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EVALUATION OF DEFORMATION MONITORING IN POWERHOUSE CAVERN IN MASJED-SOLEIMAN DAM

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Abstract

Masjed-Soleiman Dam is located in south of Iran, 25 Km away from Masjed-Soleiman city. The underground power station, at the depth of 250m, includes a 154.5m x 30m x 43m-powerhouse cavern and a smaller size transformer cavern. To check the general stability of the cavern a series of instruments i.e. extensometers and load cells were installed as the cavern was excavated. This paper reviews the geological aspects, excavation stages, support system, and some monitoring results in the powerhouse cavern. Validation of monitoring results is evaluated and some suggestions are made for improving similar monitoring programs.

1. Introduction

In recent years construction of a number of large dams and many other small dams has been started in Iran. Masjed-Soleiman dam, which is rock fill type, is one of the big projects, located at north east of Masjed-Soleiman city. The dam is 480m long, 177m high, creating a 230 million-m3 reservoir. The underground power station, at the depth of 250m, includes a 154.5m x 30m x 43m powerhouse cavern (Fig. 1) and a smaller size transformer cavern. Four 250 MW generator units are installed in powerhouse cavern.

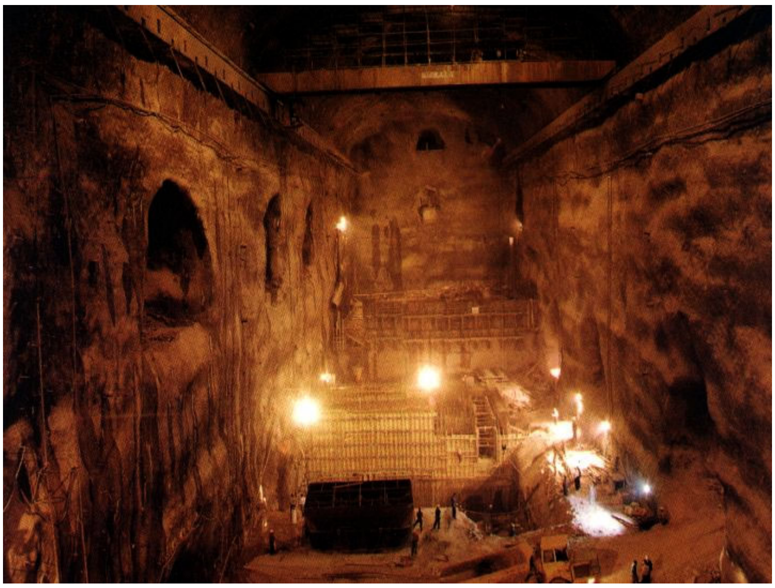

Fig. 1 General view of the powerhouse cavern during excavation

A similar underground complex is under construction, just next to the existing one, as an extension plan to increase electricity production. A complete monitoring program was executed during construction of the underground complex to measure roof and wall deformations and examine general stability of the structure. However, since this project was one of the first experiences of its kind in Iran, it suffered from some problems, which limited the applicability of the results. After describing the geological conditions and instrumentation program of the powerhouse cavern, this paper evaluates the monitoring program and results.

2. Geology of the site

The caverns were excavated in Bakhtiari Formation, mainly consisting of Conglomarate, Sandstone, Claystone and Siltstone (Fig.2). General orientation of the layers is 070/28. The caverns were excavated nearly parallel to the strike of the layers. In roof, mainly competent Conglomarate and sandstone were exposed. However, a layer of claystone was located at down stream (D/S) part of the roof, causing some instability and roof fall. Up stream (U/S) wall mainly consisted of Sandstone and Claystone. One 8m-tick Conglomarate layer was exposed at the middle of U/S wall. Conglomarate, Claystone and Sandstone could be seen in D/S wall, from top to bottom.
Two major joint sets, oriented at 063/40 and 212/19 exist in the caverns (Moshanir Lahmeyer Int.1992).

3. Cavern layout and design

Caverns dimensions were determined from dimension of the equipment i.e. the turbines, the generators and other auxiliary equipment (Moshanir Lahmeyer Int.1990). The number of generator units and space required for installation dictated the length of the powerhouse cavern. The final choice was a 30m wide, 43m high and 154.5m long powerhouse cavern and a 13.6m wide, 21m high and 110m long transformers cavern.
An access tunnel was excavated to reach the caverns location. It was devided into two to serve the different levels of the powerhaouse and transformer caverns. When the access tunnels reached the respective caverns, they were gradually elevated up to the roof level. The access was then continued to the end of the cavern. Retrieving method from back to front then excavated the roof. Benching method was used to excavate the remaining parts.

