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Effect of Installing Monobars in Stability of Powerhouse Cavern Roof in Masjed - Soleiman Power Plant Extension

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EFFECT OF INSTALLING MONOBARS IN STABILITY OF POWERHOUSE CAVERN ROOF IN MASJED - SOLEIMAN POWER PLANT EXTENSION

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ABSTRACT

Masjed-e-Soleiman Dam and Hydroelectric Power plant (170 high rock fill dam with capacity of 2000 MW) is located about 25 Km. to the north east of Masjed-e-Soleiman (Southwestern Iran) on Karun river. The powerhouse cavern is an underground structure, consisting of eight 250 MW power units (4 units each for phase 1 and extension phase). Overburden of powerhouse is 250-320 meters. The first step of project (that is a Dam with supply 1000 MW electricity), has been completed recently. In order to ensure the stability of roof of the extension p.h. cavern, dywidag brand monobars (15 or 20 m. long) with working load of 624 KN have been used. In this paper, the geological condition , rock support measures and the method statement of opening and sequences of excavation for the extension powerhouse cavern, analysis the impact of installation of monobars on cavern roof stability (on the basis of the instrumentation results) have been discussed briefly.

INTRUDUCTION

Masjed Soleiman hydroelectric power plant extension with capacity of 1000 MW is located at the distance of 25 kilometres towards the north east of Masjed Soleiman city in south of IRAN. This project (currently under construction) is an extension to already completed phase 1 powerhouse of 1000 MW power supply capacity. Powerhouse cavern is a space with dimension of 112 lengths, 30 widths and 51 heights. (Figure 1). Excavation of the extension project cavern started when for phase 1 p.h.c (which is in line with extension's cavern) testing and commissioning stages of its first turbine, Was in progress. After the excavation of extension roof cavern and based on data gathered from result of stability and instrumentation of phase one cavern, the installation of monobars in the roof cavern was deemed necessary and was therefore put in order.

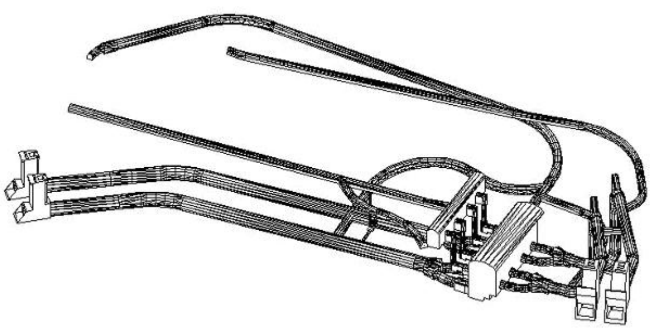

Fig.1: view of Masjed Soleiman hydroelectric power plant extension

GEOLOGY

The hydroelectric power plant is mainly located in Bakhtyari formation. The rock types of this formation are mostly conglomerate, sandstone, siltstone and claystone.

The powerhouse cavern is situated in intercalations of the said rock types, of different thickness. From geotechnical point of view, the rocks in this area may be divided into two groups. The first type consists of strong sedimentary rocks such as conglomerate and sandstone with good cementation and the second type contains fine grained rocks or mudstones(siltstone and claystone), which are mostly weak and prone to disintegration. In addition to these two types, there are layers which may be categorized as moderate rock. One of the major phenomenons, which can be considered as a type of sliding in fine sedimentary rocks, is the slickenside phenomenon. This phenomenon is directly related to the rate of moisture absorption and plasticity index of rock. As moisture in such material increases they will slide on that level and slickenside occurs. This occurrence has been encountered in claystone of the cavern roof (a least on three levels), which are branches-out locally.

A geological section of the powerhouse cavern is shown in the Figure. 2.

