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Rock Mechanics Education in European Universities: A Comparative Review of Academic Programs and Trends

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Abstract

Rock Mechanics represents a vital engineering discipline providing reliable tools to design tunnels, underground structures, slopes, dams, mines, and other facilities associated with the application of rock masses. Though necessary for civil, mining, and geotechnical engineering, the teaching of Rock Mechanics usually takes place within general engineering courses. This paper considers Rock Mechanics educational opportunities in 49 European states by studying the universities which teach Rock Mechanics or similar disciplines and analyzing their geographic distribution.

As a result, the prevalence of Rock Mechanics education was found to be closely linked with active practice of mining, tunneling, geotechnical engineering, and underground construction in particular countries. Rock Mechanics is mainly included in the programs of Civil Engineering, Geotechnical Engineering, Engineering Geology, and Mining Engineering with special topics being taught mostly on an advanced level. Despite the existing demand for specialists in the field, it is still difficult to attract young engineers due to the necessity to increase awareness, educational availability, and university-industry cooperation.

Keywords

Rock Mechanics, Engineering Education, European Universities, Geotechnical Engineering, Mining Engineering, Underground Construction.

1 Introduction

Rock Mechanics is a specific scientific branch in the field of civil, mining, and geotechnical engineering that studies the behaviour of rocks and rock masses. This science helps to safely design tunnels, underground excavations, dams, slopes, foundations, mines and other construction projects. Due to the development of underground transport systems, renewable energy systems, critical raw materials and complex infrastructure, the need for engineers that understand Rock Mechanics still persists in Europe.

Despite its significance, Rock Mechanics is a specialized discipline and is less popular than fast-growing branches such as software engineering, artificial intelligence and renewable energy. Young engineers meet with this field usually during studying in specialized programs, which makes it difficult attracting young people to the sphere.

The current paper considers the prevalence of Rock Mechanics education in European universities and factors that influence students' choice of this field. The meta-analysis was conducted in 49 countries of Europe, including both EU and non-EU countries. The study considered the problem of Rock Mechanics education in universities, shortage of engineering specialists in this field, and factors that affect the decision of students on choosing this area. Although there is no specific profession called Rock Mechanics engineer, the specialists are included into the list of civil, mining, geological, geotechnical engineers and other related fields. These occupations are experiencing shortage in numerous European countries.

The European Labour Authority (ELA) indicates that engineering and construction-related occupations still belong to Europe's shortage occupations. Shortage of specialists depends on several factors: ageing of engineers' labour market, competition from novel technologies and lower popularity of traditional engineering disciplines. However, the demand for the specialists in Rock Mechanics grows due to the need in underground construction, renewable energy infrastructure, geological storage, tunnelling and critical mineral mining.

Table 1. Shortage of Engineering Professions Related to Rock Mechanics in Europe*.

Profession related to Rock Mechanics	**European shortage situation**	**Main reasons for shortage**	**Relevance to Rock Mechanics**
Civil Engineers	Reported as a shortage occupation in many European countries	Ageing workforce, increased infrastructure demand, insufficient new graduates	Required for tunnels, foundations, dams, slopes, underground structures
Mining Engineers	Shortages reported especially in countries with active mining industries	Declining number of mining students, retirement of specialists	Directly related to rock excavation, mine stability, and rock behaviour
Geological Engineers	Shortages in several European regions	Limited number of specialized graduates	Required for geological characterization and rock mass analysis
Geotechnical Engineers	Persistent shortages due to high construction demand	Increasing complexity of projects and lack of specialists	Direct application of Rock Mechanics principles
Underground Construction/Tunnelling Engineers	Growing demand due to infrastructure expansion	Lack of experienced specialists	Requires knowledge of rock stability, reinforcement, and excavation methods

*Table source: European Labour Authority and EURES labour shortage reports. The reports identify engineering and construction-related occupations as persistent shortage areas across European labour markets.

