Geotechnical parameters of limestone from the Topola Formation in the area of Topola Village, Kavarna Municipality (NE Bulgaria)

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Abstract. The area around Topola Village is affected by landslide processes, which are the major factor in the formation of the modern relief. The terrains affected by the landslides are mainly composed of sediments of the Topola Formation. In the engineering-geological studies carried out in the region, main attention was paid to the geotechnical parameters of aragonite sediments and calcareous clays of the Topola Formation. The purpose of this article is to define the geotechnical parameters of the micritic limestones from this formation, which have a major stabilizing role on the lands affected by landslide processes. The mean values of bulk density, compressive strength and tensile strength of these rocks were determined. The quadratic deviation, the coefficient of variation, and the calculation value of the individual parameters, with confidence at 90%, 95% and 99%, respectively, were also calculated.

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INTRODUCTION

The studied area covers a part of the Black Sea coast, located between the villages of Topola and Bozhurets, Kavarna Municipality, NE Bulgaria (Fig. 1). The Black Sea coast is one of the regions of Bulgaria where landslide processes occur periodically. Favorable conditions for these dangerous geological phenomena are the geological-tectonic structures and the geomorphological properties of rocks and soils (Ivanov *et al.*, 2014). Amongst the rocks, namely the sediments of the Topola Formation play the major role in the formation of landslides in the area. For this reason, these materials are of considerable interest for applied geological investigations. Previous studies on the Topola Formation (*e.g.*, Koleva-Rekalova *et al.*, 1996, 1999; Ivanov *et al.*, 2014) have shown that the aragonite sediments and calcareous clays, and to a lesser extent the limestones that compose this sedimentary unit, are the main rock types that are affected by landslides. This paper aims to clarify the geotechnical parameters of these sediments, on which future predictions of occurrence and identification of instability could be based.

GEOMORPHOLOGICAL AND GEOLOGICAL SETTING

The area of this study is situated within the southeastern periphery of the Dobrudza Plateau, as the terrain is modeled by abrasion, erosion and gravitational processes (Frangov and Krastanov, 2015). There are some localities that evolved into linearly oriented stairs and hills of varying heights (Fig. 1). The coastal slope of the Dobrudza Plateau has an average width of 600–800 m and ends with steep, in many places up to vertical, slope. The terrain is often cut across by deep ravines. The latter drain a significant portion of the karst and fracture waters of the plateau. The slope of the plateau is non-draining, shaped depression with permanent or temporary marshes.

The region is composed of Quaternary and Neogene sediments (Cheshitev *et al.*, 1991, 1995). The Quaternary is represented by deluvial-proluvial and gravel-sandy clays with small thicknesses. The Neogene is composed of the Euxinograd, Topola and Kavarna formations. The Euxinograd Formation is built up mainly of gray, gray-blue and ochre sandy and clayey siltstones and silty clays, containing Diatomaceae and

Fig. 1. Location map of the studied area.

silicate sponges (Koleva-Rekalova *et al.*, 1996). It is covered by the Topola Formation, which mainly consists of unconsolidated aragonite sediments (aragonites), 0.30–0.50 m to 1–4.8 m thick, alternating with light gray micritic limestones (0.10–3.50 m) and green calcareous clays (0.40–3.20 m) of Sarmatian age (Koleva-Rekalova *et al.*, 1996) (see Fig. 2). The materials of the Topola Formation build huge landslide blocks (Evstatiev *et al.*, 2010). The Neogen strata have a slope of 3–5° ENE (Frangov and Krastanov, 2015).

METHODOLOGY

Thirty-seven samples of rock drilling cores of limestones of the Topola Formation were studied for determination of the bulk density. Additionally, 18 samples were examined for determination of dry compressive strength and eight samples were studied for determination of tensile strength in dry state. Physical and mechanical parameters of the rocks are used to determine the European standards. For the physical parameters, the EUROPEAN STANDART EN1936 (Natural stone test method – Determination of real density and apparent density, and of total and open porosity) was used. For the mechanical parameters, the EUROPEAN STANDART EN1926 (Natural stone test method – Determination of compressive strength) was applied.

