MINE INUNDATION

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Water influx in mines

– Normal influx

– Sudden inrush, irruption or inundation

- **Sources of normal influx of water:**
  - Stream bed seepage
  - General surface seepage
  - Barrier pillar seepage

- **Sudden irruption or inundation:** Sudden accidental inflow of large quantity of water into mine workings causing flooding of the mine

Table: Statistics of disasters due to mine inundation (irruption of water) in India

Year	Date of accident	Name of Mine	No. of persons killed	No. of persons S/Injured
1953	05.08.1953	Majri	11	0
1954	10.12.1954	Newton Chikli Colliery, MP	63	0
1956	26.09.1956	Burradhemo	28	0
1958	20.02.1958	Central Bhowrah, Jharia	23	0
1960	05.01.1960	Dhamua Main, MP	16	0
1970		Karanpura Colliery, Bihar	03	0
1975	18.11.1975	Silvewara Colliery, Nagpur	10	1
1975	**27.12.1975**	**Chasnalla**	**375**	**0**
1976	16.09.1976	Central Saunda	10	0
1983	14.09.1983	Hurrilladih Colliery, Jharia	19	0
1995	27.09.1995	Gaslitand	64	0
2001	02.02.2001	Bagdigi	29	0
2003	16.06.2003	Godavari Khani No. 7 LEP	17	0
2005	15.06.2005	Central Saunda	14	0
Total			**682**	**1**

Chasnalla Mine Disaster (1975):

- An explosion in the mine followed by flooding killed 375 miners.

- The caving in of a roof coal let in 7 million gallons of water per minute in the mine.

- Miners were trapped under a mountain of debris and drowned when the water surged into the mine.

Bagdigi Mine, BCCL, Dhanbad Disaster (2001):

- On 2nd Feb. 2001, 29 miners met a watery grave as 16 million gallons of water completely flooded the mine within minutes.

Putki Ballihari Project, BCCL (22 September, 2019): Narrow escape for 9 miners due to water inrush in 11 Seam due to coal wall burst

Classification of Mine Inundation

– Necessary to understand the causes so as to provide remedial measures to prevent reoccurrence of sudden inflows

Classified into three categories based on various past inundation:

1. Event controlled inundation

2. Accidental inundation
}
Mining induced inundation

associated with caved mine workings below either a confined aquifer or surface water bodies where inflow is followed by main and periodic roof falls.

3. Spontaneous inundation: **A natural phenomenon** associated with mining in the vicinity of karst aquifers.

Accidental inundation:

- Is a major cause of concern to the mining industry

- Greatest risk of accidental inundation is from abandoned flooded workings

- The single major cause is accidental intersection of waterlogged old workings by the current active developments.

- Caused due to flooding of lower active workings due to release of water from
  - A lake or ocean
  - A large water pool in upper seam
  - Water flooding in the adjacent old workings

Causes of inrush through accidental intersection of waterlogged old workings:

- Ineffective barrier between unknown or known waterlogged and active workings

- Incomplete/ Inaccuracy of old plans

- Absence of plans

- Incorrect interpretation of old plans

- Failure to plug boreholes

- Unknown old workings

- Incorrect seam correlation

- Failure in communication system

- Failure in management system

Causes of inundation in mines

- Surface reasons

- Underground reasons

Surface reasons: Inundations by surface waters

▪ Sudden inrush of water from the sea, lake, river or any water body (particularly in rainy season).

▪ Surface water entering shallow workings specially where mines are worked close to the outcrop : the chief source of mine water in regions of heavy or moderate rainfall.

- Boreholes kept unprotected near the river bed.

- Cracks or fissures developed on the surface.

- Surface drainage system not up to the mark.

- Wrong sitting of the shaft or incline and improper altitude.

Inundations from overlying strata

- When impervious strata are pierced by mine workings.

- When fracture planes develop in impervious strata due to subsidence communicating with water bearing strata above.

- When faults, fissures or fracture planes in communication with a water-bearing bed are intersected by mine workings.

- When mine working is too near to the surface and accidental holing has taken into a pond, stream bed, or outcrop workings.

- When boreholes drilled for prospecting have not been sealed off.

Underground reasons: Inundations by underground waters

• Failure of main pump due to mechanical or electrical breakdown.

• Inadequate pumping capacity and poorly planned mine drainage system.

• Shafts sunk through water bearing beds, if they are not provided with watertight lining.

• Failure of lining of shaft: water from various water tables through which the shaft is sunk may enter the mine.

- Failure or collapse of dams due to
  - Improper construction
  - Improper site
  - Bad workmanship
  - Bad construction material
  - Unexpected heavy roof pressure
  - Mine explosion
  - Over toping of dam

- Failure of barrier within the mine or adjoining mine.

- Intentional robbing of barrier and lack of joint survey carried out by owners.

- Wrong survey: results in
  - Accidental perforation of barrier.
  - Sudden connection of rise gallery to an old water logged gallery.
  - Connection of level gallery to an old water logged dip gallery.

- Seams in contact with or adjacent to water bearing beds.

- Fault plane making connection with upper seam or water bearing rock e.g. sandstone with varying porosity.

- Cracking of shale bed intervening between sandstone and coal bed as soon as coal is extracted allows water to pass to the coal seam.

- Approaching up-thrown working seam without proper precaution.

- Water from adjacent mines due to removal of barriers between mines.

- In case of multi seam mining,
  - intervening strata between two seams if thinned out
  - huge caving resulting in heavy inrush of water.

- Puncturing of water logged and abandoned upper seam: Due to

  – Working without records or maps.

  – Unreliable old plans.

  – Wrong survey and plotting.

  – Position of workings not indicated in abundant plan.

  – Disregard to regulation.

  – In case of existing working below water logged and abandoned upper seams, extensive falls in the working may cause the thinning partition and collapse due to the remaining strata unable to bear the wt. of the water above.

  – Entry of water into the lower seam through exploratory bore holes drilled from the abandoned upper seam in the past.

  (Precautions: any borehole drilled from the surface should be plugged with cement after acquiring necessary information. If plugging has not been done with cement and it is known to pass through waterlogged old workings above, a pillar of sufficient size must be left in the seam below).

- Inadequate precaution while dewatering water logged area.

- Blasting causing ground vibration and fracture in the strata.

- Accidental holing into the ponds, stream, bed or outcrop working.

From the observations it has been found that the following are the main causes of sudden inrushes of water:

- Holing into old working which are water logged. (Mostly in Indian Mines).

- Holing into surface water: River beds, ponds, etc.

- Holing into alluvium, moss or liquid matter (U.K.)

- Holing into water bearing strata against which the seam outcrops.

- Holing into water bearing strata particularly sandstone in sinking shaft.

- Striking an old borehole or shaft

PREVENTIVE MEASURES AGAINST INUNDATION

(1) SURFACE MEASURES: Aim at preventing dangerous accumulation of water on mine surface.

(2) UNDERGROUND MEASURES: Offer protection against inundation and thereby save life and property.

SURFACE MEASURES

Further divided into two categories,

    (a) Measures against flooding of mine main entries or outlets

    (b) Measures against seepage of surface waters

a) Measures against flooding of mine main entries:

- Locating shaft sites away from faults, river or any water body.

- Laying mouths of the shafts, inclines and adits above the HFL by 3-4 m and lining them for the first 20 m with watertight lining.

  - Mouth of the shaft should not be located at ravines.

  - Adits should be driven in a rising grade (to reduce pumping load)

- Diverting jores from shafts close in the vicinity could drain the rain water away.

- Cutting diversion drains or ditches or erecting embankments or concrete walls on the surface to intercept and conduct the surface run off water way.

- Constructing dams and reservoirs in the upper reaches of rivers to prevent their flooding.

- Filling up with debris or other sealing materials in all abandoned shafts and boreholes which has ceased to serve any purpose.

- Inclines not in use for hauling purpose should be closed by a safety steel door.

- Automatic signalling devices for consistently monitoring the water level in the water bodies near the mine should be used.

- Embankment with sufficient width and height should be provided along the river, nallah.

- Embankment with drainage channel should be provided near the subsided area.

- Drainage ditches should be provided and lined with impervious material.

- Dense surface growth and trees should be removed from mine entrance to a distance of at least 15 m.

(b) Measures against seepage of surface waters

- Straightening, cleaning, widening and grading stream channels to provide free flow of water especially in areas with vertical fractures, subsidence or high permeability rocks.

- Silting or lining stream beds with concrete or rubble masonry.

- Grouting the river bed with cement to stabilise and seal it.

- In case of near-surface mines, laying ponds and tanks dry if they form cause of water influx in mines.