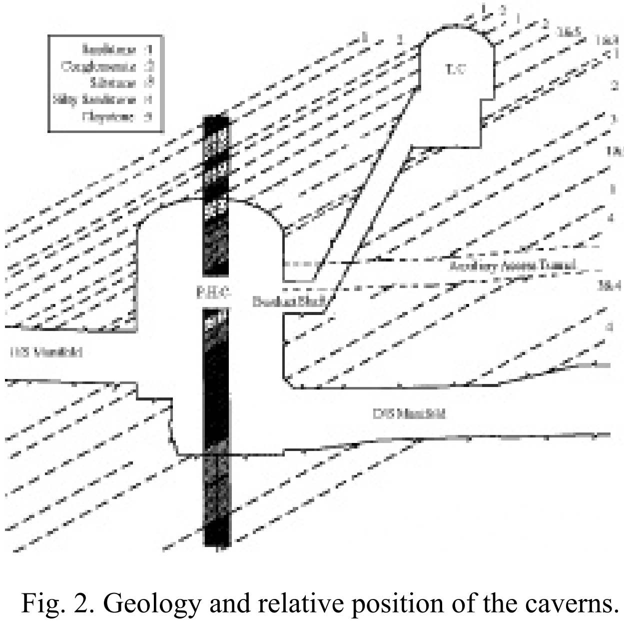

Fig. 2. Geology and relative position of the caverns.

The support was consisted of shotcerete, wire mesh, 6m and 10m long wedge anchored bolts (Pretensioned up to 100 kN), 3m to 10m grouted rock bolts and 15m to 25m double corrosion protected tendons (pretensioned up to 850 kN).
After each round of blasting, the exposed roof was immediately shortcreted. Bolt installation was sometimes delayed. Minor roof instabilities, however, appeared during the operation in Clayston and Siltstone, which were later reinforeced with additional support, especially with tendons.

4. Instrumentation program in powerhouse cavern

Four monitoring sections in the middle of the cavern, from chanage +34m to +110m where established, each contained three 15m rod extensometers and four 50 tonnes load cells in roof. Three 30m extensometers and two 50 tonnes load cells were installed at each wall in those sections (Moshanir Lahmeyer Int.1994).
In change +8m +20m +128m and +140m another configuration was used: One extensometer and four load cells of same type, in roof, at each section. In total, 16 extensometers were installed in the roof, along 3 lines parallel to cavern axis, one at centre (elevation 240.5m) and two at D/S and U/S (elevation 238.5m).
In centre line the extensometers are numbered as 1,2,3,6,9,12,15 and 16. Extensometers 3 to 12 were at middle sections. In D/S and U/S line all extensometers are at middle sections and are numbered as 5,8,11 and 14; and 4,7,10 and 13 respectively.
All extensometers had anchor points at 2m, 6m, 9m, and one anchor point at 15m or 30m.

5. Discussions: evaluation of monitoring results

In D/S, roof displacement was measured between 16.6mm and 23.8mm. The minimum of this range is for extensometer No.14 that was installed with long delay. In centre line the measured values were from 2.6mm to 23.2mm. Extensometers 6 and 16 showed large deformations. These instruments were installed in better conditions, i.e. closer to the tunnel face and in less supported area.
Roof deformation measured in U/S ranges from 3.5mm to 11.5mm. Some deep anchor points of extensometers in U/S were located in weak claystone, which resulted in loose anchorage and slipage of anchor point along the hole. Thus some of these results were obviously unreliable.
Fig. 3 shows the maximum roof displacement measured in 4 mid. monitoring sections. Measured values at D/S are higher due to the inclination direction of roof layers. As can be seen in Fig. 2 inward movement of layers in D/S, especially weak claye layer is possible and can result in more roof displacement.
In this figure it is also shown that similar deformation pattern are occurring in the cavern walls. Fig. 3 gives a picture of the wall displacement in elevation 230.5, which is at 10 meters below highest roof level. It can be seen that most extensometers in D/S wall show more displacements comparing to those of U/S wall.
One of the problems in the monitoring program of Masjed-Soleiman dam was late installation of the instruments. Due to operational difficulties and lack of enough experience of the contractor there were quite a few occasions which the extensometers were not installed on time.
Fig. 4 shows the effect of face distance at installation on maximum measured displacement of roof. Bearing in mind that the width of the opening has been about 15m (half of the width of the cavern), it can be seen that it is important to install the extensometer before the face advances about one width away from the point of installation. Obviously, within this range, the closer the extensometer is installed, the better results are obtained.
Fig. 5 depicts the effect of elapsed time between excavation and extensometer installation on maximum measured roof displacement. The effect of elapsed time was more pronounced within first four weeks. It can be noticed that time delay is less important, comparing to face effect.

