Recent Trends on Rock Bolting in Tunnel Construction

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Abstract— In this study regarding rock bolt in tunnel construction, the effect of rock bolts and shotcrete method on the stability of a tunnel below the ground as well as with in the mountains are studied. Rock bolts installed at the tunnel crown played a more important role in ensuring the stability of the tunnel roof than those installed at the tunnel sidewalls if the length and spacing were appropriate. Rock bolts installed with a certain inclination to the horizontal in the longitudinal section had the same effect as the rock bolts installed in the direction normal to the tunnel wall if the rock bolts of a certain length were installed with fairly dense spacing. This study review contains basic role of rock bolt techniques in tunnel construction. Also contains initial or construction cost at starting stage and maintenance cost, what kind of material, manpower and machinery required for construction of tunnel with this technique .for the different place which technique is better for saving time and cost of construction.

Key words: Rock bolts, tunnel construction, shotcrete

I. INTRODUCTION

Tunnel is an underground passage through a mountain, beneath a city or under a waterway or Tunnels are enclosed roadways, railways, waterways, etc. With vehicle, trains, ships, etc. access that is restricted to portals regardless of type of structure or method of construction.

Tunneling can be defined as the continuous excavation of a hole through the earth's crust. The portion where the work is carried out while its construction is called the face (heading) and all efforts are made in advancing this face as fast as possible till the end of tunnel is reached.

Rock bolts are the first line of defense protecting mineworkers from the hazards of ground falls. Because rock bolts utilize the inherent strength of the rock mass, they have many advantages when compared with earlier standing support systems. Due to of their central importance, roof bolts have received more research attention than any other ground control topic, with the possible exception of coal pillars.

Roof bolt design consists in specifying the proper bolt type, capacity, length, and pattern for a particular roof rock, stress level, and application. The interactions between these variables are very complex, and our understanding of their mechanics remains imperfect. Numerous roof bolt design methods have been proposed over the years, but none has gained widespread acceptance by the coal mining industry.

Analysis of the entire data set led to some preliminary roof bolt design guidelines. This paper will focus on the subset of more difficult conditions, those with weaker roof and higher stress. The first step is to define those difficult conditions, based on the mechanism of roof bolt support.

In conservation of historic masonries, grouting is one of the most commonly applied techniques. However, the design of adequate grout mixes, as well as the prediction of the mechanical properties of a grouted masonry is not based on quantified data regarding the bond properties of interfaces. Two types of tripartite (lime-pozzolan-cement) grouts are examined (G2 (cement 30%-lime 35%-metakaolin 35%) and G4 (cement 30%-lime 23%-milos earth 47%)), combined with three substrates (two types of limestone with different porosity (Dionysos marble and travertine and solid bricks). A cement-based grout, Gl (cement 80%-lime 20%), is used as a reference.

II. SCENARIO

Nowadays, the application of rock bolts for ground reinforcement and stabilization is of worldwide scale, and the level of bolt usage has contributed to increased variations in design and purpose. In the US coal mines, every year around 15000 km entries are excavated and about 100 million roof bolts are installed in these entries. Similarly the application of Hundreds of millions of units is installed each year in Australia, and a recent survey revealed that the worldwide usage of rock bolts was in excess of 500,000,000 annually. Below figure displays the usage of rock bolts in the past decades in the coal mining industry. Rock bolts are installed as an active support system, as they are loaded from the time of installation. This is achieved by the pre tensioning process. Bolt pre tensioning can clamp individual bedding planes together and closes the small gaps that might have occurred due to sagging after excavation. Pre tensioning of the fully grouted bolt can create much higher level of active support than the point anchored bolts such as the mechanically anchored bolts.

