

GRADUATE AND MASTER CURRICULA IN THE FIELD OF CIVIL ENGINEERING AT ESCOLA DE CAMINS OF UPC (SPAIN)

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EXTENDED ABSTRACT

This paper describes the degree and master curricula that are being implemented at *Escola de Camins* (UPC) in Barcelona. This new organization of the studies is motivated by the European convergence in the education at the university level. One of the convergence points is the ECTS (equivalent credit transfer system) in which the subjects and blocks are described.

The new curricula are developed following the structure proposed in Spain which consists of four year degrees followed by one or two year master degrees. In order to satisfy the different interests and skills of students, three different degrees have been implemented at Escola de Camins, namely Civil, Construction and Geological Engineering. Master studies corresponding to different thematic areas of specialization are also in place, as well as the corresponding doctorate studies. Masters, with the professional qualification, are still under design and will be implemented as the newly graduated reach the point to enter the master studies.

The CaminsOpenCourseWare is a newly developed platform to prepare the programs of the different courses forming the degree and master programs. It is based on the concept of competences acquired by the students in each subject or course, and it also permits to describe in more detail the way the course is organized, what is the support material to be used, how the evaluation will be done, and any other aspects of the course organization.

1. A HISTORICAL PERSPECTIVE

The Escola de Camins is the UPC-BarcelonaTech engineering school is responsible for education and research in civil engineering in its broadest sense. Namely, it comprises engineering disciplines like: structural, construction, geotechnical, transportation, urban planning, hydraulic, coastal, environmental, as well as theoretical and applied mechanics. It was created in 1973 and the studies of "Enginyeria de Camins, Canals i Ports (ECCP)" were implemented following the Spanish system at that time which implied that this was a long curriculum (5 years according to national regulations). Graduates from this degree have in-depth abilities to plan, design, construct, and operate society's infrastructure. And consequently, they are empowered to gain the technical, design, and management skills needed to consistently become leaders in education, industry, and government.

Starting in 1987, the degree: "Enginyeria Tècnica d' Obres Pùbliques (ETOP)" was implemented to fulfill the marked needs for a professional with a shorter academic curriculum (3 years according to national regulations) yet, with a deeper focus on technological and practical aspects of construction engineering. The final project usually requires at least an additional semester. Graduates in ETOP are professionals with good technological skills and usually work in project and construction of infrastructures such as roads, railways, hydraulic, ports, etc depending on their major (specialization). Master programs on specific engineering branches are standard technical and managerial complements for these graduates.

In 1990, the studies of "Geological Engineering (EG)" (5 years) were implemented to cover a professional demand in this field. Graduates in EG are professionals with a deep understanding in engineering and natural sciences. This dual thrust empowers them with the technical and managerial aspects of engineering and the fundamentals of natural science. They are especially valuable in analysis (including risk assessment), design and construction of infrastructures with particular emphasis in underground works, engineering sedimentary geology such as river or coastal dynamics, as well as environmental issues related to soils, surface hydrology and groundwater hydrology.

2. THE GLOBAL PERSPECTIVE

The Escola de Camins is a public institution that must encompass a wide range of objectives and engineering branches, which is substantiated, among other aspects, by its magnitude (viz. over three thousands undergraduate and graduate students). This implies that a large number of undergraduate and graduate degrees are implemented to embrace society needs. They incorporate all inherent disciplines to the School (viz. structural, construction, geotechnical, transportation, urban planning, hydraulic, coastal, environmental, as well as theoretical and applied mechanics), and, at the same time, the complete range: from technological aspects to basic scientific engineering issues. The latter are critical in substantiating a critical aspect in this School: cutting-edge research that advances the frontiers of knowledge and engineering capabilities in emerging disciplines as well as traditional subjects.

Consequently, each three-cycle academic degree (bachelor, master and doctorate) presents a large variety of options. At bachelor's level four options are offered: Engineering Sciences (civil), Civil Eng., Construction Eng., and Geological Eng., which range from more scientific to more technological or specialized. Following Spanish legislation, they are four-year programs designed after leaving secondary education (≥ 18 years old).

