8

Supports

"Disturbance to natural ground settings to a minimum could be considered as directly proportional to cost reduction and minimizing problems encountered during ground excavation and mining."

8.1 INTRODUCTION – NECESSITY OF SUPPORTS[1,4,5,6,7,10]

Basic factors determining the physical and mechanical properties of the rocks include:

- The depth of deposit
- The local geological structure (tectonics)
- The stratigraphy and geological age of the rock
- The weathering
- The presence of water and its condition.

The rock pressure depends upon the geologic factors (such as: the physical and mechanical properties of rock, bedding conditions, presence of water), the dimensions of excavation, and also the method of driving and the care with which the excavation has been made.

The basis of rock pressure is weight, because the upper layers of the rock press on those below them. and these Usually these forces are in balance when, the ground is stable.

After the mass of rock has been penetrated by a mine roadway or tunnel, the loss of balance results in a very short interval of time. Therefore, in those roadways and tunnels where the rock does not deform beyond its elastic limit, the support does not experience any pressure and the roadway can stand for a long time without support. For example wide excavations driven in strong unfissured rocks such as granite etc. or even the small excavation driven in dense clay can stand unsupported for even unlimited time without noticeable change.

However, since all rocks are not so strong and also the excavations can be large, the elastic deformation increase to plastic ones; the continuity of the rock is disrupted and it begins to break. The outward sign of this stage of deformation is usually deflection of roof and cracking in it, at first barely noticeable and later on steadily increasing. As the cracks widen, the beds separate and the rock drop off in sizes which vary with the rock type and its fissuring. Further fractures can cause roof falls. To maintain the size and shape of the roadway, it becomes necessary to support to resist the pressure of the surrounding ground i.e. the rock pressure.

In designing the support system it is necessary to know the direction and magnitude of rock pressure, and also, the strength of the rock around the roadway or tunnel. The change of stress caused by the deformation of surrounding rock can be regarded as bounded by so-called spheres of influence of the roadway or tunnel. In the roof this sphere of influence (fig. 8.9) includes the zone of breakage, or zone of progressive fissuring, and the active zone, both of which apply direct pressure on the roadway.[5] Outside these zones the rock is not subjected to the effects of excavation but the zones may extend later.

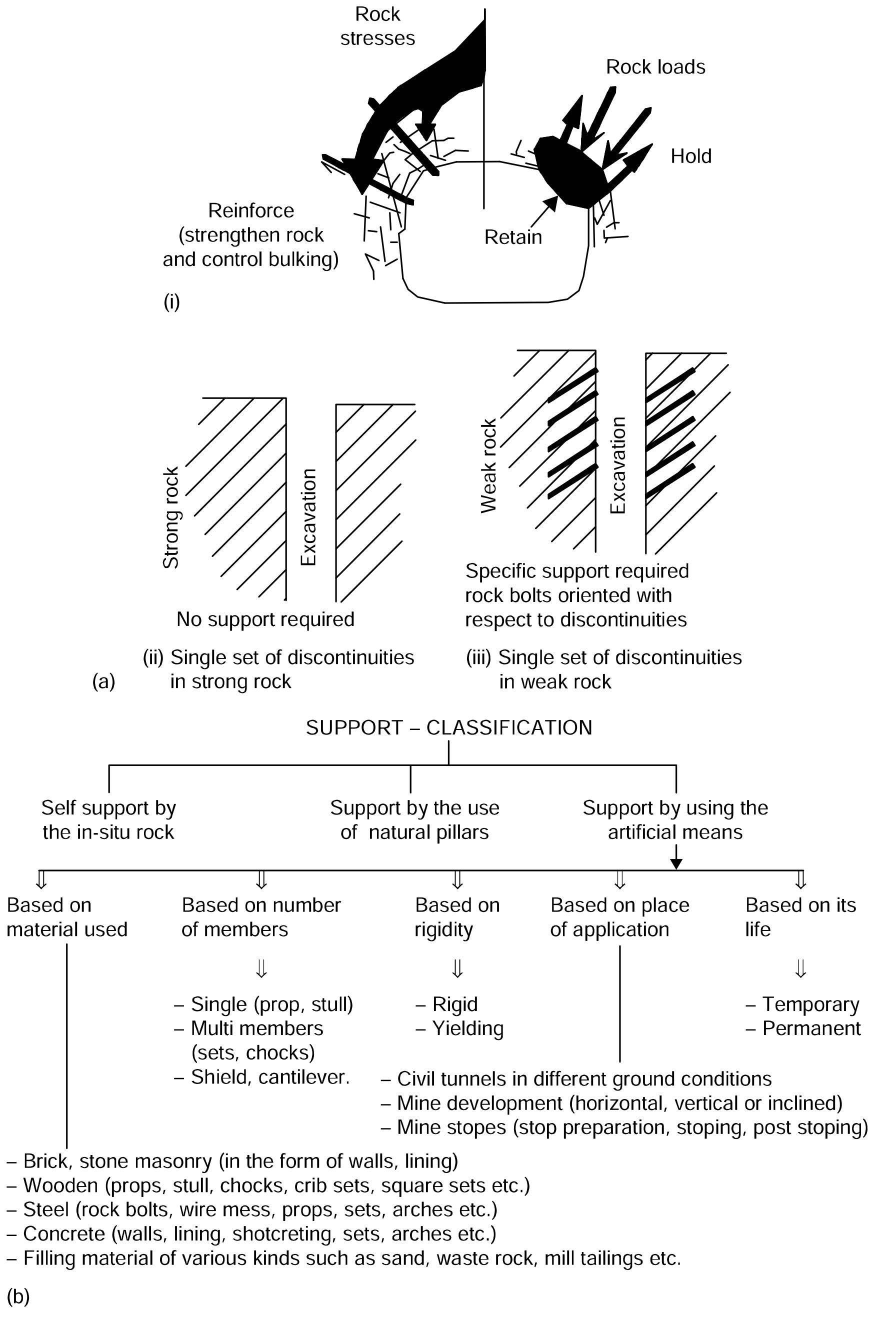

Figure 8.1 (a) Supports – some concepts. (b) Support – classification.

