COAL MINING IN INDIA: TECHNOLOGY, CHALLENGES AND WAY FORWARD

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Abstract

Though India is the 3rd largest producer of coal next to China and USA, 96% of the production comes from opencast mines, but hardly 4% from underground. In underground coal mines, drilling and blasting with loading by SDL or LHD and transportation by belt conveyors are the common technology in bord and pillar pattern whereas continuous miner-shuttle car, longwall and blasting gallery methods are being increasingly adopted.

There is unequivocal need to increase coal production from the existing to 1.5 Billion Tonnes by 2030. Government of India has an ambitious target to produce 1 Billion Tonnes of coal per year from 2025 to meet growing energy demands of its rural, urban and industrial requirements. However, the stringent environment laws, ambitious demands of land owners and e-auction of the mining rights in addition to various social obligations from all corners of society, have put tremendous pressure on the mine operator to extract coal not only safely but efficiently and economically sustainable. On the other hand, mechanization with adoption of latest mining methods is the only option left to the mine planners to make a coal mining project economically viable. This paper, in this context, discusses the related pros and cons, more especially the high speed drivage using road header and continuous conveyor invariably in green field projects, the High Wall Mining, Paste Filling Technology using coal ash with or without crushed over-burden rock. Nonetheless, the latter would be the technology to liquidate standing pillars and extract thick seams under adverse geological domains, as detailed in this paper.

It is also envisaged, here, that no mechanization can be successful unless the machines are indigenously manufactured and supplied to the mining industries based on its applicability specific to the coalfield. Similarly, the support services in the area of ventilation, strata control, support-system, fires and spontaneous heating including rescue and recovery would have to be advanced further using the latest electronics, control system and communication technologies so that the requirements are always met without facing any crisis. To adopt latest innovative approach and initiatives to analyse the system and methods; and to arrive at acceptable level of standards of safety in coal mines are need of the hour, which would help the mine operator to ascertain and eliminate specific risks, related to work, machine and environment, with an aim to have 'Zero accident' and 'Zero harm' at work places.

The manpower in coal sector is decreasing day by day with increased mechanization. Experienced and dedicated persons are retiring and such places are being taken over by machines or being filled up by new to-be-skilled employees. The system of training and skill development with new machines and technologies are falling behind resulting in accidents and loss of precious lives of the miners and supervisors. The paper emphasises to address this issue in a holistic manner.

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1.0 Introduction

Minerals and Energy are primary needs of any nation for development, progress and prosperity. India is rich in mineral resources and produces 85 minerals out of which 4 are fuel minerals, 11 metallic, 52 non-metallic and 22 minor minerals. Steel, cement and energy are the prime movers of industrial engine of any country and would remain the base-frame of advancement in future. India being the 2nd most populous country next to china needs to grow at faster pace to meet the essential requirements of its population. India has almost all the natural resources required for development and growth of modern industries such as iron ore, bauxite, limestone & dolomite, manganese and the coal. Although India is 4th largest producer of steel in the world but its per capita consumption of steel is the lowest at 86.70 kg (during 2023) as compared to world average of 233.00 kg. South Korea consumes 1057.40 kg/person with Taiwan (China) 793.4 kg/person. China and Japan's per capita steel consumption is almost same at 646.00 and 658.40 kg respectively. (Year 2023)

With the growing demands of steel in domestic market especially in housing, transport, power, roads and railways sectors, the government has proposed to enhance the existing capacity from 99.57 Mtpa during 2013-14 to 488.66 Mtpa in 2030. With this, India is expected to become the 2nd largest producer of steel in the world next to China. Presently, it is also the 3rd largest producer of coal and 4th largest producer (140.0 Mt) of iron ore in the world with Australia (525 Mt) at the top followed by Brazil (367 Mt) and China (280.8 Mt) (*Year 2018*).

Iron ore and coal are the two primary minerals required for making steel. SAIL being the most important wing of the Government in steel sector, has prepared a comprehensive document "Vision 2025" which envisages a production target of 50 Mtpa whereas the long-term policy of Ministry of Steel, Government of India envisages an ambitious plan to achieve production of 300 Mtpa by 2030. For achieving this target, a minimum of 0.8 x 300 Mtpa = 240 million tonnes of raw coking coal will be required.

Since Indian coking coal contains high ash content with low calorific value, it requires washing. But the washability index being very low, only 33 to 38% yield is achieved resulting in huge quantity of middling and rejects. It is therefore essential to install at least a total of 200 Mt capacity of coal washery to fulfil the required demand. An effort in this direction has already been taken by the Ministry of Coal, Govt. of India. The easy and good quality coal deposits at shallow depths within 300m are depleting. Coal mining is extending to deeper horizons upto 600m or beyond with inferior quality of coal that would necessitate installation of additional coal washing facilities and sustainable uses of fly ash. Extraction of coal by surface mining is reaching its limit and is likely to continue for another two to three decades. Thus, in deeper horizons, only underground mining with mass production technology would be sustainable. Bord and pillar mining would continue to be the fore-runner in extraction of coal from belowground using continuous miner shuttle car. Longwall technology has been adopted worldwide, so can be applied in Indian context suitably. Even the mine voids filling using crushed overburden from opencast mines and fly ash from thermal power plants would be highly required to prevent damage to surface land and protect surface structures thereon. India has vast reserves of iron ore and coal, let us have a glimpse of the latter.

COAL RESERVE

India has a total of 361.411 billion tonne (BT) of coal reserves with 35.105 BT of coking coal and 326.306 BT of non-coking coal (as on 1.04.2022). Coal is one of the most important raw materials apart from iron ore, limestone and dolomite that are required to produce steel.

Coal is and will continue to be the dominant source of electricity in the country. At the estimated rate of 1.5 Btpa of coal production during the next five years and beyond, it is anticipated that the coal reserve is likely to last for over 200 years whereas coking coal reserve is likely last for more than 115 years @ 300 Mtpa of projected steel production. The following table indicates the production of coking and non-coking coal during the past five years.

Year	**Coking Coal(MT)**		**Non-Coking Coal(MT)**		**Total(MT)**	
	Production	Consumption	Production	Consumption	Production	Consumption
2018-19	41.13	43.31	687.59	689.47	728.72	732.79
2019-20	52.94	50.65	677.94	656.52	730.88	707.17
2020-21	44.79	44.00	671.30	646.88	716.09	690.88
2021-22	51.70	54.40	726.49	764.81	778.19	819.21
2022-23	60.76	59.41	832.43	817.95	893.19	877.37

The following table indicates the indigenous supply and the import of coking coal during the past 5 years.