At master's level two main groups are present. Programs with a global approach and professional qualification such as the Master in *Enginyeria de Camins, Canals i Ports*, which follows Spanish professional qualification rules, the Master in *Civil Eng.*, and the Master in *Geological Eng.* Alternatively there are thematic programs more or less specialized covering all the areas of expertise in the School. Among those, several are jointly offered with other European institutions under the label of Erasmus Mundus programs: *Hydroinformatics and Water Management* (EuroAqua), *Computational Mechanics, Structural Analysis of Monuments and Historical Constructions* (SAMHC), *Coastal and Marine Engineering and Management* (CoMEM), *Flood Risk Management*. The list is completed with the following master programs: *Geotechnical and Seismic Eng.*, *Structural and Construction Eng.*, *Numerical Methods for Eng.*, *Water Resources, Marine Sciences, Environmental Eng.*, *Logistics, Transportation and Mobility*, and, *Sustainability*. The list of available Master programs is published at the *Escola de Camins* web page (www.camins.upc.edu) and information can be found following the corresponding link to other web areas of the *Escola de Camins*.

This structure of general programs (*Civil Eng.*) and specialized ones is also proposed at doctoral level. The following programs have received the maximum qualification (programs of excellence) by the Spanish evaluation agency: *Civil, Structural, Construction, Geotechnical, Earthquake Eng. & Structural Dynamics*, and *Marine Sciences*. The list of available doctorate programs is published at the *Escola de Camins* web page (www.camins.upc.edu).

3. UNDERGRADUATE DEGREES

In this section, a more detailed description of the Civil, Construction and Geological Engineering (CivE, ConsE, GeoE) undergraduate programs is presented. These new curricula are the natural transformation at the degree level of the studies described in the historical perspective.

The first one includes a general and comprehensive formation in the broad field of civil engineering (viz. structural, construction, geotechnical, transportation, urban planning, hydraulic, coastal, environmental, as well as theoretical and applied mechanics). The second is characterized by more specific technological contents. Both degrees (CivE and ConsE) have a Spanish professional qualification. Figure 1 shows the structure of the *Civil Eng.* degree. The blocks shown in the flowchart are decomposed into subjects (≥ 4.5 ECTS), most of them having 6 ECTS or more (7.5 or 9). Spanish and University regulations have favored the 1.5 ECTS multiplicity. Actually, subjects for the basic contents cannot have less than 6 ECTS.

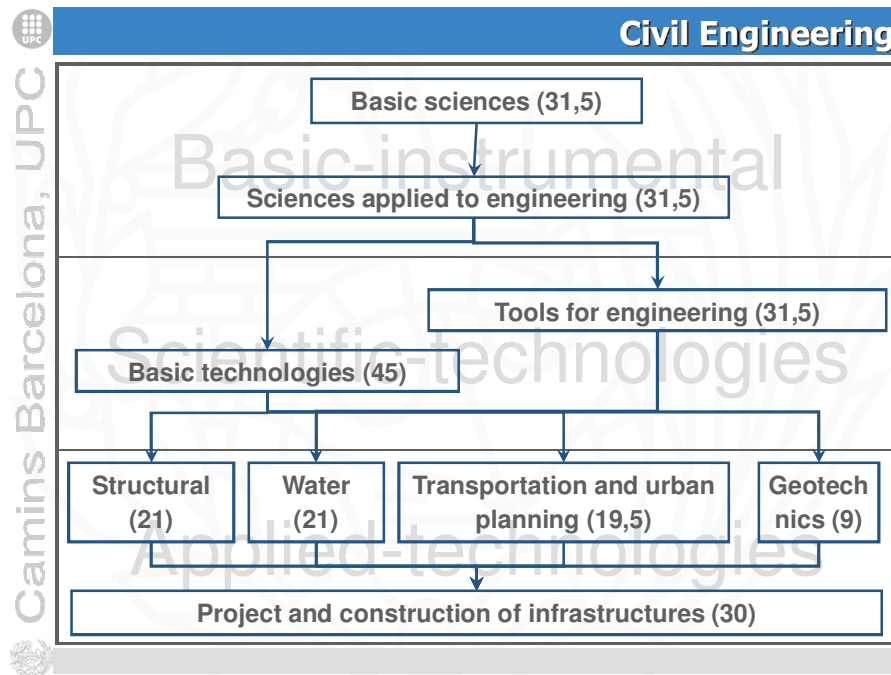


Figure 1. Structure of the degree in civil engineering

The CivE degree is characterized by a comprehensive education in civil engineering, which includes: structural, construction, geotechnical, transportation, and water (including hydraulic, maritime and water quality) engineering, as well as urban planning. Before these specialized technologies are studied, the necessary applied scientific technologies are consolidated. For instance, in the block of basic technologies modules with the basics in these technological branches are covered and, moreover, a global perspective is also presented with modules in continuum mechanics and engineering modeling. The block on tools for engineering is concerned with more instrumental topics, such as graphics, surveying, GIS and statistics.