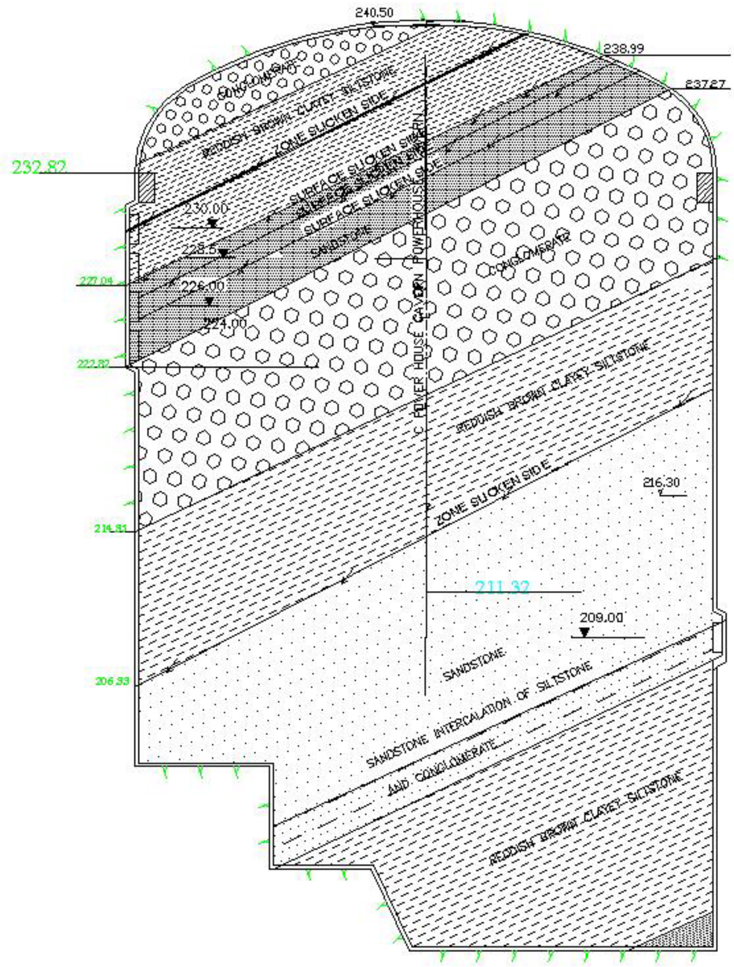

Fig.2: A view of geological cross section in power house cavern.

ROCK SUPPORT MEASURES

The support installed in the PHC, the roof area consisted of a double reinforced shotcrete Layer of 20 cm of thickness, and 6 m long fully grouted rock bolts with one bolt per 4 m2 and a nominal load of 100 KN combined with wedge anchors, 12 m in length, every 4 m2 with a nominal load of 200 KN. These wedge anchors were, however, only pre-stressed to 100 KN.The cavern roof has also been reinforced by 620 KN monobar. In downstream areas of the cavern axis, the monobars (20m.long) are installed on claystone in a 2m×2m grid and at upstream area, 15m. Long monobars are installed in 2.5m× 2.5m grid.

In walls, Systematic rock support measures designed and installed. For the entire powerhouse cavern walls fully grouted rock bolts 10m Long, 100 KN have been installed. Also for entire roof and walls of powerhouse cavern, two layers of wiremesh and 3 layers of shotcrete (20 cm in the thickness) have executed.

Cavern walls, where located in silty layers, have been reinforced additionally by 1400 KN tendons or 620KN monobars with lengths of 15 to 30 m.

POWERHOUSE CAVERN EXCAVATION STAGES

Excavation inside the space of powerhouse cavern has started since Feb.2000. The excavation of the underground powerhouse started with the opening of an access tunnel from the main access tunnel in elevation 223 (m.a.s.l.), in the centreline of the cavern in direction to the southern wall. The access tunnel was extended by construction of an inclined tunnel (with slope of about 15°) towards the roof from the end of the southern wall (Figure1), The tunnel reached the roof at chainage 32 in elev.235 (m.a.s.l.) and from there on excavation proceeded horizontally towards the end of the cavern (Figure 4,5) Opening of the roof has been done by slashing from both sides of the access tunnel according to Figure 3. The mucking was carried out through the main access tunnel**.** At this stage a rock pillar about 10m thick was left unexcavated between the extension cavern and phase 1 cavern so as to prevent any dangers from extension project's blasting operations to phase 1 cavern. (this pillar has been removed later in a proper time). The working face of the cavern roof was divided into upstream and downstream areas and each area has been excavated independently of the other (Figure 3 to 5) .The powerhouse bench down and reached to elevation 224.

From July to Des. 2002, progress of p.h.c. benching works has been slowed down due to installation of roof monobars , U/S and D/S walls of the cavern. The benching has continued after pre-stressing of the roof monobars. In order to expedite the excavation works, in lower area of cavern a space, half the width of the cavern in elevation 209, has been excavated at downstream area (Figure 5), by access gained through U/S manifolds. This space has been used for installation of monobars (in D/S wall and protection of siltstone layer between downstream manifolds No. 5,6 and 7, 8) , and as a route for traffic and ventilation purposes.

