

The Master in Soil Mechanics and Geotechnical Engineering of CEDEX/UNED

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ABSTRACT: The Master's degree in Soil Mechanics and Geotechnical Engineering organized annually by the Center for Studies and Experimentation of Public Works (CEDEX) together with the National University of Distance Education (UNED) of Spain, is the result of the evolution of a course initially of 3 months, conceived in the early 80s by Professor D. José Antonio Jiménez Salas when he combined his task as Professor at the School of Civil Engineering in Madrid with the Direction of the current Geotechnical Laboratory of CEDEX. Although he conceived it as a tool for international cooperation with the developing countries of Ibero-America, it has been strengthened, becoming a renowned postgraduate master's degree in which Spanish graduates are equally interested. Its most relevant characteristics are the following: it is an international technical specialization course in Spanish; has a teaching staff with varied affiliations (private sector, administration, and several Higher Technical Schools of Civil Engineering), which has been nourished by former students (almost 25% of teachers are former students); It has had university sponsorship, the support of technical-scientific societies, as well as professional associations. This article describes its origin, the various policies followed by the course, the evolution of the curriculum and the professional development of students.

KEYWORDS: Master's degree, soil mechanics, geotechnical engineering, Spanish language

1 INTRODUCTION

The year 2024 marked the 42nd edition of the International Master's Degree in Soil Mechanics and Geotechnical Engineering, which the Centre of Studies and Experimentation for Public Works (CEDEX) has been organizing almost uninterruptedly since 1982 (the Course was not held in 1987), as part of its knowledge transfer and training functions, as established in its statute (RD 1136/2002).

It is a master's degree with unique features, widely recognized in the sector, mainly in Spain and Latin America. Every year, CEDEX selects 25 Spanish and Latin American graduates from among those who pre-register. The Master has undoubtedly contributed to the strengthening of scientific, technical, and commercial ties between Spain and Latin America in the geotechnical engineering sector.

The first edition of the course in 1982 was held at the School of Civil Engineering of the Polytechnic University of Madrid (UPM), with the title International Course on Soil Mechanics and Foundation Engineering (see Figure 1). Five editions of the course were held at the School of Civil Engineering in Madrid, from 1982 to 1986. In 1988 it was organized by CEDEX.

Today, the CEDEX Master's Degree in Soil Mechanics and Geotechnical Engineering is a UNED master's degree that has been awarded since 2012, by virtue of an agreement between both organizations for lifelong learning activities, which is periodically renewed. According to the European Credit Transfer and Accumulation System (ECTS), the Master reached an equivalence of 60 credits.



Figure 1. Photograph of the first edition of the course in 1982 at the School of Civil Engineering in Madrid. In the center, Professor Jiménez Salas with Carlos Oteo and Ángel Uriel.

2 CURRENT STRUCTURE AND CHARACTERISTICS OF THE MASTER'S DEGREE

2.1 Objectives

The main objective of the Master is not to offer a regular university degree, but rather to provide as much as possible comprehensive professional education in the field of geotechnics, from theory to practice, to prepare students advantageously to enter a highly specialized labor market, indispensable in practically all civil constructions. The master's degree is currently aimed at civil engineers, geological engineers, mining engineers, geologists, and related professions. It is open to any nationality, although a sufficient command of Spanish is required to enroll on the course.

2.2 Syllabus

The established format of the master's degree consisted, in the first place, of a 5-month face-to-face teaching period, with four hours of morning classes plus some afternoon sessions or practices, taught from Monday to Friday in the classroom of the Geotechnical Laboratory of CEDEX. As explained below, in March 2020 it had to be converted to telematic mode, "on the fly". The teaching load is equivalent to a total of 560 hours of classes, both theoretical and practical. Currently, the teaching period is scheduled from 1 February to 30 June, with the novelty that the telematic classes are in the evening, to make the timetables in Spain and Latin America compatible.

The program establishes a second, non-teaching period from July to the end of September, during which each student has to write, under the supervision of a lecturer, a master's thesis that is defended in person before an examining board in October. Despite the uncertainties arising from the pandemic crisis, the master's degree management decided to schedule a third one-month period for the 2021 edition, which, together with the defense of the master's thesis, would include all the training activities that had been carried out in the "pre-pandemic" stage on certain afternoons during the teaching period, such as laboratory and field practical, a trip of several days to visit geotechnical works, visits to other CEDEX centers, as well as attendance at a conference organized by CEDEX or the collaborating scientific-technical societies (Spanish Society of Soil Mechanics and Geotechnical Engineering (SEMSIG) and the Spanish Society of Rock Mechanics (SEMR)).

