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Advances in the Teaching of Geotechnical Engineering in Peru

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Abstract. In Peru, the university formation in geotechnical engineering has a starting point in the contribution of professor Emilio Le Roux Catter in 1946 in the old School of Engineers, today National University of Engineering. It is then that the Soil Mechanics course was created within the civil engineering teaching curriculum.

In the decade of the 60th, thanks to the visit of renowed experts in Soil Mechanics, the specialty of Soil Mechanics receives dynamism, giving courses on: Soil Mechanics applied to Transport Roads and Soil Mechanics applied to Earth Dams. The Soil Mechanics and Pavement Laboratories were implemented in the National University of Engineering and in the Pontifical Catholic University of Peru.

In 1971, the UNI created the Graduate School and later the Master of Science Civil Engineering with a major in Geotechnics, giving a great boost to the teaching and application of Geotechnics in Peru, which came to fruition during the 1980s and in the mid-1980s, with the work of the Peruvian Committee on Soil Mechanics, Foundations and Rocks Mechanics and with the implementation of the first Peruvian Technical Standard for Soil Mechanics E-050.

Since 2011, techniques for measuring stress, deformation and water flow have been improved both in-situ and in laboratory. On the other hand, the continuous presence of seismic movements has motivated that twenty universities from the country led by the National University of Engineering, consider that the topics of dynamic characterization of soils should be integrated into the training of Civil Engineering students for which have installed a network of accelerographic stations, which favor the research carried out by undergraduate and graduate students and teachers in the area of Geotechnical Seismic Engineering

Keywords. Courses, teaching, Geotechnical Seismic Engineering.

1. Introduction

Given the importance of this event for geotechnical engineering, I consider that examining the advances in the teaching of geotechnical engineering in Peru, including the contributions that I have been able to collect from other colleagues and from the students themselves in my dual condition as professor of geotechnical engineering, specialty of soil mechanics, at the National University of Engineering (both undergraduate and postgraduate) and as specialty consultant, it is necessary.

Among the contributions mentioned that I consider significant to approach the subject under discussion, we have: "La Mecánica de Suelos en el Perú", by Eng. Genaro Humala [1], the articles "Academia y ejercicio Profesional en Geotecnia, experiencia en

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México" by Eng. Gabriel Moreno Pecero [2]; "La Formación en Geotécnica del Ingeniero Civil en América Latina, una visión global" by Eng. Mercedes Beltrán [3] and the "Historia de la Geotecnia Peruana" by Eng. Manuel Sánchez[4], "la Ingeniería y la Mecánica de Suelos" by Eng. Alfonso Alcedán [5] among others.

In his professional practice, the civil engineer has many different and important encounters with the soil. He uses the soil as a foundation for structures and embankments; and also as construction material. Likewise, he must design retention structures for excavations and underground openings, and, in general, he finds the soil in a large number of special problems. In the development of these tasks, the engineer is based on Soil Mechanics, a discipline that systematically organizes the principles and knowledge of the engineering properties of the soil.

In the Andean region of South America, before the arrival of the Spaniards, in Inca and pre-Inca times, the experts responsible for the construction of tunnels, cities, dams and canals, achieved a remarkable development solving complex foundation problems. (Wright y Valencia, 2006 [6], Wright, 2008[7], Wright et al., 2017 [8])

This paper presents the historical sequence since the middle of the last century, in the development of the teaching of geotechnical engineering in Peru, a review of the courses taught in the main universities and a proposal to redefine the programs in order to incorporate new topics associated with the latest advances in geotechnical seismic engineering, considering that education should be more than training, as well as incorporating elements of the latest technologies.

2. Process

In Peru, the contemporary university formation in geotechnical has a starting point in the contribution of the Eng. Emilio Le Roux Catter in 1946 in the old School of Engineers, today National University of Engineering. It was when the Soil Mechanics course within the civil engineering teaching curriculum was created.

In the decade of the 60th, thanks to the visit of renowned experts in soil mechanics such as doctors José Antonio Jiménez Salas, Raul Marsal and Eulalio Juárez Badillo, the specialty of Soil Mechanics receives dynamism, giving courses on: Mechanics of Soils I, Mechanics of Soils II, Soil Mechanics III, Soil Mechanics applied to Transport Roads and Soil Mechanics applied to Earth Dams. The Soil and Pavement Mechanics Laboratories are also implemented. In 1970, the "Soil Mechanics II" course is replaced by the course on Soil Mechanics Applied to Foundations ".

In 1971 the Graduate School, fist, and the Master of Science with a major in Geotechnics, later, were created, meaning a great boost to the teaching and application of Geotechnics in Peru. There, courses such as Advanced Soil Mechanics, Foundations Design, Soil Dynamics, Rock Mechanics, Applied Geology to Engineering and other elective courses are taught.

