SCIENTIFIC RESEARH FOR EARTHQUAKE PROOF SUPPORT FOR UNDERGROUND

B. K. SAMANTA, B.Tech (Hons), FCC, MMGI, MIMMA, FIE, MCSI, MNIPM
Part-time Researcher IIT(ISM)
Director, Project & Environment Consultants
Past Chairman, Institution of Engineers (I), Dhanbad LC

ABSTARCT

There is no cost-effective method for full extraction without subsidence, except partial extraction. Future reserves of coal and minerals are at depth, and mostly upper seams are water-logged. South African gold mines have been using Pipe-sticks as support. Among the high standard of earthquake resistant designs. new design concept of steel pipe-concrete composite pier exhibits not only high strength but reliance as well. The advantages of the S&T project are manifold, if proved successful both in tri-axial testing on Universal Testing Machine and field trials. Then, the method can be used for partially extracted mines or depillaring in Bord & Pillar mining or even with Continuous Miner in future. While working for Project & Environment Consultants on mining sustainability for Bharat Coking Coal Ltd (BCCL) for many years, former Director (Technical) supported the idea. A prototype was made and handed over to Central Institute for Mining & Fuel Research (CIMFR) for testing. Civil Engineering standard is there but standard for support in mining has to be developed. The manufacturer applied to the Director General of Mines Safety (DGMS) for approval and after going into details, S&T project was suggested. Collaboration is needed among BCCL, CIMFR, CMPDI, Ministry of Coal, DGMS, manufacturer of support for success of the project

1. INTRODUCTION

Government of India Coal Science & Technology (S&T) grants are awarded for useful innovations. A number of earthquake resistant features have to be incorporated applying earthquake engineering techniques, which would increase enormously the chances of survival of support in mining underground. Steel encased timber or concrete supports called pipe-sticks are quite strong and used in South African gold mines. Earthquake proof support has to be designed as permanent support with wide canopy and base plate to withstand side-wise thrust to last centuries after extraction of seam by mining. Detail geological explorations of Indian coalfields have revealed that most coal basins have multiple seams. Partial extraction of lower seams not only cause great loss of coal, but also can be source of fire in future and may also cause collapse of roof, if coal is over extracted than stipulated. For full extraction of coal as well as conservation of timber, depillaring with special support can ensure safer extraction of either lower or upper seams and is also justifiable with long term cost analysis.

World primary energy consumption was around 6% nuclear, 6% hydro and rest 88% on coal, oil and gas. International Energy Agency has commented that world reserves of coal are enormous to last more than 153 years @ present production, as compared to oil and natural gas. As of December 31, 2014, estimates of total world proved recoverable reserves of coal were about 1,237 billion short tons, (or 1.2 trillion short tons). Around 70% of the total reserve of the country is workable by underground mining, most of which are thick and contiguous seams. Indian coal reserve, as on 1st April 2016, by Geological Survey of India is 308.8 billion tonnes.

Underground mines are closing down, not only in India but in the world as cost of production has increased phenomenally. Present high production underground method like Longwall with Power Support (LWPS) is not only high capital intensive, but require large undisturbed reserve area but also difficult to maintain. Continuous Miners operate by partial extraction with risk of subsequent fires and subsidence on crumbling pillars. Sand stowing mines are not making profit, as of now, because of poor OMS and stowing lags. Moreover, total tonnage of sand stowing required is higher than the coal produced and stowing is not amenable to high production technology, required for viability. Full caving or Blasting Gallery methods are only allowed where there are no upper coal seams or surface features to protect.

2. DECISION OF DESIGN PARAMETERS

Hydraulic support systems require periodic replacement of valves and oil-seals, which cannot be done after the panel is sealed off after extraction and could be water logged for centuries. Principal design parameters of the special supports are not to allow any bed separation, control subsidence and damage to upper seams and surface structures and yet be cost effective, compared to other existing methods of support systems. With passage of time and dynamic stresses caused by nearby vehicular, railway traffic, earth tremors, even in partially extracted districts, spalling and crushing of stooks or pillars, have happened causing subsidence. When the width of excavation enlarges, the height of pressure arch becomes more and support load increases exponentially. In Longwall mining, operating with very wide faces up to 300m, require extremely high capacity self-advancing support system, allowing the roof to cave behind and damaging surface structures and upper seams. If hard sandstone roof is there, with advance of LWPS face, stress accumulates and could result in crushing of LWPS and loss of mine, as happened in Khottadih in ECL.