RESULTS

The analysis of samples of the micritic limestone from the Topola Formation yielded the following geotech-

Fig. 2. Lithostratigraphic column on the Topola Formation.

Fig. 3. Graphics of distribution by the number of values of bulk density (g/cm^3), compressive strength (MPa) and tensile strength (MPa).

nical parameters: bulk density, specific density, compressive strength and tensile strength in dry state. The obtained values were processed statistically by defining the average (arithmetic values, X), the square quadratic deviation (σ), the correction for inaccuracy ($\Delta\sigma$), the mean deviation (σ_k), the computation value of the respective parameter (C) and the coefficient of variation (V). For each of the parameters were drawn graphics of the distribution of the number of values (Fig. 3).

Of the studied geotechnical parameters, only the specific density was not processed statistically, because only one value was done ($\rho_s = 2.73 \text{ g/cm}^3$). A value of $\rho_s = 2.76 \text{ g/cm}^3$ is established for the rest of the Topola Formation (Evstatiev *et al.*, 2017). Typical for the materials in the area is the increase in specific density in depth (Ivanov *et al.*, 2015).

The values of the geotechnical parameters of the micritic limestones, at 90%, 95% and 99% confidence, are given in Tables 1–3.

The reliability of the results has also been confirmed by other authors (Evstatiev *et al.*, 2017), the parameters for the density being $\rho_n = 2.35 \text{ g/cm}^3$, compressive strength of 36.0 MPa and tensile strength of 3.7 MPa. The values obtained for these parameters at 95% confidence are the volume density $\rho_n = 2.531 \pm 0.041 \text{ g/cm}^3$,

Table 1
Determination of the geotechnical parameter bulk density

Statistical indicator	Bulk density, g/cm^3		
	90%	95%	99%
X	2.531		
σ	0.10		
$\Delta\sigma$	0.019	0.023	0.031
σ_k	0.116	0.120	0.128
C	2.531 ± 0.033	2.531 ± 0.041	2.531 ± 0.058
V , %	3.8		

Table 2
Determination of the geotechnical parameter compressive strength

Statistical indicator	Compressive strength, MPa		
	90%	95%	99%
X	34.333		
σ	15.93		
$\Delta\sigma$	4.592	5.574	7.645
σ_k	20.518	21.501	23.571
C	34.333 ± 8.609	34.333 ± 10.951	34.333 ± 16.464
V , %	46.4		

Table 3
Determination of the geotechnical parameter tensile strength

Statistical indicator	Tensile strength, MPa		
	90%	95%	99%
X	3.375		
σ	0.45		
$\Delta\sigma$	0.209	0.258	0.377
σ_k	0.658	0.707	0.826
C	3.375±0.462	3.375±0.615	3.375±1.049
$V, \%$	13.3		

X – mean arithmetic value; σ – mean square deviation; $\Delta\sigma$ – correction for inaccuracy; σ_k – corrected mean square deviation; C – computational value of the parameter; V – coefficient of variation.

the compressive strength 34.333 ± 10.951 MPa and the tensile strength 3.375 ± 0.615 MPa.

CONCLUSIONS

From the statistical processing of the geotechnical parameters of the micrite limestone from the Topola Formation were computed values for volume density, compressive strength and tensile strength in the dry state. These values can be used in future calculations of slope stability in the studied area, and they are basic parameters in the compilation of geodynamic models of the landslides in the area. From the values of compressive strength and tensile strength, parameters of the angle of internal friction and cohesion by different correlation dependencies can be calculated. This, in turn, would save significant amounts of field and laboratory tests of these parameters of the micrite limestone from the Topola Formation.

Micritic limestones from the Topola Formation have an important role in determining the coefficient of safety on the slopes. They have reinforcement properties and their non-reading, when determining slope

resistance, results in unreal values of the coefficient of safety. For this reason, separation and characterization in engineering and geological surveys is essential.

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