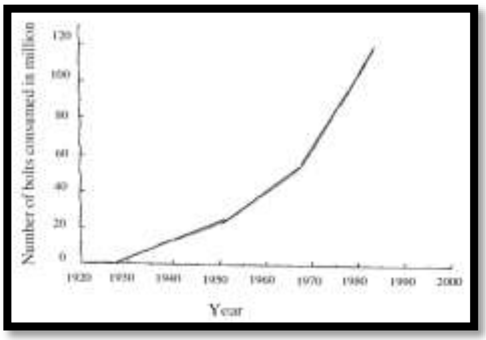

Fig. 1: Usage of rock bolts in the world

III. TYPES OF ROCK BOLT

A rock bolt is a short, low capacity reinforcement comprising a bar (or tube) fixed into rock and tensioned to a predetermined load. Some of the components of a rock bolt are defined in Figure 3.3. Rock bolts are usually less than 6m long and rarely longer than 10m.

Their working load is typically between 150 and 200kN and they would normally be formed from high yield steel bars with diameters up to 32mm. However, but unusually, working loads of up to 300kN may be specified; typically these would be formed from high yield steel bars having diameters up to 40mm. The types of rock bolt commonly used for civil engineering works include:

A. *Mechanical bolts*

Typically these have a wedge shaped shell assembly which, when expanded anchors them into the drill hole.

B. *Cement grouted bolts*

Typically these are formed by inserting the bar into a drill hole filled with grout.

C. *Two-speed resin bonded bolts*

With these the bar is fixed (and then stressed) within a fast setting resin at the distal end and subsequently bonded along the remainder of its length by a slower setting resin. Typical arrangements of these types are shown in Figures.

Rock bolts are used widely to improve the stability and load bearing characteristics of a rock mass. Often they are used to stabilize relatively small blocks of rocks in cuttings, slopes and underground excavations such as tunnels, caverns and mines. They can be used on their own or in conjunction with other support systems such as ground anchorages.

The proximal end of the bar may be threaded so that a nut and faceplate can be attached; the plate may provide local support to the rock surface and allow the attachment of mesh reinforcement which may be required for a shotcrete finish.

D. *Rock dowels*

A rock dowel comprises a bar which is inserted in a drill hole and fixed along its entire length. Movement of the rock surrounding the drill hole is relied upon to induce tension in the dowel and thereby strengthen the mass as a whole.

E. *Cable bolts*

Cable bolts utilize bundles of steel wires or fiber glass rods to form a fixed anchorage at depth. The inherent flexibility of cable bolts allows long unjointed bolts to be installed where there are cramped working conditions or where access is difficult.

F. *Self-drilling bolts*

The principal objective in the design of a roof support system is to help the rock mass create a self-supporting structure. The usage of rock bolts can be combined with wire mesh, shotcrete and concrete lining to cope with different situations encountered during mining or tunneling.

1) The objective – To develop a Self Drilling Bolt for Soft Rock applications.
2) Use hollow bar to allow flushing during drilling.
3) Mechanical anchoring and post grouting (if needed).
4) Drill, Tension and Grout.
5) Technical advantages: self-drilling, strength & Pre tension

IV. TYPES OF METHODOLOGY

Components and Sequence of Execution:

1) Fixing of Lattice Girder – lattice girder is 3 Bars of steel reinforcement placed at three corners of triangle with 8mm steel bar for connection. Easy to handle comparison of steel ribs.
2) Fixing of wire mash – generally used 6mm thick wires.
3) Sealing Shotcrete – Shotcrete 25-50mm generally.
4) Primary Lining with Shotcrete – In layers each not thicker than 150mm
5) Rock Bolting – discussed separately
6) Pipe Fore poling – Used for crown support for next Excavation cycle (for Rock Class after III only)

V. ADVANTAGES & DISADVANTAGES

ADVANTAGES

1) Simple handling and optimized installation time
2) Immediate loading-bearing capacity
3) Field-proven and reliable anchors
4) Unproblematic installation in aquiferous boreholes
5) Optimized ratio of anchor force vs. borehole diameter
6) Anchor bars allow flexible length adjustments and posterior extension on site
7) Expansion sleeves are available for different borehole diameters
8) Anchor is approved for underground application by the Regional Government Arnsberg,
9) All-purpose rock bolt system installation in jointed or soft rock
10) Standardized and field-proven rock bolts
11) Resistant against blasting vibrations
12) High bolting forces at short bond lengths

