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Risk assessment through Romanian codes in geotechnical engineering

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ABSTRACT: The paper presents matters related to risks in geotechnical works and structures in two Romanian technical regulations: Code NP 074-2007 regarding geotechnical documentations for constructions and Code NP 120-06 on the design and construction requirements for excavations in urban areas.

Keywords: code, risk, hazard, geotechnical category

1 INTRODUCTION

By its very mission, any code in the field of geotechnical engineering, be it for design or for execution, is aimed at reducing to acceptable levels risks associated with the construction of geotechnical works. In most situations, the notion of risk is not even mentioned as such.

There are, however, cases in which risks are explicitly present in the code. Two such cases, are found in the list of technical regulations currently in use in Romania. Matters related to risks in the two Codes will be presented in what follows.

2 THE CODE NP 074 REGARDING GEOTECHNICAL DOCUMENTATIONS FOR CONSTRUCTIONS

In 2007 started to be applied the Code NP 074 – 2007 regarding the geotechnical documentations for constructions [1]. This represented an improved version of GT 035 – 2002 "Guide for the elaboration and verification of geotechnical documentations for constructions", the first of this kind in Romania.

Both GT 035 - 2002 and NP 074 – 2007 stipulate that the nature and content of the geotechnical documentations are differentiated depending on the design stage and on the geotechnical category. Three geotechnical categories are introduced, as in the Eurocode 7 Part 1, in order to establish the geotechnical design requirements.

NP 074 – 2007 shows that the geotechnical category is associated with the geotechnical risk, which is low in the case of the geotechnical category 1, moderate in the case of the geotechnical category 2 and high in the case of the geotechnical category 3.

NP 074 - 2007 recommends a methodology for establishing the geotechnical category.

At first, four criteria are considered:

- ground conditions
- ground water conditions
- class of importance of the construction
- vicinities

For ground conditions, three groups are defined: good ground conditions, medium ground conditions and difficult ground conditions. As good ground conditions are considered, for instance, dense non-cohesive soils and fine soils having consistency index $I_c \geq 0.75$. As medium ground conditions are considered, for instance, medium dense non cohesive soils and fine soils having $0.5 < I_c \leq 0.75$. As difficult

soils are considered loose non-cohesive soils, fine soils of low consistency (Ic< 0.5), loesssial collapsible soils prone to large settlements when wetted, expansive clays a.o.

For the ground water conditions, three situations are considered:

a. excavation is above ground water level, no dewatering is required;
b. excavation descends below the ground water table, but routine dewatering works are anticipated, implying no damages to structures in the vicinity;
c. excavation descends below the ground water table under exceptional hydrogeological conditions, requiring exceptional dewatering works.

For the classification of constructions, the classification in four classes of importance, according to the governmental act 766/1997, is used:

- exceptional
- special
- normal
- low

The geotechnical category depends on the way in which excavations, dewatering and foundation works associated with the structure to be designed can affect structures and underground networks situated in the vicinity. From this stand point, the risk for the structures and underground networks can be considered:

a. non-existent or negligible
b. moderate
c. major

NP 074 – 2007 gives in the following table three examples of correlations between the four factors previously described:

Table 1.

Factors to be considered	Examples of corelation					
	Example 1	Points	Example 2	Points	Example 3	Points
Ground conditions	Good	2	Medium	3	Difficult	6
Ground water conditions	No dewatering	1	Normal dewatering	2	Exceptional dewatering	4
Class of importance of the construction	Low	2	Normal	3	Special exceptional	5
Vicinities	No risk	1	Moderate risk	3	Major risk	4
Geotechnical risk	Low	6	Moderate	11	High	19

The recommended methodology, in order to define the geotechnical category, implies the following steps:

- to each of the cases pertaining to the four factors specified in the table 1 is attributed a number of points, corresponding to the respective case;
- the sum of points corresponding to the four factors is made;
- to the points thus established are added points corresponding to the seismic zone in function of the design ground acceleration a_g defined in the Code P 100/1/2006, namely:
  - two points for zones having $a_g \geq 0.24$ g;
  - one point for zone having $a_g = (0.16 \ldots. 0.20)$g

The decision on the geotechnical category is made on the basis of the total number of points, according to the table 2.

Table2.

No	Geotechnical risk		Geotechnical category
	Type	Range of points	
1	Low	6 … 9	1
2	Moderate	10 … 14	2
3	High	15 … 21	3

3 THE CODE NP 120-06 ON THE DESIGN AND CONSTRUCTION REQUIREMENTS FOR EXCAVATIONS IN URBAN AREAS

NP 120-06 [2] was prepared by the authors following a number of incidents occurred during the execution of deep excavations in Bucharest, which revealed that the risks associated with such works were not properly assessed.

The list of potential users is large: investors, beneficiaries of the construction works, public authorities involved in the authorization process of constructions, designers, contractors, specialists undertaking inspection and quality control activities, specialists from insurance companies.

The scope of the Code is twofold:

- the use by the target public of the basic requirements concerning the design and construction of deep excavation;
- the definition of specific requirements for the monitoring of the new construction and of the neighbouring buildings during the execution and the exploitation.

A whole chapter in the Code is devoted to risk sources (hazards) associated with the construction of deep excavations in urban areas, which have to be considered in the design and execution of these type of works.

