CES525 - Fracture Mechanics and Applications

Course Title	Fracture Mechanics and Applications				
Course Code	CES525				
Course Type	Compulsory				
Level	MSc (Level 2)				
Year / Semester	1st Year / 2nd Semester				
Teacher's Name	Dr. Demetris Nicolaides				
ECTS	7	Lectures / week	3	Laboratories / week	0
Course Purpose and Objectives	The objective of this course is to enhance students' knowledge and understanding regarding the theoretical and mathematical concepts of linear and non-linear elastic fracture mechanics. The fundamental terms and definitions of fracture mechanics theories, along with the important models described in the international literature are presented and explained to students. Further, the applicability and limitations of each model are thoroughly discussed in class, emphasizing in the application of these theories in the design of concrete structures.				
Learning Outcomes	By the end of the course, the students should be able to: 1. Analyse the concept of categorization of engineering materials: brittle, ductile and quasi-brittle, explain the fundamental concepts of energy-based failure theory, and describe the correlation between cracks and stresses 2. Explain the limits of applicability of LEFM, describe the Griffith's and Irwin's theories of brittle fracture, explain the correlation between Griffith's and Irwin's failure criteria and analyse the possible modes of failure. 3. Explain the fundamental idea and concept of Stress Intensity Factor (K), describe methods for evaluating SIF, analyse the concept of Critical Stress Intensity Factor or Fracture Toughness (KIc) and introduce the Barenblatt's cohesive crack model. 4. Explain the tension softening behaviour, describe and explain the mechanisms responsible for the development and size of FPZ, analyse the concept of FPZ of cement-based materials and explain the size-effect on concrete strength, based on the FPZ concept. 5. Explain the limits of applicability of NLFM, analyse the principles of the Fictitious Crack Model (FCM), and describe the concept and methods of calculation of the Specific Fracture Energy (GF). 6. Describe the concept and methods of calculation of the Characteristic Length (lch), analyse the principles of the Crack Band Model (CBM)				

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<tr><td></td><td colspan="3">and explain which Fracture parameters are required for the application of the NLFM.
7. Describe test methods for the determination of fracture parameters and the determination of the tension softening response of concrete.
8. Explain how Fracture Mechanics principles are applied in metallic, ceramic and cement-based materials and structures and present relevant applications.</td></tr>
<tr><td>Prerequisites</td><td>None</td><td>Corequisites</td><td>None</td></tr>
<tr><td>Course Content</td><td colspan="3"><u>Introduction to Fracture Mechanics:</u> Analyse the concept of categorization of engineering materials: brittle, ductile and quasi-brittle. Explain the fundamental concepts of Energy-based failure theory and describe the correlation between cracks and stresses.

<u>LEFM: Linear Elastic Fracture Mechanics:</u> Explain the limits of applicability of LEFM. Describe the Griffith’s theory of brittle fracture and the Irwin’s theory of brittle fracture and also analyse the possible modes of failure. Provide the fundamental idea and concept of Stress Intensity Factor (K) and describe methods for evaluating SIF. Moreover, the concept of the Critical Stress Intensity Factor or Fracture Toughness (K_{Ic}) will be analysed, and explain the correlation between Griffith’s and Irwin’s failure criteria. Finally, the Barenblatt’s cohesive crack model will be introduced.

<u>FPZ: Fracture Process Zone:</u> Explain the tension softening behaviour of certain materials, describe and explain the mechanisms responsible for the development and the size of FPZ. Analyse the concept of FPZ of cement-based materials and explain the size-effect on concrete strength, based on the FPZ concept.

<u>NLFM: Non-Linear Fracture Mechanics:</u> Explain the limits of applicability of NLFM. Analyse the principles of the Fictitious Crack Model (FCM) and describe the concept and methods of calculation of the Specific Fracture Energy (G_F). In addition, describe the concept and methods of calculation of the Characteristic Length (l_{ch}) and analyse the principles of the Crack Band Model (CBM). Finally, explain which Fracture parameters are required for the application of the NLFM. Analyse the approximate nonlinear fracture models. Describe test methods for the determination of fracture parameters and the determination of the tension softening response of concrete.

<u>Fracture Mechanics Applications to Engineering Problems:</u> Describe how Fracture Mechanics principles are applied in metallic, ceramic and cement-based materials and structures and present relevant applications.</td></tr>
<tr><td>Teaching Methodology</td><td colspan="3">The course will be presented through theoretical lectures in class. The lectures will present to the student the course content and allow for questions. Part of the material will be presented using visual aids. The aim is to familiarize the student with the different and faster pace of presentation and also allow the instructor to present related material (photographs etc.) that would otherwise be very difficult to do. The learning process will be enhanced with the requirement from the student to solve relevant examples. These include self-evaluation exercises which will be solved in class. These exercises will not be graded. Exercises will also be given as homework which will be part of their assessment. Besides from the notes taken by students in</td></tr>
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	class, all of the course material will be made available through the class website and also through the e-Learning platform. Finally the instructor will be available to students during office hours or by appointment in order to provide any necessary tutoring.
Bibliography	**Textbooks:** 1. "Elementary engineering fracture mechanics", Broek, Martinus Nijhoff Publishers, 3rd Edition, 1982. 2. "Fracture Mechanics and Structural Concrete", Karihaloo, Pearson Education, 1995. 3. "Applications of Fracture Mechanics to Concrete, Rock and other Quasi-Brittle materials", Shah, Swartz and Ouyang, John Wiley and Sons, 1995.
Assessment	The course is assessed through mid-term examinations, term project and a final examination. The criteria for assessment can be found on the individual assignments and exams. The weights of the course assessment are as follows: Midterm Exams: 25% Term Project: 25% Final Exam: 50%
Language	English