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PHD THESIS

ANALYSE OF GEOTECHNICAL RISKS ON THE A1 HIGHWAY LOCATION, LUGOJ-DEVA SECTION, LOT 2, (KM 27 + 620 M-56 + 220 M) AND SOLUTIONS TO REDUCE THEM

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CONTENT

Synthesis of the doctoral thesis

The doctoral thesis entitled ***Analyse of geotechnical risks on the a1 highway location, Lugoj Deva section, lot 2, (km 27 + 620 m-56 + 220 m) and solutions to reduce them***, structured in seven chapters, highlights the issue of execution a goal of great importance and special complexity such as a highway.

Considering my direct involvement in the execution of the section mentioned in the title of the thesis, I had an appreciable contribution in determining the geotechnical characteristics of the foundation land and of the lands that entered the resistance structure of the highway. This allowed me to identify and assess the geotechnical risks that arose during the execution of the work, but also those that may occur during operation and to propose measures to reduce them, measures that were applied before the construction materials to be put in place, as well as solutions to stabilize the structures (embankments, excavations) during the period of use of the analyzed highway section.

The *Introduction* shows the importance of achieving such an objective for the economic and social development of Romania.

Also here are presented the purpose, objectives and research methods that were the basis for the approach to establish the geotechnical risks generated by such activities and to counteract them.

Chapter I ***The current stage of the construction of the A1 highway*** on the investigated section, after a short history of the overall project of the A1 highway, part of the IV corridor of Nădlac-Constanța Highways, details, based on the Feasibility Study, the considerations that led to the choice of a route variants that optimize costs and create as few difficulties as possible from a geotechnical point of view and of the impact on the environment for the highway section investigated in the doctoral thesis.

The Lugoj - Deva, Lot 2 motorway falls into the category of importance B - constructions of special importance, and regarding the road regime, the technical class is I. Lot 2 of the Lugoj-Deva highway, has a length of 28,600 km being divided, in turn, into five sections (A ÷ E) having a general development on the South-West - North-East direction, on a hilly relief, passing through the territories administrative of the localities: Traian Vuia, Dumbrava, Făget, Margina (Nemeşti, Zorani), Costeiul de Sus and Coșevița.

From a geological point of view, the analyzed area belongs to the Pannonian Depression, which appeared as a sedimentation basin, by sinking, on fracture lines, a portion of the Carpathian region during orogenic movements. The route of the Deva - Lugoj highway, Lot 2, crosses the Becheiului Plain on the territory of Timiș County and the Frag Hills at the border between Timiș and Hunedoara counties.

On the route of the Lugoj - Deva highway, Lot 2, the following major morphological units can be distinguished: the area of terraces and meadows; hilly area with smoother slopes; hilly area with steeper slopes.

The hydrographic network of the area crossed by the highway route on the investigated section is drained by the Bega river. To this are added anthropogenic lakes and a network of drainage and irrigation canals.

From a hydrogeological point of view, the route of the Lugoj - Deva highway, Lot 2, falls within the Timiș - Bega river basin, being delimited by two aquifer structures: groundwater aquifers and medium and deep depth aquifers.

From a climatic point of view, the researched location is located in a sector with a continental-moderate climate, with a topoclimatic plain and hilly floor, with topoclimatic shelter areas (climatic type II). The depth of frost, measured from the ground, is between 70 - 80 cm.

From a seismic point of view, the area where the highway section is located is characterized by a peak acceleration (a_g = 0.08g-0.12g), a vertical acceleration of the terrain (a_{vg} = 0.056g-0.084g) and a control period (corner) (T_C = 0.7s).

The Lugoj-Deva Highway section, Lot 2, is necessary and opportune for the creation of a modern communication route, with implications in the regional development of the area, of the fluidization of the transit traffic. Also, the construction of the Lugoj-Deva highway will increase the safety of users, will reduce travel times, and pollution currently manifested will decrease in transit areas.

On the other hand, the construction of the Highway will also have a negative impact, through the fragmentation of habitats, the removal from the economic circuit of some agricultural land areas and through pollution.

