A Strain-Gauge Borehole Extensometer

by

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Introduction

Post-pillar method of extraction is now being practiced in the mines of Indian Copper Complex (Hindustan Copper Ltd.,) at Mosaboni in Bihar, when ore body is 30-35 m thick. In this method as the face advances by horizontal cuts, a three dimensional array of pillars of 4.5 × 4.5 m cross section and with an inbetween spacing of 13 and 9m in the strike and dip direction respectively are formed. Subsequent to each cut classified mill tailings are stowed. A great interest was evinced by the management of the Indian Copper Complex to know the deformation behaviour of the post-pillars subsequent to stowing so that the dimensions of the post-pillars and the working panel could be optimised.

Development of tension (vertical) and shear (oblique) fractures in a post-pillar results in horizontal strain much larger than vertical strains. It is therefore advantageous to monitor lateral expansion of a post-pillar while investigating its deformation behaviour subsequent to stowing. Obviously simple and robust mechanical type borehole extensometers such as rockbolt extensometers (Thomas, 1968), multiwire extensometers (Whittakar and Hodgkinson, 1970), read switch extensometers (Burland *et al.*, 1973), single wire dial micrometer type borehole extensometers (Krishnamurthy, 1971) and single rod borehole extensometers (Singh, 1979) cannot be used for this purpose. Electrical type borehole extensometers (Rouse and Wallace, 1966; Pearson and Deshwar, 1967; Kruse, 1970; Gould and Dunnicliff, 1971) are required in this connection. As electrical type borehole extensometers are not available in the country, the authors have indigenously developed a straingauge borehole extensometer, the details of which are presented in this paper.

Basic System

A schematic diagram of the strain-gauge borehole extensometer is shown in Fig. 1. The system has three basic components namely (1) a strain gauge sensor, (2) hollow cylindrical body fitted with a guide tube, guide plug and brass cup, and (3) a guide rod with a conical end. The strain gauge sensor consists of an adapter, a brass plug, two cantilever beams steel blades) and a cable out plug. The two cantilever beams are rigidly clamped to the brass plug and the latter is screwed up to the base of the adapter. Strain gauges are bonded on either side of the two beams and are connected in full Wheatstone bridge configuration. The input and the output lead wires (PVC insulated, diameter : 0.8 mm) of the bridge are

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(This paper was received in October 1983, and is open for discussion till the end of April 1984)

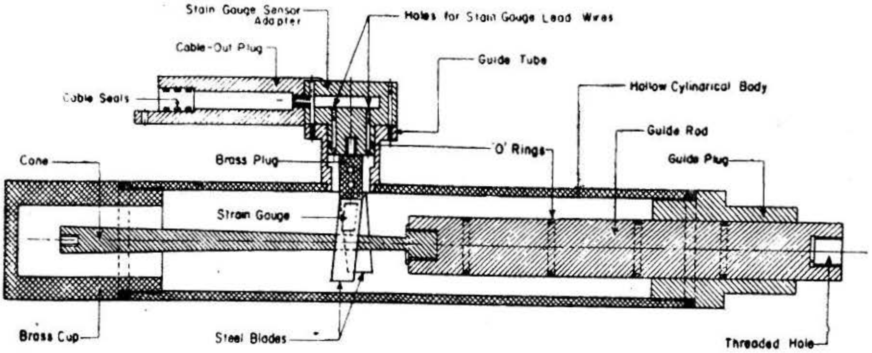

FIGURE. 1 A Schematic Diagram of the Strain-Gauge Borehole Extensometer

taken out through suitable holes made in the adapter and the cable-out plug. Then the plug is screwed up to the adapter and their contact is sealed with an epoxy resin. After connecting the lead wires with a four-core cable the cable-out plug is sealed with neoprene 'O' rings placed on the cable.

