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GEOTECHNICAL PROBLEMS OF THE CULTURAL HERITAGE MONUMENTS IN BULGARIA

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ABSTRACT

Located in a region with favourable geographically and climatically conditions Bulgaria has a rich historical and cultural heritage main part of which are its cultural monuments. As far as these monuments are situated in certain geological structures and are submitted to natural destructive geological and anthropogenic processes the question of their survival is closely related to the management of the hazardous geological phenomena. Unfortunately the geotechnical conditions at the sites of the most important cultural monuments are infavourable. The changes in their environment visibly accelerate the distructive effects on them. The most endangered monuments and sites are those of the Madara Horse-man rock bas-relief, the Ivanovo rock churches, the Stambolov Bridge and the "St. 40 Martyrs" Church in Veliko Tarnovo, the Rila and the Preobrajenie Monasteries. In certain degrees these monuments are harmed and for some of them the destruction processes are irreversible. Although most of the causes for that are clarified and technical solutions for management exist till now very few was done for the preservation of this unique cultural heritage. In such no intervention conditions a great part of them will be lost in the near future.

One of the most endangered monuments is the Madara horseman bas-relief. It is carved in the limy sandstones of the western cliff of the Madara plateau. (fig. 1). Its existence is effected by the geological processes related to the natural development of the cliff and to its surface weathering.

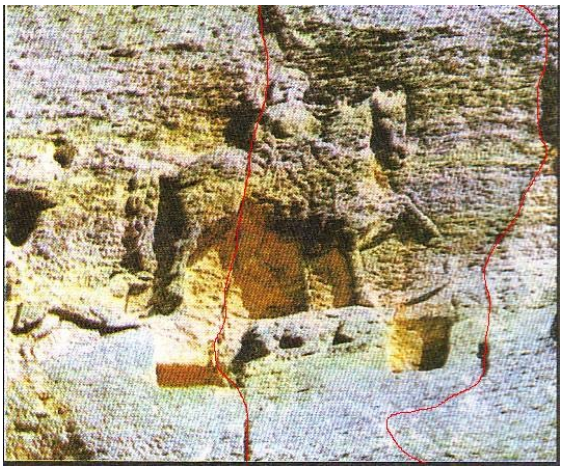

Figure 1. View from the Madara horseman and the contours of the rock block.

The cliff development is determined by Smyadovo fault structure along which the plateau was elevated. In the upper section of the cliff were revealed three parallel joints systems. During the engineering geological site study it came out that the rock cliff traveled for 60 m east for a period of 6 million years. The composition of the deluvial deposits from the cliff base revealed that the major factor for the development (destruction) of the cliff zones of the Madara Plateau were the seismic and the gravitation processes. The destruction mechanism consisted of three stages: weathering jointing of the surface zone and shaping of separate blocks in the cliff; acceleration or the process due to creep movements in the bedrocks due to the inverse geologic structure – plastic base (marls), overlaied by fragile rocks (sandstones); separate blocks demolition after earthquakes in the region. This process is proved by the big blocks floating in the deluvial deposits from the cliff toe.

The level of the cliff bearing the bas-relief had finished its second stage of development. A vertical fracture that crosses the bas-relief joins a neighbour one located at 1 m south. The two fractures completely separate a block in the massif that being interlocked with the adjacent blocks is actually stable (fig. 2). The stability calculations reveal that a strong earthquake could loosen the block ant it would fall out with a significant portion of the bas-relief. The estimated total stabilizing horizontal force is about 2300 kN. The technical solution is the anchoring the rock block.

Another significant problem is the biologic degrading of the rock due to micro-organisms decomposing the surface layer of the cliff. The process is quite vigorous and if not stopped in the following 1-2 decades all other interventions will be senseless. Our studies revealed that the microflora and microfauna populations are developed due to the changes in the humidity regime of the air and the rock respectively. During the geophysical electrical surveys it occurred that the resistivity of the lower quarter of the cliff is several times lower of those from the other levels of the cliff. The change of the environmental equilibrium after artificial foresting the toe of the plateau at the 30-ies of the last century was estimated to be the major cause for that.

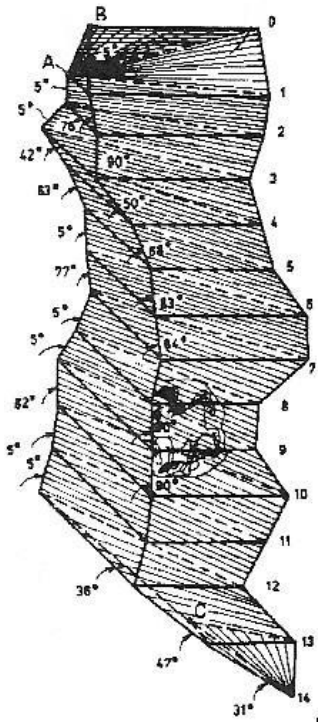

Figure 2. 3D model of the rock block bearing the Madara horseman

In general the geotechnical conditions of the site of the monuments are very well studied: the geological structure, the physical and the mechanical properties of the rock, the cliff block structure were established; monitoring of the interblocks movements is carried out; seismic microzoning of the site with static and dynamic stability calculations were carried out; the degradation has been continuously studied.