In the last part of the chapter a detail is made of the current situation of the analyzed section on the five sections in which it was divided. The area is described, the works executed on each Section (earthworks, works of art, etc.) and their stage of realization are presented.

The studied highway section is 100% executed and put into operation in March 2017 between km: 27 + 620 ÷ 43 + 000 and in April 2018 between km: 43 + 000 ÷ 47 + 090. The traffic area is the first area listed above, although the second area is also 100% functional, it is not used because Section E between km 47 + 090 ÷ km 56 + 220 is not completed.

Chapter II ***The geomechanical characteristics of the basic land and of the lands used for the construction*** of the highway is made in order to present the geotechnical investigations carried out both on the basic land and on the lands used for the construction of the analyzed highway section.

I mention that, both before and during the execution of the highway lot, as head of laboratory of the Central Construction Laboratory CCF-Bucharest I was directly involved in conducting geotechnical studies on the highway section, Lot 2 which is the subject of the doctoral thesis. At the Studies performed on the boreholes presented within this project, centralized in the Annexes attached to the thesis, we had a personal contribution to the realization, verification and centralization of all physical and mechanical tests performed on this section.

The geotechnical investigations of the basic land were carried out for each Section (A ÷ E) separately based on the 180 boreholes (with depths between 6.00 m and 35.00 m) and 33 dynamic penetrations made on this highway section. Continuous samples were collected from the boreholes, alternately every 2 meters and / or at the change of layer, undisturbed soil samples and cores that were analyzed in the laboratory, in accordance with the standards in force. If there was a water infiltration or a hydrostatic level in the boreholes, they were mentioned in the borehole.

Laboratory analyzes were performed on the samples taken, disturbed (T), undisturbed (N) and cores (C), in accordance with the standards in force. The detailed results of the laboratory tests performed, for the section that is the subject of the doctoral thesis, are given in Annexes 1-4 attached to the doctoral thesis. Laboratory analyzes and geotechnical investigations allowed a detailed assessment of the characteristics of the rocks encountered along the Lugoj - Deva, Lot 2 highway, rocks / stratifications that were divided into horizons with similar physical and mechanical properties. In Chapter II, §II.1, these characteristics are presented in detail.

Along the Lugoj - Deva highway, Lot 2, difficult lands were also encountered: low cohesive lands and lands with high swellings and contractions - PUCM (active lands) which were taken into account when designing the works.

The materials encountered in depth, which will form the foundation of the road system or the road bed are made up of: clays, sandy clays, dusty clays, clayey sands, dusty sands, sandy powders and clayey sandy powders.

According to PD 177-2001, they fall into the category of P3, P4 and P5 soils that are sensitive and very sensitive to frost. Because the construction of the highway is made of local materials, it was necessary to determine the geomechanical characteristics of the land used for construction. In terms of quality, according to STAS 2914-84, the lands for earthworks investigated up to a depth of 1.00 - 2.00 m below the red line fall into the categories: 3a-mediocre, 3b-mediocre, 4b-mediocre and 4d -rea. For the filling, in the body of the embankments, cohesive material was used.

As a result of the results obtained, through laboratory investigated (physical-mechanical characteristics, frost-thaw verification) they could be used for fillings in the body of the highway, complying with the requirements of the regulations in force.

Chapter III ***The analysis of the stability of the highway section*** is necessary to highlight the weaknesses of the construction of the highway section under study.

The method that was the basis for the analysis of the stability of the embankments is the Bishop limit equilibrium method, using the SLOPE / W program - 2007 version.

In the stability analysis, both potential circular and polygonal sliding surfaces (blocks) were taken into account. For each type of geometry of the potential slip surfaces, after determining the surface with the lowest stability factor, the program runs a procedure for its optimization. In the end, corresponding to the minimum stability factor, a surface with compound geometry resulted when in the natural terrain there are layers with significant variations of the shear strength parameters.

Settlement calculations were performed with the Settle3D program. It is used for 3D analysis of vertical consolidation and subsidence of the land under the action of surface loads (foundations, embankments).