In contrast to the Civil Engineering degree, the Construction Engineering degree (Figure 2) contains a deeper specialization in technological aspects. Consequently elective options are proposed to specialize the students according to their preferences or abilities. After some general contents in classical fields within civil engineering, an eligible block of 33 ECTS is proposed.

The ConsE degree splits into 3 alternative blocks: Civil Constructions (CC), Hydrology (H) and Transportation and Urban Services (TSU). A unique block is chosen and pursued during the fourth year. Each of these blocks contains compulsory and eligible modules and it is ended by the final graduation project. This degree is oriented to develop professional careers, for instance, in the field of construction and conservation of infrastructures in general, or in the field of hydraulic infrastructures or transportation infrastructures.

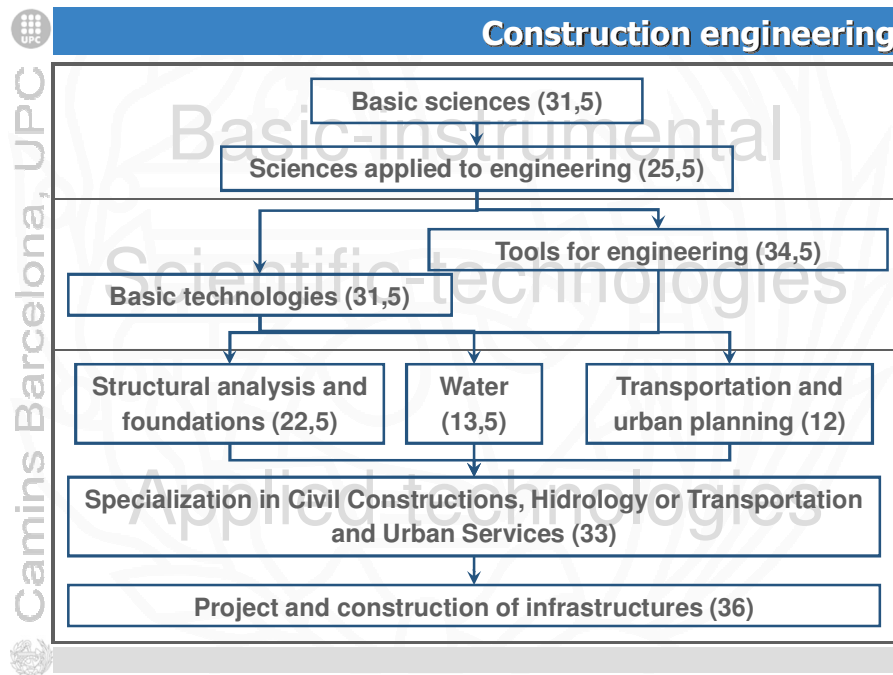


Figure 2. Structure of the degree in construction engineering

As noted previously a degree in Engineering Sciences (Civil) is also being developed in order to permit the students with a larger abstraction capacity to follow a curriculum more theoretical and fundamental. This degree is not conceived to give professional qualification.

Graduates from these previous detailed bachelors are prepared to access the Master in *Enginyeria de Camins, Canals i Ports*. This is a Master that forms professionals in the field of civil engineering which are prepared to undertake jobs and develop a career at the highest level of the administration and industry both in engineering or management orientation. The maximum duration of the Master is two years, but in practice a shortening is expected depending on the competences acquired during the degree. The students finishing the Master may develop a professional career in the field of engineering mainly devoted to design, planning and management of large infrastructures and other engineering projects. Contents of these degrees and master studies include Structural Engineering, Geotechnics, Construction Engineering, Hydraulics, Maritime and Environmental Engineering, Transportation Engineering and Urban Planning, as well as Theoretical and Applied Mechanics.

