ETE 911 Structural Health Monitoring of Modern Structures

COURSE OUTLINE

(1) GENERAL

SCHOOL	SCHOOL OF ENGINEERING		
ACADEMIC UNIT	DEPARTMENT OF MATERIALS SCIENCE AND ENGINEERING		
LEVEL OF STUDIES	UNDERGRADUATE		
COURSE CODE	**ETE 911**	**SEMESTER**	**9**
COURSE TITLE	Structural Health Monitoring of Modern Structures		

INDEPENDENT TEACHING ACTIVITIES *if credits are awarded for separate components of the course, e.g. lectures, laboratory exercises, etc. If the credits are awarded for the whole of the course, give the weekly teaching hours and the total credits*	**WEEKLY TEACHING HOURS**	**CREDITS**
Lectures	3	3
Add rows if necessary. The organization of teaching and the teaching methods used are described in detail at (d).		

COURSE TYPE *general background, special background, specialized general knowledge, skills development*	Specialization Course
PREREQUISITE COURSES:	NO
LANGUAGE OF INSTRUCTION and EXAMINATIONS:	GREEK
IS THE COURSE OFFERED TO ERASMUS STUDENTS	YES
COURSE WEBSITE (URL)	

(2) LEARNING OUTCOMES

Learning outcomes

The course learning outcomes, specific knowledge, skills and competences of an appropriate level, which the students will acquire with the successful completion of the course are described.

Consult Appendix A

- *Description of the level of learning outcomes for each qualifications cycle, according to the Qualifications Framework of the European Higher Education Area*
- *Descriptors for Levels 6, 7 & 8 of the European Qualifications Framework for Lifelong Learning and Appendix B*
- *Guidelines for writing Learning Outcomes*

Upon successful completion of the course, students will be able to:

1. Understand the fundamental principles of Structural Health Monitoring (SHM) and distinguish between non-destructive testing/evaluation (NDT/NDE) and SHM.
2. Identify damage mechanisms (cracks, fatigue, corrosion, delamination, etc.).
3. Describe and apply sensor-based methods (strain gauges, piezoelectric sensors, Fiber Bragg Gratings – FBG, acoustic emission, ultrasonics, vibration-based methods).
4. Analyze the dynamic response of structures (natural frequencies, mode shapes, damping).
5. Apply fundamental signal processing techniques (FFT, spectral analysis, time–frequency methods).
6. Understand damage indices and techniques for damage detection and quantification.

7. Design a basic SHM system for reinforced concrete, metallic, or composite structures.
8. Evaluate monitoring data using basic statistical algorithms or machine learning methods.

The course corresponds to Level 6 (EQF), fostering analytical and critical thinking skills in engineering applications.

General Competences

Taking into consideration the general competences that the degree-holder must acquire (as these appear in the Diploma Supplement and appear below), at which of the following does the course aim?

Search for, analysis and synthesis of data and information, with the use of the necessary technology	*Project planning and management*
Adapting to new situations	*Respect for difference and multiculturalism*
Decision-making	*Respect for the natural environment*
Working independently	*Showing social, professional and ethical responsibility and sensitivity to gender issues*
Team work	*Criticism and self-criticism*
Working in an international environment	*Production of free, creative and inductive thinking*
Working in an interdisciplinary environment	*……*
Production of new research ideas	*Others…*
	…….

The course aims to develop the following competencies:

- Data search, analysis, and synthesis
- Use of modern measurement and signal processing technologies
- Technical decision-making
- Independent work
- Teamwork
- Work in an interdisciplinary environment (Engineering – Materials – Electronics – AI)
- Development of new research ideas
- Exercise of critical thinking
- Design and management of technical projects

(3) SYLLABUS

The course **"Structural Health Monitoring of Modern Structures"** focuses on the principles and technologies of Structural Health Monitoring (SHM), with emphasis on reinforced and prestressed concrete structures, as well as metallic and composite load-bearing systems and asphalt pavements for road network monitoring.

Initially, the philosophy of structural monitoring is presented, together with the distinction between non-destructive testing/evaluation (NDT/NDE) and continuous monitoring systems. The fundamental damage mechanisms in concrete structures are analyzed, including flexural and shear cracking, creep and drying shrinkage, carbonation, chloride ingress, reinforcement corrosion, concrete cover delamination, and stiffness degradation. The behavior of bridges, slabs, columns, and shear walls under static and dynamic loading is also examined.