With the help of the SLOPE / W program, version 2007, the minimum effective safety factors were calculated $F_s^{efective}$ for both circular and polygonal surfaces in case of consideration and seismic effect.

Areas were identified, on sections A ÷ E, where the foundation ground does not comply with the characteristics imposed by the standards and norms in force resulting in a safety factor $F_s^{efective} < 1,1$, which required further improvements (in the design phase) that have consist of stone blockages, ballast cushions, geogrids and geotextiles.

These safety measures have been taken to increase the load-bearing capacity necessary to maintain the body of the motorway and to avoid the risk of the phenomenon of failure, cracking or uneven compaction.

The centralization of the data obtained for the five Sections on Lot 2 is presented in tables no. III.1- III.5 and in figures no.III.6 - III.17 are given the stability investigated (calculation of the minimum safety factors) using the SLOPE / W program for the calculation sections from table no.III.5. I specify that I performed such investigated for all the calculation sections on the investigated highway section based on the data in tables III.1-III.4 and the physical-mechanical properties determined and presented in chapter II, §II.1.3 .

During the execution stage, specific laboratory tests were carried out along the entire length of the highway section to verify the foundation ground, performing, according to the mandatory conditions imposed by the standards, degrees of compaction and determination of load-bearing capacity (Benkelman). The calculation sections as well as the tests performed on each section with the results obtained and the materials tested, have been centralized in Annex 5.

The conditions imposed by the norms in force, for the verification of the execution of the foundation land, of the filling in the highway embankment and of the road structure are presented in table no. III.6, and in fig.nr. III.18 are represented graphically the values obtained of the degree of compaction on the sections studied for the foundation ground.

Similar representations were obtained for the filling and the road structure, the results obtained are admissible values. As it results from the centralization of the data in Annex no. 5, the foundation ground was improved with a contribution of 2.5% hydraulic binder, in order to reduce the humidity and obtain a load-bearing capacity higher than the one required by the norm.

The deformability (deflection) of the terrain was established by measurements with lever deflectometer, according to the Norm for determining by deflectography and deflectometry the load-bearing capacity of roads with flexible and semi-rigid road structures, indicative CD 31.

The permissible values of the deflection at the level of the foundation ground, at the upper level of the embankment (without form layer) or at the lower level of the form layer are depending on the type of soil (table no. III.7 and fig.nr.III.19).

In the last part of the chapter, the dimensioning of the road structure was performed on the five Sections, which consisted in (cf. of the PD 177 - 2001 Norm): the establishment of the calculation traffic; establishing the load-bearing capacity at the level of the road bed; choosing the composition of the road system; road system analysis at the request of the standard axle; establishing the traffic behavior of the road system; checking the action of the freeze-thaw phenomenon.

The chapter ends with a series of conclusions regarding the stability of the road system related to the analyzed section.

Chapter IV ***Risk analysis on the site of the A1 motorway on the analyzed section*** can be considered basic for solving the imposed topic, because it responds to the topic of the doctoral thesis.

After some theoretical considerations regarding the definition and assessment of risks, we move on to highlight the risks that may occur along the analyzed highway section, risks associated with material damage and potential human losses caused by the occurrence of these natural phenomena, such as landslides. (slopes, slopes, etc.).

In Romania, there is so far no single method for assessing the level of major risks. The estimates that are currently being made, in this respect, are based on post-accident analyzes, respectively indices of frequency and severity of these events.

Globally, the idea of safety diagnoses in industrial units is relatively old, but even here, in a few cases, operational and generalizable working tools have not been reached. The various procedures and methods developed are either low in applicability or simplistic, not systematically addressing the full range of major risk factors.

In order to assess the risks on the site of the A1 motorway, on the analyzed section, the general characteristics of the section were established and the most important risks were identified, which must be taken into account both in the design phase of a road and in the its exploitation: geotechnical risks; network / system risks; the risk of exceeding budget and time limits; maintenance risks; rising costs; lack of traffic; lack of benefits generated by economic development.

In the thesis, the research was directed especially on the assessment of geotechnical risks, a requirement imposed by the theme of the paper and was carried out according to Standard NP 074 which introduces three geotechnical categories associated with geotechnical risk.

