CONSTRUCTION BRANCH GUIDE

I METHODOLOGICAL GUIDANCE

I.1 GENERAL ASPECTS

Due to the heterogeneous knowledge and experiences of the students of a course such as this, the provision of a multidisciplinary approach ranging from the most basic knowledge of certain essential subjects to other more difficult subjects which deepen in specific areas has been attempted. Furthermore, some freedom has been left to professors so they can approach each subject from their own perspective, losing uniformity, but gaining a variety of viewpoints. Nevertheless, the extensiveness of the F.E.M. and virtual simulation makes more teaching hours necessary in order to cover all the specific aspects of the course, therefore every subject has been limited in its length and depth to its credits or corresponding hours. Students interested in deeper understanding of certain aspects of the syllabus may start with the additional bibliography specified in the syllabus of each subject and shall consult with the professor/tutor of the subject.

It is very important to highlight that, in a distance learning course, the students must have the self-discipline to follow the timetable of teaching hours for each subject, according to the given guidelines and order of the course (section I from the general guide).

During the weeks devoted to each subject in the schedule, and two additional weeks once the subject is finished, there are four hours per week of tutorships or consultation about the taught subjects.

Finally, the continuous assessment booklets must be completed during the term of the corresponding subject and exams must be taken at the end of the term as detailed in section I.8 and I.10 from the general guide.

If the students do not take or do not pass their exams, they cannot obtain the corresponding diploma.

I.2 EXPERT MODULE SUBJECTS. THEORETICAL FOUNDATIONS

AF.1. - F.E.M GENERAL THEORY

Subject's professors: Mr. Juan José Benito Muñoz PhD

Mr. Ramón Álvarez Cabal. PhD

Mr. Mariano Rodríguez-Avial Llardent PhD

Mr. Enrique López del Hierro Fernández PhD

1. - OBJECTIVES

The aim of this subject is to consolidate the foundations of the Finite Element Method, by thinking mainly about its application in structure analysis, although the basic ideas can be generalized without any difficulty.

Furthermore, it should be pointed out that the subject starts with the most basic concepts, initially treated intuitively in order to allow them to be easily assimilated.

2. - CONTENT

The organization of basic ideas, already known to the student, is the beginning of the subject´s syllabus which tries to organize them using a matrix approach so that the structural calculation will be more effective. It will immediately set out the heart of the formulation of the direct stiffness method and the problem will be reassessed from a more powerful and general point of view. At the beginning it will also deal with the linear elements, which are easier to handle.

Subsequently, the elastic-linear problems are set out, taking a further step in the generalization of ideas, and the C_0 shape functions are studied in detail.

Finally, the theme of plates is discussed with the aim of laying the foundations for a later study about this important structural type and, above all, of presenting general ideas about the problems raised previously and the solutions adopted in cases demanding continuity C_1.

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4.6. - Contour Conditions Imposition. Displacement Calculation

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5.2. - Resolution of the Equations System. Gauss Method. Example 1

5.3. - Freedom Degrees Condensation. Example 2

5.4. - Shape Functions Synthesis. Example 3

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6.3.3. - Thermal Loads

10.8. - Conclusions

3. - BASIC TEXT AND OTHER TEACHING MATERIALS

Course Learning Units

4. - BIBLIOGRAPHICAL REFERENCES

ALARCÓN, A., ALVAREZ, R. & GÓMEZ-LERA, S. *Cálculo Matricial de Estructuras*. Barcelona, España: Ed. Reverté, S.A., 1986. ISBN: 84-291-4801-9.

BATHE, K.J. *Finite Element Procedures in Engineering Analysis*. New Jersey, USA: Ed. Prentice-Hall, Inc., 2007. ISBN-10: 097900490X / ISBN-13: 978-0979004902.

OÑATE, E. *Cálculo de Estructuras por el Método de Elementos Finitos. Análisis Estático Lineal*. España: Ed. CIMNE, 1995. ISBN: 9788487867002.

ZIENKIEWICZ, O.C. & TAYLOR, R.L. The Finite Element Method: Its Basis and Fundamental. 6th edition. Oxford, UK: Ed. Elsevier Butterworth-Heinemann, 2005. ISBN-10: 0750663219/ ISBN-13: 9780750663212.

Spanish version: ZIENKIEWICZ, O.C., TAYLOR, R.L. *El Método de los Elementos Finitos. Formulación Básica y Problemas Lineales*. 4th edition. Barcelona, España: Ed. CIMNE - Mc. Graw-Hill, 1994. ISBN: 9788495999528.

5. - CONTINUOUS ASSESSMENT BOOKLETS

In the distance learning booklets, the given exercises and problems must be directly resolved and it is necessary to use the software in order to compare the results obtained.

6. - SPECIFIC RECOMMENDATIONS

It is advisable that the problems included in the distance learning booklets are resolved as the student moves forwards in the study of the learning units for the purpose of sequentially clarifying, as soon as possible, any doubts that may arise.

7. - TUTORSHIPS: OFFICE HOURS

Professor: Mr. Juan José Benito Muñoz

Mondays, from 4:30 pm to 8:30 pm

Telephones: (+34) 91-398-64-57

(+34) 91-398-64-58

E-mail: jbenito@ind.uned.es

8. - ADDRESS FOR SENDING THE CONTINUOUS ASSESSMENT BOOKLETS

The student will upload the continuous assessment exercises in the virtual classroom.

AF.2. - INTRODUCTION TO F.E.M PROGRAMMING

Subject Professor: Mr. Luis Gavete Corvinos PhD

1. - OBJECTIVES

The objectives of this course are focused on teaching students to use and introduce desired changes on a small computer program using the Finite Element Method. To that end, the student is provided with solid basis of programming with some basic algorithms related to data structure and numerical calculation. Thus, using this basis and simple programming language the programming of the Finite Element Method is addressed.

We believe, therefore, that the objectives of the course are covered by the information provided, although students can improve the programming themselves so that the programs will be more effective. We have opted for clarity over the efficiency of the program. Therefore, we have used the BASIC language because of its ease of use and its wide dissemination.

2. - CONTENT

The Introduction of F.E.M programming course is divided into three large sections. The first section, called “Programming introduction” (Warnier Method in a freeware version), is perfectly adapted to solving mathematical problems through numerical methods. This section includes the first chapters and it gives the basis to understand perfectly (starting from scratch) the programming of complex problems. Furthermore, it includes the basic algorithms which are often used in Finite Element Method programming. Obviously, this could be totally or partly ignored by those students who already have a good knowledge of programming.

The second section constitutes the actual introduction to F.E.M programming which is performed for the two dimensional linear elasticity case using the simplest finite element (three nodes triangle). This section includes two chapters, the first one

addresses the two dimensional elasticity case including a simple graphic processor which allows the user to see the model and the calculation results; the second one contains a brief introduction to storage improvements.

Finally, the third section addresses error estimation in F.E.M. It includes a simple application example as well as its programming.

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IX. Bibliography

Annex: Creating a Shape

3. - BASIC TEXT AND OTHER TEACHING MATERIALS

Course Learning Units

4. - BIBLIOGRAPHICAL REFERENCES

ALARCÓN, A., ALVAREZ, R., GÓMEZ-LERA, S. *Cálculo Matricial de Estructuras*. Barcelona, España: Ed. Reverté, S.A., 1986. ISBN: 84-291-4801-9.

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ZIENKIEWICZ, O.C., TAYLOR, R.L. The Finite Element Method: Its Basis and Fundamental. 6th edition. Oxford, UK: Ed. Elsevier Butterworth-Heinemann, 2005. ISBN-10: 0750663219/ ISBN-13: 9780750663212.

Spanish version: ZIENKIEWICZ, O.C., TAYLOR, R.L. *El Método de los Elementos Finitos. Formulación Básica y Problemas Lineales*. 4th edition. Barcelona, España: Ed. CIMNE - Mc. Graw-Hill, 1994. ISBN: 9788495999528.

5. - TUTORSHIPS: OFFICE HOURS

Professor: Dr. Luis Gavete Corvinos

Mondays, from 11:30 am to 2:00 pm

Fridays, from 12:30 am to 2:00 pm

Telephone: (+34) 91-336-64-66

E-mail: lu.gavete@upm.es

6. - ADDRESS TO SEND THE CONTINUOUS ASSESSMENT BOOKLETS TO

The student will upload the continuous assessment exercises in the virtual classroom.

