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Role of modern strata monitoring instrumentation in PSLW face in India

Longwall mining is one of the most acclaimed and widely used in underground method for coal extraction characterized with high production, productivity and safety potentials. The interaction of powered roof supports with the roof is the key issue in strata mechanics of longwall mining. Longwall coal extraction method though showed the potential of high outputs, never rose to the expectation in India due to factors pertaining to strata mechanics problems, poor spares management, adaptation of technology without suitability analysis and unyielding exertion ethnicity. The paper attempts to discuss the role of different strata monitoring instruments installation, working principle and data monitoring procedures' in powered support longwall system in India and effective scientific tool to predict various aspects related to strata mechanics of such workings. Load density, height of caving block, distance of fractured zone ahead of the face, overhang of goaf and mechanical strength of the debris above and below the support base have been found to influence the magnitude of load on supports.

Keywords: *International longwall trends, cavability of roof, instrumentations*

Introduction

Planning Commission has noted that energy demand is growing at 7% per year. As per the Expert Committee on Road Map for Coal Sector Reforms, a shortfall of 100 million tonnes of thermal coal is expected in the country by the end of FY12. The coal reserves of India up to the depth of l200 m have been estimated by the Geological Survey of India at 276.8 billion tonnes as on April 2010 of which 108 billion tonnes are proven. To meet this demand-supply gap, the Government is looking at various alternatives e,g, FDI, acquisition of overseas coal blocks, captive mining, faster project approvals, better technology etc. With the increase in coal demand and growing awareness towards sustainable development; the coal industry has drawn a consensus over the need for increased production from underground coalmines [2]. The largest coal producing countries like China, USA and Australia are producing coal from underground mining at 95%, 33% and 20% respectively. With just 15% share of coal production from UG mines in India, there is a need for a quantum jump in production and productivity from such mines as there are more opportunities in productivity improvement and cost benefits in underground mining [3]. From the current share of 15%, the industry aims to reach a total coal production of 30% from underground mines by 2030 after realizing that the reserves that could be mined through the opencast method will get exhausted in the next 15 to 20 years and hurdles in surface land acquisition in future [1].

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Emphasis on UG mining

Currently mining is done predominantly by opencast methods to exploit the proven reserves situated within a depth of 300 m. At present, multiple clearances are required from the government for commencement of new opencast projects like site clearances for mining lease, forestry clearance and environment clearance. The process would be much simpler for UG mining as the forest land and environment clearances in respect of underground mines are relatively uncomplicated. India is a global player in coal mining with third place in total production and 5th in underground production [4]. But still have low level of mechanization and there is massive scope for improvement from 0.5 tonne per man year to 5 tonnes per man-year in underground coalmines by introducing mass production technologies like longwall mining in the immediate near future. India has huge untapped potential for underground mining with extractable reserves up to a depth of 600 m. Size of mining operation and introduction of appropriate technology is key to the success of underground mining. Bulk of the total underground coal production in India comes from board and pillar mining [2]. The contribution from mechanized longwall or from special methods like blasting gallery has remained at low level. Phased replacement of small un-economic mines with larger mines using modern technologies coupled with improvement in underground mine management practices is absolutely necessary, if underground operation are to be made profitable and competitive [7]. This calls for increasing the level of mechanization, introduction of state-of-the-art machines and ensuring their optimal utilization as per international standards. This includes introduction of mass production technology at suitable locales, replacement of manual loading by deployment of SDL/LHD and reorganization of transport system, enhancement of evacuation capacity by driving additional shafts and inclines/drifts and deployment of additional coal winning equipment and starting new projects [5].

Longwall mining

Longwall being a mass production technology well proven around the world in all conditions like steep and gassy seams with geological disturbed or strong roof conditions. In India, though the first mechanized longwall was introduced in 1979 at Moonidih, the method could not be established as major production technology as easier options like opencast mining for achieving is available for extracting shallow depth deposits. It is the need of the hour to make longwall a successful technology by using the lessons learnt during last thirty years of longwall experience [2].