In addition, Geological Engineering is a shared curriculum, also with a Spanish professional qualification, taught jointly at the *Escola de Camins of Universitat Politècnica de Catalunya-BarcelonaTech* and the *Facultat de Geologia*, this latter belonging to *Universitat de Barcelona* as it is a faculty of geological sciences. It is important to highlight that this engineering degree is intended for students aiming an engineering degree and that also like geology. The combined education in an engineering school and a geological science faculty is unique and empowers the students with abilities and skills in sciences and engineering. Figure 3 shows a block of 30 ECTS devoted exclusively to geology, note also that some geology subjects are present in other blocks, viz. mineralogy and petrology included in the sciences blocks.

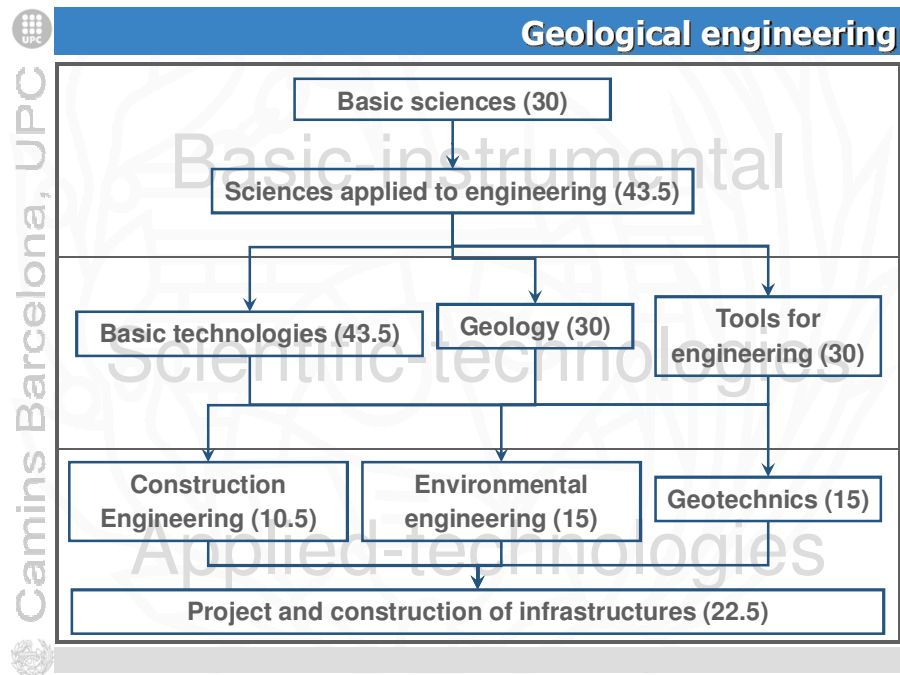


Figure 3. Structure of the degree in geological engineering

This degree focuses on three specific topics which are closely related to the types of jobs offered to these engineers; however the formation is very comprehensive without going into specialization. Master in Geological Engineering is the natural continuation of the degree, and when implemented will have an eligible block. Contents of the Geological Engineering degree and master include geotechnical constructions, environmental engineering related to the ground and natural resources.

4. CAMINS OPEN COURSE WARE (CAMINSOCW)

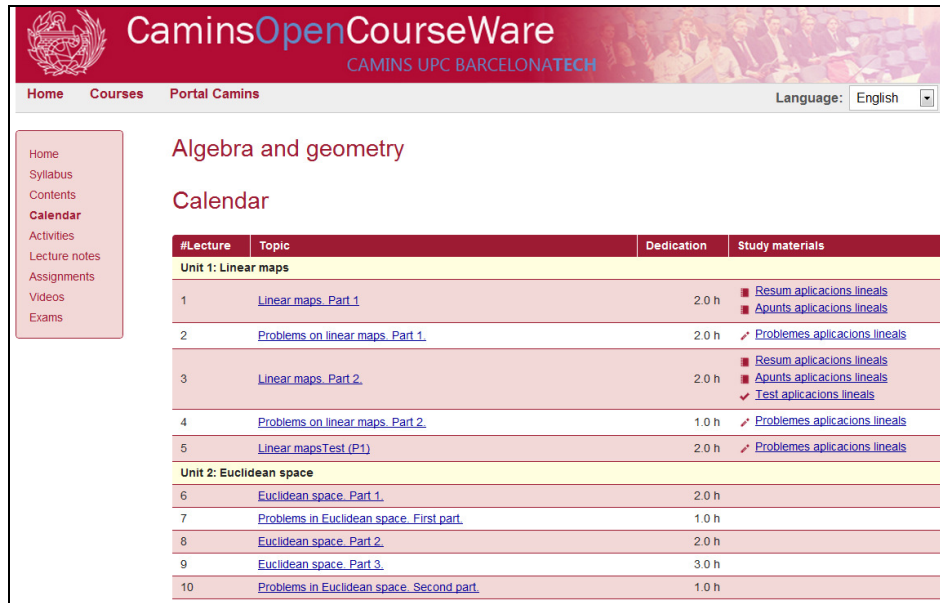
In order to develop the academic guide of each course a new platform has been developed. This platform is being used to prepare the planning of the courses including the contents, references, competences both technological and transversal (such as work in group, writing skills, or sustainability), abilities, skills, support material among other things. This is an open system in the sense that all the contents are free access via internet. The CaminsOpenCourseWare (CaminsOCW) follows the idea initially developed at Massachusetts Institute of Technology (MITOpenCourseWare).