The guide tube (length : 25 mm) is welded to the exterior surface of the hollow cylindrical body (O.D. : 50 mm, length : 250 mm) such that the diametral hole made in the hollow cylindrical body and the guide tube are coaxial and their axis is perpendicular to the axis of the hollow cylindrical body. The strain gauge sensor is clamped to the guide tube such that the cantilever beams are well within the hollow cylindrical body and their planes are parallel to the plane containing the axis of the hollow cylindical body and the guide tube. The guide tube is sealed by a neoprene 'O' ring emplaced on the adapter of the sensor (Fig. 1).

The guide rod (diameter : 25 mm, length : 230 mm) fitted with the cone (diameter : 5-11 mm, length : 150 mm) can move freely through the guide plug coupled coaxially to the hollow cylindrical body. The system is such that each of the cantilever beams is deflected outwards by 0.5 mm for every 25 mm outward movement of the guide rod. The guide plug is sealed by neoprene 'O' rings emplaced on the guide rod. The other end of the hollow cylindrical body is closed by the brass cup. All the threaded contacts are sealed by teflon thread sealant and neoprene 'O' rings. A photograph of the three basic components of the extensometer is presented in *Fig. 2*.

Protection of the Extensometer From Moisture and Water

Strain-gauge installations and lead wires of the extensometer are protected from water and moisture by using the special techniques developed by authors (Gowd and Srirama Rao, 1981) as presence of moisture and water usually results in desensitisation of measurement. Air-drying solvent thinned acrylic coating is applied directly over the strain-gauges including their terminals and bare leads of the lead wires connected to the terminals. Further polysulphide epoxy compound is applied on the strain-gauge areas to offer good protection against acids, alkalies and water. Air-drying solvent thinned nitrile rubber coating and solvent-thinned RTV silicon rubber coating are applied on the lead wires to protect them completely against water and water splash.

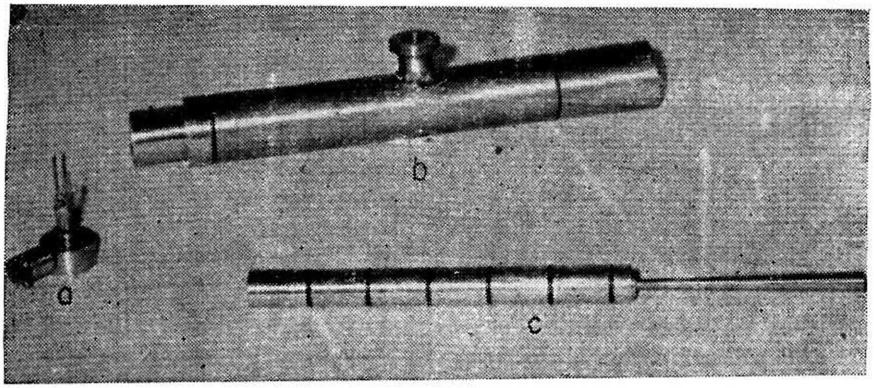

FIGURE. 2 An Exploded View of the Strain-Gauge Borehole Extensometer : (a) Strain Gauge Sensor, (b) Hollow Cylindrical Body Fitted with the Guide Plug and Guide Tube, (c) Guide Rod with a Conical End.

The soldered junctions of the lead wires with the four-core cable are coated with air-drying solvent-thinned polyurethane and then by nitrile rubber and RTV silicon rubber coating to prevent permeation of moisture into the junction areas.

The contact between the guide plug and the hollow cylindrical body, and the brass cup and the hollow cylindrical body are sealed further with nitrile rubber coating to prevent water and moisture from entering into the hollow cylindrical body. A photograph of the extensometer with its cable is shown in Fig. 3.

