
segment on Innovation of Teaching in Materials and Structures
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RILEM, The International Union of Laboratories and Experts in Construction Materials, Systems and Structures, is a non profit-making, non-governmental technical association whose vocation is to contribute to progress in the construction sciences, techniques and industries, essentially by means of the communication it fosters between research and practice. RILEM’s activity therefore aims at developing the knowledge of properties of materials and performance of structures, at defining the means for their assessment in laboratory and service conditions and at unifying measurement and testing methods used with this objective.

RILEM was founded in 1947, and has a membership of over 900 in some 70 countries. It forms an institutional framework for co-operation by experts to:

• optimise and harmonise test methods for measuring properties and performance of building and civil engineering materials and structures under laboratory and service environments,
• prepare technical recommendations for testing methods,
• prepare state-of-the-art reports to identify further research needs,
• collaborate with national or international associations in realising these objectives.

RILEM members include the leading building research and testing laboratories around the world, industrial research, manufacturing and contracting interests, as well as a significant number of individual members from industry and universities. RILEM’s focus is on construction materials and their use in building and civil engineering structures, covering all phases of the building process from manufacture to use and recycling of materials.

RILEM meets these objectives through the work of its technical committees. Symposia, workshops and seminars are organised to facilitate the exchange of information and dissemination of knowledge. RILEM’s primary output consists of technical recommendations. RILEM also publishes the journal Materials and Structures which provides a further avenue for reporting the work of its committees. Many other publications, in the form of reports, monographs, symposia and workshop proceedings are produced.

Segment on Innovation of Teaching in Materials and Structures

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Per Goltermann

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Preface

The conference “Materials, Systems and Structures in Civil Engineering – MSSCE 2016” is part of the RILEM week 2016, which consists of a series of parallel and consecutive conference and doctoral course segments on different topics as well as technical and administrative meetings in several scientific organizations. The event is hosted by the Department of Civil Engineering at the Technical University of Denmark and the Danish Technological Institute and it is held at the Lyngby campus of the Technical University of Denmark 15-29 August 2016.

This volume contains the proceedings of the MSSCE 2016 conference segment on “Innovation of Teaching in Materials and Structures”. The conference segment is organized by DTU Byg and deals with innovation and development within the field of teaching in a number of fields, dealing with materials and structures. All contributions have been peer reviewed.

Per Goltermann

August 2016, Lyngby, Denmark
Welcome

Were you aware that a part of your daily language is likely to be in Danish? A thousand years ago the Danish word “Vindue” came along with the Vikings to England. Several hundred years later it reached North America, and from there – just two to three decades ago – almost every person in the world learned to understand and pronounce this word: “Windows”, which etymologically means “an eye to the wind”.

As a child your career as construction professional may have started with LEGO, and before you went to bed, your mother told you the unforgettable fairytales of H.C.Andersen. You may have grown up with the delicious taste of Lurpak butter on your bread, and though you might find it strange that “God plays dice with the Universe”, hopefully your school teacher told you that on this topic Einstein was flat out wrong and Niels Bohr was right. Right now you may prefer to be sitting in the sun with a chilled Carlsberg beer in your hand, enjoying the iconic view of the Sydney Opera House. All of it is Danish made, and many things around you at home, if not made in Denmark, were probably brought to you by Maersk, the world’s largest shipping company, the modern Danish Viking fleet.

Though Denmark is one of the world’s smallest countries, yet it stands – along with your country – among the greatest. On top of a thousand years of outreach from Denmark, your visit to the Danes is most welcome. On your approach to Copenhagen airport you had a view to wind turbines harvesting green energy, you saw record breaking bridges, and perhaps you got a glimpse of the island Ven where the nobleman Tycho Brahe literally speaking changed our view of the world through perfection of astronomical observations with his naked eye. In Copenhagen you may appreciate a walk in the fairytale amusement park TIVOLI, and in the Copenhagen harbour you may have a rendezvous with a Little Mermaid.

Of all things in Denmark you will surely enjoy the conference and doctoral courses Materials, Systems and Structures in Civil Engineering, MSSCE 2016 which are held in conjunction with the 70th annual RILEM week. On this occasion RILEM celebrates its 70 years birthday and thus maintains generations of experience. However, new activities and the in-built diversity keep RILEM fresh and dynamic like a teenager.