Case studies by Central Mining & Fuel Research (CIMFR) of Kurja Project of SECL, and Chinakuri III of ECL, load on goaf pillars was found to be 8-10 MPa or 8000 to 10,000 KPa or *N/mm^2 or* 80000-10000 kg/cm^2 or bars of atmospheric pressure. The S&T project proposes to distribute the abutment pressure evenly by special support while extracting the ribs or stooks in depillaring. No local fall should occur, because roof bolts between the special supports, would prevent, while the abutment pressure would balance around the special supports. For example, a pillar of 30 m square, 4 m thick has coal = 30x30x4x1.4 t = 5040 t, valued at say 5040x Rs.1500/t = Rs. 75.6 lakhs. In partial extraction method, hardly 60% of coal is extracted, which would mean loss of coal worth about Rs. 30 lakhs in 1 pillar alone.

DirectorMS (S&T), Directorate General of Mines Safety agreed that the S&T project should be in 2 steps-testing of prototype in CIMFR on Universal Testing Machine (UTM) with numerical analysis and tri-axial stress analysis, with incremental load. Present DMS(S&T), Dhanbad has also agreed to help the (S&T) project with CIMFR, for developing guidelines. CIMFR has large databank of underground incumbent stress at different depths and actual diameter of support could be less for the allotted district. According to depth of seam and location, the diameter and height of special support will be determined.

Prototype design of concrete filled tubular special chocks with base plate and shield with threaded setting load device should be within Rs. 20 thousand a piece. 30 m square extracted area may require about 25 special props at 6m interval and 200 roof bolts at 2m interval, each costing about Rs. 100 only. Thus, total cost of special support works out to Rs. 5.4 lakhs making saving of coal worth Rs. 25 lakhs per pillar. In sand stowing, some coal ribs are required to be left and stowing cost for a pillar @Rs.190/m^3 for

3600 m^3 would be about Rs. 7 lakhs. Hence, compared to stowing this method would be cheaper than both stowing and partial extraction methods.

3. INTERNATIONAL ADVANTAGES

Deep reserves of coal can only be extracted by underground mining methods and the world tendency is for high-speed extraction and transport systems, for viability despite escalating cost of wages and inputs. Approval of DGMS for the earthquake proof support system will be made by both laboratory tests and underground field trial. The present S&T proposal is to establish the efficacy of the special support system in usual standard depillaring district. With the experience of the project, fast transport of the supports to the district and erection can enable application of the method of support in high production technology like Continuous Miner with comparatively much less capital investment, compatible with present Indian coalmines.

In CM technology, ribs of coal usually are left after widening the galleries, called Rooms. This experimentation would enable as to how best to extract the ribs of coal with fast setting of permanent special supports. If properly designed, there would be hardly any surface subsidence, fire and other environment problems. Before sealing off, anti-pyrogene solutions can be sprayed on the inside of panel barriers as additional precaution for prevention of spontaneous combustion.

The failure of chock shield 4x680 t with hydraulic support density was of 1.0 MPa at Churcha Colliery, caused enormous loss and closure of mine for long. Hydraulic Longwall Power Support System not only cost many crores of Rupees, but also failure rate is high. The roof is supposed to cave after extraction and if it does not fall, the hydraulic LWPS is endangered by accumulation of stress and blasting from surface has to be resorted to. During depillaring with either caving or partial extraction, timber supports are supposed to be withdrawn, but due to premature weighting, lot of timber is lost.

4. METHODOLOGY

Actual design specifications can be worked out only after testing of roof rock properties, depth of cover at the district, thickness of seam or slice, gradient of the seam at the allotted district and many other parameters of the mine of BCCL. Figure No.1 displays how abutment pressure of superincumbent strata is distributed on the coal stooks during depillaring with partial extraction.

