Geohazard as Consequence of Primary Stress State Ignorance during Design of Geotechnical Constructions

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ABSTRACT: With slope movements man does not encounter every day, but it should be noted that this happens, and it happens more often. These movements are influenced only by two factors, namely nature and humans themselves.Slope deformations are one of the most widespread and to some extent one of the most dangerous country geohazards, and represent a significant geobarriers to urbanization planning. With gradually expanding populations are extensive and demanding technical works built in increasingly complex and less favourable geological conditions.In complex geological conditions it is mainly about understanding the overall geological environment with the development and effective design of geotechnical structures designed to ensure long-term stability. The term effective design is meant a set of geotechnical construction, which complement each other, so that their final effect has the desired influence.In this paper, we have attempted to describe ways of determining global stability, which is directly conditional on the building progress of stabilizing construction.This procedure creates and directs geotechnical engineer. Any change in construction has an impact on the global calculation, which should be adapted and subsequently verified. This calculation also influences new geological and geomechanical conditions that are specified by the construction process. Contractor but these essential steps, due to time and cost skips and thus embarks on the risky work, often with fatal consequences.

1 INTRODUCTION

Mechanism of slope movements is defined as the inherent natural procession of general development and the course of slope mass movement conditioned by the geological – tectonic structure of a slope, by slope site topography as well as by operating natural and human activity factors. On the basis of the specific deformation and kinetic mutual coupling of separate parts of a moving mass in entire zone of a slope movement, this integrating mechanism determines that in a given space and time there develops and proceeds a characteristic type of downward slope movements and also a resulting type of slope failure, always with minimal energy consumption. The mass movement mechanism and the type of slope movement, as well as its velocity, can however change in space and time.

2 SLIDING

The most widespread slope movement is sliding. It is distinguished by the gravitational movement of soil or rock mass in solid (hard) to plastic state (from very stiff to soft consistence) on a slope without loss of contact with the bed ground.

Analysis of slide movement in respect to kinetics is based on Newton´s law of motion, valid for the acceleration of solid bodies in the gravity field. With respect to the variable geometry of landslide, their surficial topography and their sliding surfaces, is possible to solve the kinetics of slide movement just in simple cases or in particular parts with clearly defined sliding mass path.

3 LANDSLIDES AND LINE CONSTRUCTION

Slope deformations generally have a negative impact on planned construction. The greatest interest is mainly focused on landslides threatening the new family houses.It being remembered that many times the owners, who decided to build on the slope without the help of a geologist or geotechnical engineer, can often experience this situation. Linear structures, however, represent a strategic building that has a very wide use for the population and the state.

The complicated geological structure complex in the interaction with the construction of highways and the related occurrence of slope deformations is the biggest problem of most states in the world.

Although the maps of slope stability, in which the landslides and other slope deformations are registered, is being developed.During construction it, the responsible geotechnical engineer often encounter unexpected complications.

Project planning counts on what has been documented in the past, and therefore are realized remedial arrangement which resulting from a previous survey. As already mentioned, there are cases when the combination of adverse natural conditions and anthropogenic intervention of construction into the natural environment activate slope deformations. One of the most frequent building interventions in the rock environment during construction is the undercut. Nothing unusual, but from stability viewpoint, it is very dangerous. Although the stability ratios are calculated, due to the construction of supporting walls, the slope deformations are often unpredictable and thus annoying and mainly overcharge the actual construction.

4 STABILITY ASSESSMENT OF SLOPE DEFORMATIONS IN HIGHWAY CORRIDOR

As an example, paper describes the construction of a highway in complicated geological conditions, where the alternation of solid and plastic layers occurs. This alternation results in several shear areas at different depths.

The most significant exogenous geodynamic phenomenon for near the highway included landslide, which is a response to the geological and tectonic structure of the area and its hydrogeological conditions. Slope deformations, that are in multiple locations combined with a movement of rubble´s layers, cover the bulk of the area slopes engaged motorway route (or a range). We decided to focus on the first section of the highway, which almost represents one potential landing gear that directly threatens the adjacent railway station and, therefore, the direct northern rail link connectingthe Czech Republic, Poland and Slovakia. This section is divided into several homogeneous units.

4.1 *Section 1*

The route undergoes extensive stabilized slope deformation at the final development stage. First 120 m is applied to potential landslides a frontal planar slip surface in a depth of 7.0 to 8.0 m.

