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IIT(BHU) VARANASI

STUDENTS' NOTES

TOPIC-UNDERGROUND COAL MINING-IV

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WINNING & WORKING OF COAL

The winning and working i.e. Method of working can be basically divided into the following:-

(i) O/C working, also known as Surface Mining or Strip Mining.
(ii) U/G mining

Surface Mining is the process of obtaining coal by exposing it after removal of the overlying rocks called overburden, if any. Therefore, it is mainly applied where the coal is available at shallow depth so that the cost of removal of OB is within limit.

The principal conditions where O/C mining can be applied, are as below:-

(a) Availability of Land:- As coal has to be excavated by its exposition by removing the overlying OB, hence the land is damaged. Also, land is needed for piling up OB thus removed and for other purposes.

Hence, the first important criteria for application of surface mining is availability of Free Land.

(b) Area of the deposit:- As O/C mines are highly productive so it must have sufficient reserve to justify the investment made, life of HEMMS, Life of the mine etc.

(c) Stripping Ratio:- It is a ratio of volume of OB to be excavated for getting one tonne of coal. Economically, O/C mining may be extended upto a depth where the cost of mining coal and removing OB doesn't exceed the cost of mining by U/G.

(d) Gradient/Inclination of the deposit:- Gently dipping seams are more suitable for O/C mining, as they provide better stability for working of HEMM.

(e) Thickness of the deposit:- Thick and highly thick, seams can be more effectively worked by O/C mining. In such cases the % of extraction can be achieved upto 100.

(f) Capital Investment:- O/C mines require high capital as they have to install heavy machineries which cost high.

(g) Availability of Skilled manpower:- In general, O/C coal mines are highly mechanized. Therefore, it needs high skilled operators for its proper operation.

(h) Grade of coal:- Even low grade coal can be economically extracted from O/C method which may n't be feasible for U/G mining.

(i) Gassiness of the seam:- Even highly gassy seams can be effectively and more safely worked without any danger of explosion due to gas, if worked by O/C method of mining.

(j) Stability of overlying strata:- O/C is suitable in case of weak or very weak overlying strata as there is no danger of roof fall or Rock burst as in U/G methods.

(k) Rank of coal:- As there is quality deterioration in case of O/C mining, so the coal obtained should be able to fetch its market

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U/G METHOD OF MINING COAL.

As in case of U/G mining, the mineral is obtained without its exposition. Therefore, it is necessary to make access into the mineral deposit either by driving INCLINE OR VERTICAL SHAFT. Basically, U/G Mining is applied where O/C mining isn't feasible either due to economical, technical or other reasons. Therefore, for deep sited deposits, U/G mining is a must.

U/G Method of Mining coal is divided into three stages, name ly-

→ Access or reaching the coal seam.

⇒ Development of the coal seam ie preparation of the seam for final extraction.

⇒ Final extraction of coal, called depillaring in case of B&P method.

CLASSIFICATION OF U/G METHODS OF MINING COAL

It is basically classified as,

(i) Bord & Pillar

(ii) Longwall → advancing
→ Retreating.

(iii) Special methods viz → inclined Slicing
⇒ Horizontal Slicing
→ Sublevel caving
→ Blasting Gallery Method
→ Hydraulic Mining.

BORD AND PILLAR METHOD

It has two distinct phases of operations - Development and Depillaring.

Development consists of driving a series of narrow roads, called Galleries, parallel to each other (from the main entry, either shaft or incline), separated by solid blocks of coal either rectangular, square or rhombhus shaped, called Pillar. This process of 'development' is also known as 'First Working'. The pillars so formed are extracted at a later stage, either after development of the whole mine or a particular area in the mine.

This process of pillar extraction is called Depillaring or Final Stage of Working.

TERMINOLOGY

LEVEL GALLERIES :- The roadways driven along the strike line of the coal seam is known as level galleries or simply, levels. The levels in a mine are generally designated as 1L, 2L, 3L ..., considering shaft/approach level as zero level. All the level, below the shaft level on the dip side) are designated as +ve and on the rise, it termed as -ve as -1L, -2L, ---.

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DIP-RISE GALLERIES.

The galleries connecting the level galleries and driven along the dip-rise direction of the coal seam, is called Dip Galleries and are designated as, 1D, 2D, ...

Main Dip :- The dip galleries originating from the shaft level which is used for coal or mineral transport is called Main Dip. The dip, just adjacent to main dip on both sides, is called Companion Dip.

CROSS CUT :- It is a narrow roadway driven along the apparent dip direction of the coal seam. The purpose of the cross cut is to reduce the gradient of the road, usually haul road and to bring the coal from a distant place by the main haulage installed along the main dip.

BYE-PASS :- A small narrow gallery, driven to connect the shaft on both sides in order to go from one side of the shaft to other side of it.

PANEL / DISTRICT

The area consisting of (5-6) level galleries and dip galleries separated by solid coal from the sides is called a DISTRICT / PANEL.

PANEL BARRIER :- The solid coal left, between two consecutive districts or panels is called Panel Barrier.

WORKING FACE :- An advancing gallery from where coal is obtained either by cutting or blasting is called face.

GEOMETRY OF BORD & PILLAR MINING.

GALLERY SIZE.

The width of the galleries depend on, the purpose, method of drivage and mode of transport or Loading m/c. employed. Higher the gallery width, higher should be the size of the pillar to withstand. In general, the width of the galleries are kept 2.4m, 3.0m, 3.6m, 4.2m and 4.8m. The height of the galleries are restricted to 3m or less depending on the seam thickness.