International longwall trends

Longwall production increased from 1000t/day in 1980's to 35000t/day in 2010. Longwalls can be introduced with minimum proved extractable reserve of 100mt, a minimum life of the mine of 25-30 years deploying high-speed development systems using bolter miners/CM/RH for continuity of longwall operations and longer panels. Essential requirements for longwall success include system approach for selection of equipment, detailed ventilation studies for providing effective ventilation including air cooling arrangement, scientific assessment of support requirement and strata behaviour, modern roadway support systems, developing and adopting world class operating and maintenance practices, quality training of the longwall team, and modern transport system for speedy transport of men and material as well as for the equipment transfer. Mines are with state-of-the art technology to achieve 3 to 5mt of output, wherever favourable reserves are available. In USA, Australia and China, longwalls are being operated with production ranging from 2mt to 10mt with a face width ranging from 150m to 400m. Average production from each Longwall face is more than 3mt/year. Trend is towards wider faces of around 400mtrs and longer panels of around 4000m with only one longwall face per mine, two gate roadway system deploying continuous miners with shuttle cars and bolters, height of extraction upto 4.8mtrs and a depth of up to 600mtrs. Support capacity ranging from 700t to 1700t with 2 legged - 1.75m and 2m width, shearer capacity ranging from 600kW to 3000kW, AFC capacity ranging from 1500t/hour to 5000t/hour AFC power ranging from 2×500kW to 3×1200kW, coal clearance system of 6000t/h in mains and 3500t/h in longwall with conveyor widths of 1800mm and 1500mm respectively with a speed of 4.0mtrs/sec are the need of the day [8].

Cavability of roof rocks in mines

The term cavability of roof relates to the caving behaviour of the roof strata over the coal seam. Cavability of the roof in a mining lease hold plays an important role in the success of longwall caving in the locale. A roof may be considered to be readily cavable when the following conditions are satisfied.

i. The overlying roof rocks fill the goaf as soon as the supports are advanced/withdrawn.
ii. The fractured rock fallen from the roof as debris fills in the goaf completely behind the support.

The fulfillment of the above requirement is possible only when a sufficient thickness of roof in the overlying strata in a coal seam is involved in the caving process. The thickness of strata in the immediate roof involved in the caving process can be expressed in the following relationship:

$$t = h / (k-1)$$

where t = thickness of immediate roof need caving,

h = thickness of extraction

k = bulk factor of the rockmass in the caving height.

The value of the 'bulk factor' depends mainly on the nature and strength properties of the overlying formations.

The bulk factor for blasted material where good fragmentation has been obtained, a value of 1.5* has been very frequently quoted. In the coal measure rock the value of bulk factor is frequently quoted as 1.2* though higher and lower values are also noted at many places. The thickness of overlying roof which should cave to fill the goaf completely with different values of bulk factor. It can be seen that for a value of 1.2 the immediate roof need to be caved to fill the void completely is 5 times the height of extraction.

iii. The line of break in the roof at the goaf edge should incline in the direction of debris.
iv. There should not be formation of cavities in the upper roof strata which may result roof collapse in the working area. In a very few cases the roof comes closer to the criteria laid down above, the more cavable it is.

Instrumentations

There are several number of instruments used to measure the load on roof near the excavation point in the coal mine, bed separation and convergence. Instruments are given below:

1. Load cells
   i. Vibrating wire type anchor bolt load cell
   ii. Vibrating wire type roof support load cell
   iii. Mechanical load cell
2. Remote convergence indicator
3. Wire type extensometer or tell tale

LOAD CELLS

Load cells are very important for measuring the tensile strength and compressive strength of the roof strata.

- These load cells are used for measuring tensile load in rock bolts, tie backs in underground cavities.
- Compressive load of coal roof/hard roof.
- To measure the compressive load at crown/rib support in roadways.
- Some load cells are designed as three/six wire systems to nullify the eccentric loading effect. The average of three/six wire gives actual load which is more accurate.