4.2 *Section 2*

The section of the highway is situated in the accumulation of potential frontal landslide. The rock environment disturbed by sloping movements reaches a depth of 2.1 m - 3.0 m. The depth of the sliding body according to the piezometric borehole is 5.0 m.

4.3 *Section 3*

This section includes a large sliding area with two staged, stepped slides of 250-300 m in length, interconnected by two smaller flat landslides. The surface layer is damaged to a depth of 4 - 5 m by a potential landslide, where a basic shear surface is assumed to be 9.5-10.5 m deep.

4.4 *Section 4*

Here is the highway route situated in a compound stabilized slope deformation. The construction sites are situated in the frontal landslide with a thickness deluvial landslide at 7-8 m. The central part of the territory is violated planar and current stabilized landslides, the upper part of the slope deformations are broken by rubbles. The depth of the shear area is 7.0 m below the terrain.

4.5 *Section 5*

This is a section where the rock environment is damaged by stabilized frontal landslide with a depth of shear area of 2.1 m - 4.1 m.

Already on the basis of this sectional division and a short description of deformations, it is obviously what challenging geological environment. In general, we encounter several, mutually interconnected shear surfaces, either at the basal level (deeper shear areas) or the level of deluvial rubbles movement (shallow shear surfaces).

5 DESIGN OF GEOTECHNICAL CONSTRUCTION FOR LANDSLIDES STABILIZATION

Whole, the above described part of the newly built highway has been divided into six homogeneous units and on the basis of geological survey was proposed set of geotechnical constructions, whose task is to stabilize the slope deformations. Figure 1 showsone of these variants.

Figure 1. Schematic cross section

Given that the problem is not only shear surface but a number of independent ones, it was necessary to choose the most advantageous construction process that would already have its own built steps created a motion-preventing construction unit.

Calculation of stability ration took place on two levels.

1. Calculation of the global stability of the section, account of the construction process and each step has been assessed separately, to avoid accidental triggering of slope movement. If the step results in a decrease of stability to the previous step, this step is reviewed and selected other process so as to still ensure the continuity of the construction (Figs 2 - 5).

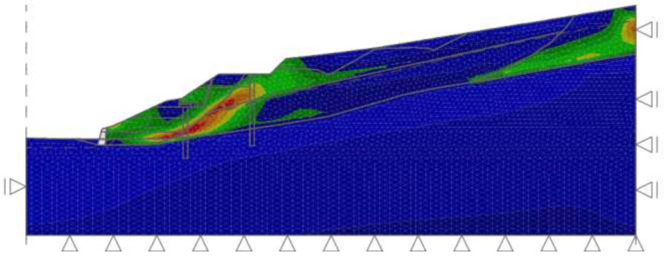

Figure 2. Shape of the shear surfaces for the first construction step (Phase 0 represents the initial stress state)

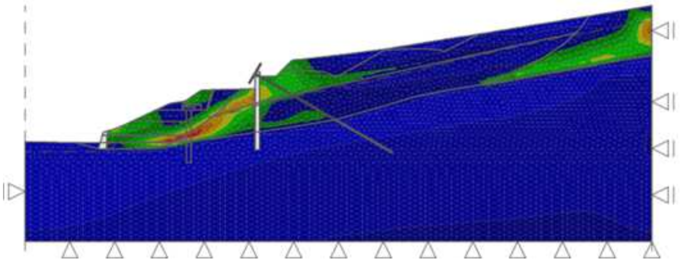

Figure 3. The redistribution of the shear displacements after completion of the first object, which now allowed the start of release the landslide

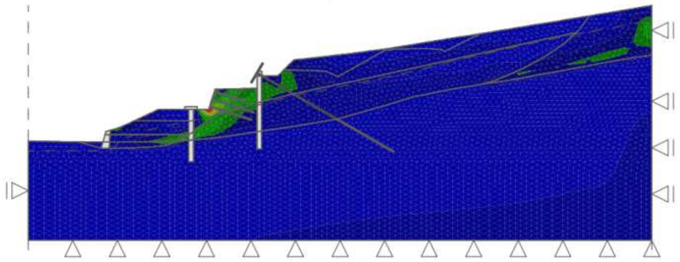

Figure 4. Construction of another pilot wall, the task of which will be primarily to secure the left-hand highway