The strength of rock is measures by the specimen collected, which are taken after the redistribution of stresses and from the neighborhood of the excavation. The established factors that contribute determination of rock pressure are summarized below:

- The stressed state of rock mass and the mechanical properties of the rock;
- The shape, dimensions and location of the excavation;

- The duration of the exposure of the rock excavation; and,
- The depth of excavation.

8.2 CLASSIFICATION OF SUPPORTS

Proper selection of support is very vital to mines and tunnels. In mines it determines safety of work, ore production cost, losses and dilution, intensity of mining and productivity of the mine. Mining operations disturb the *stressed equilibrium state* of rock that is found in solid. Stress field called rock pressure develops around the workings. It acts upon the surrounding rock, pillars and supports. Thus, all these elements constitute a support network in any mine.

Similarly in civil tunnels support determines safety during its drivage and afterwards, tunneling rates and costs. A line diagram given in figure 8.1(b) represents supports of various kinds with their sub-classification.

8.3 SELF SUPPORT BY IN-PLACE (IN-SITU) ROCK

Use of the in-situ rock to support the rock is the best way of designing supporting system wherever feasible. *A competent rock is defined as the rock, which, because of its physical and geological characteristics, is capable of sustaining openings without any heavy structural supports.*[12] Rock mechanics tests are performed to evaluate the structural properties of the in situ rocks. If the rock is to support effectively it must not be allowed to loosen. This, in turn, requires a careful blasting and selection of properly shaped openings. The size should be kept as minimum as possible. Adherence to these practices could prove a useful guideline to minimize the need of artificial supports.

8.3.1 SUPPORT BY THE USE OF NATURAL PILLARS

Pillars of different kinds practically form a near-rigid type of supports. In some methods they form the integral part of the stope design e.g. board and pillar; room and pillar; stope and pillar; post and pillar etc. whereas in other they are used to maintain stability between the stopes (all stoping methods for steeply dipping deposits). Ore pillars are left either forever or for the duration of working of a given section. Depending upon the purpose and arrangement, the pillars can be classified as under:

- *Protective pillars*: These pillars are required to preclude caving of shafts or a particular structure.
- *Level pillars*: These are the pillars left above and under the workings of main horizons of the levels/sections to support them. Crown pillar and sill pillars belong to this category.
- *Rib/block/side pillars*: These pillars are left between two adjacent stopes or blocks.

The support with ore pillars is a simple and economic method. However, it is not practicable in the areas of high-grade deposits, ore of high values and also in the situations, in which even if, the grade not very much above the cutoff grade.

8.3.2 USE OF ARTIFICIAL SUPPORTS

An artificial support is needed to maintain stability in the development and exploitation (stoping) openings, and systemic ground control throughout the mine. Application of artificial support is made when caving or self-supporting system cannot be exercised. As illustrated in figure 8.1(a);[11b] any support component perform one of the three functions: (i) to hold loose rock, key blocks, and other support in place; (ii) reinforce the rock-mass and control bulking; and (iii) retain broken or unstable rock between the holding and reinforcing element to form a stratified arch.

The prevalent types of artificial supports can be classified based on various criterions. Prominent amongst them are the material of its construction, the life it requires to serve, its characteristics in terms of rigidity or yield it can provide to the superincumbent load (as in certain circumstances some yielding is acceptable and preferred) and few others. Adapting these criterions, the classification has been outlined in figure 8.1(b).

8.3.2.1 *Brick and stones' masonry*[7]

Material such as local stones and bricks, which can be dressed and sized properly and easily, available at the low cost are used for the mine roadways' and tunnels' lining and forming the arches (fig. 8.6(a)). A wall by itself does not form a mine support but girders or bars are placed over it. Arching can be constructed using suitable stones and bricks particularly at the mine portals.

8.3.2.2 *Wooden (timber) supports*[4,7]

Wooden supports are used in underground mining and tunneling operations since their inception. Different types of timber such as red wood, Sitka spruce, Douglas and white fir, and many other types, which can be locally available, are used to construct the wooden supports. The wooden supports are light in weight. Wood can be easily cut, manipulated, transported and put in the form of a support. It can be reused and gives indication before its failure. It is the best suited for the temporary support works. In any situation if used it should be able to bear the load safely and its consumption should be minimum to economize on its material and erection costs. Its strength depends upon its fibrous structure.[4] Presence of knot, non-concentric layers, fiber's inclination, out side and inside cracks are the common defects, which are observed in the timber used for this purpose (fig. 8.2(i)). These defects further weaken it. Humidity also affects its strength as many funguses that live in humid conditions affect it. It is a combustible material and needs due precaution against the outbreak of fire. The wood when cut from the forests is wet and needs it's seasoning i.e. allowing it for its natural drying. Wood is considered wet if moisture is $>30\%$ and dry when it is below 20%.[7]

To make timber resistant to fungi, bores and insects it should be treated with preservatives, which can be organic or inorganic types. Tar and creosote oil are the common organic compounds, which are used; whereas salts such as zinc chloride, copper sulfate, iron sulfate and lime wash are the common inorganic compounds to treat the timber. These preservatives can be applied by various techniques and prominent amongst them are: spraying or brushing, cold dipping, hot and cold open tank treatment and pressure tank treatment. In some mines special treatment to the wood is given to make it fire resistant.

