Assessment of stability and design of supports for underground excavations

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Abstract

Modes of instability are classified and explained. Required measures for different modes of failure are described. Need for instrumentation and its importance is emphasized.

Assessment of Stability

Stability of any underground excavation is controlled by two effects. One of them is stresses in the ground vis' a vis' the strength of rock. The other is because of the structure of the rock mass.

Stress Controlled Instability

The intended location of the tunnel experiences the in-situ stresses caused by rock cover and locked in tectonic stresses. The act of excavation magnifies these stresses at the boundary of the tunnel (Fig. 1).

If the magnified stress levels exceed the compressive strength of rock, instability problems would manifest. The measures to handle such a situation would be to decrease the stress levels and to increase the compressive strength of rock mass. The stresses reduce by allowing deformations up to a point. The compressive strength of the rock mass increases by confining the rock mass. As confinement would tend to arrest deformations leading to non reduction of stresses, the timing and sequence of these two measures become important (Fig. 2).

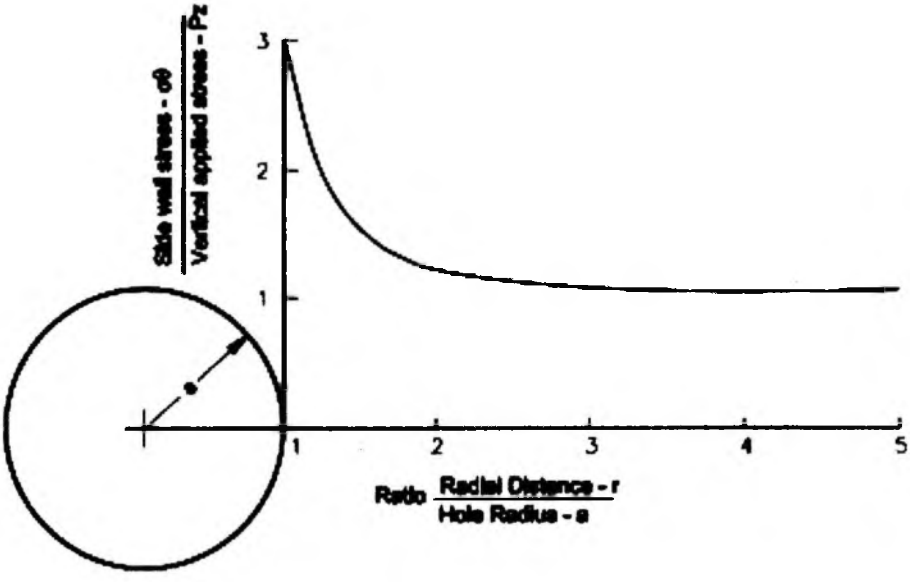

Fig. 1: Variation in ratio of tangential stress óè to vertical applied stress Pz with distance, r along horizontal axis for k = 0

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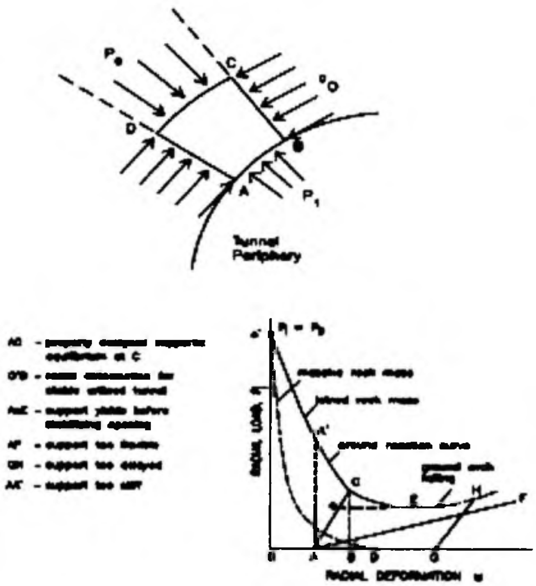