Vibrating wire type anchor bolt load cell

Application

Hollow/anchor bolt load cells are used to monitor the load in rock bolts in tunnel roof and wall.

- Load testing of drilled shafts.
- Load in pre-stressing and other cables.
- General compression load applications.
- In supports of underground excavation for example under vertical steel and wood posts.

Installation

- The anchor bolt load cell is generally installed with roof bolt/anchor bolt as shown in the Fig.1.
- The roof bolt is grouted in the hole leaving 6" anchor outside the roof.
- Mount the load cell with the anchor rod giving initial pre tension load of approximately 1-2 tonne by tightening the bolt through the torque wrench.
- Care should be taken while tightening the bolt that both top and bottom surface of load cell should be properly attached with packing plates to avoid eccentric loading.

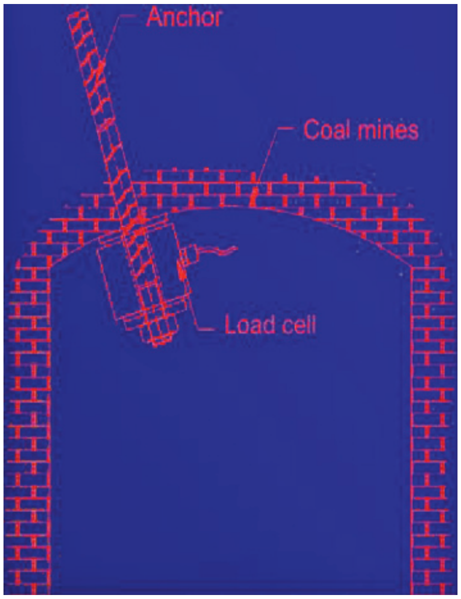

Fig.1 Vibrating wire type anchor bolt load cell

Data monitoring

- After installation take the initial frequency of all the three wire through readout unit and programme the unit.
- Take the data in engineering unit from the three sensors.
- Add it and divide by three to get the average data.

Vibrating wire type roof support load cell

Application

The roof support load cells are used to measure the load of roof near the excavation point in the coal mine.

- These are used to monitor load under roof bed in mines and underground excavation.
- To monitor load at rib supports in roadways.
- To monitor load at crown of rib supports in tunnel.
- These are used to monitor the compression load in pile foundation.

Installation

- In coal mine we recommend that the load cell should be installed under the steel prop.
- Hydraulic prop or wood prop are also used as shown in the Fig.2.

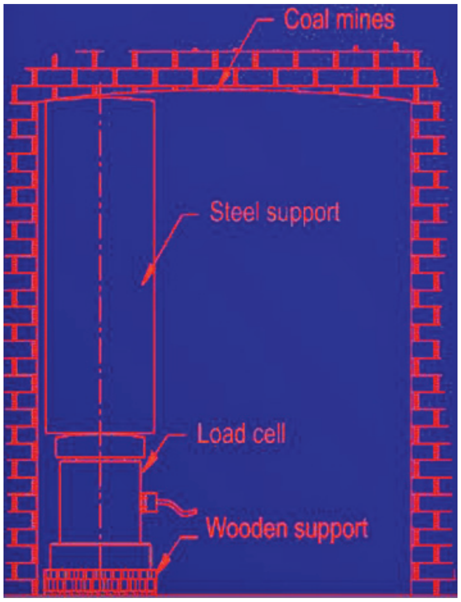

Fig.2 Vibrating wire type roof support load cell

- However in some cases where floor is full of mud, water etc., It can be installed over the prop also.
- Before installation the surface should be made plane and load cell position should be vertical.
- The steel/hydraulic/wood prop should be installed vertically over the load cell to avoid the eccentric loading on the load cell.
- Give the initial load of about 2/3 te.

Data monitoring

- After proper vertical installation of load cell take the initial frequency reading of each wire with the help of readout unit.
- Programme the readout unit as per the procedure and data asked by the readout unit.
- Measure the individual readings of each wire in tonnes add it and divide by three to get the average load of that load cell.