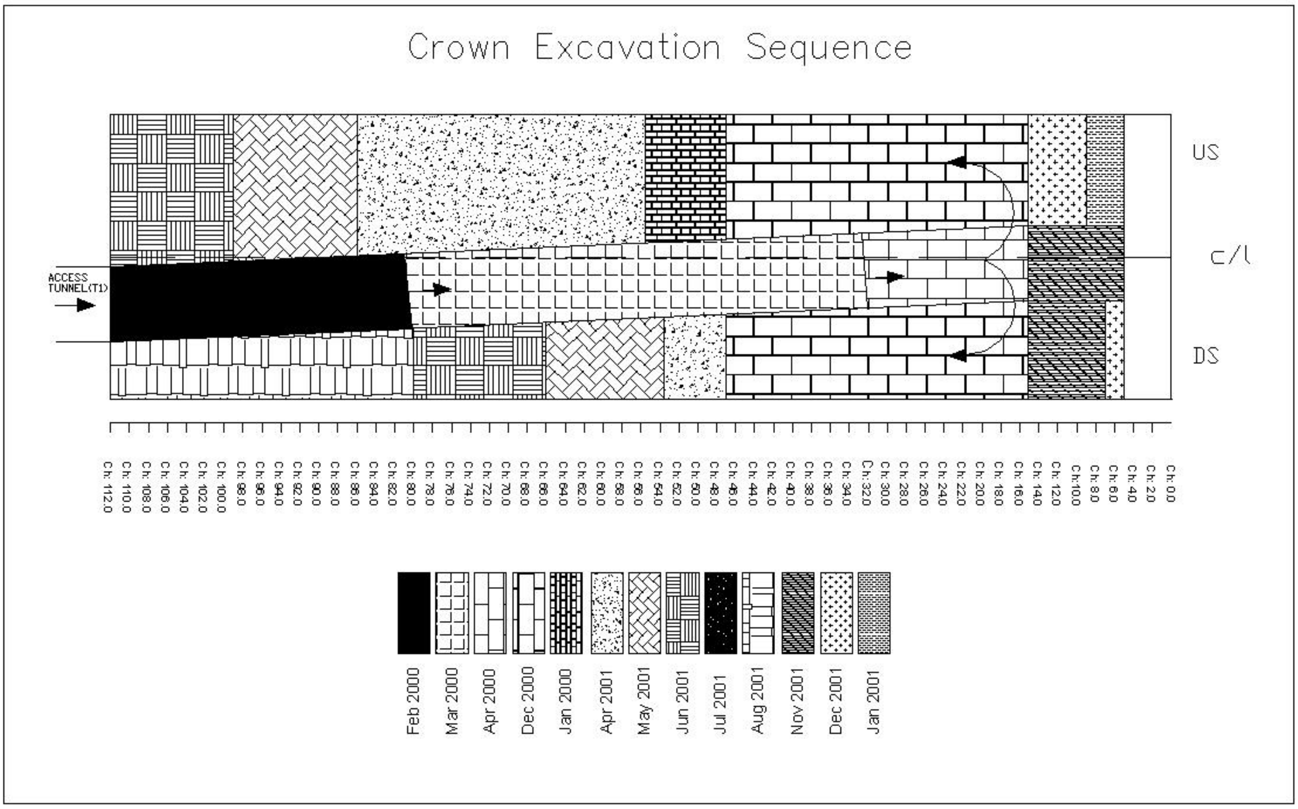

Fig. 3: view of access tunnel and excavation sequence in roof of the power house cavern