2 Rock Mechanics in European Universities

Considering the aforementioned lack of engineers in the field of Rock Mechanics, an analysis of the state of teaching Rock Mechanics in European universities allows understanding whether the current educational courses are able to provide enough qualified specialists for future needs. It is shown that the field of Rock Mechanics remains a specific area of engineering studies, which is most often found in the course of civil engineering, geotechnical engineering, mining engineering, engineering geology, and geological sciences. The geographical spread of universities where Rock Mechanics is taught is unequal in Europe and strongly influenced by the requirements of national industries, local geology, and underground construction.

Table 2. Rock mechanics courses per country in Europe.

Country name	**Number of universities with rock mechanics courses**	**Names of universities with rock mechanics**
Albania	1	Polytechnic University of Tirana
Andorra	0	None
Armenia	1	National Polytechnic Univ.of Armenia (NPUA)
Austria	1	Univ.of Natural Resources and Life Sciences, Vienna (BOKU)
Azerbaijan	1	Azerbaijan State Oil and Industry Univ.(ASOIU)
Belarus	2	Belarusian National Technical Univ.(BNTU); Belarusian State Univ.(BSU)
Belgium	1	Université libre de Bruxelles (ULB)
Bosnia and Herzegovina	3	Univ.of Sarajevo; Univ.of Tuzla; Univ.of Zenica
Bulgaria	2	Univ.of Mining and Geology "St. Ivan Rilski"; Univ.of Architecture, Civil Engineering and Geodesy (UACEG)
Croatia	1	Univ.of Zagreb
Cyprus	2	Univ.of Nicosia; Univ.of Cyprus
Czechia	2	Charles Univ.(Prague); Brno Univ.of Technology (BUT)
Denmark	1	Technical Univ.of Denmark (DTU)
Estonia	1	Tallinn Univ.of Technology (TalTech)
Finland	1	Aalto University
France	6	Université Paris-Saclay; Université Grenoble Alpes; Université Savoie Mont Blanc; Université de Montpellier; Université de Poitiers; Conservatoire national des arts et métiers (Cnam)
Georgia	0	None confidently verified
Germany	2	Technical Univ.of Munich (TUM); Univ.of Siegen
Greece	4	National Technical Univ.of Athens (NTUA); Univ.of Patras; National and Kapodistrian Univ.of Athens (NKUA); Univ.of Thessaly
Hungary	1	Univ.of Miskolc
Iceland	1	Univ.of Iceland
Ireland	1	Univ.College Dublin
Italy	4	Univ.of Bologna; Univ.of Siena; Univ.of Perugia; Univ.of Padua
Kazakhstan	4	Nazarbayev University; Ualikhanov University; Yessenov University; Caspian University
Latvia	0	None confidently verified
Liechtenstein	0	None confidently verified
Lithuania	1	Vilnius University
Luxembourg	0	None confidently verified
Malta	1	L-Università ta' Malta (UM)
Moldova	1	Univ.of Moldova
Monaco	0	None confidently verified
Montenegro	1	Univ.of Montenegro
Netherlands	1	Delft Univ.of Technology (TU Delft)
North Macedonia	2	Ss. Cyril and Methodius Univ.in Skopje; Goce Delčev Univ.of Štip
Norway	1	Norwegian Univ.of Science and Technology (NTNU)
Poland	3	AGH Univ.of Krakow; Gdańsk Univ.of Technology; Silesian Univ.of Technology
Portugal	3	Univ.of Coimbra; NOVA Univ.Lisbon; Univ.of Porto
Romania	3	Univ.of Bucharest; Univ.of Petroșani; Petroleum-Gas Univ.of Ploiești
San Marino	0	None confidently verified

Serbia	1	Univ.of Belgrade
Slovakia	2	Comenius Univ.Bratislava; Slovak Univ.of Technology in Bratislava
Slovenia	1	Univ.of Ljubljana
Spain	4	Universitat Politècnica de Catalunya (UPC); Univ.of Cantabria; Univ.of Granada; Univ.of Zaragoza
Sweden	2	KTH Royal Institute of Technology; Luleå Univ.of Technology
Switzerland	2	ETH Zurich; EPFL
Türkiye (Turkey)	7	Atılım University; Çankaya University; Istanbul Technical Univ.(ITU); Middle East Technical Univ.(METU); Çukurova University; Karadeniz Technical University; Pamukkale University
Ukraine	5	Zhytomyr Polytechnic State University; National Univ.of Water and Environmental Engineering; National Technical Univ."Dnipro Polytechnic"; National Univ."Yuri Kondratyuk Poltava Polytechnic"; Ukrainian State Univ.of Science and Technologies
United Kingdom	4	Imperial College London; Univ.of Leeds; Univ.of Strathclyde; Univ.of Exeter