The event takes place in northern Copenhagen, Lyngby, at the campus of the Technical University of Denmark, 15-29 August 2016. MSSCE 2016 aims at extending the borders of the RILEM week by including doctoral courses, by involving a palette of RILEM topics in the conference and workshop activities, and by collaborating with other scientific organizations. The insight and outlook provided by this event make it RILEM’s technical and educational activity window.

It is a pleasure to share with you what is unique to RILEM and Denmark!

Ole Mejlhede Jensen, Technical University of Denmark
Honorary president of RILEM 2016, Chairman of MSSCE 2016
LEARNING TRADITIONAL BUILDING TECHNIQUES BY PRACTICAL WORK AND IMPLEMENTED THEORY

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Abstract
At Campus Gotland studies in building conservation have been conducted during 25 years and practical courses have been developed as an essential and characteristic pedagogical element in the education. In order to learn the students reading, understanding and maintaining traditional building techniques, structures and materials they get to follow traditional wood and stone building techniques varying from choosing and producing raw materials to restoring old structures and materials. In wood building they start from choosing timber on root, building traditional timber structures i.e. log houses, and continue restoring wooden constructions and wooden details. In stone building the students tasks ranges from visiting the stone quarry, burning lime, mixing mortars, carving stone and learning traditional masonry building techniques. The practical field work is combined with implemented theory about material science, structural analyses, building archaeology and historical building traditions. It leads to knowledge about sustainability and cultural values but also about the importance of choosing authentic materials of high quality and durability and skilled craftsmen with great knowledge and understanding about historical building techniques, in contrast to the building industry of today. This paper describes/discuss the pedagogical model of the Building conservation program with examples from the course Traditional building techniques in stone and wood.

1. Introduction

During the last 25 years building conservators has been educated at Campus Gotland. Our students are today to be found as professionals in the building sector as well as in the cultural heritage sector. The tasks in the sectors span from preserving to developing the built cultural heritage. The profession demands that our students have sufficient knowledge about the built heritage. We believe that it only can be reached through an education that combines theory and practice. The aim of this paper is to describe and discuss the pedagogical model of the
Building conservation program with examples from the course Traditional building techniques in stone and wood.

Higher education should according to Swedish law [1] be based on scientific knowledge and empirical and practical experience. This has been the motto in the development of education in conservation at Campus Gotland since it first started. Conservation as an academic discipline deals with material cultural heritage and its preservation, development and sustainable management. One important part of material cultural heritage consists of the built environment and the buildings as such. To be able to reach the objectives stated in the law, education need to be formed and permeated by the essence of understanding a phenomenon regarding if it is a building, a building material or a more complex built construction. To be able to understand a phenomenon connected to the built environment you also need to understand the creation and the basis for emergence of this phenomenon from different perspectives. These perspectives stretch from the theoretical understanding of material, history, construction and culture, to the practical experience of craft, use, etc. and the most important of all the interrelation between these parameters in order to attempt to understand the meaning of the phenomenon. This is not new, but in education about buildings and construction it is not common to use this pedagogical idea of how knowledge could be perceived, presented and produced.

1.2 Theory meets practice – practice meets theory in conservation

An awareness of knowledge as something that is beyond and above consumption of knowledge was raised at Gotland University during the development and implementation of liberal education as a common ground for education [2]. One of the pillars of liberal education is the relationship between brain, heart and hand in order to facilitate the students’ possibility to assimilate and process knowledge to understand the multi-dimensional surrounded environment. This is also one of the basics for conducting education in conservation at the building conservation program.

There is in the world of research a perceived bridge between theory and practice which have been facilitated by using the concept applied theory instead [3]. In education “learning by doing” has become a concept in practitioners’ education [4]. Our aim is to use both the applied theory and the learning by doing for a higher reason and with the objective to reach a reflective understanding of a phenomenon. We have also extended the interpretation of practice in higher education to include craft as a practical element in the academic discipline of conservation. Molander [4] has described this as a process that in much looks like the hermeneutic learning cycle where practice feeds theory and the other way around and where the act of reflection is driving the making of knowledge.

