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The stability of large chambers in karst caves - A case study on the Abisso di Trebiciano (Trieste; Italy)

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The Abisso di Trebiciano is a vertically developed limestone cave located near Trieste (length: around 700 m, depth: 330 m). The cave morphology consists of a vadose shaft zone that leads approximately 270 m below the surface into a large chamber, the A. F. Lindner hall. This chamber has a surface area of 130 x 80 m and a flat roof between 30 and 60 m above the ground. A river runs through the base of the big hall, belonging to the Reka-Timavo system, and floods the A. F. Lindner hall completely after high precipitation events. The Abisso di Trebiciano was thoroughly studied by different authors under various speleological, hydrological and geological aspects and provides an excellent case study.

The aim of this work was to examine the stability of the A. F. Lindner hall, study the breakdown mechanisms and to investigate the genesis and further development of the chamber. For this purpose a research study was designed that includes speleogenetical considerations as well as different aspects of rock mechanics and classical engineering geology.

Field observation include a detailed mapping of the hall with laser distancemetre, a description of the breakdown blocks, the walls and roof surfaces as well as the discon-

tinuities.

The A. F. Lindner hall is situated in the “Rupingrande Dolimite Layer” of the “Formation dei Calcari del Carso” with an UCS of 95 MPa. The bedding is subhorizontally orientated with a thickness in the order of 1.5 m. It was possible to distinguish four subvertical to vertical sets of joints with a spacing in the order of meters.

As a first step we used “classical” engineering geological rock mass classifications to verify if they are also implementable for karst voids. Rock mass classification schemes have been developed to formalise an empirical approach to tunnel design, in particular for determining support requirements. While the classification schemes are appropriate for their original application, considerable caution must be exercised in applying rock mass classifications to other rock engineering problems.

The Rock Mass Rating System (RMR – Bieniawski, 1989) gives us a value of around 80, what corresponds with a “good” to a “very good rock” and an average stand-up time of 20 years for a span of 15 m. However the A. F. Lindner hall has a span of around 60 m, which should under RMR considerations collapse immediately. Using the Q-Index (Barton et al. 1974) gives us a value of around 11 which would also refer to a very good rock mass quality. To estimate the (unsupported) stand-up time it is need introduce an Excavation Support Ratio (ESR safety factor; e.g. for a non-entry mining stope ESR of 5). The ESR of the A. F. Lindner hall is around 11.5 and therefore it would be non recommendable to enter the chamber under Q-Index considerations.

However this rough overview showed that rock mass classification systems in use for tunnelling are only applicable with severe limitations for the estimation of the stability of karst conduits.

As a further step different rock mechanics concepts have been compared for rock failure analysis.

To estimate stress induced failure the stress distribution around the chamber was modelled with a 2D finite-element program (Phase2, ©ROCSCIENCE). The geomechanical properties and behaviour of the rock mass was introduced by using the Geological Strength Index (GSI of 78; HOEK & BROWN, 1997) as well as with rock mechanical laboratory tests. The GSI was not assigned like usually done by the description of the rock mass but by the description of the breakdown blocks (average volume of the blocks 2 - 3 m^3). The analyses of the stress distribution showed, that the highest probability for stress related failures (σ_1= 25 MP) are along the walls of the A. F. Lindner hall. This result would correspond to a time dependent stress induced failure in the order of some 10^4 years; therefore the failure rate can be considered as a very slow breakdown process.

Next the applicability of the "fixed beam model" (Davies, 1951) for the breakdown phenomena in the A. F. Lindner hall was examined. The fixed beam model deals with a rock mass that is characterised by prominent bedding whereas the previous model of stress induced failure assumed a homogenous rock mass. The bedding thickness (1.5 m; deduced by analysis of the breakdown blocks) and the rock properties would allow a theoretical critical span for a fixed beam of around 30 m, and 17 m for a cantilever beam. Therefore the A.F. Lindner hall would be instable and evolve to a dome shaped hall. However this is not the case: the ceiling of the hall is more or less flat.

As a last step, the discontinuities were analysed using stereographic projection and the "key block theory" (Goodman & Shi, 1985) for wedge/block failure. The joint sets allow the existence of 3 different block shapes that would fail. This was also confirmed by the shape analysis of the breakdown blocks that are often related to 2 bedding planes and 2 - 3 joints as well as 1 - 3 breakaway surfaces.

These results lead to the conclusion that the genesis of the A .F. Lindner hall in the Abisso di Trebiciano is predominantly related to time depended stress induced failure and to key block failure. The stress related failures would be particularly responsible for the lateral development on the other hand key block failure can occur everywhere in the chamber.
The breakdown processes in the A.F. Lindner hall are very time depended (in the order of 10^3-10^4 years) therefore the chamber can be considered as stable in human timescale, although labile in larger timescale.