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SEPARATED GEOTECHNICAL ENVIRONMENTS DURING THE RESEARCH OF THE TERRAIN AT THE LOCATION PLANNED FOR THE CONSTRUCTION OF THE SILOS IN KOZLUK NEAR ZVORNIK

Đurić Neđo[1], Đurić Dijana[2]

[1]Academy of Sciences and Arts of the Republic of Srpska, Bosnia and Herzegovina
e.mail: nedjo.djuric@anurs.org
Faculty of Civil Engineering Subotica, Univercity of Novi Sad, Serbia,

ABSTRACT

The construction of high-rise objects in solid rocks characterized by frequent changes in its vertical profile requires a more detailed study of lithological layers, tectonic characteristics and analysis of physical and mechanical parameters. Layers of different strength and characteristics in all elements make it possible to separate it by geological environments, in order to choose the most favorable one for the foundation of objects. As part of the construction of additional silos at the existing "Molaris" Mill complex in Kozluk near Zvornik, research was conducted at the central points of the future facilities and the immediate surroundings.

Investigation works up to a depth of 12.0 m defined all the complexity of the terrain structure in a small area. Conducted research on rock samples from exploration works and from the open terrain profile showed differences in the physical and mechanical characteristics of softer rocks susceptible to solubility in water. Separated environments show that the foundation of objects cannot be done only in one environment, given the folds of the layers in a very small area.

Key words: *geotechnical environment, object foundations, characteristics of the rocks*

INTRODUCTION

At the location of the complex of facilities of the "Molaris" Mill, the construction of additional silos is planned on the plateau between the existing facilities and the cut part of the slope. In that area, the slope used to be characterized by a steep fall towards the Zvornik - Bijeljina regional road. Over time, it was cut and buildings were built on the plateau, which is at the level of the regional road. The present day appearance of the slope in the back of the buildings is of the type of subvertical incision of about 6.0 m.

The bedrock on the plateau is characterized by solid rocks, which can be connected to the rocks on the open part of the slope. Conducted field research showed that the terrain in the vertical profile is characterized by a folded shape with a synclinal dip of layers around 45^0. Softer marly rocks alternate with fairly solid sandstones of different colors in the profile. By comparing the rocks from the vertical profile obtained by exploration works and the same rocks on the open terrain profile of the subvertical cut, the differences in the softer marl rocks are shown.

The diversity of layers or geological environments in the part of the foundations of future facilities will require a specific way of connecting the construction of the building with the construction of the terrain. The degree of cracking of rocks that have been separated into geological environments is quite present. By implementing the results obtained by field and laboratory tests through the RockLab system, the parameter values reduced to the natural estimated state are significantly lower.

BASIC CHARACTERISTICS OF THE TERRAIN

The terrain of the immediate location has not been specifically studied, except as part of the preparation of the Basic Geological Map of SFRY. sheet Zvornik 1:100 000. Basic data on geological, geomorphological and structural-geological characteristics of the terrain are given in the Map Interpreter for the mentioned sheet, which are not sufficient for the details of the location where the objects are being built [1]. Previously built buildings also did not have the necessary documentation, but the construction was carried out on the basis of direct observation of the terrain during the arrangement of the plateau and the cutting of the slope.

By studying the terrain at the location of the future facilities and the immediate surroundings, certain characteristics of the terrain were recorded. It represents the extreme marginal parts of a slightly steep to steep slope with a fall of about 10-20%, and a drop angle of about 9^0 in the slightly steep, or 18^0 in the steep parts of the slope. The orientation of the slope is in the east-southeast direction, that is, with an azimuth of about 100^0. The edge of the slope is contoured on the western side by the terrace sediments of the Drina River.