The screenshot displays the CaminsOpenCourseWare (OCW) website. The header includes the Camins UPC BARCELONATECH logo and navigation links: Home, Courses, Portal Camins. A language dropdown is set to English. On the left, a sidebar lists engineering fields: Civil engineering, Construction engineering, and Geological engineering. The main content area features a large image of a bridge over water, with a text box titled "Civil engineering" describing the program's objective: to train generalist engineers with a good formation in basic sciences and a broad vision of civil engineering. Below this, a "Courses" section lists various subjects, each with a color-coded icon indicating its category. On the right, a detailed list of courses is shown, organized by grade level (First-grade, Second-grade, Third-grade, Fourth-grade) and subject area. Each course entry includes a color-coded icon and a brief description.

Figure 4. View of the CaminsOCW first page and list of courses forming the Civil Engineering program. The colors indicate the different blocks in which the subjects are grouped.

The screenshot displays the CaminsOpenCourseWare (OCW) website, specifically the syllabus page for the course "Algebra and geometry". The header includes the Camins UPC BARCELONATECH logo and navigation links: Home, Courses, Portal Camins. A language dropdown is set to English. On the left, a sidebar lists navigation options: Home, Syllabus, Contents, Calendar, Activities, Lecture notes, Assignments, Videos, and Exams. The main content area is titled "Algebra and geometry" and "Syllabus". It includes a "Course description" section stating that students will acquire a general understanding of linear algebra, analytical geometry in two and three dimensions, and methods for solving linear problems encountered in engineering. Below this, a "Learning results" section lists four outcomes: 1. Interpret vector spaces; 2. Solve linear equation systems manually and using basic software; 3. Produce geometric interpretations of concepts in vector calculus; 4. Use algebraic methods applicable to vectors, matrices, operators and tensors, including basic operations, reduction to canonical form and change of base. The "Course contents" section lists topics: Logic, set theory and algebraic structures; Vector spaces, including matrix algebra; Systems of linear equations, linear applications and bilinear forms and the basic algorithms used to solve them; Euclidean spaces; Determinants and their applications, in particular for calculating areas and volumes; Analytical geometry; Linear operators: Endomorphisms and spectral theorems, affine Euclidean spaces, eigenvalues and eigenvectors; Tensor algebra: Basic operations, change of base and tensor calculus. The "Generic objectives" section states: "Delve into the mechanisms of logical reasoning. Studying methods of solving linear problems that appear frequently in engineering. Submit items tensor algebra and analytic geometry." The "Learning objectives" section states: "Ability to solve the types of mathematical problems that may arise in engineering. Ability to apply knowledge of: linear algebra; geometry; differential