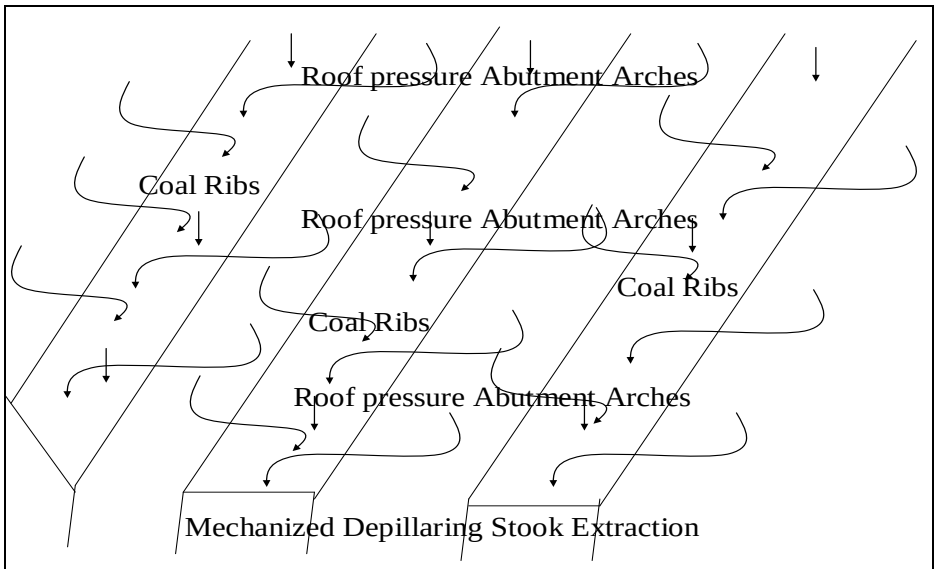


FIGURE NO – 1: PARTIAL EXTRACTION ABUTMENT

Many kinds of solid steel supports like rectangular or triangular chocks are being used under dangerous roof junctions. But, even these supports are required to be withdrawn in caving system for deployment elsewhere. Such supports are very heavy and also much costlier, and prone to erosion in water-logged condition. Figure No.2 shows similar distribution of abutment load on the special supports, while the roof-bolts will prevent bed separation, ensuring undisturbed upper seams and surface structures.

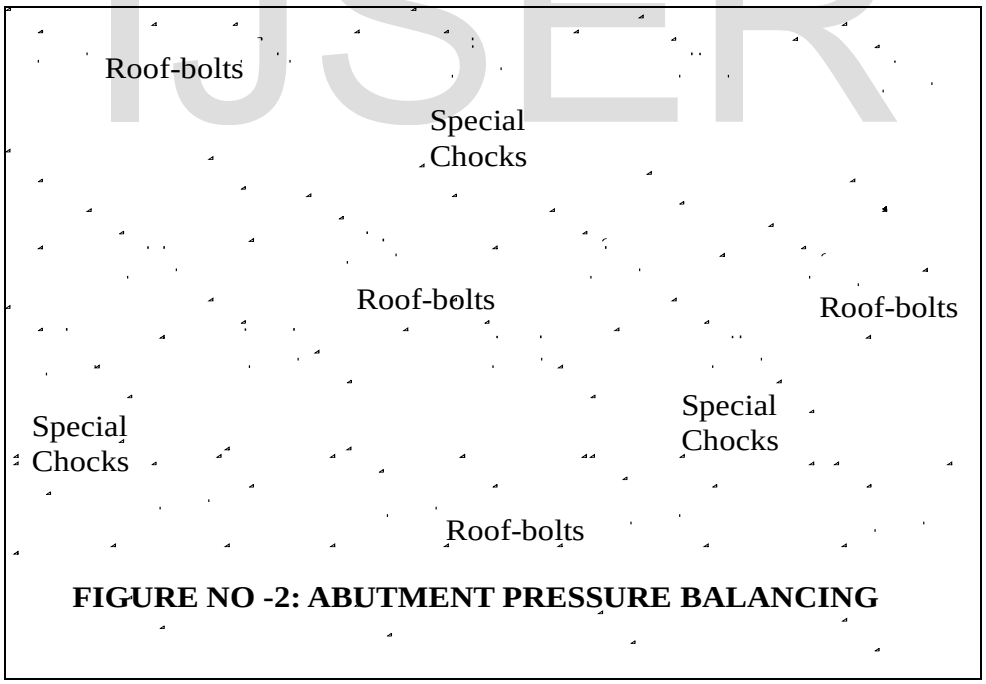


FIGURE NO -2: ABUTMENT PRESSURE BALANCING

The design contemplated here for entire district support is a mix of rock bolts and special support with application of tubular frames filled with concrete, extended shield cover, square-threaded tightening device on wide base plate. The special supports are for taking abutment loads, while rock-bolts are for preventing bed separation of strata. Special support should be erected, with highest setting load possible with the jack lever device, as soon as a stook is extracted. Rock bolts would be fixed all around up to 2

pillars of extraction, as is normally stipulated with DGMS permission. Systematic Support Rules imposed by DGMS in depillaring is usually at 1.2 m spacing for timber or rock bolts.