2. PILLAR SIZE AND SHAPE.

The shape of the pillar may be square, rectangular or rhombus. From the strata control point as well as operation point of view, square pillars are best suited. As the load on a square pillar is distributed uniformly over the whole pillar, square pillars are more suitable than rectangular or rhombus pillars. Stress concentration of rhombus pillars at its corners is very high and liable to collapse at a premature age. However, rhombus pillar allow easy

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U/G METHOD OF MINING

movement of mobile coal getting Equipments like Shuttle car and Gathering Arm Loaders.

The size of the pillar depends on depth and the vertical load which the pillar has to carry and also on the time factor. Once a pillar is formed, the total vertical load acts on the pillar. The size of the pillar should be sufficiently high to withstand the amount of vertical load.

SIZE OF PILLAR AS PER CMR-1957.

DEPTH OF WORKING FROM SURFACE. (m)	WIDTH OF GALLERY ϕ3m	ϕ3.6m	ϕ4.2m	ϕ4.8m.
	The distance between centre of adjacent pillars shall'nt be less than			
≤60 m	12 m	15 m	18 m	19.5 m
60 m ≤ 90 m	13.5 m	16.5 m	19.5 m	21.0 m
(90–150) m	16.5 m	19.5 m	22.5 m	25.5 m
(150–240) m	22.5 m	25.5 m	30.5 m	34.5 m
(240–360) m	28.5 m	34.5 m	39.5 m	45.0 m
>360 m	39.5 m	42.0 m	45.0 m	48.0 m

FACTORS AFFECTING THE PILLAR SIZE.

The size of pillars in B & P mining is affected by Following Factors

(i) DEPTH OF WORKING :- Higher is the depth of working from surface, higher load will act on the pillar and therefore, the size of the pillar would be more. At great depth (>400m), it is however questionable, where the B & P mining can be technically employed as the load of the overlying rocks may exceed the ultimate strength of the pillar with inevitable crushing of the pillars.

(ii) NATURE OF COAL

The strength, chemical composition, porosity etc influences the size of the pillar. Coal with higher compressive strength may take higher load compared to the lower strength rock with same size of pillar. Friable coal is softer and therefore in such cases, large size pillar is required at a particular depth.

(iii) TIME FACTOR.

Higher the time interval between the formation and extraction of pillars, larger should be the pillar size since the strength of pillar deteriorates as the time passes away.

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(IV) GEOLOGICAL FACTORS :- The existance of fault, cleavage plane, fractured zone, dyke, sill etc in the vicinity of the workings usually demand large pillar. Presence of water, also, has bearing on the pillar size.

(V) NATURE OF FLOOR AND ROOF

A strong floor tend to crush the pillar whereas in a soft floor, the pillar try to enter ie creep, demanding larger size pillar.

(VI) Effects of plane of weakness like slips, bedding planes etc

(VII) Characteristics of the strata above and below the coal seam

DESIGN OF PILLAR.

There are several methods of determination of optimum pillar size.

(I) CONVENTIONAL METHOD : AS PER COAL MINES REGULATION.

Coal mines regulation has stipulated the minimum size of the pillars at different depth and gallery width. These standards have been determined keeping minimum safety of 2 for depth less than 360m. However, for depth greater than 360m, the factor of safety of the pillars aren't sufficient and need to be revised.

(II) EMPIRICAL FORMULAE.

Several empirical formulae have been devised by different scientists after studying several cases of pillar failure. The base of each formula is to determine the strength of the pillar and then determining the suitable size considering a suitable factor of safety - 2.

(a) Salomon & Munro formula

This formula is for square pillars. According to this formula, $S_p = 73 \frac{W_p^{0.46}}{h^{0.66}}$ kg/cm², Where S_p = Pillar strength

$= 1320 \frac{W^{0.46}}{h^{0.66}}$ PSI

W_p = width of pillar in metre

h = height of the pillar in metres

(b) Bieniawski's Formula

Strength of Pillar, $S_p = \left[400 + 200 \cdot \frac{W_p}{h}\right]$ PSI where W_p and h are in inch

(c) Holland & Gaddy's formula

$S_p = \frac{K\sqrt{L}}{h}$ PSI where S_p = Pillar strength.

h = height of the pillar in inches

L = Least width of the pillar.

$K = S_c \cdot d^{0.5}$

where d = edge length of the coal specimen in inches.

K = coef. depending on strength of coal.

S_c = compressive strength of coal specimen in PSI

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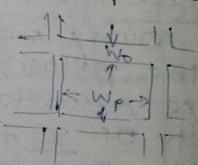
3. SCIENTIFIC METHOD

The primary purpose of coal pillar is to take the load of the overlying strata when a pillar is formed. The load history on a pillar can be considered to comprise of two stages:- the loading before mining but immediately after development of entries/galleries and the abutment pressures induced by subsequent loading.

(a) Premining Loading: Tributory Area Theory.

In the U/G Bord and pillar mining, the area supported by a pillar covers the area above it and neighbouring area tributory to it. In other words, a pillar uniformly supports weight of the overlying rocks and one half the width of the galleries on all sides of the pillar. Thus, in a typical Bord and Pillar layout, the average stress on the pillar is given by the following expressions –

(i) For square pillar: $\sigma_a = \frac{(W_o + W_p)^2 \rho g H}{W_p^2}$



where σ_a = Load (vertical) per unit area

W_o = Bord or gallery width.

W_p = Pillar width.

ρg = unit weight of rock per metre of depth (T/m³/m of depth)

H = depth below surface.

(ii) In case of rectangular pillar, $\sigma_a = \frac{(L_p + W_o)(W_p + W_o)\rho g H}{W_p \cdot L_p}$

where σ_a = Average pillar stress = Load per unit area.

L_p, W_p = edge to edge dimension of the pillar.