Year	**Coking Coal(MT)**		**Non-Coking Coal(MT)**		**Total(MT)**	
	Indigenous	Import	Indigenous	Import	Indigenous	Import
2018-19	43.31	51.83	689.47	183.51	732.79	235.34
2019-20	50.65	51.83	656.52	196.70	707.17	248.53
2020-21	44.00	51.19	646.88	164.05	690.88	215.24
2021-22	54.40	57.12	764.81	151.50	819.21	208.62
2022-23	59.41	56.05	817.95	181.61	877.37	237.66

From the above, it is evident that India is mostly dependent on import of coking coal mainly from Australia and for non-coking coal from both Australia and Indonesia including South Africa. The import of coal has put tremendous pressure on foreign exchange reserve (FER) similar to that of crude oil. The international price of coking coal has moved to $ 280 per Tonne i. e. (280 x 83.35 = `23,338/Tonne in 2023 and that of thermal coal is $112 per Tonne i.e. (112 x 83.35 = `9335 per Tonne in December, 2023.

In the light of the above, it is essential to look at our own resources and explore possibilities and technical options to reduce import of coal for production of steel, cement and power in the country.

Classical and conventional approach is not going to fulfill the ambitious target of coal production in the country. It is, therefore necessary to change the mining from semi-mechanized to mechanized system using the latest technology, materials, skilled and devoted manpower through the help of R&D and innovations in each field.

2.0 Present Trend and Future Scenario of Coal Mining in India

India has a mixed blend of mining from small manual mines to large mechanized opencast and underground mines. In coal sector 96% of the production comes from opencast mines whereas hardly 04% from underground. Most of the opencast coal mines are mechanised using shovel-dumpers whereas in some of the mines Draglines, Surface Miners. Larger capacity machinery such as 20-40 m^3 shovels and 370-420 Tonnes dumpers are being used. In underground coal mines, drilling and blasting with loading by SDL and LHD on to belt conveyor in bord and pillar workings are common whereas continuous miner-shuttle car, longwall and blasting gallery methods are being adopted in some of the mines. However, the pace of mechanization in underground coal mines is by and large very slow. In coal sector itself, there are more than 250 coal blocks likely to be allocated to both public and private sectors for captive as well as merchant mining. All these mines are likely to come up into production during the next five years. The mining activities in such mineral blocks are likely to be undertaken mostly through outsourcing by national or international mining companies.

3.0 High Wall Mining (HWM)

The mines are being planned by opencast methods from existing 150- 250m to 450-500 m depth from surface at stripping ratio ranging from 1 in 4 to 1 in 15. The over burden dumps of heights ranging from 60 to 400m with internal or external dumps are also being planned. The mines are planned to be operated with deployment of heavy earth moving machinery of very high capacity i.e. 40 m^3 shovels, 80 m^3 draglines and 470 tonnes dump trucks, Surface Miners, Stacker Reclaimers/Spreaders and in-pit crushers along with high-capacity conveyors. Almost 60% of the opencast mines which were started during the past 15 years are closed due to being reached at uneconomical stripping ratio. HWM may become an alternative for coal production subject to its technical and economical suitability.

HWM technology has been established in some of the mines of M/s. South Eastern Coalfields Limited (SECL); of M/s. Singareni Collieries Company Ltd. (SCCL), recently one of the coal mines of M/s. TATA Steel in West Bokaro, Jharkhand. This mining is suitable as an economically viable technology to extract thin seams which were thought to be un-mineable in the past. Trench Mining using the High Wall Miner is being successfully used in Sharda Opencast mines of Shohagpur Area of SECL situated in Anuppur district of M.P. where 1.1 – 2.2m thick seam is being extracted.

Fig.1. High Wall Mining at Sharda OC, SECL

Fig.2. High Wall Mining at West Bokaro, TSL

It is possible to apply Paste Filling Technology to be used in the extracted voids in HWM to get maximum coal recovery without affecting the surface land and/or without any acquirement of surface land. On the other hand, the HWM team is also exploring the possibility of use of High Wall Miner in underground where the large area of the coal seam may be extracted by sitting from a single location. Once this innovation is made successful, it will not only provide a Remote-Controlled Mining Technology (RCMT) for underground coal mining but would also improve the standard of safety in coal mines.

The opencast mines working at higher stripping ratios (> 5) are facing acute problems of land acquisition and Slope failures both in the open cast benches as well as in over-burden dumps. A number of bench failures in OC workings and dump failures in over-burden dumps have occurred during the last 5 years in Wardha Valley coalfield of M/s. Western Coalfields Limited (WCL) in Maharashtra. Slope Stability Radars (SSR) have been deployed to monitor the bench and dump slope in such mines.

On 17.08.2015 there was an incidence of major bench failure in Manikpur Opencast mine of M/s. South Eastern Coalfields Limited SECL) situated in Korba Area in Korba district of Chhattisgarh where 3 to 5 numbers of over-burden benches each of 10 m height, to a total extent of 250m length x 50m width x 30 to 45m height had failed which also dragged 30m high old over-burden dump into the failure zone which moved horizontally upto 70m. Fortunately, no men or machinery was deployed at the bottom of such benches and the cracks on surface had developed on 22.10.2014 which culminated into failures after about 14 months' time lapse since development of cracks on surface leading to the total collapse of benches.

Fig 3 Bench Failure at Manikpur Opencast Mine of M/s. SECL

The depth of opencast mines is increasing from 200m to 450m in which shovel dumper mining is being adopted. But due to increase in input costs and limited productivity from this technology, it has become more important to undertake an R&D initiatives and innovations to maximize the efficiency and profitability through.

4.0 Underground Mining

Coal mines are being planned now to be operated primarily by continuous Miner-Shuttle Car or by Longwall technology. The mines are planned of capacities varying from one to five million tonnes per annum.

Fig. 4 Conventional Bord and Pillar workings and Subsidence after Extraction

Therefore, most of the underground coal mines are running in loss from a minimum of Rs.300 to maximum of Rs.11,000 per Tonne. Most of the new seam or green field projects are, therefore being planned either with continuous miner-shuttle car or by longwall mining, so that high production could leverage capital and recurring costs. Paste filling technology can provide a solution not only to control subsidence to a reasonable level, but also to manage the high stress regime expectedly at greater depth.

5.0 Paste Filling Technology (PFT) an Alternative to Hydraulic Sand Stowing:

Millions of Tonnes of good quality coking and non-coking coal standing on pillars are lying locked up below built-up areas, railways, roads and important surface features including forests. There is no suitable technology to liquidate such pillars below surface features.

However, an attempt is on the anvil in three underground coal mines to undertake an R&D Project to extract coal seams under extremely difficult mining conditions below built-up areas, National Highways and Railways and underneath highly water-charged aquifer "Kamptee Series" using Paste Filling Technology (PFT) with coal ash and crushed over-burden waste along with mobile continuous conveyor for fast evacuation of coal matching to filling rate. Out of the three mines selected for the PFT, one mine i.e. Durgapur Rayatwari Colliery (DRC) in Chandrapur Area of M/s. Western Coalfields Limited (WCL) is having very thick seam having thickness varying from 16 to 21m dipping at 1 in 5- 6. The PFT there will be used for multi-lift working where the seam is highly susceptible to spontaneous heating and fires. One unit of DRC is closed only due to spontaneous heating and fires whereas in another unit, the developed pillars are kept submerged under water due to the reason that the moment the workings are dewatered and fallen coal is cleaned for starting depillaring with sand stowing, it catches fire leading to stoppage of working.