MECHANICAL LOAD CELL

Features

- Accurate and reliable.
- Easy installation.
- Negligible positioning effect.
- Long term stability.
- Rugged construction.
- Hermetically sealed.

Mechanical Load cell model SME 2570 is very suitable device for load measurement in underground. Few applications are given below:

- Load testing in pre-stressing and other cables.
- Load testing in piles and drilled shafts.
- General compression load applications.
- In supports in underground excavations for example under vertical steel or wood posts.

Fig.3 Mechanical load cell

REMOTE CONVERGENCE INDICATOR

Application

- Convergence meter model SME 2540 is a device for measurement of convergence in mines and underground convergence between roof and floor of the cavity.
- System is available with different types of sensors like linear potentiometer type displacement sensor or vibrating wire type displacement sensor for accurate remote measurement.
- Remote type system is generally used where access is not always.

Installation

- The remote convergence indicator should be installed vertically by measuring the roof height where it is to be installed.

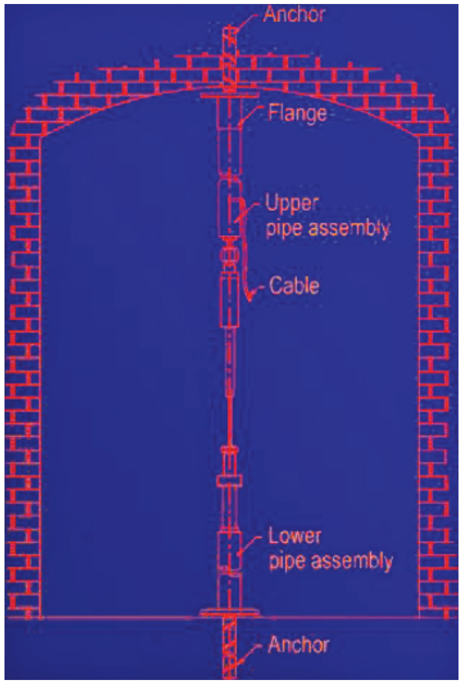

Fig.4 Remote convergence indicator

- Drill two holes of 42mm dia. of 1 feet depth in roof and floor. Grout the upper and lower pipe with flange and anchor with the help of quick setting cement.
- The installation height can be adjusted by adding/ removing the pipe and adjusting the pipe length.
- Fix the sensor in between two pipes as shown in the figure by taking out sensor rod of about 80 to 90% of its capacity.

WIRE TYPE EXTENSOMETER OR TELL TALE

Tell-tales are safety devices which provide a continuous visual indication of the level of roof deformation that has taken place within the monitored height following installation. It is a very sophisticated instrument and which is very very necessary for continuous monitoring of the roof in the underground coal mines. The Rotary Telltale design has been developed to give a resolution of 1mm. This accuracy is important at sites where roof deformation levels are generally low. It is generally placed in the junctions of the galleries.

- Monitoring height is generally decided basing on the method of extraction, height of extraction, lithology and geotechnical parameters of the strata.
- Movement between adjacent anchors is calculated by subtracting the movement of the lower anchor from the movement of upper anchor.
- Analysis of the data obtained from instruments gives an idea of the horizon of the weak planes along which bed separation or fracture is taking place and
  - Immediate roof convergence
  - Bed separation between layers

– Progressive failure height of the strata

– Ensure efficacy of bolting and influence of extraction or development

It should be the the responsibility of the miner each shift to record the tell tales by colour for all active areas in the section. A book should be kept at the section waiting place in which each shifts tell tale readings are recorded.

Fig.5 Rotary tell-tale

Where a colour change takes place this should be reported on the shift in-charge's statutory shift report, together with comment on any remedial actions taken. In addition the Miner records the millimeter reading of the relevant tell-tales.

So, we can measure the convergence from the colour in tell-tale instrument. Colour incorporate with the convergence and actions should be taken by the officials are given below:

Action Levels

We can indentify convergence from the colour in rotary tell-tale.