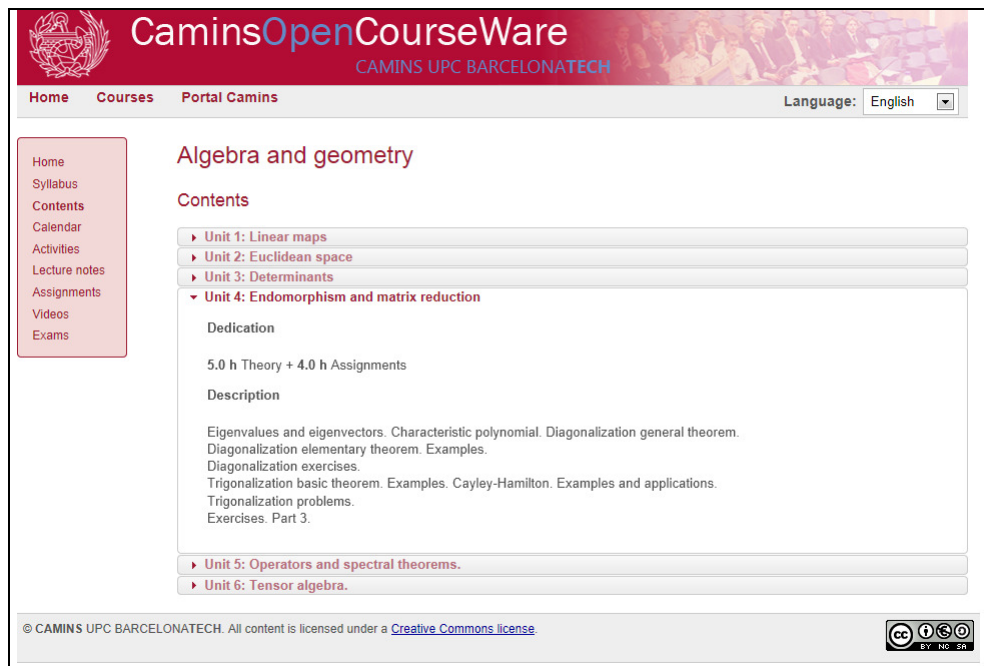
Figure 5. View of the syllabus utility for one of the courses that is included in the CaminsOCW.



The screenshot shows the 'Calendar' utility for the course 'Algebra and geometry'. The page has a header with the CaminsOpenCourseWare logo and navigation links. A sidebar on the left contains links to Home, Syllabus, Contents, Calendar, Activities, Lecture notes, Assignments, Videos, and Exams. The main content area displays a table with columns for #Lecture, Topic, Dedication, and Study materials.

#Lecture	Topic	Dedication	Study materials
Unit 1: Linear maps			
1	Linear maps. Part 1	2.0 h	Resum aplicacions lineals Apunts aplicacions lineals
2	Problems on linear maps. Part 1.	2.0 h	Problemes aplicacions lineals
3	Linear maps. Part 2.	2.0 h	Resum aplicacions lineals Apunts aplicacions lineals Test aplicacions lineals
4	Problems on linear maps. Part 2.	1.0 h	Problemes aplicacions lineals
5	Linear mapsTest (P1)	2.0 h	Problemes aplicacions lineals
Unit 2: Euclidean space			
6	Euclidean space. Part 1.	2.0 h	
7	Problems in Euclidean space. First part.	1.0 h	
8	Euclidean space. Part 2.	2.0 h	
9	Euclidean space. Part 3.	3.0 h	
10	Problems in Euclidean space. Second part.	1.0 h	

Figure 6. View of the planning using the calendar utility for one of the courses that is included in the CaminsOCW.



The screenshot shows the 'Contents' utility for the course 'Algebra and geometry'. The page has a header with the CaminsOpenCourseWare logo and navigation links. A sidebar on the left contains links to Home, Syllabus, Contents, Calendar, Activities, Lecture notes, Assignments, Videos, and Exams. The main content area displays a list of units with expandable sections for Unit 4 and Unit 5.

Unit	Topic	Dedication	Description
Unit 1	Linear maps		
Unit 2	Euclidean space		
Unit 3	Determinants		
Unit 4	Endomorphism and matrix reduction	5.0 h Theory + 4.0 h Assignments	Eigenvalues and eigenvectors. Characteristic polynomial. Diagonalization general theorem. Diagonalization elementary theorem. Examples. Diagonalization exercises. Trigonalization basic theorem. Examples. Cayley-Hamilton. Examples and applications. Trigonalization problems. Exercises. Part 3.
Unit 5	Operators and spectral theorems.		
Unit 6	Tensor algebra.		

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Figure 7. View of the Contents utility for one of the courses that is included in the CaminsOCW.

The main objective of the CaminsOpenCourseWare is to describe students for each subject: objectives, competences and abilities achieved in it, how this is done, any material that the students should use, the distribution of the contents in lectures, laboratory sessions, other practical sessions, computer sessions and how the acquired abilities and skills are evaluated. Figure 4 shows a snapshot of the web site and the list of courses as they are organized by years. The colors indicate the block that each course belongs and this is related to the flowcharts described above in this paper.