To define the geotechnical risk, five factors were taken into account: field conditions; groundwater and surface water; the importance class of the construction; the neighborhoods and the seismic area, to which points were assigned depending on the concrete conditions of the analyzed section, conditions that were presented in detail in the thesis.

Analyzing the geotechnical risks on the site of the Lugoj-Deva highway, Lot 2, we established that the highway falls into geotechnical category 2 with moderate geotechnical risk, which demonstrates that there are no serious geotechnical problems for the analyzed highway section.

Regarding the network / system risks, they refer to the construction of other connection sections. If the studied motorway section (Lugoj-Deva) remains isolated, it will not be economically viable.

Risks of exceeding the budget and time limit may occur as a result of delayed land acquisition, identification and relocation of utilities, etc., if it is considered that this part of the highway depends on the construction of other sections, so delays in procurement and implementation that would may appear on the other sections is exceptionally reflected on the Lugoj-Deva section, Lot 2. Also, the procedures for obtaining land may be considerably delayed by the lack of a clear record of the owners of each plot of land, physical locations and boundaries between they.

The maintenance risk can be major if we consider the history of road network maintenance in Romania, which has demonstrated an inadequate allocation of resources, resulting in the fact that in many places the road network does not meet the needs of traffic.

In terms of investment costs, costs were slightly higher than estimated, but, given the complex nature of the land, according to estimates, the final capital costs for the Lugoj-Deva highway, Lot 2, were within the agreed margin. +/- 20%. It seems that there are no substantial risks, which would involve extraordinary differences in investment costs and lead to an increase of over + 20%.

It is anticipated that there will be no shortage of traffic, it will continue to increase and as long as the introduction of tolls is not expected in the short term, there is no reason to assume that this traffic will not use the highway, where it provides the right level of service. However, there may be an inverse risk, in the sense that the motorway attracts and diverts considerable traffic flows to it.

This section of highway depends largely on the economic development of the area along it. Therefore, the risk would be that the economic development will be very slow, making it possible that the highway will not produce the anticipated benefits. However, given the timely execution of road works on this part of Corridor IV, the risk is considered to be minimal.

Chapter V ***Solutions for reducing the geotechnical risks on the location of the investigated highway section*** completes the requirement imposed by the topic of the doctoral thesis.

This chapter presents the solutions / measures to reduce the geotechnical risks on the site of the investigated highway section regarding the ground and groundwater and surface water conditions.

As a complementary measure that can contribute to reducing the geotechnical risk, a series of solutions have been given related to the protection of the environment in the area related to the highway section.

With regard to improving the quality of the base / foundation soil, the stabilization process consisted of introducing and mixing additives (stabilizing agents) into the soil, in powder or suspension form, for the main purpose of improving volume stability, strength, permeability and durability of the soil.

The materials used to stabilize the foundation ground were cement and lime, both as unique binders and mixed with other materials such as: fly ash, bentonite, fumed silica, bitumen, blast furnace slag, etc.

The technologies and procedures used to stabilize the foundation lands were: shallow piles, Jet grouting and Compaction grouting presented in detail in the thesis. The solutions to improve the stability of the resistance structure, to prevent, combat and remedy landslides proposed and presented in detail are: geometric, hydrological, mechanical, physical, chemical and biological.

Regarding the solutions for improving the quality of the base terrain as well as the stability of the resistance structure, the following can be concluded:

• the main effect of the stabilization of the foundation land consists in the increase of the shear resistance of the earth, which leads to the obtaining of a superior load-bearing capacity, respectively to the possibility of supporting higher loads. In addition to increasing the resistance, the stabilization process also has effects on the permeability of the soil in the sense of decreasing it, which means a stabilization of volume variations. As the permeability decreases, so does the degree of compressibility of the soil, thus providing greater safety to buildings located on such land;

• the stabilization procedure was chosen depending on the geotechnical characteristics of the site, the economic conditions as well as the execution conditions (existence and location of the execution equipment);

