UNIVERSITY OF PETROŞANI
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RESEARCHES THAT REGARD THE STABILITY OF SURFACE STRUCTURES, THE INCREASE OF THE QUALITY OF THE ROCKS USED IN CONSTRUCTIONS AND THE DECREASE OF THE IMPACT UPON THE ENVIRONMENT

DOCTORAL THESIS

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Key words: useful rocks, geo - mechanic characteristics, admissibility conditions, stability of embankments and roadbeds, road infrastructures, dumps, decantation ponds, impact upon the environment.

The relevance of the doctoral thesis is given by the need to provide the stability of the slopes, civil and industrial constructions, terrestrial networks located on embankments and slopes.

The doctoral thesis is structured in eight chapters, of which the last chapter sets forth the conclusions and the personal contribution of the author. There is also an introduction and a bibliography, which include 94 titles, of which 9 belong to the doctoral student.

As part of 25 contracts, the doctoral student made ground and laboratory researches and the results were used in the process of carrying out the doctoral thesis. The thesis includes 110 pages.

66 calculation relations, 17 figures, drawings, schemes and graphs as well as 127 tables are also included in the thesis.

Let’s also note that the bibliography consulted includes 94 references from Romanian and foreign specialized works; among which a series of articles and papers that disseminate part of the author’s own results should be set forth.

The results of the researches were included in 9 scientific papers published as a single author or as co-author.

The analysis of the content of the thesis emphasizes a series of aspects characterizing each chapter.

The introduction of the doctoral thesis includes 2 pages.

The first chapter, called **Geo-Mechanic Characteristics of the Foundation Rocks and Lands**, including 15 pages, carries out a full and complex geo-mechanic characterization of the rocks used for road infrastructures and foundation lands. The chapter operates with the mineralogical and petrographic analysis of the 5 types of rocks used for building road

infrastructures. In addition, the chapter analyses both the geo-mechanic features of the rocks and, from a rheological perspective, the clays that were found in most drilling made in the foundation lands on which road infrastructures are located.

Chapter 2, called **Admissibility Conditions of the Rocks Used for the Infrastructure of Road Networks**, includes 6 pages and analyses the admissibility conditions of the rocks used for the infrastructure of road networks. The doctoral student analysed the geo-mechanic and technological features of the magma rocks used for the road infrastructures. He also analysed and classified the rocks depending on the admissibility conditions stipulated by the standards in force.

The doctoral student carried out researches of the samples of magma rocks coming from the mining perimeters of Şoimoş Lipova, Cerbia Zam, Certej Floroaia and Valea Căpitanului, Pietroasa, Almaşul Mare, Dobra and Săvârşin. These rocks were ranked depending on admissibility conditions and were all considered to own an EXCELLENT quality. The researches carried out showed that all the rocks under analysis could be used for building road networks.

Chapter 3, called **Researches that Regard the Quality of the Rocks Used in Constructions, the Increase of the Reliability of the Surface Structures and the Decrease of the Impact upon the Environment**, includes 9 pages and analyses the quality of the rocks used in constructions, the increase of the reliability of surface structures and the decrease of the impact upon the environment. In this chapter, the quality of the rocks was analysed through 4 caser studies.

Chapter 4, called **Analysis of the Stability of Slopes and Surface Structures**, includes 28 pages where the doctoral student analyses the most modern methods for questioning the stability of the rocks in the foundation land upon which road structures are going to be located.

The chapter reviews the geo-technical researches upon the rocks collected from the County of Hunedoara and carries out a geo-static study of geo-technical parameters. The most recent analysis methods for the stability of the slopes were also scrutinised. A systemic approach of the stability issue, of the disturbing factors of the system and sub-system of the strength condition of the massif were also under discussion.

The doctoral student carried out 3 case studies regarding the stability of the roadbeds made in a homogeneous rock massif, through Fellenius, Maslov-Berer and Bishop methods.

He also made a case study concerning the stability of DN 76 Deva – Oradea and determined the stability of the roadbeds depending on the height and tilt of the slopes through Fellenius, Jambu and Bishop Methods.

In addition, the doctoral student determined, based on the case studies, the reaction of the system to the disturbing factors and the reaction of the system to these factors.

The doctoral student determined the height of the work stages depending on the manner of extracting the rocks through mechanic actions or through explosives.

Chapter 5, called **Geo - Technic Characteristics of the Rocks in the Foundation Land**, includes 27 pages, where the author carried out the geo-technical characterisation of the rocks in the 24 drills made in the foundation land on DN 75 Brad – Ştei.

