Engineering Geology a basic tool for civil engineering works

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ABSTRACT: Engineering geology, as a specialized branch of geology, used in civil engineering, represents the groundwork on which the geotechnical and rock mechanics studies have to be based, in order to assure the efficient design and planning of the foundations and the general stability of the buildings.
Engineering practice has shown that when the geological aspect is underestimated, especially for the important buildings such as dams, tunnels, bridges, etc the risk of major troubles is to be taken into account.
After a short record of engineering geology's development in Romania, the paper underlines the main importance of the geotechnical and rock mechanics studies of the buildings' sites, taking into consideration the sum of geological conditions, and the ability of the civil engineer to correctly understand and analyze the received information. In the end of the paper, the engineering geology training program of the Technical University of Civil Engineering Bucharest is presented.

1 OVERWIEW

Geology is one of the Earth Sciences; it studies the solid matters that constitute the Earth as well as the processes that shape the components of Terra. As such, Geology encompasses a wide range of fields and related disciplines, namely: Mineralogy and Petrology, Paleontology (Micropaleontology, Palynology), Stratigrafy, Tectonics and Structural Geology, Geophysics, Ore Deposits Geology, Engineering Geology and Hydrogeology or Geohydrology, and so on.
Over the last decades, a new branch is gaining importance that is Environmental Geology. The field of geology which applies engineering principles to the study of geological materials related to explorations and exploitations of rocks quarry, mineral deposits, coal mining, oil pool, geological condition in sites for constructions as part of the engineering design, is called Technical Geology or Geological Engineering. Engineering Geology is a relatively recent branch of geology that has grown out of the interaction between the fields of geology and the civil engineering.
Engineering Geology studies rocks and earth materials as foundations sites for constructions, the influence of underground caves like tunnels, pits, gallery, electric plants etc, slope stability or rocks obtained for quarry exploitation.

Engineering Geology falls into three categories:

- General Geology applied in civil engineering
- Geotechnics
- Rock Mechanics

Initially, it was Geotechnics which studied the foundation soils, concentrating mainly on shallow deposits (soils). Geotechnics is practiced by civil engineers, it begin with the construction works and is closely related to a number of fundamental sciences like Physics, Chemistry, Mechanics, Strength of Materials, Elasticity, Hydraulics, and so on.

The basics of Modern Geotechnics or Soil Mechanics trace back to the XVIIIth century. A number of theories elaborated are still valid, like: Earth pressure – Coulomb (1773) & Rankine (1853), theory of the flow trough granular media –Darcy (1856), stress distribution inside an elastic isotropic homogeneous medium – Boussinesq (1885) & Flamant

(1892) and others. From the end of the XIXth century to the first half of the XXth century, Geotechnics advanced significantly.
A number of celebrated researchers like Atterberg, who defined the limits of plasticity for cohesive soils, and Mohr, who formalized the Strength theory – failure criterion, contributed essentially to the flourishing of Geotechnics. The slope stability was investigated by Fellenius, Bishop, Janbu, Maslov , and so on.
One of the most acclaimed Geotechnical scientists was the Austrian Terzaghi author of *Erdbaumechanik* (1925). Terzaghi has outstanding contributions on the theory of consolidation and shear strength of clayey soils, tacking into account the pore pressure. As a result of the development of large-scale building, like dams, tunnels, mines and quarry excavations, etc., during the second half of the last century, the study of rocks became imperative. Talobre (France), Muler (Austria), Rocha (Portugal), Obert & Duwall (U.S.A.) are among the scientists who contributed essentially to the development of Rock Mechanics.
The fact that computers were widely used after 1950, rapidly increased performances as well as expectations in the field research of soils and rocks. With the development of constructions considering soil-structure interaction, there was an increasing need that geotechnical and geomechanical studies in the design and performance prediction of the foundations of buildings, bridges and other structures to take into account the geological characteristics of the site.
The disasters caused by the Malpasset (1959) and Vajont (1963) dam failures due to geological reasons raised awareness of the importance of geological investigation on building sites; it became obvious that once neglected, the geological factor could create havoc.