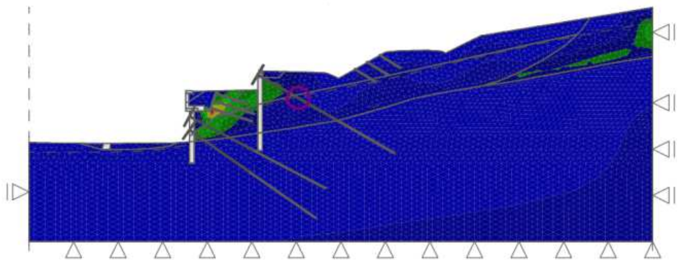

Figure 5. The final stability system of highway

2. Calculation of internal stability of individual structures to determine internal forces and subsequent dimensional evaluation (Figs 6, 7)

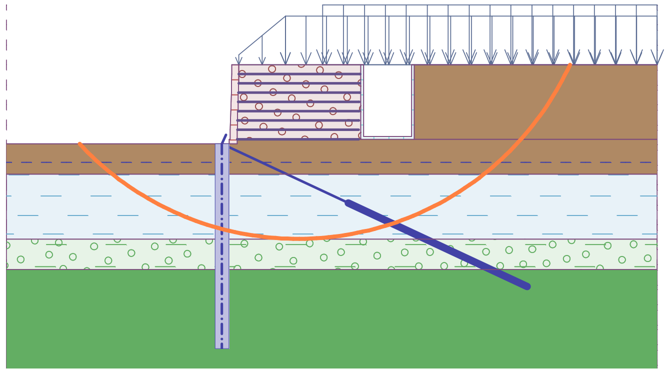

Figure 6. An example of determining global stability for part of a construction with a reinforced structure

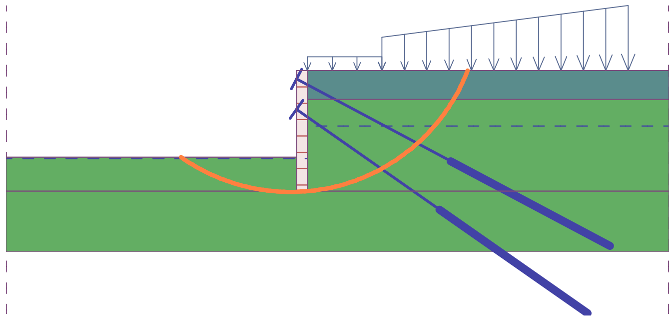

Figure 7. Another part of the same object and determination of global stability for piles and anchors

Many times, there is a requirement for control of project documentation sometime, directly from the contractor, supported global stability assessment for individual objects of the construction system. However, this requirement is often based on a misconception that the system can be divided into parts and they carry a proportion of the total degree of global stability.

6 CONSTRUCTION PROCESS AND GLOBAL STABILITY

The main task of the geotechnical engineer is to propose a set of measures that will, by their nature, prevent landslides. A set of constructions means that individual parts fulfil their partial role until the builds up the next part (gravitational walls, piles, MSE wall) and jointly take over the stability role as a whole.

The individual steps of geotechnical construction must be assumed and, on the basis of the primary stress state in the mass, it must be ensured so as to avoid landslides.

Each step must be supported by stability recalculation and only on the basis of it can bechosen the next procedure or take an auxiliary measure.

In such a construction process, geotechnical engineer works with time as a variable. This procedure must be followed by the contractor and cannot be diverted from it because even the minimum change may mean collapse.

Geotechnical engineer is in constant contact with the geologist who is present on the site. Each change from the assumption is immediately analyzed and inserted into the design model to verify the calculations. In case of non-compliance, they are immediately proposed measures. This does not mean an unnecessary increase in the cost of the work and the time of construction is not extended.

Other examples are the sum of the most common geohazards of the contractor in violation of geotechnics and ignoring nature.