The doctoral student carried out a case study that concerns DN 75 Brad – Ştei, where he made geo-technical analyses of the foundation land for the rocks collected through 24 drills and set forth the geo-physical features of the foundation land. The case study resulted in a series of conclusions that regard the geo - technical features of the foundation land and

made recommendations on the foundation depth and conventional pressure of the foundation land for each drill and layer.

Chapter 6, called **Methods for Increasing the Quality of Foundation Lands**, includes 7 pages and displays researches that regard the increase of rock quality through hydraulic binding agents' stabilisation and the stability of the optimal percentage of hydraulic binding agent. The doctoral student made researches targeting the use of the sterile rocks in dumps and ponds for road infrastructures and the possibilities for stabilizing the sterile land in dumps and ponds as well as for increasing the quality of sterile rocks. A vast case study focuses here upon the possibilities for using the sterile rocks in dumps and ponds for building road infrastructures and concrete.

Chapter 7, called **Decrease of the Impact upon the Environment**, includes 7 pages and carries out an analysis of the legislative framework and EU legislation that concern the management of waste from the mining industry and the procedures employed for decreasing the impact determined upon the environment by the waste resulting from the mining industry.

This chapter also focuses on researches that concern the condition of the tailing ponds and sterile dumps having resulted from the exploitation of deposits in the mining industry. The doctoral student also carries out an assessment of the slipping probability, the impact of waste deposits upon the environment and the relocation of waste deposits.

The chapter sets forth a series of conclusions regarding the rehabilitation of the areas affected by the mining waste deposits, which include the use of waste for concrete and the integration of the dumps and tailing ponds within the initial circuit.

Chapter 8, called **Conclusions and Original Contribution**, includes 3 pages and sets forth the conclusions and the personal contribution of the doctoral student.

The chapter includes 18 of the most important conclusions, which resulted from the researches of the doctoral student, and 29 personal contributions having resulted from his own research.

Conclusions:

The research made by the doctoral student sets forth the following:

1. The geo - technical features of the rocks belonging to the foundation land where road infrastructure is going to be located shows that most of the rocks from the foundation land are clays.
2. The geo - mechanic analysis of the rocks used for road infrastructures are magma rocks, collected from the quarries in Şoimoş Lipova, Cerbia Zam, Brănişca, Dobra, Valea Căpitanului, Săcărâmb, Almaşu Mare, Căzăneşti and Pietroasa.
3. The magma rocks analysed were ranked within stability classes and I have noticed that they rank within class A, so that they are recommended for use in road infrastructures and concrete.
4. The rheological features show that the analysed clays may be classified within the 2nd rheological class, displaying a behaviour characterising a Burgers model, with mostly irreversible deformations.
5. The class of the rocks determined depending on the technological features shows that all the rocks own an EXCELLENT quality and may be used for building road infrastructures.
6. I carried out a geo - statistic study of the parameters that influence the stability of the embankments and slopes.

7. I analysed the stability of DN 76 Deva - Oradea, through 24 drills as well as the geo-technic characterising of the rocks from these drills.
9. I settled the foundation depth and the specific pressure for the rocks in each drill.
10. Although we initially considered that the sterile deposits having resulted from the mining exploitation cannot be subsequently used, I showed that mining sterile may be used for getting non - traditional construction materials, while the dumps and ponds may be reintegrated within the previous natural circuit.
11. In Romania, 64 tailing ponds, with a surface of 1,350 ha, which contain over 350 million cube meters, namely over 875 million tons of sterile resulted from mining activities.
12. The modern methods for capitalising mining waste may have a positive impact on the environment and the economic climate.
13. Their mineralogical and chemical composition make mining waste good for producing non - conventional concrete.
14. I carried out a classification of the mining waste from a geo-technical and geo-mechanical perspective in the case of the dump belonging to Cuprumin and the tailing pond from Valea Ștefancei I.
15. I tested the concrete samples made from rocks, mining waste and cement and studied the possibility of capitalising and using each type of rock and mining waste, depending on the geo - technical features and the admissibility conditions of the rocks in the building industry.
16. The concretes made from the sterile rocks in Roşia Poieni, and cement own superior geo-mechanic features as compared to the ones made from natural aggregates and cement.
17. The concretes made from the pond sterile and cement own a compression resistance which is 3.2% higher than that of those made from natural aggregates and cement, while the concrete samples made from sterile dump and cement own a resistance which is 6.18% higher than that of those made from natural aggregates and cement.