Fig. 2: The concept of ground reaction curve for rock tunnels

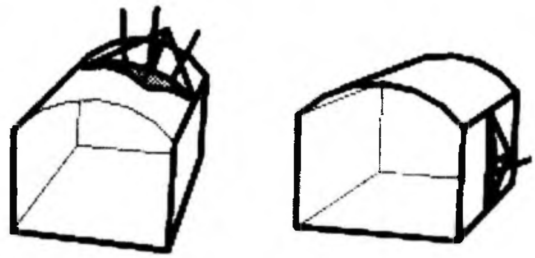
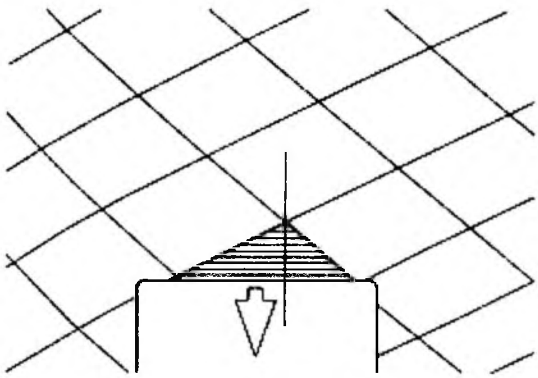


Fig. 4: Measures for possible modes of failure



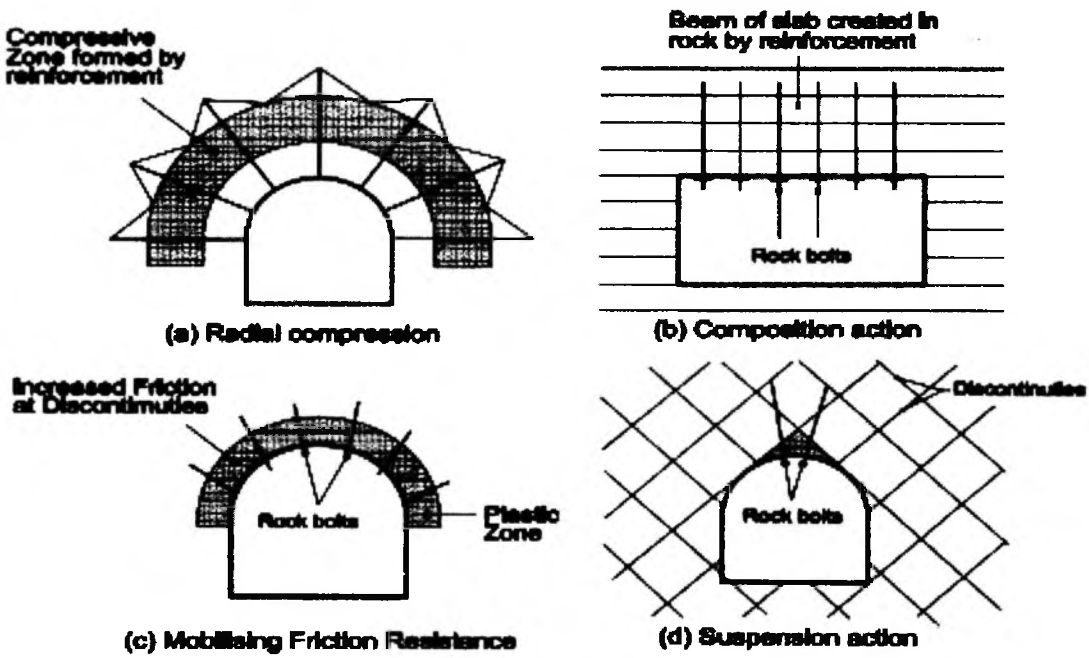


Fig. 5: Measures for possible modes of failure

Structurally Controlled Instability

When stresses are not high with respect to strength of the rock, the geological structure of rock mass dominates in creating instabilities. As the geological structure of rock mass at a site is already known, and so is the disposition of the intended excavation, the mechanisms of failure can be identified prior to excavation (Fig. 3) and so can the mitigating measures for possible modes of failure (Fig. 4, 5)