AF.3.- NUMERICAL CALCULATION

Subject Professor: Mr. Luis Gavete Corvinos PhD

1. - OBJECTIVES

The purpose of this text is to introduce to the student basic numerical calculation techniques, which are employed in the Finite Element Method, and to serve as the first contact base with the numerical methods.

Thus, all the mathematical concepts have been simplified as much as possible and a series of examples has been provided in order to facilitate the students' work. Being a "distance learning" course, it is necessary that the text is accompanied by the required self-taught manual.

Furthermore, the numerical techniques needed in order to do static and dynamic analysis by finite elements in linear and non-linear cases have been covered.

2. - CONTENT

The text has been structured with two simple introductory chapters containing basic introductory concepts about matrices and numerical calculation followed by a second part of numerical calculation.

This second part has a chapter on interpolation (focused on Lagrange Interpolation) with some "spline" function concepts. Subsequently, the numerical integration is covered, focusing on Gauss integration.

Three chapters are dedicated to the basic concepts of numerical Algebra: a) equation systems; b) non-linear equation systems; c) eigenvalues and eigenvectors. The intention is to cover the most common algorithms areas in the finite elements programs.

There is also a chapter based on the resolution of the second order differential equation systems which originate from the dynamic analyses, and there is another chapter which contains an introduction to the equations in partial derivatives and methods of resolving them.

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9.9. - Brief Development of F.E.M. History

X. Bibliography

3. - BASIC TEXT AND OTHER TEACHING MATERIALS

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4. - BIBLIOGRAPHICAL REFERENCES

Software: manuals

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TURNER, P. *Numerical Analysis*. Lancaster, UK: Ed. Macmillan Press Ltd, 1994.

5. - CONTINUOUS ASSESSMENT BOOKLETS

6. - SPECIFIC RECOMMENDATIONS

7. - TUTORSHIPS: OFFICE HOURS

Professor: Dr. Luis Gavete Corvinos

Mondays, from 11:30 am to 2:00 pm

Fridays, from 12:30 am to 2:00 pm

Telephone: (+34) 91-336-64-66

E-mail: lu.gavete@upm.es

8. - ADDRESS FOR SENDING THE CONTINUOUS ASSESSMENT BOOKLETS

The student will upload the continuous assessment exercises in the virtual classroom.

AF.4. - LAWS OF MATERIALS BEHAVIORBEHAVIOR

Subject Professors: Mr. Enrique Alarcón Álvarez PhD
Mr. Alberto Fraile de Lerma PhD

1. - OBJECTIVES

The main objective of the subject is to show the possibilities of representing the non-linear behavior of the materials through mathematical models.

Therefore, it starts with hyperelastic materials which allow us to observe the importance of thermodynamic concepts in materializing reversibility and, later, it sets out the Clausius-Duhem equation as a restriction to the satisfaction of any formulation.

The thermodynamics of irreversible processes based on the local state principle allow the outlining of a global frame where the theories of viscoplasticity, damage, etc. are found, which, in themselves, constitute another objective of the course.

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3.4.1. - Functional Formulation. Creeping and Relaxation Functions

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4.2.1.1. - Von Mises Yield Surface

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4.3. - Plasticity. Analysis by Finite Elements

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4.3.2. - Non-linear Finite Element Method: Algorithm

3. - BASIC TEXT AND OTHER TEACHING MATERIALS

Course Learning Units

4. - BIBLIOGRAPHICAL REFERENCES

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5. - CONTINUOUS ASSESSMENT BOOKLETS

6. - SPECIFIC RECOMMENDATIONS

7. - TUTORSHIPS: OFFICE HOURS

Professor: Dr. Enrique Alarcón Álvarez. enrique.alarcon@upm.es

Professor: Dr. Alberto Fraile de Lerma. alberto.fraile@upm.es

Mondays, from 4:30 pm to 8:30 pm

Telephones: (+34) 91-336-53-40

(+34) 91-336-30-21

8. - ADDRESS FOR SENDING THE CONTINUOUS ASSESSMENT BOOKLETS

The student will upload the continuous assessment exercises in the virtual classroom.

II. EXPERT MODULE SUBJECTS. THEORY AND PRACTICE: CONSTRUCTION BRANCH

AP.1. - INTRODUCTORY COURSE OF THE USE OF THEORETICAL AND PRACTICAL SOFTWARE

Subject lecturer: Mr. Ronald Siat Caparrós

1. - OBJECTIVES

The finite element method is only feasible through the use of a computer and appropriate software; therefore it is necessary to supplement theoretical training in the method with the use of specific software. To that end, CivilFEM has been chosen since it is specially designed for Civil Engineering, in addition it has an Educational license for students, suitable for this kind of course, and it is also a standard software in F.E. programs, which allows the knowledge taught in the course to be put into practice.

The aim of this subject, as its name indicates, is to introduce the student to the use of an analysis program based on Finite Elements and so that the student can feel sufficiently at ease from the beginning to acquire knowledge continuously during the course in the rest of the subjects of Theory and Practice.

2.-CONTENT

This subject is eminently practical and both its content and its structuring are focused on the student becoming familiar with the use of the program from the beginning of the course since it will be useful throughout, and will be the means of materializing and applying the knowledge acquired with the different subjects.

The subject has been structured in various chapters in such a way that each one covers a theme delimited from a conceptual point of view. Before this there is a brief introduction to the finite element method.

3. - BASIC TEXT AND OTHER TEACHING MATERIALS

The teaching material for this subject is composed of CivilFEM software and the *Basic Text* prepared for this subject.

4. - BIBLIOGRAPHICAL REFERENCES

Complementary documentation is provided in the software interactive help section.

5. - CONTINUOUS ASSESSMENT BOOKLETS

The student must follow the proposed exercises in order to do a self-evaluation.

These exercises will be also useful for the student evaluation and qualification. The student will have to prepare a commands file, for the resolution of each example, ready to be processed by CivilFEM.

The exercises must be presented with a brief text in which the steps followed and decisions taken in order to resolve the exercise are described. If possible, the text should contain the most representative graphic outputs or screenshots of each exercise.

6. - SPECIFIC RECOMMENDATIONS

It is recommended to study this subject by carrying out the practical exercises with a computer, consulting to the software's online help.

7. - TUTORSHIPS: OFFICE HOURS

Professor: Mr. Ronald Siat Caparrós

Thursdays, from 10:00 am to 2:00 pm

Telephone: (+34) 91-386-22-22

Fax: (+34) 91-386-45-80

E-mail: r.siat@ingeciber.com

8. - ADDRESS FOR SENDING THE CONTINUOUS ASSESSMENT BOOKLETS

The student will upload the continuous assessment exercises in the virtual classroom.

AP.2. - MODELING TECHNIQUES. USE OF AUTOMATIC MESHING

Subject lecturer: Mr. Ronald Siat Caparrós

1. - OBJECTIVES

Obtaining a proper model is frequently the longest step when carrying out an Analysis, through the use of a Finite Element Method Application program, especially in those cases in which the models present complex geometrical shapes.

Similarly, the accuracy of the results will depend largely on obtaining a model of elements with proper shapes and sizes (mesh density).

The course's goal will be to introduce the student to the modern techniques of Solid Model generation and Automatic Meshing of them, under meshing specifications given by the user, which allows the efficient control of the elements' shapes and the mesh density.

To achieve this, the generation techniques of Solid Models and Meshing of the practice program CivilFEM will be described in detail.

2.-CONTENT

The course is divided into chapters in which the student will be familiarized, step by step, with the geometry creation. The student will also work on the creation tools of the finite elements (mesh) model and the application of the boundary elements and load.

3. - BASIC TEXT AND OTHER TEACHING MATERIALS

The teaching material for this subject is composed of CivilFEM software and the *basic text*: *Solid and Automatic Meshing Modeling Techniques* provided by the course.

4. - BIBLIOGRAPHICAL REFERENCES

The bibliographical references are the same ones as in subject AP.1.

5. - CONTINUOUS ASSESSMENT BOOKLETS

Some exercises that the students must do are proposed.