The wood is used as props (fig. 8.2(a) & (b))[7], stulls (fig. 8.2(c))[7], chocks (fig. 8.2(d)[7] & (e)), cogs, square-sets (fig. 8.2(f))[7], bars (fig. 8.2(g)), multi member sets (fig. 8.2(h))[7] and as lagging between support and the ground. A new development that

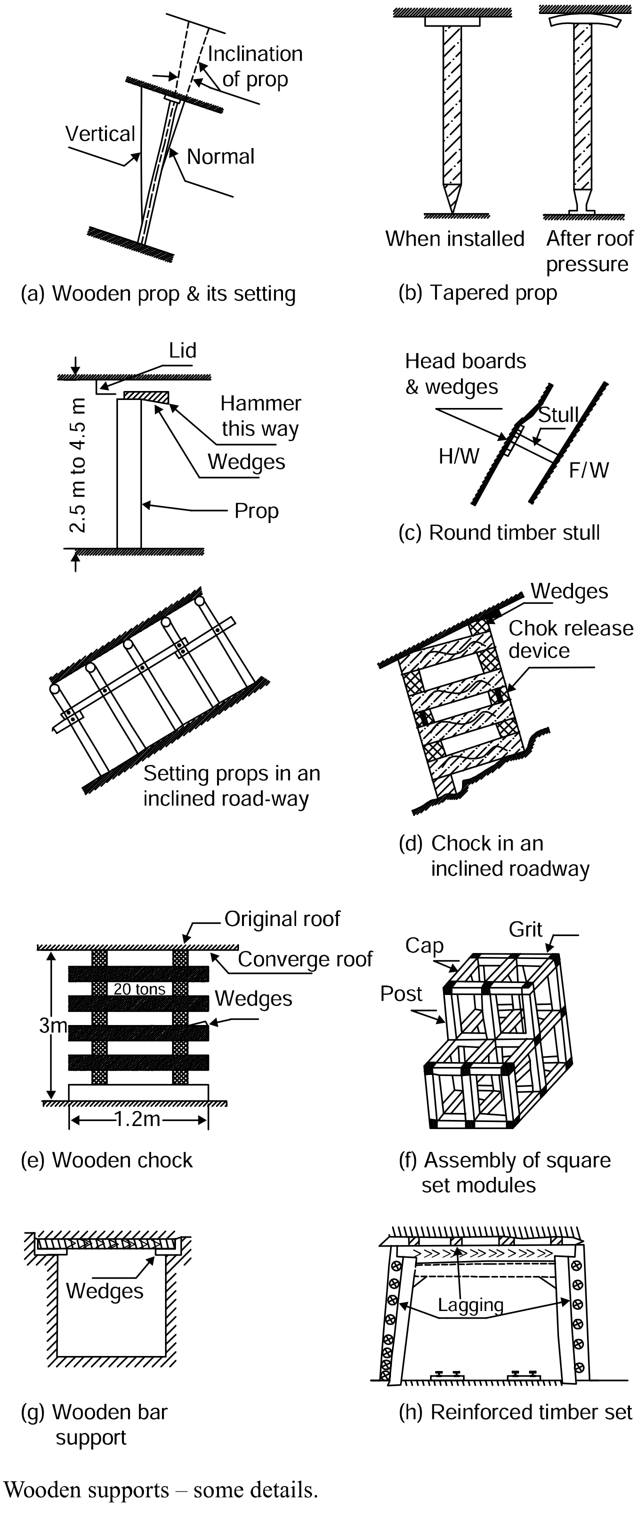

Figure 8.2. Wooden supports – some details.

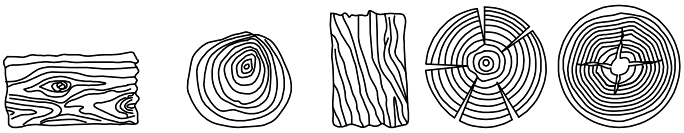

Figure 8.2 (*Continued*).

has been incorporated in some of the South African mines is the use of timber filled pipes props, called pipe sticks, in which the timber protrudes from each end of steel tube. The timber acts as the axial load-bearing member, and the steel pipe provides lateral constraint, thereby greatly improving the yieldability of the prop. The pipe stick is a 150–200 mm diameter wooden prop encased in 3–4 mm thick steel pipe.[16]

Besides the advantages as outlined in the preceding paragraphs, timber has the advantage of flexibility and can accommodate large strains before it breaks. Crushing of timber becomes apparent long before its failure. One limitation of timber used as lagging between steel supports is that it tends to rot.

The erection and use of timber in different forms has been illustrated in figure 8.2.[7] Use of timber in the form of reinforced sets (fig. 8.3(a)),[7] junction support (fig. 8.3(b))[7] and in the process of fore polling (fig. 8.3(c))[7] has been illustrated in figure 8.3. Sylvester, monkey winch and power driven winches are the devices used to withdraw props.[7] A chock-releasing device is used to withdraw chocks.

8.3.2.2.1 *Calculations with regard to wooden supports*[4,15]

As given by Saxena and Singh (1969):

Load bearing capacity of a prop:[15] $P = 47.2 - 1.5\,h/d$ (8.1)

Whereas: P – Load bearing capacity of prop in tons;
h – Height of prop in mm;
d – dia. of prop in mm.

