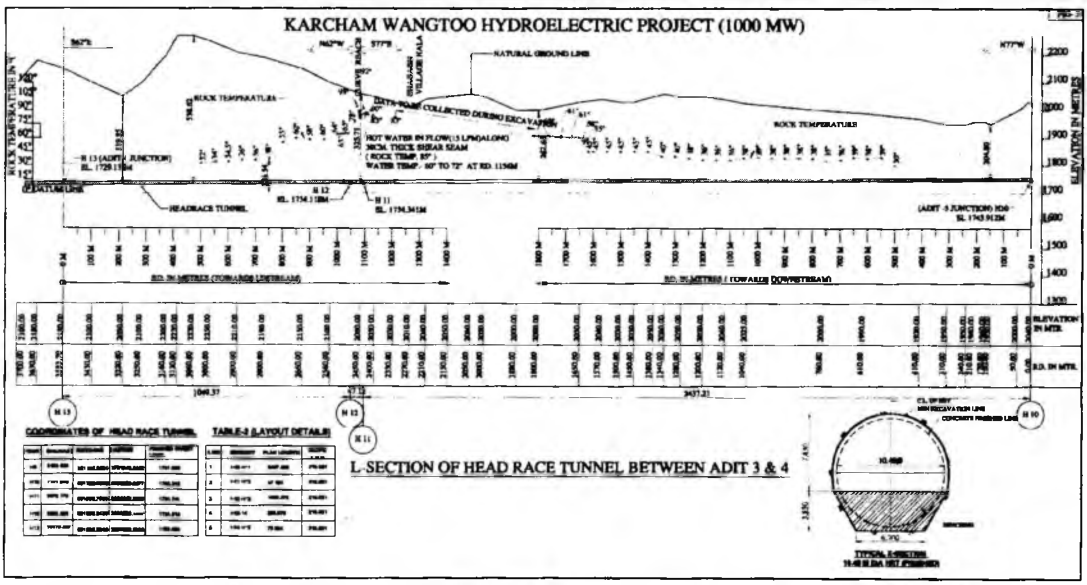


Fig. 5

Analysis of the Observations & Suggested Method of Excavation

It can be seen from Table-1 that the Nonel Detonators could not detonate even upto a temperature of 80°C. However, it detonated when it received blazing fire. The exact response of the detonator, when placed inside the hole, where there is an accumulation of temperature and pressure under confinement is not precisely known.

Henceforth, it is not advisable to insert the detonator inside the hot holes. Similar is the case with explosive (emulsion) and detonating cord. During the burning of the explosive, there is a continuous release of its energy to the atmosphere and, as such,

Table 1: Test results of explosive and accessories

Sl. No.	Material tested	Approx temp in °C	Procedure of testing	Results
1.	Nonel detonator	60	Heating of water with the help of immersion rod in a steel tub	No detonation, heating continued for 30 minutes.
2.	Nonel detonator	80	Heating of water with the help of immersion rod in a steel tub	No detonation, heating continued for 45 minutes.
3.	Emulsion explosives (40mm dia)	90-100	Heating of water with the help of immersion rod in a steel tub	No detonation.
4.	Nonel detonator	More than 200	Detonator exposed to a blazing fire by burning dry wood after spraying liquid petrol over it. The distance between the wooden material and detonator was less than 5 cm.	The detonator got fired immediately when received the blazing fire.
5.	Emulsion explosives (40mm dia)	60	Heating of water with the help of immersion rod in a steel tub	No detonation.
6.	Emulsion explosives (40mm dia)	100	Heating of water with the help of immersion rod in a steel tub	No detonation.
7.	Emulsion explosives (40mm dia)	More than 200	Explosive cartridge along with detonating cord was exposed to blazing fire by burning dry wood. The cartridge was just in touch with fire.	Explosive and D-cord burnt completely, No detonation.

it does not produce confinement/ pressure accumulation. As per the Directorate General of Mine Safety regulation, blast holes having temperature above 80°C should not be charged and detonator should not be placed inside the blast holes. For this reason, It was instructed at the site that a prolonged quenching of blast holes with chilled water is to be done to lower down the temperature well below 80°C and in reality it was done during the visit.