A small-developed district ready for depillaring or partially extracted district in safe condition can be suitable and beneficial for trial. In low grade coalmines where stowing is not subsidized and there are upper seams or surface structures to protect, partial extraction is adopted. Proposed method will basically replace coal stooks or ribs right from start of depillaring with special support, bearing equivalent abutment pressure, without allowing bed separation with roof bolts or accumulation of stress, as if no coal is extracted. Wide flat base plate and shield plate at the top of the special tubular prop filled with concrete is to resist bending moments and to ensure distributed load instead of point load.

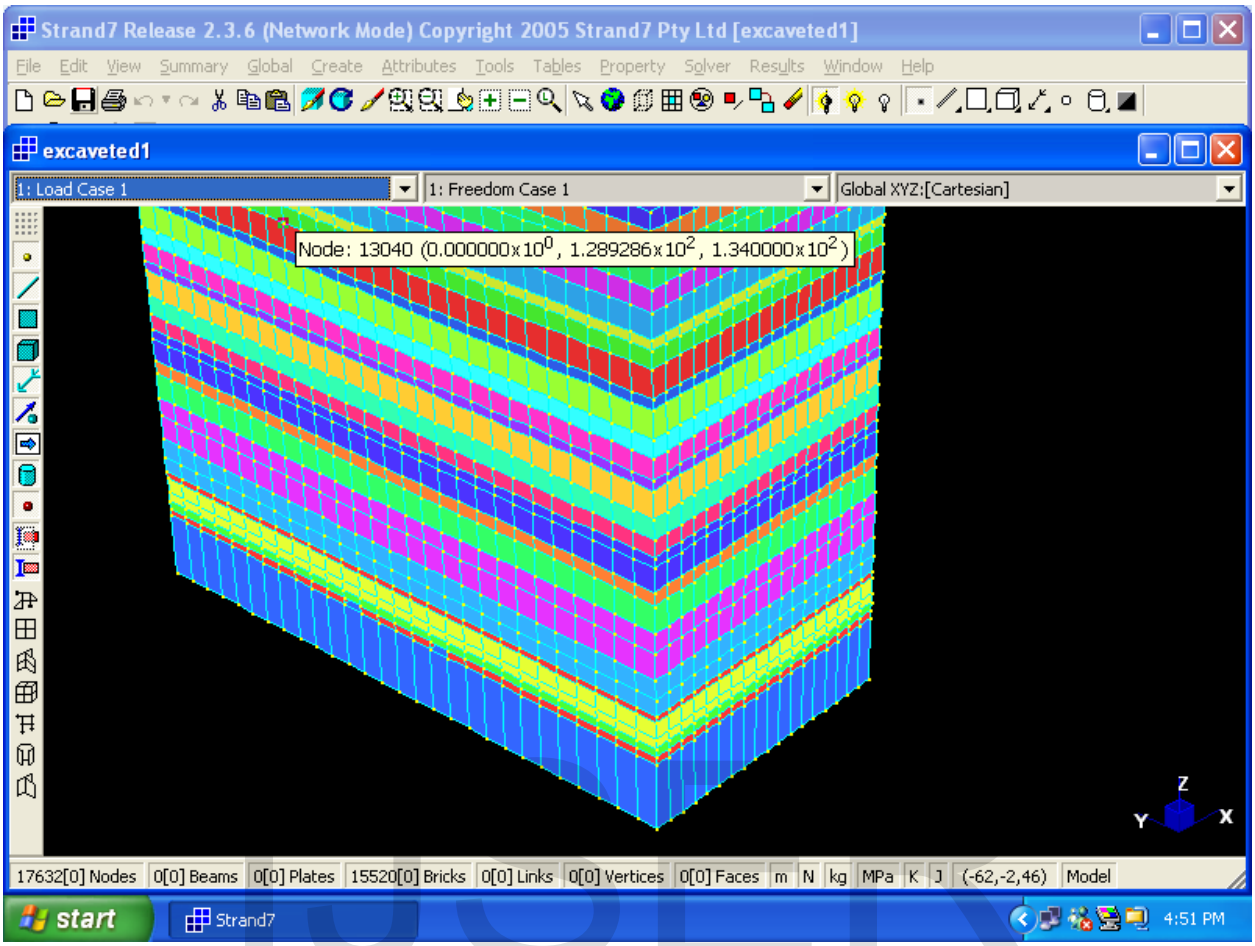
All such supports would be thickly coated with anti-corrosive marine paints or metal clad so that after depillaring even if the district gets filled with water, the supports would not be affected for centuries. If necessary, metal cladding of non-corrosive type would be applied on the special supports. Of course the panel barrier has to be solid coal for isolation purpose and another advantage is that much of the abutment pressure on the panel barrier will be shared by all the special supports.