Subsequently, the sensor technologies and measurement systems applied to concrete structures are developed, such as:

- Surface-mounted and embedded strain gauges
- Reinforcement corrosion monitoring sensors
- Piezoelectric ultrasonic sensors
- Fiber optic sensors (Fiber Bragg Gratings – FBG)

- Acoustic emission techniques
- Accelerometers for dynamic identification
- Infrared thermography and impact-echo methods

Particular emphasis is placed on the dynamic identification of concrete structures, on changes in natural frequencies and mode shapes as indicators of damage, and on the evaluation of stiffness reduction due to cracking or corrosion. Fundamental signal processing techniques are presented (spectral analysis, FFT, filtering, time–frequency techniques), along with an introduction to damage indices for the detection and quantification of structural deterioration.

The course concludes with applications to bridges, buildings, dams, and other infrastructure systems, as well as an introduction to data-driven approaches and basic machine learning techniques for classifying operational states (healthy – degraded – critical condition).

The theoretical instruction is supported by laboratory exercises and the analysis of real or simulated data from concrete and/or metallic structures, aiming to bridge theory with practical application in modern infrastructure engineering.

(4) TEACHING and LEARNING METHODS - EVALUATION

DELIVERY *Face-to-face, Distance learning, etc.*	In class, lectures
USE OF INFORMATION AND COMMUNICATIONS TECHNOLOGY *Use of ICT in teaching, laboratory education, communication with students*	Within the framework of the course, modern data acquisition, processing, and analysis technologies are utilized, with the primary laboratory equipment being the PASCO cable-stayed bridge model. This system enables the experimental investigation of the static and dynamic behavior of a bridge through integrated accelerometers and dynamic measurements. Experimental data acquisition is performed using DAQ systems and the LabVIEW environment, which is used for: • Real-time signal acquisition and recording (load variations, accelerations), • Development of virtual instruments (VIs) for monitoring structural response, • Simultaneous multi-channel measurements and data synchronization, • Visualization of time histories and spectral plots, • Basic signal processing (filtering, FFT, natural frequency estimation), • Development of automated loading test scenarios. Through LabVIEW, students become familiar with the concept of real-time monitoring systems and the development of simple algorithms for detecting changes in the dynamic behavior of the structure. Particular emphasis is placed on variations in natural frequencies and internal cable forces as indicators of potential structural deterioration. Furthermore, data are exported for additional analysis

	in MATLAB or Python, where spectral analysis techniques, damage index calculations, and basic pattern recognition methods are applied. In this way, students cover the complete SHM system cycle: from sensing and data acquisition to analysis, interpretation, and technical evaluation of structural integrity. The integration of Information and Communication Technologies (ICT) in the laboratory transforms the course into an applied learning environment, simulating the technologies used in real bridge and infrastructure monitoring systems.
TEACHING METHODS *The manner and methods of teaching are described in detail.* *Lectures, seminars, laboratory practice, fieldwork, study and analysis of bibliography, tutorials, placements, clinical practice, art workshop, interactive teaching, educational visits, project, essay writing, artistic creativity, etc.* *The student's study hours for each learning activity are given as well as the hours of non-directed study according to the principles of the ECTS*	

Activity	***Semester workload***
Lectures	30
Laboratory practice	9
Homework	26
Project work	10
Course total	**75**

STUDENT PERFORMANCE EVALUATION *Description of the evaluation procedure* *Language of evaluation, methods of evaluation, summative or conclusive, multiple choice questionnaires, short-answer questions, open-ended questions, problem solving, written work, essay/report, oral examination, public presentation, laboratory work, clinical examination of patient, art interpretation, other* *Specifically-defined evaluation criteria are given, and if and where they are accessible to students.*	LANGUAGE OF EVALUATION: Greek METHOD OF EVALUATION: Assessment includes: Written final examination (theory and problem solving), and/or Individual project presentation Clear grading criteria are communicated to students at the beginning of the semester.

(5) ATTACHED BIBLIOGRAPHY

- *Suggested bibliography:*

Structural Health Monitoring of Civil Infrastructure Systems **Edited by:** Vistasp M. Karbhari and Farhad Ansari, 2009, **ISBN:** 978-1-84569-392-3

Structural Health Monitoring: A Machine Learning Perspective, **Authors**: Charles R. Farrar, Keith Worden, 2012, Online ISBN:9781118443118