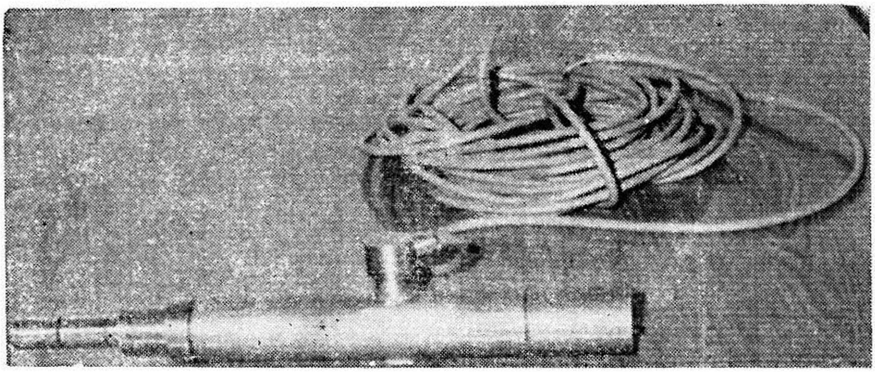

FIGURE. 3 Strain-Gauge Borehole Extensometer.

The performance of the extensometer was tested in the laboratory under extreme humid conditions by immersing it along with its cable in water for about a week. The observations indicate that the output of the extensometer remains stable correct to $\pm 3\ \mu\varepsilon$ even under such conditions. Calibration curve shown in Fig. 4 demonstrates that the

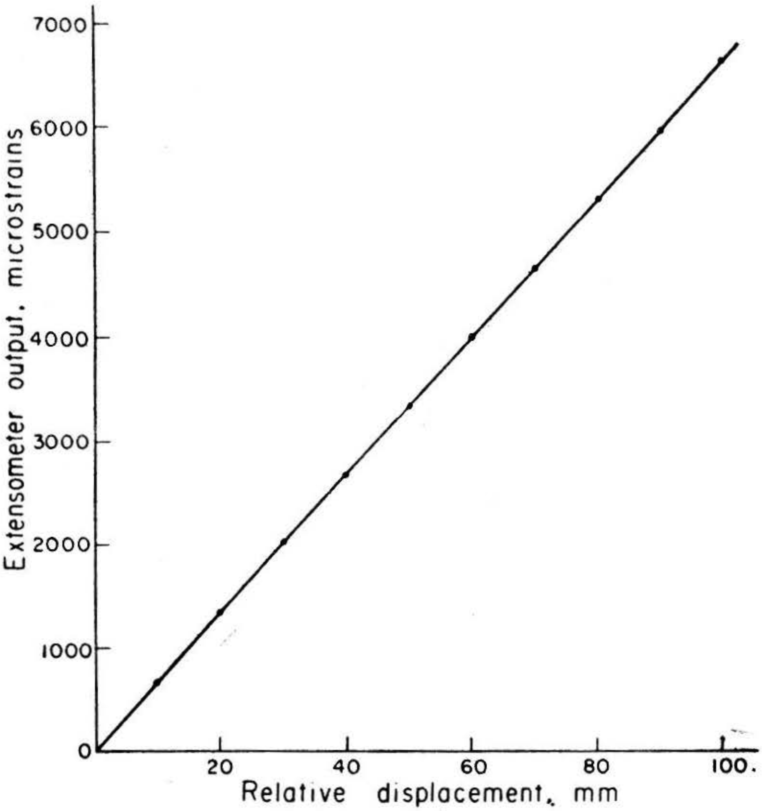

FIGURE 4 Calibration Curve of the Strain-Gauge Borehole Extensometer

extensometer output increases linearly. The sensitivity of the extensometer is about 67 $\mu\varepsilon$/mm and hence it can monitor strata movement accurately correct to ± 0.02 mm.

Installation

The extensometer was installed on January 25, 1980 in one of the Post-pillars in the No. 2 panel (300 S) in the 9th level (300 m deep) of Surda mine of the Indian Copper Complex at Mosaboni. A horizontal hole of 33 mm diameter was drilled into the pillar to a depth of 2.5 m. At its collar the hole was widened to a diameter of 50 mm upto a depth of about 25 cm. At the closed end of the borehole an expansion shell type rock bolt was anchored and then coupled suitably to the guide rod of the extensometer. The extensometer was then firmly anchored to the borehole using fast setting cement sand mortar. The extensometer cable was laid through a G.I. pipe line whose far end was terminated into a small steel drum in a nearby manway. The drum remains tightly closed except when it is opened to monitor the extensometer output.