6. - SPECIFIC RECOMMENDATIONS

It is advisable to study this subject by doing the practices with a computer and consulting the software's online help.

7. - TUTORSHIPS: OFFICE HOURS

Professor: Mr. Ronald Siat Caparrós

Thursdays, from 10:00 am to 2:00 pm

Telephone: (+34) 91-386-22-22

Fax: (+34) 91-386-45-80

E-mail: r.siat@ingeciber.com

8. - ADDRESS FOR SENDING THE CONTINUOUS ASSESSMENT BOOKLETS

The student will upload the continuous assessment exercises in the virtual classroom.

AP3. - APPLICATION PRACTICES. EXAMPLES

Subject lecturer: Mr. Ronald Siat Caparrós

1.-OBJECTIVES

The objective of the course is to complete, with exercises which must be done using CivilFEM for ANSYS, the concepts explained previously in the theoretical and application courses of the modules AF and AP. Teaching the student to use parametric design and other techniques is also aimed for, as well as the completion of practices which help in the learning process.

2.-CONTENT

The exercises represent a review of the concepts introduced in the subjects taken until now, as well as the correct use of the CivilFEM software.

The proposed exercises give a general overview of the field of Civil Engineering, which involves both the generation of models and the verification of structures, both concrete and metallic, through resolved examples.

3. - BASIC TEXT AND OTHER TEACHING MATERIALS

The teaching material for this subject is composed of the given and resolved exercises and CivilFEM software.

4. - BIBLIOGRAPHICAL REFERENCES

Subjects of this course:

-AF.1: FEM general theory

-AF.3: Numerical calculation

-AP.1: Introductory course to use of the practice program

-AP.2: Solid and meshing modeling techniques.

This documentation is online in the help section of the practice program.

5. - CONTINUOUS ASSESSMENT BOOKLETS

The student must send five exercises equal to the ones resolved, which are indicated in the booklet, but modifying the geometrical and load data.

These exercises will be also useful for the student evaluation and qualification. The student will have to prepare a commands file, for the resolution of the example, ready to be processed by CivilFEM.

The exercises must be presented with a brief text in which the steps followed and decisions taken in order to resolve the exercise are described. Ifpossible, the text should contain the most representative graphic outputs or screenshots of each exercise.

6. - SPECIFIC RECOMMENDATIONS

This subject must be taken after having finished subject AP.1, so that the different chapters' main teachings can be completed and assimilated through practice.

Each exercise should not take more than three hours, although it is recommended that the student practices as much as he/she can do with the menu in the post-process phase and analyses and interprets the physical sense of the results obtained.

7. - TUTORSHIPS: OFFICE HOURS

Professor: Mr. Ronald Siat Caparrós

Thursdays, from 10:00 am to 2:00 pm

Telephone: (+34) 91-386-22-22

Fax: (+34) 91-386-45-80

E-mail: r.siat@ingeciber.com

8. - ADDRESS FOR SENDING THE CONTINUOUS ASSESSMENT BOOKLETS

The continuous assessment exercises will be published in the virtual classroom.

Iii SPECIALIZED MODULE SUBJECTS

III.1 MODULE A

A.1. – FEM THEORY APPLIED TO STRUCTURE DYNAMIC ANALYSIS

Subject professor: Dr. Francisco Montans Leal

1. - OBJECTIVES

The initial objectives are to analyze the problems that are actually presented when a structure calculation is going to be made with a commercial Finite Element program and to provide some criteria to resolve these, to focus later on some specific structural types such as plates and sheets.

Finally, it is also intended to provide the essential concepts and to identify the fundamental parameters which characterize the dynamic behavior of structural systems.

2. - CONTENT

In the first chapter, it is intended to present an overview of the problems and different decisions that a structural designer must make when he/she makes a structural analysis.

The second chapter deals with plate and sheet theories. In addition, the plate theory is established for thin plate cases from the hypothesis of Kirchhoff and for thick plates from the Mindlin-Reisner hypothesis. In both cases, the study addresses the case of linear elasticity for homogeneous, isotropic, of constant thickness, perpendicular charged to its mid-surface plates.

Both linear theory and the membrane theory are developed for the constant thickness of thin sheets, and also for the linear case, making the assumption ofsupposing homogeneous and isotropic material.

In the last chapters, the structural dynamic analysis is addressed. Thus, after a brief introduction and a review of the essential concepts, the treatment of the systems is studied with a degree of freedom in order to continue, after the mass and consistent damping matrix have been introduced, with the study of structural systems whose dynamic response can be characterized through a number of finite degrees of freedom.

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II. Plates and Sheets

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2.1.1. - Introduction

2.2. - Thin Plates

2.2.1. - Kirchhoff Hypothesis

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2.2.3.-Boundary Conditions

2.2.4. - Elements Library

2.3. - Thick Plates

2.3.1. - Mindlin-Reisner Hypothesis

2.3.2. - Efforts. Thick Plates Equation

2.3.3. - Boundary Conditions

2.3.4. - Elements Library

2.4. - Sheets

2.4.1. - Introduction

2.4.2. - Efforts. Equilibrium Equations. Displacements

2.5. - Thin Sheets

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2.5.3. - Membrane Theory

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IV. Systems with a Freedom Degree

4.1. - Displacement Equation Formulation

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V. Systems with N Freedom Degrees

5.1. - Formulation of Displacement Equations

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5.3. - Undamped Free Vibrations. Natural Frequency and Vibration Modes. Vibration Modes Properties.

5.4. - Dynamic Response Analysis. Normal Modes Method

5.5. - Damped System Response

5.6. - Modes Superposition

3. - BASIC TEXT AND OTHER TEACHING MATERIALS

Course Learning Units

4. - BIBLIOGRAPHICAL REFERENCES

ALARCÓN, A., ALVAREZ, R. & GÓMEZ-LERA, S. *Cálculo Matricial de Estructuras*. Barcelona, España: Ed. Reverté, S.A., 1986. ISBN: 84-291-4801-9.

CLOUGH R.W. & PENZIEN J. *Dynamics of Structures.* 2nd edition. London, UK: Ed. Mc Graw-Hill, 1993. ISBN-10: 0071132414 / ISBN-13: 9780071332411.

HOU-CHENG HUANG. *Static and Dynamic Analysis of Plates and Shells.* Berlin, Germany: Ed. Springer-Verlag, 1989. ISBN-10 : 0387195386 / ISBN-13 : 9780387195384.

LAROZE S. & BARRAN, J.V. *Mécanique des Structures. Solides Èlastiques, Plasques et Coques. Vol. 1. Paris, France : Ed. Eyrrolles-Masson.*

PRZEMIENIECKI J.S. *Theory of Matrix Structural Analysis.* New York, USA: Ed. Dover Publications, 1986. ISBN-10: 0486649482 / ISBN-13: 9780486649481.

RAO S.S. *Mechanical Vibrations.* 5th edition. Singapore: Ed. Pearson Education Center, 2011. ISBN: 9788177588743.

TIMOSHENKO, S. & WOINOWSKY-FRIEGER, S. *Theory of Plates and Shells*. New York, USA: Mc Graw Hill, 1989. ISBN: 9780000858206.

Spanish version: TIMOSHENKO, S. & WOINOWSKY-FRIEGER, S. *Teoría de Placas y Láminas.* Bilbao, España: Ed. Urmo, 2005. ISBN: 9788431401160.

ZIENKIEWICZ, O.C. *Finite Element Method*. 5th edition. Oxford, UK: Ed. Butterworth-Heinemann, 2005.

Spanish version: ZIENKIEWICZ, O.C. El Método de los Elementos Finitos. Barcelona, España: Ed. Reverté, S.A., 2004.

5. - SPECIFIC RECOMMENDATIONS

It is generally advisable to resolve the simple exercises analyzing the results which are obtained with different meshes and to verify to what extent the hypotheses made are fulfilled in the theoretical approaches.

On the other hand, it should not be forgotten that only with training in calculus canclear criteria be acquired. Therefore, it is recommended that students try to do similar exercises to the ones proposed for continuous assessment, but using problems from his/her professional activity as a base.