• cement stabilization is effective in the case of clay soils and less effective in the case of organic soils or those with high plasticity. However, in the latter case it is possible to obtain increases in strength by the addition of an additional source of calcium, which provides an additional amount of calcium ions necessary for the chemical reaction to take place;

• lime stabilization is quite effective especially in the case of clay soils. In the case of granular soils or those with small clay fractions, the efficiency of the method is quite low. In general, lime is effective for soils whose plasticity limit is between 10% and 50%;

• where the use of cement or lime does not lead to the desired strengths, these materials can be mixed with others to obtain the desired properties. The composition of the stabilizing agent will be made only after knowing the initial geotechnical characteristics of the earth;

• in recent years the land stabilization procedures have developed more and more, now it is possible to stabilize the land to great depths (45 m), and, in special conditions, even to greater depths. The stabilization of the foundation lands by means of the columns with stabilizing agents has a double role, with effects on the improvement of the geotechnical characteristics of the surrounding land, as well as with the role of resistance piles for the respective construction.

As a general conclusion, the entire foundation ground of the studied highway was stabilized with different binders depending on the description of the material, in order to obtain a superior load-bearing capacity. For the same reasons, part of the filling material used in the body of the motorway was stabilized to obtain the necessary load-bearing capacity.

We found, through direct participation in the execution works of the analyzed section, that a large part of the solutions to improve the stability of the resistance structure, presented in this doctoral thesis, were put into practice in the studied section (berms, benches, gutters), walled ditches, drains, geotextile drains, hydraulic binders for improvement, compaction and reinforced earth structures with geosynthetic materials, etc.).

As remediation works, protection, support and consolidation of the road body were proposed: anti-capillary layers, interception drains, geogrids, reinforced earth support structures, continuous foundations of parapets and reinforced gutters and surface water evacuation works. (ditches, gutters and drains).

The proposed environmental rehabilitation solutions will also have the role of stabilizing the resistance structure of the highway. These consist of: planting ornamental trees and shrubs of different species and sizes; lawning of slopes related to the section; installation of geogrids in order to stabilize the slopes. The indigenous plant background consists of species of trees, shrubs and grasses. In figures no.V.11 - no.V.13 are presented the solutions for locating this vegetation on the highway section.

In order to assess the functional risk and plan the actions in case of identification, following the inspections, of the damages of some road structures, the way of highlighting, explaining and taking action to remedy them was shown.

At the end of the chapter, some considerations were made on the need to monitor the construction (of the highway section) after its commissioning.

The monitoring program must take into account the indications from SR EN 1997-1- Chapter 2.7, Observational Method and also be prepared in accordance with the provisions of Order 847/2014 - PCU004 being carried out by the Contractor.

The monitoring of the embankment will be done by installing the following tools:
extensometric rods, metal parts (s) for precision topographic measurements and metal nails, positioned in connection with the connecting plates of structures / works of art.

The control methods provided are: instrumental and topographic control, topographic control and visual control for the entire project in order to identify any undulations / waves / repulsions of the asphalt or damage that may occur and which are due exclusively to possible landslide failures by loss of load capacity.

The chapter ends with a series of recommendations for reducing the geotechnical risks on the analyzed highway section:

- in all areas where the road is excavated to make guard ditches, berm ditches, immediate protections on the slope by revegetating the entire surface of the slope (achieving twinning steps) and anti-erosion systems (eg. protections with geosynthetics in weak areas cohesive);

• for embankments higher than 6.00 m and / or those located in the major riverbeds, valleys and ponds, floodable areas where the foundation soil is composed of fine and very fine particles, the slope inclination will be determined on the basis of a calculation stability;

• for embankments located on lands with low load-bearing capacity (swampy areas), it is necessary:

- excavation of unsuitable material from the foundation and its replacement with cushions of granular material or broken stone (broken stone blockages) and / or the use of geosynthetic materials;
- ensuring a high degree of compaction of the foundation layer;
- surface water drainage

• low-consistency soils such as: muds, muds, peat soils with a water-soluble salt content of more than 5%, lumps of earth or soil with putrescible substances (furrows, branches, roots, etc.) are not used in the embankments;

• the construction of embankment embankments, in which 4d (inorganic) symbol lands are used, the quality of which is bad, it is recommended either to replace them or to stabilize them. The average thickness of the vegetal soil on the area of the embankments is 0.40 m.