On the other hand, at the Pontifical Catholic University of Peru (PUCP) the Soil Mechanics course has been taught since 1957, with Engineer Ricardo Valencia Menegotto as its creator and first Professor. Subsequently, courses such as Soil Mechanics I, Soil Mechanics II, Soil Mechanics III and Pavements were dictated. Later prominent professionals, such as the Msc José María Corzo López de Romaña, who was a disciple of Professor Arthur Casagrande at Harvard, made their appearance. In the 60's, also in the PUCP, the corresponding laboratories were implemented. After the earthquake of 1970, the PUCP dictates the course of Soil Dynamics in the Graduate

section, being the Msc. Pedro Repetto Peirano, disciple of Professor Harry Bolton Seed, one of his teachers [1].

During the decade of the 80s and in the mid-90s, a major advance in geotechnics came with the creation and contribution of the Peruvian Committee on Soil Mechanics, Foundations and Rocks Mechanics, organizing a series of symposia and courses, establishing the Emilio chair Roux Catter course. The implementation of the first Peruvian Technical Standard for Soil Mechanics E-050 was also very significant.

Since 1990, there is a new momentum in the field of Geotechnical Engineering. The techniques of stress measurement, deformation and water flow have been improved both in-situ and laboratory. The seismic effects in the soil are investigated by accelerographs, geophysical equipment and in the laboratory by cyclic triaxial tests, among others. In the static part tests on large samples to minimize scale effects have been developed.

3. Results

In the last International Congresses of the International Society of Soil Mechanics and Geotechnical Engineering (ISSMGE) and in the Pan-American Soil Mechanics Congresses, the concern for the training in Geotechnical Engineering received by future civil engineers has been well known. In our Latin American region, the pioneering work of the Mexican Society of Soil Mechanics stands out, expressed in its Biannual Congress and National Meeting of Teachers, an event in which not only what to teach, but also how to teach has been analyzed, as an example to follow for other countries.

As professor Moreno Pecero G. (2005) [2] suggests, to teach engineering, including of course Geotechnical Engineering, the teacher requires to have certain special qualities:

- Teaching should not be his main task, but rather make students learn to think.
- In addition to his knowledge he must provide the generous and guiding plenitude of his being in balance with his appearance.
- That title is received not by normative mechanisms but by spontaneous consensus.
- He must fully trust and feel genuine respect for the students.
- He must preach with the example that education is not only the work of intelligence but also of the heart.

Starting from such premises, Professor Beltrán M (2005) [3] considers that the experiences lived by the student of Geotechnical Engineering will be indelible if he can observe "first hand" the behavior of the soil, "check the existence of the flow of water in the various types of soil, verify the consequences of the expansion of soils or faults that occur in an embankment built on soft ground. The experience organized by didactic models that ensure the understanding of principles and processes, will transform the opinion on geotechnics of "a subject that must be approved as a requirement to continue his studies, in an interesting subject".

On the other hand the question of what is the minimum level of knowledge that the student of Civil Engineering must acquire in the area of Geotechnics to be able to solve the engineering problems either at the level of design, construction or supervision arises. The answer varies according to the reality of each country, however a minimum group of subjects for basic training in Geotechnics will always exist.

Currently in Peru, it is observed that the curricular plans corresponding to the area of Geotechnics, in the different universities, both public and private, are heterogeneous,

both of the subjects included, and in the time dedicated to them, as can be seen in Tables 1 to 5.

Table 1. Curriculum Plan of the National University of Engineering (UNI).

Category	Course	Credits	Weekly hours
Obligatory	General Geology	4	6
	Soil Mechanics I	4	5
	Soil Mechanics II	4	5
	Applied Geology	4	6
	Total		**22**
Electives	Soil Dynamics	3	4
	Rocks Mechanics applied to Civil Engineering	4	5
	Finite Elements applied to Geotechnics	3	4
	Soil Mechanics applied to foundations	4	5
	Soil Mechanics applied to transport routes.	3	4

Table 2. Curricular Plan of the Pontifical Catholic University of Peru (PUCP).

Category	Course	Credits	Weekly hours
Obligatory	Geology	3	3
	Geology Laboratory	0.5	1
	Soil mechanics	4.5	5
	Soil Mechanics Laboratory	1	2
	Foundation Engineering	4.5	5
	Total		**16**
Electives	Geotechnical design	3.5	3
	Floors	3.5	3
	Geotechnical Engineering Topics	3.5	3
	Design with Geosynthetics	3.5	3
	Design of Earth Dams and Tailings	3.5	3
	Advanced Soil Mechanics	3.5	3

Table 3. Curricular Plan of the Ricardo Palma University (URP).