W_o = Gallery width.

EFFECT OF ABUTMENT PRESSURE INDUCED

As soon as an opening is made, the vertical load directly above the opening, shifts to both sides of the excavation and the pillar experiences extra load, leaving a destressed zone or relaxed zone in the roof rock. The shape of the destressed zone resembles an arch which is called Pressure Arch. The maximum span of the pressure arch increases with depth which is given by the relation $W_{pa} = (0.15h + 6)$ where W_{pa} = minimum width of the maximum pressure arch in feet, h = depth below surface in feet.

Also, the magnitude of the maximum pressure at abutments increases with depth.

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It has also been established that the increase in pressure on the pillar due to pillar extraction is equal to $\Delta \sigma_a = -0.11A + 0.356A^2$ where A = percentage of the pillar extracted.

Thus, total vertical stress or pressure acting on the pillar due to mining is given by,

$$\sigma_a = \frac{(W_o+W_p)^2 \rho g h}{W_p^2} - 0.11A + 0.356A^2 \quad \text{for square pillar}$$

$$\sigma_a = \frac{(W_o+W_p)(L_o+L_p)\rho g h}{W_p \cdot L_p} - 0.11A + 0.356A^2 \quad \text{for rectangular pillar.}$$

(b) Strength of Pillar : Ultimate Strength Theory.

Strength of coal can be determined by insitu tests of cubical or cylindrical specimen in the laboratory. These specimens are 2-6 inch in diameter and of various heights. To make the laboratory result more representative of field conditions, specimen from various parts of the pillar are taken to get an average result. For this purpose, a minimum of 10 specimen is taken and analyzed.

However, this method has got certain disadvantages also. Small specimen seldom represent the large UG coal pillars as numerous fractures in a pillar can't be truly reproduced in the laboratory. A smaller specimen contain less deffects and exhibits higher strength. Insitu strength test can reduce both size and environmental difference and can produce more representative result. Therefore, correction for size effect & shape effect are made onto the results obtained from laboratory test, to get a fair strength of the coal pillar.

(31)

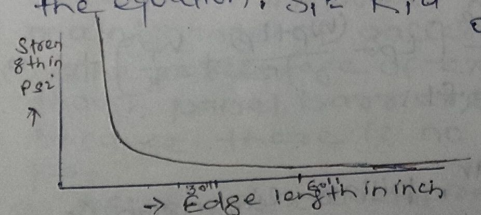
EFFECT OF SIZE.

Coal strength is higher for smaller specimen and decreases exponentially as the size of the specimen increases, until it reaches an asymptotic value. The relationship between the size and strength of the specimen can be generated by the equation, $S_1 = K_1 d^{-a}$ where S_1 = uniaxial compressive strength of cubical specimen. in psi

K_1 = constant

a = constant

d = edge length of the specimen in inches



The strength becomes almost constant for specimen size of more than 5 ft = 60" side length of the cube.

10 No. of specimens are tested for strength in the laboratory and then, the data of strength versus size is used to find the value of K_1 and a.

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EFFECT OF SHAPE.

Coal strength depends even more on the shape of the specimen than size. The W:H ratios of the pillars of the same width may differ if the seam height is different at different location.

It has been observed that the strength of coal varies as the square root of the least lateral dimension divided by the thickness of the seam.

A generalized equation for the laboratory sized specimen is, therefore, $S_2 = K_2 \left[\frac{W^b}{H^c} \right]$, where S_2 = uniaxial compressive strength of coal pillars of width W and height H.

K_2 = strength of cubical specimen representing the UG pillar.

b, c = constants.

Thus, strength of the pillar with various $\frac{W}{H}$ ratio are determined. The strength of cubical specimen K_2 obtained after size effect manipulation is substituted for obtaining value of S_2.

(c) The Progressive Failure Theory

The concept of this theory is based on the assumption that a pillar willn't fail instantaneously as in the case of ultimate strength theory, but the failure will start as the galleries are opened. This failure initiates with numerous cracks & propagates progressively and then ultimately, the pillar fails.

The different formulae for pillar strength as per Progressive Failure theory are as below:-

A. For Wide Pillars:

(i) For Square Pillar

$P = 4\rho g h (W_p^2 - 3 W_p h H) \times 10^{-3} + 3 h^2 H^2 \times 10^{-6}$ Tonnes.

(ii) Rectangular Pillar

$P = 4\rho g h (W_p \cdot L_p) - 1.5 (W_p + L_p) h H \times 10^{-3} + 3 h^2 H^2 \times 10^{-6}$ te.

Where $W_p > 0.003 hH$ ft for wide pillars.

B. For Narrow Pillars for which $W_p < 0.003 hH$ ft.

(i) Square Pillar Strength $= 444 \rho g \frac{W_p^2}{H}$ te.

(ii) Rectangular " " $= 1333 \rho g \cdot \frac{W_p^2}{H} \left[L_p - \frac{(W_p + L_p)}{2} + \frac{W_p}{3} \right]$ te.

Where ρ = te/ft³, W_p, H, h, L_p = ft.

FACTOR OF SAFETY

With FOS = 1.5 = $\frac{\text{Strength of pillar}}{\text{Load on pillar}}$, pillar dimension is determined by Trial and error method. Load is calculated by Tributory area method and strength is calculated by Laboratory testing with suitable adjustment for shape and size effect.

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PANEL SYSTEM AND OPEN SYSTEM IN BORD AND PILLAR W

The Bord and Pillar development may be done either by Pane system or by Open System.

PANEL SYSTEM.

