EDITORIAL

Evolution of Supporting Himalayan Rocks for Underground Works

It's five decades since underground excavation has been undertaken in Himalayas. The underground excavation in Himalayas is totally different from what is done in volcanic rock or granite and similar other rocks. This is because of in-situ stress in the rock which initiates collapse of rock unless movement of rock joints is prevented by rock supports of various types.

Various practices have been evolved to support underground excavation in Himalayas. Before deciding the type of treatment, a general assessment of the rock strength as well as jointing pattern, shear zone, underground water etc. are measured and remedial methods worked out.

Probe drilling in excess of 20 metres depth to determine the ground conditions, which are likely to be encountered. On getting information of rock head, grouting is usually adopted.

M/s Amberg Measuring Technique of Switzerland has recently started marketing an instrument for tunnel seismic prediction. This system called TSP 203 is specially developed for underground construction. It evaluates seismic echo signals reflected from changes in elastic characteristics normally associated in discontinuities in rock masses. TSP provides accurate spatial information concerning geology and rock mechanical properties in front and vicinity of face. The range of this equipment is from 100 metre to 1000 metre. This equipment is not in use in India yet, but it is expected to be used in near future.

Umbrella Arch Method is used where tunnels are excavated by drill and blast method. What we mean by "umbrella arch" is usually obtained by means of a series of holes, hole diameter ranges between 100 and 180 mm that are drilled, evenly spaced, along the contour of the tunnel vault in such a way to form an half cone whose generatrices lie as much as possible parallel to the tunnel axis. Similar holes can be drilled, if needed, also along the contour of the sides of the tunnel cross section. Then steel pipes of suitable diameter, perforated along the lower side, are placed in the holes and grouting agents (usually water-cement grouts) are pressure injected in the pipes.

The umbrella combines the advantages of modern forepoling system and of a series of grouting injections, it allows the excavation to progress safely (and at comparatively high speed), with a full control of subsidence through heterogeneous rocks having poor geomechanical properties as alluvial deposits, moraines, mylonites. A limit to the useful application of the method is posed only by ground water under high pressure.

The load acting on the tunnel vault (and the horizontal thrust on the tunnel sides, if the umbrella is intended to protect also the sides) is first calculated with the usual procedures. The pipes composing the umbrella are then designed as almost horizontal, fixed end beams.

Static stability is usually checked by calculating the bending and shear stress arising in the pipes from the anticipated loads and taking into account only the steel section of the pipes as resisting section (a reductive factor is applied to account for the pipe perforations). It must be noticed that the umbrella forms, all round the tunnel vault, a shell of grouted and reinforced rock. Thanks to the arched shape that could sustain a part of the rock load. It is wise, however, to disregard in the stability calculations because its effectiveness depends upon the perfect accomplishment of grouting and cannot be warranted in advance (it can be checked only during the excavation, too late to correct defects, if any).

The maximum allowable span between umbrella supporting structures is calculated on the basis of the above mentioned shear and bending stress calculations. Bending stresses pose the most severe limit to the span under the usual load conditions. Stresses do not depend much upon the changes of hole spacing (that must be chosen according to the ground properties (grain size, permeability, etc.); on the contrary, they are strongly influenced by the type of end constraints of the beams. Therefore the correct construction of an umbrella arch requires a careful check of the

grout injection through the pipes and an effective support-rock coupling. It can be safely supposed that the loads acting on the umbrella are evenly transmitted to the support, and steel arches must be chosen as support structure, because rock bolts do not represent a reliable and continuous support.

Drilling is performed by large (100-180 mm) drills and requires usually 3 to 5 shiftings of the drilling machine (to obtain a 15-20 holes umbrella).

The most critical problem is represented by hole divergence from the tunnel axis, that should be as small as possible, never exceeding 15 deg. Actually some overlap between two subsequent umbrella arches must be warranted so that the end of the first umbrella can provide stability to the excavation face and support the tunnel vault when the next umbrella must be built, thus allowing safe working conditions.

It is apparent that, as excavation economy is concerned, single umbrella arches span must be maximized. Unavoidable hole divergence, however, poses a limit to the span, because the influence radii of grouting of adjacent holes must overlap, and moreover, unconsolidated rock must not remain between the umbrella arch pipes and the tunnel vault; it is not advisable to exceed the distance of 2 m between the tunnel vault and the umbrella arch pipes.

Placement of the pipes in the holes can be made difficult by caving of the hole wall, or by hole shrinking. A very effective method to overcome such difficulties is to adopt an eccentric bit drill; in that case the pipe can follow the drill bit, as drilling progresses. Pipes usually employed are commercial steel pipes in lengths of 3 or 6 m that can be welded together in the contractor's workshop, or at the excavation face (when eccentric bit drill is used), to obtain the desired length. Outside diameter of pipes commonly ranges between 80 and 140 mm, and wall thickness between 3 and 10 mm. Perforations in the pipe wall, through which the grouting mixture is injected in the rock are preferably made only in the two thirds (away of the hole mouth) of the pipe length; excessive flow back of grout in the tunnel through the annular gap between hole and pipe is so avoided.

Grouting mixture injection does not require sleeve pipes, because a large diameter pipe allows to effect the injection along the pipe length, without appreciable pressure drop. Pressure injection can vary, being a function of cover thickness and of rock permeability, usually ranges between 3 and 10 bar.

In a number of cases which were designed and inspected, it has not been found necessary to resort on special grouting mixtures. Cement water grout proved always to be satisfactory with a cement to water ratio between 1/1 and 2/1 (sometimes it proved to be useful to increase the grout fluidity by adding a small amount (5-10%) of bentonite.

As the umbrella arch is set, excavation can progress along the useful length of the umbrella without noteworthy cautions. However, care must be taken to place very carefully the supports (as mentioned, support is usually provided by steel arches) so that the umbrella is immediately supported. Moreover, the span of the pipes must never exceed the designed length.

As hazardous working zone is the part immediately close to the face, where the pipes rest on the last arch on one side, and not the partly consolidated core of the face on the other side; accordingly, to the character of the rock, it may be necessary at each advance step (that coincides with the interval between the steel arches, usually 0.5 to 1.5 m) partly support and consolidate the face with sprayed concrete or with injections of grout.

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