2.3 Contents

The thematic content is divided into three units, each subdivided into modules, generally for one week's duration. This is complemented by sessions on advanced geotechnics (Table 1). As can be seen, the syllabus far exceeds that of all undergraduate and master's degree courses related to Soil and Rock Mechanics at a technical college.

The numerical methods and modelling module, so that it is not limited to theoretical explanations of the fundamentals, incorporates a good number of sessions in which students are taught to solve typical problems using a three-dimensional commercial numerical code (Midas GTS NX) based on the finite element method. CEDEX activates a license for each student, valid for the duration of the course. Practical work is also done with other numerical codes oriented to Rock Mechanics (Rocscience).

2.4 Lecturers

Approximately 25% of the 80 teachers are exstudents. As shown in Table 2, the affiliations of the professors are varied (private sector, administration, and various engineering schools of civil, mining and geology).

Some of the topics related to special geotechnical equipment and works are commonly addressed by experts from the Association of Soil and Subsoil Technology Companies (AETESS), who add their professional experience to the theoretical concepts. Moreover, many professors also offer to act as tutors or members of the examining boards that assess the master's theses.

Table 1. Content of the modules, arranged into units and sessions on advanced geotechnics.

First Unit	Second Unit	Third Unit
Principles of Soil Mechanics I	Shallow foundations	Earthworks and fills
Principles of soil mechanics II	Deep foundations	Tunnels
Principles of soil mechanics III	Slope stability	Soil improvement
Field investigation Earth	Retaining walls	Dam & tailing geotechnics
Principles of rock mechanics		Numerical methods and modeling
(+ 3 lab sessions + field practical)		Environment / Energy Geomechanics
		Soil dynamics (+ lab session)

Sessions of Advanced Geotechnics: (N° of lectures in brackets): Clay mineralogy (1); Foundations of offshore structures (2); Geotechnical reliability and risk assessment (1); Constitutive models (2); Critical State Theory (4); Eurocode 7 (1); Limit State: upper and lower bound theorems (2); Unsaturated soil mechanics (4); Reservoir geomechanics (2)

2.5 Coursework and criteria of evaluation

Upon enrolment, students receive documentation in electronic format for the development of the course, as well as a few relevant technical publications and regulations and additional links.

As part of the assessment, students take an exam at the end of each thematic unit (Table 1). In addition, students are given assignments, usually one per week, to be submitted and graded individually, although peer discussion is encouraged during the resolution process. Other tasks are also proposed that are closer to professional reality, with more open solutions, and are solved in groups, to promote collaborative skills and a critical sense.

The average mark for the teaching period is the result of weighing the average of the marks of the three mid-term exams, which are taken at the end of each unit, with those of the tasks. This average mark must be at least a 5 to pass, an essential requirement to be able to prepare the master's dissertation. If the examining board approves the work submitted, the final grade is calculated as 75% of the mark for the teaching period and 25% of the mark for the dissertation.

Table 2. Affiliations of the lecturers (~81 in total) that contribute to the Master.

Administration & Government Owned Institutes, ~45%
Geotechnics Laboratory + Structures & Materials Laboratory (CEDEX) - Core Lecturers, 70%
Instituto Geológico y Minero de España (IGME)... »National Geological Survey
Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas (CIEMAT)
(» CEDEX, but attached to the Ministerio de Ciencia, Innovación y Universidades)
Centro Internacional de Métodos Numéricos en la Ingeniería (CIMNE)
<u>Ministerio de Transportes y Movilidad Sostenible.</u>
Dirección General de Carreteras» Roads
Puertos del Estado » Spanish National Port Authority
<u>Ministerio para la Transición Ecológica y el Reto Demográfico,</u>
Dirección General del Agua» Water Resources
Confederación Hidrográfica del Ebro» River Ebro Authority
Bundesanstalt für Materialforschung und -prüfung (BAM)
(» German counterpart of CEDEX)
Academia (in brackets n° of lecturers), ~30%
(the Spanish universities and faculties below are public)
<u>Civil Engineering Schools:</u> Madrid (9); Santander (2); Barcelona (4); La Coruña (1); Alicante (1); Valencia (1)
<u>Other:</u> Geology Faculties: Madrid (1); Mining Schools: Madrid (1); Vigo (2)
<u>Engineering Schools from abroad:</u> University College of London (1); Universidad Nacional de la Patagonia (1); Universidad Nacional de Educación a Distancia (1)
Contractors and Engineering Offices, ~25%
<u>From members of AETESS: ~33%</u>
<u>Companies:</u> Acciona, Arup, Eptisa, Gemigeo, Geobrugg, Ferrovia, Repsol ~33%
<u>Offices:</u> ByA, Icyfsa, Ingeap, Ingeniería del Suelo, Tunelestat, Uriel & Asociados ~33%
<i>Approximately 81 lecturers in total; Nearly 25 % of the lecturers are outstanding alumni.</i>