In panel system of Bord and Pillar development, the workings are done in districts or panels separated by a solid coal barrier of the order of 20-40 m or one pillar between two consecutive panels. The solid barrier may have connections to the panels with minimum number of opening essentially required for the purpose of ventilation and transport. Thus in this system, the panel/working district is separated from three sides and kept open on one side only with minimum number of entries.

OPEN SYSTEM.

In open system of development, no panel barrier is left and the whole mine is viewed as one unit and developed with the formation of pillars starting from the shaft/incline mouth. Open system of development has many disadvantages compared to panel system.

ADVANTAGES OF PANEL SYSTEM

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(i) Ventilation of the workings are easier as fresh air can be provided to each panel by splitting air from the main intake.

(ii) In the event of fire, explosion, air-blast etc, these can be localized within the panel as the affected panel can quickly and easily sealed off without affecting the other panel since there are few number of entries.

(iii) Seams liable to spontaneous heating are more effectively developed by panel system as chance of fire is minimized due to fresh and more effective ventilation.

(iv) The panel barriers provide effective support and the chance of premature collapse of pillar is minimized. It results in lower support consumption and better maintenance of galleries.

(v) The percentage of extraction is generally high even though panel barriers aren't extracted. It is so because there is no coal loss due to premature collapse.

(vi) After the development of a panel, the same can be depillared irrespective of its location in the mine. This eliminates the supervision, maintenance and risk of danger of the developed galleries left for excessively long period

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1. The flow of gas, water etc from the depillared panel is restricted to other panel.

2. The cost of construction of isolation stoppings around the panel before and after depillaring is minimized.

GOVERNING FACTORS FOR PANEL SIZE.

The size of the panel is governed by :-

(i) INCUBATION PERIOD :- It is the time between the pillar is left under a condition prone to spontaneous heating and actual occurence of fire.

Higher is the incubation period, larger may be the pillar size and vice-versa.

(ii) EXTRACTION RATE :- The coal within the panel must be depillared within the incubation period of the coal seam, which varies depending on the rank/maturity of the coal. In general, incubation period of JCF = 13-15 month and that of RCF = 9-12 month.

CALCULATION FOR EXTRACTION PERCENTAGE DURING DEVT.

Case 1. When extraction height = seam thickness.

Let, W = Width of pillar edge to edge.

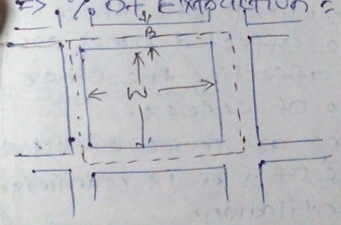
B = Gallery width.

H = extraction height

= Seam thickness

⇒ Coal extracted during formation of one pillar $= [(W+B)^2 - W^2]H$

⇒ % of Extraction $= \dfrac{\text{Total coal extracted}}{\text{Total coal reserve}} \times 100$



$$= \frac{\sum [(W+B)^2 - W^2]H}{\sum (W+B)^2 H} \times 100$$

$$= \frac{(W+B)^2 - W^2}{(W+B)^2} \times 100 = \frac{(B^2 + 2WB)}{(W+B)^2} \times 100$$

Case 2. When seam thickness h > extraction thickness H

% of extraction $= \cancel{(W+B)^2 h - W^2 H}$

$$= \frac{\left\{(W+B)\frac{B}{2} \times 2 + 2W \times \frac{B}{2}\right\} H}{(W+B)^2 h} \times 100 = \frac{(B^2 + 2WB)H}{(W+B)^2 h} \times 100$$

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FACTORS AFFECTING METHOD OF MINING.

There is no thumb rule to spell out the exploitation system suitable for a given deposit. Neither there is a single design of mining layout capable of meeting the wide varieties of conditions that exists in different coal fields, but identification of certain factors will provide a guideline for the choice of a certain method of work. The following factors are considered before selecting proper method of mining.

1. GEOLOGICAL FACTORS.

(a) Thickness of the Deposit.

As per Indian Standards, coal seam thickness classification is as below→

less than 1.5m → Thin Seams.

1.5 - 4.5 m → Medium thick seam.

greater than 4.5m → Thick seam.

Seams within a thickness of 2-3 m is most favourable for Bord and Pillar mining in single section workings from the safety point of view.

Thin seams can be worked economically by LW methods. Thick seams require extraction in lifts either by LW or B&P or some special methods like BG, Hydraulic mining etc.

(b) DEPTH from Surface.

As the depth increases, the vertical strata pressure increases and therefore, B&P method needs large size pillars to be left for the stability of workings. Due to high roof pressure, support of B&P faces becomes difficult as more wide area in aggregate is exposed. At high depth greater than 250m, LW mining is the best method from the strata control point of view as well as for the purpose of ventilation and safety also. Bord and Pillar is suitable for shallow to medium depth.

(c) GRADIENT OF THE SEAM

For flat or moderately dipping seam upto 15°, either Bord and Pillar or LW method can be applied. But for steep seams, some special methods like inclined slicing, horizontal slicing or Shield Mining are required.

(d) NATURE OF ROOF AND FLOOR.

Strong roof and floor is desirable for any method of working. However, in LW mining, the roof must be sufficiently strong as much larger area is exposed in the working front requiring more support.

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(e) PRESENCE OF DIRT, BAND ETC

For LW mining with shearer, the seam must be free from any band as shearer can't cut the band. Moreover, the band poses difficulty in separating from the coal thereby deteriorating the coal quality. In Bord and Pillar method, the band can be drilled and blasted down separately.

(f) GEOLOGICAL DISTURBANCES

LW mining is best adoptable in disturbance free area. It is very difficult to change or modify the LW layout once started in the event of presence of faults, dykes, etc. Conversely, B & P method can be negotiate the geological disturbances with little difficulty.