1. Ignoring the construction process (Figs 8 - 11)

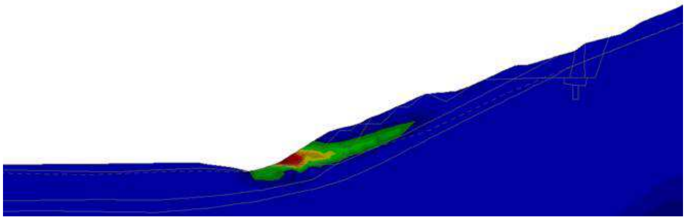

Figure 8. Primary stress state with identified landslide

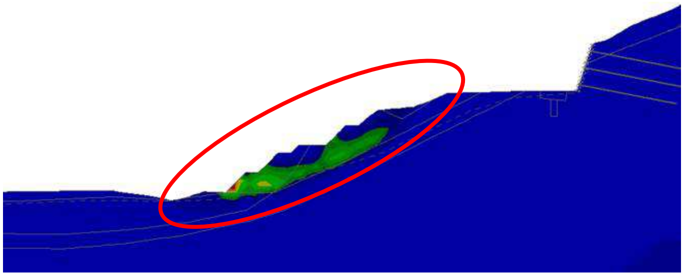

Figure 9. Primary stress state with identified landslide

Figure 10. Slope adjustment without free cut

Figure 11. Slope adjustment without free cut

2. Ignoring the construction time (Figs 12, 13)

Geotechnical engineerprescribed not only the construction process but also the time steps that need to be accomplished.This had to be completed within the day so as not to damage the structure.

Nailed slope had to be secured byconcrete in a day to prevent degradation of the soil and the change in mechanical properties.

Figure 12. More than a week open unsecured excavation and one-day rain

Figure 13. Crack zone

7 RISK ANALYSIS AND LIKELIHOOD OF OCCURRENCE OF AN UNDESIRABLE EVENT

In geotechnical engineering, it is necessary to assume that a fault on the part of the contractor will occur during the design itself. It is in this area of construction that the manufacturer's mistakes are of a great nature and have dangerous consequences for the proposed work. It is necessary to count on them during the design and thus to prevent, respectively at least reduce the negative impact of improper work. This analysis will increase the safety of the building and increase the safety of workers.

As mentioned above, frequent errors in the process of design geotechnical structures are neglect, resp. simplifying undesirable effects on the building structure. But, if we are aware of these risks, it is possible to analyse them and under considerationthe likelihood of an undesirable occurrence with regard to other aspects of the design under consideration.

Generally, the risk can be understood as a probability of occurrence of an undesirable and unintended event and a negative consequence of this event. So, if we talk about risk, we are talking about the probability that a threat may occur. The risk is accompanied by uncertaintyIt is the event with which the risk is associated may or may not occur. On the other hand, it is a loss, which is the result of unexpected consequences.

The first stage in risk analysis is their identification, a savoir identification of risk, and the identification of the risks that may affect the building structure. Creating a list of potential risks is based on the fact that everything can occur during the static calculation solution and what events it does. At present, there are many techniques and methods for identifying risks (Fig. 14).

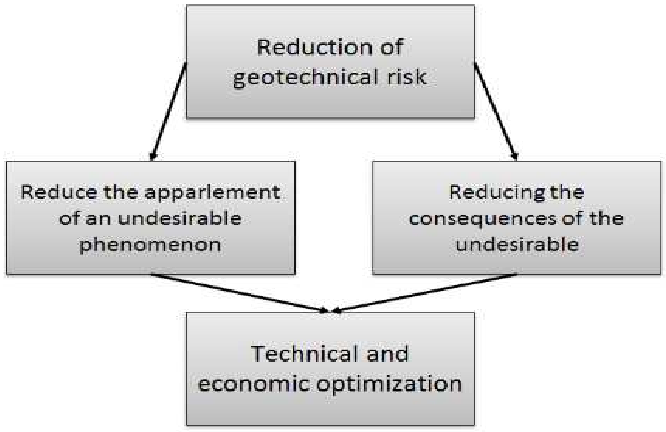

Figure 14. Reduction of geotechnical risk

The next step is the risk analysis itself. It serves to sort the risks according to their impact on project goals. Quantitative risk analysis serves to determine the likelihood of risks and to link these risks to the objectives of the project. Various risk analysis methods can also be used for building and designing building structures. However, the mathematical method, the method of scenario analysis and the method of using experience are the most optimal.

