## 5.3 Grouting:

Appropriate type of grouting (cement/ chemical/resin based) besides reducing the permeability of strata also increases the stability of the ground.

A grouted body in form of close ring is created ahead of tunnel advance (Fig. 13.01). This ring helps in resisting hydrostatic pressure also.

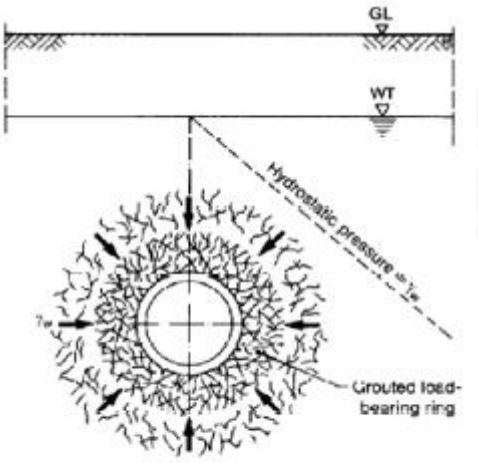



**Fig. 13.01: Grouting**

## Ground Freezing:

In this method, the pore water is converted to ice by circulation of a chilled liquid via a system of small diameter pipes placed in drilled holes.

Ice creates a frozen mass of soil and/or rock particles, with improved compressive strength and impermeability.

Brine is typical cooling agent, although fast acting liquid nitrogen can be used for projects where the freeze only needs to be quickly established and maintained for a short period of time.

Ground freezing can temporarily seal and consolidate the ground under conditions that are water-bearing but not suitable for grouting. The availability of technology and experience for ground freezing is rather limited in India.

## GROUTING:

Several types of grouting are used to modify and/or stabilize soils in-situ. Recent improvements in grouting have made it a valuable tool in both groundwater control and soil stabilization for tunneling projects.

**It can be very effective in following situations:**

To strengthen loose or weak soil and prevent cave-ins due to disturbance of loose, sensitive or weak soils by the tunneling operations.

To decrease permeability and in-turn groundwater flow.

To reduce the subsidence effects of dewatering or to prevent the loss of cines from the soil.

To stabilize sandy soils those have a tendency to run in a dry state or to flow when below the water table.

## Location for Grouting:

Grouting can be carried out in the tunnel excavation as face grouting or as radial grouting from the excavated tunnel or from a pilot tunnel (Fig. 14.05).

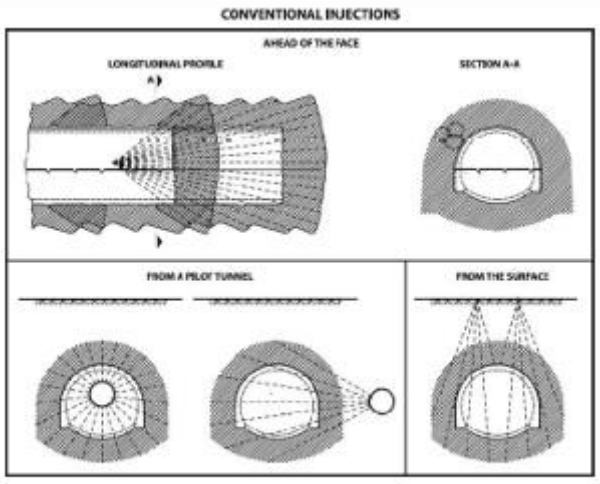
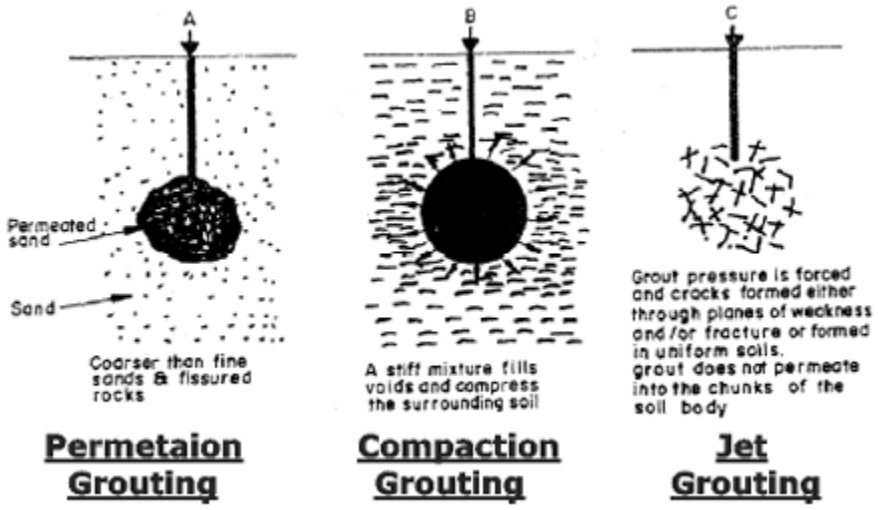



**Fig. 14.05: Grouting Locations**

Groutability of Ground is primarily determined by the permeability of the ground or the percentage fines (passing 75 micron sieve).

The thumb rule is that soil having less than 10% fines could be successfully grouted and those with more than 20% fines could not.

However, advancements in grouting technology have raised this limit approximately by 5%. Groutability is also assessed by using Groutability Ratio (N), as given in Table 14.01




## TYPES OF GROUTING:

Three ways of introducing grout material into the soil are possible (Fig. 14.06):

### (A) Permeation Grouting:

In this method, the grout fills the voids in the soil and there is no change in volume or structure of the original ground.