Considerable similar problems exist at the site of the Ivanovo rock churches. The religious complex was carved in the limestone cliff of the Canyon of Cherni Lom River. The rock Monasteries (churches) are located in additionally enlarged and shaped karstic caves. With the time blocks falling has occurred from the ceilings and the walls. In most of the churches the processes are irreversible. Real possibilities exist to preserve the tourist site "The Church" only if appropriate enforcing intervention is realized. The studies revealed the seismic and gravitation character of the development of the massif – strong earthquake induces rock blocks falling down. Practically this means that for long time periods there should not be disturbing movements while during an earthquake a massive block fall is expected.

The study of the Ivanovo Monasteries is in their initial stages although the first fragmentary studies were carried out 30 years ago. The detailed investigations of the site in the spring of 2002 supplied valuable data for the joints systems, the dimensions of the rock blocks from the cliff, some initial data for the physical and mechanical properties of the rock and the hydrogeological conditions (fig. 2). The necessary continuation of the studies should be spotted on the strength of the massif, the seismic microzoning, the modeling of the static and dynamic stability of the cliff.

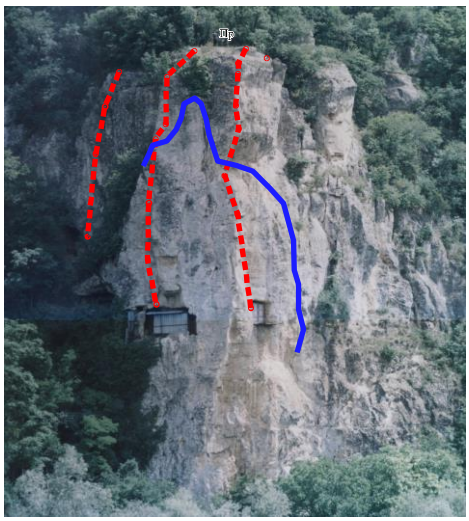

Figure 3. View to Ivanovo rock church and the contours of the external block and survey profiles.

The site of the Preobrajenie Monastery complex including the "The Assu" Church as a cultural monument famous with its frescoes named "The Circle of Life" and the bell-tower built-up by the famous Bulgarian constrictor Koljo Ficheto also is exposed to complicated geotechnical conditions. The Monastery was established in the XIVth century. It was located north of Veliko Tarnovo on a deluvial plane level at the toe of a picturesque 120 m high limestones cliff of the canyon the Yantra River. The Monastery was partially destroyed after the falling of rock block during the Gornooryahovo earthquake in 1913. In 1974 a landslide developed in the deluvial slope completely destroyed the eastern wing of the complex and directly endangered the Church. In consequence the landslide was reinforced by back ties and drainage gallery. In 1991 as a consequence of intensive rainfalls a 300 m^3 rock-fall occurred from the cliff and completely destroyed the western wings of the Monastery. No casualties occurred by chance. The chance preserved the Church when the rock flow was divided to two by a tree and run beside its sides (fig. 4).

The geotechnical problems of the Preobrajenie Monastery are very well studied. All practical aspects are embraced: strength of the massif, seismic microzoning, static and dynamic stability of the cliff including with FEM, prognosis for the cliff development was stated. On the base of variants studies a project for cliff reinforcement was designed. Regardless of the fact that at certain moment the financing was secured the project was not realized.

The geotechnical problems of the Stambolov bridge in Veliko Tarnovo are related to the stability of a rock slope. The bridge conects the central part of the town with "Sveta Gora" hill. It was built in 1922 and presents a metal arch structure fixed by two bearings at both practically vertical Yantra River banks. Survey investigations revealed some displacement of the left foundations of the bridge where visibly the road was settled and the stone masonry confining the left flank embankment partially collapsed. The river terrace at the site is an erosional type. The height of the bank ranges between 25-28 m. The slope consists of limestones, rated by their uniaxial strength as "very strong". The subsurface

zone of the slope is fractured due to neotectonic and contemporary tectonic movements, weathering and technical activities. At the area of the left foundation the joints are with unfavourable orientations towards the abutment reactions. Separate fault lines were revealed with the boreholes drilling. Their width was in the range of 0.1-0.6 m and they were marked by brecciaed zones in the limestones and fill of dark grey tectonic clay. The values of the abutment reactions related to the deformation properties of the fracture rock cliff suppose that displacements in the bridge are quite likely. In the case of a strong earthquake from the Gorno Oryahovo focus zone they could go beyond the critical values. The technical solution of the problem is anchoring the slope in the area of the abutments where the anchors will play a double role: hardening of the rock foundation to the depth of the active zone and preventing movements of loaded joint pyramids with critical dimensions.

