MINING METHODS (UNDERGROUND COAL)

1.0 INTRODUTION TO UNDERGROUND COAL MINING:

1.1 Classify Underground Coal Mining Methods.

Method of winning coal in underground mines are classified into two main categories:

1. Bord and pillar (also known as pillar and stall) and its modification.
2. Longwall
   (i) Advancing. (ii) Retreating.

The following methods which are derivatives of the above principle systems have since acquire distinctive nomenclature:

(i) Room and pillar (ii) Level mining (iii) Horizon mining (iv) Slicing.
(v) Sublevel caving.

2.0 BORD AND PILLAR METHOD:

2.1 Describe the various application of Bord & Pillar method.

Drivage of Roadways, development of mine by the method of working known as bord and pillar consists of driving a series of narrow roads, separated by blocks of solid coal, parallel to one another, and connecting them by another set of narrow parallel to one another, and connecting them by another set of narrow parallel roadways driven nearly at right angles to the first set. The stage of formation of a network of roadways in known as development of first working. The coal pillars formed are extracted after the development of the mine leasehold and this later stage of extracting coal from the pillars is known as depillaring.

The bord and pillar method is adopted for working,

1. a seam thicker than 1.5 m.
2. a seam free from stone or dirt bands. Stone or dirt bands, if present in a seam, can be easily disposed of for strip packing in longwall advancing method of mining.
3. seam at moderate depth
4. seams which are not very gassy.
5. seams with strong roof and floor which can stand for a long period after development stage is over.
6. coal of adequate crushing strength.

2.3 Describe depillaring method with stowing and caving.

DEPILLARING WITH STOWING: Depillaring with stowing is a method of pillar extraction in which the goaf is completely packed with incombustible material and in generally practiced where it is necessary to keep the surface and strata above the seam intact after extraction of coal. The following circumstances would require adoption of depillaring with stowing.

1. Presence of water-bearing strata above the coal seam being extracted e.g. Kamptee series in Wardha Valley coalfield of Maharashtra. Enormous quantities of water beyond the economic pumping capacity may enter the mine through cracks in the strata.
2. Railways, rivers, roads, etc situated on the surface, which cannot be diverted.
3. Presence of fire in a seam above the seam to be extracted.
4. Existence of one or more seams of marketable quality extractable in the near future.
5. Restrictions imposed by local or Government authorities for the protection of the surface.
6. Extraction of the full thickness of a seam thicker than 6 m, as thicker seams cannot be extracted fully by caving method.
7. Extraction of seams very prone to spontaneous heating, of very gassy nature or liable to pumps.
8. surface buildings which cannot be evacuated.
9. Tanks, reservoirs, etc. which cannot be emptied.

DEPILLARING WITH CAVING : We shall consider here the arrangements preparatory to depillaring by caving method :

1. If there is a seam above, developed and filled with water, of goafed and wear logged, it has to be dewatered. In case the top seam is developed, and abandoned temporarily, pumps can be installed in it for dewatering. Top seam may be dewatered through a shaft if it is on the dip side and is accessible on the surface.
2. The plans are brought up-to-date showing all the new constructions, position of boreholes, staple pits, etc. The position of fault planes and dykes in the leasehold and also in the area of an adjacent colliery should be shown.
3. the adjacent mines likely to be affected by depillaring e.t.; mines on the dip side that will have to pump extra water, have to be informed.
4. Adequate number of supervisory staff, workers and specially the mines who have experience of depillaring, have to be appointed; strength of timber men may have to be increased.
5. there should be adequate stock of the following materials
   (i) Timber : the demand is heavy during depillaring. In a thick seam the size of props normally not required during development will be in demand during depillaring. Construction of cogs requires logging sleepers in a large number.
   (ii) Fire fighting equipment and fire sealing equipment e.g stone dust, bricks, lime, cement, C.G.I sheets, flame proof brattice cloth, etc.
   (iii) Protective equipment like helmets, shoes, etc.
6. Production during depillaring is likely to be high and the magazine capacity, number of tubs in circuit, haulage capacity and strength of trimmers may have to be increased.
7. Capacity of pumps should be increased to deal with extra water coming underground through surface cracks.
8. Outbye pillars have to be stabilized by sand stowing or substantial timber supports, preferably chocks.
9. Isolation stopping must be constricted to form artificial panels of convenient size within which any heating or fire caused during depillaring may have to be confined and sealed.
10. Systematic timbering rules are to be framed and explained to the supervisory staff and timber men.
11. In a mine every working place, where practicable, should be provided with at least two ways affording means of escape to the surface.

2.4 State precaution against frre and water during and after depillaring.

PRECAUTION AGAINST FIRE DURING AND AFTER DEPILLARING : It is necessary to take steps to prevent spontaneous heating in the goaf and to prevent the spreading of heating or fire.

1. Depillaring operations should be carried on in panels. Such panels may be formed during the development of the district by solid coal barrier all round the district with only essential galleries for transport and ventilation, and the panel should contain only such number of pillars as can be extracted within the incubation period which, however, is not known during the development stage unless experience is available of the adjacent collieries practicing pillars extraction by caving in the same seam. Where the panels are not formed or, if formed, contain such large number of pillars as cannot be extracted within the incubation period, it is imperative panels are formed by isolation stopping built of brick in lime or cement.
2. Depillaring operations should be conducted from dip to the rise, so that goaf can be submerged in water. If however, the seam has a mild gradient or if depillaring is conducted with a diagonal line of extraction, the goaf on the rise side is not drowned under water.
3. An attempts has to be made not to leave any coal in the goaf as far as practicable. This however, becomes difficult unless the roof is good and ermits complete extraction from

stooks.