2. NATURAL CAUSES.

(a) GASSINESS OF THE SEAM.

For gassy seam, LW method is always preferable from ventilation point of view. Gassy seams require better ventilation for dilution of gas which is best possible by LW method, as in this method fresh and sufficient quantity of air reaches the face.

In B & P method, directing the air to working faces through a number of opening is a major problem.

(b) SPONTANEOUS COMBUSTION.

Coal liable to spontaneous combustion should be worked by LW method, as in Bord and Pillar method; lot of coal is left in the worked out area which may ultimately lead to fire if not ventilated properly.

(c) DEGREE AND PRONENESS TO BUMP.

Liability to bump of coal substantially influences the method of work. High degree of support & quick and smooth release of pressure is needed in such cases. LW advancing with ribs 1.5 m wide and packed with 3-4 m wide packing on either side is best method of working under such conditions.

(d) STRENGTH OF COAL.

Strong coal can be worked by drilling and blasting with Bord & Pillar mining whereas weak and friable coal can be mined with LW or some other special methods like Hydraulic Mining.

3. OTHER FACTORS.

→ For high production and productivity → LW method.
→ LW is cheaper than B/P in terms of cost.
→ Surface features and equipment availability.

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APPLICABILITY OF BORD AND PILLAR WORKING.

The Bord and Pillar mining is adopted under the following conditions.

1. The method is best suited for seam with thickness range of 2m to 4.5m. However, thick seams also, can be worked by Bord & Pillar method in section/ lifts.
2. The depth of working should be moderate (upto 200m). However, there are instances that B & P have been adopted even at a depth of 400m successfully.
3. Seams not liable to spontaneous combustion and are highly gassy.
4. Strong roof and floor.
5. High coal strength.
6. Numerous faults, folds, dykes etc.
7. Presence of band in the seam.
8. Sufficient capital isn't available.
9. Availability of sufficient man-power.

ADVANTAGES OF BORD AND PILLAR METHOD

1. QUICK OUT-PUT: Immediate output can be obtained as soon as the mine is opened. Thus, there is quick return of capital invested.
2. LOW CAPITAL INVESTMENT
A Bord and Pillar panel with mechanized loading and transport producing 500 TPD needs only 6-7 crores of investment whereas a LW face with powered supports needs about 80 crores.
3. UNIFORM OUTPUT THROUGHOUT THE LIFE OF THE MINE.
Bord and Pillar district can be shifted and equipped from one place to another in no time whereas salvaging of a LW panel takes about 2-3 months time.
4. MORE POPULAR IN/AMONG WORKERS :- Since the method doesn't demand any strict cycle, workers like the method best.
5. No unproductive work is required.
6. Requirement of skilled manpower is less.
7. During development stage, the geology of the area, quality parameters of the seam is established.
8. The method is flexible and can be applied under any type of geological disturbance.
9. Selective mining below important surface features can be easily done.

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10. The band, if any in the seam can be easily dealt with.
11. It doesn't need elaborate support arrangement.

DISADVANTAGES

1. Sluggish ventilation :- As the ventilating air reaches the face after travelling through a large number of galleries, it picks up heat and humidity and more number of stopping
2. Supervision is difficult :- As the workings aren't concentrated rather scattered, lot of exposed area needs to be supervised.
3. Strata control problem.
4. Low extraction percentage, high loss of coal.
5. More chance of fire.
6. Low output, low productivity and high cost of production
7. Labour oriented, needs large work force.
8. Difficult to work at higher depth.
9. Chances of spontaneous heating, premature collapse & overriding of pillars.
10. Chances of air-blast.

CYCLE OF OPERATION IN BORD AND PILLAR DEVELOPMENT

It consists of the following operations.

COAL WINNING

The principal mode of coal winning, whether by BP or LW or any other UG coal mining method, may be affected by any of the following means.

(a) Pick Mining :- It is a very primitive method of coal winning. The method consists of cutting coal manually by picks. The system yields very low production but gives very good roof control. The method is suitable for highly gassy seam where winning by other methods may cause fire and explosion.

(b) Solid Blasting :- This is a widely used method and gives higher amount of coal in less time period. The method consists of drilling holes in the coal face with the help of hand held electric rotary drill, capable of drilling about 1.2 to 1.5 m. long and 36 mm or 42 mm dia holes into the coal face and then charging the holes with P_5 explosives in conjuction with delay electric detonators and then firing all the holes by a suitable exploder.

This method is applicable in II and Ist degree mines and also in IIIrd degree mines with some special precautions. It yields high amount of coal and productivity is high.

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The method doesn't require any other m/c for giving undercut or free face. However the roof gets disturbed due to blasting vibration and chances of ignition of gas in gassy seam may occur.

The holes are drilled in different patterns. The important patterns are :-

(i) Burn / Parallel cut (ii) Wedge cut (iii) Coromant cut (iv) Fan cut (v) Pyramid cut and (vi) Cone cut.

Burn / Parallel cut is invariably used in soft rock blasting like coal because of its ease of drilling holes. The cut consists of drilling holes perpendicular to the coal face at an uniform spacing about 0.3m from the roof, floor and sides.

Wedge cut is generally used in hard rock, and for higher blasting efficiency. It needs drilling of holes in a fixed pattern with certain inclination. In wedge cut, the holes are so inclined that they form a wedge at the centre.

Fan cut is generally applied in LW mining where as Coromant cut is applied in tunnel / drift blasting.

EXPLOSIVES :-

The explosives to be used in UG coal mining must pass the special tests for inclusion in permitted group. The permitted explosives used in UG coal mine are -

P_1 → Ajax G, Polar G, Indo Coal 1, Vicking G, Monodyne, Godyne etc.