Permeation grouting may be done with either cement based or chemical based grout, with latter being necessary for satisfactory penetration of fine soils.

This type of grouting can be used for creation of a support ring around the tunnel excavation boundary or to create support for foundation of any structure in the vicinity of tunnel.

**(B) Compaction or Displacement Grouting**:

In this method, soil is densified during tunneling by injection of a stiff grout. The thick mortar mix acts as a radial hydraulic jack, creating bulbs or lenses and thus displacing and compressing the surrounding soil.

This type of grouting is useful in controlling settlement of foundation of structures located above the tunnel or underpinning of foundations of structures located in vicinity of the tunnel.

(A) **Jet Grouting** :

In this method, the ground is fragmented by deliberate hydro fracturing, in order to increase total stresses by wedging action of successive thin grout lenses, to fill unconnected voids and possibly consolidate the soil under injection pressure.

- Jet grouting can be used for:
- Forming an umbrella (canopy) ahead of the face.
- Reinforcing and stabilizing the tunnel face.
- Reinforcing the walls of tunnel.
- Underpinning the steel ribs.
- Creating impermeable diaphragms (e.g. before starting the excavation with TBM).

Jet grouting is applied mainly horizontally or at a slightly upward or downward angle from within the face of the tunnel.

An improvement of the roof arching behaviour is achieved by applying one or more layers of jet grouting columns in stages corresponding to the excavation operations.

An improvement of the stability of the face is achieved by placing individual jet columns parallel to the direction of advance in the working face.

Less common in tunneling is vertical or steeply inclined jet grouting, except in shallow tunnels where it is applied from the surface.

From within the tunnel vertical or steeply inclined jet grouting is mainly applied to underpin the bottom of the roof arch.

**Grouting Material**:

The most commonly used grout material is cement. In special cases chemical products such as resins or foams are also applied. In these cases, the environmental and safety restrictions have to be considered specially. Fig. 14.07 may be referred as a rough guide for assessing material of the grout to be used.

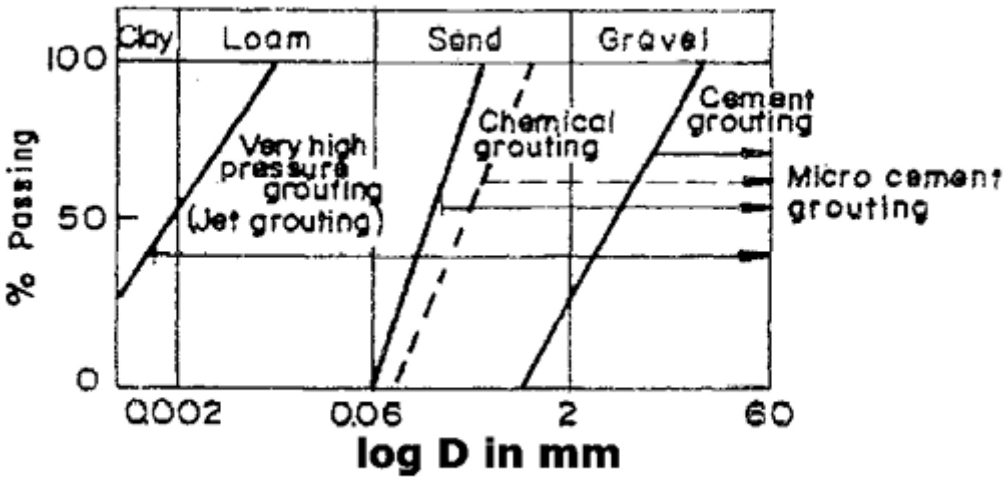



**Fig. 14.07: Grout Material Suitability**

**Ground Freezing**:

In this method, pore water present in the soil is converted into ice by extraction of the latent heat.

The ice then acts like a cement to bind the soils grains together, thereby raising the strength and lowering the permeability of soil mass.

This method is successful only when sufficient water pore water is present in the ground. It may be noted that presence of organic material or salt water will result in greater difficulty in freezing.

Another major deterrent is moving ground water, which makes the freezing difficult.

**Following advantages can be derived by the freezing**:

- Makes water-bearing strata temporarily impermeable.
- Increases compressive and shear strength of ground.
- Provides structural underpinning (temporary supports).

**Refrigeration Process**:

The typical freezing installation consists of a refrigeration plant that cools a brine solution, which is then pumped down the center of an annular freeze pipe to the bottom of the hole, returning via the outer annulus in contact with the soil.

The warmed brine is returned to the refrigeration plant and the cycle continues. In practice, a number of freeze pipes are connected to a pair of headers for the flow and return lines.

For tunnel construction, it is not necessary to maintain continuous freezing and keep on lowering the temperature of the soil, the only requirement is that pore water should be kept at a temperature below the freezing point.

For special purposes, especially for projects of limited extent and duration, boiling of liquid nitrogen in the freezing elements may be appropriate.

**Ground Freezing Techniques**:

Following ground freezing techniques are known:

(A) Continuous frozen bodies which provide long term load-bearing. The freezing is achieved by a drilled tube system, through which coolant is pumped.

(B) Short-term local freezing of damp zones close to the face or in the immediate vicinity outside the excavated cross section.