Table 1 Changing of colour with the convergence in tell tale

Colour	Convergence
Green	0 - 5 mm
Yellow	5 - 10 mm
Red	10 mm+

Actions

From the upper table, we have to determine the convergence. Then suitable steps should be taken by the management are given below:

Table 2: Necessary actions taken due to colour changes

Colour	Action
Green	No action required, continue routine monitoring
Yellow	Install additional reinforcement. Length and type of support to be determined by investigations co-ordinate by shift in-charge/mine overman/roof control officer
Red	Restrict access. Consult shift In-charge/mine overman/roof control officer.

Single point rotary tell tale extensometer

Features

- It is useful where the conventional method of roof support testing is not convenient or possible.
- Movement of strata is indicated on the scale with a magnification 1:15
- It gives visual indication to workmen regarding the status of roof stability.
- Rapid and simple to install.
- Rotary type are useful for variable depth.

Auto warning telltale

- RMT's auto-warning tell-tale has been designed to
- provide additional instantaneous warning of movement occurring in a rockbolted excavation.
- This is of particular value in dynamic mining situations, such as pillar extraction operations, where workman and equipment are operating close to a developing goaf.
- The LED is configured to flash when the B indicator
- shows greater than 25mm of roof deformation.
- The trigger level on the B indicator is factory set and
- cannot be adjusted by the user, but alternative trigger
- levels can be factory set on request.