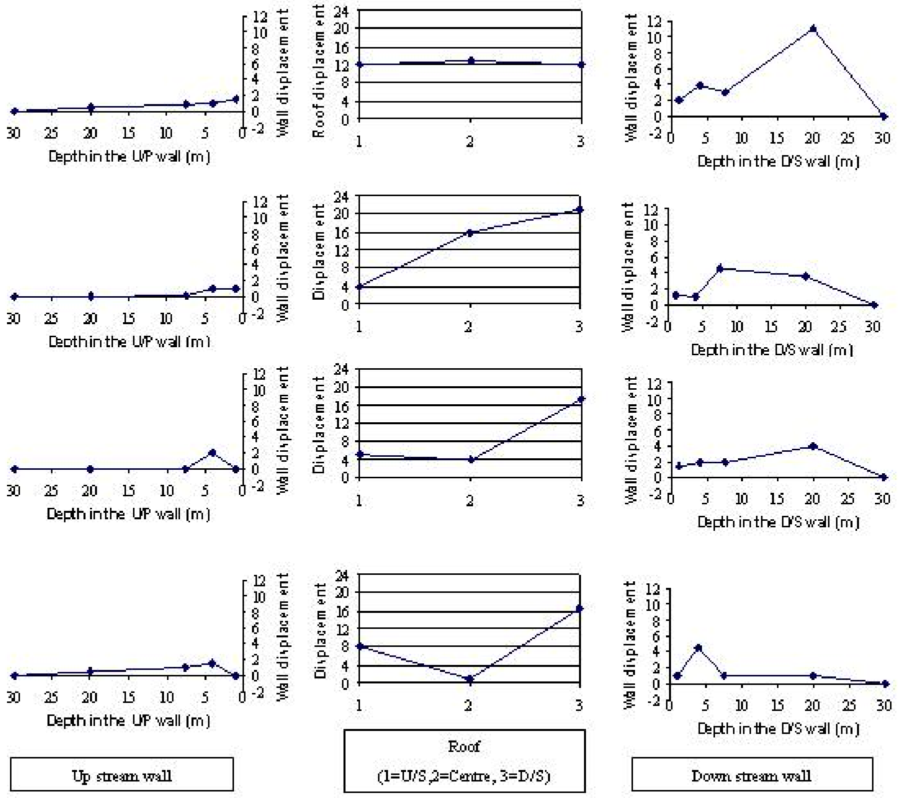

Fig. 3 Roof and wall displacement in D/S and U/P

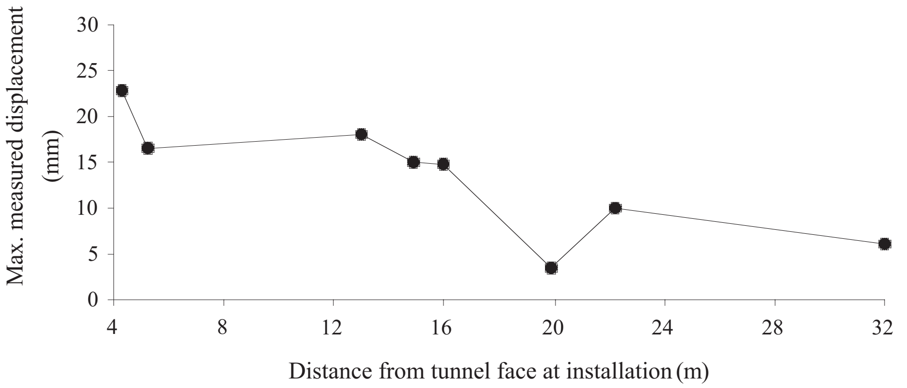

Fig. 4 Effect of face distance at installation on maximum measured displacement

Variation of maximum measured displacement with distance between last row of installed anchors and face position is shown in Fig. 6. It is understood that quick installation of the anchors could not highly affect measured roof displacement. In contrary, immediate shotcrete usually could result in better roof support.

Blasting effect should be detectable in deformation measurement results. The extensometers, which were installed closer to the face, could show this effect clearer. To establish the relationship between face distance at installation of extensometer and blasting effect measurement, roof displacement measured and immediately after first blast was judged (Jafari, A. and Ghaffarzadeh, R. 1999). Fig. 7 shows the result. It can be concluded that the instruments should be installed closer than one width (in this case about 14-15m) to the face in order to measure the deformation resulted from blasting operations.