- Diverting streams, if possible, to new and safe channels

- Fissured or ground with cracks should be protected by pillars left intact in underground.

- Cracks appearing on the surface should be blanketed with clay or moorram or grouted with cement.

- Backfilling surface excavations or subsided areas with impervious materials to an established hydraulic gradient that will ensure natural drainage.

- Diverting run-off to prevent its in filtration into fissured on subsided areas.

- Conducting run-off across pervious or subsided areas of the mining property by means of flumes.

- Grouting overlying strata to reduce permeability.

- Leaving outcrop barrier pillars of adequate size.

- Selecting a method of extraction by which the strata subside uniformly without fracturing. For extraction under important waterways, hydraulic stowing is the best method of roof control.

- Afforestation along river banks.

- Sealing off unused boreholes.

- If there is presence of unconsolidated deposit within the mine boundary, the nature of such deposit should be shown on working plan.

- All opencast mines near old workings should be surveyed regularly and officials be informed about all such programmes.

UNDERGROUND MEASURES

➢ 1. **Lowering of water table:** Lowering of the water table by borehole pumps was extensively applied for a long time but it suffers from the disadvantage that a stage might be reached when further dewatering will severely interfere with water resources, wells etc.

• **Leaving safety water pillars or barriers:** A safety pillar is that portion of the bed that is left unmined

– Below an overlying water formation along boundary line or lines of adjoining properties
– Between parts of a mine
– Below surface streams, tanks and lakes
– Around shafts
– Along major faults

- Its principal function is to act as dam to prevent water accumulation.

- Its vertical thickness is generally 20m and should not be less than 20m.

- The width of the safety pillars between adjacent mines $\not\subset$ 20m on either side of the boundary line at right angles to it.

- Each pannel should have substantial safety barriers on three sides with a minimum no. of entries or drivages through them -–so that after mining each panel can be isolated from other.

- Supporting roadways not coming under the influence of mining operations with water tight lining.

- Cementation of fractured strata.

- Driving drainage tunnels to dewater the properly.

- Providing adequate sump and pumping capacities at predetermined pts. for dealing with inrushes of water even where safety pillars are provided.

- Erecting water dams or hydraulic seals to seal abandoned sections of the mine.

- Erecting bulk head doors in mine workings with immediate danger of inundation.

- Providing additional lodgement capacity in worked out areas to which sudden inrushes of water may be directed in an emergency.

Barriers or Safety water pillars

- It is the portion of the bed that is left unmined in order to isolate the water body.

  - Between two mines (adjoining mines)
  - Below an overlying water formation along boundary line or lines of adjoining properties
  - Below surface streams, tanks and lakes
  - Around shafts
  - Along major faults

- Its principal function is to act as a dam and

- Prevent water accumulation from suddenly breaking into mine workings.

Size of water barriers

Factors affecting size of barriers

- Depth, inclination and thickness of coal seam.

- Geological disturbances

- Max. hydrostatic head

- Nature & characteristics of coal and adjoining strata.

- Permeability of strata

- Rate of water flow in mine

- No. of water tables present

- Method of working

- No. of working seams

- Susceptibility of coal to oxidation & weathering

Outcrop barrier pillar

GROUND WATER LEVEL

H

V

Hob

SATURATED ZONE

H_W

H_c

MINE WORKS

W
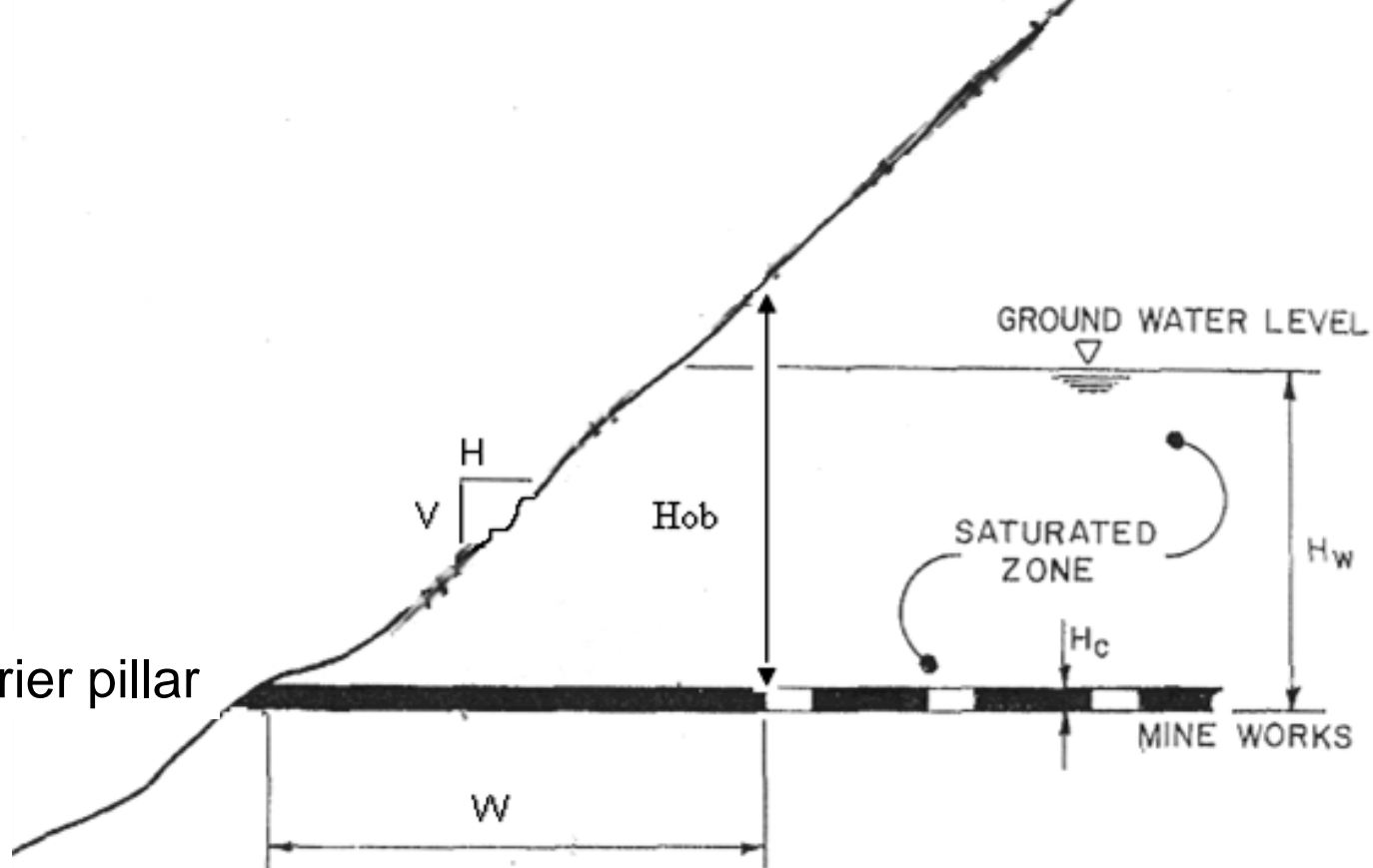
S = GROUND SLOPE H:V
H_c = COAL BED THICKNESS
H_W = HYDROSTATIC HEAD (FT.)
W = BARRIER WIDTH (FT.) = H_W + 50 ft
H_{ob} = Overburden Thickness $\geq$ 100 ft

Empirical Guidelines

Ashley's formula (G.H. Ashley, 1930): developed in Pennsylvania to design the size of outcrop coal barrier from impound water and protect active workings from inundation.

Width of barrier (m), $W = 6.1 + 4T + 0.1 D$

T = Thickness of coal seam, m

D = Depth of OB (m) or hydrostatic head (m) whichever is greater

- Min. width - 20 m

- Avg. width - 40 to 60 m

CMR

Rule of Thumb Formula:

- Mostly used to compute the width of coal barrier in the coalfields.

$$W = 50 + H$$

Where

   W = Barrier width, feet

   H = The maximum water head, feet

Advantages of barriers

- Reduces water flow and seepage from other mine.

- Reduces pumping cost.

- Confines explosion, fire, noxious gases, etc.

WATER DAMS

- Water damps are permanent artificial barriers or seals built in mine workings under any one of the following circumstances.

  - To guard against irruptions of water from adjacent water-bearing strata.

  - To guard against irruptions of water from adjacent old workings.

  - To prevent inundation of dip side workings by isolating the adjacent flooded areas.

  - When approaching waterlogged workings and draining of the water by means of borehole.

  - To limit the amount of pumping by allowing water in worked out areas to accumulate behind the dams.