4. In shallow seams, to prevent breathing of air to the depillared area through cracks to the surface, the cracks have to be blanketed with a layer of sand or earth nearly 1.2 m thick. Such blanketing is often done on the surface before depillaring commences. After the cracks are formed, it is dangerous to cross the cracked surface.

PRECAUTION AGAINST WATER DURING AND AFTER DEPILLARING: These may be summarized here as follows:

1. Enough allowance should be made for inaccuracy in the plans. Inaccurate mine plans have been the cause of accidents due to inundation in 90% of the cases during depillaring. All the features required to be shown in the plan under the regulations should be clearly shown. A common omission is boreholes, as these are not conspicuous, and often forgotten after prospecting.
2. When depillaring zone is within 60m of waterlogged area, advance boreholes have to be drilled. Volsafe machine for drilling at any angle is suitable for the purpose.
3. Depillaring below a water-logged area should be avoided. Streams, rivulets, etc. on the surface should be diverted if the expenditure is justifiable.
4. If overlying strata contain a water-bearing stratum, unless pumping capacity is adequate, caving method should not be adopted.
5. No depillaring operations should be conducted in an area which is likely to cause subsidence of the surface below the highest flood level of river, stream, or lake.
6. When depillaring in bottom seam is to proceed from rise to dip, the top seam may be dewatered in stages by advance boreholes from bottom seam with prior permission from the DGMS.

2.6 Define contiguous seam / 2.7 working of contiguous seam.

If two seams are separated by a parting of less than 9 m they are known as contiguous seams. Their working, if both have to be worked at a time or one after another, needs prior approval of the DGMS. A thick seam may be worked in two sections, one at the floor and the other near the roof and the parting between any two such sections of a thick seam or between two contiguous seams should be not less than 3 m thick. Id the seams are within 9 m of each ther, the pillars and galleries in one seam should be vertically above or below the pillars and galleries in the other seam if they are not steeply inclined. This condition is not applicable if the parting is more than 9 m. where the seams are not contiguous but separated by a parting upto 30 m thick, their development in panels is often planned in such a way that the panel barriers are vertically above or below those in adjacent seams but the pillars and galleries inside the panels are not vertically pillar it is recommended that top and bottom seams should be under the charge of the same overman. The thickness of the parting should be ascertained from time to time by drilling boreholes at junctions of galleries after alternate pillars. In a thick seam if there is any band of stone, shale or inferior coal which is not workable economically, such that the thickness of parting is brought up to 3 m or more. Such bands help to maintain definite floor and roof gradients and nearly uniform thickness of section under development. They also help in reducing the roof convergence.

When working contiguous seams development of bottom-most seam is usually in the dip direction for water consideration and development in other seams is in other direction, towards the rise of strike so that the property is proved during development stage.

One haulage may serve both the seams through a drift. In such a case output from the seams can be brought to one seam, preferably the lower seam, from where it is hoisted up. A pit is normally sunk upto the bottom seam and coal of top seam is lowered by jig arrangement to the bottom seam.

It is a common practice to keep the bottom seam advanced at least one pillar ahead of the top seam and water of the top seam is allowed to gravitate to bottom seam though bore holes or a drift so that top seam workings are dry. From the bottom seam the water is pumped to the surface or to the main sump.

2.8 Describe working of seams above and below goaved out area.

WORKING OF SEAMS ABOVE GOAVED OUT AREA :
Under Regulation 104, no work in a higher seam or section shall be done over an area in the lower seam or section which may collapse. The working in the upper seam is, therefore possible only when it is virgin and the lower seam goaf has settled down. As stated earlier, it takes 3 to 5 years for a goaf to settle down. An attempt can be made to work such virgin seam if the parting between the seams is 30 m or more. With a parting less than this, the top seam may be assumed to be unworkable.

If the top seam is developed before depillaring in the bottom seam, roof of the top seam develops numerous cracks with depillaring in bottom seam and it is too dangerous to work in top seam.

WOKING OF SEAMS BELOW GOAVED OUT AREA : With the parting between the seams thicker than 9 m it is not necessary to insist on simultaneous pillar extraction. The usual arrangement is that the seams are extracted in a descending order. The following points may be borne in mind:

1. The extraction in the lower seam should be conducted under a settled goaf of the top seam so that the parting is not subject to the impact of kinetic forces let loose when the strata movements in the goaf takes place. A period of 3 to 5 years is considered sufficient to allow the goaf to settle.
2. Steps should be taken to guard against inundation from water-logged top seam goaf.
3. The main fall is much quicker if top seam is goafed and extraction must be planned with this in view
4. Heavy timbering is essential because of the dead weight of top seam goaf.

2.9 State advantages and disadvantages of Bord & Pillar method.

ADVANTAGES OF BORD & PILLAR METHOD :

1. Roads and airways are in solid coal and their maintenance cost is low throughout the life of the mine
2. Coal output is obtained while roadways are being made during the development stage, and naturally during the depillaring stage, thus providing a continuous flow of coal after the seam is touched.
3. Unlike in longwall mining no unproductive work of dining, strip packing, etc. is involved.
4. The development stage reveals the geological disturbances enabling the management to plan accordingly.
5. The working team is usually small at working faces. This helps in simpler methods of calculation of work performance, smoother and more co-ordinate work. The effect of absenteeism is not significant.
6. Surface features like railways, important buildings, rivers, etc. which should not be disturbed by underground methods of mining can be well supported during the development stage by the solid pillars of coal and later by only partially extracting the pillars if stowing is not practicable.