Buckling Strength of a prop:[4] $\sigma = (\Pi^2 E/\lambda^2)$ for $\lambda > 100$ (8.2a)

$$\sigma = \sigma_c\ (1 - a\lambda + b\lambda^2)\ \text{for } \lambda < 100$$
Slenderness ratio $\lambda = 4l/d$ (8.2b)

Whereas: l – is length of prop;
d – dia. of prop;
E – elasticity modules of timber;
σ – buckling strength of timber;
σ_c – crushing strength;
a, b quality constants for mine timbers a = 0, b = 2.

Bending strength of timber:[4]

Bending strength or modules of rapture $\sigma_b = M_{max}/W$ (8.3a)

$$M_{max} = P_K\, l/4 \quad (8.3b)$$

$$W = bh^2/6 \quad (8.3c)$$

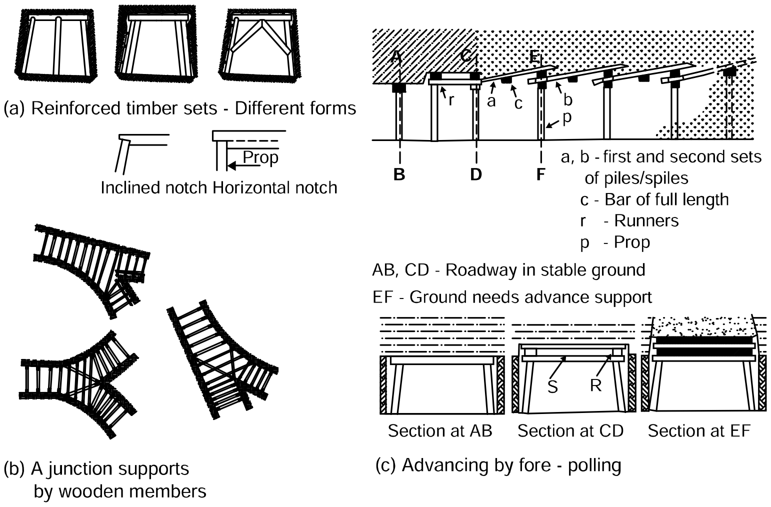

Figure 8.3 Wooden supports – some details of their use.

$$\sigma_b = (8.3b)/(8.3c) = (3P_k l)/(2b\,h^2) \qquad (8.3d)$$

Whereas: σ_b – bending strength i.e. modules of rapture
M_{max} – Maximum bending movement
W – section modules
l – span, length of beam
P_K – breaking load;

To calculate load on a wooden gallery:

Everling formula:[4]

$$h = \alpha L_a \qquad (8.4a)$$

Pressure on support in ton./m² $\quad \sigma_t = h\gamma \qquad (8.4b)$

Load per unit length, t/m $\quad q_t = \sigma_t\, a \qquad (8.4c)$

Total load produced by parabolic dome $\quad P_t = \alpha La^2\, a\, \gamma \qquad (8.4d)$

Whereas: h = height of load in meters,
α = loadings factor; depends upon rock formations under normal conditions 0.25–0.5; for bad roof with cracks, it may be 1–2.
L_a = span of set at the roof/back in meters. or length of cap on wooden set.
a = distance between two adjacent sets.
γ = rock density in tons/m³.

Protodyakonov Formula:[4]

Load height (parabola height) in meters, $\quad h = l/f \qquad (8.5a)$

$$f = \sigma_c/100 \qquad (8.5b)$$

Pressure on support in ton./m², $\quad \sigma_t = h\gamma, \qquad (8.5c)$

Load per unit length, t/m, $\quad q_t = \sigma_t\, a \qquad (8.5d)$

Total load produced by parabolic dome, $P_t = (4/3)\ l\ h\ a\ \gamma$ (8.5e)

Whereas: f = Protodyakonov constant, may be taken as 0.01 of compressive strength of the rock in which gallery is driven.
σ_c = compressive strength of rock in kg/cm^2
2l = gallery width in m.

Note: other nomenclatures are the same as mentioned above.

8.3.2.3 *Steel supports*

Steel is an expensive material but it is widely used to manufacture the mine and tunnel supports due to the following facts:

- It is free from natural defects
- It has high Young's modules of elasticity [up to the order of 2 millions kg/cm^2][4]
- It is least affected by temperature and humidity
- It can be reused.

Various types of steel sections can be used to manufacture the mine supports; prominent amongst them are listed in table 8.1 (particularly to manufacture beams or sets): Using steel the following types of mine supports are manufactured:

1. Steel props: 1 – Friction (fig. 8.4(c) & (d)); 2 – Hydraulic (fig. 8.4(a))
2. Steel chock (hydraulic) (fig. 8.4(b)), Cantilevers i.e. powered supports (fig. 8.4(b)).
3. Steel beams and sets
4. Steel arches: 1 – Rigid; 2 – Yielding
5. Shield support (fig. 8.4(b))[14]
6. Steel tubing
7. Wire-mess, roof truss and Rock bolts.

8.3.2.3.1 *Steel props, powered and shield supports*

There are two types of steel props: friction and hydraulic, *having yielding characteristics* which is a desirable feature for their use in the mines particularly at the longwall faces. The former works on the principle of friction and the latter on the hydraulic. The construction details of these props have been illustrated in figure 8.4. Characteristics curves as shown in figure 8.4(c)[7] and figure 8.4(a)[7] for friction and hydraulic props respectively, depicts their working behavior under the roof pressure. Friction props suffer the disadvantage of aging of friction surfaces and human errors in pre-loading the props. Hydraulic props work better than friction props with easy setting and withdrawal mechanisms. Figure 8.4(e) illustrates friction props installation scheme at a longwall face.