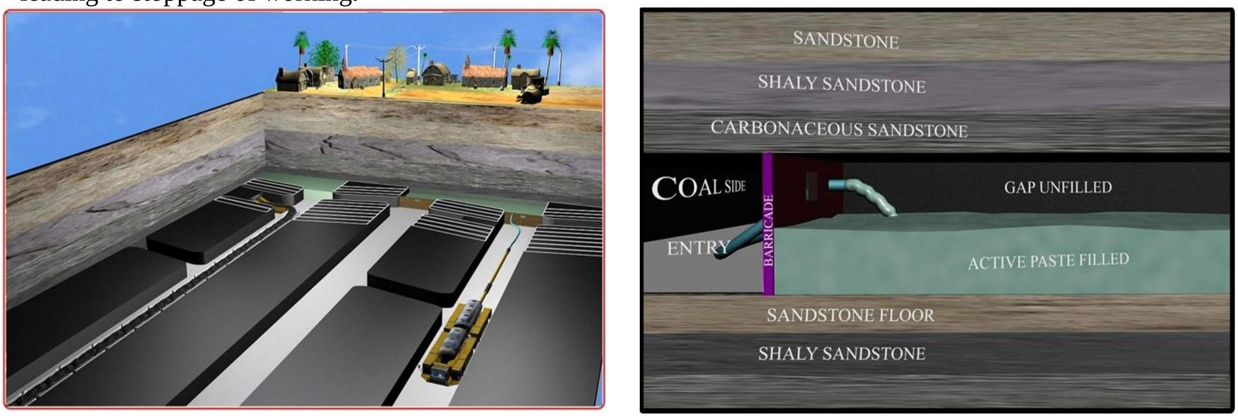

Fig. 5 Paste Filling Technology (PFT) with Continuous Mining

Case Study of Durgapur Rayatwari Colliery in Chandrapur Area of M/s. WCL where the PFT is proposed under the following conditions:

i. This is a case of very thick [16 to 21m] seam mining dipping at 1 in 5 [adverse gradient] unsuitable for trackless mining;

ii. Immediate overlying strata is composed of loosely cemented sandstone with intercalation of clay which is highly water charged aquifer "Kamptee Series" posing serious threats of inundation into the underground workings and potholing on surface;

iii. Surface area is densely populated with important features such as State High Way (Chanda-Mul Road), MEL Railway Line, MEL Plant, 11 KVA overhead line, Forest Training College, Forest Colony, Reserves forest land having dense forest, Refugee Camp & Bengali camp, Ambedkar Community Hall, and Hutments;

iv. The seam is highly susceptible to spontaneous heating and fire which resulted into sealing of Incline No. 7 & 8 Unit and drowning of the dip side workings standing on pillars in DRC No. 3 & 4 Units.

Since there is no established technology to extract very thick seam of this nature under the above-mentioned scenario, an R & D Project has been proposed to be undertaken to utilize the available coal ash from the Chandrapur Supper Thermal Power Plant and or Crushed and sized over burden [OB] from the Durgapur opencast mine to fill in the mine voids using Paste Filling Technology [PFT] and extract the coal seam to its full thickness. Paste Filling Technology in Thick Seam in multi-Lifts working is shown in ***Annexure-1.***

This R&D initiative would provide a sustainable method and solutions for thick seam mining and application of past filling technology in coal mining in the country including use of fly ash and also the over burden waste of opencast mine for mine voids filling which will replace hydraulic sand stowing. In addition, the technology will relieve the mine operator from the problems of acquisition of surface land and associated hurdles.

5.1 Prevention and Control of Subsidence using Goaf Blasting Technique (GBT):

In normal extraction with caving, the surface land gets damaged due to subsidence. In order to protect surface land from damage due to subsidence, hydraulic sand stowing or partial extraction methods are used in which percentage of extraction becomes very low to the tune upto 25% and highly precious coal resource is lost forever. Mine void filling using PFT is an option for this condition. This technique is based on the principle of bulking factor (40 to 50%) of blasted sandstone which would be used to fill up the voids calculating the caving height and the bulking with compaction factor taking into account. The blasting technique would be primarily three-dimensional cylindrical column blasting using VCR blasting front in 3m crater pattern. This is an innovation of the author to establish this technique for prevention of subsidence due to coal mining. The brief of the GBT is described below.

5.2 Goaf Blasting Technique (GBT) To Control Subsidence:

Case Study Jhilimili Mine under Baikunthpur Area of M/s. South Eastern Coalfields Ltd.

There are only two workable seams namely Seam V and Seam IVB, which are being worked through Incline No. 1, 2 and 3. Thickness of Seam V varies from 2.54 to 5.2m and that of seam IVB is 1.5 to 1.8m with parting varying from 20 to 22m. Seam V is the topmost seam whereas Seam IVB is the bottom seam. The gradient of the seam is 1 in 22 N 21.5^0 E. The depth of cover of seam V varies from 23m to 121m whereas that of Seam IV varies from 45m to 143m. Coal seams are of degree I gassiness.
A generalized section of strata showing both the coal seams is shown in ***Annexure-1.***

Development of Seam V: Seam V is being developed on bord and pillar system with pillars of size 25m x 25m and galleries 3.8 to 4.0m wide x 2.5m height. 1.5 to 2.5m coal is left in the roof. Immediate roof above coal seam is mostly medium to fine grained sandstone with coarse grain sandstone at some places. The RMR of the sandstone roof is 56. Development is being done by drilling and blasting using coal drill, UDM with coal loading by LHD of normal height & $1.5m^3$ bucket. Development of the seam is almost complete and there is no place for working.
Development of Seam IVB: Seam IVB is being developed on bord and pillar system with pillars of size 25m x 25m and galleries 3.8 to 4.0m wide x 1.5 to 1.8m height. Immediate roof is mostly medium to fine grained sandstone. The RMR of the sandstone roof is 52. Development is being done by drilling and blasting using coal drill, with coal loading by SDL of normal low height & $1.0m^3$ bucket. The development working in this seam is also completed.