DISADVANTAGES OF BORD & PILLAR METHOD :

1. Ventilation is sluggish, as compared to longwall method, at the working places.
2. The extraction losses are generally higher than in other methods of mining.
3. Work is carried on at a number of working places creating problems of supervision.
4. At great depths, the working by this method becomes difficult as effects of roof pressure are not easily controllable; heaving of floor and creeping of roof may result in loss of roadways.
5. The effects of subsidence and interaction on other seams are not even and not easily predictable or controllable.

3.0 LONGWALL METHOD:

Longwall method of working consists in laying out long faces (60-200 m long) from which all coal in working section of the coal seam is removed by a series of operations, maintaining a continuous line of advance in one direction and leaving behind the vois (called goaf). The roof over the goaf is partially or completely supported by walls of stone (called pack walls), sand or other material like crushed stone to prevent collapse of roof and only a small strip 3 to 6 m wide and parallel to the face is supported by timber or steel props, bars or chocks in a systematic manner. Alternatively the roof over the goaf is allowed to cave in but the roadways are secured by packwalls and chocks if they have to be used.

ADVANTAGES OF LONGWALL METHOD:

1. It is simple and offers concentration of work areas, being capable of giving the maximum yield per hectare of coal seam area. Concentration of work permits good supervision.
2. All the seam section is extraction in one operation, enabling the maximum extraction percentage.
3. Ventilation of working is rendered easier with simple and direct air routes.
4. The roof weight acting on the face assists in loosening the coal, yielding the greatest proportion of large coal. Cleats and slips in coal can be advantageously used to make easier winning and with proper attention to strata control techniques, friable and weak proper attention to strata control techniques, friable and weak coal can also be won without much difficult.
5. Dirt bands in the seam can find useful purpose in packing of the goaf
6. Floors liable to creep can be better controlled in this system as there are only a few roadways to be cared for.
7. Seams liable to spontaneous combustion can be satisfactorily worked by this system as conditions exist whereby all the coal which is a potential material of heating is removed.
8. It lends to mechanization with the least capital cost per te of annual output. Where longwall advancing is adopted, it makes possible a quicker return on investment by enabling the mine to attain its optimum output within a short time.
9. It provides the most successful method for working beneath another worked-out seam.

DISADVANTAGES OF LONGWALL METHOD:

1. In longwall advancing method roadways are to be maintained in worked-out areas and entail substantial recurring maintenance costs. Sometimes there is convergence of roof in the roadways which are required to stand for long.
2. In the case of longwall advancing with caving a large expanse of goaf left behind constitutes a vast reservoir of firedamp, a potential source of danger.
3. In the case of longwall advancing with strip packing, if roadway packs are not well maintained against leakage, ventilation current may short-circuit through the goaf, which is both wasteful and dangerous (as it may cause incipient heating of small coal left in the goaf.

3.1 Describe Longwall advancing and retreating methods.

LONGWALL ADVANCING METHOD: In longwall advancing extraction of coal commences from the vicinity of the shaft pillar and proceeds outward towards the boundary of the mine or panel. Approach to the face is by parallel roads, formed at a specified distance apart which is equal to length of the face. The roof over the goaf may be supported by pack walls or sand stowing or allowed to cave in. In longwall retreating pairs of headings are driven in solid coal, certain interval apart, to a predetermined boundary where they are connected by along roadway to provide a longwall face. Extraction of coal then commences from the boundary and the coal face retreats towards the shaft. In this system goaf packing is not essential for roof support if subsidence of surface or strata above the seam is permitted.

Longwall method is the standard method of working in coal seams in Britain, Germany and other European countries. In India only a few mines have adopted it and that too in conjunction with hydraulic sand stowing, with very few exceptional cases of longwall with caving.

The roads at either end of the face are known as gate roads. Usually the coal transporting gate road is the intake airway and the other gate road is the return airway. The coal transporting gate road is called the haulage gate and the other gate, tail gate. If rope haulage is used in the haulage gate, it serves for material supplies and also for coal transport. But if a belt conveyor is used in the haulage gate, the other gate road (tail gate) serves for material supplies and is called supply gate.

LONGWALL RETREATING METHOD : The longwall retreating system combines the advantages of pillar and stall method and longwall method. The roadways formed in the initial stages are supported by solid coal pillars and the property explored during the formation of roads – an advantage with pillar and stall working. When the retreating longwall working commences the face offers the additional advantage of longwall method. Moreover spontaneous heating, if any, that may occur in the goaf can be easily isolated. Ventilation planning is easier, leakages being very few. These combined advantages make longwall retreating a popular choice if longwall has to be adopted in a mine

Application of the method therefore lies in working

1. thin seam (as than 0.7 m)
2. seams with dirt bands.
3. seams with tough roof which can be induced to bend gradually and settle on packs, or seams with weak friable roof which may cave in the goaf.
4. contiguous seams, if solid packed faces are laid out causing little disturbance.
5. gassy seams, which require meticulous planning of ventilation.
6. seams which are to be mechanized for large planned outputs.

3.3 Describe cyclic and non-cyclic Longwall layouts.

CYCLIC LONGWALL : On a conventional longwall face equipped with coal cutting machines, face conveyors (belt or scraper chain type), the operations at the face follow a definite sequence and a cycle of operations covers a period of 24 hrs. A straight line of face is essential for installation of belt or scraper chain conveyors. Where sand stowing is adopted for stowing the goaf, the maximum distance between the packed goaf edge and the face is restricted generally to 6 m for proper roof control. The cycle of operations is usually as follows on a stowed face if coal cutting machine and manual loading of coal on the face conveyor are adopted.

