TEACHING SAFETY AND SUSTAINABILITY ISSUES IN CIVIL ENGINEERING MASTER COURSE

M. SAVOIA[1], N. BURATTI[1], P. PRINOS[2], J. AZEVEDO[3], L. CASTRO[3], G. DE ROECK[4], G. LOMBAERT[4], P. DIAZ SIMAL[5], J.B.M. SEGURA[6], G. MAGENES[7], A. BLOODWORTH[8]

[1] DICAM, University of Bologna, Bologna, Italy
[2] Dept. of Civil Engineering, Aristotle Univ. of Thessaloniki, Thessaloniki, Greece
[3] DECivil, IST, ULisboa, Portugal
[4] Dept. of Civil Engineering, KU Leuven, Belgium
[5] Universidad de Cantabria, Santander, Spain
[6] Dept. of Hydraulics Engineering, Universidad Politecnica de Valencia, Valencia, Spain
[7] Department of Civil Engineering and Architecture , University of Pavia, Italy
[8] Faculty of Engineering and the Environment, University of Southampton, Southampton, UK
e-mail: marco.savoia@unibo.it

Conference Key Areas: Curriculum development, internationalization, sustainability in engineering education.
Keywords: Civil Engineering; Safety; Sustainability; Natural Hazards.

INTRODUCTION

The performance of the built environment and constructions are of major concern for Europe’s long term goal of sustainable development. At the same time, the quality of life of all European citizens needs to be improved and the safety of the built environment with respect to anthropic and natural hazards, such as flooding and earthquakes, needs to be ensured.

Education has a central role to play in the transformation of the construction sector which is required to meet increasing demands with regard to safety and sustainability. It is well recognized that one of the factors with most impact on the levels of regional sustainability is education (Velasquez,1999). Nevertheless, the assumption that environmental issues should be addressed by environmental specialists and not by civil engineers is still a common issue, and must be overcome (Cortese, 1997).

This paper presents the SASICE project, funded by the European Community in the context of the Lifelong Learning Programme (Erasmus Curriculum Development Program) and coordinated by the University of Bologna. The aim of this project is to promote the integration of safety and sustainability in civil engineering education. The universities participating to the project constitute a network of high level competence in civil engineering. Strategies to improve lifelong learning include the development of adapted teaching moduli, exchange of professors and joint curricula.

[1] Corresponding Author - M. Savoia
Marco.savoia@unibo.it

This paper focuses on the central part of the project, i.e. the development of teaching moduli in 4 thematic areas selected at the beginning of the project.

The main target of the SASICE project is to enable students to introduce these advanced topics in their curricula and to attain specific skills and expertise in safety and sustainability in Civil Engineering.

The following sections present the content of the teaching moduli of the project and the way that students could benefit from the whole process.

1 THE SASICE PROJECT

The aim of the SASICE Erasmus Curriculum Development project is to promote the integration of safety and sustainability in civil engineering education. The coordinating organisation is the University of Bologna, and nine partner universities from different countries are involved (University of Bologna, Aristotle University of Thessaloniki, Instituto Superior Tecnico, KU Leuven, Universidad Politecnica de Valencia, Universidad de Cantabria, University of Pavia, Université Joseph Fourier Grenoble, University of Southampton). The consortium is formed by universities covering different regions of the EU with diverse social models, so providing a unique exchange experience for education and research to future students, as well as broadened employment possibilities after graduation. All the partner universities have internationalization of education as a strategic priority, and some of them already have Master courses taught in English in collaboration with internationally recognized European or US partners. The partner universities also have a long tradition in collaboration in different areas of Civil Engineering, as evidenced by the projects funded by the European Community in which partners are involved. Almost all Universities are partner of Associations on Higher Education in the field of Engineering, as SEFI (European Society for Engineering Education), which has a task force dedicated to Sustainability in Engineering Education, and EUCEET (European Civil Engineering Education and Training), so allowing to disseminate the project results on a large scale during and after the project.
The programme focuses on how to form a new generation of civil engineers in different regions of the EU, with a deep knowledge on safety and sustainability, as well as assessment and design methods and guidelines adopted in different European countries, thus striving to achieve the goals of the Lisbon agenda. The main target is to enable students to introduce these advanced topics in their study plans and curricula and reach, at the end of their studies, a specific skill and expertise in safety and sustainability in the Civil Engineering field.

The project is organised in five parts:

1. analysis of the needs in close consultation with all stakeholders;
2. development of teaching moduli on safety and sustainability in civil engineering;
3. integration of the teaching moduli in existing and new joint university curricula;
4. pilot implementation of the moduli with an international exchange of professors between Universities;
5. development of innovative ICT-based content and services.

Teaching moduli have been developed in 4 thematic areas (see *Fig. 1*):

1) Safety in construction,
2) Risk induced by Natural Hazards Assessment,
3) Sustainability in construction,
4) Sustainability at the territorial level.