5. NUMERICAL MODELING

Based on studies of various numerical modeling, the project required establishing that negligible subsidence can be predicted on supporting the galleries and depillaring stooks using the support system contemplated, mainly combination of special chocks and roof bolts. Software mostly used in India like FLAC or FLAC3D, need special hardware configuration in a computer and normally not easy with a PC. In this case STRAND7, new Australian software was used for developing the stability model.

Considering a standard coal mining district, with coal and rock properties fed into STRAND 7 Software at IIT(ISM), Mining Department Computer, model output displays, as shown in Figure No- 2A.

FIGURE NO-2A: COMPUTER MODEL DEVELOPED FOR STABILITY



The model should display insignificant subsidence or disturbance in the upper seams and also surface structures. Mine subsidence research in India and abroad has indicated that only when very large unsupported area is left underground, upper seams and surface is affected and so DGMS permits up to 90 m^2 area, temporarily in depillaring (*Sarkar, B. N and Samanta, B.K, 1993*). Taking in to consideration, average physico-mechanical properties of coal and rocks, the model has been designed with the properties of the supports. Once, the mine and the district is identified by BCCL, rock samples from the roof and coal samples would be taken to the CIMR laboratory for determining physico-mechanical properties. In-situ tests also would also be made with Rock Mechanics Instrumentation of CIMFR inside the mine. In case of massive sandstone roof, .the special supports have to be stronger and widely spaced, while in weak shale roof, the supports would be lighter with closer spacing. Statutorily, the office of the Director General of Mines Safety, Government of India, grants depillaring permission. Therefore, as per advice of S&T wing of DGMS numerical model is being done and DGMS has to be associated till finalization of the design and implementation. The seam thickness 2-2.5 m, gradient 1in 6 to 1in 9, depth 200-300 m, setting load of special support 50 t at 5m intervals, rock bolts 2m apart and other properties are assumed as given below in Table No.1.

TABLE NO-1: SOME PROPERTIES OF COAL MEASURE ROCKS

SL.NO.	TYPE OF ROCK	SP.GR	COMP. STR.	TEN. STR.	SHEAR STR.	MOD.OF ELASTICITY
1	Sandstone	2.69	1335	89	118	74700

2	Sandstone	2.58	829	67	76	22300
3	Sandstone	2.54	595	48	59	28300
4	Shale	2.55	771	81	74	30700
5	Siltstone	2.42	858	45	117	50500
6	Siltstone	2.53	551	32	66	26700
7	Sandstone	2.69	648	65	84	34500
8	Coal	1.45	85	20	32	28410
9	Coal	1.42	109	26	14	41000
10	Shale	2.70	482	116	111	35720
11	Coal	1.40	107	31	26	34750
12	Coal	1.38	115	28	12	37930

6. DEVELOPMENT OF DESIGN

Quantity and specification will be determined by the size of the depillaring district. The project was held up for long, as BCCL was carrying out investigation by GM(Safety) & GM(UG), before processing recommendations to CIMFR. In S&T project plan as discussed, CIMFR will design in two phases, Laboratory testing, numerical analysis for support design and then field trial in mine allotted. The S&T proposal will then be forwarded to GM(S&T), CMPDI, who may suggest changes or recommend to the Ministry of Coal. Actual work on S&T project will then be started by Project Leader of CIMFR. Provisional planning of the S&T project has been done as given below. Final schedule of the Earth-quake Proof Support S&T will be finalized by CMPDI.