6. - TUTORSHIPS: OFFICE HOURS

Professor: Dr. Francisco Montans Leal

E-mail: fco.montans@upm.es

7. - ADDRESS FOR SENDING THE CONTINUOUS ASSESSMENT BOOKLETS

The student will upload the continuous assessment exercises in the virtual classroom.

A.2. - INTRODUCTION TO DYNAMIC ANALYSIS WITH PRACTICAL SOFTWARE

Subject lecturers: Mr. Miguel A. Moreno Fdez. de Yepes PhD

Mr. Ambrosio Baños Abascal

1. - OBJECTIVES

The purpose of the subject is to introduce the student to the basic concepts of Dynamic Analysis of structures by using the practice program to solve distinct types of dynamic analysis that can be resolved with the same method, so that the theoretical concepts that have been taught can be assimilated and the resolution of real problems can be made with a Finite Element program.

2. - CONTENT

The subject is structured into fourteen chapters which describe the different types of analysis and how to do them, and gives examples of what each one resolves.

1. Basic Functions of the Dynamics in a 1 Degree of Freedom System.
2. Modal and Prestressed Modal Analysis.
3. Spectral Analysis.
4. Damping in Dynamic Analysis.
5. Transient Analysis.

3. - BASIC TEXT AND OTHER TEACHING MATERIALS

The teaching material for this subject is composed of the given and resolved exercises and CivilFEM software.

4. - BIBLIOGRAPHICAL REFERENCES

The references are related to the modules previously studied:

-AF.1: FEM general theory

-AF.3: Numerical calculation

-AP.1: Introductory course to using the practice program

-AP.2: Solid and meshing modeling techniques.

As well as the documentation that is online in the help section of the practice program.

5. - CONTINUOUS ASSESSMENT BOOKLETS

The student must follow the instructions given in the virtual classroom by the professor.

6. - SPECIFIC RECOMMENDATIONS

This subject is very large and interestingand it offers complete and exhaustive treatment of the different types of dynamic analysis that are made today using Finite Elements software.

7. - TUTORSHIPS: OFFICE HOURS

Lecturer: Mr. Ambrosio Baños Abascal

Tuesdays, from 3.30pm to 7.30pm

Telephone: (+34) 91-386-22-22

Fax: (+34) 91-386-45-80

E-mail: a.banos@ingeciber.com

8. - ADDRESS FOR SENDING THE CONTINUOUS ASSESSMENT BOOKLETS

The student will upload the continuous assessment exercises in the virtual classroom.

A.3. - DYNAMIC ANALYSIS PRACTICES

Subject lecturers: Mr. Miguel A. Moreno Fdez. de Yepes PhD

Mr. Ambrosio Baños Abascal

1. - OBJECTIVES

The main goal of this subject is to complete, with exercises that have to be made using CivilFEM, the concepts explained in the Theoretical and Application subjects of module A.

2. - CONTENT

Various exercises are proposed, involving the following topics: Modal Analysis, Transitory Analysis and Spectral Analysis.

3. - BASIC TEXT AND OTHER TEACHING MATERIALS

The documentation provided with the proposed and resolved exercises.

4. - BIBLIOGRAPHICAL REFERENCES

Subjects of this course:

A.1. - Static and Dynamic Structural Analysis Foundations

A.2. - Dynamic Analysis Course. Application with the Practice Program

CivilFEM Documentation

5. - CONTINUOUS ASSESSMENT BOOKLETS

The student must follow the instructions given in the virtual classroom by the professor.

6. - SPECIFIC RECOMMENDATIONS

This subject must be taken after having finished subject A.2 using the user's guide and the documentation of the given software, so that the different chapter's main teachings can be completed and assimilated through practice.

Each exercise should not take more than five hours, although it is recommended that the student practices as much as he/she can with the menu in the post-process phase and analyzes and interprets the physical sense of the results obtained.

7. - TUTORSHIPS: OFFICE HOURS

Lecturer: Mr. Ambrosio Baños Abascal

Tuesdays, from 3.30pm to 7.30pm

Telephone: (+34) 91-386-22-22

Fax: (+34) 91-386-45-80

E-mail: a.banos@ingeciber.com

8. - ADDRESS FOR SENDING THE CONTINUOUS ASSESSMENT BOOKLETS

The student will upload the continuous assessment exercises in the virtual classroom.

III.2 MODULE B

B.1. - F.E.M THEORY APPLIED TO NON-LINEAR STRUCTURES CALCULATION

Subject professor: Mr. José Mª Sancho Aznal PhD

1. - OBJECTIVES

The purposes of this subject are to know and understand the formulation using the Finite Element Method of non-linear problems in structures from an engineering perspective, the application to large displacement, large deformations and stiffening by stress problems; as well as the introduction to non-linear mechanics of solids, and in addition to beam elements formulation and its solution methods.

2. - CONTENT

INDEX

4.3. - Arch-length Methods

4.4. - Instability Points Calculation. Linearized Buckling

3. - BASIC TEXT AND OTHER TEACHING MATERIALS

Teaching Units

4. - BIBLIOGRAPHICAL REFERENCES

Teaching units and references are in the same unit.

5. - CONTINUOUS ASSESSMENT BOOKLETS

6. - SPECIFIC RECOMMENDATIONS

7. - TUTORSHIPS: OFFICE HOURS

Professor: Dr. José Mª Sancho Aznal

Fridays, from 10:00 am to 2:00pm

E-mail: jose.sancho@upm.es

8. - ADDRESS FOR SENDING THE CONTINUOUS ASSESSMENT BOOKLETS

The student will upload the continuous assessment exercises in the virtual classroom.

B.2. - INTRODUCTION TO NON LINEAR ANALYSIS WITH PRACTICAL SOFTWARE

Subject lecturer: Mr. José Luis Cuadros Fernández

1. - OBJECTIVES

The first objective of the course is to find answers to some basic questions of the non-linear structural calculation such as the following: What is a non-linear structure? What kinds of problems require a non-linear analysis? What are the causes of non-linear behavior? What is different in a non-linear analysis? What is different in a non-linear analysis by finite elements? What are the essential peculiarities of a non-linear analysis by finite elements? The second objective is to learn to solve the questions through the use of a Finite Elements program like MSC Patran/Nastran.

2. - CONTENT

The content of this subject is structured into different chapters in which are described the different non-linearities, the proceedings to address them, examples of each one and recommendations for their treatment.

In this subject the various types of non-linear behaviors with MSC Patran/Nastran are studied, which can be grouped into three main groups:

- Geometric non-linearities
- Material non-linearities
- "Status" change in contact non-linearities

Furthermore, some examples of the application of the different types of non-linear behavior are presented.

3. - BASIC TEXT AND OTHER TEACHING MATERIALS

The teaching material for this subject is composed of the presented and resolved exercises and CivilFEM software.

4. - BIBLIOGRAPHICAL REFERENCES

Subjects of this course:

-AF.1: FEM general theory

-AF.3: Numerical calculation

-AP.1: Introductory course to using the practice program

-AP.2: Solid and meshing modeling techniques.

This documentation is online in the help section of the practice program.

5. - CONTINUOUS ASSESSMENT BOOKLETS

The student must follow the instructions given in the virtual classroom by the professor.

6. - SPECIFIC RECOMMENDATIONS

This subject is very large as the non-linear problems are found in a wide range of technical applications.

It is advisable for students, after carefully studying each chapter, to follow the resolution of the exercises and the problems highlighted in the subject text on their computers and to resolve the exercises of subject B.3 in the continuous assessment booklet.

7. - TUTORSHIPS: OFFICE HOURS

Lecturer: Mr. José Luis Cuadros Fernández

Tuesdays, from 3:30 pm to 7:30pm

E-mail: jl.cuadros@ingeciber.com

8. - ADDRESS FOR SENDING THE CONTINUOUS ASSESSMENT BOOKLETS

The student will upload the continuous assessment exercises in the virtual classroom.

B.3. - NON-LINEAR ANALYSIS PRACTICES

Subject lecturer: Mr. José Luis Cuadros Fernández

1. - OBJECTIVES

The main goal of this subject is to complete, with exercises that have to be done using Patran/Nastran, the concepts explained in the Theoretical and Application subjects of module B.

2. - CONTENT

The exercises refer to each non-linearity dealt with in the application course.