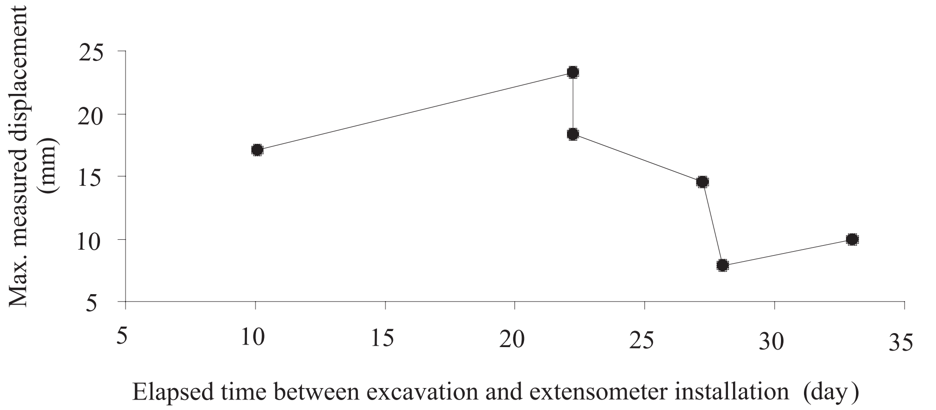

Fig. 5 Effect of time elapsed at installation on maximum measured displacement

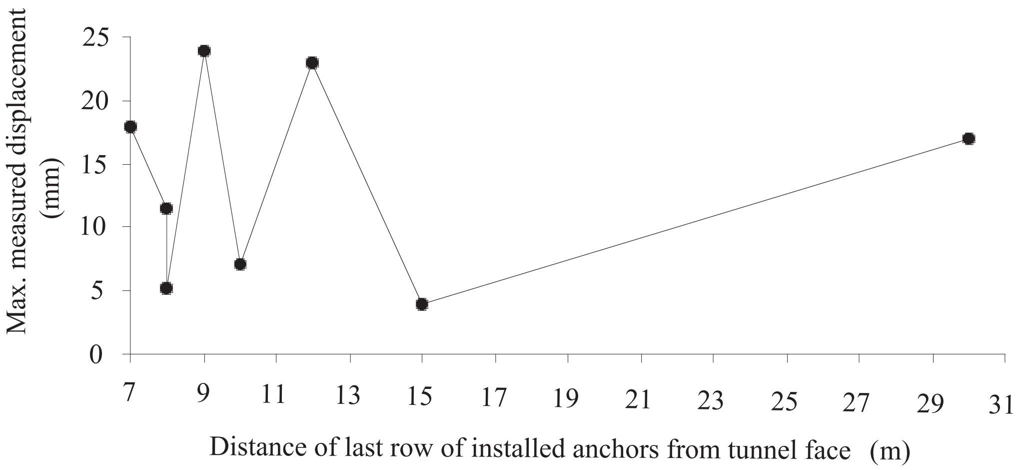

Fig. 6 Relationship between anchor installation and roof displacement

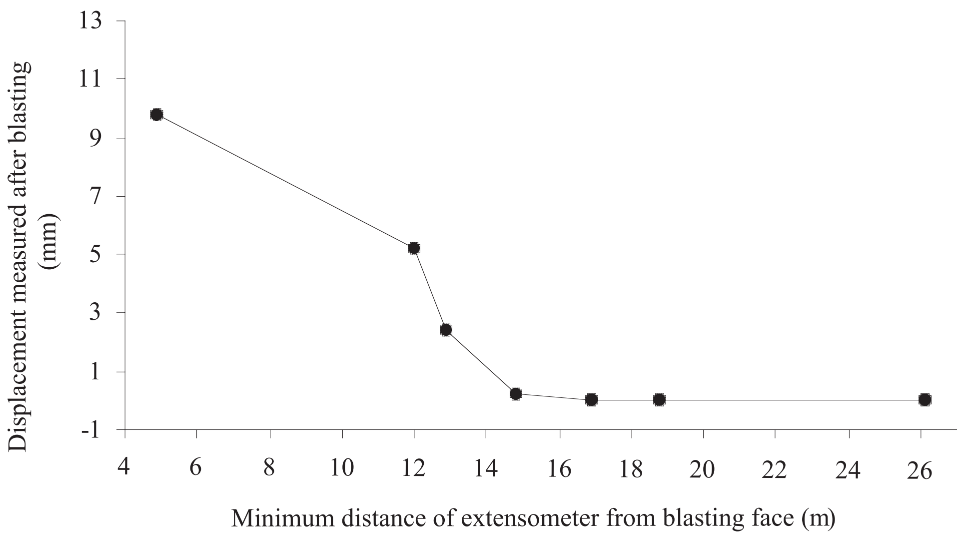

Fig. 7 Effect of face distance on measured displacement after blasting

6. Conclusions

Rock displacement in Masjed-Soleiman cavern was measured using rod extensometers. Some problems and shortcomings were found during the course of monitoring program. It was found that the extensometers should be installed as close as possible, (closer than one width), to the tunnel face to have a meaningful monitoring result. However, time delays were found to be less important.

One of the purposes of utilization extensometers is capturing the effect of blasting on rock displacement. Minimizing the face distance at installation (less than one width) is also important from this point of view.

The host rock of the anchor points of the extensometers, can affect monitoring performance. Weak rocks, especially claystone and similar type of rocks can result in anchorage loss and invalidity of measured values.

Acknowledgements

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