Category	Course	Credits	Weekly hours
Obligatory	Geological Engineering	2	3
	Soil Mechanics I	3.5	5
	Soil Mechanics II	3.5	5
	Foundations	3	4
	Floors	4.5	**4**
	Total		21
Electives	Geotechnical design	4	4

Table 4. Curricular Plan of the San Ignacio de Loyola University (USIL)

Category	Course	Credits	Weekly hours Semanales
Obligatory	Geology	2	4
	Soil Mechanics	4	6
	Geotechnical Engineering	4	4
	Foundations	2	4
	total		**18**

Table 5. Subjects of the area of Geotechnics, taught in other Universities.

Other Universities	Compulsory Subjects
University of Piura	Applied Geology, Soil Mechanics, Geotechnical Design
Peruvian University of Applied Sciences	Geology, Soil Mechanics, Geotechnical Engineering.
National University Federico Villarreal	Geology, Soil Mechanics I, Soil Mechanics II, Floors
Private University Antenor Orrego	Geology, Soil Mechanics I, Soil Mechanics II, Floors

The professional practice in soil mechanics is complex, since knowledge and experience are requiered. For example, when a hydroelectric project has a dam component, a detailed geotechnical study of the foundation and quarries is required. Normally it will be necessary to apply analytical methods to the design to evaluate infiltration, slope stability, static deformation and seismic action. In addition, the design of the related works, such as spillways, diversion tunnels, components; and of course the costs and budgets should be considered.

When the student of Civil Engineering finishes his career he has many limitations to face this type of projects, so these shortcomings would have to be compensated through postgraduate programs; however, currently the only university offering the Master's Degree in Civil Engineering with a mention in Geotechnics is the National University of Engineering (Table 6).

In the Peruvian case it is imperative to take into account that the country is located in an area of high seismic hazard, due to the interaction of the Nazca plate and the South American plate, as well as the activity of surface geological faults, which also generate earthquakes of considerable magnitude in the interior of the country.

Table 6. Postgraduate Curriculum Plan of the National University of Engineering (UNI).

Category	Course	Credits	Weekly Hours
Obligatory	Advanced Soil Mechanics	4	4
	Foundation Design	4	4
	Rocks Mechanics	4	4
	Geology Applied to Engineering	4	4
	Seminar in Geotechnical Engineering	3	3
	TOTAL		19
Electives	Geophysics Applied to Civil Engineering	4	4
	Soil Dynamics	4	4
	Experimental Soil Mechanics	4	4
	Numerical Methods Applied to Geotechnics	4	4
	Land Dams and Castling	4	4
	Theoretical Soil Mechanics	4	4
	Special Problems in Geotechnics	4	4
	Slope Stability and Earth Push	4	4
	Design with Geosynthetics	4	4
	Foundations Design by State Limit	4	4
	TOTAL		**40**

The continuous presence of seismic movements has motivated that different Universities from the regions outside of Lima, led by the National University of Engineering, consider that the topics of dynamic characterization of soils should be integrated as part of the training of the students of the career of Civil Engineering not only at the theoretical level but at the experimental level. In that sense, a network of accelerographic stations, which will allow the development of research for undergraduate and postgraduate students and teachers in the area of Seismic Geotechnics, was implemented.

To continue with the advances of teaching in Geotechnical Engineering in Peru it is necessary to propose a minimum program that incorporates new topics associated with the latest advances in seismic geotechnical engineering and with basic subjects for training in Geotechnics of the future professional in Civil Engineering Undergraduate level as proposed in Table 7. Additionally, each University must consider elective Geotechnical courses according to the orientation of the student's interests.

Table 7. Basic Proposal for undergraduate courses in Geotechnics

Category	Courses	Credits	Hours		
			Theory	Practice and / or Laboratory	Sub Total
Obligatory	Geology	4	3	3	6
	Soil Mechanics	4	3	2	5
	Soil Dynamics	4	3	2	5
	Foundation Engineering	4	3	2	5
	Total		**12**	**9**	**21**

Another important aspect that should be considered is that professional practice in our countries should be developed in an environment of honesty and commitment to society. This commitment consists of benefiting the community, giving support to the less favored strata. Taking the words of Father Pedro Arrupe S.J., general of Jesuits to educators, "we must form men for others", which in our case would have to mean "to train civil engineers to serve society".

4. Conclusions

- In Peru, the contemporary university education in geotechnics began in 1946.
- Geotechnical professors must have certain special qualities so that the teaching of their subject matter is useful and responds to the needs of today's world.
- Courses in the area of Geotechnics and their contents should be standardized, both at the level of each country and at the regional level, to meet a basic minimum of knowledge.
- Subjects of dynamic characterization of soils should be integrated as part of the training of the students of the Civil Engineering career, not only at the theoretical level but at the experimental level.
- The deep knowledge of Geotechnics as well as its multiple applications corresponds to the postgraduate level. In Peru, the Master's programs in Geotechnics must be increased.

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