Role of geotechnical instrumentation in construction stage of Hydro project – a case study (Rampur HPS 412 MW)

Chadha, A.K.
Chief General Manager (Geology) SJVN Limited, Shimla, India
Dutt, Mahesh
Manager (Geology) SJVN Limited, Shimla, India
Kumar, Ajay
Deputy Manager (Geology) SJVN Limited, Shimla, India
Devi, Sudha
Deputy Manager (Geology) SJVN Limited, Rampur HPS, Shimla, India
Badoni, Brijesh
Deputy Manager (Geology) SJVN Limited, Shimla, India

Abstract

Geotechnical Instruments is a vital tool to ascertain the unforeseen difficulty or problems in Hydro Power Projects. Construction of Hydro power projects in the Himalayan Geology is full of challenges. Predication of tunnelling media is useful in design and construction methodology. Behaviour of rock mass in underground as well as open excavation is becomes a necessary factor to ensure safe and hazard free environment for worker. Timely prediction of unfavourable condition not only helps to achieve the milestone but also save money and life of the people.

Rampur Hydro Power Station of 412 MW installed capacity is located on River Satluj, a major tributary of Indus basin, in Shimla and Kullu district of Himachal Pradesh in North India. The plant is designed in tandem with run of the river plant Nathpa Jhakri (1500 MW). Survey and investigation of the project completed in the year of 2004. After the techno economic clearance in Dec 2005, the construction started in Feb 2007. After the seven years of construction period, the project commissioned in May 2014. By December 2014, all the six units were synchronized with the Northern power grid and added 412 MW to the nation. The project comprised of 15.117km head race tunnel, 162.5m deep surge shaft open to sky, a Multifunction , three pressure shafts, Power house, collection Gallery and outfall channel. During construction of tunnel, Power House, collection gallery /TRT many problems were faced which were tackled as these are being assessed with the regular monitoring of geotechnical instrumentation.

The present paper focus on type of instruments installed at various project components, and their role to forecast the instability during the actual execution of the project, safe work environment and inputs for design as per behaviour of rock mass during the construction of Rampur HPS (412 MW).

1. Introduction:

Hydro power is neat and clean energy but the development of the hydro power projects is full of challenges. Construction of the hydro power projects are time taking. Underground excavation works are full of risks, a small collapse/rock bursting can endangered life of people and also affect the cost of the project. In Rampur project we able to provide safe work environment by proper checking and monitoring process through instrumentation and visually.

Geotechnical instruments are the instruments which used to know the dynamic behaviour of sub surface strata. To ensure Hazards free work environment at project site Geotechnical Instrumentation is necessary. In underground or open excavation stability of slopes and behaviour of underground rock mass became a major parameter to plan the construction methodology, which can only be ensured by measuring the stresses through instrumentation.

Rampur HPS lies in lesser Himalayan zone. It comprised of 15.117km head race tunnel which was excavated through five adits ,162.5m deep surge shaft open to sky, a Multi junction, three pressure shafts, Power house, collection Gallery and outfall channel. The construction phase of the project was full of challenges. Excavation of project components have been face many Geological challenges like squeezing condition in tunnel, Collapse of southern wall of Power house , Collapse of collection gallery , Slide of northern slope of outfall area, Slide of surge shaft slope. But in all these adversities we were successful to save our man power and machinery. In this paper we will discuss on few cases where Geotechnical instrumentation helps us to predict the unforeseen adversities.

2. Geology of the Project area:

The project is located in lesser Himalayan zone, characterised by rugged topography with lofty hills. The Geological exploration/ investigation of Rampur HPS project was carried out by Geological Survey of India Northern Wing GSI and established that the rock formation of the project area belongs to Precambrian age. There is no major fault or folds in the area but due to local fold and fault the strata is disturbed at many places. In general the Rampur group is sandwiched between older Jeori-Wangtu-Gneiss Complex (JWGC) and Kullu group with thrusted contacts and gentle to steeper dips (20^0 to 73^0).