DISADVANTAGES

1) Heavy equipment used
2) High initial cost
3) Technical person required

VI. CASE STUDY

A. *M5 EAST TUNNELS*

The M5 East will be a four-lane divided carriageway connecting to the existing M5 motorway in Sydney's southwest to General Holmes Drive adjacent to Sydney International Airport in the East. In August of 1998, the Roads and Traffic Authority of New South Wales (RTA) awarded the design, construction, and 10 year operation and maintenance contract to the joint venture of Bauderstone Hornibrook Bilfinger + Berger (BHBB JV). BHBB JV subsequently awarded a subcontract to provide design of the project to Hyder Consulting (Hyder). Hyder retained Jacobs Associates as sub consultants to provide tunnel excavation and support design. Principal elements of the project include 4 km of open dual lane carriageway, 3.8 km twin dual lane tunnels; a 700 m long cut and cover river crossing and two viaduct structures. The focus of this paper is the design and construction of the twin rock tunnels. The Main tunnel consists of twin drives of between 49 m and 56 m area.

Geotechnical Considerations: The geology underlying the proposal belongs to the Hawkesbury Sandstone Group. The soils generally have a shallow to moderately deep upper horizon of earthy sands and yellow sands, followed by a thin horizon of siliceous sands with localized occurrences of greyed podzolic and yellow podzolic soils which are associated with shale, with moderately deep (<100cm) siliceous sands and leached sands along drainage lines. The level of erosion hazard of these soils for non-concentrated flows is high to very high. The level of erosion hazard of these soils for concentrated flows is high to extreme. The project passes primarily through the Gymea soil landscape. Small sections of the project may also intersect with the Hawkesbury soil landscape.

Pedestrian cross passages were required at 120 m intervals, and one vehicular cross passage located at near mid-point of the tunnels is also required. There are three entry/exit ramps running parallel and connecting with the tunnels at the eastern end.

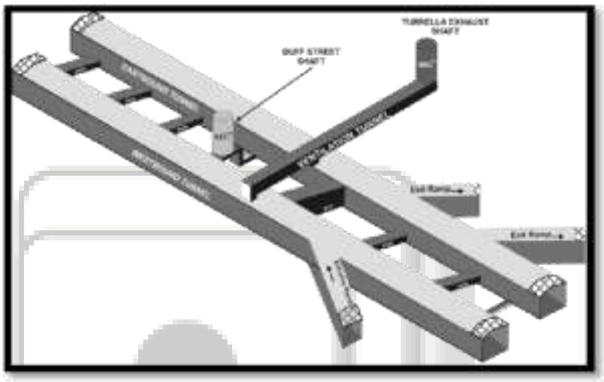

Fig. 2: M5 tunnel layout

One 400 m long exit ramp connects at the Princes Highway, and 100 and 200 m long entry and exit ramps, respectively, at Marsh Street. At these ramps, the tunnel cross section increases to 80 m2. In addition to the tunnels associated with autos, the ventilation system required that fresh air be supplied, and exhaust removed via an intake/exhaust tunnel and shafts. The intake shaft is 66 m deep, and the exhaust shaft, located at the other end of a 700 m long exhaust tunnel is 43 m deep. A simplified view of the tunnel and its ancillary structures is shown on Figure.

B. Permanent Lining of Rock bolts

Combining geotechnical assessment with practicality of tunnel construction, the team determined that three different ground classifications would best suit both inputs. Put simply, Type 1 consist of massive Sandstone with Siltstone laminations less than 5 mm thick, Type 2 consists of Inter bedded Siltstone and Sandstone or Siltstone, and Type 3 consists of Dyke, Fault, or Crushed rock zones. The rock support for both Type 1 and Type 2 conditions was determined to rely on rock bolts for the majority of support. It was assessed that running or raveling would not be an issue. Bolts would hold the laminations together, and shotcrete could be used generally speaking to maintain the rock conditions – namely keep the rock mass from weathering. A cross sectional view of Type 1 & 2 rock support is shown in Figure 2. The rock support for Type 3 conditions consists of rock bolts and shotcrete, in a more traditional arched shape. This Type 3 support was anticipated to occur over 5% of project.