  - Also used to intentionally flood a portion of a mine in case of a fire.

Selection of site for dam construction

For selecting the suitable site the following pts. must be borne in mine:

- **The ground must be strong, solid and sound** – shaly sandstone are most suitable while sandstones, conglomerates, and clayey shales are unsuitable.

- If dam is to be erected in a pervious or fissured ground, the ground should first be injected with liquid cement.

- **Head of water to be withstood by the dam** – should be as small as possible.

- The site should be easily accessible.

- The site should be self-draining –to facilitate erection and inspection.

- Sites to be correctly prepared by cutting into the sides, roof and floor so that the dam has a firm grip with the surrounding ground.

Types of dams:

Based on the design and shape:
1. Straight or flat dams
2. Cylindrical or arched dams
3. Spherical dams

Based on the materials used in construction:
1. Clay dams
2. Timber dams
3. Brick dams
4. Brick-and-concrete dams
5. Concrete dams

- In mines, brick-and-concrete and only concrete dams are commonly used for reliability, greater strength.

The factors governing the design of a dam :

- **Size of roadway**
  - For the same water head, a dam built in a larger roadway cross-section will be required to withstand greater total thrust than when it is erected in a smaller roadway cross-section

- Total thrust = water pressure × area of dam

- **Nature of the adjacent strata**
  - Dams built in weak ground (low σ_c and shear strength) must be of greater dimensions than those built for the same head of water in strong ground in order that the ground doesn't fail in shear.

- **Estimated water pressure**
- **Materials used in construction:** Permissible compressive strength of the material used in construction influences the size of the dam.
- **Form of dam:** Determination of dam thickness is important.

FLAT DAMS

- For small water pressures, a brick or concrete dam, 1 to 2 m thick, hitched into the sides, roof and floor is adequate.

- With larger pressures, two or more single bricks or solid plug of mass concrete will serve the purpose.

- Bricks used – must be hard burnt with σ_c 15 to 18 MN/m^2.

- For concrete dams, blast furnace slag cement or Portland cement may be used.

- The proportion of cement must be 20% and that of the aggregate 65% of the concrete mass.

- Ratio of sand to aggregate must be 2:3.

Fig. Brick dam

Concrete or Grouted Crushed Mine Rock.
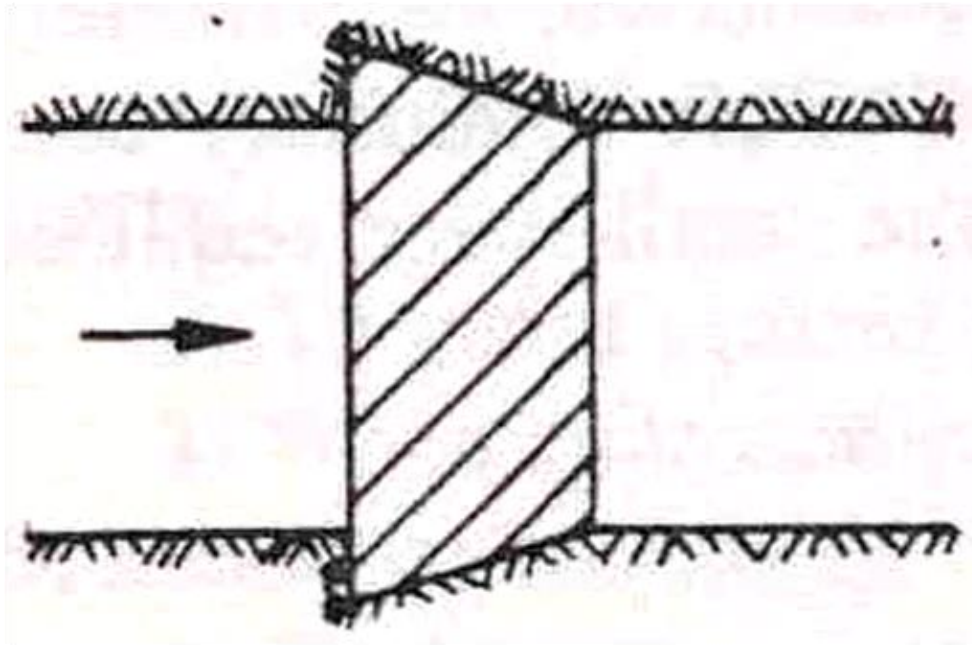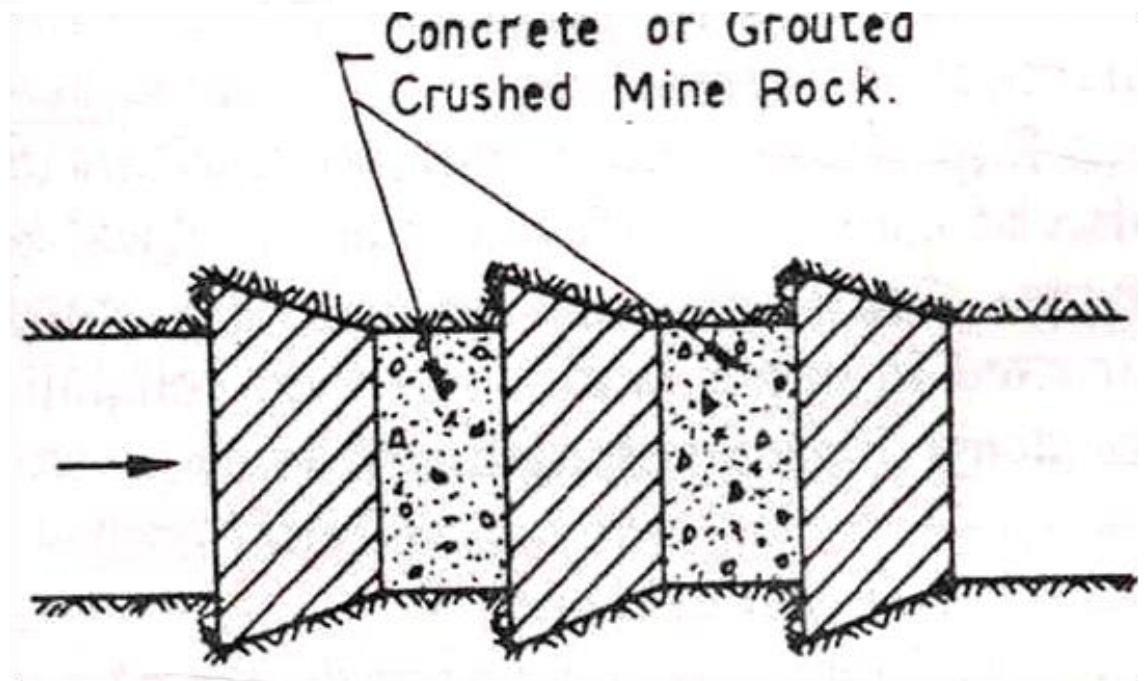
Fig. Brick dam for larger pressures
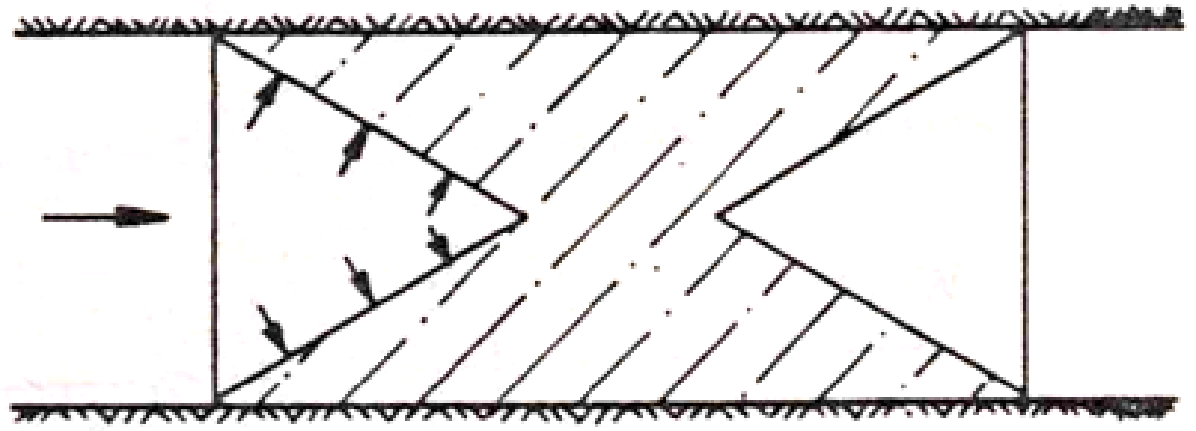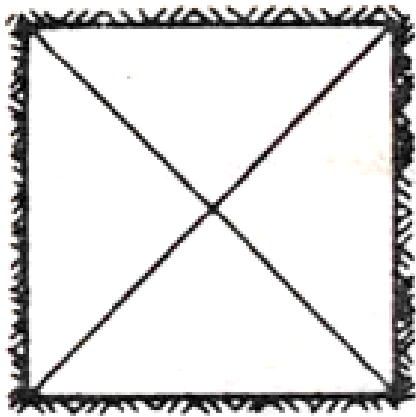
Fig. Parallel plug dam

Design of the flat dam

- The total length of plug dam is based on the **shear strength** of

  – the construction material used or

  – of the ground whichever is less, is used in the design of the dam.