Proposal for Depillaring in Seam V
The development workings in seam V are almost completed. Therefore, the proposal is to start depillaring from the dip side and retreat towards rise in systematic manner. The surface area over seam V workings is totally forest land with dense forest containing hills and valleys, which are not easily accessible. Total extractable coal reserve standing on pillar is about ***14.60 Million Tonnes(Mt)***.
With the present policy of DGMS arising out of Anjan Hill Mine Explosion, no permission for depillaring with caving is being considered without obtaining surface right either from the land owner or from the forest department.
The thickness of ***seam V*** varies from ***2.54 to 5.2m*** with depth of cover ranging from ***15 to 121m***. The depillaring with caving under such low cover would lead to subsidence on surface from 1.067 to 4.0m, which would not only be very difficult to control and fill but also exorbitantly costlier. The grade of seam V coal is G-5 & G6 with GCV ranging from 5500 to 6100 kcal/kg and the selling price@ ` 2800/ Tonne.
Seeing the quality of coal and the reserves left to be extracted, it becomes more important to explore possibilities of adopting some new technology so that such type of scares coal resource in the country is not lost forever. In addition, if the seam V at this mine is not liquidated, it would lead to locking up of the underlying coal seams such as seam IVB- 6Mt, III- 2.2Mt, II- 9.4 Mt & I-0.7 Mt with total coal reserve of about ***32.90 Million Tonnes***.

In view of the above difficulties, a proposal was received in RI-V, CMPDIL, Bilaspur to suggest suitable method so that the coal from Seam V can be extracted. The problems have been examined in CMPDIL based on the details of workings of seam V and the strata overlain at Jhilimili Mine and it is proposed to extract the coal seam by **Gob Blasting Technique (GBT) method** to fill up the caving zone in the goaf to such an extent that there will not be any subsidence on surface. Details of the method and Technology are described in the following sections.
The proposal is to extract seam V in ***Panel – T21,*** where the thickness varies from 4.76 to 5.18m. Depth of cover varies from 99 to 121m and the surface contour is almost flat. The pillars are 25m x 25m [centre to centre] with gallery 4.0m wide and 2.5 to 3.0m high leaving 2.18 to 2.46m coal in the roof. The Lithology of the strata above the coal seam in the panel is shown at *Annexure-1*.

Factors affecting subsidence on Surface

Extraction of coal seam with caving normally results in subsidence on surface unless the depth of cover exceeds the critical depth specific to the thickness of extraction and to the critical width to height (thickness) ratio of the coal seam.

In this proposal, regular blasting in the goaf upto a height of 15m from the roof has been proposed to be carried out so that even @ of 40% swelling factor, the 2.54 to 5.18m thick voids created after depillaring will be adequately filled up and compacted to prevent subsidence reaching on surface.

In the literature, it has been indicated that sandstone has 65% bulking factor (k) but in this proposal only 40% bulking factor has been assumed in spite of the fact that even DGMS considers 50% bulking factor with blasting.

Subsidence Data and Subsidence Control Measures

In normal caving of 3.50m thick coal seam at ***89 to 95m cover***, only cracks were developed on surface without subsidence in ***10 LE depillaring panel*** of ***Seam I of Katkona 1 & 2 Incline*** Mine in the Area.

Hence the Critical Subsidence Rate of the Strata = 3.5/89 to 95

$Subsidence_{Critical\ Rate}$ ***= 0.037 to 0.039 m/m-Depth***

Therefore, for 4.7 to 5.18m thickness of extraction ***at 98.0m*** (BH NO.JG-80)& at ***120m depth***, expected subsidence will be: (4.7 to 5.18) - 0.035 x 98 = ***1.074 to 1.554m. whereas at depth of cover at 85 cover with 2.54m thickness of extraction (BH No. JG 51). = 0.039 * 85 = 3.315; subsidence expected = 2.54-3.315 = (-) 0.775m.***

In case of critical Subsidence rate @ 0.039 for a depth of 98m, the subsidence expected = 3.822 , net subsidence = 4.7-3.822 = ***0.878m*** & for 5.18m thickness at 98m cover, expected subsidence = 5.18- 3.822 = ***1.358m***.

Hence the expected subsidence over the panel at critical rate of subsidence is expected to be within ***0.90 to 1.60m at depth of 98m.***

BULKING FACTOR (k) : 40 % (After Blasting) = 0.40 x 15 = 6.00m

COMPACTION FACTOR(C_f) : 15% (Due to Roof sagging on blasted muck): = 0.15 x 15 = 2.25m

Swelling of Blasted Rock := BF-CF = 6.00 – 2.25 = ***3.75m***

Thickness of Extraction := 4.7 to 5.18m

Therefore, the 3.75m net swelling of the blasted rock will neutralize the 0.90 to 1.60m expected natural subsidence with an additional buffer of 2.15 -2.85m expansion of the blasted rock.

Method of Extraction

The pillars 21m x 21m (corner –Corner) will be splitted by driving 4.5m wide gallery with full height of extraction i.e. 2.54 to 5.18m against the sandstone roof. The split pillar of 10.5m size on both sides of the split gallery will be extracted in slices not more than 4.8m width leaving at least 3.0m rib against the goaf. The rib so left may be extracted while retreating. Long hole drilling in fan pattern will be drilled from the original gallery to cover upto 15m height above the coal seam and upto the centre of the split gallery covering 10.5m block of split coal. The fan drilling will be done at an angle of 20^0 inclined from vertical towards goaf. The fan/ring spacing will be 3.75 to 4.0m whereas the toe-burden of the holes in the fan/ring will be 2.8 to 3.25m. The diameter of the shot hole will be 51 to 57mm. The Fan drilling will be done only in the original galleries. The permitted explosive of 40mm diameter and 400 to 500mm long cartridges along with shock tube nonel will be used for blasting the sandstone strata in the goaf. The charge density will be kept 2.5kg/m of the shot hole as per the specified design. Minimum 2 to maximum 3 millisecond short delays will be used in each shot hole to blast the entire 15m section of the roof in successive shots of cylindrical charges keeping the charge weight per delay to be maximum 5.0 to 7.5kg.

The Slicing and the drilling pattern are shown in ***Annexure-1.*** In case this technique is established, it will be an important tool to prevent subsidence on surface and there will not be any requirement to acquire surface land for depillaring at the same time the surface land will not be disturbed due to coal mining underneath.

5.0 Mines Safety in India

Mining accidents are accident that occurs in the process of mining metals or minerals. Hundreds of miners die from mining accidents each year, especially in the process of coal mining and hard rock mining. Coal mining is more dangerous than non-coal mining.

5.1 Analysis of the causes has been given in the table below:

Table

Major Cause Group	% Influence	Cumulative Influence (%)	Priority Level
Roof & Side Falls	27	27	I
Dumper & Trucks Transport	25	52	I
Non-Transportation Machinery	12	64	II

Fall of Persons & Object	9	73	II
Electricity	5	78	I
Other Causes	22	100	III

6.0 ***Prevention of Mine Accidents***

About accidents, it is generally said that they do not happen; they are caused by:-

- Process failure
- Environment failure
- Human failure.

6.2 Occupational Safety and Health Risks in Mines:

(a) System or Process Risk

(i) Identification of Dangers and Hazards

Safety Audits and Inspections are the primary approach to identify system/process safety and hazards involved at each stage of operations and also to check whether appropriate measures to eliminate hazards and risks are adopted and put in place.