Table 8.1 Common steel sections[4] used for manufacturing the mine supports.

	Steel sections		
Parameters	Rail	Clement	Toussiant Heinzmann
Unit weight, kg/m	33.5	14	21
Rankin Ratio*	1.5	5.3	1.3

* Ratio of compressive strength to buckling strength in a beam of 2 m length.

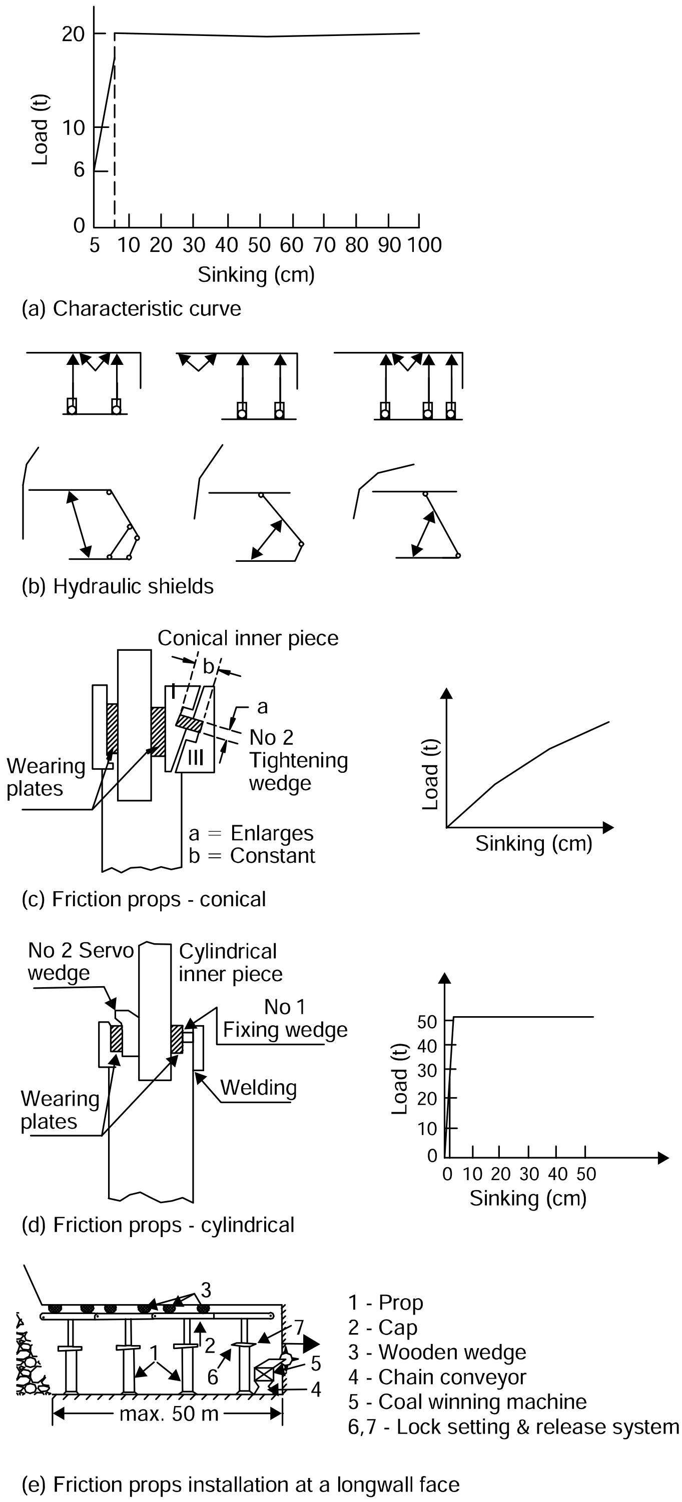

Figure 8.4 Hydraulic and friction props – some details. Hydraulic chocks and shields.

Self advancing or power operated support (fig. 8.4(b)) *(powered support)*[14] (figs 16.24(e) and (f)) system consisting of an assembly of hydraulically operated steel hydraulic support units which are moved forward by hydraulic rams coupled or connected by pin or other means to the face conveyor. This type of support provides unobstructed room for plough or shearer and flexible conveyor equipment with roof-beams cantilevered from behind the working face.

Shield support: When considered shield support figure 8.4(b)[14] in conjunction with drivage or tunneling work different types of shields are employed to support different types of ground. It may cover the entire rock surface, including the face, or just the curved surface, or it may give partial shielding in the crown only. It can be self propelled as part of a tunnel borer or independently propelled for use with a partial face TBM or other form of a mechanical miner. With the advent of tunnel boring, now the shield can be carried, similar to the shell of a tortoise, as apart of a self-propelled boring machine. A finger shield consists of parallel steel strips separated by gaps, through which the rock bolts can be installed and inspection can be carried out.

Its other application is mainly in coalmines. In any design a shield support consists of a canopy, a base, hydraulic legs and controls system. To cope up with easily caving faces during longwall mining these supports have been developed.

Steel sets: Steel sets constructed of 'H' sections are used to prepare supports of different curvature (fig. 9.20). The advantages include ease and speed of installation, a relatively reliable and high load carrying capacity and little maintenance it requires. High cost, and difficulty in adapting in the varying ground conditions, requirement of more space than shotcreating and rock bolting are some of its limitations. However, it is used as a permanent support in many mines.

Steel Arches: Basically there are two designs of steel arches: *Rigid and Yielding.*

Rigid arches: These are used as permanent support and popular in mines to support the permanent workings (fig. 9.20). Two, three or four segments arches forming near semicircular design are mostly used. The arch shape is more efficient use of the steel sections than flat cross bars. With an arch, the steel member is in compression instead of bending.