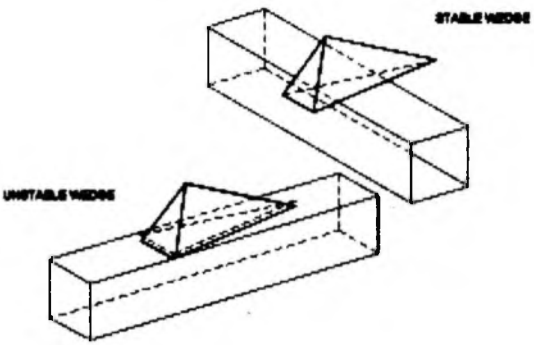


Fig. 6: Optimisation of stability by changing excavation oreintation

Fig. 7: Excavation Shape Controlled by Geological Structure

Design of Supports

Design of supports is done in many steps. The steps generally followed are:

- **Empirical approach**: This approach defines the support based on the size of the excavation. For example length of rock bolts to be between 1/3 to 1/2 of the span of the excavation.
- **Precedent practice:** A large amount of data for supported tunnels exists. The precedence are classified with respect to rock mass characteristics defined by RMR and Q. Support measures can be chosen from tables and charts.
- **Rational Methods:** The methods which physically define the failure type and dimensions and support requirements can be computed.
- **Computer Models:** Tailor made programs or Finite Element methods fall in this category.

The present discussion focuses on the rational methods.

Once the dominating mode of failure is determined, the support levels can be decided not only to counter the forces causing instability but also to improve the rock mass strength.

If dominating mode of failure is governed by in-situ stresses and the excavation medium is not exceptionally poor, the support measures must be able to yield and deform along with the excavation boundary while simultaneously resisting such deformations. Yielding arches, untensioned rock bolts and shotcrete are the elements, which deform under stress and simultaneously provide confinement to rock mass. Conventional steel sets are not able to deform because they are stiff and, therefore, would tend to attract more load.

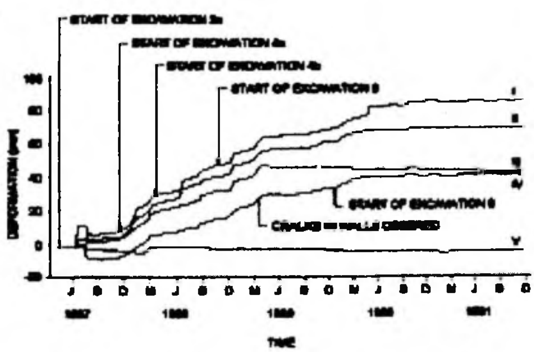


Fig. 8: Chamera- I – Deformation of Power House roof- Typical extensometer data

If the dominating mode of failure is governed by geological structure, the main supporting measure should be provided immediately after excavation and should provide active support so that the frictional resistance between the rock joints can be fully utilized in aiding the rock mass to support itself. End anchored tensioned rock bolts and shotcrete would be the elements, which would be the suitable choice for such excavation medium.

Instrumentation

To check the veracity of nominated support, instrumentation of excavation is of utmost importance. It not only demonstrates the sufficiency of the design measures, it warns in advance of occurrence of an event, if support measures are insufficient.

In Chamera – I project, the instrumentation results dictated suspension of further excavation activity of powerhouse cavern (24.5m span) for almost a year and enhancing the support levels before balance benching could resume (Fig. 8).

Conclusions

A quick assessment of stability requires the layout of the excavation, geological map of the area and a geologist's hammer. More sophisticated measures like field and laboratory tests can then be chosen to verify the first impressions and as inputs to detailed designs of rock support measures. To verify the designs and to monitor the response of the excavation to design measures being implemented, instrumentation of the excavation is essential.

Bibliography

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