A. shift-Coal cutting and drilling
B. Shift-Shot firing, dressing down roof and sides, and roof supporting by props and chocks.
C. Shift-coal loading and erecting extra supports at local places of bad roof after coal removal.
D. Shift-same as A shift
E. Shift-Same as B shift.

Where stowing of goaf is not practiced and the roof is allowed to cave in, it should break regularly along a line parallel to the face but without burying the props, conveyor or machine near the face. Such line along which the roof should break must provide strong support to the roof by chocks and strong props. Systematic timbering rules approved by the DGMS are applicable to all longwall faces.

NON-CYCLIC LONGWALL : It may be noted that in a cyclic longwall system, each phase of operations like cutting, blasting, loading, etc. should be completed in the shift allotted for the work. This is unavoidable for smooth operation of the working cycle. Coal is available however only in one shift in a day of three shifts.

The supports and conveyor are installed in straight lines parallel to the face. Such straight lines are marked on the roof by stretching a string covered with chalk powder. Development of flexible chain conveyors which capable of snaking i.e. operating even when all its pans are not in a straight line, has enabled operations at longwall faces to be conducted in a non-cyclic manner. Such conveyors are also known as phyton conveyors. A flexible chain conveyor needs no dismantling and it can be always kept close to the face, which need not be in a straight line, by hydraulically or pneumatically operated pusher rams placed every 3-4 pans apart along the entire length of the conveyor. By installing such conveyors mechanical power loaders can be employed at the face for loading the coal direct into the conveyor. Since a zigzag or stepped face can be worked when flexible chain conveyors are installed, the coal cutting and loading operations can be carried out in all the three shifts without the need to follow a rigid cycle of face operations. The robustly built conveyors in this group are known as armoured chain conveyors and on them can be mounted coal cutting machines, coal ploughs and shearer loaders. When such combinations are used at the longwall face, props are not erected between the face and the conveyor, thereby providing what is called a prop-free erected behind the conveyors, i.e. goaf side, or by hydraulic shields or hydraulic chocks.

4.0 THICK SEAM MINING

4.1 Define Thick Seams.

In India coal seams over 4.5 m thick are considered as thick seams. This norm varies aboroad from country to country, in Russia and China a seam over 3.5 m thick, in Germany 1.5 m thick, in France 4 m, In Japan 2.25 m thick, In order west European countries the figure is 2.5 m.

Seams thinner than 1.5 m present problems of manual tub loading, walking, installation and use of machines, etc. but thick seams present technical problems in complete coal extraction, roof control, dealing with spontaneous heating, etc. AT Kunstoria colliery, to quote an example, the seam thickness is 8.4 m. during development by continuous miner 3 m thickness of coal near the floor was developed by bord and pillar, In the depillaring stage due to lack of stowing material only the 4.8 m seam thickness is extracted in one lift and the remaining coal is allowed to fall in the goaf is lost.

In underground coal mines with thick seams, the ventilation is sluggish, mechanization is difficult as heavy un-widely supports are required. Bumps are common in thick seams. Air blasts pose a problem and the percentage of extraction is poor resulting in loss of large quantity of coal which remains underground and is a potential for risk.

4.2 Classify Thick seam Mining.

A seam upto 3 m thickness can be extracted in one lift, slice or section by longwall advancing or longwall retreating. It can also be developed by bord and pillar followed by depillaring with caving of with stowing. The percentage of coal extraction varies from 80% to 90%, high percentage being possible with the adoption of stowing.

A seam over 3 m thickness and upto 6 m thickness is generally extracted in 2 lifts (or slices or sections, as they are sometimes called) through seams upto 6 m thickness have been extracted by developing on bord and pillar pattern upto 3 m height and depillared to full height by caving in one lift.

If coal seam of similar thickness is initially developed by bord and pillar in top section, increasing the height of development galleries and split galleries by taking our floor coal creates problems of drainage, ventilation, coal loading etc. though they can be generally overcome.

The percentage of coal extraction is some what low, 70% to 80%, as thicker chowkidars and robs at the goaf sides have to be left institute for safety. In seams of thickness 4.5 m and above, roof testing is not satisfactory, the roof support by props not reliable and ventilation is poor. Normally the DGMS does not give permission for depillaring with caving in one life in seams thicker than 5.5 m.

4.3 Blasting Gallery & Sublevel Caving.

BLASTING GALLERY : Blasting Gallery method envisages drilling and blasting the entire thickness of the seam by successive blasts while retreating along the level gallery which is driven along the floor of the seam. A panel of about 1000 m X 120-150 m is divided into sub-panels of 150 m X 120-150 m by driving main rises. A barrier of about 15m is left in between the panels. It is necessary to adopt this sub-panel in to restrict the size of panel so that the extraction is completed within the incubation period (in III seam incubation period is between 12-18 months) the sub panel, after extraction of the coal, is to be sealed off effectively. The sub-panel is further divided into two parts by driving a central main to reach the boundary of the panel. Such rooms are driven at 13-15 m X 60-65 m is formed in between the rooms. The main rise and central main drives are 4.7 m in width to facilitate the housing of chain conveyor and also the movement of LHDs and jumbo drills.

All the development is done along the floor of the seam, to a height of about 3 m. It is essential to stick to the correct sizes of rooms and rises as otherwise it is likely to land into roof control problems at a later stage. The development of rooms and rises is done by road headers as this would ensure the correct size of galleries as well as the required progress.