It may be pointed out here that the most vulnerable part of the blasting sub-system in any underground excavation is the detonator, the behaviour of which is exactly not known to us. With this limitation in hand, it was proposed to advance the excavation work in the following sequences:

a) Initially, a pilot blast (approx 3x4m^2) should be advanced first using the blast pattern shown in Fig. 6 with a maximum hole depth of 2 m. The limited depth of 2 m was advised only to relinquish the charging time within a short span of time (30-40 minutes).

b) Before conducting the widening blast, the blast holes/ existing tunnel face should be treated with chilled water to drop down the temperature below 80°C.

c) Charging and firing of remaining portion (other than pilot blast) within short time to avoid any immature detonation.

d) The pilot blast was to be conducted as per the cut hole pattern shown in Fig.7.

e) The periphery holes are to be drilled at 30 cm spacing c/c and alternate holes are to be charged. It was specifically proposed to release temperature from dummy holes, in a case, when adjoining holes have been charged.

f) Complete charging & firing of widening blast within 45 minutes to avoid any deflagration & immature detonation.

g) No placement of detonator within the holes. Only detonating cord is to be connected for the corresponding rows/ delays. The nonel detonators of required number are to be tied on the surface of the tunnel face (Fig. 7) with the detonating cord surrounded by moist/ chilled cotton so as to restrict the temperature within the acceptable range.

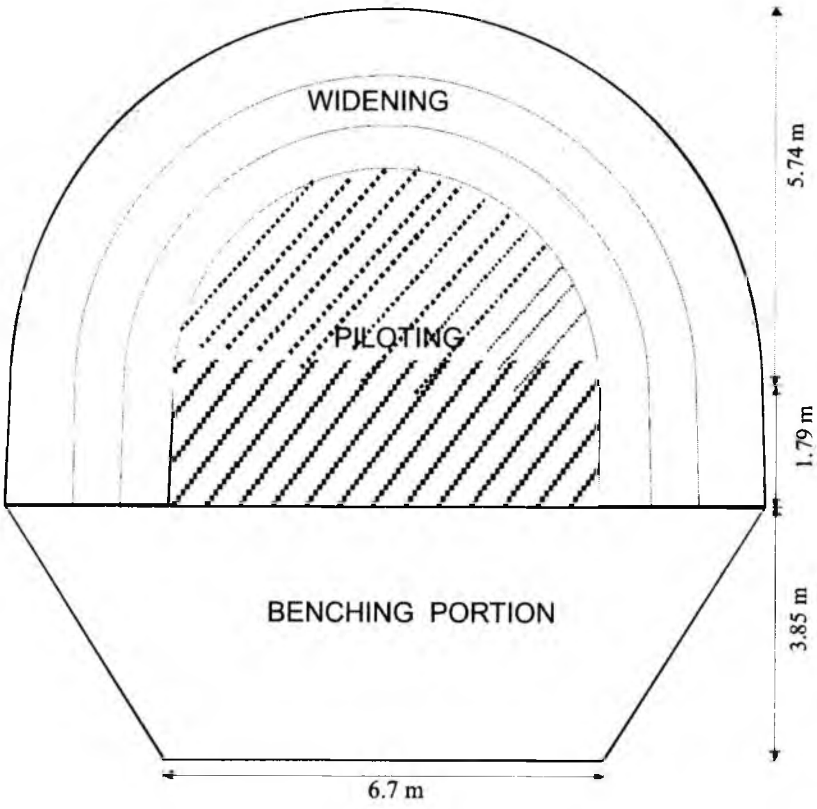
h) The excavation work was advised to proceed with limited depth (not more than 2 m) with piloting and widening sequence method of advance so as to finish the task in quick/safe span of time. Such a sequence of excavation would definitely bring down the progress of the work, but with an element of safety, considering the temperature threat of the nature.

i) Full face blasting, while placing the detonator inside the hole, can be done only when the entire temperature of the face comes down below 60^0 C.

j) No electric detonator can be used until the temperature becomes normal.