Yielding arches are composed of three sections. The top section slides between two side elements. After a regular interval (may be a fortnight or so), the tightening elements are loosened; and the arches slide, converge, and thus, relieve stresses accumulated on them. This step eliminates their deformation. Toussaint Heinzmann patented first yielding arches. The profile is shown in figure 9.20. More designs were brought about later on. In some cases the yielding can be provided with insertion of wooden pieces between the steel elements.

Steel Tubing: Cast iron steel tubing are used to permanently line the shaft walls during its sinking when the other methods of lining cannot work effectively; particularly where freezing method to treat the ground is applicable. These are technically known as English and German tubing (figs 14.7(c) and (d)). In both cases, the tubing is built up of cast-iron rings, each of which comprises a number of flanged segments shaped to suit the curvature of the shaft.

8.3.2.3.2 *Rock bolting*

The use of rock-bolts in underground mines and civil excavations is increasing rapidly since its use in 1918[8] in the underground mines of Poland. It has very largely replaced timber, made the excavation safer, released space previously obstructed by timber, and gave improved ventilation. Today in all types of mines, caverns and tunnels its use is extensive and at the increasing trend. Paragraphs below, outline the theory and concept to understand its functioning.

If L is the width of an opening and a uniform load q is applied to it, then maximum bending will be in the center of this opening and the magnitude of this bending stress can be calculated using the following relation:[4]

$$\sigma = (0.75\, q\, L^2) / (bh_1^2 + bh_2^2) \quad (8.6a)$$

Whereas; h_1 and h_2 are the thickness of two rock layers and b is their width.
If these two layers are tied together, the bending stress can be expressed as:[4]

$$\sigma' = (0.75\, q\, L^2) / b(h_1 + h_2)^2 \quad (8.6b)$$

If $h_1 = h_2 = h_0$

Dividing eq. (8.6a) by eq. (8.6b), we get: $\sigma'/\sigma = 1/2$ i.e. the bending stress becomes just half.

This explains the concept of beam theory that works for layered or stratified deposits when rock bolts are used to support them. The concept is that by bolting the immediate roof acts as a beam to support the over lying strata. This has been illustrated in figure 8.5(b). The other concept behind roof bolting is the theory of suspension that states that using the roof bolts the immediate roof is suspended to the main roof which is stable and strong, as illustrated in figure 8.5(a). Rock bolts also reinforce the rock by pressure arch[9b] and support of discrete blocks, as shown in figure 8.5. Use of rock bolts in the mines is extensive. It can be used as permanent support to support the roof and sides of the main roadways, roadway junctions and wide chambers. In the stoping areas it finds wide applications to support brows of the draw points and other openings that require immediate and temporary supports.

To support the roadway junctions (2-way staggered, 3-way or 4-way) and galleries the usual pattern adopted in the mines have been illustrated in figures 8.6(f) and (g).[6] The number of bolts per square meter is called 'bolt density'. The spacing between the rows of roof bolts, and within a row, can be calculated using the guidelines outlined below. The dia. and length range:[6] 5/8″ dia. 36–72″ length (in 65% cases); 3/4″ dia. 60–120″ (30% cases); 1″ and more dia. 60″ and longer (5% cases).

Rock bolt calculations[4]

$$\text{Length of rock bolt } (l) = \text{Thickness of immediate roof} + 0.: \quad (8.7a)$$

$$\text{Number of bolts, } m \geq (L\, h\, c\, \gamma)/R \quad (8.7b)$$

$$\text{Allowable axial force, } r \geq (0.785\, d^2\, \sigma_a)/n \quad (8.7c)$$

$$\text{Bolt density } m_o = m/(L\, c) \quad (8.7d)$$

$$\text{Bolt spacing, } b = L/m \quad (8.7e)$$

Whereas: h – thickness of immediate roof, in m
l – length of rock bolt, in m
m – number of rock bolts
L – Gallery width, in m
c – distance between rows of bolts, in m