P_3 → Unigex, Permadyne, Indocoal 3, REL 3.

P_5 → Soligex, Pentadyne, Indocoal 5

The explosives are available in cartridge form, 20-30 cm long, 32-36 mm dia, weight varying between 150-250 gm.

(35)

(c) Undercut blasting / Free Face Blasting

In UG development work, solid blasting isn't much effective in the sense of coal winning. Also, there is danger of gas ignition and roof deterioration due to blasting vibration. In order to avoid risk of ignition in case of gassy seam and to obtain better yield of coal per round of blast, it is mandatory to go for Free face blasting.

The method consists of creating a free face at the coal face and then normal drilling and blasting at the face.

The free face can be created by the following :-

(a) Undercutting or midcutting by coal cutting machine.

(b) drilling a large central hole by Auger drill machine.

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Coal Cutting Machine (CCM) consists of a cutting unit with a jib of 1.5-1.8 m. length, fitted with movable chain with cutting picks. The jib is movable (slewable) along the horizontal axis. It is a skid mounted machine and the movement is achieved by the help of haulage unit installed within the body of the machine. The chain is driven by an electric motor. By anchoring the rope from the haulage unit to steel or wooden prop in well selected position and by hauling upon one or both of the ropes the cutter may be manoeuvered to any position. Normally, it is made to haul itself while cutting or sumping in along the face. The length of the m/c is 7'6" and speed of the cutter chain is 2 ms^{-1}. The haulage speed along the face is 0.9 m min^{-1}. Flitting speed is 8 m min^{-1}.

Recently, Crawler mounted CCM, also has been introduced in the coal industry.

CCM gives about 6" (150 mm) thick cut, the depth of the cut being 6" (150 mm) higher than the length of the hole.

FREE FACE BY AUGER DRILL

Auger drill is a drill machine capable of giving large diameter holes upto 400 mm. The m/c can be either trackmounted or mounted on the top of loading m/c. The m/c consists of all the components of a conventional drilling m/c. It can give large central hole upto 400 mm and 3.2 m. long.

No. of Holes and Amount of Explosives

The number of holes and the amount of explosives required in a development face, basically depends on factors like - strength of the coal to be blasted, whether free face has been given or not, strength of the explosives used, dia. and length of holes, pattern of holes, dimension of the roadway, presence of cleavage plane in the coal, fragmentation required etc.

The complex relation of the above factors is difficult to determine. Leaving aside the empirical relationship, thumb-rule is always applied to determine the number of holes and amount of explosives.

No. of Holes = 1 hole/m^2 for coal
= 3 " " for hard stone
= 2-2.5 " " soft rock.

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Amount of Explosives = 0.5 kg/m3 for coal without free face
= 0.8 " " ore
= 1.2 " " hard stone.

EMPIRICAL RELATION

No. of holes, $N = 37.5 + 0.13A - 1.15H$ where,
A = X-sectional area in ft^2
H = Blasting index
= 8 for hard rock
= 17 for medium rock
= 24 " soft rock.

Amount of Explosives, E in Pound
$= (72.4 + 0.0644AP - 4.37H)$
where A = Area of X-section in ft^2
P = Perimeter in ft
H = Blasting Index.

(d) Coal winning by continuous cutting m/cs

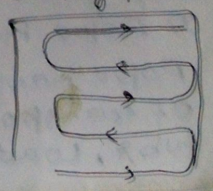
Road header and dint header are the two principal continuous cutting machines used for development of coal seam by LW method. These machines give fast rate of advance desirable for LW mining system.

(i) Road header is a boom type of machine designed to cut medium hard rock with a compressive strength of upto 1000 kg/cm². It is a crawler mounted m/c which is operated by electro-hydraulic motors. The main parts of the Road header are –

(i) A telescopic boom with a cutting head fitted with a number of cutting picks. The cutting head can be rotated in either direction and the boom can be swivelled horizontally as well as vertically.
(ii) Gathering arm/plate below the bottom to collect the coal after it has been cut.
(iii) A chain conveyor fitted below the chassis just after the gathering plate.
(iv) chassis.
(v) Crawler chain.
(vi) Discharge belt conveyor.

The machine is invariably fitted with roof bolting m/c. The m/c can be operated at a gradient upto ±16°.

Cutting Pattern



SPECIFICATION OF ROAD-HEADER.

Length = 7.47m
Width = 1.91m
height = 1.65 "
Ground pr = 1.3 kg/m²

cutting below floor = 100mm.
No. of picks = 96.
Cutter motor power = 100 kW.
Track motor = 2×11 kW
conveyor " = 2×11 kW.

cutting head = short twin cylindrical/single spherical.
Max^m cutting reach = 4.8 m width, 3.75m high.

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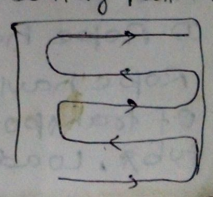

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Track motor = 2×11 kW
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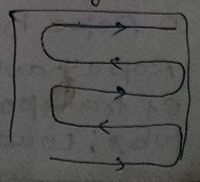

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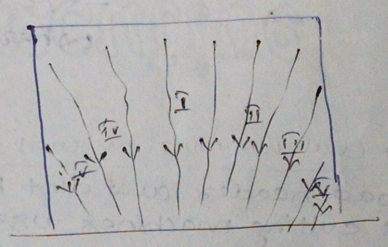
② Cutting by DINT-HEADER.

Dint Header is a cutting m/c same as Road Header, performing the same work. The only difference is in construction and function of cutting unit. In Dint header, the cutting unit consists of a box or boom where pick boxes along with picks are placed on a series of chains moving on a sprocket. The picks attack the coal on the front side of the face like scooping action. The box or boom is placed at one particular place and the coal is cut. When the boom enters the coal face to a certain depth, then the boom is withdrawn and placed at other side of the face to give similar cut at that place. In this way, the whole face is cut from one place to other.