Chapter VI ***Research on the construction of tunnels on Subsection E2*** can be considered a detail on the underground execution of a segment of the highway section analyzed in the thesis.

As this part of the motorway in Lot 2, subsection E2, between km 52 + 880 and km 55 + 420, crosses an irregular hilly area, in order to avoid the construction of large ditches, it was proposed to cross it with 3 tunnels, a solution that later it was modified and it was decided that in the end only two tunnels with a length of approximately 2.13 km would be executed.

From the multitude of problems related to the execution of a tunnel, this chapter investigates the following aspects: geotechnical investigations of the areas to be crossed by tunnels, analysis of tunnel stability, static verifications of the final support / lining, a possible tunnel execution technology and, Finally, some considerations regarding the monitoring of tunnel execution.

Based on the general characteristics of the area, geology, geomorphology and climatic conditions presented in Chapter I of the thesis, but with details and in this chapter it was established that the area crossed by tunnels falls into geotechnical category 3 with major geotechnical risk.

The stability analyzes were performed with the MEF Plaxis® 2D v.2015 program, with which the calculation models with finite elements in flat deformation (2D) were built, in the hypothesis of the elasto-plastic behavior of the ground in which the tunnels are dug, taking into account consider the stress-strain characteristics.

The calculations were performed at the operating limit state (SLE) and the ultimate limit state (SLU, groups 1 and 2) in static conditions, as well as at the ultimate limit state (SLU) in earthquake conditions.

Two cross-sections were investigated, representative of the entire route of the galleries / tunnels, namely:

• section 1, in which the thickness of the rocks covering the tunnel is approximately equal to its digging diameter (16-18 m);

• section 2, in which the thickness of the rocks covering the tunnel is equal to the maximum value encountered along its route (35 m).

The calculations were carried out, in steps, in 16 phases resulting in the calculation schemes presented in table no. VI.4. For the section where the thickness of the rocks covering the tunnel is equal to the maximum value encountered along its route (35 m) (section 2).

The calculations made allowed to obtain the entire evolution of the state of stresses and deformations of the tunnel (gallery) -ground complex. It was possible to evaluate the extent of the plastic areas around the excavation and the order of magnitude of the movements on the perimeter of the gallery. At the same time, the states of solicitation were obtained in the pre-lining and the final lining in different phases of execution. Thus, it was possible to evaluate by numerical modelling with finite elements, for the two representative sections of the tunnel route, the following geomechanical characteristics that affect in the long term their resistance structure: total displacements / deformations (SLE investigated); relative shear stresses τ / τ_{max} (SLE and SLU investigated - group 2); bending moments in the final support / lining (investigated SLE, SLU- group 2 and SLU with earthquake).

The distributions of the analyzed geomechanical characteristics (SLE and SLU) for section 1, phases 15 and 16 are represented in figures VI.3-VI.8, and in figures VI.9-VI.14 the distributions of the same phenomena for section 2, phases 15 and 16.

Static checks of the final support / lining were made in the two sections characteristic of the route of a gallery / tunnel (1 and 2) and depending on the reference limit state (SLU and SLE). The choice of the size of the support / lining was based on the Norm with the code NP112-2014.

Tables no. VI.5 and VI.6 summarize the results of the calculations to verify the stability of the final support / lining of the tunnels taking into account the values of the geomechanical characteristics established using the MEF program (Plaxis® 2D v.2015), results that were partly set out in the preceding paragraphs.

Considering the values of the safety coefficients determined for the two calculation elements (eraser and cap) it can be concluded that the dimensions chosen for the final support / lining of the tunnels are satisfactory for the stability of the construction as a whole.

Analyzes to determine the behavior of the rock / earth mass during the excavation of the gallery / tunnel and to identify possible interventions to stabilize the excavation and stop the deformations within acceptable limits showed that the fronts are unstable in the absence of reinforcements, which requires support / linings immediately behind the advancing front.