2. Education in Building Conservation

Conservation as an academic discipline has its beginning in the 1970’s when a gap of knowledge was noticed concerning the built heritage. Education in architecture had since the 1950’s turned its focus to design and new constructions. At this time the society was going through one of the most pervasive changes where city centres were demolished and restructured for modern city development. Slowly the opinion for saving/preserving the built heritage grew. A new academic discipline and soon also a profession were developed as an answer
to the gap of knowledge in society about building conservation. The need for strengthening the understanding of the applied field of conservation was highlighted in the 1980’s and that was the starting point for the higher education in building conservation on Gotland. The need to be fulfilled concerned communication, respect and understanding between different professionals, craftsmen, engineers, architects, conservators etc., all with different roles in a restoration project [5].

The challenge was to plan for an education where the objectives of better understanding both of the process and the skills needed within a restoration project was met. The first years the education in building conservation was characterized by trial and error which soon developed into more thought and worked through educational activities. In the beginning of this century the education developed from courses into a three year bachelor program. In focus for the education was, and still is, the understanding of the building and the built environment from a multidisciplinary perspective and with a pedagogical idea where theory fed practice and the other way around.

The multidisciplinary approach is represented by the content in the courses and by the teachers originated from different academic disciplines such as engineering, history, archaeology, history of architecture, conservation and architecture. Technical and natural science meets the humanities and social sciences every day within both education and research at the department of conservation. The bridges between the scientific cultures are not totally extinguished but live an inconspicuous life. A challenge is to not take this state for granted but work on the art of understanding scientific positions of each other in everyday life when planning for future courses and educational activities. In the applied courses teaching is also done by craftsmen specialized for example in masonry, carpentry, timber building or traditional paint which bring a third dimension or culture into the educational work.

The courses in the program aims today at giving the students depth and widening perspectives on the built heritage and tools and methods to face the applied activity of building conservation.

**Figure 1: Aspects and perspectives on built heritage.**

### 2.1 Traditional building techniques in stone and wood

In the course *Traditional building techniques in stone and wood* the students will meet theory in practise from their very first day. The practical field work is combined with implemented
theory about material science, structural analyses, building archaeology and historical building traditions. The course are divided into four parts; wood buildings, stone buildings, constructions and building archaeology and each part will here be described concerning content, structure, pedagogical model and theory. It leads to knowledge about sustainability and cultural values but also about the importance of choosing traditional materials of high quality/durability and skilled craftsmen with great knowledge and understanding about historical building techniques, in contrast to the building industry of today. Teachers on the course are – besides researchers with expertise in lime mortar, masonry, wooden constructions, building archaeology and stone conservations – highly skilled craftsmen with a great theoretical as well as practical knowledge experienced in the field of restoration of historic buildings.

As geology and material access have had a large impact on the local historical building techniques students are taught to see how raw materials of the region has influenced form, materials and building techniques before industrial revolution formed national and international standards. As the course is held on the island of Gotland this set an example. Gotland is a lime stone rock with smaller amounts of sandstone. The soil can provide good sand and clay. The preferred wood for construction was often pine wood or oak. Hence, the traditional building techniques and materials on Gotland are mainly limestone buildings, sandstone buildings and wooden bole houses.

The course in traditional wooden building starts in the forest where students are taught about qualities of timber from historic times to modern. It is here essential to learn how to read the threes in order to find the most suitable threes for different building techniques, constructions parts or simply quality wood for windows, panels etc. When the material is chosen, different species for different purposes, the students is felling the trees using traditional tools and methods such as Scandinavian forest axes or timber saws. With saws, forest axes and broad axes the timber is then formed into logs and log houses.

Figure 2: Forest axe.

The theory is based on building handbooks from 19th to 18th century, research reports about Swedish wood building traditions and restoration theory. The main objective of this part is to learn about qualities in wood, used in different time periods, construction parts and building techniques as well as traditional surface working techniques for wood, with axes, planes or saws – to be able to analyse, understand and respect the qualities of material and craftsmanship in the constructions and building parts.
Figure 3: Students in action under the course working with wood, mortar and stone.
The stone building course starts in the limestone quarry where students study different qualities of limestone; as a geological phenomenon, as building stone and for lime burning. They are then choosing stones with qualities suitable for 1) stone carving and 2) lime burning.

For lime burning students build a small lime kiln, due to techniques and practical knowledge preserved on Gotland since medieval times. The lime kiln is burnt continuously during approx. 80 hours and the students watch and fire the kiln day and night to hold the needed lime burning temperature of 900°C.