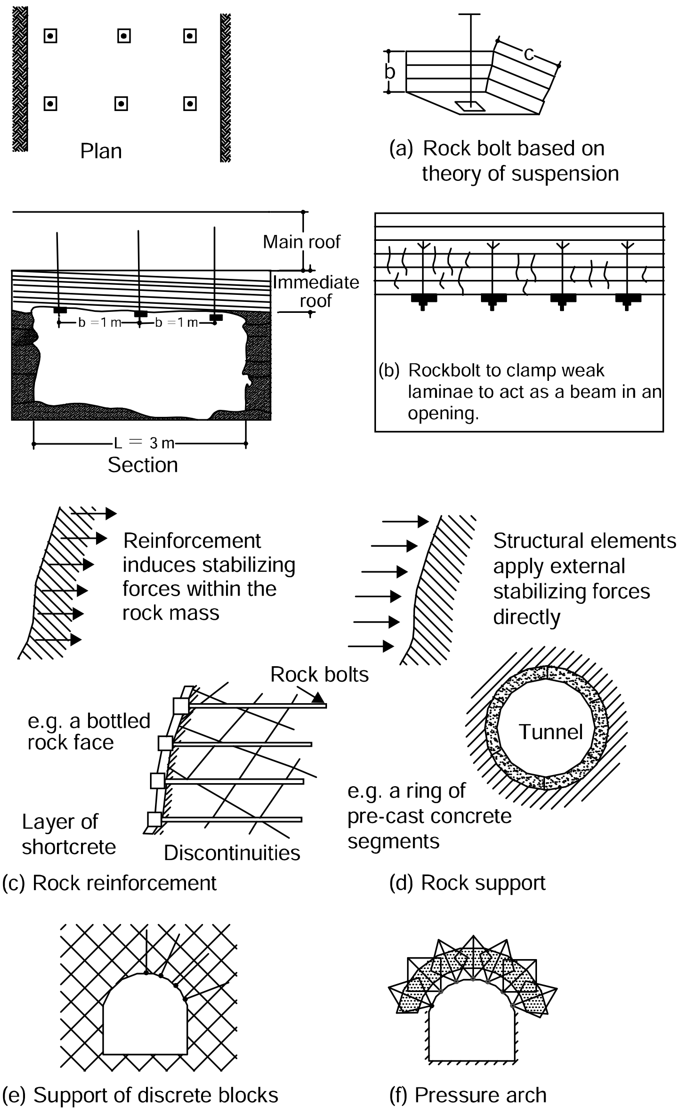

Figure 8.5 Rock bolts – related theories. Rock reinforcement and support – some concepts.

γ – immediate roof's rock density in t/m^3
n – factor of safety
σ_a – yielding strength of steel in $tons/m^2$
d – diameter of bolt in m
R – allowable axial force in tons.

To calculate the anchorage force to keep the bolt in position[4]

$$\mu = k\,q \tag{8.8a}$$

$$P = F_t\, q\,(\sin\alpha + \mu \cos\alpha), \text{ in kg.} \tag{8.8b}$$

Whereas: P – anchorage force to keep the bolt in place, in kg
F_t – area of anchorage, in cm^2

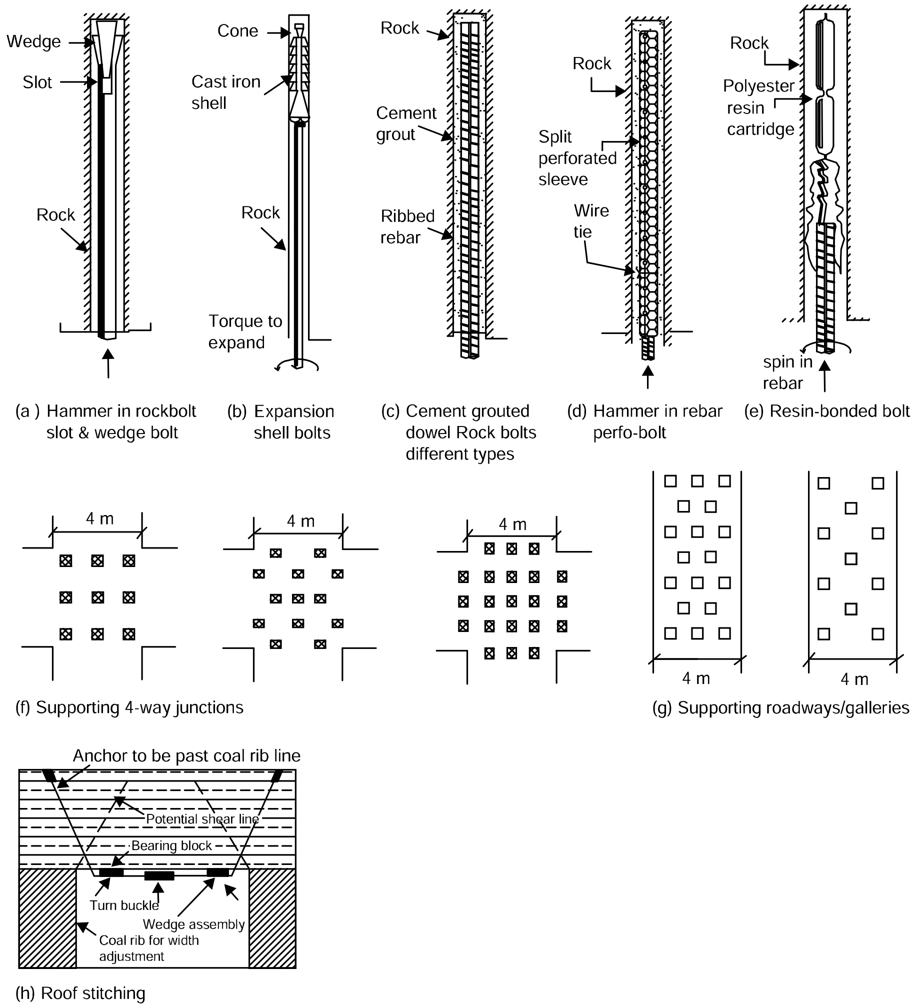

Figure 8.6 Rock bolts of various types. Rock bolting patterns.

q – bearing capacity of rock, in kg/cm^2
α – conical angle of the wedge
k – coefficient = 0.0014
μ – coefficient of friction between roof rock and bolt steel.

Classification of rock bolts[4,7,8,9,13] Following are the rock bolts of various types. They have been also illustrated in figure 8.6.

1. Slot and wedge
2. Expansion shell
3. Bolts with distributed anchorage: 1 – Grouted dowels. 2 – Cable bolts; 3 – Perfo types.
4. Special types of bolts – such as resin bolts.

Slot and wedge bolts: These bolts were the earliest, although they are not the best, but still continue to be used for some temporary support applications. They consist of a steel bar with a slot cut at one end, which contains a steel wedge (fig. 8.6(a)). The wedge end is placed in the hole first and the wedge is driven into the slot by hammering the exposed end of the bolt. Expanding halves grip the hole, allowing the bolt to be tensioned and carry load. Blast vibrations and ground movement easily loosens bolts of this type. Holes for the bolts are first drilled using a suitable drill. The hole length is 5–7 cm less than the bolt length.