- The dam must be designed such that

  Head of water on the water side of the dam × area of the face exposed to it = the safe shearing strength × shearing surface area

Force/thrust to which the dam is subjected = P. b. h

$$\textbf{P.b.h} = \textbf{(2 . t . b + 2 . t . h)}\,\boldsymbol{\tau}_{\textbf{s}}$$

$$= 2t\,(b + h)\,\tau_{s}$$

$$\textbf{t} = \textbf{Pbh} / \textbf{2 (b + h)}\,\boldsymbol{\tau}_{\textbf{s}}$$

where $\quad$ t = Length/thickness of flat dam, m.

b = width of the dam, m

h = Ht. of the dam, m

P = Max. estimated water press, N/m^2

τ_s = Safe shearing strength of the material or the ground which ever is less, N/m^2

ARCH DAMS

- An arch dam distributes the thrust acting on it by arch action to the abutments in the ground containing it.

- It may be designed as one or more arch rings each of which is considered to be subjected to a constant radial hydrostatic press.

- The radial thickness of an arch ring may be approx. determined by using the cylinder formula and by considering the dam to be segment of a thin cylinder subjected to an external water pressure.

PLAN
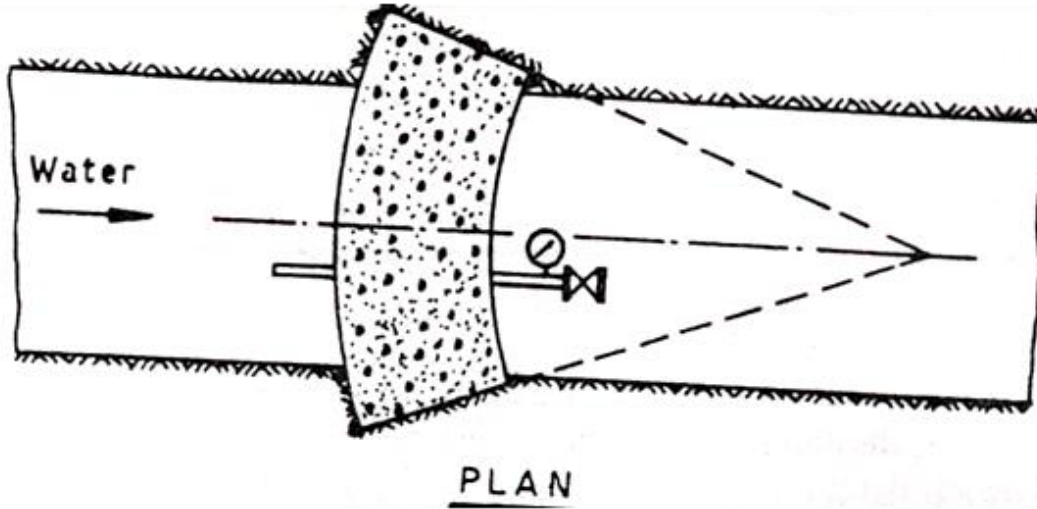
Fig. Concrete Arch Dam

ELEVATION

PLAN
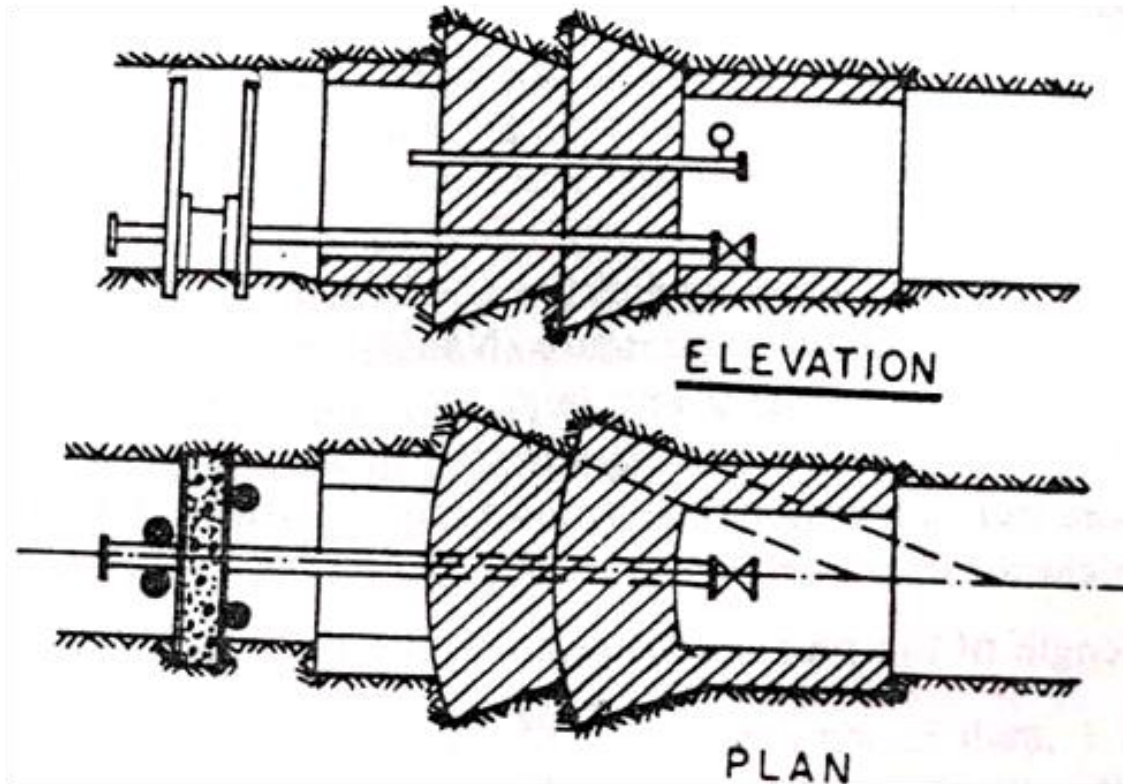
Fig. Brick Arch Dam

$$t = \frac{Pr_e}{\sigma_s} = \frac{Pr_i}{\sigma_s - P} \, (m)$$

P = is the maximum water press (N/m²)

r_e – external radius of arch rings (m)

r_I – internal radius of arch rings (m)

σ_s – safe compressive stress of material used (N/m²)

where P ≥ σ_s, a series of arch rings have to be put (generally 2 to 4), each ring being designed for a water press of P/n.

Where,

n = the no. of rings.

Thickness of each ring is

$$t = \frac{r_i}{\dfrac{n\sigma_s}{P} - \mathbf{1}}$$

The internal radius, r_i can be deduced from the relation, $r_i = \dfrac{b}{2\sin\dfrac{\alpha}{2}}$

b = width of the roadway (m)

$\dfrac{\alpha}{2}$ = half central angle of the arch
= 20º to 30º in strong ground
= 15º to 20º in moderately strong ground
= 15º in weak ground

For hard rocks, safe comprehensive stress = $\dfrac{\mathbf{1}}{\mathbf{6}} to \dfrac{\mathbf{1}}{\mathbf{10}}$ of their ultimate comprehensive strength

In other types of rocks, the following values may be taken :

- Soft S.St, limestone – 20 to 30 kgf/cm^2

- Clayey shale – 8 to 25 kgf/cm^2

- Very hard coal – 20 to 25 kgf/cm^2

- Friable coal – 3 to 10 kgf/cm^2

- Concrete best material for dam construction

- Bricks: difficult to make watertight contact with the surrounding ground.

Prof. Aldis, UK derived the following formula for determining the thickness of an arch dam:

$$t = r_i \left(\frac{1}{\sqrt{1 - \dfrac{2h}{\sigma_s}}} - 1 \right)$$

Where

r_i = internal radius of the dam (m)

h = max. head of water (N/m²)

σ_s = safe compressive stress of the material used (N/m²)

The factor $\dfrac{2h}{\sigma_s}$ must be less than 1 if the expression under the root is not to be imaginary.