The lithology of surge shaft is and pressure shaft is Quartzite, Mica schist, amphibolites .The main discontinuity was foliation which was dipping in the NNW direction with angle 28-35 degree. The Power House area was excavated in Phyllites of different grades i.e. carbonaceous Phyllites and ferruginous phyllite with clay coated / infillings along the foliation plane and thinly laminated. At many location the localized warping introduced by crushed Quartz veins in scattered manner and some veins are in boudin shape. Due to highly foliated, clay rich the carbonaceous phyllite when came in contact with water loses its strength and was difficult to excavate.

3. Geotechnical Instrumentation in RHPS:

In Rampur project both underground and open excavation was involved, different types of Geotechnical instruments were installed to monitor dynamic behaviour of rock mass in open &underground during construction stage. Head race tunnel was monitored with Rib Load cell, Bi-reflex Paper Target and Inclinometer. The area around Power House was monitored with MPBX, Inclinometer, Anchor bolt Load cell, Strain bar, Stress Cell, Peizometer and Bi-reflex Paper target. The types of instruments installed in different components are given in Table 1.

Table 1
The types of instruments were installed in different components of Rampur HPS during construction stage of project

Sr. No.	Instrument Name	Parameter measured	Location
1	Multiple Point Borehole Extensometer (MPBX)	Deformation, Settlement	Power House and back slopes
2	Piezometer	Pore pressure	Surge shaft to Power House
3	Inclinometer	Lateral displacement	Surge shaft and Power House back slopes
4	Strain bar	Joint opening	Structural joints
5	Stress cell	Stress between rock and concrete	Collection Gallery and South slopes
6	Rib load cell	Load from the rock cover , deformation	Head race tunnel
7	Anchor bolt load cell (ABLC)	Load in anchor head	Power House and back slopes

3.1 Role of Geotechnical Instrumentation:

The stress adjustment during the underground excavation is always expected, but by calculating the scale of it we can plan and mitigate the impact of any adversities. In Rampur project instrumentation data helped us to save the time and life of people in some major slide and tunnel collapse.

3.2 Squeezing condition in tunnel:

Tunnelling in Rampur Project was done through different rock types like Quartzite, Phyllites and Amphibolites. Squeezing problem was faced at some reaches in Kunni, Goshai and Baeladit. Squeezing is the movement of the rock mass inward the tunnel (design) perimeter. In HRT Bael U/S, squeezing condition encountered in almost 200mtr reach i.e. 750m-950m. The reach was monitored with the help of bi-reflex target and rib load cells.