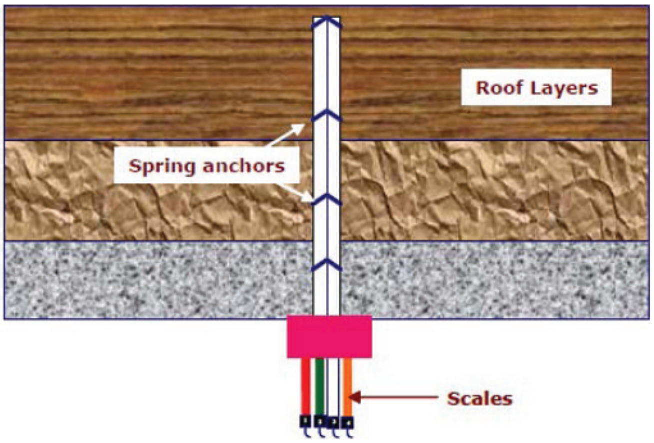

Fig.6 Spring type tell-tale extensometer

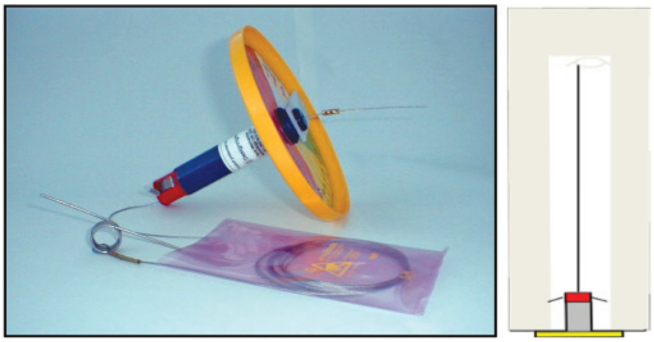

Fig.7 Rotary tell-tale a resolution of 1mm

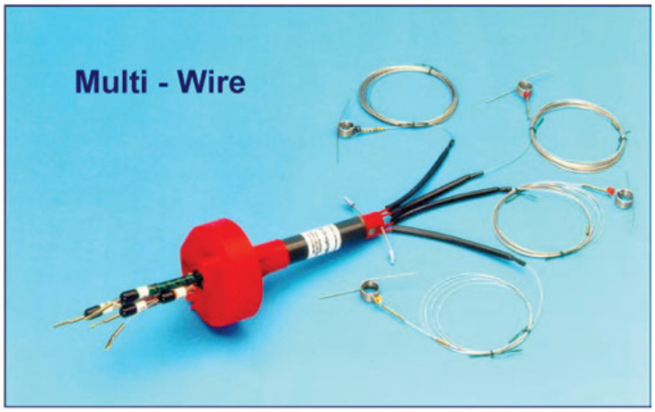

Fig.8 Multi wire tell-tale

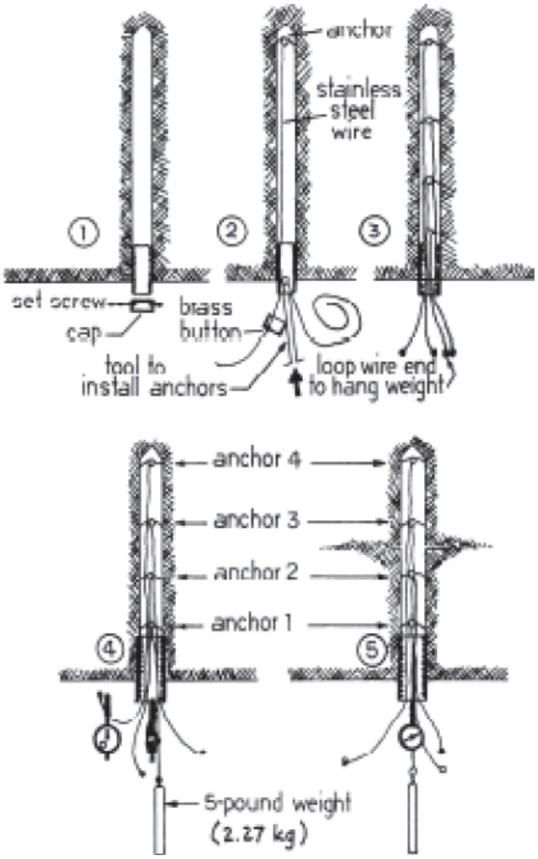

Fig.9 Multi wire tell-tale application in field

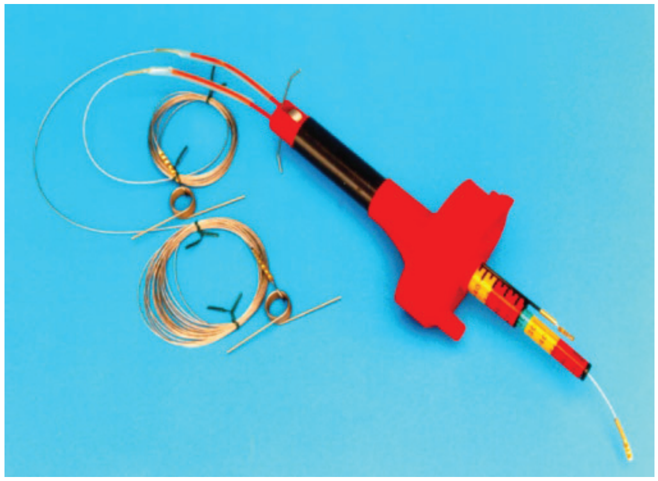

Fig.10 Dual height tell-tale

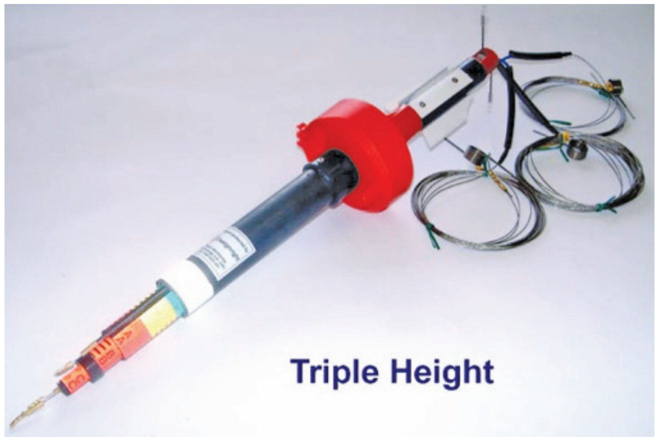

Fig.11 Triple height tell-tale

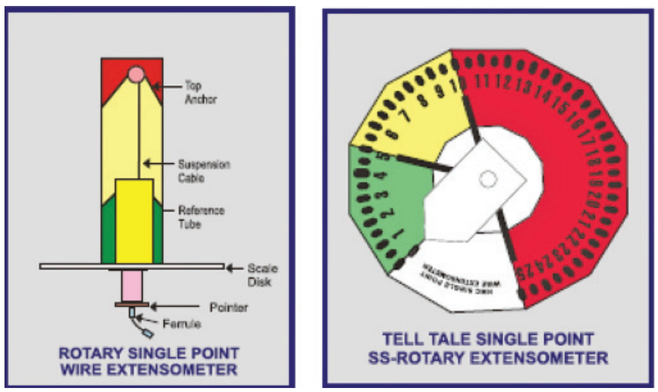

Fig.12: Single point rotary tell-tale extensometer

Sonic probe extensometer

PRINCIPLE OF SONIC PROBE EXTENSOMETER

- The principle of the sonic probe relies on the magnetostrictive properties of the probe material.
- An electric pulse in the head of the probe drives current up the length of the wand.
- Interaction with the field produced by the toroid magnet induces an ultra sonic signal that travels back to the head in the wave guide.