It is greater than 1 when the building material is not strong enough

Spherical dams

- These consists of two or more spherical rings with abutments in the surrounding ground.

- For the same head of water, their thickness is less than that of the arch dams.

- These are difficult to built.

- Aldis derived the following formula for determining the thickness of a spherical dam:

$$t = r_e \left(1 - \sqrt[3]{1 - \frac{1.5h}{\sigma_s}} \right)$$

r_e = external radius of the dam

CONSTRUCTION OF WATER DAM

- A small wall on the inbye side of the dam up to a ht. of 0.6 to 1 m made of brick in cement, concrete, or clay rammed between two board walls.

- Pipe of 75 to 200mm is fitted depending upon the rate of water overflow to keep the site dry with several flanges to keep it embedded in the dam.

- Side, roof and floor cut – depth of cut varies from 0.6m to 10m depending upon ground condition

- Put air pipes: 20-25 mm near the roof

- Put cement pipes: 30 – 50 mm in dia.
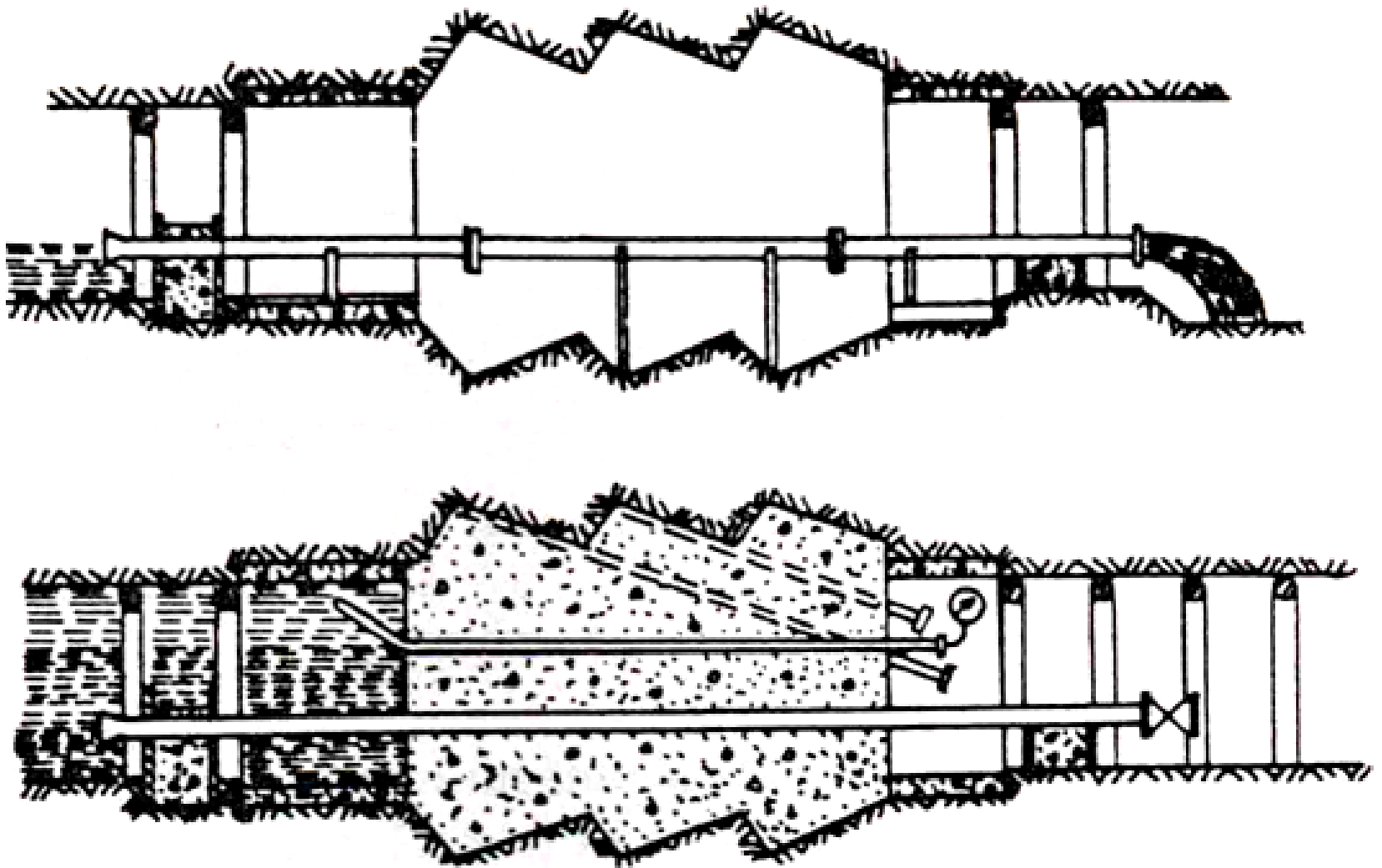
Fig. Construction of Flat Concrete Dam
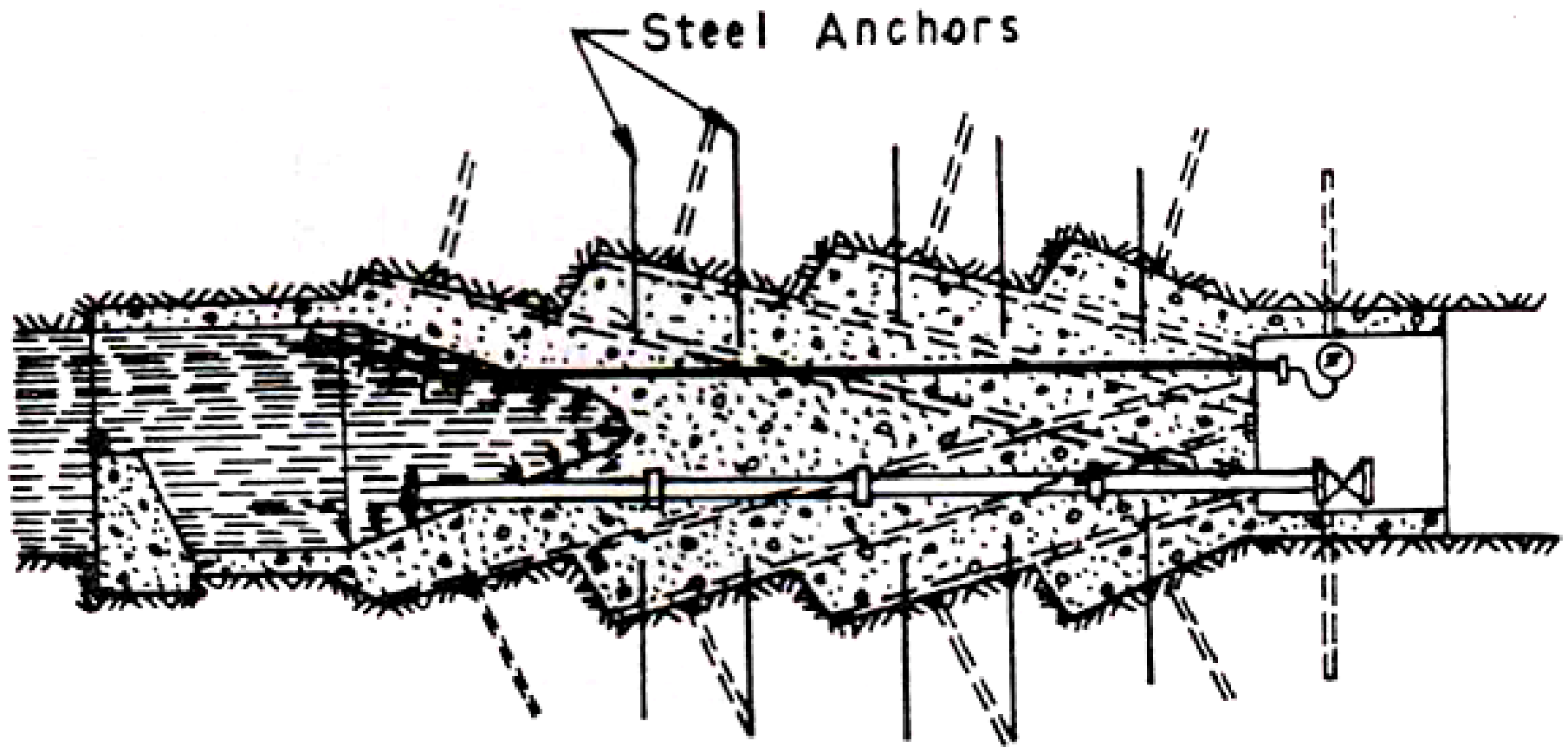
Fig. Construction of Flat Concrete Dam for Water Pressures 12 to 15 bar
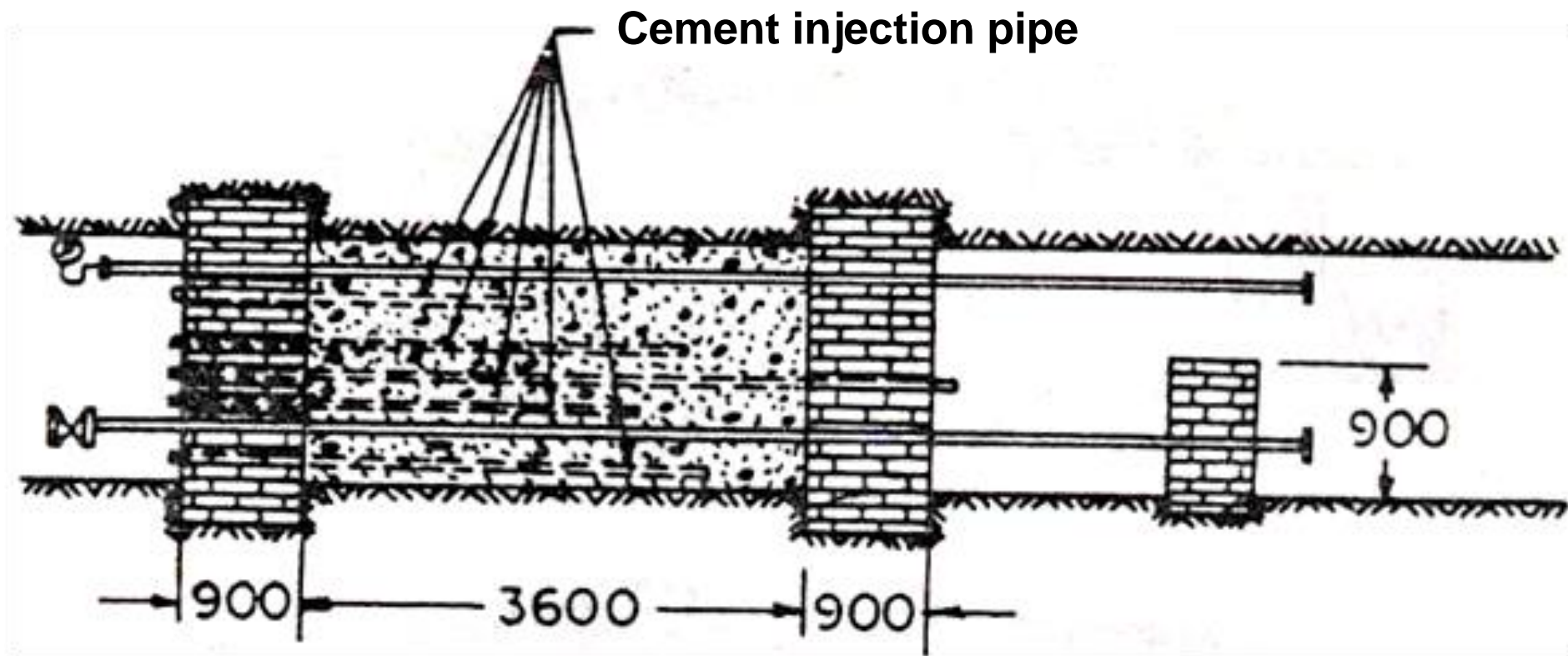
Fig. Brick-and-Concrete Dam used in British mines