According to the aforementioned BGM sheet Zvornik, R 1: 100 000 and its interpretation, the structure of the slope includes Upper Eocene (E_3) deposits, which in the milder parts are covered by thin deluvial (d) curtains. This unit includes bank quartz sandstones, conglomerates, friable gray, greenish, sometimes ferruginous sandstones, clays, clayey marls and very rarely clays. Rhythmic sedimentation is observed, with a pronounced presence of sandstone, and to a lesser extent conglomerate and fine-grained sediments of clays and clayey marls. The general direction of deposition of the layers is north-northeast (the angle of deposition ranges from about 355^0 to about 10^0), and the dip angle of the layers is from about 23^0 to about about 28^0.

During the engineering geological mapping of the core, all lithological members were followed in detail. The sampling schedule was adapted to the position of the lithological members in depth in relation to the exploration works [1,2]. Due to the synclinal deposition of the layers, the sampling depths are different, but they represented the continuity of the same layers between the exploration works. At the same time, the position of the lithological members was defined according to their vertical occurrence and horizontal extent. The layers of clastic rocks of the substratum of the terrain, which according to the engineering geological classification belong to semi-stony rocks [2], were separated:

Fine grained to medium grained sandstone

- Medium grained sandstone (1)
- Fine grained to medium grained sandstone (1)

Clayey marl (2)

- Sandstone fine grained to medium grained (1)

Clayey, sandy marl (3)

- Sandstone medium grained (1)

The layers of lithological members alternate rhythmically, forming an incomplete flysch sequence with the absence of certain members in the vertical column [2,3,]. The relationship of the mentioned rocks in the vertical profile is shown in Figure 1.

The characteristics of the lithostratigraphic assemblage classify the terrain and the immediate surroundings as conditionally favorable to favorable terrain. From a geotechnical point of view, terrains with a permissible load of > 300 kN/m2 belong to terrains of favorable stability, if other factors such as the disintegration or cracking of rocks, the inclination of the slope and strata are favorable [1,2].

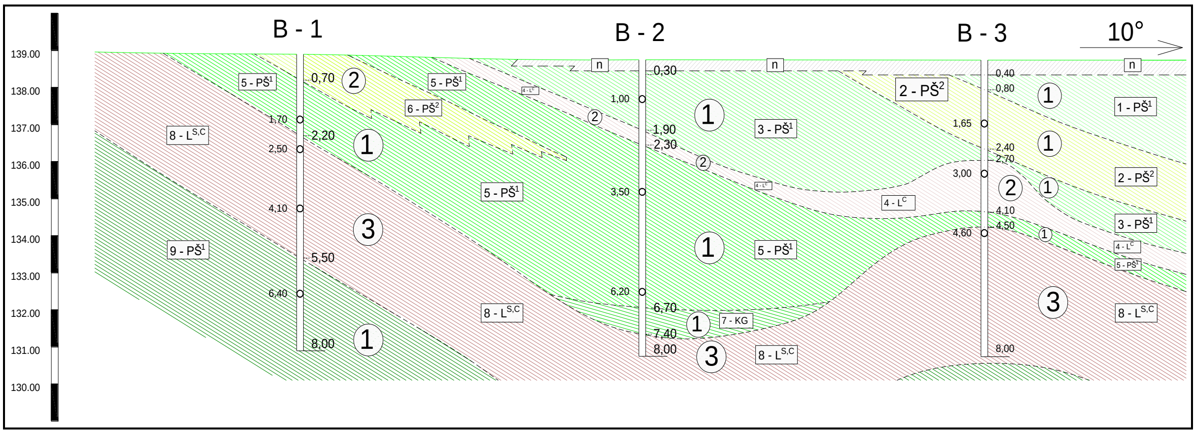

Figure 1 Terrain profile along the axis of future objcts

Directly at the location of the future buildings, the terrain in the vertical profile is characterized by layers of variable characteristics due to the presence of soft marly rocks [3]. The steep slopes of the layers make it difficult to build foundations in the same layer, which is why it was necessary to separate geological environments with the same or similar characteristics.