SPECIFICATION

Height = 1.65m
Width = 1.28m
Length = 5.74m
Type of cutting load - Chain type
Max^m gradient = +14°, -9.5°
Max^m cutting reach = 1.65 m x 2.6m.
Cutting below floor = 50mm.
No. of picks = 540 ✓
Ground pressure = 1.26 kg/m²
Motor Power = 90kW.



2. LOADING.

Loading of coal after winning from the working faces can be done by the following ways. →

(i) When the coal is won by cutting with the help of cutting m/cs like Roadheader or Dint header, the coal gets automatically loaded into chain chainveyor through the gathering arm.

(ii) When the winning of coal is affected by Drilling and Blasting, the blasted coal can be loaded by - manual method, scraper, side discharge loader, Load Haul dump, Gathering Arm Loader etc. These loaders are applicable under different conditions.

3. TRANSPORT

The common types of transport system in UG are (i) Rope haulage system (ii) conveyor system.

Rope haulage system is most commonly used mode of transport in UG coal mining. The set of loaded coal tubs, loaded either manually or by mechanical

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loaders, can be haved either by a single direct haulage or by a combination of Tugger, endless and direct haulage from the working district/panel to the pit-bottom or surface.

Tugger Haulage is placed in the district, endless haulage along the level gallery and direct haulage at the outbye of the district or at the surface.

Rope haulage transport system is an intermittent type transport system and is used for low production upto 500 TPD from a panel.

The common transport system within the panel or the district are (i) Tugger haulage (ii) Chain conveyor. Tugger haulage is a small capacity haulage which can be shifted easily and quickly from one position to other without dismantling. The haul-length of the tugger haulage is restricted upto 250 m depending on the gradient and capacity. Thus, the total haul length along levels shouldn't exceed 250 m in a panel.

Chain conveyors are small capacity (40-100 TPH) transport equipment, available for a length of 100-120 m. In order to avoid spillage and long breakdown, not more than two conveyors are placed with their drive head pointing towards each other placed along the dip, discharging to another common conveyor

4. SUPPORT

The different types of supports, used in UG coal mining are as below:-

- timber prop, wooden cogs, X-bars.
- steel props, steel chocks or cogs.
- Roof bolts or stitches, arches.
- Friction props, hydraulic props.
- Powered supports.

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DESIGNING THE LAY-OUT OF A BP DEVELOPMENT DISTRICT.

It involves estimation of the following:-

1. Dip length of the panel or no. of levels in the panel. It depends on the production, no. of loading m/cs being used and the transport system adopted.

→ From production point of view, the no. of faces available in a panel is (2n-1) where n = no. of levels in the panel.

→ The production from 1 blast per face, generally varries from 15-25 te depending on the geology of the gallery, Thus, for a given particular production, the no. of levels can be estimated, assuming that 1 blast / shift / face is given.

→ If loading m/cs like SDL, LHD / GAL is applied, the m/c must go on getting coal for loading purpose. The hourly loading capacity of the m/c can be estimated and then the number of level galleries can be ascertained.

Conventionally, for each loading m/c, at least two faces must be available.

→ Transport system, actually limit the no. of levels in a panel.

REQUISITES OF THE LAYOUT OF A PANEL.

The layout of a panel / district, whether BP or LW, must show the following:-

(i) the dip direction with amount.
(ii) the entry galleries to the district.
(iii) the working faces.
(iv) the transporting system.
(v) " ventilation system
(vi) Relative position of the equipments / machines being used.
(vii) Support system.
(viii) Estimated production and productivity if desired.

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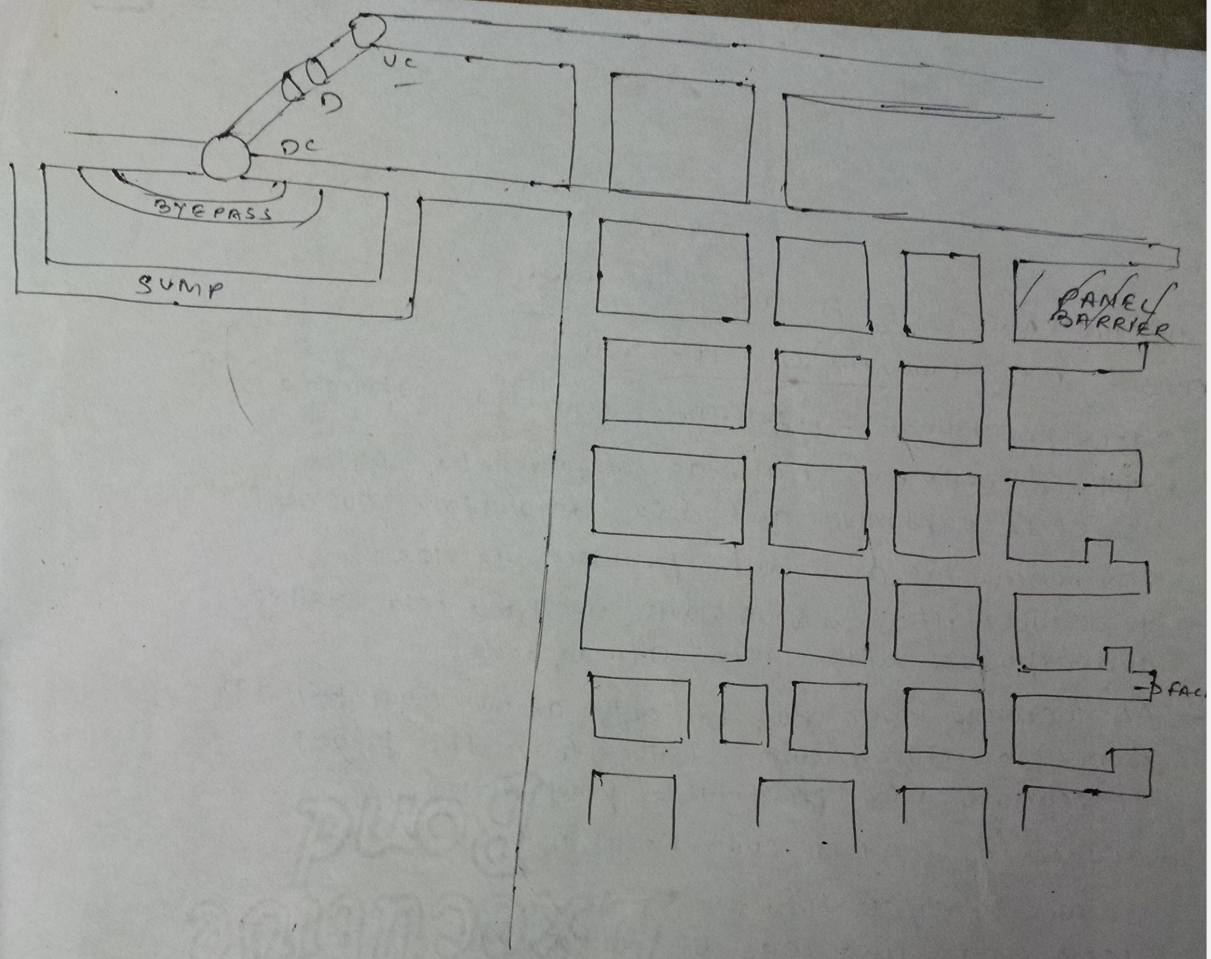