For the construction of each tunnel, it is planned to divide its length into two different sections, each characterized by small differences related to the execution technology.

For each of them, the works that will be executed, at the stage of the current knowledge of the land stability, are the following:

- <u>For the entrance section and the next 20 m</u>: outdoor micropilots; consolidation of the front with VTR elements (classic tubes); excavation of rocks in the tunnel section; temporary support / lining consisting of welded mesh shot and metal belts (double T profiles); the realization of the overturned arch / eraser on the already excavated section of the tunnel; making (depending on needs) radial anchors; making radial drainage tubes and collector; waterproofing with PVC membrane protected above and below by geotextile of minimum weight 400 g / m2 coupled with PVC membranes of thickness ≥ 2 mm; final support / final reinforced concrete lining throughout the section.
- <u>For the current section</u>, the same steps presented above are valid, with the following modifications: there are no micropilots; the final support / final lining can only be reinforced at the overturned spring / eraser and not in the cap. In addition, an additional procedure can be considered, namely the radial arrangement of anchors on the cross section of the tunnel.

The tunnel execution technology presented in this chapter is the one also proposed in Technical Project, but currently the E2 tunnel section is again tendered, so it is possible that the new designer will propose another tunnel execution technology, such as it would be the one with drilling the ground on the whole section of the tunnel.

The geotechnical researches carried out and presented in the thesis remain basic and can be used for any chosen technological variant.

The construction of a gallery is always accompanied by a change in the state of effort-deformation of the land around it, which leads to active stresses on the support of the gallery (tunnel lining, in our case) and sealing structures, stresses that may depend on many factors. influence cannot be accurately predicted in the design phase.

That is why it is indispensable to set up an instrumentation network, during the execution of the work, through which to permanently control the deforming behavior of the lands and its evolution. Based on the measurements, it is possible to highlight, in advance, any anomalies or situations of potential danger that require additional interventions, namely the adoption of execution methodologies different from those normally used.

Monitoring consists in: controlling the state of stresses-deformations of the land inside the excavations; checking the safety of excavations during the construction of structures; providing data on the execution technologies adopted; evaluation of the effective behavioral response of the massif to the applied calculation hypotheses.

The parameters that need to be monitored are: the distribution of deformations in the field; displacements of the excavation walls (convergence) and of the advancing front (extrusion); ground-presupport interaction pressures; lining demands (supports).

Chapter VII ***General conclusions and personal contributions*** summarizes my entire approach to solve the given topic and ends with a timely presentation of personal contributions to research conducted to meet the stated goal.

Given my direct involvement in the execution of the highway section, Lot 2, Lugoj-Deva, I consider that the main contributions I have made to solving the topic of the doctoral thesis can be summarized as follows:

• studying and investigating the location conditions (geographical, geomorphological, climatic, biodiversity, human settlements in the vicinity and the current stage of works) of the section of the A1 motorway, Lot 2;

• centralization of materials encountered in drilling and delimitation of the horizons of alluvial deposits;

• performing, verifying and centralizing all physical and mechanical tests performed before and during the execution period of this section;

• checking the quality of the materials used and the quality of execution;

• determination in the laboratory and in situ of the geotechnical characteristics of the materials underlying the foundation of the highway and of the deformability conditions of the natural terrain along the section with the identification of all the rocks encountered after the discovery of the studied section;

• determination in the laboratory of the physical-mechanical characteristics of the lands used for the construction of the highway (embankments) on the section studied;

• determining the stability of the investigated highway section using the SLOPE / W program - 2007version;

• dimensioning the road structure related to the investigated section;

• risk analysis, in general, the detailed geotechnical ones that may appear on the investigated section with the classification of this section in the geotechnical category 2 with moderate geotechnical risk;

• establishing and detailing solutions to reduce geotechnical risks on the site of the investigated highway section;

• establishing the geotechnical characteristics of the areas to be crossed by tunnels and their stability;

• proposing a possible tunnel execution technology on Subsection E2.