BRIDGING OF KARST STRUCTURES WITH GEOSYNTHETICS AND CONCRETE SLABS

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ABSTRACT

Traffic routes in areas affected by karstification constitute a technical challenge for all those involved in their construction. The course of action and the measures taken for ensuring a safe construction of the structures and the lasting serviceability of the traffic routes are varied (1,2). One of the main aspects of high-speed railway lines in karstic ground conditions is the bridging of karst structures. The overall stability and load-bearing capacity of all structures have to be ensured in line with state-of-the-art technology throughout the anticipated operating period. Extensive studies reveal that - even under those difficult ground conditions - a high degree of reliability regarding load-bearing capacity and serviceability may be achieved by strengthening measures which may be a reasonable combination of ground stabilisation and structural measures of both earth and rock structures and permanent way.

BACKGROUND & CONCEPTION

In karstified regions all cavities influencing the load-bearing behaviour and deformation behaviour of the permanent way have to be filled in such a manner that they do not migrate or sag markedly. A special ground investigation has to be done to ensure that larger karst cavities exceeding 1.5 m are detected. Such investigations are possible from a technical and economic point of view (1,2). For smaller karst cavities (less than 1.5 m) the probability of detection is very small and thus their existence cannot be ruled out with sufficient certainty. In areas where such small cavities may exist because of the geological and hydrogeological boundary conditions, measures have to be foreseen to avoid any collapse and to achieve sufficient ductility of the overall structure. These measures have to be carried out over the whole area as such cavities cannot be located. Two different methods - geogrids and concrete slabs - constitute suitable measures. They will bridge karst cavities. This strengthening of the ground is also done where there is a fair possibility that sinkholes will develop in future and thus influence the deformation behaviour of the permanent way (3,4,5,6).

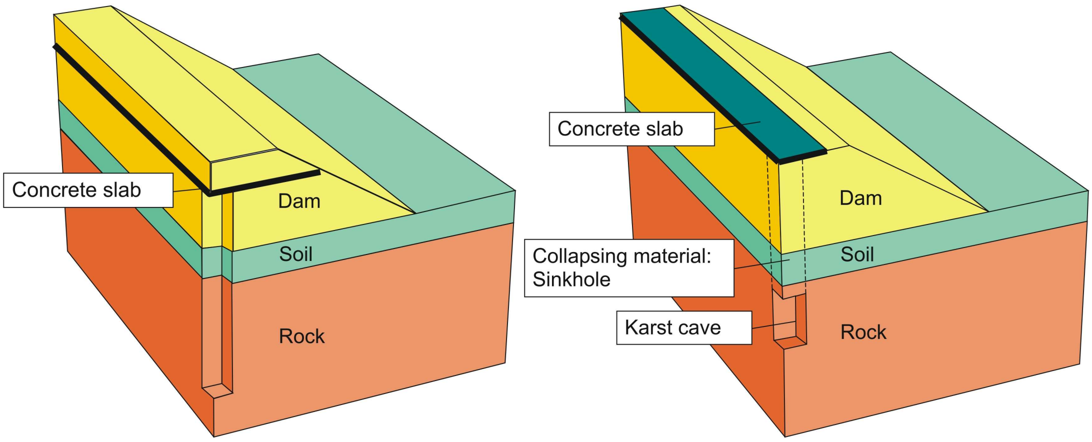

Fig. 1: Placement of concrete slab

All strengthening measures have to be arranged in such a way that they do not cause any dynamic response to the permanent way. They either have to be installed directly into the load-bearing system of the permanent way (e.g. concrete slabs) or placed in those zones which are subject to minor dynamic stresses and strains (Fig. 1 and Fig. 2). For slab tracks it can be assumed that with an overburden of about 3.0 to 3.5 m there will be no damaging stresses and strains from railway traffic affecting the strengthening measures. This implies that in cuts entailing karst- and sinkhole hazards only reinforced concrete slabs are suitable, functioning in a similar way to a reinforced concrete bridge or the tunnel invert. Geogrids are only suitable in the special case of deep replacement of soil below the cut. For dams the preferred strenghtening plane is the foundation zone of the dam. The mentioned overburden should be maintained in this case, too. The arrangement of geogrids for dams immediately below the permanent way is generally not possible as, in addition, in order to improve the load-bearing and deformation behaviour, a 3 m thick cement stabilised bearing layer (CSBL) is to be installed over the geogrids.