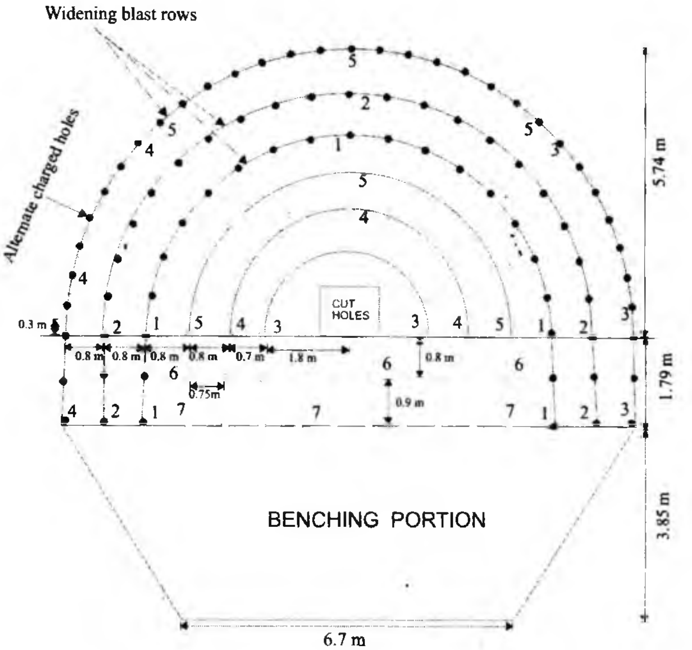
Conclusions and Recommendations

1. Charging should be done quickly using detonating cord and the concerned delay numbers as shown in Fig.7.
2. The delay detonators should not at all be placed inside the holes unless the temperature of the tunnel face becomes normal.



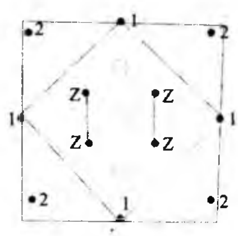
Long probing holes of 45 mm dia, of about 50 m depth suggested to be upto 76 mm for at least 6 an depth for maximum release of temperature.

Fig. 6: Sequences of excavation of Adit-4 (upstream) HRT.



Note:

Depth of hole = 2 m
Delays Z- 5& 6, 7 = Ist Stage (Pilot blast)
Delays 1 - 2 = 2nd Stage (Widening blast)
Delays 3, 4 & 5 = alternate hole to be charged(periphery)
Explosive in periphery holes = 0.385 kg (1 cartridge) of 40 mm dia.
Explosive in other holes = 0.67 kg (2 cartridges) of 40 mm dia.
Deck charging should not be done to save time



CUT HOLES

Fig. 7: Drilling and firing pattern of adit-4 (upstream) HRT

3. Only nonel detonators are to be used in blasting operations and they should be tied-up on the tunnel face with detonating cord for the corresponding sequences of initiation as shown in Fig. 7.

4. The detonator should be rapped by moist cotton so that the temperature of the detonator does not exceed the critical limit.

5. Under the threat of the nature, it is not wise to expect a high rate of advance at the Adit-4 (U/S), it is always desirable to move safely and slowly in tune with the nature's recommendation.

6. At any place where ever the overburden exceeds 300m, the problem of rock burst can not be overlooked. There is an evidence of such problem at Dul Hasti

Hydro Electric Project where the rock burst phenomena was very common, when depth of cover exceeded 300 m. It was only the thick quartzite band (thickness more than 0.8 m) from which the rock burst phenomena could be observed. The burst was mainly confined at the junction of side wall and crown. Interestingly, the throw was limited, mainly confined near the side wall of the tunnel.

7. A rock burst is a spontaneous, violent fracture of rock that can occur in deep mines. The opening of a mine shaft relieves neighboring rocks of tremendous pressure, which can literally cause the rock to explode as it attempts to re-establish equilibrium. Rock bursts are a serious hazard; in South Africa, they kill roughly 20 miners each year.

8. It is highly recommended in such cases for every human being, executives and VIPs to maintain their position at the centre line of the tunnel mainly, if they visit the tunnel.

References

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