1. Linear and Nonlinear Analysis of a Cantilever Beam
2. Normal Modes Analysis of a Pre-stiffened Blade
3. Necking of a Test Specimen
4. Creep of a Steel Tube
5. Balljoint Analysis
6. Buckling of a Composite Plate
7. Rubber Door Seal
8. Thermo-Structural Analysis of an Integrated Circuit Board
9. Dynamic Collapse of a Cylinder

3. - BASIC TEXT AND OTHER TEACHING MATERIALS

The basic documentation of the subject is provided with the proposed and resolved exercises.

4. - BIBLIOGRAPHICAL REFERENCES

The references are the same asin the application subject.

5. - CONTINUOUS ASSESSMENT BOOKLETS

The student must follow the instructions given in the virtual classroom

6. - SPECIFIC RECOMMENDATIONS

This subject must be taken after having finished subject B.2 using the user's guide, the analysis guides and the online documentation of the corresponding on-screen commands, so that the different chapters main teachings can be completed and assimilated through practice.

Each exercise should not take more than five hours, although it is recommended that the student practices as much as he/she can with the menu in the post-process phase and analyzes and interprets the physical sense of the results obtained.

7. - TUTORSHIPS: OFFICE HOURS

Lecturer: Mr. José Luis Cuadros Fernández

Tuesdays, from 3:30 pm to 7:30pm

E-mail: jl.cuadros@ingeciber.com

8. - ADDRESS FOR SENDING THE CONTINUOUS ASSESSMENT BOOKLETS

The student will upload the continuous assessment exercises in the virtual classroom.

III.3 . MODULE E

E.1. - ADVANCED CALCULATION OF METALLIC STRUCTURES

Subject professor: Mr. Ramón Álvarez Cabal PhD

1. - OBJETIVES

In this module, it is intended to show the theoretical approaches which support the current calculation tools and verification of structures. This will facilitate, in our view, the application of such tools according to what is described in the following module.

Apart from this basic objective, some purely descriptive units relative to the material, the actions, the security approach etc. are introduced in order to help the students who address, for the first time, metallic structures, the necessary semantics (product description, the relation between the values of the basic parameters, the initial hypothesis, etc.) which will allow comfortable reading of the rest of the course. We understand that these aspects become particularly important within a distance learning course.

2. - CONTENT

UNIT	ISSUE	TITLE
INTRODUCTION		PRESENTATION
	THE PROJECT	PROJECT BASIC CRITERIA
		STRUCTURAL FEASIBILITY
		ACTIONS
		THE MATERIAL
	PLASTIC ANALYSIS	PLASTIC BEHAVIOR OF MATERIALS AND SECTIONS
		METHODS OF PLASTIC ANALYSIS
		APPLICATIONS

ANALYSIS	GEOMETRIC NONLINEARITY	EQUILIBRIUM OVER THE DEFORMED SHAPE SNAP-THROUGH STABILITY PROBLEMS
		EQUILIBRIUM OVER THE DEFORMED SHAPE NON-HOMOGENEOUS PROBLEMS
		ANALYSIS METHODS
VERIFICATIONS IN E.L.S.		DEFLECTIONS VERIFICATION
		VIBRATIONS, DURABILITY

VERIFICATIONS IN E.L.U.	VERIFICATION OF THE MATERIAL	PLASTIFYING CRITERIA
	VERIFICATION OF THE SECTION	SECTIONS CAPACITY (TENSION, COMPRESSION, FLEXION, AND SHEAR)
		STABILITY OF SHEET METAL
		EFFORT INTERACTION
	VERIFICATION OF THE BEAM	TRUSS GIRDERS
		COMPRESSED BEAMS
		BENDING OF BEAMS
		EFFORTS INTERACTION
	VERIFICATION OF THE STRUCTURE	STABILITY
	VERIFICATION OF THE UNIONS	UNIONS TECHNOLOGY
		UNIONS RIGIDITY
		JOIN RESISTANCE
	FIRE DESIGN	FIRE
	FATIGUE VERIFICATION	FATIGUE

3. - BASIC TEST AND OTHER TEACHING MATERIALS

The basic teaching material consists of a series of specific notes on the module.

Additionally, the collections of exercises about Composite and Metallic Structures of the E.T.S.I from the U.P.M available in Publication Section of the school are recommended (Spanish language).

4. - COMPLEMENTARY BIBLIOGRAPHY

It is not strictly necessary, but it will be convenient for the student to access the following regulations.

1. NORMATIVA SOBRE MATERIALES

1.1. EURONORMA 10025 (Antigua UNE 36080)

Edita: AENOR

2. NORMATIVA SOBRE ESTRUCTURAS METÁLICAS EN GENERAL

2.1. E.A. 95 “Estructuras de Acero en Edificación”

Edita: Ministerio de Obras Públicas, Transporte y Medio Ambiente.

Nota: Son las antiguas normas M.V. reeditadas.

2.2. EUROCÓDIGO 3 “Proyecto de Estructuras de Acero”

Edita: AENOR

2.3. S.I.A. 161 “Constructions metalliques”

Edita: Société suisse des ingenieurs et des architectes.

3. NORMATIVA SOBRE ESTRUCTURAS MIXTAS EN GENERAL

3.1. EUROCÓDIGO 4 “Proyecto de Estructuras mixtas de Hormigón y Acero” Parte 1.1

Edita: AENOR.

4 NORMATIVA SOBRE PUENTES METÁLICOS

4.1. RPM - 95 “Recomendaciones para el proyecto de puentes metálicos para carreteras”

Edita: Ministerio de Fomento

4.2. RECOMENDACIONES PARA EL PROYECTO DE PUENTES DE ACERO

Edita: Ensidesa

Nota: Aunque no se trata de normativa, constituye en realidad un resumen muy elaborado de la B.S. 5400.

4.3. BS 5400 “Steel, concrete and composite Bridges”. Part 3: “Code of practice for design of steel bridges”

Edita: British Standards Institution

5. NORMATIVA SOBRE PUENTES MIXTOS

5.1. RPX - 95 “Recomendaciones para el proyecto de puentes mixtos para carreteras”

Edita: Ministerio de Fomento

5.2. BS 5400 “Steel, concrete and composite Bridges”. Part 5: “Code of practice for design of composite bridges”

Edita: British Standards Institution

6. NORMATIVA SOBRE SOLDADURA EN GENERAL

6.1. ANSI /AWS D 1.1 - 95 “Structural welding code. Steel”

Edita: American Welding Society

5. - TUTORSHIPS AND TIMETABLE

Professor: D. Ramón Álvarez Cabal

Tuesdays and Wednesdays, from 7.30 pm to 9.00 pm

Telephone number: (+34) 91- 336- 31- 35

E-mail: ralca@mecaest.etsii.upm.es

6. - ADDRESS FOR SENDING THE CONTINUOUS ASSESSMENT BOOKLETS

The student will upload the continuous assessment exercises in the virtual classroom.

E.2. - METALLIC STRUCTURES COURSE. APPLIED TO THE PRACTICAL SOFTWARE

Subject lecturer: Mr. Juan Carlos Lancha Fernández PhD

1. - OBJECTIVES

In this module, it is intended to show the students the basic concepts of advanced analysis of metallic structures by using the practice software in order to solve the different types of analysis which can be carried out with this software. In this way, the theoretical concepts are put into practice and assimilated, so that the resolution of real problems using finite element software is possible.

2. - CONTENT

The subject is divided into 17 lessons grouped into 10 subjects and 3 units, in which the different types of analysis, how to do them and a few resolved examples are described.

Below the different units and subjects are detailed.

Unit 1: Global Analysis Method

- 1.1: Plastic Analysis
  - 1.1.1: Types of Plastic Material Behavior
  - 1.1.2: Plastic Approach at element level
- 1.2: Geometric Nonlinearity
  - 1.2.1: Stiffness
  - 1.2.2: Linear Buckling: Euler Load
  - 1.2.3: Nonlinear Buckling: Equilibrium over the deformed shape
  - 1.2.4: Large Distortion

Unit 2: Ultimate Limit State

- 2.1: Nonlinear Deflection Analysis
  - 2.1.1: Nonlinear Deflection Analysis
- 2.2: Vibrations
  - 2.2.1: Analysis of eigenfrequencies

Unit 3: Limit Service State

- 3.1: Resistance to the Section: Plasticity and Dent
  - 3.1.1: Elastic Strength

3.1.2: Plastic Strength

3.1.3: Resistance to local buckling

3.2: Strength beam. Buckling of elements.

