Rock Deformation by Extensometers for Underground Powerhouses of Sardar Sarovar Project (Gujarat)

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Abstract

Any point inside the mountain is subjected to stresses from all the directions. Excavation of any cavity like an underground powerhouse or boring of a tunnel, results in the release and readjustment of three dimensional stresses around the cavity. This results in displacements/ deformations which are time dependent. Extensometer is used to measure deformation of a section of rock mass and adjacent surrounding strata with the help of anchors at different depths. The depth of anchor varies with the type of rock strata and the location of the fixed point with respect to which the deformations are to be measured. This paper deals with the instrumentation for deformation of rock mass using extensometers in underground powerhouse of Sardar Sarovar Project, Gujarat for long term monitoring along with results and conclusion.

Keywords: Instrumentation, Underground Powerhouse, MPBX, SPBX, Deformation etc.

I. INTRODUCTION

Nowadays underground structures are very important. Based on observations of engineering properties by instruments installed in the underground works acts as guide for any proactive remedial actions. If the underground excavation encounters a known or unexpected major geological feature such as a fault, shear zone or a highly jointed weathered rock zone, instrumentation can be used to monitor its behaviour. The use of proper instrument at appropriate time can give very valuable information, which can help to prevent a likely major mishap.

Disturbances in rock and soil masses may be influenced by geological or structural factors outside the immediate periphery of a tunnel. Simple measurements, such as convergence, may detect the disturbance but fail to provide much information on its exact nature at depth, or its causes for potential precautionary or remedial measures. In such instances, instruments installed in boreholes can be used to test ground movement at different depths into a rock mass, and to provide good sample distribution and data redundancy even under conditions of limited site accessibility. Instrumentation used in the construction of underground powerhouses, tunnels and subways can be implemented in three stages before, during construction and during operation.

A. Description of Instrument:

Extensometer is used to measure deformation of a section of rock mass and adjacent surrounding soil with respect to a deep anchor. The depth of anchor varies with the type of rock strata and the location of the fixed point with respect to which the deformations are to be measured. In order to assess deformations and stress changes of different sections of rock mass, multi-point bore hole extensometers (MPBX) as compared to single point bore hole extensometers (SPBX) are used. MBPX contains a number of anchors (2 to 6) at different depths. The displacement ranges commonly used are from 50 to 150 mm, various types of transducers can be used, ranging from mechanical devices such as vernier calipers and depth micrometers to electronic sensors such as bonded and weldable strain gauges, potentiometer, and linear variable differential transformers (LVDT). SPBX and MPBX are available in both mechanical and electronic types. The electronic version is preferred in applications where access at the head of the extensometer for the purpose taking reading is not easily available. The cabling to the electronic SPBX or MPBX, and the instrument itself, has to be carefully protected during excavation and blasting. Cable free instruments are also now being tried to do away with the difficulties of cable protection. Electronic transducers permit remote readout, the use of automatic and semi-automatic data systems, and simple interfacing with computers. Mechanical transducers have the advantage of simplicity and low cost.

Figure 1 shows one such instrument, the multiple position bore hole extensometer (MPBX). A typical borehole extensometer consists of an instrument head, usually mounted at the collar of a drill hole, and one or more in-hole anchors, each fixed in position at a known initial depth in the hole. Each anchor is connected by means of a rod or wire to an individual transducer in the instrument head. As the rock or soil mass is deformed, the distance between each in-hole anchor and the instrument head changes, and the changes are measured by the individual transducers.
Extensometers provide direct measurements of displacement magnitude, usually noted in relation to time. Changes in time and magnitude are used to calculate deformation rate (time rate of change of magnitude) and acceleration (time rate of change of the deformation rate). Extensometers measure only that component of displacement which is acting parallel to the axis of the borehole.

**B. Selection of Type of Extensometer:**

The selection of an extensometer for a particular application requires consideration of the nature of the geologic mass, desired hole depth, number of anchors, probable deformation magnitude, required sensitivity and readout mode (mechanical or electronic).