RESEARCH METHODOLOGY

For a more detailed study of the terrain, a research methodology was chosen that will supplement the existing knowledge and study the area of the location itself in detail. It included:

- Field research was carried out that supplemented the data of the Basic Geological Map of SFRY, Zvornik sheet, 1:100 000.
- Research works along the axis of future buildings up to the depth of the influence of their load defined the lithological members and their occurrence in depth.
- Laboratory tests included the determination of physical-mechanical and resistant-deformable characteristics of rocks in conditions of 18 – 20^0 C.

During tests in the field and in the laboratory, the data of quasi-homogeneous sediments of the first and long marly layers were correlated, for the possibility of observing them as one layer.

RESEARCH RESULTS

The geotechnical characteristics of the terrain were determined from the aspect of the terrain's properties as a working environment in which the facilities will be based. For the analysis of the geotechnical conditions for the design and construction of silo facilities at the location "Molaris" in Kozluk, the City of Zvornik, the construction of the terrain was analyzed in detail in relation to the lithological types of rocks, their position within the studied depth of the terrain as well as their mutual position, then their condition, composition, engineering geological and hydrogeological characteristics and physical - mechanical and resistant - deformable characteristics [4,5,6,7,8,9]. Correlation of the data obtained by exploratory drilling was carried out with the data of the open terrain profile located a few meters from the planned facilities, Figure 1. The subvertical cross-section of the slope shows all the complexity of the geological structure, which is also confirmed by exploratory drilling.

The terrain of the researched location, as well as the immediate surroundings to the depth of the research investigation, are built by sediments - lithological members with different physical - mechanical and resistant - deformable characteristics. Through a detailed analysis of their parameters, it was concluded that the construction of the terrain of the researched location generally consists of three (3) geotechnical environments, Figure 1. With stricter detailing, some sub-environments could also be separated. For this level of research and foundation of objects, the separated environments are characterized by lower mean values of the same or similar layers. The separated environments are:

- Geotechnical environment 1, represents a complex of layers of sandstones in more horizons of different colors.
- Geotechnical environment 2, clayey, worn out, brittle marl of gray color.
- Geotechnical environment 3, clayey, worn out, brittle marl of reddish brown color.

Geotechnical environment 1 is a complex of layers built from large clastic rocks sandstone deposited in several horizons. Sandstone rocks are fine grained to medium grained, poorly weathered to hard and well cemented material, varying in color from light gray to gray with occasional shades of reddish brown. The higher horizon is registered at different depths due to the synclinal alignment of the layers. It starts from a depth of 0.40 m and goes up to max. 2.7 m.

The lower horizons are at greater depths, although due to the cyclinal deposition of the layers, they appear in one part from the surface of the terrain. On the terrain profile, Figure 1, the middle is marked with numerical code 1, and the lithological layers with geomechanical sandstone codes as 1-PŠ1, 2-PŠ2, 3-PŠ1, 5-PŠ1, 9-PŠ1. At the bottom of the synclinal part, a layer of well-cemented conglomerate, with a lenticular character, was identified as 7 KG. The values of the parameters are in a smaller range, depending on the horizon from which they were taken, and lower mean values were adopted, table 1.

Average RQD of the environment 1 ranges from 63 to 76%.

As an environment for the foundation of objects, it is a favorable medium, stable, incompressible and has a permissible load that corresponds to individual silo objects.

Table 1. Parameters of geotechnical environment 1.