(ii) Risk or Hazard Potential

The sources of dangers, frequency of occurrences, duration of occurrences, energy release rate and quantum of undesirable effects/damages including the personal exposure level define the hazard or risk potential of any process, system or environment. It is an essential component for risk and disaster management plan.

(iii) Danger Zones and Risk Contour Plans

No process, system or place is considered safe and secured for all times. Under the changing systems and parameters, there are always possibilities of failures and if not contained or controlled and risks managed, they may lead to accidents. It is, therefore essential to define danger zones and draw risk contours to minimize hazard potential and personal exposure to such dangers and risks. In this context, the following examples are of importance:

Definition of Zones from the sources of Inflammable/Noxious Gases

Zone 0 : It is an area lying within such distance from the source of inflammable/noxious gases where the % concentration of such gas will always be within explosive or danger limits.

Zone 1 : It is an area lying beyond zone 0 where there are all possibilities that % concentration of such gas is likely to be within explosive or danger limits.

Zone 2 : It is an area lying beyond zone 1 where there are no possibilities that % concentration of such gas is likely to be within explosive or danger limits.

(iv) ***Hazard/Risk Control System/Process and Measures***

Whenever a system, process or machinery is designed, all standards and parameters are tested and fitted according to the need, requirements and the environments where they are to be used. There is always process safety and control measures included which keep the system/process within desired operational limits. Whenever such processes, system, machinery or control system fail to operate within its limits, it leads to risks and failures. Thus the provisions for trials, testing and Life Cycle tests are introduced which ensures required reliability.

(b) Personal Hazard and Risks

Wherever and whenever a person is working or present, there are always entities and parameters whether natural or artificial that affects human being favourably or adversely. It is expressed in terms of success and risks. Personal hazard/risks are normally considered in terms of risk to injuries, risk to life and risk to health. Accordingly, the personal risks are identified and assessed for every activity in the process and environment based on which safety and protective measures are incorporated /provided. This is determined by:-

- Personal Hazard/Risks type identification
- Personal Risk Exposure Profile
- Personal Risk Mapping

(c) Monitoring Control Measures and Parameters

Operational, control and safety parameters incorporated in the system/process/method are measurable and are provided with their limits. In early sixties, discrete measurements and analysis approach were being adopted for analysis and control but now a days on-line monitoring and diagnostic controls system are being adopted not only to maximise productivity, reduce waste but also to increase safety and reliability.

(d) Success Rate and Failure Analysis

Data generated over a period of times are analysed to know success and failure rates. Based on such results, the system, process or method should be changed or modified in time. This also helps determining the probability factor for success or failure, which is required to calculate the risks and associated standards and parameters.

(e) Protective Measures

In cases where the risks and dangers associated therewith are not eliminated, protective measures are incorporated in the system, process or methods which are maintained and monitored. It has been seen in many

cases, such measures are provided in the beginning but not maintained or updated that results in accidents or disasters. Personal protective equipment (PPE) is also provided wherever needed to protect persons from dangers or risks. In cases, the risks and dangers are existing in spite of being provided with safety measures, the personal exposure to such risks is minimized by remote
operations and not allowing any person to be exposed to such dangers or risks.

(f) Emergency Preparedness and Disaster Management
In spite of taking all preventive measures and control, there have been instances of accidents and disasters. In order to save lives and property in cases of such incidences, there has been provisions made to have an emergency plan which is mandatory for each mine and such plan envisages all likely emergencies in the mine and accordingly suitable measures are provided to deal with. Disaster control and management organisation is also incorporated in mining sector to deal with emergencies of all types and natures. Mine Rescue Room, Rescue Stations, Emergency organization etc are existing in mining sector.

(g) Skill Development, Training and Personal Awareness
Skill development and training are essential constituents of any project and are being provided. But updation of skill and refreshing are not considered as important as production and profitability which leads to lack of knowledge, skill and awareness resulting in accidents and disasters. Safety, skill development and training are not considered at par with the production streams in many of the organisation. But organisation which has considered this as an essential organ, have made significant achievements in safety and health standards all over the world. Personal awareness to risk and dangers associated with one's own area of operation and the associated safety measures have resulted saving many lives and property at the time of accidents and disasters. Therefore, this needs to be taken care on priority. 3D Simulation using Artificial Intelligence are the latest tools for imparting training and inciting awareness amongst all sections of persons connected with the project. Customised 3D Modelling with Artificial Intelligence of each project needs to be introduced.

Skill Development Programmes (SDP) using appropriate training tools like Simulators, Virtual Reality Modules, Risk Observatories etc need to be initiated in all the subjects applicable to a particular mine. The SDP is required to be made mine specific and also the system and method specific.

There is need to collaborate educational institutions, research and development organizations and all other associated industries to develop appropriate technologies for coal mining. There is a need to undertake R&D studies and encourage innovations in the fields of strata control and rock mechanics, mining methods and mechanization, roof supports and mine fill technology, ventilation and fire control including emergency response and safety management. With the help of multidisciplinary approach backed up by R&D initiatives and innovations, it would not be a far dream to achieve targeted production, productivity with "Zero accident and Zero Harm" at work place in coal mines.

(h) OSH Database and Risk Observatory
It is also felt necessary to have all types of information at one place so that the person or the organisation concerned access such information and utilise them for their needs and requirements. This not only eases out the searching of suitable system and parameters but also provides guidelines to be adopted. With the use of computerisation and networking along with internet accessibility, certain organisation have made good progress in this direction and are providing such services either on charge basis or free. A concerted effort in this direction is being made in mining sector also.

7.0 Research and Development Initiatives

In the background of the future scenario of coal mining, it is essential to focus more attention on the following subjects especially on application research:

(i) Strata Control and Monitoring for deep mining conditions:
- ✓ Mechanics of Caving, Instrumentation and Monitoring
- ✓ Support Design and Monitoring
- ✓ Standards and Parameters for different types of Supports
- ✓ Sampling and Testing of Supports and Support materials
- ✓ Composite Materials for Supports

(ii) Mine Environment Management and Control
- ✓ Gas Emission Characteristics of coal seams
- ✓ Thermal Emission and Detection parameters
- ✓ Ventilation Characteristics of Deep Mine
- ✓ Methane and Coal Dust Emission and Control

(iii) Coal Characteristics and Classification – Proneness to Spontaneous Combustion
(iv) Fire Detection and Control System
(v) Pit and Dump Slope Stability
(vi) Mine Filling Materials and System
(vii) Mine Subsidence and Control

(viii) Communication and Tracking of Man and Machinery in Mines
(ix) Skill Development and Simulation for Mining Methods and Machinery
(x) Mine Statistics and Database Management

8.0 FRESH INITIATIVES WOULD FULFILL THE NATION'S DEMAND

If India has to fulfil demands of 1.4 Billions of its population, country needs to grow in agriculture and mineral sectors at a rapid pace developing and using the most productive, safe and sustainable technologies. Appropriate technologies will lead the country to path of success and progress. It is hoped that in next ten to twenty years, the mineral industry would change the development domain of the industry and the nation.