**C. Details of Sardar Sarovar Project, Gujarat:**

Sardar Sarovar Project is an inter-state multi-purpose joint venture for four states of Gujarat, Madhya Pradesh, Maharashtra and Rajasthan with a terminal major dam on river Narmada near village Navgam in Bharuch District of Gujarat. This dam is the second highest concrete dam (163 m) in India. The first is the Bhakra Dam (226 m) in Himachal Pradesh. The project on full completion will create additional irrigation potential of 17.92 lakh hectares and serve 12 districts and 62 talukas of the state. Power benefits of 1450 MW will be shared among MP, Maharashtra and Gujarat in the ratio of 57:27:16.

**D. Distress Zone in Powerhouse Cavern:**

The underground powerhouse cavern of Sardar Sarovar Project mainly consists of hard and competent sub-horizontal basalt flow, separated by pockets of hard and compact agglomerate. The basalt is intruded by vertical/inclined dolerite dykes and sills. Faults of small magnitude displace the dolerite dykes and sills. The shear zones and instrumentation on upstream and downstream wall of underground powerhouse have been shown in Figs. 3 and 4 respectively.
E. Instrumentation by CSMRS:

CSMRS has initially installed instruments in 1992 and thereafter at various locations as given in Table 1 and regular monitoring of rock deformation being done using these instruments since July, 1992.

Table – 1

<table>
<thead>
<tr>
<th>Sr.No.</th>
<th>Instrument</th>
<th>Location</th>
<th>EL (m)</th>
<th>Chainage (m)</th>
<th>Date of installation</th>
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<td>20.00</td>
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<td>01/1993</td>
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<td>1566.39</td>
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</table>

II. DATA REPRESENTATION AND INTERPRETATION OF MPBX INSTRUMENT

Extensometer measurements are in the form of displacement magnitude, noted in relation to time at different depth from the face of excavation. Time is the most useful independent variable, and it facilitates the comparison of extensometer data with information from other sources.

The information necessary for at least a preliminary evaluation of safety and stability can be extracted quite easily from the raw (field book) data, or from simple graphs of displacement versus time. Hazards are reflected in unprocessed data in stepwise or exponential changes in successive readings, and all data should be scanned routinely for any such indications. Perhaps needless to say, early detection is extremely important in providing a maximum amount of time for precautionary or remedial actions.

To prepare displacement graphs, a reference datum is identified and a format selected. In extensometer applications, the instrument head is located in the part of the geologic mass, which is being most actively deformed. Extensometer holes are drilled deep enough to place the deepest in-hole anchor well beyond the zone of influence of the deformation. The graph showing displacement of the deepest anchor then be plotted as a straight line and used as a reference datum of ordinate for the calculation of displacements measured at successively shallow anchor depths.

A. Data Analysis:

Rock deformation analysis by using Borehole Extensometers (MPBXs & SPBXs):
1) **Upstream Wall of the Powerhouse Cavern**

UBH 2 R/ (EL: 20.05 m; CH: 1570.95 m) showed insignificant movements with fluctuations (rebound) for all rods. However, fluctuations in movement can be correlated with reservoir water level variations.

2) **Above Crown of Powerhouse Cavern**

Four MPBXs were installed up to the crown of powerhouse from rock surface through the rock cover above the cavity.

CMX 2 (EL: 93.0 m; CH: 1508.0 m) showed no significant movement for all rods since September 2004. Fluctuations (rebound) in movement can be correlated with reservoir water level variations.

3) **Drainage and Grouting Gallery**

Out of seven nos. SPBXs installed in drainage and grouting gallery, one instrument is not working due to damage. Insignificant movement with fluctuations since December 2004 (DGX 7).
III. CONCLUSIONS

Based on instrumentation work in the powerhouse of Sardar Sarovar project in Gujarat, the MPBX showed insignificant movements with fluctuations (rebound) for all rods. However, fluctuations in movement can be correlated with reservoir water level variations.

The present trend showed stabilized behavior in the powerhouse cavern. However, long term monitoring is further continued to monitor the effect of post commissioning of flood gates of the project.

REFERENCES