Profile mark	Lithological type	Geomechan. mark	Physical - mechanical parameters	Adopted parameters of the environment
1-PŠ^1 2-PŠ^2 3-PŠ^1 5-PŠ^1 9-PŠ^1	Fine-grained to medium-grained sandstone, poorly worn out to hard and well-cemented material	Weakly petrified to strongly petrified rock	γ = 23,66 – 26,30 kN/m³ φ = 27,0 – 32,0^0 c = 2,10 – 2,70 MPa/m^2 σ = 12,80 – 29,97 MPa ν = 0,20 – 0,26 E_{din} = 22403 – 36816 MPa	γ = 24,00 kN/m³ φ = 29^0 c = 2,40 MPa σ = 21,00 MPa ν = 0,23 E_{din} = 29000 MPa

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Geotechnical environment 2, clayey marl, worn out, brittle, gray in color with the characteristics of a quasi-plastic environment built of fine clastic rocks - clayey marl. It appears from the surface of the terrain and dips synclinally up to 4.5 m, with a thickness of about 3.0 - 4.0 m, and in the extreme part of the syncline it decreases to 0.4 m, Figure 1. On the terrain profile, it is marked with the number 2 and geomechanical with the designation of layer 4-LC. The parameter values are in table 2.

Table 2. Parameters of geotechnical environment 2.

Profile mark	Lithological type	Geomechan. mark	Physical - mechanical parameters	Adopted parameters of the environment
4-L^C	Clay marl, worn out, brittle	Weak petrified rock	γ = 24,06 kN/m³ φ = 26º c = 2,10 MPa/m^2 σ = 5,23 MPa ν = 0,22 E_{din} = 15782 MPa	γ = 24,00 kN/m³ φ = 25^0 c = 2,0 MPa σ = 5,0 MPa ν = 0,21 E_{din} = 15500 MPa

Average RQD of the environment 2 ranges around 55 %

Environment 2. is a conditionally favorable environment for the foundation of objects. In its natural state, it is stable and has a satisfactory load capacity. Engineering activities may come into contact with water from atmospheric precipitation, when it very quickly destroys its physical and mechanical characteristics to the limit of soft marly clay. At the same time, it is transformed into an unfavorable environment for the foundation of objects. If the foundation of the buildings is carried out in the middle 2, it is necessary to isolate them from contact with water.

Geotechnical environment 3, with the characteristics of a quasi plastic environment, is made of fine clastic rocks marl of clayey, sandy, brittle, dark red-brown color with rare inclusions of gray hard sandstone. It appears from the surface of the terrain and goes to a greater depth from 2.2 m to 7.4 m, that is, it follows the synclinal deposition of contact layers.

The middle has an average thickness of 2.5 - 3.5 m in the area of the silo facilities, Figure 1. On the terrain profile, it is marked with numerical code 3 and geomechanical code of layer 8-LSC. The parameter values are given in Table 3.

Table 3. Parameters of geotechnical environment 3.

Profile mark	Lithological type	Geomechan. mark	Physical - mechanical parameters	Adopted parameters of the environment
8-L^{SC}	Clayey, sandy, weathered, brittle marl	Weak petrified rock	γ = 23,57 – 25,50 kN/m³ φ = 25º c = 2,30 MPa/m^2 σ = 3,64 – 4,91 MPa ν = 0,25 – 0,31 E_{din} = 11552 – 11661 MPa	γ = 24,50 kN/m³ φ = 25^0 c = 2,2 MPa σ = 4,0 MPa ν = 0,27 E_{din} = 11600 MPa

Average RQD of the environment 3 ranges around 69 %.

Environment 3 is favorable for the foundation of buildings in their natural state. It represents a stable environment, where the rock is weakly compressible to incompressible with a permissible bearing capacity that corresponds to the designed silo facilities. In contact with water, the physical and mechanical characteristics are reduced and it passes into a conditionally favorable environment. During the execution of the works, it is necessary to take measures to protect the rocks from contact with water.

By analyzing rock strength using RocLab, lower parameter values were taken for input data. The degree of reliability of the input data of field and laboratory research in the part of investigative works is satisfactory. The data for the rock mass taken from the RocLab program package are quite well chosen [10,11,12]. Characteristics of environments recalculated in RocLab are given in table 4.