2. THE DEVELOPMENT OF ENGINEERING GEOLOGY IN ROMANIA – AN OVERVIEW

By the end of the XIXth century and the beginning of the XXth century, Romania developed an interest in Engineering Geology. In the beginning, the research focused on the geomechanical characteristics of building stones excavated from various quarries (Pascu, Cantuniarii, Mazilu & Juncu). The first to hold the departmental chair of General Geology applied in civil engineering was Prof. Munteanu Murgoci at "National School of Bridges and Roads" (1908 – 1920). It was Pache Protopopescu who continued, at the University "Polytechnic" - the Department of Civil Engineering, to teach the course initiated by Murgoci. Cantuniari conducted a course of Technical Geology at "Special Civil School"
By the second half of the XIXth century, the civil engineers qualification curriculum included General geology courses designed to provide students with a basic understanding of Mineralogy, Petrology, Structural Geology and so on. For a long time, such courses were taught by outstanding specialists in General Geology, unfortunately lacking the required technical –engineering perspective – a prerequisite for applying Geology principles in building.
The interval spanning the end of the XIXth century to the first half of the XXth century saw a period of growth in daring schemes of constructions in Romania. The dream of most famous civil engineers who made a unique contribution to the history of techniques in Romania like Saligny, Leonida, Beles, Pavel, Mateescu and others was to accomplish outstanding construction works, like bridges over Danube, Danube – Black Sea channel, the regularization of the Dambovita River in Bucharest, schemes of hydro energetic use and hydrotechnic arrangement of the hydrographic network of Romania, the Bucharest metro and so forth. Sadly, before and during the interbellum period, the Romanian economy was just not strong enough to finance more than a limited number of constructions, like the bridges over Danube; the Fetesti – Cernavoda Railway Bridge is the pride of the Romanian constructors.
In Romania, the Engineering Geology developed as a separate scientific discipline by the second half of the XXth century; the daring constructions planning, the hydro energetic and the hydro technical works design, mainly, gave a great impetus to this branch of geology.
After the Second World War, the constructions branch had a central role in the rapid development plans of Romania. The Romanian geologists confronted with the harsh reality of huge constructions, starting with the second half of the last century when the Bicaz dam was built. Such large-scale constructions of vast technical complexity require ample studies of general geology in the geotechnical activity, applied to the assessing, planning and accomplishment of these targets. At the time, the best Romanian geologists were asked to elaborate engineering geology studies for those constructions; unfortunately, although they were great specialists in General Geology, they lacked the adequate engineering expertise.
In 1948, the education reform brought about the creation of a Faculty of Engineering Geology, in Bucharest, at the Institute of Mining and Geology of Bucharest to provide high education in the field of Engineering Geology.
In Romania, the first chair of Engineering Geology and Hydrogeology was created at the Technical Faculty of Geology and was held by Professor Stefan

Ghika Budesti.
From 1952 to 1957, Technical Faculty of Geology was hosted by the Mining Institute in Bucharest; from 1957 to 1974, it became part of the Institute of Petroleum, Gas and Geology in Bucharest as the Technical Faculty of Geology. Since 1974, when the Institute of Petroleum, Gas and Geology was moved to Ploiesti, the Technical Faculty of Geology has been hosted by the Bucharest University and called the Geology and Geophysics Faculty.
Over the last 50 years, more than 2500 de engineering geologists graduated from the Technical Geology and Geophysics Faculty of the former Institute of Petroleum, Gas and Geology in Bucharest and, subsequently, the Bucharest University; there are also the graduates from the Mining Institute in Petrosani, and those from the Polytechnics Institutes and the Technical Universities in Bucharest, Iasi, Cluj-Napoca and Timisoara, who specialized in the field of Geotechnics and Engineering Geology. They are the engineering geology, geotechnical and hydro geological staff in a range of national institutes of research and development, like: the Institute for Hydro energetic Studies and Designing (I.S.P.H.), the Institute of Land Design and Reclamation (I.S.P.I.F.), the Research and Design Institute for Water Management(I.C.P.G.A.), "Auto Naval and Auto Transport Designing Institute"(I.P.T.A.N.A.), "Research and Studies Institute for Railways (ISPCF), "Mining Designing Institute"(IPROMIN), "Mining Research Institute" (ICMIN), "Hydro technical Research Institute (I.C.H.) and the graduates of the regional planning institutes (I.P.J.).
The outstanding contribution of the Technical Schools of Geology should be also mentioned since generations of technical geologists and geophysicists were graduates of these schools; a number of these graduates, who worked in the civil engineering field, offered their valuable expertise in prospecting by exploratory drilling and tunnels and in geotechnical, geophysical, hydro geological *in-situ* tests. Also, they gave technical assistance on constructions sites as specialists of the analysis and design institutes. Moreover, there are graduates of these schools work in the geotechnical and rock mechanics laboratories as specialized technicians.