- This acoustic signal is converted into an electrical signal and the time between pulses resolves the differences in position of the anchors as the speed of sound in the wave guide is known.

FEATURES

- Quick, easy installation and readout
- Portable, reusable sonic probe and sensor

- Remote electronic readout
- Reads inter-anchor strains directly
- Up to 20 anchors in one borehole
- High accuracy and sensitivity

Fig.13 Auto warning telltale

Fig.14 Sonic probe extensometer

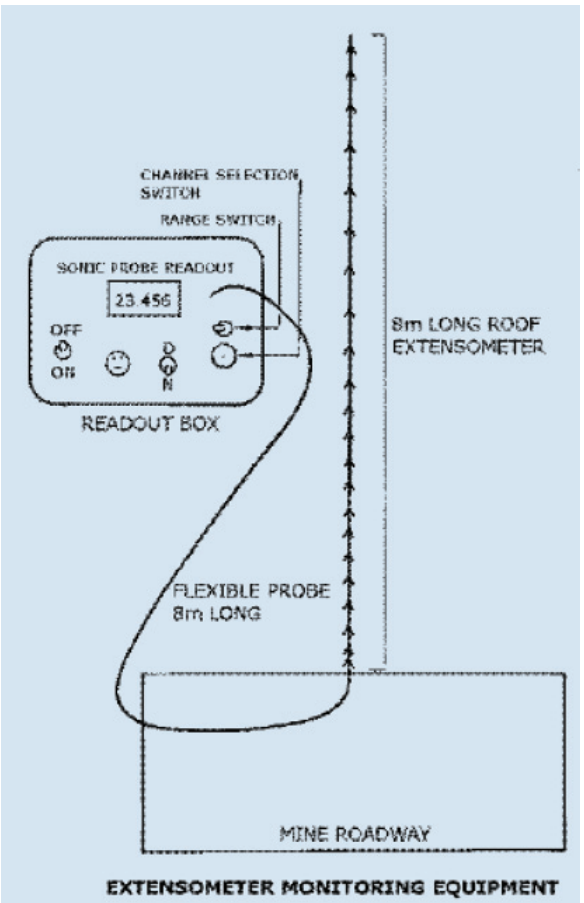

Fig.15 Application SPE in mines

Conclusion

The main findings of this study instruments are used for total convergence, during the first use of a roadway as a main gate, depends on the time, the distance from the longwall face, the loading region, the support type and pattern, and the static and dynamic support loads. Face management and apposite support design is necessary to perk up production performance in longwall mining.

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