SUBLEVEL CABING : After extraction of 2 slices with the artificial roof of wire netting 4.8 m thickness of coal on the floor of the seam is still left to be extracted. Out of this 4.8 m of coal, the top 2.4 m which constitutes 4th slice is not extracted by usual process of coal cutting, drilling, blasting, conveyor, shifting etc. entry is made to the 5th slice (bottom-most slice of 2.4 m thickness) by suitable gate roads and the slice is extracted in longwall retreating manner. The roof for the 5th slice is solid coal and not the artificial roof of wire netting. The progress in the main face (5th slice face) is made by blasting only. The minimum span of the face is two bars i.e. 2.5 m while the maximum span 3 bars or 3.75 m and each face advance by blasting is 1.25 m. When the goaf edge bars and the props are withdrawn, the coal of the 4th slice (called sub level) of 1.25 m width and 2.4 m height caves down usually by itself in the goaf, though sometimes it is necessary to bring it down by blasting.

At this face second wire netting is added along the roof of the main face (5th slice face) as the face progresses, mainly for the purpose of containing the sub level coal between the 2nd wire netting and the original netting lying below subsided goaf. The roof netting also prevents the immediate splash of broken coal which can inflict injury to the workmen and dislodge the supports inside the face. For extracting the sub level coal, it is necessary to puncture the netting at places or roll it up in sections. Big chunks of the sub level coal need secondary blasting and all the coal cannot be recovered resulting in loss of 10 to 20 % (of the sub level coal). The coal remaining in the goaf is a source of spontaneous heating. The second wire netting (along the roof) has to be extend as the face advances.

5.0 HORIZON MINING :

Horizon mining is a system of mining, applicable to inclined or undulating seams and also to relatively flat seams where these occurs in groups whereby all the coal seams are extracted between predetermined horizons, level, or planes. It involves driving main roadways horizontally (or almost so) through the measures or strata from the shaft at pre-arranged intervals of depth, and these road-ways form, as it were, the main arteries of the mine, through which coal is transported throughout the life of the mine, or of the horizon concerned. At least two levels are driven at different horizons; lower level, called the haulage level, is used for haulage and serves as intake airway and the upper level called the ventilation or return level, is used as return airway and supply road. Connections are made to each of the seams lying between these two levels and the portion of each seam intersected by the levels is divided into sections of suitable size either by staple or blind shafts or, in rare cases, by inclined roads.

Laterial drifts or roads, or simply laterials, are those roads driven parallel to the strike from the shaft and they may be sited in one of the coal seams or, more usually, in the strata below the lowest coal seam in the borizon concerned. The term cross measure drifts, or simply cross-cuts, is used for all the approximately level main roads driven in rock at right angles to the line of strike, i.e. in the direction of the full dip or rise of the strata. In general, the cross-cuts in the various horizons should be driven directly above one another. A network of these roadways, laterials and cross cuts driven at the same depth of horizon, constitutes a horizon or level. Vertical distance between horizons is 60-200 m.

Horizon mining is actually not a method of mining in the sense long wall or bord-and -pillar is, but is a method of lying out the workings and roadways in a coal seam and cross measure strata for speedy transport. The actual method of mining may be longwall, bord and pillar or room and pillar though the method that has been normally adopted has been longwall advancing or longwall retreating as the countries that have first tried horizon mining and later developed it, were accustomed to longwall methods of mining. The usual methods of transport are the conveyors on the faces and gates, spiral chutes in the staple shafts leading to haulage level, and locomotives in the haulage level . Seams are worked in descending order.

5.1 State conditions, advantages, disadvantages, of Horizon Mining

CONDITIONS OF HORIZON MINING :

1. Large capital expenditure on shaft sinking and drifting is required before production starts. Interest on capital and depreciation of machinery as well as civil works is therefore heavy.

To justify it the mine must have large reserves and production should be high over a long life. Production of at least 50,000 te per month from one pair of shafts may be considered the lower limit under Indian conditions and the life of the mine, not less than 30 years.

2. The property should be preferably virgin.
3. The reserves should be established by well organized prospecting and drilling programme.
4. The seam density i.e. the number and thickness of seams within the given vertical distance should be high.
5. The strata should be strong as each horizon requires shaft insert and long drifts that last for nearly ½ to 3/4th of the life of the mine.

Other factors which need to be considered before opening a mine apply in the case of horizon mining as well.

ADVANTAGES OF HORIZON MINING :