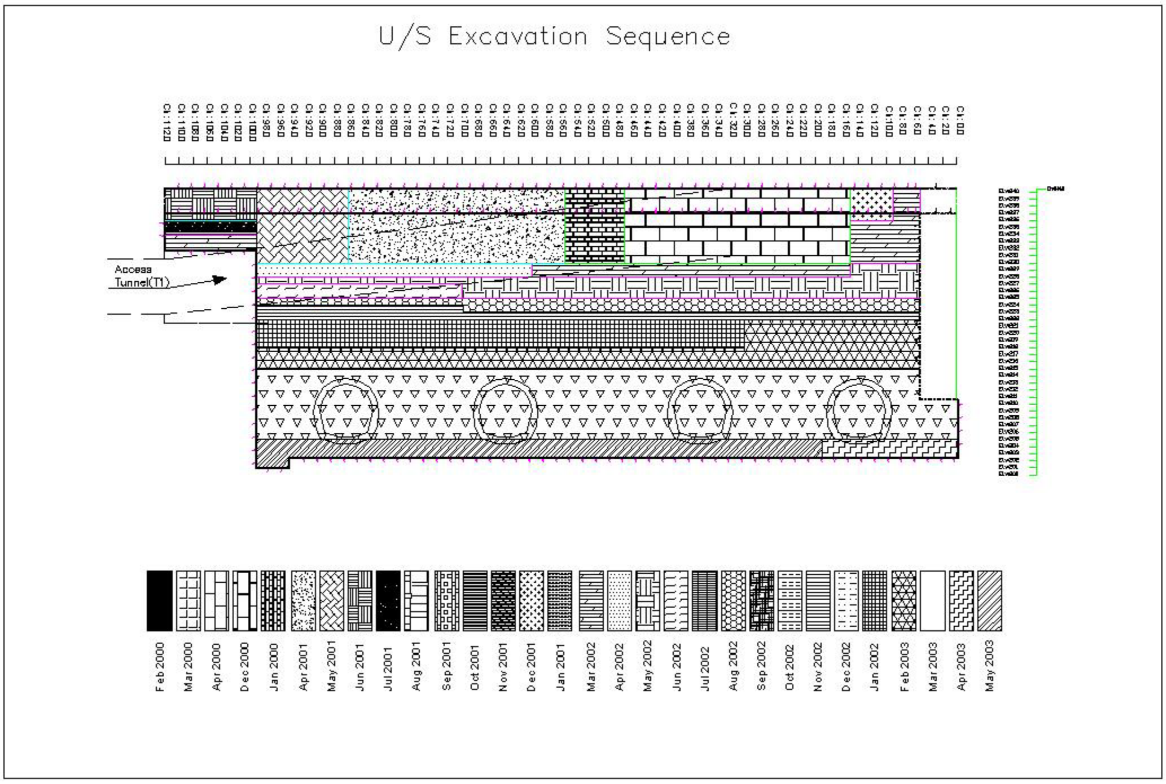

Fig.4: the schematic view of the steps for access and excavation of U/S part of the cavern