Dewatering of water-logged workings

The necessity of dewatering water-logged workings arises :

- **When safety barrier between an active and inactive mine is considered unsafe** as a protection against a hydrostatic head.

- **When it is desired to extract reserves left in an abandoned mine filled with water from an adjacent active mine** by draining water from the abandoned mine.

- **When an active mine or part thereof is inundated and the mine is to be quickly brought into production.**

Methods of dewatering

The method of dewatering to be adopted depends on

- Whether an entire mine is flooded

- Layout of the mine.

- Location and extent of water-logged workings

- Time available for dewatering operation

- Power supplies available.

- Physical condition of the shaft(s) and the mine.

Dewatering methods

a. Dewatering of flooded mine in which water has risen into the shaft(s)

- Dewatering may be done by suspended
    - Electrical vertical centrifugal/turbine pumps
    - Air-lift pumps or
    - Electrical submersible pumps installed in the shaft.

- When electricity is available, submersible pumps (multistage centrifugal type) offer the easiest means of dewatering mine shafts.

b. Dewatering water-logged old workings by means of narrow mine roadways and advance boreholes
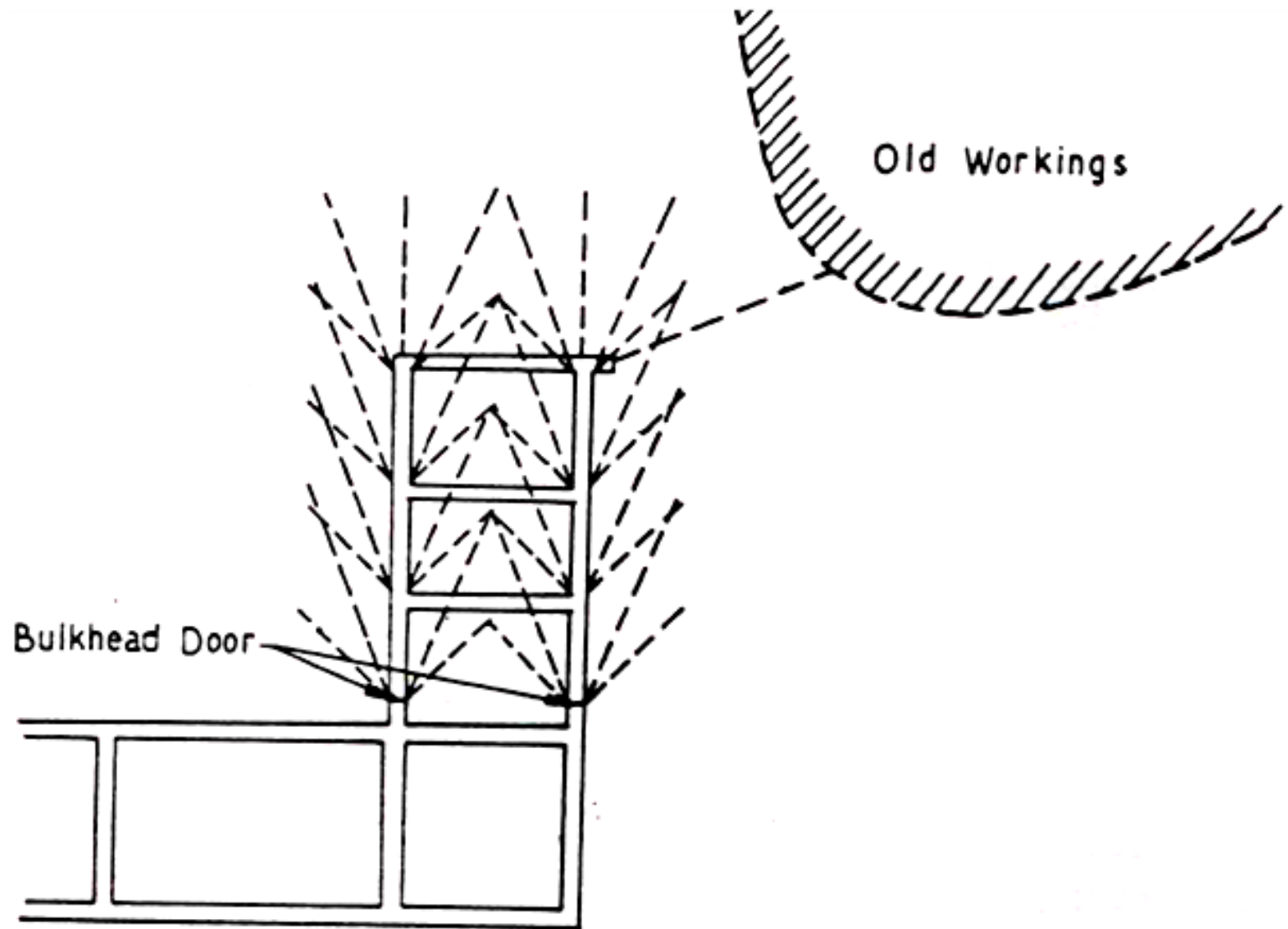
Fig. Dewatering water-logged old workings by means of narrow mine workings and advance boreholes

- This method is feasible only when
    - When the water pressure is less.
    - It is possible to approach a water-logged area sufficiently near to it

- The safe distance up to which the workings may be driven depends on
    - The water pressure and
    - The nature of ground.