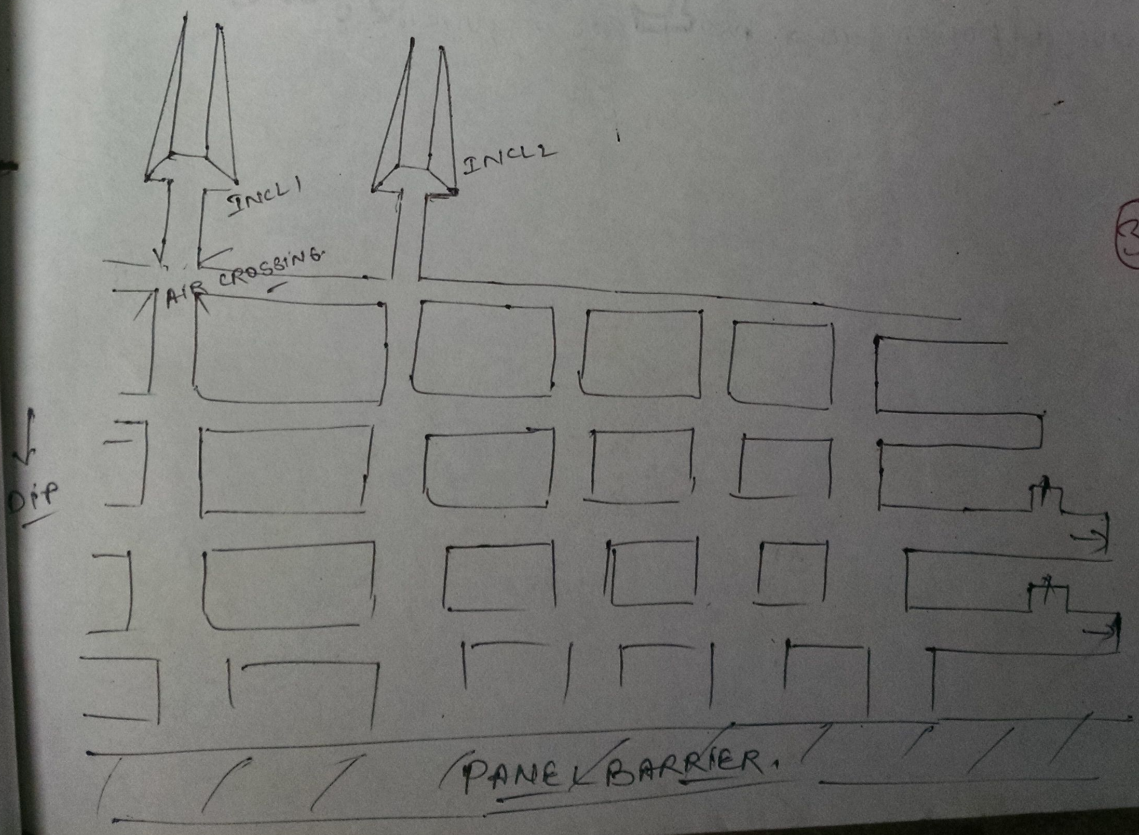

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DESIGNING THE

ADVANTAGES OF AUGER CUM DRILL OVER BOS (Blasting Off the Soil)

- Yield per blast = 1.5-2 times more as compared to BOS.
- Explosive required = half as compared to BOS.
  Use of P5 explosive and delay detonators not req^d.
- Environmental and dust problems is less.
- it reduces the arduous work of hand held drilling and exposure to dusty atmosphere.
- An increase over BOS by ~~only~~ about 50 te per day from two auger cum drills from the panel is economically profitable proposition.

Advantage of Auger cum Drill over CCM

- reduced cycle time
- less wear and tear of cutting tools
- reduced power and manpower requirement.

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