Results

The deformation of the post-pillar is being successfully monitored till today since January 25, 1980. The data obtained so far is presented in

Fig. 5. The figure indicates that the instrumented part of the post-pillar has undergone a systematic lateral expansion at a rate of about 0.05 mm/day till the commencement of fourth fill (stowing). During the fourth fill the instrumented part of the post-pillar rapidly contracted by about 4.3 mm. This might be explained in terms of the concept of effective stresses. Water pressure generated in the pores and fractures of the pillar might have decreased the vertical stress in it (pillar) leading to its contraction. Subsequent to the completion of the fourth fill the pillar again started expanding rapidly in the lateral direction till it recovered to its original level. This rapid expansion might be due to the natural dewatering of the fill in the course of time. The figure shows that the instrumented part of the post-pillar lying within the fill deformed insignificantly subsequent to dewatering and the minor variations in the deformation are correlatable with the mining activity, viz stripping of the pillar, accumulation of muck around pillar, clearing of muck pile etc. Effect of the fifth fill on the deformation of the instrumented part of the pillar is similar to that of the fourth fill. These observations suggest that the post-pillars lying within the fill remain stabilised without undergoing any significant deformation perhaps due to the confining action of the latter (fill).

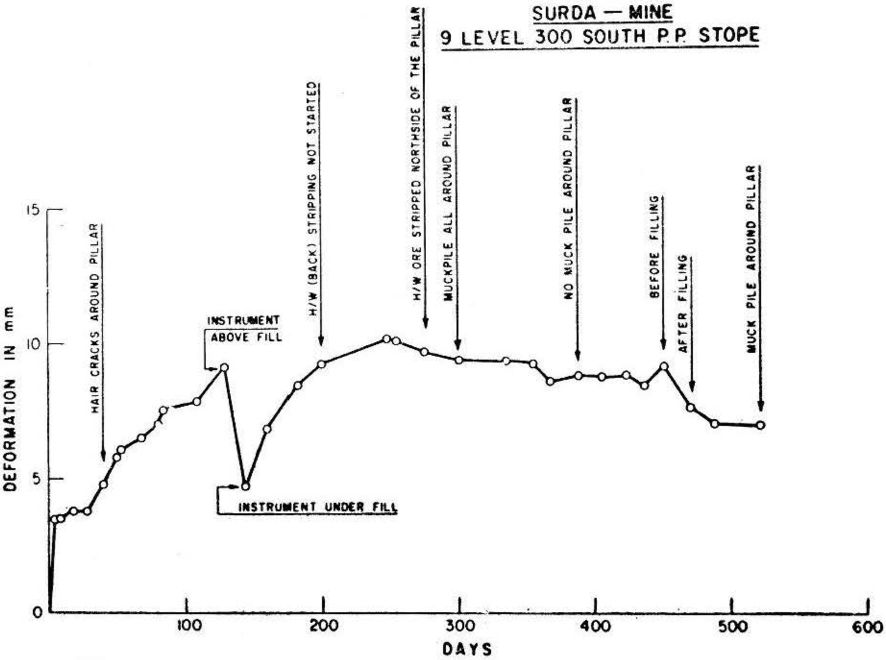

FIGURE. 5 **Lateral Deformation of a Post-Pillar in the P.P. stope (300 S, 9 level) in Surda Mine of Indian Copper Complex (H.C.L.) at Mosaboni Subsequent to the Third Fill.**

Acknowledgements

The authors are thankful to the management of Indian Copper Complex for partly providing the financial assistance to the project. Thanks are due to Dr. N. M. Raju, Scientist, Central Mining Research Station for his help in installing the extensometer. The authors are grateful to Dr. Hari Narain, Director N.G.R.I. for his great interest in the work.

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