In what follows, risk sources mentioned in NP 120-06 are briefly presented:

1. risk sources generated by the position of the site in the urban plan
   Sites located in urban areas are distinguished by at least one of the following peculiarities:
   - the presence in the immediate vicinity of buildings and/or historical monuments;
   - existence on the site or in the immediate vicinity of underground networks (water, sewage, gas, electricity etc);
   - the proximity of public transport means;
   - various surcharges;
   - juridical aspects regarding the limits of the property and effects generated by the new construction beyond these limits.
2. risk sources generated by the geometrical characteristics of the deep excavations
   The shape and dimensions in plane, as well as the depth of the excavation, represent sources of risk.
3. risk sources generated by the ground conditions on the site
   A heterogeneous stratification, including layers with unfavorable mechanical properties, a groundwater level above the final level of the excavation or of a water layer under pressure below the final level of excavation, the lack of an impervious layer to allow the embedment of a trench wall or a sheet pile wall, are just some examples of sources of risk due to the geotechnical or hydrogeological peculiarities of the site.
   A second group of risks associated with ground conditions derives from the fact that ground investigation is based, inevitably, on a limited number of borings, open pits and field tests and on laboratory tests on a relatively small number of samples. Hence, the risk of not putting into evidence geological peculiarities with great relevance for the design and execution of the excavation or geotechnical parameters representatives for various layers.
4. risk sources occurring at the design of the deep excavation
   Even when ground conditions are well established and the design is entrusted to specialists using methods accepted in the current design practice, one should recognize that the accuracy of geotechnical computations is limited. This requires the use of a design strategy able to diminish or eliminate this source of risk, in first-place by adopting adequate safety factors.
5. risk sources occurring at the execution of the deep excavation
   Regardless the solution adopted, deep excavations should be considered as works with special character. Each component of such a work brings, through the technics and materials used, its own source of risk. To add those presented by a contractor without the experience of works in similar ground conditions or lacking adequate equipments.
6. risk sources generated by the seismic action
   Romania is a country of high seismicity. The Code NP 120-06 shows that the occurrence of an earthquake during the life of the work should be considered for both the work itself and for the buildings and installations in the vicinity. Check must be performed, to observe that stresses and deformations are within acceptable limits.

In other chapters of the Code, particularly those devoted to various solutions which can be selected for deep excavations, details of possible sources of risk are given.

For instance, in the case of diaphragm walls, a number of sources of risk are identified, such as:

- the use of a bentonite suspension with unfavorable characteristics resulting from preparation or produced by the seepage, which could lead to the collapse of the wall during excavation;
- a too high velocity in the circulation of the ground water, which could remove fine particles from the freshly poured concrete and affect the imperviousness of the wall;
- an insufficient difference between the level of the mud in the trench and the ground water level, with unfavorable consequences on the stability of the wall during excavations;
- lack of ensuring a non-interrupted development of execution phases (excavation of the panel, placing the reinforcement cage and joints formwork, concreting, removal of formworks) and lack of compliance with the minimum and maximum time intervals admitted between phases, with negative consequences on the capacity of the wall to retain water, both along the panels and at joints;
- the use of too long panels, reducing the number of joints but increasing the risk of a non-adequate concreting and the development in the concrete mass of mud inclusions, through which significant volumes of water can flow, particularly under high water pressures (when the high level of the groundwater is associated with a very deep excavation);
- a too high density of bars in the reinforcement cage (bars too close to each other), with unfavorable consequences on the quality and imperviousness of the concrete;
- the way in which are made the vertical joints between panels as well as horizontal joints between the wall and the slab;
- lack of the required verticality of the panel.

The Code enumerates also the sources of risk linked to the use of ground anchors with unfavorable consequences particularly in situations of superposition of factors such as the high level of the groundwater table, the influence of the variation of this level on layers of soils easily carried by the flow of water, the large depth of the excavation, the creep of clay soils, the great length of anchors, the presence in the immediate vicinity of buildings and utilities.

The responsibility of the Contractor to ensure a good sequence among the phases of the excavation works and a tight correlation between excavation works and construction works to follow, is underlined in the Code. Large time intervals between the correlation of the excavation and construction works such as placing the reinforcement bars and concreting the slab represent a major source risk both for the excavation itself and for the structures in the vicinity.

Reference is made in the Code to the Eurocode 7 Part 1 and to the series of European standards on the execution of special geotechnical works.

A distinct chapter is reserved in the Code to monitoring works, pertaining both to the excavation itself and to constructions in the vicinity. A monitoring project, as part of the project of the deep excavation is compulsory. The Code stipulates that the costs incurred by all monitoring works must be supported by the investor of the new structure the deep excavation is aimed for.

4 CONCLUSIONS

The two technical regulations in Romania to which reference was made in the paper are different in character. One is devoted to geotechnical documentations (NP 074-2007), developing the concept of geotechnical category of relevance for ground investigation and for method to be used in the design process. The second one (NP 120-06) refers to works which quite often cause much trouble: deep excavations in urban areas.

The two regulations have in common the objective of making aware the parties involved, including the owner/investor, of the risks inherent to geotechnical works and to help them to take appropriate measures.

Both technical regulations are under revision, based on the experience gained in the 5 – 6 years of use.

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