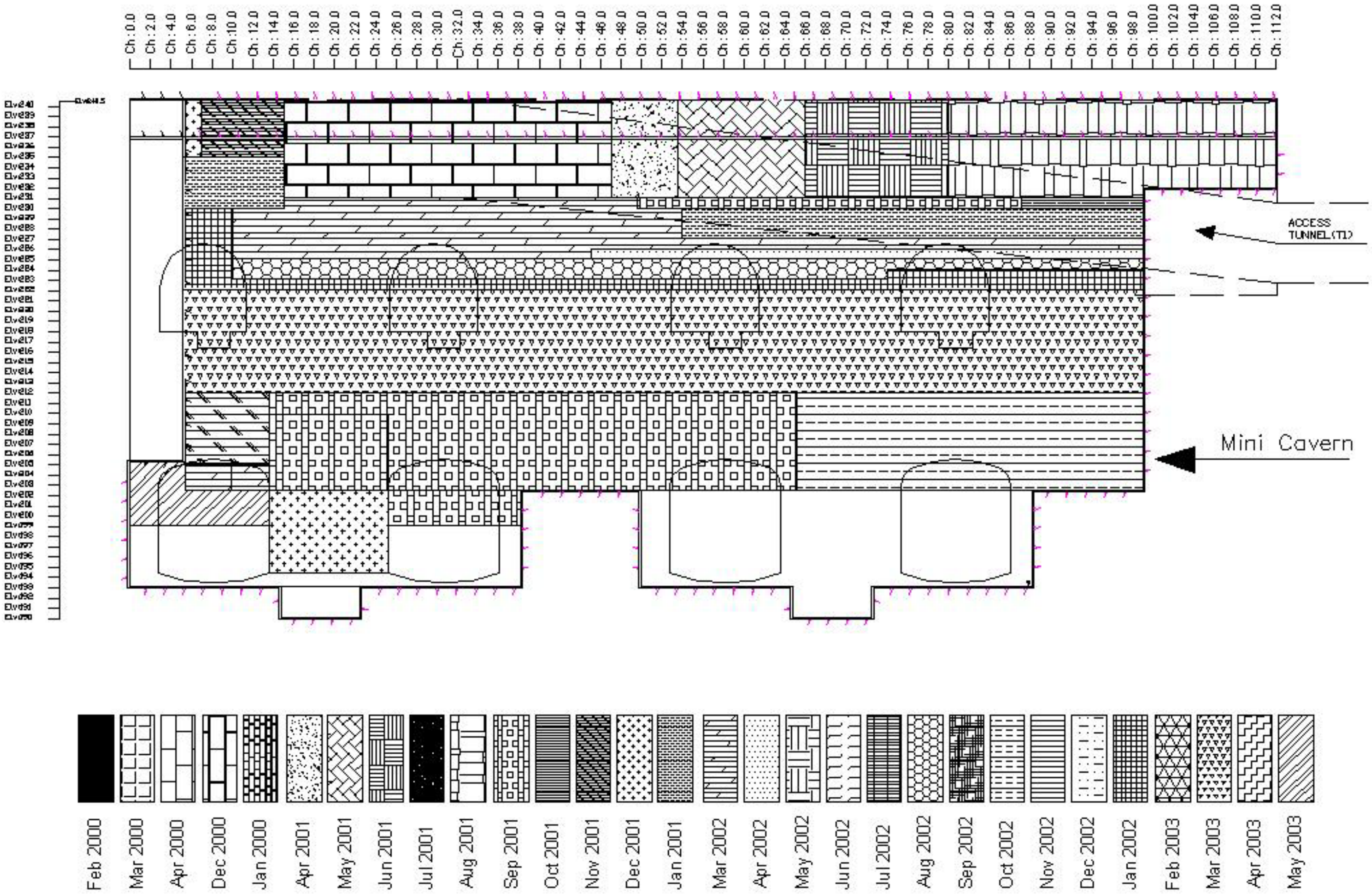

Fig.5: the schematic view of the steps for access and excavation of D/S part of the cavern

5. MONOBARS

Because of the existing claystone layer at D/S area and mudstone intercalations at U/S area of roof cavern, pursuant to analysis performed by available software, installation of 620KN monobars in the roof cavern was considered as to ensure the stability the powerhouse cavern.

As per the design, 5 rows of monobars in a 2m×2m grid and 4 rows in a 2.5m×2.5m grid were installed respectively at downstream and upstream roof areas.

The monobars are dywidag type with working load of 620 KN and locked at 400 KN and a total of 445 pieces (168 pieces of 15m long at U/S and 277 pieces of 20 m long at D/S) have been installed (Figure 6 and 7).

Since during the installation of monobars, the invert level was at EL 224 and access to cavern roof was not possible, therefore drilling, installation and pre-stressing of these monobars were carried out from the platform mounted on the temporary crane. Due to working condition and critical importance of the stability of various parts of the cavern roof, installation and pre-stressing of the monobars were carried out at 6-month of time intervals (Figure.6).