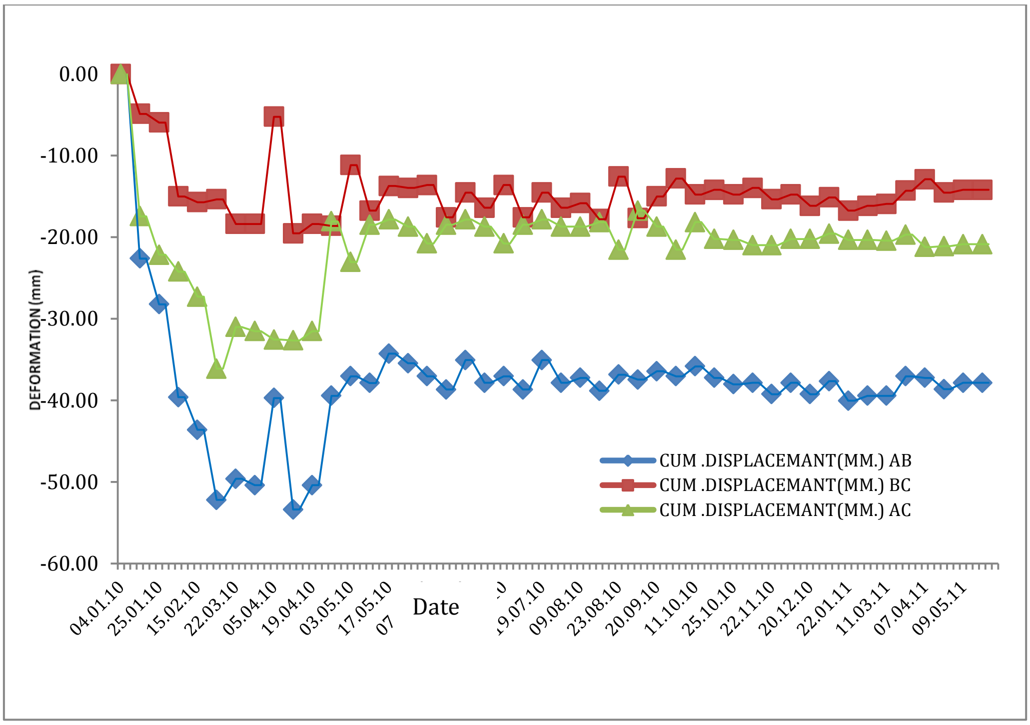

Figure 1 Time vs Def. Graph of target at RD-750.10m, U/S HRT, Bael, RHEP

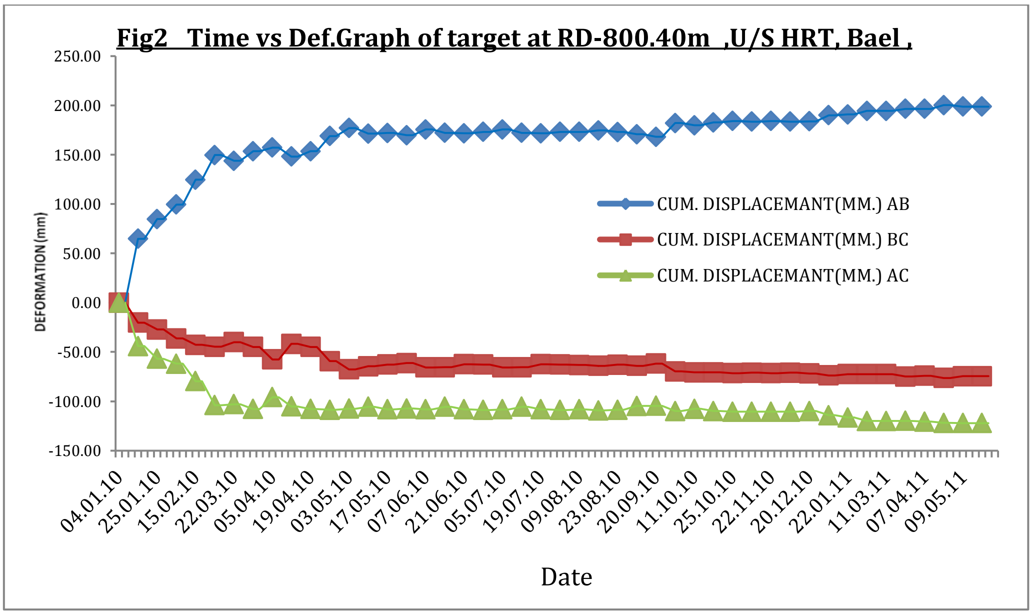

Figure 2 Time vs Def. Graph of target at RD-800.40m, U/S HRT, Bael, RHEP

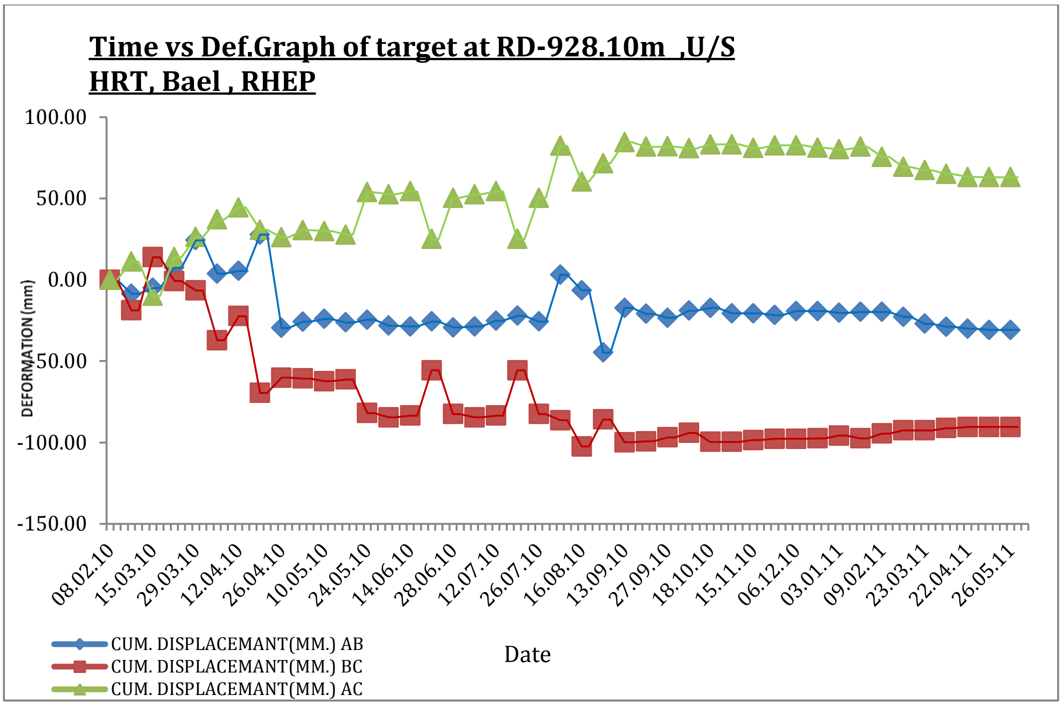

Figure 3 Time vs Def. Graph of target at RD - 928.10m, U/S HRT, Bael, RHEP

U/S HRT Bael was 1900m in length and movement observed between Rd 750-950m, after that almost 1000m tunnel was to be excavated. Heading excavation was u/s of this portion, any adversities between these RD's might be hampered the work and also result causality or fatal accidents. In this reach, a continuous movement inferred from bi-reflex target data shown in the *Figure 1 to Figure 3* at different RD's. The same was confirmed by twisting of steel ribs and detachment of steel lagging.

Precautionary measure taken:

- With the help of the instrumentation data extra/Vertical truss was provided where deformation was continued.
- Rib of 200x200 ISHB was installed instead of 150x150 ISHB, where the same strata encountered in u/s.
- The excavation methodology changed for benching, this reach was benched down in phases, 2m down for 10mtr length at right side then at left side.
- Before benching between 750m-950m, the benching and kerb concrete was completed u/s of this reach.
- Benching done with hydraulic hammer/excavator and avoided by drill blast method particular in deformed reaches.

With the help of instruments data we able to manage/plan our activities and resources and achieved asking rate.

3.3 Northern slope collapse of outfall channel:

Total length of Outfall structure is 133.19 m from outlet portal of TRT to River Satluj. It was excavated in carbonaceous and ferruginous phyllite with clay coated / infillings along the foliations and plane along with Quartz veins. Rock was dipping into the hill in NNE to NNW direction at an angle of 50^0-60^0.The construction of the outfall structure from RD 37 m (TRT gate) to RD 47 m was in progress. The invert of the outfall channel was at El 859m; at right side of it approach road to Power house was at Elevation 880m.Above the road the slope consisting of RBM was protected with RCC cladding wall (Photo 1).

Photograph 1 depicting the Northern slope of outfall channel

Photograph 2 shows instruments installed at slope.
Above & below the Power house road EL880 m

Cutting of the northern slope below the road (880m) was done in steps. After the completion of the excavation work reinforced wall casting was in progress. (photo1). The instruments were installed well before the excavation activities .Slope above the road 880 m was being monitored regularly with bi-reflex target, Inclinometer and anchor bolt load cell (photo 2).When excavation started little movement observed in the inclinometer reading and bi-reflex data in southern direction (table 1),but increased with time and as excavation progressed (fig 4)