The topics have been selected based on an extensive analysis of the need for highly qualified education on safety and sustainability involving all relevant stakeholders (European and national authorities, companies, research institutes, professional organizations and universities) (Terti et al, 2011).

The development of flexible teaching moduli supported by powerful ICT services will allow exploiting the results in a wide spectrum of educational settings within higher education institutions. The project will also stimulate legislative or technical changes required to facilitate the development of joint programmes.

	CONSTRUCTION	ENVIRONMENT
SAFETY	WP6	WP7
SUSTAINABILITY	WP8	WP9

WP6 - Safety in Construction
WP7 - Natural Hazards and Management of Risk
WP8 - Sustainability in construction
WP9 - Sustainable Development & Environmental Protection

Fig. 1. The four project work-packages for the development of the teaching moduli.

2 TEACHING MODULUS N. 1: SAFETY IN CONSTRUCTION

2.1 Motivation

Presently, building codes require constructions to be designed in order to satisfy given levels of safety with respect to some performance criteria. For new constructions, these requirements are clearly stated in European design codes (Eurocodes), whereas for existing constructions, the criteria for assessment and for design of strengthening interventions are not uniform across European countries. Existing constructions include residential and commercial buildings, bridges and retaining walls, some of which are of historical and cultural importance. They can be very sensitive to actions such as earthquakes and the effects of pollution and climate change if these have not been accounted for in the design. Consideration of sustainability issues is leading to a drive to refurbish and extend the life of existing constructions rather than to demolish and replace them.

The aim of this modulus therefore is to present best practice from across Europe on the assessment, repair and strengthening of existing structures. The focus of the module is on masonry, steel and reinforced concrete structures. The context is first set by a general introduction that includes what can be learned by examining past structural failures. The modulus is then divided into three parts, looking firstly at assessment techniques for existing structures (focusing on field-based methods of survey and assessment), then moving on to estimating the safety margin of existing structures using probabilistic methods of assessment of structural strength and loadings. Finally, the modulus examines repair and strengthening techniques that are available for structures and foundations, and techniques for the selection of these. Lessons learned from recent events will be the main subject for the case studies in the final part of the course (Savoia et al., 2013).

2.2 Learning outcomes

Having successfully completed the modulus, students will be able to demonstrate knowledge and understanding of:

- Past structural failures and what can be learned from studying them;
- Logical methods in which to execute the survey of an existing structure for assessment purposes;
- Practical methods for determining in situ the strength of construction materials and for monitoring structures in service, their applicability and limitations;
- Construction service life and how to determine serviceability failure;
- Appropriate methods for modelling and analysing a structure to determine its load effects for assessment;
- Methods for arriving at design values for material strengths and actions for assessment;
- Probabilistic reliability theory and its application in calculating the safety margin of constructions;
- Methods for repair and strengthening of a range of structure types, their applicability and limitations;
- Appropriate methods for upgrading foundations of existing structures.

2.3 Assessment and feedback methods

The assessment of the learning outcomes of the teaching modulus will be performed by individual coursework assignments:

1. Forensic investigation of a past documented structural failure (short essay);
2. Case study of the assessment of an existing structure (report);
3. Calculation of the safety level of an existing structure (report and calculations);
4. Proposal for the repair/strengthening of an existing structure (report and calculations).

3 TEACHING MODULUS N. 2 – NATURAL HAZARDS AND RISK MANAGEMENT

3.1 Motivation

Geological, hydrological and meteorological events such as volcanic eruptions, landslides, floods, tsunamis, earthquakes and snow avalanches cause life losses and economic damage every year. To predict, manage and communicate the hazards associated with such events a clear understanding of their physical nature is required. Explanation of the causes and impact of hazards requires understanding not only of environmental hazards but also diverse social, economic, cultural, institutional, and other factors which shape vulnerability. Theories of social vulnerability and protection, sustainable development and disaster risk management, the causes and consequences of natural disasters, and decision-making processes and interventions to reduce disaster risk will be the subject of the teaching modulus. The links between hazards, vulnerability and disasters, and the factors affecting the governance of disaster risk management will be also examined.

The modulus is structured into three main sub-modules: (a) Physical and socio-economic processes and systems, (b) Risk management framework and (c) Case studies. The first treats the physical processes of extreme events. Basics from meteorology, hydrology, economics, engineering and planning sciences are mapped out. The second deals with risk analysis (hazard determination, vulnerability determination and risk analysis), risk evaluation and mitigation measures (structural and non-structural) within the system of an integrated risk management. Finally, case studies (floods, earthquakes, landslides) will be presented to the students and analysed.