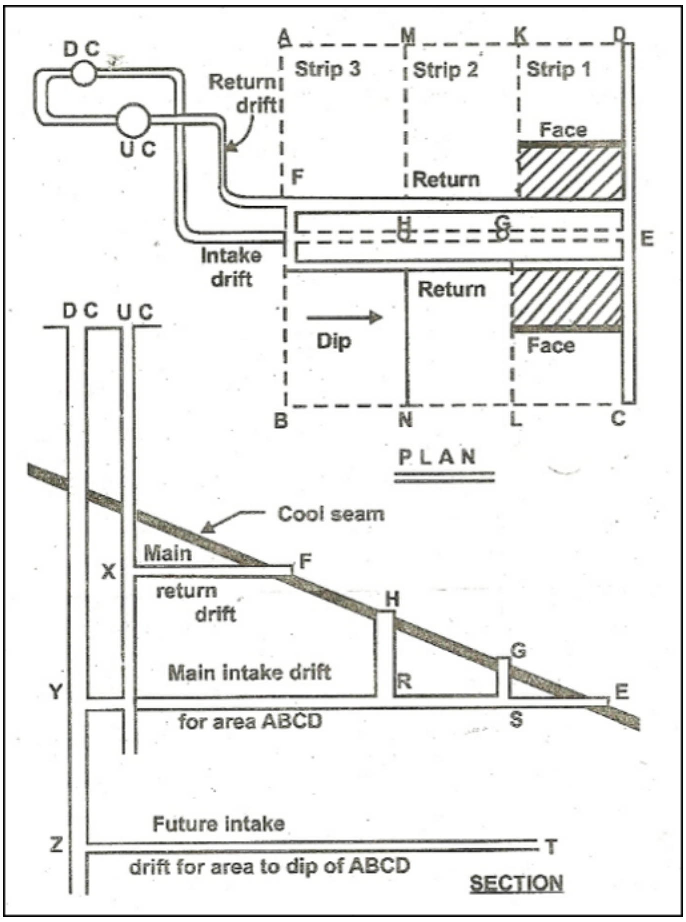
1. It provides the main road for efficient and adaptable haulage systems. A locomotive haulage, in its most efficient form capable of dealing with outputs of the orders of 3,000 tonnes/day or more, is possible. Outputs are concentrated at a few loading and hoisting points, permitting mechanization in transport and hoisting and achievement or large production rates.
2. It makes possible a highly efficient ventilation system, there being two separate independent roadways intake and return, without the possibility of any air losses and short circuit. Pressure difference between the intake and the return is easily maintained. There is a further advantage in deep workings, in that, fresh air is not heated before it reaches the faces to the same extent as in in-the-seam mining development. Also emission of gas through the strata is usually much less and the fresh air does not get vitiated through its passage along the airway, an aspect which is of impotance when high outputs of the order of 10,000 tonnes per day are to be obtained.
3. Maintenance cost of roadways is the least thfoughtout the life of the horizons, as the roads are in stone.
4. It is easy to work several seams at a time.
5. It is eminently suited for inclined (beyond 10°) and disturbed seams and for areas of high seam density.
6. These are stands explored geologically as the lateral and cross-cuts are driven in the initial days of mine life.

DISADVANTAGES OF HORIZON MINING :

General considerations before adopting horizon mining, stated earlier, indicate the disadvantages of the system. High capital expenditure for development work and long gestation period are the main disadvantages. Any seam which is not worked before abandoning an upper level and staple shafts is virtually lost, as against the in-the-seam mining, where any unworked weak can still be worked at any time in the future.

5.2 Describe the layout of Horizon Mining.

Given figure illustrates the system in its simple form, having regard to single, uniformly inclined seam lying to the dip of the shafts. The first step is to drive main cross-measure drifts, XF and YE respectively, from the shafts in the direction of the full dip of the strata to intercept the seam at points F and E. The first (upper) drift XF forms the main return airway, and the second (lower) drift YE forms the main intake airway for the first area of coal to be worked, namely ABCD on the plan. Ultimately, air will pass down the DC shft, along drift YE, then ascensionally up the seam from E to F, and so to the UC shaft via drift FX. The vertical interval between the two drifts varies in different cases according to the dip of the bends, the number of seams to be worked, and other factors, but may range between 60 and 200 metres. The next stem (in the particular case under consideration) is to drive lateral level roadways EC and ED in the seam (see plan) from point E, at right angles to the main drift YE. The roadway CED represents the main intake and conveyor level for the first pair of working faces, the loading point into tubs or mine cars being at E.



6.0 HYDRAULIC AND PNEUMATIC STOWING :

6.1 Describe Hydraulic Stowing.

HYDRAULIC STOWING : This process is widely used in India in those collieries which are situated within 16 km of rivers giving plentiful supplies of sand, the commonest stowing material in our mines.

The following factors have made stowing possible in many Indian mines :

1. Availability of sand from rivers flowing near the collieries within 16 km.
2. Roof and floor of seams are not affected by water.
3. Seams not being very deep, humidity is not a major problem.
4. Mines are usually at depth exceeding 100m and the seams are inclined. Hydraulic sand stowing is not successful where the seam is at a low depth from the surface and is flatter than 5°

From the stage of collection sand at river and till the sand is packed in the goaf, the following operations are necessary :

1. Gathering of sand at the river bed.
2. Transport of sand from river end to the bunkers on surface at the colliery.
3. Transport of sand hydraulically from the bunkers to the underground stowing site through pipes.

4. Stowing of the sand in the area from where coal has been extracted.

Before introducing sand stowing arrangements at any colliery it is necessary to make bore holes in the river bed to ascertain the depth of sand, to estimate its reserves and to explore the possibility of continuous supplies its reserves and to explore the possibility of continuous supplies to meet the demands. One of the coal extracted needs theoretically nearly 1.3 te of sand in a virgin area. Where old workings have to be stabilized and the pillars to be extracted, the ratio may extend to 2.5 te of sand for every te of coal extracted from old workings. In workings which are developed by bord and pillar method, if the depillaring is to be in conjunction with stowing, nearly 1.8 te of sand per the of coal extracted during depillaring will be essential. In longwall advancing working, nearly 1.4 te of sand per te of coal raised is required. Wastage or losses account for additional 10-15 %.

PNEUMATIC STOWING : The stowing material may consist of washery refuse, boiler ashes, surplus pit rubbish, picking from the screening plant, or shale bands from the coal seam. Sand alone is not used as it is heavy and abrasive. A mixture of sand and washery dirt may be suitable. Debris containing much clay material is also unsuitable because it clogs the pipes. Very dry material should be dampened to allay dust. Damp material is less abrasive and gives tight packing in the goaf.