The objective is viable alternative underground system to stowing and partial extraction methods for full extraction of coal. Prototype design of the proposed new support is shown in Figure No.-3 given below for further investigations. For faulted or weak zones, triangular chock based on similar design would be finalized. The basic design has to be approved by DGMS for implementation

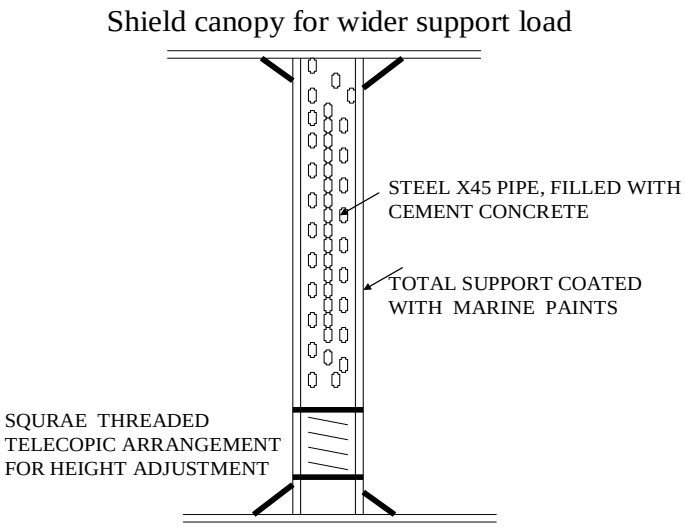


FIGURE NO – 3: DESIGN OF THE SPECIAL SUPPORTS FOR FULL EXTRACTION

6.1 Investigation underground and applicability

Cost effective, user friendly, reliable design would be decided upon mutual consultations. Figure No.4 shows the panel layout of the proposed scheme.