3.2 Learning outcomes

Having successfully completed the modulus, students will be able to demonstrate knowledge and understanding of:

- Types of natural hazards and their consequences;
- The concepts of potential damages, tangible and intangible losses and vulnerability;
- Models and estimation of vulnerability;
- Hazard risk mitigation using structural and non-structural measures;
- The components of the risk management framework;
- Estimation, assessment and reduction of risk;
- The Source-Pathway-Receptor- Consequences Model (SPRC);
- Data requirements and calculation methods for hazard, vulnerability and risk.

3.3 Assessment and feedback methods

The assessment of the learning outcomes of the teaching module will be performed by individual coursework assignments:

1. From Sub-module 1: Evaluation of methods for assessing damages and vulnerability in the risk management framework (report and calculations);
2. From Sub-module 2: Application of the risk analysis methodology to a real case (report and calculations);
3. From Sub-module 3: Analysis of a case study and investigation of proposed alternatives for mitigation measures (report and calculations).

4 TEACHING MODULUS N. 3 – SUSTAINABILITY ISSUES IN CONSTRUCTION

4.1 Motivation

The construction industry plays a great role as a large consumer of materials and energy. Sustainability is a problem that cannot be faced at a country level only, because the positive/negative consequences on the environment of a sustainable construction/technique often can be recognized at a very large scale (typically transnational). At the building scale, sustainable construction aims to provide long-lasting, healthy, and useful buildings, while consuming limited finite resources of materials and energy by using durable, recyclable, and renewable materials, through energy-efficient design, and by using environmentally neutral energy sources (wind, sun, geothermal, etc.) and mechanisms (shading, simple evaporation cooling, etc.).

Sustainability can be achieved by considering different aspects of the construction process, from the material production, to the impact of the construction techniques on the environment, to the energy saving of the final construction, to its durability during time. A “cradle-to-grave” analysis of building products, from the gathering of raw materials to their ultimate disposal, provides a better understanding of the long-term costs of materials. These costs are paid not only by the client, but also by the owner, the occupants, and the environment. Most of the environmental impact is related to the material production. For instance, concrete is one of the most widely used construction materials in the world. However, the production of Portland cement leads to the release of significant amounts of CO2 and other GHGs.

It is also important to consider the different phases in the lifetime of constructions. Large quantities of waste are generated during construction, and when buildings and structures are decommissioned and demolished at the end of their lives. Improper management of these construction and demolition (C&D) wastes often results in considerable environmental impacts. Using alternative management routes could result in both environmental and cost savings. The material waste generated on a building construction site can be considerable. The selection of building materials for reduced construction waste, and waste that can be recycled, is critical in this phase of the building life cycle. The problem of remediation techniques of contaminated sites is also a very important issue.

A key aspect of moving toward performance-based outcomes in sustainable design is the use of Life Cycle Assessment (LCA) to determine the embodied environmental effects of materials, rather than relying on singular material properties such as recycled content or distances travelled after the point of manufacture. LCA is a methodology for assessing the environmental performance of a product over its full life cycle. However, the LCA tools that are currently available are not widely utilized by most stakeholders, including those designing, constructing, purchasing, or occupying buildings.

Life Cycle Assessment (LCA) is a structured and internationally standardised method that transposes Life Cycle Thinking (LCT) principles into a quantitative framework. LCA quantifies all relevant emissions, resources consumed/depleted, and the related environmental and health impacts associated with any goods or services. Therefore, LCA is a vital and powerful tool to effectively and efficiently help make consumption and production globally more sustainable. The principles of Life Cycle Design provide important guidelines for the selection of building materials. Each step of the manufacturing process, from gathering raw materials, manufacturing, distribution, and installation, to ultimate reuse or disposal, is examined for its environmental impact (Kohler, 2007).

In the teaching modulus, all these aspects will be considered, and quantitative techniques and protocols to quantify and certify the sustainability of a construction, such as the Athena or the ITACA protocols, or the LEED system of certification of the United States Green Building Council (USGBC) will be presented to the students.

4.2 Learning outcomes

Having successfully completed the modulus, students will be able to demonstrate knowledge and understanding of:

- Basic notions on sustainability (environmental, economic, social) and environmental footprint of engineered systems;
- Performance-based design and life-cycle planning;
- Sustainability in construction: material’s, management, occupancy, end-of-life costs, reuse/recycling;
- Life Cycle Analysis and mathematical tools required;
- Energy efficiency in buildings and renewable energy with emphasis to building applications;
- Protocols for rating systems for the design, construction and operation of high performance green buildings;

4.3 Assessment and feedback methods

Assessment of each part of the module will be by individual coursework assignment:

1. Sustainability issues, examples of sustainable actions in building design (short essay);
2. Life Cycle Analysis: definition of variables, solution strategies, examples (report and calculations);
3. Issues on protocols for rating systems in building design (report and calculations).