3.2.1: Simplified Approaches of Beam Buckling Analysis

3.3: Structure Stability

3.3.1: Global Buckling

3.4: Joints

3.4.1: Joint Strength

3.4.2: Nonlinear joints behavior

3.5: Fire

3.5.1: Heat transfer Analysis

3.6: Fatigue

3.6.1: Fatigue Resistance Analysis

3. - BASIC TEST AND OTHER TEACHING MATERIALS

The teaching material consists of a series of specific notes on the module.

4. - COMPLEMENTARY BIBLIOGRAPHY

Additionally, checking the documentation provided with the practice software is recommended.

5. - TUTORSHIPS: OFFICE HOURS

Lecturer: D. Juan Carlos Lancha Fernández

Mondays from 4.00 pm to 8.00 pm

Telephone Number: (+34) 91 348 46 71

E-mail: jclancha@invi.uned.es

E.3. - METALLIC STRUCTURES PRACTICES

Subject lecturer: Mr. Juan Carlos Lancha Fernández PhD

1. - OBJECTIVES

The objective of this subject is to complete, with exercises that have to be done with CivilFEM software, the assimilation of the concepts explained previously in the subjects E1 and E2.

2. - CONTENT

Some practical exercises to which provide the statement and solution are proposed.

3. - BASIC TEXT AND OTHER TEACHING MATERIALS

The basic documentation of the subject is provided with the proposed and resolved exercises.

4. - BIBLIOGRAPHICAL REFERENCES

The references for this subject are subjects E1 and E2 of this course.

5. - ADDRESS FOR SENDING THE CONTINUOUS ASSESSMENT BOOKLETS

The student will upload the continuous assessment exercises in the virtual classroom.

III.4. MODULE H

H.1. - ADVANCED CALCULATION OF CONCRETE STRUCTURES

Subject professor: Mr. Eduardo Salete Casino PhD

1. - OBJECTIVES

This subject is aimed at those engineers or architects who had contact with disciplines such as the Material Resistance, Structural Calculation and Reinforced Concrete during their university studies.

Therefore, this subject does not start from scratch as it is supposed that students already have the knowledge required. But, in case it is necessary to explain, repeat or remind about some concepts which were supposed to be essentials for the development of some topic, the professor of the subject will explain these concepts.

The purpose of this subject is to further the calculation methods for concrete structures and to serve as a theoretical basis to the study of the corresponding theoretical and practical subjects H2 and H3.

2. - CONTENT

The syllabus of this subject has twelve chapters whose organization is described below:

The first chapter focuses on the materials that compose reinforced concrete, that is to say, concrete and steel. It also analyses the characteristics of these materials and takes into consideration the magnitudes which will be used later.

The second chapter analyzes the actions that can affect a structure and the concepts of ultimate limit state design (ULS) and service limit state (SLS) are defined.

The third chapter defines the stress-strain diagrams of the materials, differentiating between the characteristic diagrams and the calculation ones.

The fourth chapter is an exception within the general concept of the subject because it is dedicated to the study of a very particular case: the rectangular cross-section that is subjected to normal stresses acting in one of its planes of symmetry.

The fifth chapter is essential in order to understand how the analysis of reinforced concrete sections subjected to normal stresses is addressed currently. In this chapter, concepts like strain domains, pivots or interaction diagrams, etc. are also introduced.

The sixth chapter analyses the concept of D- Region and develops the strut-and-ties methods which are not only useful for the study of these areas, but will also form the base for addressing the verification of reinforced concrete sections against shear and torque, which is developed in chapter seven.

The eighth chapter looks at the instabilities of linear elements subject to compression, or buckling, reaching the conclusion that the best way to address the problem is not apply to a safety factor to the load, but rather to consider it as an eccentricity to be added to the calculation. In addition, the shrinkage and creep phenomena in concrete are studied.

The ninth chapter develops the topic of plates. It starts with the classic Wood-Armer method which is valid only for bending stress and torques, later analyzing the CEB-FIP method that allows the inclusion of additional forces in the plane (axial and in-plane shear forces), whose formulation is deduced by applying the strut-and-ties method.

The tenth chapter looks at a very complex problem which cannot be addressed without a computer's help: 'the non-linear calculation of concrete structures'. This study is carried out using a simplified method of the moment-curvature diagram.

The eleventh chapter looks at the evolving study of shell structures, which is essential to address construction processes, following an accurate procedure that turns to the introduction in the virtual temperature calculation.

In the last chapter, prestressed concrete is studied, paying special attention to the calculation of losses in cables.

Finally, it is important to highlight that although the goal of this bookis not to make an annotated transcription of reinforced concrete regulations, neither has it been forgotten that these kinds of studies are regulated by different codes in different countries, therefore there are frequentreferences to these codes (specially to the Spanish national standard EHE, to Eurocode 2 and the CEB-FIP Model Code).

Nonetheless, the main objective of this book has been to show the theoretical concepts of the course in the most accurate manner.

3. - CONTINUOUS ASSESSMENT BOOKLETS AND ADDRESS FOR SENDING THESE

The student will upload the continuous assessment exercises in the virtual classroom.

4. - TUTORSHIPS: OFFICE HOURS

Professor: Dr. Eduardo Salete Casino

Tuesdays, from 9:00 am to 1:00 pm

Telephone: (+34)91-386-22-22

Fax: (+34)91-386-45-80

E-mail: e.salete@ingeciber.com

H.2. - INTRODUCTION TO CONCRETE STRUCTURES ANALYSIS WITH PRACTICAL SOFTWARE

Subject lecturer: Mr. Eduardo Salete Casino PhD

1. - OBJECTIVES

The main objective of this subject is for students to come into contact with and handle in a practical manner the basic concepts of advanced calculation of concrete structures through finite elements software.

The use of the practice program allows different types of analysis to be addresses and in this way students can put into practice the theoretical knowledge acquired in the theoretical part of this module.

2. - CONTENT

This subject is divided into nine chapters; however, the first one is the index, so there are, in fact, eight teaching chapters.

Chapter 2 is an introduction to CivilFEM software and a reminder of the subjects AP1, AP2 and AP3.

In chapters 3 and 4 the materials and sections that are used in general reinforced concrete are dealt with.

Chapter 5 deals with the checking and design of reinforced concrete cross-sections according to the regulations.

Chapter 6 deals with the checking and sizing of plates.

Chapter 7 is an introduction to non-linear calculation by finite elements (this chapter is looked at in greater depth in module B: Non-Linear Analysis).

The following chapters are about advanced non-linear analysis:

Chapter 8 deals with structural stability.

Chapter 9 introduces student to the simulation techniques of construction processes.

3. - BASIC TEXT AND OTHER TEACHING MATERIALS

The teaching material consists of the documentation provided, as well as the proposed exercises in the continuous assessment booklets.

4. - BIBLIOGRAPHICAL REFERENCES

The references are the documentation provided with the practical software.

5. - CONTINUOUS ASSESSMENT BOOKLETS AND ADDRESS FOR SENDING THESE

Students must solve the proposed exercises as they progress in the subject and must send the exercises through the virtual classroom.

6. - TUTORSHIPS: OFFICE HOURS

Lecturer: Dr. Eduardo Salete Casino

Tuesdays, from 9:00 am to 1:00 pm

Telephone: (+34)91-386-22-22

Fax: (+34)91-386-45-80

E-mail: e.salete@ingeciber.com

H.3. - CONCRETE STRUCTURES PRACTICES

Subject lecturer: Mr. Eduardo Salete Casino PhD

1. - OBJECTIVES

The objectives of this subject are to complete, with exercises that have to be done using CivilFEM software, the assimilation of the concepts explained previously in subjects H1 and H2 of INTRODUCTION TO CONCRETE STRUCTURES ANALYSIS WITH PRACTICAL SOFTWARE and to enable students become familiar with the use of the software.

2. - CONTENT

The subject includes four exercises corresponding to the advanced calculation of beams and plates:

Exercise 1: Reinforcement design of beams subject to biaxial bending.