The main advantage of the matrix method is the ability to capture a great deal of interrelationships between the rock environment and the building structure. The Scenario Analysis method has the ability to use simulation patterns of construction behaviour. In practice, it is being used less and less. The method of exploiting experience is in turn based on similarities with other similar constructions, which have been proposed under similar geological conditions. However, as geological conditions are predominantly different in each building, this method of analysis is rarely applicable.

8 LESSONS FOR CONTRACTORS

8.1 *Application of the observation method*

Natural or artificial environment from natural materials can never be considered as homogeneous, even though we are thinking in static assessment. Its real characteristics and the type of behavior of building structures in the rock environment cannot be reliably determined at the stage of preparing the project documentation. And itcannot do even the finest computational procedures (Fig. 15).

Figure 15. An insufficient observation method can cause more damage than this exemplary little slider

The use of the observation method during construction will allow the quality of construction projects to be improved. To a certain extent, take into account the behavior of each part of the construction in specific cases. Indeed, the behavior of the construction structure after completion as a whole is decisive. It is therefore necessary to pay increased attention to the monitoring proposal. However, in order to be able to proceed with the design of the observation method during construction, it is necessary to accept a certain acceptable risk during the design.

8.2 *Procedure of construction*

Another important part of static assessments is, of course, the stage of construction - the construction process, which in most cases is determined by the contractor himself. In this section, all stages of earthworks and building construction should be modelled as they will be carried out on site.

The problem is whether or not to consider this part of the assessment or to simplify it in the calculation model. At that time, complications also occur in simpler constructions, when this fact is neglected most often. It is not a complete rarity when the proposed abutment walls in the landslide area are also modelled in the 15 stages, only to ensure stability at each stage of construction.

8.3 *Geotechnics is no science*

Geotechnics is no science. This argument we often encounter in practice is very erroneous. Geotechnical constructions account for about 5-10 % of all costs on the financial side of the construction site. For civil engineering, it is 30 %, and for water constructions the share of geotechnics is up to 50 % of the total cost of the construction work. The largest share of these buildings is of course underground, where the share of geotechnics represents up to 95 % of all costs. Based on these statistics, it is clear that the impact of geotechnics is significant for all types of construction and cannot be neglected under normal conditions.

9 CONCLUSION

With slope movements man does not encounter every day, but it should be noted that this happens, and it happens more often. These movements are influenced only by two factors, namely nature and humans themselves.

In complex geological conditions it is mainly about understanding the overall geological environment with the development and effective design of geotechnical structures designed to ensure long-term stability. The term effective design is meant a set of geotechnical construction, which complement each other, so that their final effect has the desired influence. Therefore, the calculation is conditional on precisely the construction process and the time dependence. This is the primary input that geotechnical engineer should identify at the beginning of the design work. This procedure is unalterable and all other work has to come from it. Based on this, it is then possible to simply involve individual suppliers in the building process and effectively manage the overall process.

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11 REFERENCES

Rozsypal, A. 2001. *Control monitoring and risks in geotechnics (Kontrolní sledování a rizika v geotechnice),* Bratislava ISBN 80-88905-44-3

Hulla, J., Turček, P., Baliak, F., Klepsatel, F. 2002 *Assumptions and reality in geotechnical engineering (Predpoklady a skutočnosť v geotechnickom inžinierstve)*, Bratislava ISBN 80-88905-42-7

Fussgänger, E. 2016 *Slope movements and disorders and their geomechanical assessment (Svahové pohyby a poruchy a ich geomechanické posudzovanie)*, Bratislava ISBN 978-80-8076-124-0

Boehm, B.W. 1991 *Software Risk Management: Principles and Practices*, USA IEEE 0-8186-3342-5/93

Frankovská, J. - Durmeková, T. *Specific Features of Weak Rock Laboratory Testing. In 15th European conference on soil mechanics and geotechnical engineering*: Proceesings. Geotechnics of hard soils - weak rocks.Athens,2011. Amsterdam: IOS Press, 2011, s.337-342. ISBN 978-1-60750-800-7.

Frankovská, J. - Kopecký, M. - Turček, P.*The correlation of surface area with hydraulic conductivity of fine-grained soils*.In SGEM 2014.GeoConference on Science and Technologies in Geology, Exploration and Mining: conference proceedings. Sofia: STEF 92 Technology, 2014, P. 893-900. ISSN 1314-2704.ISBN 978-619-7105-08-7.