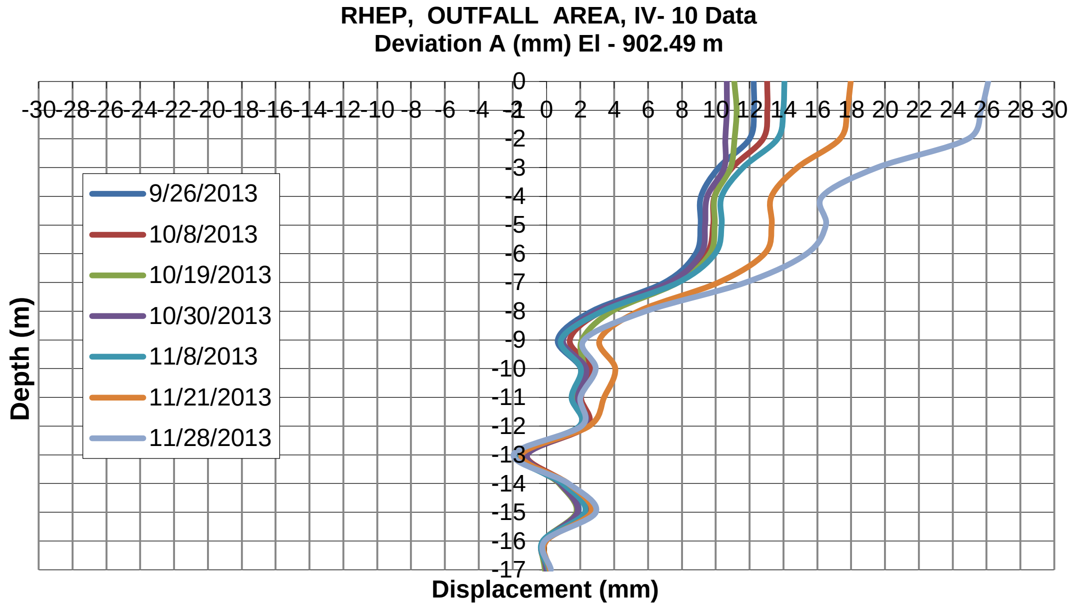

Figure 4 Inclinometer data showing continuous movement in southern direction.

Table 1
Bi-reflex target data, installed on northern slope of outfall

Target No.	R.D.(m)	Installation date	RELATIVE diff(mm) from 27.11.13 to 28.11.13			Cumulative since installation		
			N. (DIFF.)	E. (DIFF.)	EL. (DIFF.)	N. (DIFF.)	E. (DIFF.)	EL. (DIFF.)
1	61.5m	11.1.13	-17	27	-14	-78	11	-22
2	70.1m	11.1.13	-48	18	-12	-149	6	-18
3	80.5m	24.9.13	-12	7	-28	-69	8	-58
4	92.8m	24.9.13	-49	0	-25	-103	-1	-56
5	53.5	11.1.13	-14	-4	-10	-48	0	-42
6	66.2m	11.1.13	-25	7	-26	-61	10	-45
7	84.5m	11.1.13	-49	1	-36	-157	-10	-64
8	98.1m	11.1.13	-48	4	-28	-160	-10	-59
9	107.1	11.1.13	-35	5	-44	-153	-32	-63
10	65m	24.9.13	-43	3	-13	-87	0	-27

Precautionary measure taken:

- On 28.11.13 the reading taken shown drastic change, as seen in Fig 4 and table 1, the same was conveyed to contactor and supervisor of the site.
- Surface cracks were also appeared at the road (El 880m). The labour working at raft of outfall channel was taken off from there and adjoining reaches.
- Machinery also moved to safer area.
- Route to Power house was also diverted, and road seized to transport and pedestrian.
- All the precautionary action taken well before the collapse of the slope on same day around 1:40 pm.

It is important to mention that about 50 workers, two excavators & twin cutter were evacuated before the collapse, keeping in view the safety and collapse took place. The photo 3 & 4 depicting the area before & after slide, as well as extent of slide.

Photograph 3 Before slide

Photograph 4 After slide

The instrumentation done in whole HRT, surge shaft slope, Power house and collection gallery. Data interpretation & its analysis always helped us to manage resources to tackle different challenges and to provide safe work environment for people.

4. Conclusions:

1) By proper monitoring of structure, analysis of instrumentation data and coordinating with working agencies we can save the life of the people working over there.
2) It may interpreted from the above case history that instrumentation is useful during construction stage of the project ,with disciplined and ethical of instrumentation we can minimise the impact of any adversities.
3) Cost of the Geotechnical Instrumentation is negligible as compared to the cost of the project but its use can be more in terms of cost.
4) Result may be obtained by regular monitoring and correlation of data with the construction activities.
5) It is mentioned that construction department should take seriously about the instrumentation work.

5. References:

1. Geotechnical reports (Unpublished) of RHEP-412 MW, SJVN Limited.
2. DPR, Rampur HEP.
3. Various instrumentation reports, RHPS.