Exercise 2: Reinforcement design subject to shear and torsion.

Exercise 3: Reinforcement design of concrete shells.

Exercise 4: Nonlinear calculation of a beam.

3. - BASIC TEXT AND OTHER TEACHING MATERIALS

- The subject's texts
- Provided software and interactive manuals

4. - BIBLIOGRAPHICAL REFERENCES

The references are the manuals and interactive help section of the software.

5. - CONTINUOUS ASSESSMENT BOOKLETS AND ADDRESS FOR SENDING THESE

Students must solve the proposed exercises as they progress in the subject and must send the exercises through the virtual classroom.

6. - TUTORSHIPS: OFFICE HOURS

Lecturer: Dr. Eduardo Salete Casino

Tuesdays, from 9:00 am to 13:00 pm

Telephone: (+34)91-386-22-22

Fax: (+34)91-386-45-80

E-mail: e.salete@ingeciber.com

III.5. MODULE I

I.1. - FEM THEORY APPLIED TO GEOTECHNICS

Subject professors: Mr. Enrique Alarcón Álvarez PhD

Mr. Ignacio del Rey Llorente PhD

1. - OBJECTIVES

The course is divided clearly into two different parts from the perspective of limit state. In the first section, the basis for the study of service situations is established, while in the second section breaking (ultimate) situations are presented.

2. - CONTENT

Part I

The service limit states are dedicated to the calculation of instantaneous and deferred displacements in the ground and they are explained in the first six chapters of the syllabus:

Chapter 1: General Overview and rock and soil taxonomy.

This chapter is an introduction in which the students familiarize themselves with the concepts that will be studied. The emphasis will be on understanding that soils and rocks have to be treated as structures. It is important to note the coexistence of three physical states in the soils defining the different parameters of state that will be used for reference in diverse variables throughout the course.

Subsequently, the classification criteria is studied; in order to define the influence of plasticity and water on soil structure, the difference between the granular and cohesive soils is established.

Different systems of classification for soils and rocks are analyzed and compared.

Chapter 2: The Continuous model. Terzaghi principle.

A relation between the subject and elasticity theory is established in order to make the students understand that soil must be treated as a continuous medium. This fact is

related to the previous chapter when equations are made taking into account the water effect which allows the formulation of the Terzaghi principle or effective stresses.

Three essential relationships are set out in this chapter: total stress balance, compatibility and Behavior Law between effective stresses and deformations. The non-linear character of soil and the need for tests in order to characterize the laws of behavior of the material are highlighted and discussed.

Chapter 3: Wave Propagation

The quantification of motion in a point facing excitations of dynamic origin is dealt with in this chapter. It begins by defining the different types of waves which are generated and the formulas for linear homogeneous elastic mediums through the particularization of the Navier equation. Wave reflections and refractions in laminated soil are also studied.

A section which explains how wave propagation theories can be used to identify the properties of soil is included and, finally, the importance of water in propagation mediums is studied.

Chapter 4: Neutral pressures and filtration force in steady state

This chapter starts by defining permeability as resistance of the medium when water passes through and the d'Arcy's Law and the Bernoulli's Equation in fluids for permeameter resolution are immediately established. The problem is generalized in order to write the filtration field equation in steady state. Different methods are explained in order to evaluate neutral pressure.

Finally, the equilibrium equations are formulated and the filtration forces which generate the fluid movement are defined, which explains the siphoning phenomenon.

Chapter 5: Transient filtration. Compression and Consolidation

The relation between neutral pressure variation over time and the soil skeleton deformation that defines the consolidation process is explained. It is formulated by means of the continuity equation, the material behavior law and the d'Arcy equation for filtration. With the Terzaghi-Rendulic hypothesis, the result is the diffusion

equation. The problem is resolved and the dimensionless coefficients are defined: time factor, consolidation degree and isochronous.

This chapter has a section focused on the characterization by means of testing of soil properties that take part in the consolidation process.

Chapter 6: Settlement Calculation

As has been formulated since the beginning of the course settlement calculation is the final objective of the first part of the subject. This chapter starts by describing the different types of settlements: instantaneous, consolidation and secondary, and goes into more detail in the formulation of each one.

The Skempton approach is followed and this allows neutral pressure to be calculated by means of its two parameters obtained in an experimental way through triaxial testing without drainage. The method proposed by Skempton and Bjerrum for the consolidation settlements calculation in clay is also studied, starting with the results of the oedometer test.

The general problem is formulated in an elastic medium with the coupling of the diffusion and Navier equations using effective stresses.

Finally, the Schmertmann method for settlement calculation on sand is explained.

Part II

In the second part of the subject, the study of ultimate limit states is addressed. The first two chapters analyze the calculation tools while the remaining chapters include the usual applications.

Chapter 7: Soil Cutting Resistance.

This section looks at and describes failure situations due to material breaking, the plastic behavior of the materials helped by Appendix I, which is completely dedicated to plasticity concepts, and two models for soil: the Morh-Coulomb model or the two parameter models in which the resistance curve is approximated by a straight line and the three parameters model of the Cambridge school or the Cam-Clay model.

The stress trajectories in different situations generated using the triaxial test are described and related to the behavior of soil against different loads.

Chapter 8: Estimation method of the ultimate loads.

The formulation of problems and their resolution is extremely complex; therefore it is necessary to resort to approximated methods. Thanks to the kinematic and static methods it is possible to approach their solution from an insecure or secure point of view respectively, and they help with understanding ways of soil breaking when faced with different situations and loads. Finally, the limit equilibrium method, where the previous methods are combined, is presented.

Chapter 9: Walls and screens.

The problem is tackled by defining the thrust or the interaction force between the soil and the structure, approaching the ultimate situations through the classic methods of Rankine and Coulomb.

The second part of the chapter is focused on the security check in different limit states.

Chapter 10: Slope stability

A relation of calculation procedures based on the limit equilibrium method, considerate classical and mainly developed by Swedish School is established.

The complexity of the models continues increases through the exposition of the explanation.

A section is included with the Taylor Abacus that, although limited to simple situations, has been extensively employed due to their ease of use.

This chapter concludes by showing the possibility of resolution by using the finite element method.

Chapter 11: Tunnels

The last chapter of the course is focused on the study of tunnels. It starts with empirical methods based on the assumption of pressure distribution around an excavation.

It continues with the exposition of construction pressures according to the Austrian method widely employed during the last third of the 20th century. A first way of dealing with calculation is approached using the characteristic curves method.
Finally, the possibility of using the finite element method to make a simulation of the drilling process is proposed.

3. - BASIC TEXT AND OTHER TEACHING MATERIALS

Subject text.

4. - BIBLIOGRAPHICAL REFERENCES

ATKINSON, J.H. & BRANDSBY, P.L. The Mechanics of Soils. An Introduction to Critical State Soil Mechanics (University Series in Civil Engineering). ED. MC GRAW-HILL, 1978. ISBN-10: 0070840776 /ISBN-13: 978-0070840775

BERRY, P.L. & REID, D. An Introduction of Soil Mechanics. Ed. Mc GrawHill, 1987. ISBN-10: 0070841640 /ISBN-13: 978-0070841642.

CRAIG, R.F. Craig's Soil Mechanics. 7th edition. New York, USA: Ed. Spon Press, 2004. ISBN-10: 0415327032 /ISBN-13: 978-0415327039.

GULHATI S. K. Engineering Properties of Soils. Ed. Mc Graw Hill Education, 1979. ISBN-10: 0070964343 / ISBN-13: 978-0070964341

JIMÉNEZ SALAS, J.A. Geotecnia y Cimientos III. Cimentaciones, Excavaciones y Aplicaciones de la Geotecnia. Vol. 2. Alcorcón, España: Ed. Rueda, 1998. ISBN-10: 8472070174 /ISBN-13: 978-8472070172.

JIMÉNEZ SALAS, J.A. & DE JUSTO, J.L. Geotecnia y Cimientos I. Propiedades de los Suelos y de las Rocas. 2nd edition, Vol. 1. Alcorcón, España: Ed. Rueda, 1981. ISBN: 9788472070080.