According to the data obtained, it becomes evident that there is Rock Mechanics education both in EU and non-EU states; however, there are considerable differences in geographical distribution of this field of studies. The maximum number of institutions teaching Rock Mechanics can be found in such states as Türkiye, France, Greece, Italy, Ukraine, Kazakhstan, Spain, and the UK, what demonstrates intensive work in mining, construction, and underground engineering spheres. In Western and Central European countries, such as Switzerland, Germany, Austria, Norway, Finland, and the Netherlands, Rock Mechanics is included into the advanced geotechnical and engineering geology program of studies. Southern European countries, such as Italy, Spain, Greece, and Portugal also use geological peculiarities and infrastructure needs requiring knowledge of Rock Mechanics. States where mining is especially developed, such as Poland, Romania, Bulgaria, Türkiye, and Kazakhstan, also have a considerable number of educational institutions teaching Rock Mechanics. At the same time, in some small states, there are no courses in Rock Mechanics, namely Andorra, Liechtenstein, Luxembourg, Monaco, Moldova, San Marino, Latvia, and Georgia. In most cases, Rock Mechanics is taught as a part of general civil, geological, or geotechnical engineering curriculum.

3 Discussion

Rock Mechanics education spread corresponds to the engineering needs of particular countries. The countries with significant mining industry, underground construction, mountainous landscapes, or complicated geology have a larger number of universities providing education on this subject. Countries where mining, tunnelling, and infrastructure development are especially prominent include Türkiye, France, Italy, Greece, Spain, Ukraine, and Kazakhstan. In addition, Switzerland, Austria, and Norway have fewer institutions but specialise in the field related to underground engineering. Eastern European countries such as Poland, Romania, Bulgaria, Serbia, and North Macedonia continue providing Rock Mechanics education because of the traditional mining and civil engineering industry in these countries.

Rock Mechanics is rarely taught as a separate study direction and is included in Civil Engineering, Geotechnical Engineering, Engineering Geology, Mining Engineering, Underground Construction, or Tunnelling Engineering curricula.

3.1 Educational Trends

It should be noted that Rock Mechanics is usually included in the educational process in a later phase. At undergraduate level the students learn related disciplines such as Engineering Geology, Soil Mechanics, Geotechnical Engineering, and Mining Engineering. More specialised topics, namely rock mass classification, stability of excavations, reinforcement, numerical modelling, and tunnelling are introduced at later stages.

Since the introduction of Rock Mechanics happens when students choose a specialisation, the awareness of the field may be less than for other engineering subjects.

3.2 Future Challenges

Despite the stable demand for specialists in Rock Mechanics, attracting new generations of engineers to the field becomes more difficult since the interests of the younger generation are more directed towards fast-developing areas like IT or Artificial Intelligence. At the same time, there is a growing demand for specialists in Europe owing to underground transportation development, renewable energy facilities construction, carbon sequestration, mineral extraction, and infrastructural projects. Therefore, growing interest of future students will require earlier introduction of Rock Mechanics, closer cooperation with industry, and additional practical experience.

4 Conclusion

In Europe, Rock Mechanics is still an important but specialised part of engineering education. Most European countries had universities with the subject, especially where there were strong mining, tunnelling, geotechnical and infrastructure sectors.

This subject is not a stand-alone degree, but is usually part of larger engineering courses, and more often taught as a specialisation in advanced engineering courses. Interest in traditional engineering disciplines is on the decline, while the demand for Rock Mechanics specialists is increasing. Future generations of engineers will be attracted to the field by increasing public awareness, improving practical training, and demonstrating its importance to today's engineering challenges.

References

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