Underground Mining of Metalliferous Deposits
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Lecture 46
Rock Bolting-I

ROCK BOLTING

The history of rock bolting dates from the end of the 19th century. However, rock bolting were not used extensively until forty or fifty years late. The earliest reports of anchoring bars into rock to secure a roof dated from 1918. The first attempt to use anchorage in mines was made as early as 1926. Nowadays, the range of applications for rock bolts has widened due to advances in rock mechanics and the increasing use of rock reinforcement in underground excavations, as an alternative to more traditional forms of supports. Also, the development of new rock bolt concepts has lead to use of rock bolts in non-traditional applications. Design of rock reinforcement systems today is faced with optimization with respect to both safety and economic considerations.

- The principal objective in the design of a support system is to help the rock mass to support itself.
- This applies to rock reinforcement systems, e.g., where the rock bolts actually form part of the rock mass, as well as to rock support systems e.g. steel sets which do not form part of the rock mass but support it externally.
- The rock bolt reinforces and mobilizes the inherent strength of the rock mass. Steel set or shotcrete support systems, however, restrict movements of the rock mass externally.
- There are a number of reasons for the widespread use of rock bolt reinforcement systems. For example;

  Versatile, can be used in any excavation geometry

  Usually simple to apply

  Relatively inexpensive

  Installation can be fully mechanized.

  improved ventilation (because of less air resistance)

TYPICAL ROCKBOLTING SYSTEMS

The different types of rock bolts can be divided into three classes;

Mechanically anchored rock bolts

Resin or Cement bonded rock bolts and

Friction anchored rock bolts.

- The most commonly used rock reinforcement is either tensioned (active) or un-tensioned (passive).
- The materials used for rock bolt vary widely: timber, bamboo, steel, fibre-glass and polyester resins.

MECHANICALLY ANCHORED ROCKBOLTS

- The expansion shell anchored rock bolt, of standard or bail type, is the most common form of mechanically anchored rock bolt.
- A wedge attached to the bolt shank is pilled into a conical expansion shell as the bolt is rotated. This forces the shell to expand against and into wall of the borehole.
- For application in permanent reinforcement systems, the void between the bolt and the borehole can be post grouted.
- They are designed for use in moderately hard to hard rock conditions and not recommended for use in very hard rock, since a very hard rock will prevent the expansion shell from “gripping” the rock, and the anchor will slip under load.

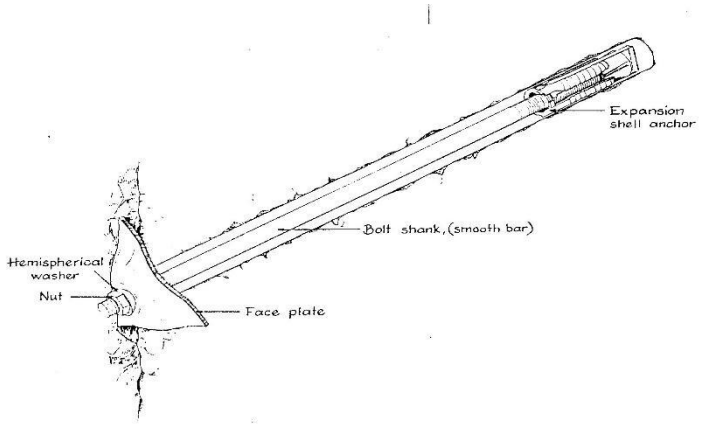

Figure 1. Slot and wedge bolt

GROUTED ROCKBOLTS

- Grouted rock bolts have been commonly used worldwide for the past fifty years both in mining and civil engineering applications.
- The most commonly used grouted rock bolt is the fully grouted rebar or threaded bar made of steel.
- Cement or resin are used as grouting agents.
- The rebar used with resin creates a system commonly used for tensioned rock bolts but the rebar or the threaded bar with cement grout can also be used for un-tensioned bolts.

- Both systems are used for temporary as well as permanent support under various rock conditions.
- Resin grouted bolts provides high load-bearing capacity then the Cement grouted bolts and are suitable for the majority of ground conditions.

FRICTION ACHORED ROCKBOLTS

- Friction anchored rock bolts represent the most recent development in rock reinforcement techniques.
- Two friction anchored rockbolt types are available, the Split Set and Swellex.
- For both types of rock bolt system, the frictional resistance to sliding of the rock on the steel (for the Swellex combined with mechanical interlock) is generated by a redial force against the borehole wall over the length of the bolt.
- The anchoring mechanism of the Split Set rock bolt arises from frictional forces to load which approaches the ultimate load bearing capacity of the bolt, when the bolt will slide. The bolt can then accommodate large displacements without failing.

- The anchoring mechanism of the Swellex rock bolt depends on frictional force combined with mechanical interlocking.
- The anchoring of the Swellex is provided by frictional forces to a load which approaches the ultimate load bearing capacity of the bolt.
- Mechanical interlock between the bolt and the rock then prevents the bolt from sliding.
- The property of the Swellex rock bolt implies that the full strength of the bolt is utilized.
- A higher pull-out resistance is then obtained.