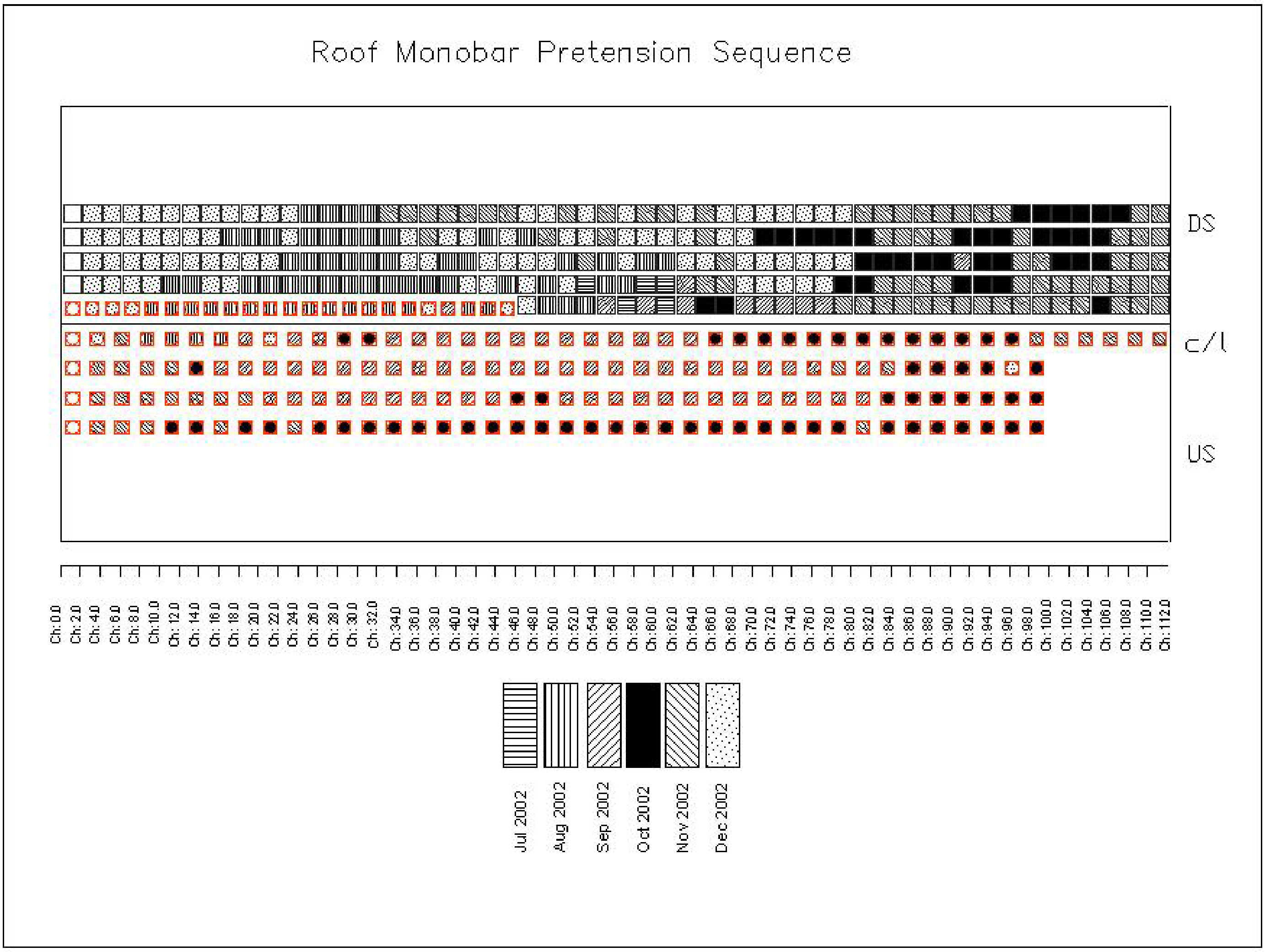

Fig.6: A view of location and sequence of pre stressing for monobars in roof of powerhouse cavern

Figure 7 shows a schematic view of the long monobars / tendons placed in the roof and walls of the p.h.c. Installation of longer monobars at D/S side(30 m)were due to presence of claystone layer in that area.

6. INSTRUMENTATION

Six rings of instrumentation have been designed for powerhouse cavern. At chainages : 8, 21,43,71,93 and 107 (Table No.1).
A set of instrumentation has been installed at three positions in the cavern roof (U/S, D/S and centre of the roof). These instrumentations consist of load cells and extensometers (Figure.8)

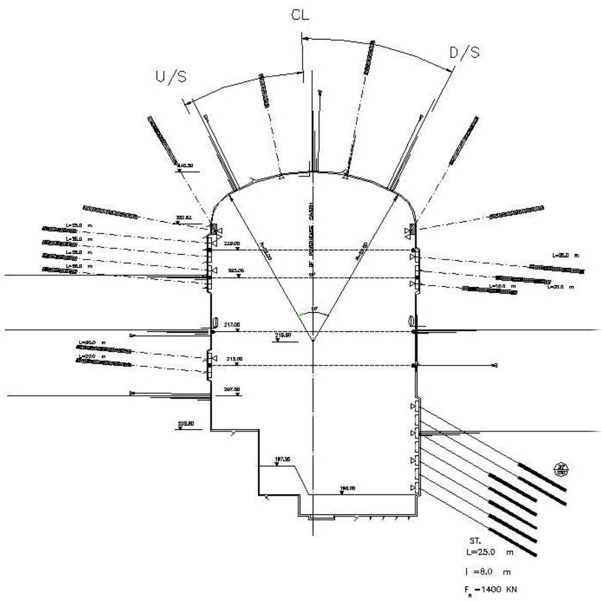

Fig.7: A view of the long monobars / tendons placed in the roof and walls of the p.h.c.