Expansion shell bolts: It contains toothed blades of malleable cast iron with a conical wedge at one or both ends (fig. 8.6(b)). One or both of the cones are internally threaded onto the rock bolt so that when the bolt is rotated by a wrench, the cones are forced into the blades to press them against the walls of the drillhole. The grip increases as the tension increases. These are the least expensive and very widely used for short-term support in underground mines. They are most effective in hard rocks and in soft rocks they tend to slip and loosen. In some mines this loosening is avoided by introducing a cement grout through a plastic tube running alongside of the bolt. Few days after its installation, the nut should be once again tightened, as it gets loose during the initial few days after installation due to the active workings in the nearby areas.

Grouted dowels: A dowel is a fully grouted rock bolt without a mechanical anchor, usually consists of a ribbed reinforcing bar, installed in a drillhole and bonded to the rock over its full length (fig. 8.6(c)). Dowels are self-tensioning when the rock starts to move and dilate.[8] They should therefore, be installed as soon as possible after excavation, before the rock has started to move, and before it has lost it's interlocking and shear strength.

The normal grout mix consists of sand cement ratio as, 50/50 or 60/40. Water to cement ratio should not be greater than 0.4 by weight.[8] Grout injection particularly in the upholes requires care to ensure its complete filling. Sometimes air pockets may be left in the hole, which are difficult to detect. Pneumatically operated grout pumps/loaders are used to fill the holes, to which the bar is driven. The dowel is retained in upholes either by a cheap form of an end anchor, or by packing the drill hole collar with cotton waste, steel wool or wooden wedges.

Cable bolts: Grouted cables, called cable bolts can be used in the stoping areas to support the back to prevent its fall or caving, also to stabilizing and prevent caving of the hanging wall by installing these bolts horizontally or at a certain angle. In some of the Australian mines cable bolts up to 18 m length have been used successfully. Upward cable bolting of open stopes' crown pillars can provide improved support within it. This allows an increase in stope span, and reduction in pillar dimensions and can eliminate need of any other type of support within it.

Used and old haulage or hoist ropes can be used for this purpose after removing grease and washing them. Almost the same technique is used to stitch a weak flat roof or back. This technique is known as roof stitching and similar to this is a roof truss as shown in figure 8.6(h).[6]

Perfo-bolts:[4] In this system (fig. 8.6(d)) instead of pumping the grout into the hole, it is trawled into the two halves of a split-perforated sleeve. The halves are placed together and bound at the ends with soft iron wire, and the tube full of cement is inserted in the hole. The dowel is then driven by sledgehammer into the sleeve, forcing grout out through the perforations and into contact with rock. This practice is very popular in Scandinavia countries for its application in all types of rocks.

Installation of reinforced concrete roof bolt consists of two operations: filling the hole with grout and placing a roof bolt into the hole. In absence of compressed air, the grout in some cases is injected into the hole with the aid of a hand-grouting gun.

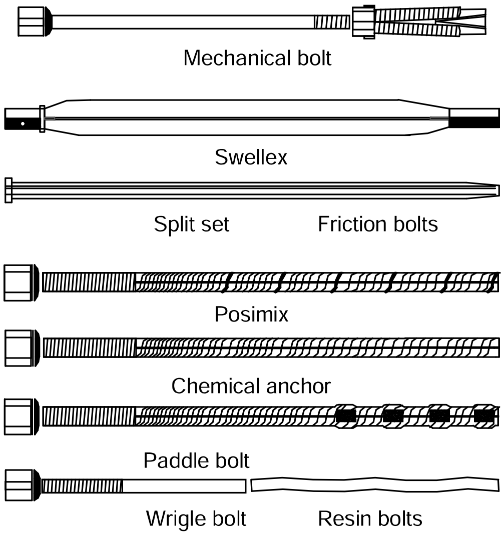

Figure 8.7 Rock bolts – some prevalent designs.[9b]

Resin grouted bolts:[4] Where high and quick strength is required, the resin bolts (fig. 8.6(e), 8.7) although costlier, find applications. In this practice a ribbed reinforcing rod is cemented into the drillhole by a polyester resin, which in few minutes changes into a thick liquid to a high strength solid by a process of catalysts-initiated polymerization.

In comparison to cement grouts, resin has the advantages of its quick setting and reaching the full strength quickly i.e. within 2–4 hours. The bond strength is much stronger than the cement grout. Complete grouting combined with tensioning can be achieved by inserting several slow setting cartridges behind the fast ones. If the resin starts to set before installation is complete, the bolt is left sticking out of the hole and is practically ineffective.

Wire mesh: This is also known as screen. This is available in different wire gauge thickness and mess apertures. Its main purpose is to support the rock between bolts, which is particularly necessary when the rock is closely jointed and the bolts are moderately to widely spaced. It can also serve as reinforcement for shotcrete.

In Figures 8.8(a) to (d), application of split set dome plates, split sets (rock bolts), sheet mesh and cables (strand Graford) at Mount Isa Mines for good and poor ground conditions, used for the long-term and short-term accesses, have been illustrated. These hard rocks mines have attained a depth up to 1.8 km.

8.3.2.4 *Concrete supports*

High compressive strength, easy to erect and manufacture, fire resistant, smooth finished surface and suitable under the adverse mining conditions including presence of abnormal make of water, are some of the advantages a concrete support commands over the steel and wooden supports. Low tensile strength, failure without warning and requirement of curing time for its setting are some of its limitations. Concrete finds its application for the following types of mine supports:

- Shaft lining
- Mine roadways lining