3. THE ENGINEERING GEOLOGY COURSES OFFERED FOR A DEGREE IN CIVIL ENGINEERING AT TECHNICAL UNIVERSITY OF CIVIL ENGINEERING IN BUCHAREST

The big diversity of constructions and also the variety and complexity of geological conditions from the constructions' sites, impose as a necessity the inclusion of the courses of Engineering Geology in the training programs for civil engineers. Engineering Geology must be taught before other essential courses, such as: Geotechnics and Foundations, Rock mechanics, Construction materials, Hydro technical, and others. That's why students are trained in Engineering Geology in the second year of studies, when almost all their knowledge is the one that they achieved in high school.
The course of engineering geology must fulfill the following conditions: the scientifically level must be high but in the same time not so complicated, so that the students could understand it; it must not abound in details concerning geotechnical and geomechanical matters and also must not include some calculation methods referring at rock mechanics because there special courses on this subjects; to synthesize the optimal volume of useful information of General geology necessary for the training of civil engineers; the appearance of the course must be simple, direct but also attractive.
The geology engineering course with predilection in General geology applied in the constructions domain is taught in the second year of study to students from three different faculties who totalize a number of 450 students with the following specializations

- Hydro technical constructions
- Railways and bridges constructions
- Civil engineering constructions
- Environment engineering
- Sanitary and environment engineering

For the firs two specializations - the course contains 14 units, 2 h each and 7 units of practice, 2 h each. For the last three specializations - the course contains 7 units, 2 h each and 7 units of practice, 2 h each.
The course of Engineering Geology is adapted for each specialization.
The professors teaching team is composed by a professor, a senior lecturer, a lecturer and an assistant, and they all activate in the Geotechnics and Foundations chair.
All the members of the team are graduated in geology and they all have the basic qualification of an engineering geologist. All the members have a PH.D graduation except from the assistant who is still working on it.
In the actual shape the engineering geology course assures that the students will understand the minimal notions of geology which are necessary for the following courses: Geotechnical and Foundations, Rocks Mechanics, Construction materials, Hydro technical constructions.

4. CONCLUSION

In the Engineering Geology field there are engineers trained in geology and civil engineers trained in civil engineering. The cooperation between the engineering geologist and the civil engineer is possible if each of the specialists does his best to understand and train himself in the other's field.
The Civil Engineer, who is the beneficiary of the technical geological studies, should be familiar with the fundamentals of geology in order to assess correctly the information he receives from the engineering geologist.
Two experienced specialists in Engineering Geology, namely Robert F. Legget and Allen. Hathway, wrote in „Geology and Engineering" " ....every civil engineer must have a basic training in geology – not to be an expert in the field but to appreciate the vital significance of geology in all civil engineering operations, and to know when expert geological advice is needed" It is not enough for a good specialist in Engineering Geology to be either a good geologist, or a good geo technician, or, even, a good specialist in rock mechanics. Such a specialist must know thoroughly the fundamentals of all these fields in order to be able to understand correctly how they interfere and draw adequate conclusions.
The conclusions of some specialists regarding the consequences of ignoring the geological features – which seem to be relatively unimportant - when drawing a building project are especially interesting. They emphasize that, sometimes, ignoring the geological conditions can lead to serious damage.
Two years after the failure of the Malpasset dam, Karl Terzaghi wrote: " A conventional site exploration, including careful examination of the rock outcrops and the recovery of cores from two-inch boreholes by a competent driller, would show- and very likely had shown- that the rock contains numerous joints, some of which are open and filed with clay. From these data an experienced and conservative engineering geologist could have drawn the conclusion that the site is a dangerous one...the most advanced means of rock exploration at our disposal...would have added no significant information to what was known concerning the safety of the left abutment of the dam, before the failure occurred"
There are numerous cases when the building plans benefited from the geotechnical and geomechanical studies elaborated in accordance with the specific technical regulations but without taking into account the general geological features of the building site.
In her „Environmental Geology", Carla W. Montgomery, referred to the reservoir Vajont dam as follows:" It is also very much to the discredit of those who chose the site that the dam and reservoir were ever put in such a spot. Ample evidence of slope instability dated back long before the conception of the dam. With more through study of the rocks' properties and structure and the possible effects of changing water levels, the Vajont tragedy could have been avoided"

5. *References*

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