- It can be determined by using the formula: $s = pb/4\tau$

Where

s = shortest distance between approaching mine working and water-logged area

p = water pressure

b = length of the longest side of the roadway section (m)

τ = shear strength of the ground

- Drivage of dewatering workings must take place with simultaneous boring to avoid being too near to the water.

- Holes must be drilled in all directions in which water accumulation is expected, with at least one hole (better 2 holes) bored straight ahead of face.

- Minimum length of boreholes is calculated from the relation

$$\mathbf{L_{min} = s + l}$$

Where

s = shortest safe distance between the approaching working and water-logged area as calculated

l = expected length of pool

- Drivage of the workings must be stopped at the first appearance of

    – water coming out of the borehole, fine cracks and cleavage planes becoming moist and
    – sweating of the place.

- The pillar between the working faces and water-logged area will then be bored with a single borehole for tapping water.

c. Dewatering by means of long boreholes

- This method is adopted when the water pressure is very high.

- Exact knowledge of location of water logged area is necessary for success of this method.

- Tapping is done from great distance by using special boring apparatus.

- Narrow roadway(s) to be driven in order to have a suitable location with respect to the water pool.

Disadvantages of this method:

- Long advanced boreholes may completely miss narrow old workings containing an accumulation of water.

- An advanced borehole through highly stressed ground may completely close due to strata pressure thus giving wrong impression that the old mine workings are free of water.

Safety boring machines

- Rotary core boring machines equipped with a special safety boring outfit is used -

  a. For tapping old water-logged workings by means of long boreholes or

  b. For putting advance boreholes when driving exploratory headings.

- Well-known boring equipments are:
  1. Craelius
  2. Longyear
  3. Burnside boring machines

- Holes can be bored at any desired angle safely and easily.

Special features:

- Boring takes place through a pipe which can be rapidly secured in hole by means of iron wedge.
- Flow of water can be controlled at any stage of the boring.
- Water can be safely drained out from the holes.
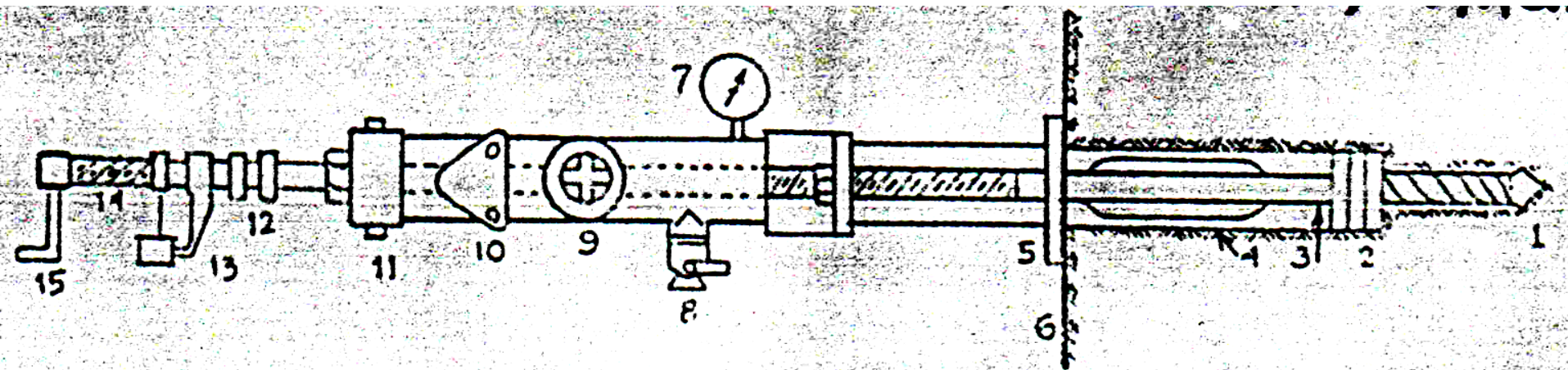
Safety Boring Apparatus

(1) Bit, (2) Flange and washers, (3) Bore rod, (4) Boring Tube, (5) Outer flange. (6) Coal face, (7) Pressure gauge. (8) Debris Cock, (9) Hand wheel (10) Main valve, (11) Stuffing box, (12) Coupling, (13) Eccentric operated reciprocating pump, (14) Worm screw, (15) Handle.

ELEVATION

DEBRIS COCK

BORING ROD — STUFFING BOX AND GLAND — FULLWAY CONTROL COCK — FIXED CROSSHEAD — LOOSE CROSSHEAD — LOOSE M.S. SLEEVE TUBE — BORING TUBE — LOOSE RINGS — SCREWED END RING

CROSS PIECE WITH RUBBER CLAMPS — SCREWED FLANGE — RUBBER SEAL EXPANSION BOLTS — SLEEVE RUBBERS — BORING BIT

SECTIONAL PLAN

PLAN
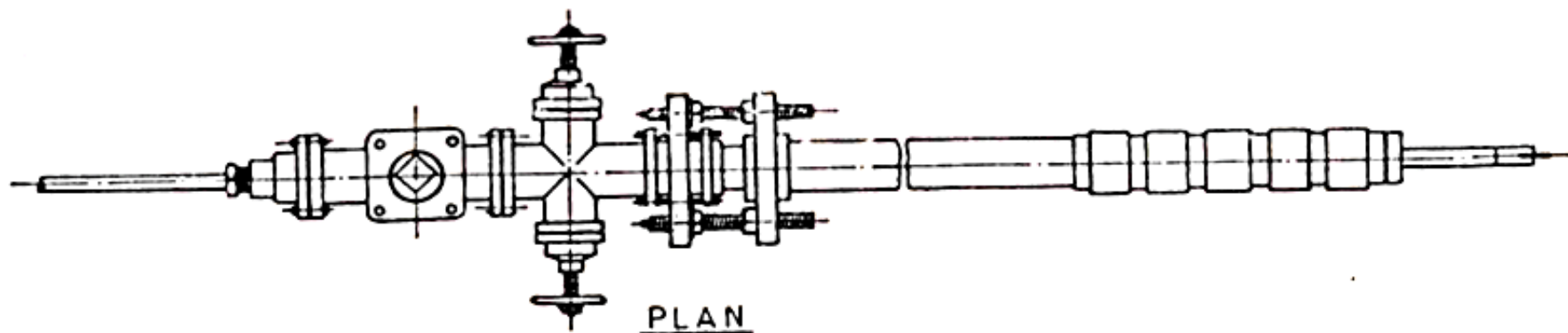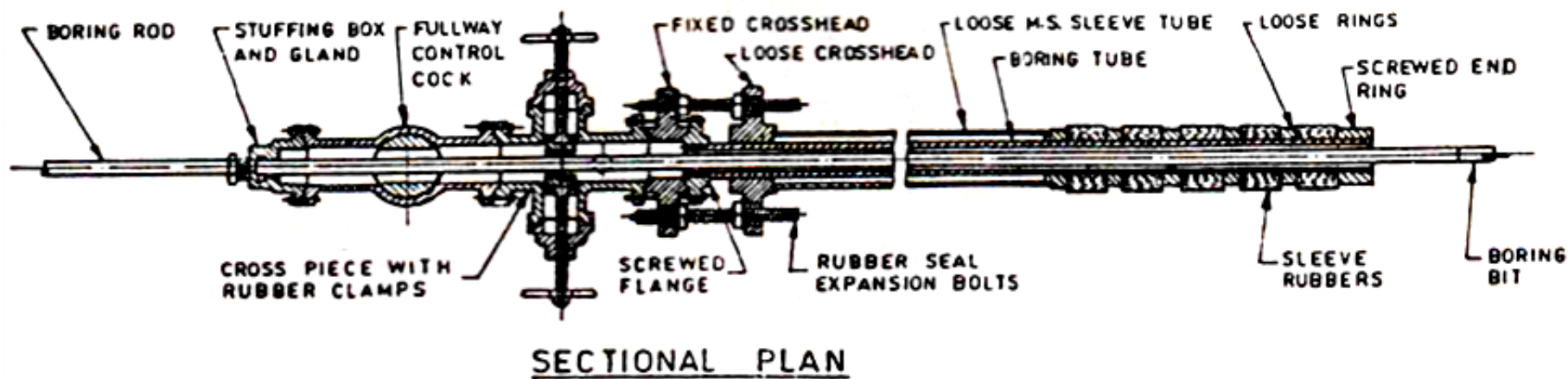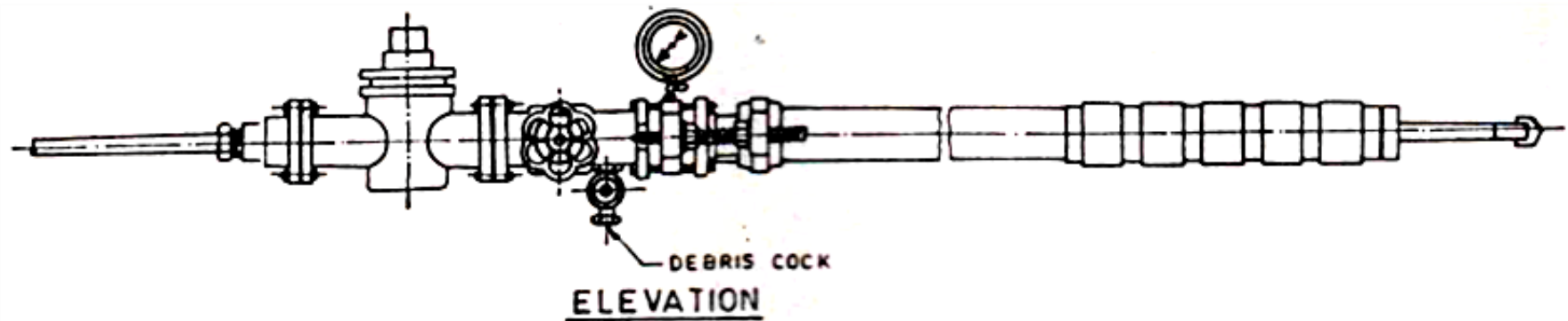
Fig. Burnside Safety Boring Apparatus