3 A LONG-LASTING MASTER ON GEOTECHNICS AT CEDEX

3.1 How it came into being, initial conditions

The real germ of the master's degree dates to 1965; it was the so-called "Curso de Especialización en Transporte y Mecánica de Suelos para Ingenieros Latinoamericanos", held at the Transport and Soil Mechanics Laboratory of the CEDEX (the current Geotechnical Laboratory), with the collaboration of the Institute of Hispanic Culture and the School of Civil

Engineering in Madrid. Based on that experience, in 1982 Professor José Antonio Jiménez Salas, a true pioneer of geotechnical engineering in Spain, conceived and founded the International Course on Soil Mechanics and Foundation Engineering, mainly aimed at Latin American postgraduates to contribute to the promotion of technical development in those countries. Figure 2 shows a photograph of the 5th edition in 1986. It should be borne in mind that a few years earlier (between 1975 and 1980) all the volumes of the book "Geotecnia y Cimientos" had just been published, coordinated by him, in the Rueda publishing house, an almost encyclopedic work, and written by a large group of younger engineers, his disciples, who followed in his wake and formed part of the initial lecturers of the course.

Reading the biographical notes of Prof. Jiménez Salas in the tribute book by his epigones (SEMSIG, 2000), the special issue of the Revista de Obras Públicas (ROP, 2016), as well as in the tribute held at the Royal Academy of Sciences on his centenary, his devotion to education is evident. His international prestige, his extraordinary teaching skills and the highly qualified group of fellow researchers who assisted him, from the School and the Geotechnical Laboratory of CEDEX, led to the dissemination of the course in countries of linguistic affinity.

3.2 From the school of civil engineering to CEDEX; primary consolidation

After its initial stage at the Escuela de Caminos, the VI International Course on Soil Mechanics, and Foundation Engineering (1988) moved definitively, and uninterruptedly to date, to CEDEX, with the director of the Geotechnical Laboratory, at that time Prof. Carlos Oteo, being entrusted with the direction of the course. Figure 3 shows a photograph of the opening session of the 6th edition in 1988. It should be noted that the course was not held in 1987, (Pardo de Santayana, F. et al, 2020).



Figure 2. Students and coordinators of the 5th edition of the International Course on Soil Mechanics and Foundation Engineering (1986). This was the last edition held at the School of Civil Engineering in Madrid.



Figure 3. Welcoming session for the 6th edition of the Course already in one of the classrooms of CEDEX (1988). From left to right, Mr. Marcelo Rodríguez (CETA); Prof. Jiménez Salas; Ms. Isabel Vilches (CETA); Prof. A. Serrano (Director of CETA); Prof. Carlos Oteo (Director of the Geotechnical Laboratory).

3.3 Becoming a Master and joining a host university; secondary consolidation

From 2000, under the direction of PhD. Vicente Cuéllar, following the extension of its teaching load (from 3.5 to 5 months), and with a lecturer unparalleled in the Spanish language, the course acquired the status of master's degree,

attracting more attention from Spanish graduates, in a context of prosperity and growth in construction activity.

With the arrival of the Bologna process, in 2009 CEDEX joined forces with the UPM to develop an already mature course into a university master's degree (60 ECTS credits), under the name of Master in Soil Mechanics and Geotechnical Engineering, with the defense of a master's thesis being compulsory from then on. In the 2012 edition, the master's degree was transferred to the UNED as host university, maintaining all its standards and structure.

Figure 4 shows four of the graduating classes (1992, 2002, 2012 and 2022) from four different decades, Díez Torres, J.A. et al, 2023).



Figure 4. Photographs of four graduating classes: 1992, 2002, 2012 and 2022.

3.4 The change from face-to-face to telematic mode

In mid-March 2020, due to the state of emergency that was declared due to the outbreak of the coronavirus pandemic, and with the agreement of the students and teaching staff, it was decided to continue the classes online, and, given that the state of emergency was extended on several occasions, the teaching period had to be completed in this format.

This experience led to a radical change in the management and organization of the master's degree, so that the 39th edition in 2021, also considering health-related uncertainties, was held in the new format with the three periods described in the previous sections, including the face-to-face activities in October (Figure 5). The following courses have already been held in this mixed telematic and face-to-face format with highly satisfactory results.

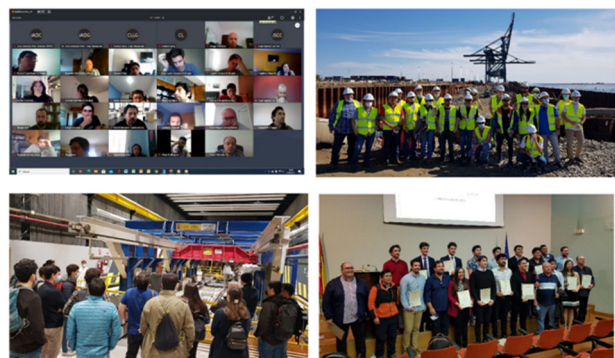


Figure 5. Different activities during 2021.