9.0 ACKNOWLEGMENT

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ANNEXURE-1

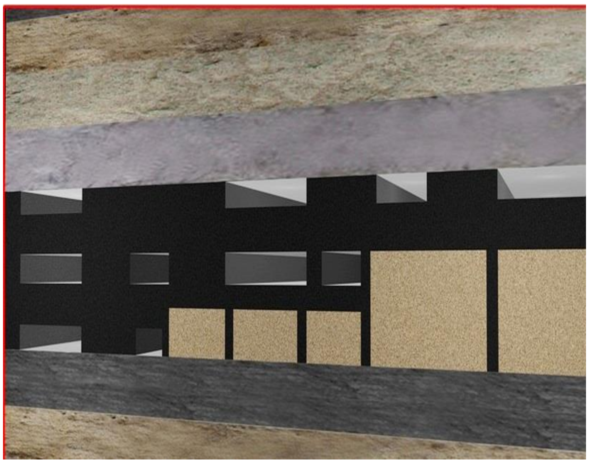


Fig. 6 (a) Conventional Stowing in Multi-section

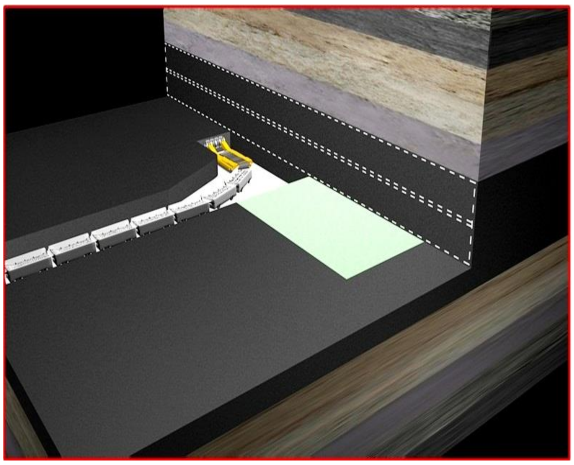
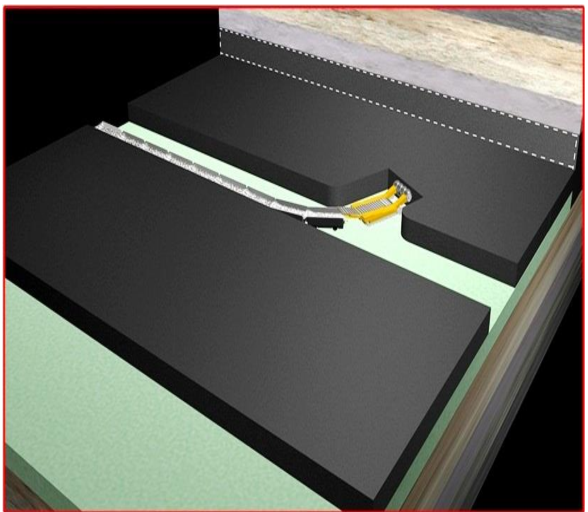
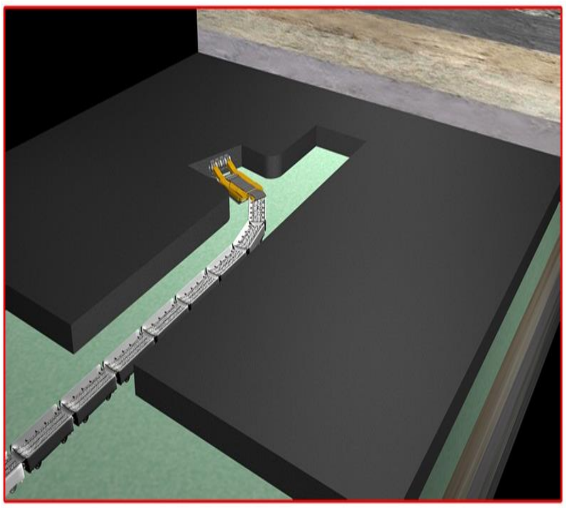


Fig. 6(b) Paste Filling Technology





7 (a) Multi-section PFT

Fig. 7 (b) Multi-section PFT

Fig. 8: A generalized section of strata showing both the coal seams is depicted below:

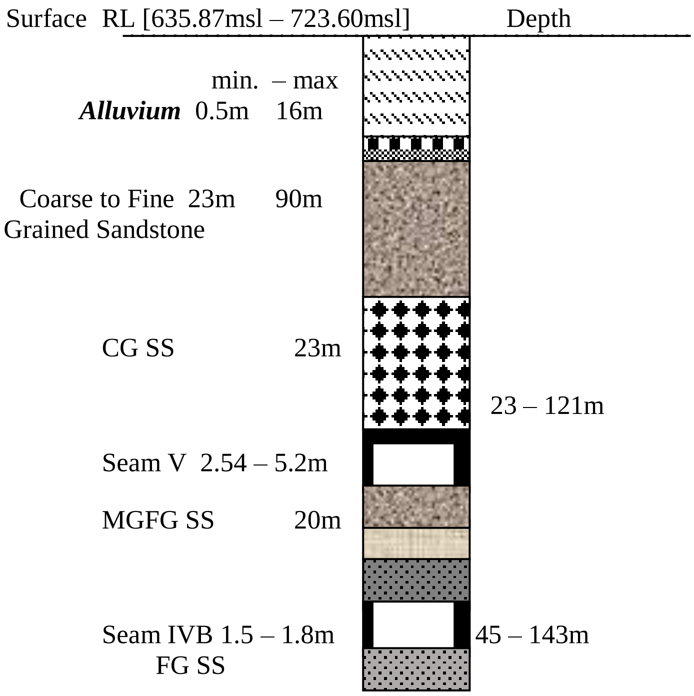
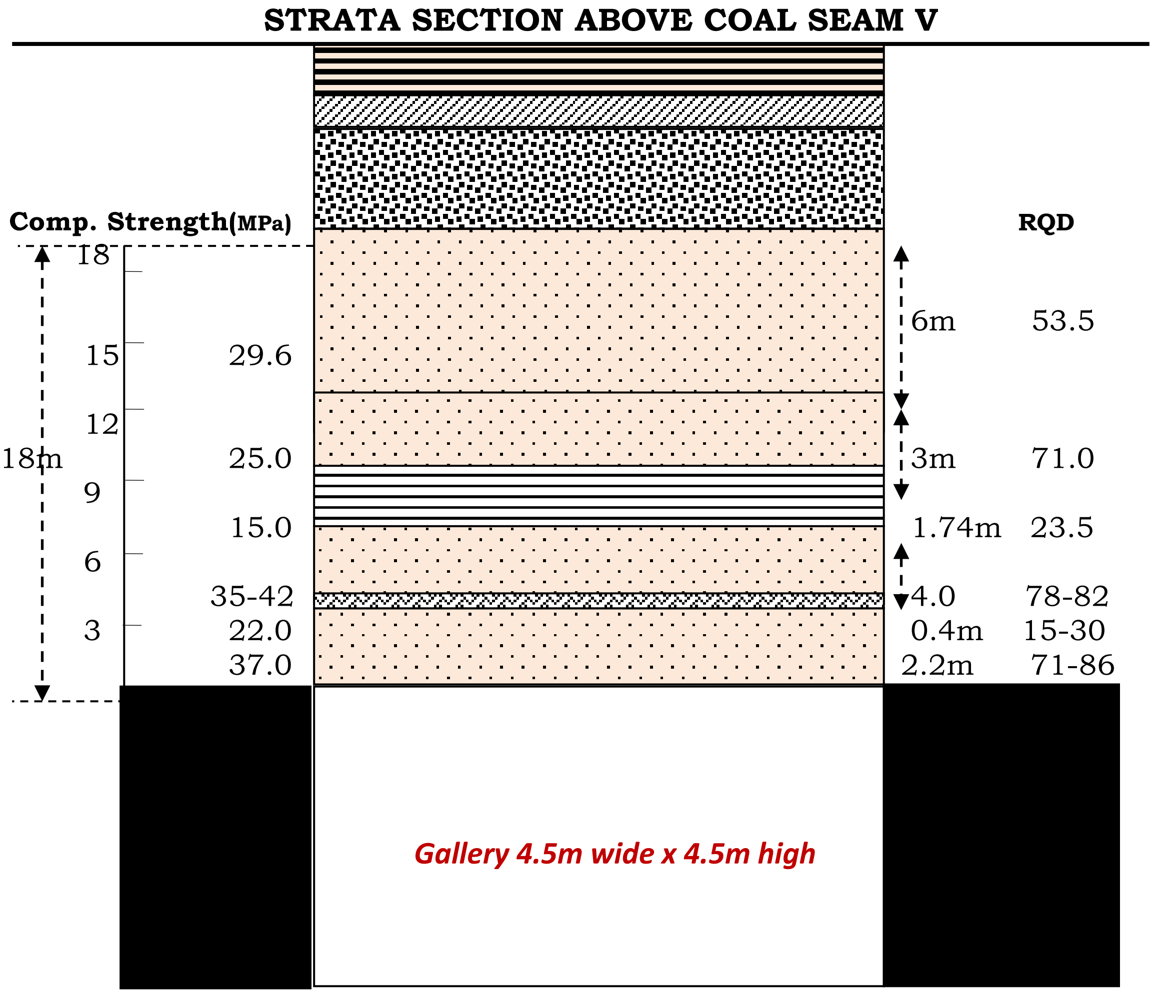
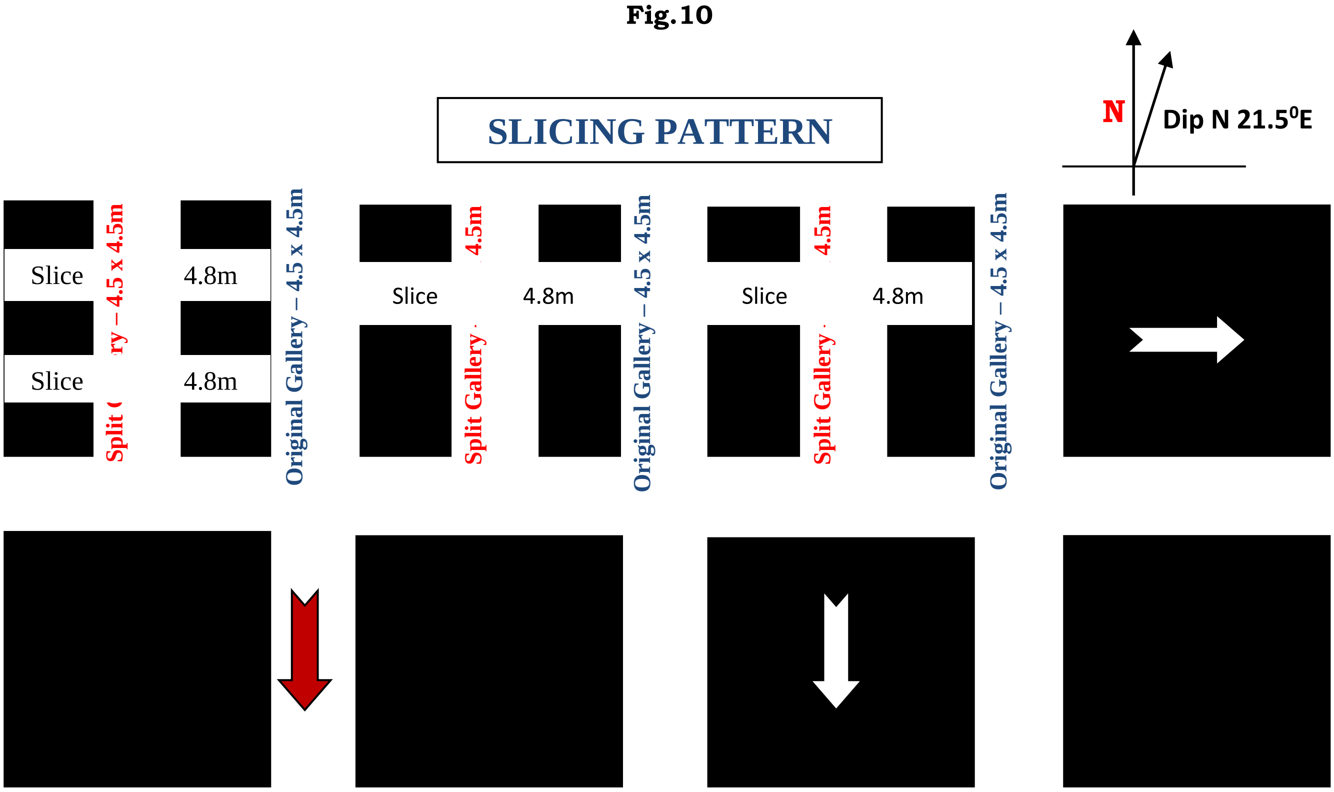


Fig. 9



STRATA SECTION ABOVE COAL SEAM V
Comp. Strength(MPa)
RQD
18
15
12
9
6
3
18m
29.6
25.0
15.0
35-42
22.0
37.0
6m 53.5
3m 71.0
1.74m 23.5
4.0 78-82
0.4m 15-30
2.2m 71-86
Gallery 4.5m wide x 4.5m high

Fig.10



SLICING PATTERN
N
Dip N 21.5°E
Slice
Slice
4.8m
4.8m
Original Gallery – 4.5 x 4.5m
Split Gallery
4.5m