Constructional features

- **Boring tube**

- **A mild steel sleeve tube:** contains sleeve rubbers

- **Boring rods:** have diameters of 38 mm (heavy type) and 33.3 mm (light type) and lengths 1.52 m (5 ft) and 3 m (10 ft).

- **Boring bit:** made of tungsten-tipped wet drilling bits of 56, 73 and 95 mm dia.

- **Tungsten carbide-tipped reamers:** have diameters of 111, 121,146 and 222 mm.

- **Debris cock:** Removes the debris.

- **Pressure gauge:** To record the water pressure when it is tapped.

- **Hand wheel:** To prevent damage of stuffing box due to water pressure when it is tapped. Hand wheel valve comes in action when water is tapped in the machine.

- **Stuffing box:** It is an assembly which is used to house a gland seal. It is used to prevent leakage of fluid, such as water or steam, between sliding or turning parts of a machine part. Prevents any leakage when drill rod rotates and is in action.

- **Coupling box:** The rod attachment/detachment is done through this.

- **HP Pump:** Reciprocating pump is used to flush the water into borehole to clean the chippings.

- **Main valve:** Comes in action when the rod is being removed.

Precautions when approaching water-logged workings

- An escape way (preferably a level one) must be provided for safety of men engaged in dewatering operation.

- The escape way must be properly supported, free from obstructions, and be electrically lighted.

- If an escape way is steeper than 3º, it must be provided with a water drain, a raised traveling way and a rope railing.

- Dewatering mine workings must be well ventilated to remove any noxious gases, viz. CO_2 and H_2S that may occur. If thorough ventilation is not possible, provision for auxiliary ventilation (preferably forcing system) should be made.

- Open lights should not be used. Only electric safety lamps should be used.

- Only experienced miners equipped with self-rescuers would be employed in dewatering operation.

- For rescue of men overcome with gases, a rescue team equipped with respiratory protective apparatus should be stationed near the place of work.

- The final boring and tapping of water should be done by the rescue men only.

- During tapping, workers from adjacent mine workings should be withdrawn.

- Necessary materials for erection of a dam should be stored at a suitable place and the dam site prepared.

- A bulk head door must be built if high water pressure is expected.

- All dewatering operations must be done according to a definite plan prepared by the mine management.

- All operations must be done under the supervision of an experienced supervisory official.

- The actual tapping operation must take place in the immediate presence of the official. In difficult cases, the presence of the mine manager is recommended.

Pattern – I	Pattern – II
- - Each central boreholes (0,0) well in advance - Drive bore holes 1 and 2 at 45º and 22 to the left flank, drive boreholes 3 and 4 at 22 and 45º to the right flank, length of borehole < 5m - Advance exploratory heading to B by 5m	- Assume exploratory heading at A - Keep the central hole, well in advance (0,0) (each 2' from the side) - Drive bore holes at 1,2,3 at 12 , 23, 45º to the right flank and 4,5,6 to 12 ,23, 45º on the left flank - Extend the exploratory heading to B by 3m repeat as above

$\frac{1}{2}^{o}$

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- for concrete   n – damg completn. And giving water press

- (N/m²) $\sigma_s = \dfrac{\sigma_{28} Log n}{r \log 28}$ σ_{28} – 28 day compress stress

- for bricks   r – factor of safety

- σ_{ult} – ultimate compressive stress of brick

- 1.5 to 2 for bricks

- 2 to 3 for concrete

$$\sigma_s = \frac{\sigma_{ult}}{r}$$

- Hudspeth method
- Complicated and costly to carryout
- A, B, C headings 8ft in advance and 20m apart
- Prior to beginning of heading 'B' is 5m in advance than A and C. The work then proceeds as follows:
- Inner flank holes (1) are bore from A and C at angles of 37° to intersect approximately 20m from B
- Heading B is advanced by 10m as shown above to (2)
- Two holes (3) are bored at right angles from heading B extending across the front of A and C. Also two flank holes (3) are bored at 45° m outside flank of A and C intersecting other two holes marked (3)
- Headings A and C are advanced 10m as shown at (4)
- Inner flank holes (5) are driven from A and C at an angle of 37° and total procedure is repeated as above.

- **Fixing of the m/c**
- Hole of 45, 57, 75 or 100mm is bored for 1 to 2m, then first 1m of the hole is enlarged or rimed out to 4 ins. Dia (100mm)

Boring against water needs for:

- close control of direction and elevation
- Ability to control or cut off the flow of water if and when encountered by the boring so that it may be drawn off at will
- Ability to withdraw the boring rod whilst the bore hole is under pressure
- Sealing to prevent by passing of the control valve by the water running through the strata

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┌─────────────────┐     ┌─────────────────┐     ┌─────────────────────┐
│ Inner rod is    │     │ Inner rod is    │     │ Rubber rings and    │
│ boring rod with │ ──▶ │ surrounded by   │ ──▶ │ brass rings are     │ ──▶
│ bit             │     │ boring tube     │     │ placed on the outer │
│                 │     │                 │     │ side of the boring  │
│                 │     │                 │     │ tube                │
└─────────────────┘     └─────────────────┘     └─────────────────────┘
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┌─────────────────────┐     ┌─────────────────────┐     ┌─────────────────┐
│ Boring rods may be  │     │ Wet boring is       │     │ Debris cock to  │
│ solid or hollow – if│     │ preferred, because  │     │ discharge the   │
│ it is hollow – a    │ ──▶ │ when the hole is    │ ──▶ │ debris.         │
│ small pump is being │     │ going to sweat, the │     │                 │
│ put for supplying   │     │ borer may not know  │     │                 │
│ water for wet boring│     │ it.                 │     │                 │
└─────────────────────┘     └─────────────────────┘     └─────────────────┘
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┌─────────────────────────────┐     ┌─────────────────────────────┐
│ Two hand wheels one at each │     │ Full way control cock shuts │
│ side on being screwed up,   │     │ off the water when bore     │
│ force packing material      │ ──▶ │ rods have been with drawn.  │
│ against the bore rods and   │     │                             │
│ stop the flow of water if it│     └─────────────┬───────────────┘
│ should happen to break away │                   │
│ – when the stuffing box is  │                   ▼
│ off and the bore rods are   │     ┌─────────────────────────────┐
│ still in position           │     │ Pressure gauge is also      │
└─────────────────────────────┘     │ fitted to record the        │
                                     │ pressure                    │
                                     └─────────────┬───────────────┘
                                                   │
                                                   ▼
                                     ┌─────────────────────────────┐
                                     │ If wet boring is practised, │
                                     │ then sludge travels between │
                                     │ boring rod and boring tube  │
                                     └─────────────┬───────────────┘
                                                   │
                                                   ▼
                          ┌────────────────────────────────────────┐
                          │ Advance – 16m/shift manual             │
                          │          10 – 12m/hr with power        │
                          │          driven.                       │
                          │ Boring rods with diameter – 38mm       │
                          │ (heavy type)                           │
                          │                    - 33 mm (light type)│
                          └────────────────────────────────────────┘
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