The crushed material passes from the crusher through 65 mm to 75 mm aperture wire screen to a storage bunker. Tubs are loaded at the storage bunker and then lowered underground when coal-winding is slack. There should be sufficient storage room underground to stock these tubs and adequate haulage facility so that during stowing shift the stowing operations are continuous and materials are supplied to the stowing plant without interruption. Underground, the loaded tubs are taken to a tippler which tipples the martial on the feeding hopper of the stowing machine which is situated at a convenient point near the goaf to be packed.

The compressed air required for the stowing operations is supplied from the surface through pipes of 200 mm to 300 mm dia. Smaller size pipes are rarely used. The surface air compressor is multistage, has a large capacity of 55 to 85 m^3 of free air/min, consuming 400 to 600 HP, and compresses the air to nearly 6 kgf.cm^2. The stowing pipes are of high carbon steel 10 mm thick, in lengths of 3 m. Roadway pipes may be with flange joints but pipes at the stowing range have quick release couplings (Victaulic or hamecher type) with rubber seals. The compressed air ranges in the shaft and galleries are fitted with automatic water drainage devices and pressure gauges at intervals.

7.0 SUPPORT AND ROOF CONTROL IN MINES :

State properties of various types of roof & roof behavior.

The immediate roof in a roadway or workplace in a coal seam may consist of coal, sandstone, fireclay or shale.

Coal roof is common in all seams more than 3 m thick if coal near the floor is worked. It is reliable and with occasional dressing down of the hanging portions will not prove dangerous when it stands for long eriods, even a year or more. Compressive strength of coal varies but may be considered as 2.25 kg/mm^2 (1.5 te per square inch).

Sandstone roof bends slightly before breaking and will give enough warning before fracture. It is therefore, reliable and is considered good in mining terminology. Coal parts radily from sandstone roof. Crushing strength of sand stone is nearly 13.5 kg/mm^2.

Shale roof is treacherous and most unreliable. It rarely gives any warning before collapsing. It weathers quickly when exposed to atmospheric action and spalls off, that is one layer after another comes down at intervals. It is a good practice to keep 0.6 m of coal intact near a shaly roof during development of a mine if the seam thickness so permits. The coal left intact in the roof may be completely extracted when depillaring the area.

Two terms, laminated roof and massive roof, are generally used in mining in case of roof consisting chiefly of sandstone. Laminated roof is common in most of the coalfields. During depillaring operations, if the roof is laminated, local roof fall occurs 4 to 0 hours after props are withdrawn. This relieves the coal pillars of local weight and is, therefore, an advantage when extracting the pillars. Massive roof consists mostly of sandstone which has no laminations.

PRESSURE ARCH THEORY IN LONGWALL WORKING :

When a longwall face is newly opened between two headings, or gate roads, say, 100 m apart, and the face advances from a solid coal pillar or coal rib, the higher strata in the roof from a sort of bridge (or arch) across the excavated area from solid coal of the face to solid coal of the coal pillar or coal rib behind. Timber or steel supports will support the immediate roof. As the face advances and the space of the arch increases the load due to upper strata increases over the abutments of the arch until the bridge breaks down and the roof comes down in the goaf.

The pressure arch in longwall workings has its apex or crest at a minimum height above the seam at nearly 2 times the length of the face. If the depth of the coal seam exceeds twice the length the pressure on account of weight of the rocks outside the pressure arch is transmitted to abutments. If the depth is less, the static pressure of the rocks above the goaf are right up to the surface is to be supported by the props, checks and the packs or stowing in the goaf. Perhaps for this reason longwall faces with caving have caused difficulties in roof control at depths of less than nearly 100 m.

It will be clear that failures of underground coal pillars and roadways are the combined effects of the induced stresses in the surrounding rocks and coal and the inability of the rocks and coal to withstand them. For example, a pillar fails when the applied axial stress in the roof rocks at the edges of a rectangular opening exceeds the shed strength of the immediate roof, it fails in shear. How a rock responds to possible state of stress as well as the reasons for its failure should be underground by engineers planning underground supports and workings.

TESTING OF ROOF :

In many situations the roof of mine roadways and faces is required to be systematically supported at regular distances apart, whether or not the places have been tested and found to require supports. Where such systematic support is not considered essential, it is the duty of mine official to test regularly and systematically the places where workman have to pass or work. This testing is usually done.

1. Visually with the help of a strong light,
2. By hearing the sound of the roof and side or a prop set when tapped with a stick, and
3. By feeling the vibrations when the roof is tapped with a stick.

Visual test aims at detecting any cracks in the roof or sides or any signs of weight on supports such as bending of lids or burr of the tapered end of the existing prop, water percolation from roof, or increased flow of water percolation. These indicate the need for additional supports.

A good roof or side gives a ringing sound when tapped with a stick ; dull or dummy sound indicates the need for supports. When testing the place, the official should stand to the rise side of the place being tested as loose chunks of rock of bad roof may give way when tapped. The roof above gallery height of 2.5 m may be tested with a bamboo with its testing end shod with iron. Caution is necessary when testing the shale roof, which emits a ringing sound even when the roof is bad, if the thickness of the shale bed is greater than 0.3 m. A prop, if already erected, may be tapped to get an indication of weight on it; a ringing sound indicates good condition but a dull and heavy sound gives a warning of bad roof condition, requiring additional supports.

Vibration test is done by experienced men by resting the palm of the hand against the roof when tapping it with stick and feeing the vibrations, which are different for bad and good roof conditions. This is possible for height not exceeding 2.2 m.