For each of the courses a number of sections should be filled (Figures 5, 6 and 7): Calendar, Contents, Activities, Lecture Notes, Assignments, Videos and Exams. In this system, the calendar is the most important section and most of the others develop automatically as they are dependent sections of the calendar. This means for instance that when the planning of the course is done using the calendar, the contents are also generated and the table of contents is automatically constructed.

In addition to the CaminsOCW, the students use a system based on Moodle called ATENEA for the daily activity. This is a more dynamic system which permits to manage assignments, to answer questions, to modify or include new material according to the course evolution.

5. SOME CONSEQUENCES OF THE BOLOGNA PROCESS

In this section some of the consequences of the implementation of the Bologna process are highlighted.

Credit transfer system (ECTS): This is probably the most important improvement which implies that effort is centered in hours of study of students, new standard in Europe, and favors mobility. In addition, a common system of qualification is desired and an ECTS grading scale has been proposed by the European commission.

Mobility: The target is that every student does mobility during the university studies. Actually, the engineering degrees above mentioned have a minimum of mobility compulsory or eligible. One semester at a foreign university following some courses is essential for the final formation of engineers. This is supported by the Erasmus programs but more resources are required. On the other hand, a number of double diploma and interchange agreements are being developed, some of the coming from the existing ones in the old system, but others which are easier to develop thanks to the ECTS system. Mobility is already quite significant at present.

Cyclicality: The studies are cyclic in the new curricula and this was not the case for the traditional system which was based on two categories of engineers (3 and 6 year duration) with little permeability when it was designed. This has some implications and modifies the traditional system in Spain. The classical 5-6 year curricula permitted students to follow the studies at a slow velocity and with minimum marks. Even though they were good the system permitted some slow rate of passing the courses. Now, both the marks and the velocity obtained by graduated will be very important for the admission to Master studies, and therefore the performance of the students is expected to improve as the organization is more competitive. In other words, at the entrance to the system there is no guarantee that a certain reputed master can be finished.

Controllability: The CaminsOCW described above is a new concept for contents, activities, bibliography, and other things publication in which much more transparency of what the students should learn is set up. The system is new and the feedback from professors and students is still not available. The learning methods and the evaluation methods are shown in detail. Concerning the teaching, it is clear that a transformation from the classical lectures to more participative classes is essential. One point is that at present practically all the support material is available through internet. The Escola de Camins is a center with significant scientific production and this should have a consequence on the material and the contents that are included, especially at the Master level.

Profession: Graduated in Engineering can access the professional marked. However, it is expected that a large number of the continue studies at the Master level. This is a consequence of several factors for instance economical as the access to jobs is delayed especially in developed countries or because the students believe that the basic formation at the degree level should be complemented by more technological and specialized courses. The orientation of master courses can be: professional, academic or scientific, thematic, or combination of them.

6. CONCLUSIONS

Following the European convergence of university studies, four year degrees (240 ECTS) are being implemented at *Escola de Camins*. After a historical and global perspective of the *Escola de Camins*, the structure of the recently developed and implemented degrees has been described in the paper.

Three degrees which permit three different professional curricula correspond to the transformation of the formerly existing curricula. The new programs are: Civil Engineering, Construction Engineering and Geological Engineering. At present, the students willing to follow a career in this field are applying for one of them. As the degree is finished a number of possibilities are offered in terms of Master studies, some of them clearly oriented to professional career with comprehensive background and other with a specialized program that permits to get a more profound knowledge in most of civil engineering areas. Some of them follow international Erasmus Mundus structure. Finally, the contents are sometimes oriented to scientific career and belong to eligible subjects which are necessary for carrying out later a doctorate.

A new platform has been developed at *Escola de Camins* in order to open new possibilities for planning the courses and give more transparency to what should be included in each course. The CaminsOpenCourseWare is operative and the courses for the three degrees have been planned using the new platform, as briefly introduced in this paper. This is an accumulative process and it is expected that it will improve during the complete implementation of the new degrees and masters.

REFERENCES

1. www.camins.upc.edu: web page of Escola de Camins
2. ocw.camins.upc.edu: web page of Camins Open Course Ware
3. ocw.mit.edu: web page of MIT Open Course Ware.