Tabela 4. Parameters of geotechnical environments calculated in RocLab

Parameters	Geolog. environment 1		Geolog. environment 2		Geolog. environment 3	
	Intact rock	Massive in RocLab	Intact rock	Massive in RocLab	Intact rock	Massive in RocLab
γ (kN/m³)	24	24	24	24	24,5	25,4
φ = (^{0})	29	37	25	31	25	28
c = (MPa)	2,4	1.343	2,0	0.255	2,2	0.178
σ = (MPa)	21	1.559	5,0	0.268	4,0	0.179
GSI	-	59	-	48	-	45
m_i	-	19	-	12	-	9
σ_{RM}	-	5.418	-	0.911	-	0.594
E_{din} (MPa)	29000	6.510	15500	1.250	11600	1.000
ε_{RM} (MPa)	-	2.518	-	339	-	224

γ – volumetric weight	m_i – a constant that depends on characteristics of the rock
φ – angle of internal friction	σ_{RM} – total strength of the rock mass
c – cohesion	E_{din} – Modulus of elasticity dynamic
σ – uniaxial compressive strength	ε_{RM} – Modulus of deformation
GSI – geological strength index	

DISCUSSION

The values of adopted parameters for separated environments are based on laboratory tests and rock quality assessment during its mapping. Taken lower average values are realistic for tests on monolithic samples [14,15,16]. The rocks in the area of the future silo facilities do not represent continuity, but there are certain mechanical discontinuities along which there may be a complete absence of cohesion forces. Therefore, there is a significant difference in strength between monolithic parts of the mass and real rock massif, as well as between different varieties of lithological members and their mechanical discontinuities.

When defining geotechnical environments that are engaged as a working environment for the foundation and construction of objects, the selection of physical-mechanical parameters relevant for geostatic calculations was made on the basis of:

- results of laboratory tests of solid rock samples, taking into account the degree of their representativeness and test conditions
- data on the real characteristics of the rock masses of the marly complex and the sandstone complex (lithological heterogeneity, structural textural characteristics, degree of cracking and characteristics of cracks, degree of surface degradation, etc.)
- existing empirical correlation links between physical mechanical characteristics, structural characteristics and rating of rock mass (Analysis of Roc/Soil Strength using RocLab)

The values obtained by the analysis in RocLab for the analyzed environments are significantly lower and they reflect the actual situation in the complete block of the rock massif. The degree of detail of the data research for this analysis was not sufficiently observed in a wider area, although in the immediate vicinity there is an open terrain profile above the height of the foundation of the building.

This method shows us the general state of the rock massif in conditions of a well studied state of the lithological members and the degree of their cracking. The results of the state of stress in the rock massif as a whole and the rocks taken in the exploration works always differ, considering that the exploration works show the real state in the point section along the vertical. It is more or less different from the situation in the immediate surroundings, which depends on the structural geological characteristics of the terrain.

CONCLUSION

The complexity of the geological structure in the small area where characteristic facilities such as silos are being built required a more detailed study of the terrain at the micro-location. Geological research carried out, which included investigative works and laboratory tests, provided basic data on the characteristics of the terrain. The presence of an open terrain profile in the immediate vicinity made it possible to correlate data with relevant works in macroscopic observation. Correlations of laboratory tests are not relevant because the rocks on the open terrain profile have been exposed to different climatic changes for years.

Frequent lithological shifts of smaller or larger layers in a small area and their synclinal bedding made it impossible to choose an adequate layer for building foundations. That is why layers with approximately the same characteristics were grouped into geological environments. Three geological environments were separated, which, in addition to the parameters of laboratory tests, were also processed through the RocLab system.

A more detailed look at the lithological composition, especially on the open terrain profile, shows that the rocks in this zone have no continuity, but a lot of mechanical discontinuities. By translating field and laboratory data through the RocLab system into the real state of the rock massif, the obtained values for the geological environment are significantly lower, but more reliable for defining the foundation conditions of the silo structures.

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