Visual test is carried out if the roof is upto 5 m high by a strong focused beam of light from a torch or an electric lamp. For vibration test a bamboo end is kept pressed on the roof by one worker. A second worker taps the roof by another bamboo and vibrations are felt on the first.

MATERIALS EMPLOYED FOR SUPPORT :

The following materials are commonly used for mine supports entirely as such or in combination:

1. Timber, usually sal (and in some areas, teak) is used for props bars, chocks or cogs, and laggings.
2. Iron and steel in the from of bars, props, arches, corrugated sheets and roof bolts.
3. Brick or building stone in masonry walls, or archings.
4. Reinforced concrete or precast concrete blocks as roadway lining.
5. Roadway ripping, dirt bands and shales as packwalls.
6. Sand, earth, boiler ash, washery rejects, mill tailing, slage from blast furnace for smelting Iron and crushed stone as packing of goaf and filling or voids.

Research into strong, lightweight materials for underground supports has shown that the most promising one is glass fibre-reinforced plastics. These have not been introduced in our mines as yet. Tests in Russia have shown the CBAM framed supports or development roads weight ne seventh or one eighth as much as precast reinforced concrete and one third as much as timber frames. CBAM is a Soviet glass fibre product.

Precast concrete assemblies as support have been seldom used in our mines. They have the serious disadvantages of great weight and difficulty in handling.

The type of support to be built up depends on the importance of the place to be supported, the period for the support, its cost and availability.

CLASSIFICATION OF SUPPORT :

SAFARI SUPPORTS : The conventional method of supporting galleries in coal mines is by means of wooden cross bars. For fixing these cross bars, holes are to be made in the coal pillars manually by crowbar. This is time consuming and the whole operation of fixing one cross bar, this method takes about 2-21/2 hours. Therefore the supports lag much behind the working face. For quick setting of the cross bars, the manual cutting of holes in the coal pillars is eliminated by drilling holes with the usual coal drills and a support, known as safari support, is installed to support the roof. This support consists of a pair of clamps of mild steel on which a cross bar is placed to support the roof. Each clamp consists of an angle iron frame to which semicircular m.s. bracket is welded as a seat for the wooden cross bar and in the angle iron two holes, 35 mm. dia. And 175 mm apart, are provided for two m.s. rods of 32 mm dia. 700 mm long. The two m.s. rods of each clamp are inserted into the holes drilled in the coal pillar. The cross bar is placed in position over the two brackets and tightened against the roof with wooden wedges.

SIDE SUPPORT : Wooden lagging are placed tight between vertical props and pillar where the sides are weak and need support. Sometimes the timber set of prop and bar has to resist pressure from sides which tend to crush into the roadways. Notching is useful in such cases. The props should be set at an angle of 14° to 20° off the vertical and the feet well sunk into the floor.

An alternative method of resisting side pressure is to sink the props well into the floor and to reinforce the timber-set by an additional bar or stretcher, which may be nailed to the props. As this reduces effective height of roadway, its use may not be advisable in roadways of less than 2 m height, used by basket loaders.

SUPPORT BY WOODEN COG, CHOCK OR CHOCKMATE : A chock, cog or chockmate is a combination of sleepers above one another in a criss-cross manner. It supports a much larger stretch than a prop and is used in places where the roof is bad over a wide area and neds a substantial support. Cogs are also erected where main roadways have to pass through area having coal pillars of inadequate size. The term chockmate is generally used in metal mines.

Cogs are required under the Regulation at goaf edges, at junctions of splits and galleries in depillaring areas in bord and pillar working, and at break-off line at the goaf on longwall faces.

Only rectangular sleepers, or alternatively, sleepers having their two opposite sides chopped flat, should be used. The minimum length of sleepers of a cog to support roof at a height upto 3 m may be 1.2 m but for a roof height in excess of 3 m it may be 1.5 m. The sleepers should have a minimum cross section of 100 mm x 100 mm.

The cog should not be normally erected on loose floor or debris, but on natural floor or on secure foundation. The floor area over which the cog is to be erected may be excavated for a depth of 25 to 50 mm and should be made nearly flat in seams of mild inclination.

The chock should be tight against the roof and this may be tested by hammering for looseness at the uppermost sleepers.

SUPPORT OF A ROADWAY : Where the roof of a roadway is bad over some distance bars resting in holes of coal pillars and tightened against the roof by wooden laggings may be erected at intervals of 2 to 3 m. If the coal pillars are not strong enough of the road is through a fault zone, the wooden bars are supported on timber props. This is a common practice. Where the roof pressure is likely to be heavy bars may be supported on timber chocks. A method of supporting a wide junction by cogs and bars. No props should be erected at such a place where they are likely to be dislodged by moving or derailed and runway tubs. The bars may sometimes be placed on bricks walls constructed on solid foundation of coal floor with 150 mm layer of concrete at the base.

SYSTEMATIC TIMBERING : Systematic timbering is the term used for erecting supports in such a manner that the distance between supports are according to a specified pattern as laid down by the Manager and approved by the Directorate of Mines Safety. Systematic timbering is essential in the district of bord and pillar workings where splitting of pillars or depillaring is going on, on every longwall working face, in every working ina disturbed or crished ground and at other place where the DGMS may so direct. The type of supports to be erected, whether cogs, props, or bars are also specific in the order governing systematic timbering. In every case of systematic timbering, it is essential that additional supports shall be erected as and when necessary. Manager has to hand over copies of systematic timbering rules to all the supervising officials and has to post such copies at conspicuous place in the mine.