Original contribution

The original contribution set forth by the hereby research is as follows:
1. I carried out the geo-mechanical characterisation of the rocks used for road infrastructures and foundation lands.
2. Relying on the laboratory tests, I made a ranking of the rocks under the admissibility conditions settled by the standards in force.
3. I carried out three case studies that concern the quality of the rocks used for building road infrastructures.
4. I made a vast case study for DN 76 Arad - Oradea. I characterised the rocks belonging to the 24 drills from the point of view of their geo-technical features: colloidal activity of clays, plasticity and compressibility, and I settled the geo-technical category for each layer in the 24 drills.
5. I settled conventional pressure as well as foundation depth for each layer and drill.
6. For all drills, foundation is recommended to be done on layer III, made from grey dense clay, as a foundation rock.
7. Minimal foundation depths vary between 4.40 meters and 7.20 meters.
8. Only in the case of the rocks belonging to the geo-technic profile VII-VII, area F19÷F21, foundation is recommended to be done on layer I, made of brownish – yellowish dense clay,

which belongs to the category of difficult foundation rocks, with very increased activity, while the minimal foundation depth is 2.00 meters.

9. The foundation lands, in accordance with Ts -1994, ranks within the *very hard* category in the case of clay layers and within the *hard* category in the case of the sandy and sand clay-dust layers.

10. I carried out, for the first time, the rheological characterisation of the clay rocks in the foundation land of road infrastructures.

11. I carried out the statistical analysis through a TCWIN - dedicated software and I concluded that the variation of cohesion and of the inner friction angle occurs in accordance with a polynomial function.

12. I carried out the statistical analysis of the geo - technical parameters determined in the laboratory for 120 rock samples, collected from the queries included in the study.

13. I noticed that the loss of the stability of the roadbeds and slopes may occur through the coming out of fracture surfaces within the massif, through developing non-elastic deformation areas or stress - rupture areas or through the consequences of the secondary tension condition created within the massif after building the roadbed.

14. I assessed for the first time the stability of the slopes through introducing the rheological parameters within the calculation of the stability coefficient.

15. I calculated the stability coefficient, depending on cohesion and humidity, settled under a rheological context.

16. I calculated the decrease of the resistance of clay rocks in time, while considering the humidity of the rocks, which might be influenced by the increase of the level of underground waters as a result of floods or abundant rains and the seismicity of the land.

17. I studied the case of an embankment with a 1:1.5 incline, at 10 meters depth, made in a homogeneous clay with the following geo - mechanic features: volume density of $2 \cdot 10^4$ [N/m^3], cohesion of 0.02 [MPa] and inner friction angle of 20º, and I estimated the stability of the embankment through Maslov - Berer method.

18. Through Bishop Method, I considered an embankment with a 1:1.5 incline, with an inclining angle of 33º 41'and o 10 meters height, which is made in a homogeneous clay rock, with the following geo - mechanic features: volume density of 20 kN/m^3, cohesion of 0.02 MPa and an inner friction angle of 20º

19. I applied Bishop method for an embankment with an inclining of 31º and 15 meters height, made in clays displaying a volume density of $1.9 \cdot 10^4$ N/m^3, a cohesion of 0.25 MPa, a friction angle of 38º and for the same embankment, which at 5 meters depth intersects an aquifer layer, displaying the following features: a cohesion of 0.25 [MPa], a friction angle of 12º.

20. I analysed the stability of the embankment through GeoTecB software specialised in geo-technics, in the case of Fellenius, Jambu and Bishop Methods.

21. I noticed that the roadbed on which DN 76 Deva – Oradea is located, is stable under natural humidity condition; nonetheless, stability decreases during the rainy periods, when sub-unitary values of stability coefficient resulted.

22. I carried out an analysis of the present condition of the waste deposits from the mining industry and I made a classification of the mining waste from geo-technical and geo-mechanical perspectives.

23. I carried out tests on the concrete samples made from rocks, mining waste and cement.
24. I studied the possibility of capitalising waste depending on their features.
25. I identified the possibilities of using each type of rock and mining waste, depending on the geo - technical features and the admissibility conditions for the use of rocks in construction.
26. I carried out trials that concern the matching of admissibility conditions in the case of the rocks and aggregates used for road infrastructures.
27. I analysed the impact of the mining activity on the environment factors as well as on local community.
28. I proposed new, modern methods for capitalising mining waste, which exert a positive effect on the environment.