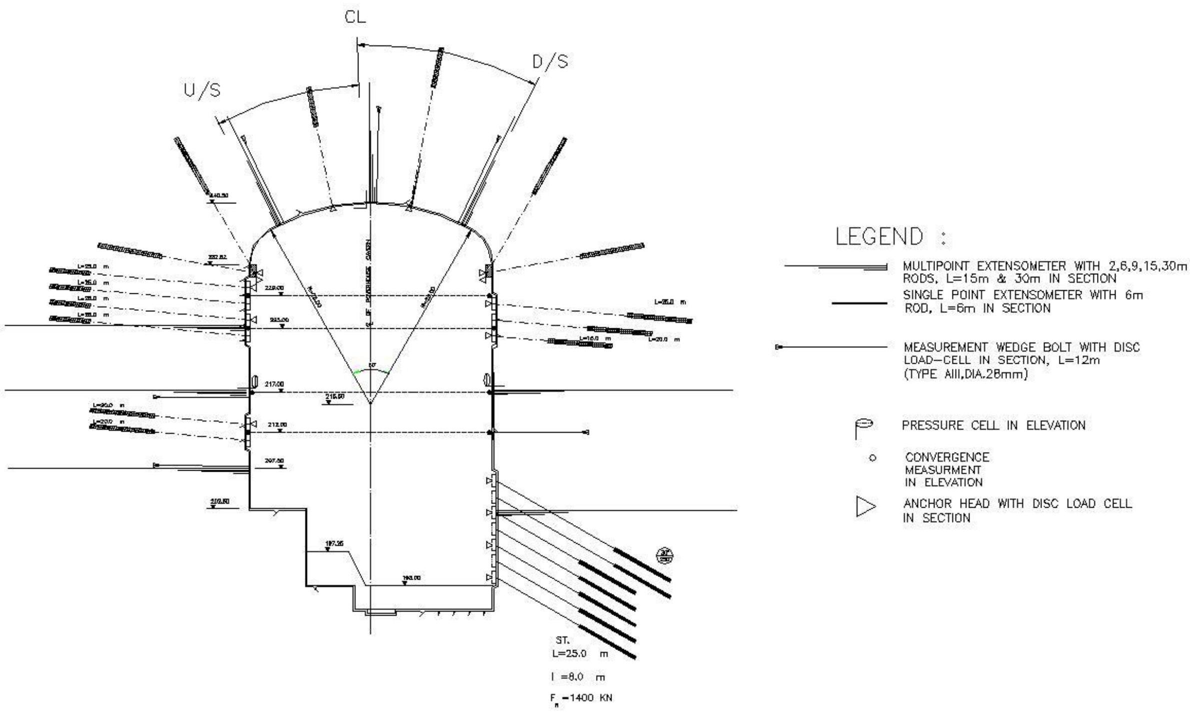

Fig.8: A view of the instrumentation of the ring at chainage 71 of extension project`s powerhouse cavern

RING NO.	Chanage(m)	Position	DATE			Total Displacement Before Installation Monobar(mm)	DISPLACEMET RATE (mm/s)		(B/A)%	COMMENT
			Blasting	Install Extensometer	Pretension Monobar		(A) Before Installation	(B) After Installation		
1	8	U/S	15-Dec-01	31-Dec-02	23-Nov-02					The Extensometer Installed After Pretention Monobar
		CL	15-Dec-01	25-Oct-02	22-Nov-02	0.09	0.003	0.002	50	
		D/S	15-Jan-01	2-Nov-02	5-Dec-02	0.35	0.013	0.001	1200	
2	21	U/S	2-Oct-00	12-Nov-00	27-Oct-02	1.5	0.001	0.001	0	
		CL	1-Apr-00	13-Nov-00	31-Jul-02	10.32	0.017	0.009	89	
		D/S	2-Oct-00	16-Jan-00	6-Dec-02	14.01	0.004	0.001	300	
3	43	U/S	8-Dec-01	17-Jan-02	1-Oct-02	4.42	0.005	0.002	150	
		CL	23-Feb-01	14-Jan-01	29-Sep-02	7.57	0.006	0.001	500	
		D/S	23-Feb-01	4-Apr-01	15-Nov-02	19.27	0.029	0.018	61	
4	71	U/S	1-Apr-01	13-Apr-01	2-Oct-02	4.47	0.004	0.002	100	
		CL	20-Jun-01	23-Jul-01	24-Sep-02	26.75	0.075	0.042	79	
		D/S	20-Jun-01	23-Jul-01	9-Dec-02	22.81	0.04	0.016	150	
5	93	U/S	7-May-01	4-Jul-02	1-Oct-02	5.49	0.003	0.002	50	
		CL	14-Sep-01	29-Jan-02	17-Oct-02	1.28	0.002	0.002	0	
		D/S	14-Sep-01	29-Jan-02	11-Nov-02	4.75	0.017	0.012	42	
6	107	U/S	9-Jun-01	25-Aug-01						There isn't monobar
		CL	15-Jun-01	25-Aug-01	14-Oct-02	24.66	0.04	0.015	167	
		D/S	23-Nov-01	21-Feb-02	27-Oct-02	3.72	0.011	0.008	38	
AVERAGE OF DISPLACEMENT RATE DECREASE(%)									186	

Table 1: Instrumentation results and impact of installation of monobars on cavern roof stability