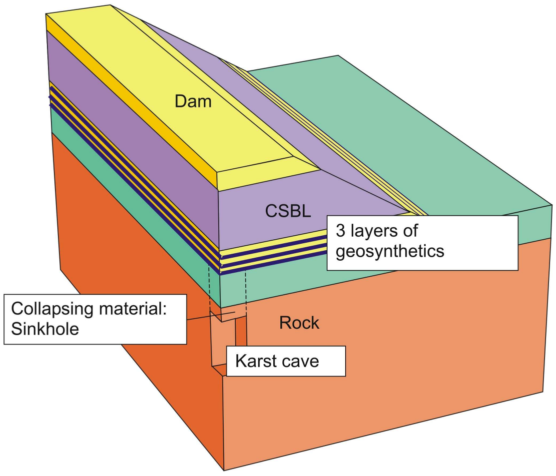

Fig. 2: Placement of geogrids

For practical reasons the load-bearing and general stability investigations and serviceability analyses are carried out using 3-dimensional continuum models (Fig. 3, 5, 6). The load-bearing behaviour of the concrete slab is quite simple, but for geogrid constructions there is a change of the system with increasing deformation. With increasing deflection the overlying dam becomes part of the load-bearing effect of the overall system due to arching effects (Fig. 3, 4, 5).

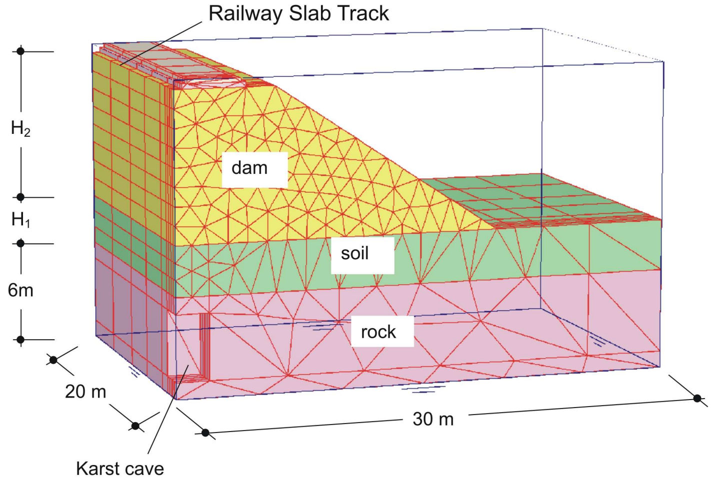

Fig. 3: FE-model for 3-dimensional calculations

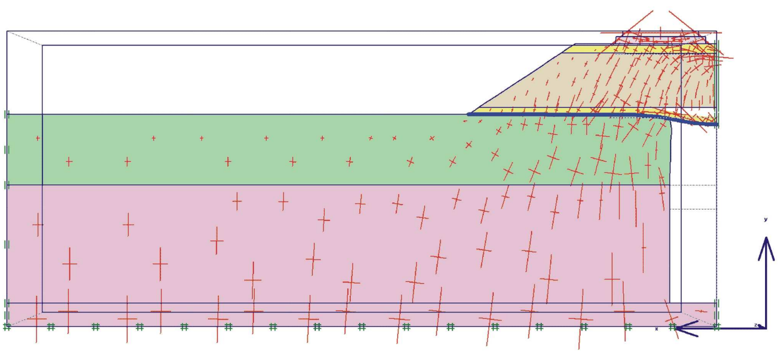

Fig. 4: Typical arch effect at high deformation with geogrid constructions

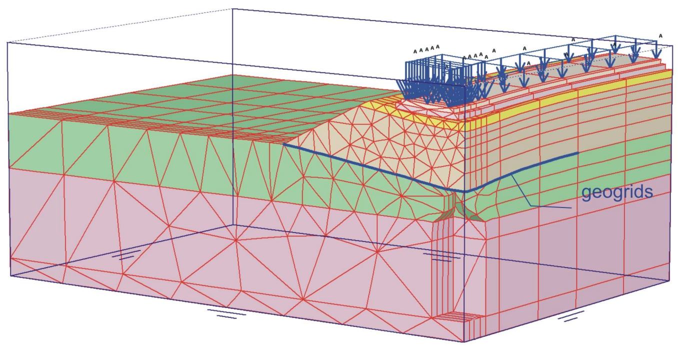

Fig. 5: Typical deformations due to UIC loads

For load-bearing capacity analyses of the reinforced concrete slab the values of the pertinent regulations apply, and for the geogrids the occurring values have to be compared to those mentioned by the manufacturer and to those that take into account the reduction factors such as long-term behaviour, dynamic impacts, etc. (see Table 1). The underlying concept for the analyses is based on partial safety (8).