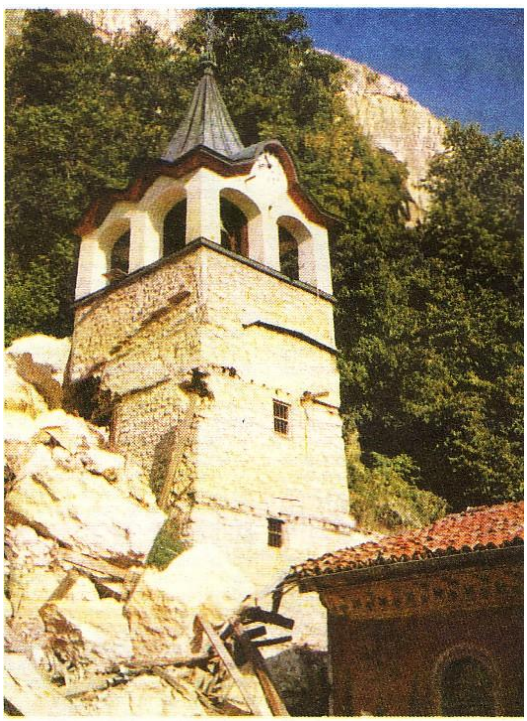

Figure 4. View to Preobrajenie Monastery bell-tower after the rock-fall in 1991

Another cultural heritage monument in region – the "St. 40 Martyrs" Church – suffers different kind of problems. The church and the ossuary are located at the foot of "Tzarevetz" hill on the low bank of Yantra River. The church foundations are in deluvial soils (sandy clays) lying over a bedrock of marls. The building is systematically inundated. The recent investigations revealed to a great extend the engineering geological and hydrogeological conditions of the site. It became clear that the inundations are related to high groundwater in the slope deposits caused by high river levels. To protect the monument a grout curtain was recommended but still not designed. The irresponsible attitude towards the monument was revealed with the last natural disaster at its site in January 2003. A massive leak from a destructed water-supply pipe caused a destruction of the ashlar retaining wall above the church and the stone and backfill materials endangered the metal scaffolding bearing the structural columns in the church.

Quite serious are the geotechnical problems at the Rila Monastery site. The present monastery complex is built up on quaternary deposits presented by gravels and boulders with sandy filling interlayered by plastic clays up to 3.0-3.5 m thick. The total thickness of the quaternary deposits is ranging to 16-45 m with free groundwater level is 5-9 m deep. The monastery buildings are with shallow foundations – 3.0-3.5 m deep. The inside area of the complex was filled up with up to 9 thick embankment (cultural layer). From engineering geological point of view the site is very well studied. Seismic microzoning was carried out. The present state of the buildings is bad and at some sections is critical. The revealed structural failures include fracturing along bearing walls, around windows and below the top mouldings. Most damaged is the eastern edge of the south wing where the building is with maximum height (28 m). Fractures occur in the central and western sections the south wing, less fractured is the eastern wing. The monitoring of the fixed marks reveals movements along the fractures.

The geotechnical conditions of the site are complicated by the high level of realized and the expected earthquakes in the region. According to the Paraseismic Regulations the expected seismic activity for a 1000 year period is of 9° MSK. The maximum realized seismic activity is of 9° MSK.

Three initial hypotheses for the destructing factors were tested: overall failure of the stability of the terrain; suffusion settlements of the terrain; local and total failure of the bearing capacity of the soil (fig. 5).

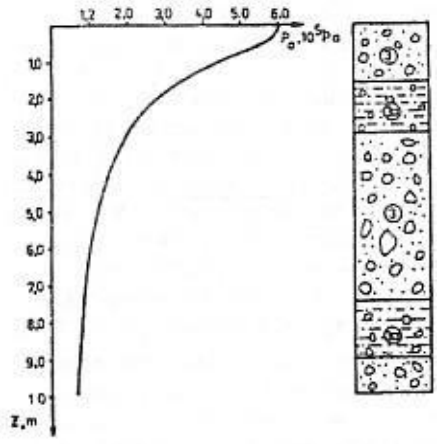

Figure 5. Stress distribution under the south wing foundations and the geological structure of the soil base (3 – alluvial gravel and boulders with sandy filling, 3a – soft and plastic alluvial clays)

The calculations results rejected the first two of them. The comparison between the foundations loading and the soil bearing capacity revealed that they are very close in range while the foundation loading is higher that the dynamic bearing capacity of the soil. So it was accepted that structural failures are consequent to a local stability failure of the soils probably initiated from the Krupnik earthquake in 1904. Further they continued due to creep processes in the soft clay interlayers. In 1934 the construction of abutments at the eastern and southern walls probably stabilized the structure. During the 60-ies parts of them were demolished and

that caused new activation of the movements. Before any action for reinforcement of the monastery buildings it is necessary to decrease the loads on the soils. The possible technical solutions include widening of the foundation and/or meliorating their bearing capacity by micro-piles.

The conclusion from the present review is that the unique cultural heritage monuments in Bulgaria are endangered by unfavourable geological processes some of them being in critical situations. Although the conditions and the trigger factors of the destructive processes are well studied and for son of the monuments technical solutions for reinforcement exist practically no action for their execution is realized. The main reason is no much the financial shortage as the lack of geotechnical competence of the decision taking authorities which results in refusing to take any responsibility while their inaction dooms the future existence of the monuments.

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