In table No.1, the position of the roof extensometers, location of the first blasting operation and the date of pre-stressing of monobars are indicated. Also, the total dispacement measured by extensometers, prior to pre-stressing of the monobars and the percentage of increase in displacement of these instrumentations, before and after pre-stressing of monobars are listed.
It should be noted that in general the results for extensometer and load cells are compatible. As observed, following the installation and pre-stressing of the monobars, rate of increase in displacement has been reduced significantly.
As could be derived from table No.1, the ratio between the rate of increase in displacement after installation of monobars and this rate before their installation, shows that in average, the rate of increase in displacement, has decreased by 186%.
With progress of the cavern benching works and after pre-stressing of the monobars, the rate of increase in displacement had decreased considerably (Figure.9).

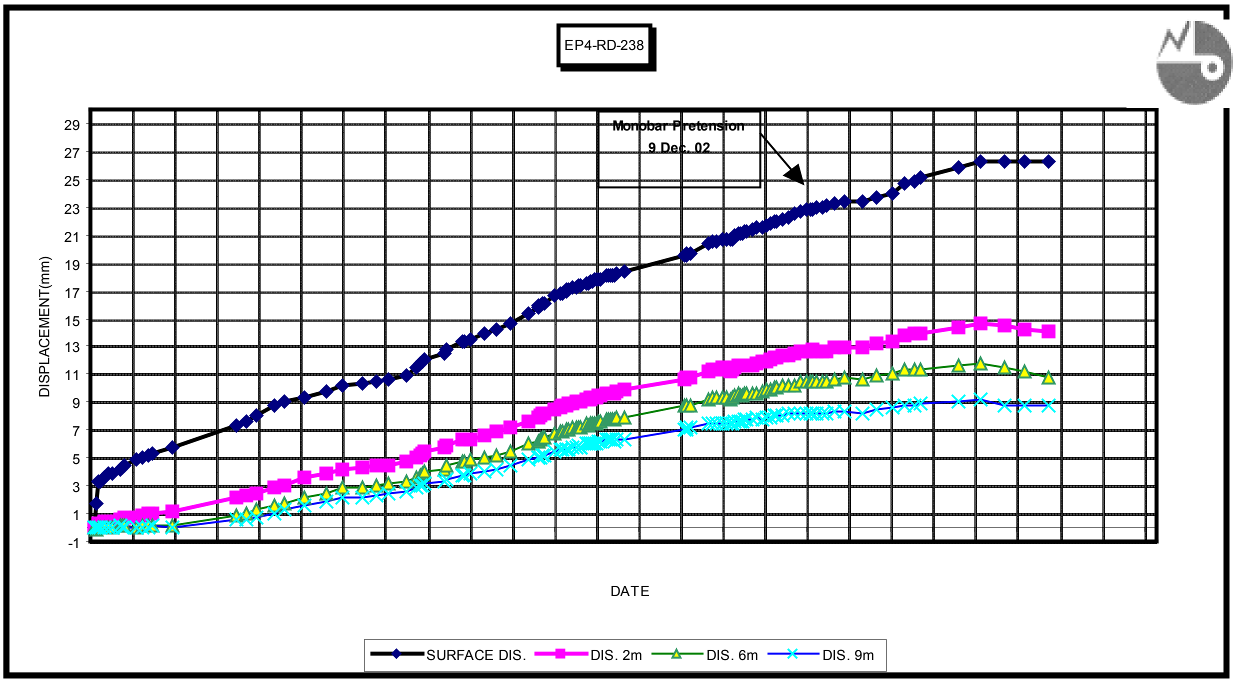

Fig.9: Extensometer curve in change 71 m in downstream roof power house cavern

MINI CAVERN

As mentioned before, in order to expedite the progress of excavation work, a space, half the width of the cavern was excavated at downstream area (Figure.4), via access from upstream manifolds. This excavated space, which was named mini cavern had been used for installation of monobars of the downstream wall and protection of the siltstone pillars between mainfolds No.5 & 6 and No.7 and 8. Since these pillars were to be preserved before benching had reached their elevation (El.209m), therefore with minicavern, the excavation of entire cavern had actually been expedited time wise.

CONCLUSION

Some conclusion has been gained through this case study like:

*Method statement of opening and excavation of this cavern from top to down, excavation of minicavern in lower part of cavern to expedite the entire works.
*Reinforcement of roof cavern to stabilize claystone layer by installing of monobars (from platform erected on crane) during excavations of powerhouse cavern
*Using of instrumentation results to determining the impact monobars installation on stability of the powerhouse cavern roof.

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