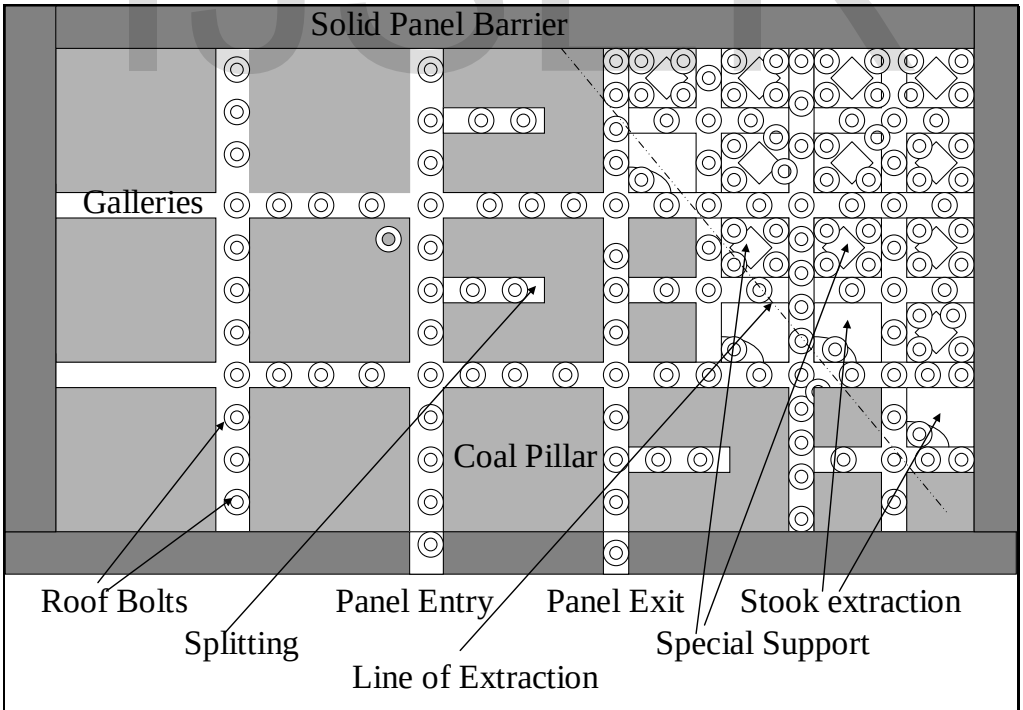


FIGURE NO- 4: DEPILLARING PANEL LAYOUT WITH SPECIAL SUPPORTS

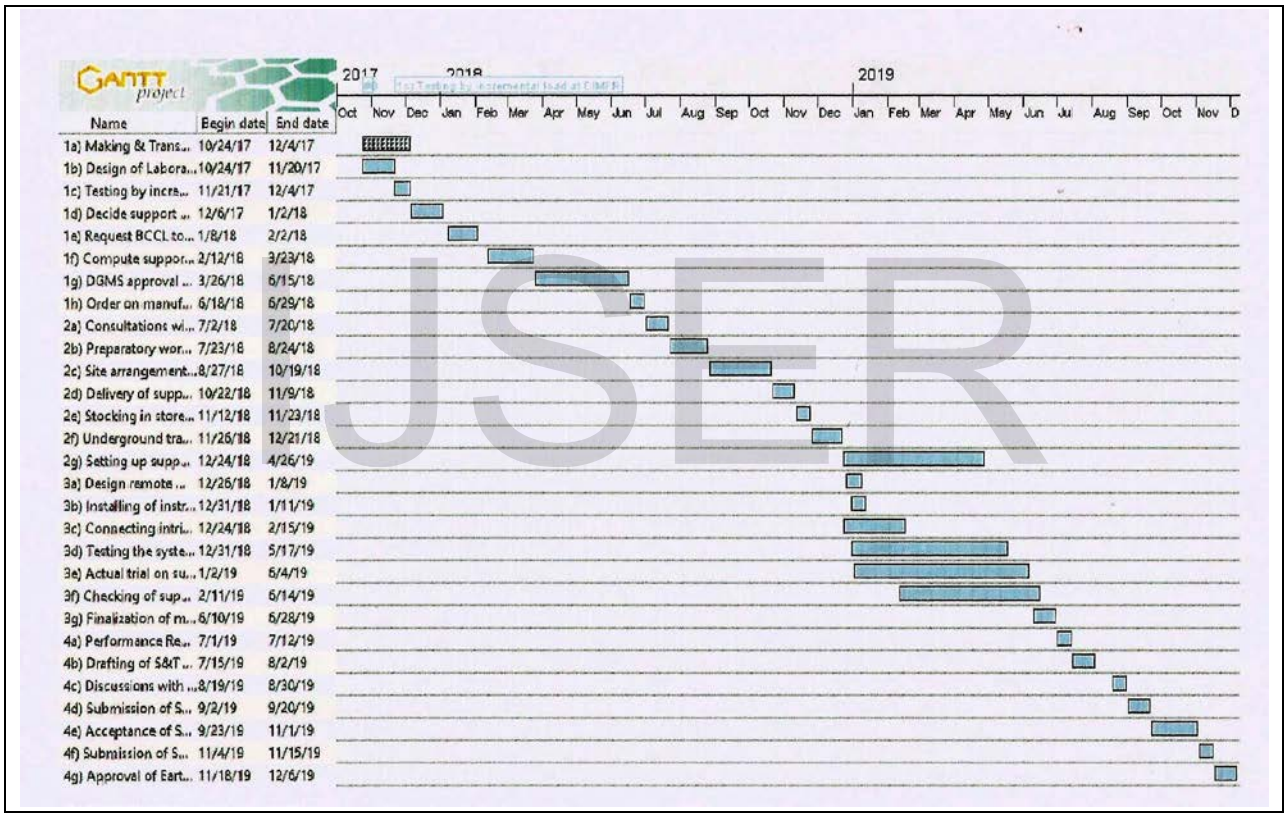
7. ACTIVITIES & OUTLAY

Since, it would be a new kind of study, there could be some unforeseen delays. It is programmed that all the activities would be completed within 2 years, after communication of sanction of the project proposal from the ministry. Activities under indicated packages are tentative and can be modified according to the results of investigations. However, all attempts would be made to control time and cost overruns by proper planning and scheduling along with close monitoring. That is why collaborative agency was required, permitted under S&T guidelines for CMRI vehicle and tour restrictions with provisions of expert deputation.

7.1 PERT Chart

Major activities for the draft schedule of the S&T project developed over computerized Gantt Chart is shown below in Table No – 2

TABLE NO-2: SCHEDULE OF THE S&T PROJECT



7.2 Capital and Revenue Estimate

By analysis of the different activities, resources required, the total outlay for the S&T project would depend upon actual cost of earthquake proof support, parameters of depillaring panel, assuming a small 6/8 pillar district is envisaged. The main units are surface work-shop, Special supports testing modification, Remote monitoring station with all auxiliaries including electrical will be required. Capital expenditure of the project has to be spread over next 2 years like Site Workshop- Tools, Tackles, Welding Set etc.; Remote Monitoring System etc. Hardly any timber would be used in depillaring experimentation; which would be great saving.