5 TEACHING MODULUS N. 4 – SUSTAINABLE DEVELOPMENT AND ENVIRONMENTAL PROTECTION

5.1 Motivation

Environmental issues are closely linked to the way development theory and practice are conceived and applied. In this context, the concept of sustainable development has rapidly emerged as an approach similarly advocated and criticised by local and international organisations, broadly described as an envisioning strategy to save the earth for future generations. A central concern of this modulus will be to give a critical understanding of the Sustainable Development debate and practice, unveiling the political, social and economic forces underlying environmental conflicts and exploring concrete approaches to address their causes. Special focus will be how Sustainable Development and Environmental Protection must be considered and integrated - in the areas of Hydraulics and Hydrology; Sanitary Engineering, Geotechnics; Geomatics (Geo engineering); Transportation and Road Constructions, Buildings Performance and Urban Development.

5.2 Learning outcomes

Having successfully completed the module, students will be able to demonstrate knowledge and understanding of:

- Population, economic, and environmental impacts;
- Carbon and climatic alterations;
- Local and regional environmental problems;
- EU environmental legislation;
- Environmental impact assessment (EIA), Strategic Environmental Assessment (SEA), environmental risk assessment (ERA);
- Sustainable development concepts and challenges;
- Life cycle assessment (LCA), Life cycle cost, and Eco labelling;
- Environmental management and sustainable design.

5.3 Assessment and feedback methods

The assessment is done with two practical individual project works. In the first project work, the environmental impact of a product (material) is assessed using specific LCA software. The second project work 2 aims at proposing improvements (ecodesign of the product) leading to a better environmental performance. The list of products (materials) to analyse will be supplied to the students.

6 OTHER OBJECTIVES OF THE PROJECT

The final year of the SASICE project is mainly devoted to the pilot project, where the moduli developed in safety & sustainability will be taught in a coordinated manner. A teaching plan has been prepared, including an exchange of professors between the partner universities. Moduli considered as the key points of the proposal will be taught in several universities. The evaluation of the course by mid-term tests, final exams, and homework will be done in the same way, and using evaluation criteria agreed by the partners. A final report will be prepared containing, from each modulus taught in different Universities, a report of the teacher and the results of questionnaires submitted to the students. It will be important to understand how a coordinated teaching method can be developed, in line with the traditions of the partner universities.

The teaching activities of the partner universities will be supported by ICT-based contents and services. The main instruments will be the recording and webcasting of lectures from selected teaching modules. This will take the form of live webcasting, where selected lectures are recorded and broadcasted live so that students from different universities across different time zones can participate simultaneously, or as a library of recorded lectures which can be browsed by the students.

7 CONCLUSION

The SASICE project focuses on safety and sustainability education in civil engineering. The aim is to form a new generation of civil engineers with a deep knowledge on safety and sustainability problems, assessment and design methods and guidelines adopted in different European countries, thus striving to achieve the goals of the Lisbon agenda. The consortium is formed by 9 universities representing very different regions of the EU, so providing a unique experience for education and research to future students, as well as broadened employment possibilities after graduation. The joint development of teaching moduli by universities from different countries and with traditionally different methods (inductive vs. deductive methods) allows experimenting with novel techniques for academic teaching. Joint degrees contribute to putting into evidence university excellence and European competitiveness. The quality control guarantees excellence in teaching and research supervision, sharing their expert knowledge. The programme will contribute to the quality and visibility of European higher education through implementation of a well-defined joint curriculum offered jointly by some of the partners.

8 ACKNOWLEDGMENTS

SASICE project (51083-LLP-1-2010-1-IT-ERASMUS-ECDSD) is funded by the European Community through the Lifelong Learning Programme. The support is gratefully acknowledged.

REFERENCES

Cortese, A.D. (1997), Engineering education for a sustainable future, Second Nature, Boston, MA.

Velasquez, L. E. and Munguia, N. (1999), Education for sustainable development: The engineer of the 21st century. *European Journal of Engineering Education*, Vol. 24, No. 4, pp. 359-370.

Terti, G., Savoia, M., Azevedo, J., Bloodworth, A., De Roeck, G., Esteban-Chapapria, V., Lobo, A., Lombaert, G., Magenes, G., Prinos, P. and Viggiani, G. (2011), SASICE: Safety and Sustainability In Civil Engineering, Proc. of the First EUCEET Association Conference, Patras, Greece.

Savoia, M., Mazzotti, C., Buratti, N., Ferracuti, B., Bovo, M., Ligabue, V. and Vincenzi L. (2012), Damages and collapses in industrial precast buildings after the Emilia earthquake, International Journal of Earthquake Engineering, Vol. 2-3, pp. 120-131.

Kohler, N. (2007), Life cycle analysis of buildings, groups of buildings and urban fragments, in Deakin, M., Mitchell, G., Nijkamp, P., Vreeker, R. (Editors), Sustainable Urban Development Volume 2: The Environmental Assessment Methods, Routledge.