During the classroom phase in October, several excursions are organized, including a 5-day field trip. During this trip, students visit ongoing geotechnical worksites in a region of Spain, guided by professors involved in the works. The aim of these excursions is twofold: to offer real contact with geotechnical activity and techniques in situ; and to encourage fraternization not only among classmates, but also with professionals and former students working on different sites and with the teachers. It should not be forgotten that this is an international course with a strong presence of Latin American students, which enriches the group both technically and humanly. Figure 6 shows the number of students by nationality since the 1988 course. Despite the cultural links between the Ibero-American countries, there are marked differences in idiosyncrasy, social origin, and barriers among the students.



Figure 6. Flyer of the 2024 edition (42nd), and of students' nationalities since 1988. The ratio between Spanish students and students from other countries is around 45%.

In this sense, the heterogeneity among peers is a source of additional learning that arises spontaneously when socializing among them for more than 6 months. Thus, Figure 7 shows some examples of different activities and experiences that take place during the teaching period, (ROP, 2023)

The increase in the demand of students who want to take the CEDEX/UNED Master in Soil Mechanics and Geotechnical Engineering, recently observed with the new adaptation to the telematic mode ("telepresence", to be more precise), is the best proof of the good health of this course in the current context.



Figure 7. "A picture is worth a thousand words"; A) Bridge "Constitución" (Cádiz); B) In class (until 2019); C) Near the El Escorial Monastery, after the geomechanical survey; D) Visiting a tunnel for the high-speed line in Galicia.

3.5 CEDEX's Master in Soil Mechanics and Geotechnical Engineering impact on their graduate's professional life

The CEDEX's Master in Soil Mechanics and Geotechnical Engineering is highly prestigious among companies in the geotechnical engineering sector, being valued for its high academic level and the quality of its training, both in Spain and in Latin American countries. We know that for many alumni, completing this master's program has been a turning point in

their professional careers. This training has enabled them to access better working conditions and more relevant positions within the field of geotechnics.

On the CEDEX website (www.cedex.es), various opinions and references from former students can be found, reflecting how this program has positively influenced their professional trajectories. These testimonials represent the evidence to the significant impact the master's program has on the professional development of its graduates.

4 CONCLUSIONS

In the authors' opinion, learning and teaching in this field of geotechnical engineering leads to success when there is a good syllabus, a large and varied lectures, and an international environment where students interact as a group to complete the master's degree. In addition, the heterogeneity among peers (ages, perspectives, professional backgrounds, countries, degrees, etc.), in a global context, is an unparalleled source of learning that comes from selfless sharing of more than 6 months of hard work. The variety of specializations of the more than 80 lecturers is one of the key factors in its success, as it provides students with both theoretical foundations and applicability to their daily professional work. The geographical diversity of the students' origins means that the course undoubtedly contributes to the consolidation of the Ibero-American geotechnical community.

Finally, and given that technical writings in Spanish are strongly promoted by the academic committee of the Master as a means of transmitting knowledge and to counteract the unnecessary use of Anglicisms, the authors perceive that the course also contributes to the strengthening of geotechnical and engineering terminology among the Spanish-speaking community.

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6 REFERENCES

- Díez Torres, J.A., Asanza Izquierdo, E., Pardo de Santayana Carrillo, F. & Laina Gómez, C. 2023. El Máster en Mecánica del Suelo e Ingeniería Geotécnica del CEDEX/UNED. Memorias del XXVI Congreso Argentino de Mecánica de Suelos e Ingeniería Geotécnica, Comodoro Rivadavia (Argentina).
- Pardo de Santayana Carrillo, F., Asanza Izquierdo, E., Díez Torres, J.A. & Muñiz Menéndez, M. 2020. Master's Degree on soil mechanics at CEDEX: An example of collaboration among government, academia, and industry. International Conference on Geotechnical Engineering Education. Athens (Greece).
- Revista de Obras Públicas (ROP). 2016. Homenaje a José Antonio Jiménez Salas en el centenario de su nacimiento. *Monográfico N.º 3573*.
- Revista de Obras Públicas (ROP). 2023. El Máster en Mecánica del Suelo e Ingeniería Geotécnica del CEDEX-UNED en su cuadragésima edición. *Monográfico N.º 3640*
- SEMSIG. 2000. Libro homenaje a José Antonio Jiménez Salas. Geotecnia. Ministerio de Fomento. Centro de Estudios y Experimentación de Obras Públicas (CEDEX), págs.: 363.