JIMÉNEZ SALAS, J.A., DE JUSTO, J.L. & SERRANO, A. Geotecnia Y Cimientos II. Mecánica del Suelo y de las Rocas. 2nd edition. Alcorcón, España: Ed. Rueda 1981. ISBN: 9788472070219.

5. - CONTINUOUS ASSESSMENT BOOKLETS AND ADDRESS FOR SENDING THESE

The student will upload the continuous assessment exercises in the virtual classroom.

6. - TUTORSHIPS: OFFICE HOURS

Professor: Dr. Enrique Alarcón Álvarez

E-mail: enrique.alarcon@upm.es

Professor: Dr. Ignacio del Rey Llorente

E-mail: idelrey@etsii.upm.es

Mondays, from 4:30pm to 8:30pm

Telephone: (+34) 91-336-53-40

(+34) 91-336-20-21

I.2. - INTRODUCTION TO GEOTECHNICAL ANALYSIS WITH PRACTICAL SOFTWARE

Subject lecturers: Mr. Ronald Siat Caparrós

Mr. Román Martín Martín

1. - OBJECTIVES

The main objective of this subject is for students to come into contact with and handle in a practical way the basic concepts of geotechnical application calculation using finite elements software.

2. - CONTENT

The subject is divided into several chapters through which the capacities of the geotechnical module of CivilFEM for ANSYS, provided to the student as software for application and practice, are shown.

It is intended to link what has been studied in subject I.1 with a practical application about the finite element models of a different nature (structural, filtrations, etc.).

3. - BASIC TEXT AND OTHER TEACHING MATERIALS

- Subject texts
- Software provided and interactive manuals

4. - BIBLIOGRAPHICAL REFERENCES

The references are the manuals, interactive help section of the software and the CivilFEM workbook.

5. - CONTINUOUS ASSESSMENT BOOKLETS AND ADDRESS FOR SENDING THESE

The student must solve the proposed exercises as he/she improves his/her knowledge of the subject and must send them through the virtual classroom.

6. - TUTORSHIPS: OFFICE HOURS

Lecturer: Mr. Ronald Siat Caparrós

E-mail: r.siat@ingeciber.com

Lecturer: Mr. Román Martín Martín

E-mail: r.martin@ingeciber.com

Tuesdays, from 11:00 am to 1:00 pm

Thursdays, from 4:00 pm to 6:00 pm

Telephone: (+34) 91-386-22-22

Fax: (+34) 91-386-45-80

I.3. - INTRODUCTION TO GEOTECHNICAL ANALYSIS. PRACTICES

Subject lecturers: Mr. Ronald Siat Caparrós

Mr. Román Martín Martín

1. - OBJECTIVES

The main objective of this subject is to complete with exercises the concepts studied in previous subjects I1 and I2. The geotechnical exercises will be done with CivilFEM, this will allow the students to be familiarized with the software.

2. - CONTENT

The subject sets out different exercises corresponding to typical cases of geotechnical analysis. The exercise statements are described in the documentation.

3. - BASIC TEXT AND OTHER TEACHING MATERIALS

- I1, I2 and I3 subject texts
- Software provided and interactive manuals

4. - BIBLIOGRAPHICAL REFERENCES

The references are the manuals, interactive help section of the software and the CivilFEM workbook.

5. - CONTINUOUS ASSESSMENT BOOKLETS AND ADDRESS FOR SENDING THESE

Students must solve the proposed exercises as they progress in the subject and they must send the exercises through the virtual classroom.

6. - TUTORSHIPS: OFFICE HOURS

Lecturer: Mr. Ronald Siat Caparrós

E-mail: r.siat@ingeciber.com

Lecturer: Mr. Román Martín Martín

E-mail: r.martin@ingeciber.com

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IV MASTER'S FINAL PROJECT

A. Master's Final Project Assignment

In order to assign the master's final projects, there are two options:

1. *Making a master's final project proposed by the course*

The course has proposed various Master's Final Projects, related to the student´s specialities, so that the students can choose the most appropriate one:

- Interpolation Methods and Numerical Approximation -1.
- Interpolation Methods and Numerical Approximation -2.
- Posteriori Error Estimation in the Finite Element Method.
- Fire Resistance 2D Analysis of the World Trade Center.
- Jules Verne's Cannon.
- Dynamic Analysis Of The Structural Response Of A Tall Building Subjected To Aircraft Impact.
- Design Methods of Reinforced Concrete Shells
- Comparison of Winkler Soil Models with a Three-dimensional Elastic Model.
- Buckling Analysis of Concrete Piles.
- Study of Embedment Depths in Diaphragm Walls.

According to the project chosen, a tutor will be assigned to the student.

2. *The student wishes to propose a specific project*

Students can propose their own topic for their final projects which may be of interest to the company where the student works, or it can be related to the student's personal interests or their future plans for professional activity.

When proposing the final project, students must take into account the size limitations of the educational practice program unless they have access to university facilities with greater capabilities, or a commercial installation in their respective companies.

Similarly, the final project must be related to the *Specialized Module Group* covered . Students should indicate on the application form the professor/lecturer that they would like to be their tutor for their Master's Final Project. The professor/lecturer should correspond to the modules studied by the students.

The Final Project must have the entity and the appropriate scope to be finally accepted.

To apply, students must send the application form according to the these guidelines by e-mail to the following address: c.pizarro@ingeciber.com / g.ramos@ingeciber.com (the application form has a maximum of 3pages).

B. Awards for the Master's Final Project of the Theoretical and Practical Application of Finite Element Method and CAE Simulation

Competition Explanation

The Theoretical and Practical Application of Finite Element Method and CAE Simulation Master concludes, at its highest level, with the Master's Final Project. This project gathers all the knowledge acquired by the student throughout his/her study phase of the Expert and Specialist modules, and concentrates in a sole project all the student's aptitudes and capabilities with a common goal.

The training acquired by students, in addition to their own personal career, will substantially influence the industrial capacities of our society, providing it with highly qualified technicians for its development, prosperity and wellness.

For these reasons, we wish, on an annual basis, to reward the dedication of the student and the excellence of the best Master's Final Project presented on the course. The National Distance Learning University (UNED), through its Superior School of Industrial Engineers, rewards in this way the student's effort and his/her contribution to the study of the practical application of the Finite Element Method.

Competition Foundations

1. *Organization*

The competition is organized by the Superior School of Industrial Engineers of UNED, with its headquarters at the following address: calle Juan del Rosal, 12, 28040, Madrid. To contact with the secretariat of the master's, you should follow the established channels (c.pizarro@ingeciber.com/ g.ramos@ingeciber.com) to which you should send any correspondence.

2. *Competition's aim*

To reward the best Master's Final Project made in the corresponding Theoretical and Practical Application of Finite Element Method and CAE Simulation Master's.

3. *Participation*

In order to participate in the Competition it will be an essential that the Master's Final Projects have received at least a grade of "good" (ECTS: C) during the academic year corresponding to the competition. All the projects made during the course which fulfill this characteristic will participate in the Competition.

4. *Competition schedule*

The competition will be annual.

5. *Projects presentation*

All the students, who have received a mark of "good" or better in the Master's final project during the academic year in which the competition is held, will be automatically entered in the Competition.

If the student does not want to participate in the Competition, he/she must notify the master's secretariat.

The presentation implies agreement, to the Competition Rules in their entirety.

6. *Steering committee, selection criteria and awards of prizing*

The Directors of the Superior School of Industrial Engineers of UNED or the Commission delegated will be the responsible for the judging of the files and the awards of the prizes. The committee will be composed of the School Director or his/her delegate, the Director, the Coordinator and two master's professors.

The jury's decision will not be open to appeal and they will indicate the projects considered to merit the prize, and are also able to declare the prize unawarded.

The winners will be contacted in due time and will be made public before the prize-giving.

7. *Appraisal criteria*

The projects will be evaluated according to their grade of:

- Difficulty: up to 5points
- Originality and Innovation: up to 5 points

8. *Awards*

The prize that the Jury of the Master's Final Project award will be the following:

- The enrollment fees corresponding to the Master's Final Project.

9. *Ownership and Submission of the projects*

The intellectual property of the winning projects and the material property of the documents that integrate them will correspond to the Author of these. The Superior School of Industrial Engineers of UNED reserves the right to keep in its documentary collection winning projects which considers of special relevance or merit.