C. Rock Bolt Design

Design of the rock support system included use of empirical relationships by Sharp, Enders bee, and Mellors, 1984; Stacy and Page, 1986; and others to assess rock bolt lengths, as well as an in-depth review of case histories in and around Sydney. To determine rock bolt capacity requirements both suspension bolting and arch building analysis were utilized. Between these, it was determined 200 kN rock bolts were required to support all rock classes. The most challenging part of the rock bolt design was accommodating the RTA's 100 year design life constraints. There is aconsiderable amount of concern and uncertainty associated with the long-term durability of rock bolts (Baxter 1996). It was determined that double-corrosion protected rock bolts would be required to meet the 100 year design life. The team reviewed other projects where galvanizing and epoxy coating seemed to be the most routine method of achieving this, however, the effectiveness of either as double protection is questionable, and the ability to install epoxy coated bolts efficiently without scratching and chipping, in a one-pass environment, is very difficult.

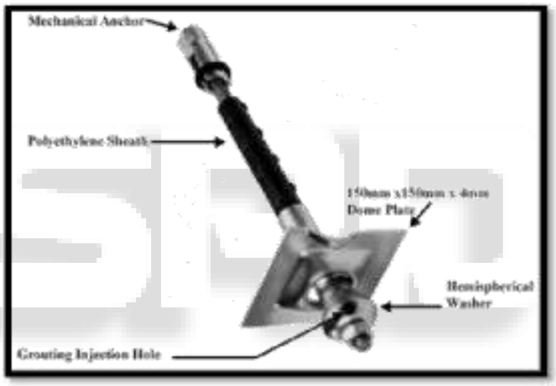

Fig. 3: CT bolt

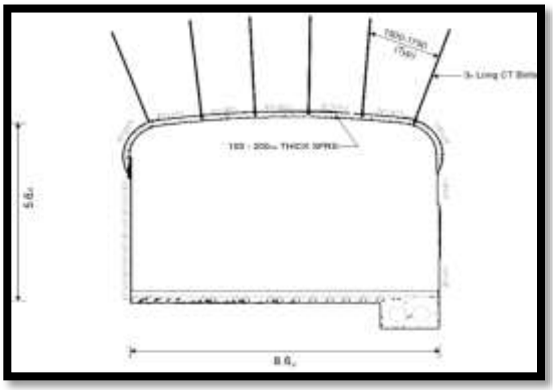

Fig. 4: typical tunnel support

With these design inputs 3 m long CT Bolts, with 211 KN yield were specified. The CT bolt, as shown in Figure 3, consists of a steel bolt contained within a deformed plastic tube, and a helical "loading bulb" for grouting. For M5, mechanical anchors were added to provide active rock support upon installation. Once installed and tensioned to 50 kN, the bolts are then grouted, using thixotropic grout, injected through the load bulb, up the inner shaft, and down the outside of the bolt, providing true double protection. Once the grout cured, the bolts behaved like a pre-tensioned dowel. Throughout the design, Strata Control Systems, of Australia, assisted the team as the anchors and details were added to the bolt. They also supplied the CT to the project.

VII. CONCLUSION

In this study paper, various bolts studied which are used for tunnel construction for giving supports and for making homogeneity between all rocks.

Rock bolts is beneficial for slope stabilization and also used for load transfer from soft strata to hard strata. As far as safety aspect concern it gives better results because of its stabilization and homogeneity between all rocks.

Overall rock bolts is superior for the tunnel construction and it gives enhanced suitability for all types of geographical cuts with using variety and suitability of bolts.

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