ROCK BOLTING MECHANICS

- The main function of rock bolting is to bind stratified or broken rock layers together and prevent falls.

- There are four concepts based on which rock bolt reinforcement of surrounding mine openings is carried out.
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ARCHING OF ROOF ROCK

Arching is the oldest concept of stress redistribution around excavation which results in the formation of parabolic self-bearing arches. The rock above the arch is stable, whereas below the arch it is unstable and has a tendency to fall. To prevent ground falls, the unstable rock could be suspended from the arch by means of rock bolts.

SUSPENSION OF WEAKER STRATA

When an underground opening is made, a stratified immediate roof tends to sag and separate from main roof. The sags and separations of the immediate roof are reduced or eliminated when roof bolts are tightened and hung from the self supporting main roof

BEAM BUILDING OF WEAKER STRATA

When the immediate strata surrounding the opening is consists of thin layers, the layers tends to sag and separate along the bedding planes. Clamping a number of thin layers of the immediate strata into thicker one using rock bolts reduces sagging and eliminates separation between the bedding planes. The installed bolts induce frictional force along the bedding plane and stabilize the immediate strata. The magnitude of the frictional force is proportional to the tension applied on bolts.

KEYING OF LOOSE SINGLE BLOCK

In underground coal mines, the stratified immediate roof is very often intersected by planes of weakness, with either one or several sets oriented in different directions with respect to the roof line. Besides joint plane in rock mass without any particular pattern delineates wedge or loose rock cause instability. Rock bolting across these planes of weakness will prevent or reduce movement along the planes of weakness. This is commonly known as keying.

BOLTING PRACTICES IN INDIAN MINES

- Recent amendments in CMR 1957 recommended methodology for design of roof bolt system in Indian coalmines based on RMR using CMRI-ISM Rock mass classification. Based on RMR, bolting systems in different geo-mining situations are recommended.
- The bolting density for the three types of roof, where bolting has been recommended as given below:

  Poor (RMR value 20-40): 1.2 to 1.5 bolts/sq.m.
  Fair(RMR value 40-60): 1 bolts/sq.m
  Good(RMR value 60-80): 0.7 bolt/sq.m.

- At junctions, the density should be increased by 25%.
- The bearing plates should be not less than 5 cm.sq. or equivalent area.
- The bolt angle should generally be normal to the bedding plane in rectangular roadways. The rib side bolts may in certain cases, be inclined outwards.

Drilling of holes

The hole diameter for bolting, should not be more than 8mm to 12mm larger than the bolt diameter, for full column cement grouted bolts.

Rock bolting material

The following materials should only be used:

i) Roof Bolts:
Materials: Tor-steel/M.S. (IS: 1786-1985/IS: 226-1975/IS: 15790)
Rod length: 1.5m
Rod diameter: 20-22mm (ribbed bar)
Length of the thread: 125-150 mm
ii)Rock Bolt Bearing plate (IS:226-1975):
Material: MS
Size: 150 mm sq. or equivalent, Thickness: 6mm
iii) Nut for Rock Bolt (IS:1363, Part-3, 1984):
Shape Rock Bolt: Hexagonal,
Height: 20 mm
iv)Threads – on bolt & nut:
It should confirm to tolerance class of 8g and 7H respectively (IS:4218-1967)

v) Cement capsules for grouting Rock Bolt:
Length: Not exceeding 400 mm
Diameter : 30-32mm
Type: Quick setting (the grout should provide a minimum anchorage of 3T after 30 minutes, 5T after two hours,10 T after 24 hours and 12 T after 28 days of setting.)*
* As per DGMS/Tech Circular (Approval) N0.05, Dated27.12.2010

SELECTION OF ROCK BOLT

Types of bolt	Types of anchor	Suitable strata type	Comments
Pointed anchor bolt (tensioned)	Slot & wedge	Hard rock	Simple and cheaper
	Expansion shell	Medium hard rock	Reusable bolt and expensive
	Resin grout	All strata especially for weak rock	Good anchorage and expensive
	Quick setting cement cartridge	All strata	Immediate support
Full-length-grouted bolt (non-tension)	Cement injection	Most strata	Simple and inexpensive
	Perfo	Most strata	Simple and effective Relatively expensive
	Quick setting cement cartridge	Most strata	Immediate support
	Resin grout	All strata especially for weak rock	Good anchorage and expensive
Split set	Full column friction	Most strata	Yieldable support Immediate support
Swellex	Full column friction	Weak rock	Immediate support in poor rock condition
Cable bolt	Cement injection	Weak rock	Mining thick coal seam and wide orebody
Wooden dowel	Resin grout	Medium hard rock	Simple and cuttable
Bamboo dowel	Slot & wedge	Medium hard rock	Simple and cuttable

Figure 2. Selection of Rock bolt

CAUSES OF ROCK BOLT FAILURE

Bolt failure depends on the following parameters:

1. Improper hole size
2. Weak rock at the anchor point
3. Creep effect
4. Wear and damage of hardware components

5. Blast vibration/seismic effect
6. Delay in installation
7. Poor installation
8. Application tension on bolt beyond bolt capacity
9. Improper selection of bolt
10. Improper design