Serviceability	Load-bearing capacity / Dimensioning
Deformation measurements of the overall system	**Pre-failure-behaviour** Axial forces N_k in geogrid **Post-failure-behaviour** Stresses in the earth arch
Verification of serviceability comparing actual radii and differential settlements with limit state valves	**Verification of load-bearing capacity** Axial forces in geogrid Anchoring lengths Arch stresses (mobilised angle of friction)

Tab. 1: Required verification

In particular the following points have to be verified:

- Serviceability
  - Deformation of the overall system
  - Comparison of actual radii and differential settlements with limit state values
- Load-bearing behaviour
  - Axial forces in geogrid (pre- and post-failure)
  - Stresses in the CSBL (arch)
  - Anchoring length of geogrids

In order to verify the serviceability the settlement (Fig. 5) of the permanent way was evaluated according to Fig. 6 showing the displacement values and the corresponding radii of curvature in the longitudinal and transverse direction. These values are compared to the comfort criteria and other limit values specified by the Client.

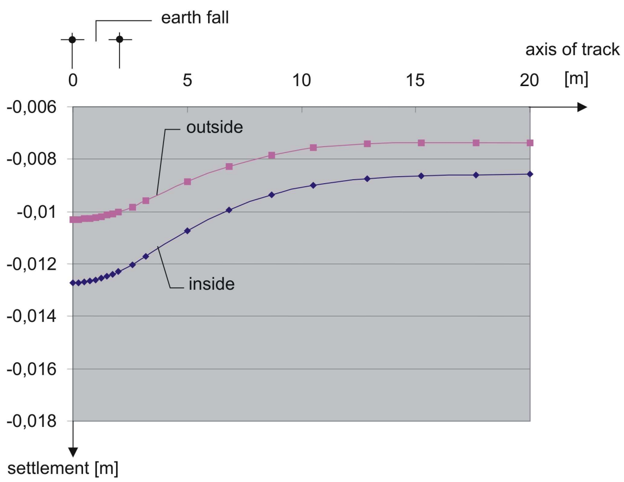

Fig. 6: Settlement at the inside and outside of the Slab Track

The durability of the strengthening measures depends not only on correct dimensioning and construction but also on

- the durability (life span) of the used materials,
- stability of the chimney below the strengthening measures and
- in case of using geogrids the preservation of the stability of the ground above the strengthening measures.

As regards these tasks it can be assumed that the used reinforced concrete has unlimited durability. Industry today supplies long-term durable geosynthetics as well as geogrids. When the ambient conditions for the proposed geogrids are met a durability of 120 years can be assumed, without any significant deterioration of the material properties.

CONCLUSION

The following comments are meant to serve as guideline for selecting the necessary strengthening measures in general and in particular for designing the constructive strengthening measures (bridging):

- The preferred strengthening measures comprise reinforced concrete slabs and geogrids. Depending on the properties of the rock mass, the installed dam materials and the height of the overburden, the use of

  - 0.6 to 1.0 m thick reinforced concrete slabs or
  - 1- to 3-layered geogrid systems

  can prevent a collapse of the permanent way in case of sinkhole cross-sections of up to 4 x 4 m in an economic way.

  Constructive strengthening measures can be designed in such a way that the radii of curvature at the trackway do not fall short of the corresponding limit values.

- Every strengthening measure shall be planned in detail for the specific route section and designed based on Finite Element calculations. While reinforced concrete slabs mainly function like foundation slabs, geogrid systems are to be understood as membrane-like tension members between the abutments of ground arches.

- In non-cohesive soils the initial cross-sections of sinkhole chimneys cannot be kept stable which means that the strengthening measure either has to be arranged below the non-cohesive layers or these layers have to be stabilised themselves.

- In order to integrate the soil above the strengthening measure into the load-bearing system by providing a permanently stable arch, at least for geogrid systems CBSL with a thickness of about 3 m shall be installed.

- Additional deformations at the trackway are important indicators for a developing sinkhole. Deformation measurements should therefore support the track geometry inspections in all critical route sections and whenever a marked trend of track subsidence becomes discernible in a specific route section.

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