Steel X45 specification pipes can be suitable can be suitable for strength and antirust properties can be suitable with Chemical composition (weight %): C- 0.472, Si- .501, Mn- .151, Cr- 8.00, Mo-9.00, Ni - 1.00 V W Others; High temperature mechanical properties: tensile strength (N/mm^2)- 600; Modulus of elasticity [10^3 N/mm^2]: 205; Density [g/cm^3]. Main items are Consumables, salaries and allowances, travel expenses, other costs (expert visits, miscellaneous). Total Capital + Revenue has to be computed, including Institute overhead charges @15% and then Grand Total of the S&T Outlay will be determined.

8. SANCTION & IMPLEMENTATION

On receipt of letter by the beneficiary, in this case BCCL, CIMFR will draft proposal and then it would be sent to CMPDI, which is the processing agency for Coal S&T projects. CMPDI can suggest some amendment of the draft and then CMPDI informs to submit in required number of copies for putting up to SSRC under Ministry of Coal.

After sanction letter is received, all parallel activities are started like laboratory testing, numerical modeling for support parameters at different depths. Then, BCCL will be requested to identify the trial underground district in consultation with DGMS and earthquake proof support parameters will be computed. Time schedule for delivery of special supports at the site of depillaring finalized. Preparatory works for trial underground, at site will be done, like isolation stoppings etc. Advance support to be erected to prevent any chance of bed separation, special supports with roof bolting will be erected right from start and continued through entire depillaring operations. DGMS would be monitoring from time to time and their suggestion would be mandatory.

Officials of BCCL, like GM of the area, Agent and Manager of the mine, have to keep vigil during implementation. Piezo-electric sensors to be fitted over special chocks by CIMFR, have to be remote monitored for analysis of super-incumbent pressure, to make alteration if required. After extraction coal with erection of supports from the panel, the district has to be isolated. Even then, remote monitoring of identified supports could continue for confirmation of parameters for few months. Consequent upon successful monitoring, project completion certificate has to be given to the ministry. Then, DGMS is expected to give approval of earthquake proof support design system for future implementation.

9. CONCLUSIONS

Some of the special features are that Earth-quake proof Support system are:-

1. Special supports with roof-bolts to endure forever, after coal extraction.
2. Remote monitoring of load at vulnerable sites should continue for about 6 months.
3. This method would be difficult to implement in very thick or highly pitching seams.
4. Higher percentage of extraction by underground method is ensured.
5. Future design of special support for Continuous Miners can be evolved.

Recent investigations in Rock Mechanics and technological development would help evolve standard for earthquake proof mine support designing. The success of the S&T project will have far reaching advantages in the mining industry for underground extraction, not only in India, but across the world. Safety measures during implementation of the project are: -

1. Latest design for electronic remote monitoring of loads on roof supports,
2. Testing of sample of roof rock and coal, strength test of sample roof supports on UTS,
3. The maximum surveillance will be of the special supports of new design.
4. The special supports with wide base plate and shield kind of canopy
5. Designed not only for distribution of load, but also to counterbalance the creep of strata.

It would be the safest method to extract seams below waterlogged goaves, which cannot be kept always dewatered, although legally required, up to 60 m, especially during monsoon. Disaster like Central Saunda in June ’05, where 14 employees lost their lives, due to geological faults causing premature caving of the roof, connecting the upper seams, inundating the mine, could be averted. IIT, Khargpur wanted to help in prototype building, modeling and numerical analysis. During my visit to USA, Arch Coal showed interest in the project.

Although, for earthquake proof structures, IS-4326 Civil Engineering standard is available and so for developing mining standard, CIMFR will get opportunity by this S&T project. The advantages of such a method in suitable conditions are listed below:

1. Highest percentage of extraction in underground method;
2. Prevention of damage to upper seams or surface structures;
3. Safety of workmen against roof collapse, bumps and air blast;
4. Safety against inundation from upper waterlogged workings;
5. Coal is nonrenewable resource and once left in the mine cannot be recovered later;
6. Conservation of timber, the present undergrounds supports material and forest.
7. Special supports are stronger and much cheaper than steel chocks.

An underground panel of many pillars, saving of coal alone would be several Rs. Crores, apart from savings in safety of upper seams and surface structures. There would be less chance of fire; percentage of extraction can be even greater than Longwall method.

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