Fig. 11

DRILLING PATTERN IN ORIGINAL GALLERY

Surface Area in Forest Land **Depth- 88 97m**

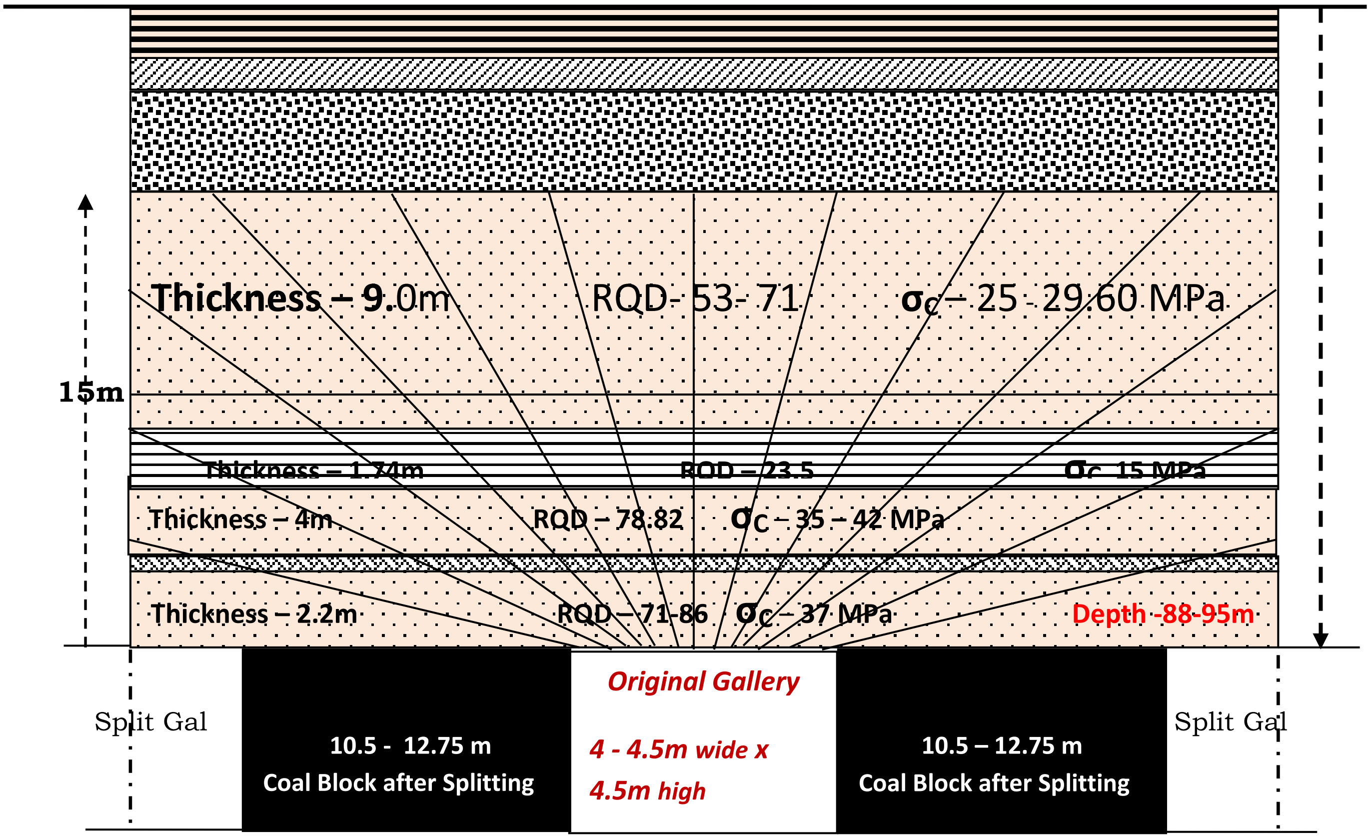


Fig. 12

Note: *Thin band of shale in 0.4m thick with* ***15 to 30 RQD*** *and* ***22 MPa*** *Strength is lying at 3m above the coal seam.* **BLAST PRARMETERS: Dia of the hole – 57mm, Toe Burden – 3.0 to 3.75m**

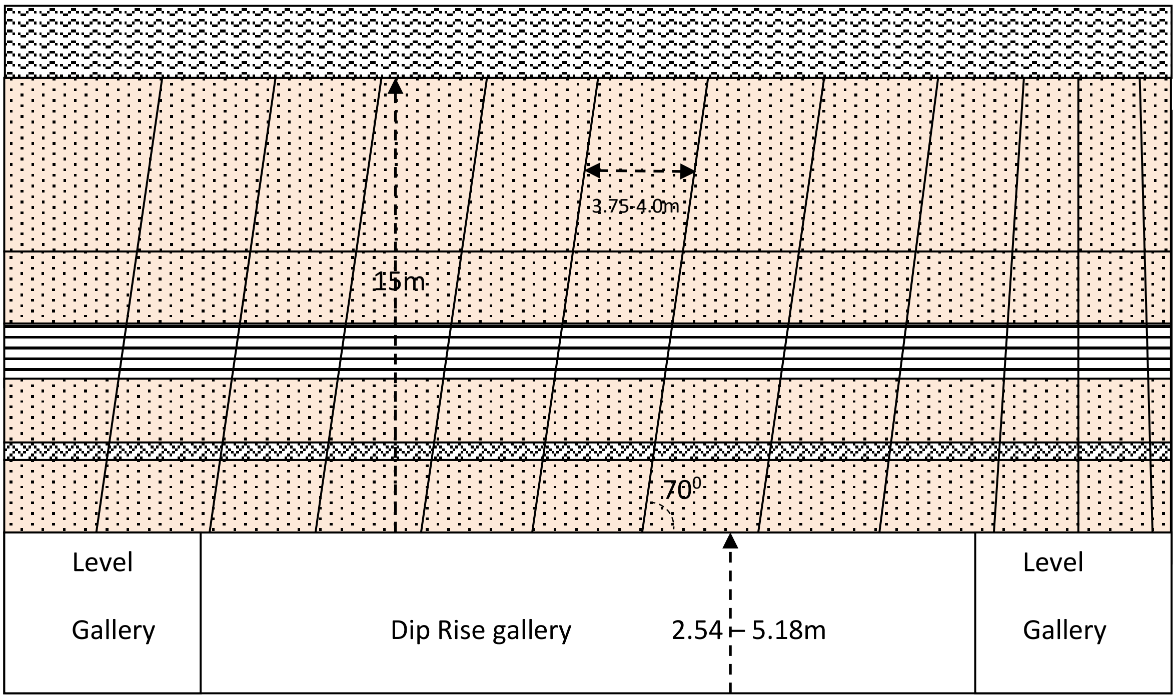


Fig. 13

Figure showing blasted muck swelled and filled up in goaf