Figure 4: Traditional lime burning in field kiln.

After lime burning they try different slaking techniques such as wet slaking, dry slaking, earth slaking and hot mix, the slaked lime is used for bedding mortars for brick masonry, lime render and lime wash – different qualities for different purposes. Our students try the craftsmanship of masons in order to be able to read and respect old masonries, their materials, techniques and tracks of skilled craftsmen. Following the lime from quarry to render also yields respect for historically well preserved materials (on Gotland there are for example many medieval external lime renders in good condition). In this part of the course they also restore a historic building where the task is to identify authentic mortar and techniques for restoring a lime render or plaster.

Stone carving is also part of the course and the aim of this is to give them knowledge to read historic stones, carved by hand as the traces of tools are characteristic for different time periods. Differences in stone qualities are studied from the aspect of carving but also from the aspect of durability, degradation and conservation [10]. They get to study and analyse stones in a façades and this is also a way of getting knowledge and respect for the buildings once made by skilled craftsmen showing great cultural value in its materials, aesthetics expressions and building techniques.

The theory is based on modern research reports, chapters from old handbooks (from the 19th and early 20th cent.) and from reports on Swedish stone building traditions. The theory is implemented through lectures, surveys, demonstrations, discussions and literature seminars. The practical knowledge is always complemented with narrative descriptions and discussions,
but it is of great importance that the students get to work with their hands long enough with all different materials and techniques in order to make them get a feeling and deeper understanding for the craftsmanship and the different materials in order to make them comprehend the importance of high quality materials combined with skills in craftsmanship. The examination is made through smaller reflective essays were the students describe all the different items in the course based on their practical experiences, literature and theory discussions.

The more theory-based moments in the course are about Conservation, Construction and Building Archaeology. In those moments the students get practical exercises and excursions in order to get deeper understanding of the theory; i.e. they study stone deterioration in combination with conservation techniques in field. Within construction for example they build up brick vaults and small scaled rafters, expose them to load to see how the collapse take place. They also study medieval vaults and rafters in the churches on Gotland to learn how to read and understand the function of the constructions, their cultural value and common deteriorations and threats.

Building archaeology is taught through lectures and method studies in field. The essential knowledge is here to learn to read, document and interpret historic buildings to find out and describe its context. The knowledge from the practical as well as the historical/theoretical parts of the course about stone and wooden buildings is essential for the student’s ability to gain this knowledge.

3. The relation between education and research

In conservation there is a rather unique tradition in the research field when it comes to combining theory with practice. All the teachers on the course have in different ways performed or participated in research projects in the applied field of conservation where interaction between different professionals has taken place. Among the group of teachers are also highly skilled craftsmen who have a great theoretical knowledge and who have been engaged in several research projects during the years. The fields of research that are mainly covered are civil engineering (material and construction) in combination with applied building conservation, stone conservation and building archaeology [6, 7, 8, 9, 10, 11]. The close relation between research and education is exemplified by the participation of students in the production of burnt limestone for pointing mortar used for the reconstruction of Visby city wall.

4. Discussion

The objectives and aims of higher education in Sweden is divided into three categories; knowledge and understanding, skills and abilities and finally values and attitudes, which in this context will be used as a framework for discussing the benefits of using practical work with implemented theory in courses at the building conservation program. The discussion will go beyond the particular objectives stated in the specific course document.
4.1 **Knowledge and understanding**

Knowledge and understanding is the aim of all higher education. As an organization with the objective to produce higher education in building conservation the main goals are to give the students tools to develop their own reflective knowledge and understanding. The university is in this case the facilitator of knowledge and understanding. We believe that the multidisciplinary approach and the applied theory – practical based pedagogy are the key factor for deeper understanding and the possibility to analyse phenomenon, in this case traditional building techniques, from the material to the construction, from different perspectives. The reflective communication between theory and practice helps the understanding of materials and constructions with the aim to conduct professional documentations, descriptions, analyses evaluations and to understand how preventive and sustainable management of cultural heritage can be conducted. A recently conducted study where student alumni’s where asked about their experience of the education after some years as professionals the multidisciplinary together with the integrated practical elements were ranked as one of the highest educational benefits [12]. Another objective of higher education is to create good conditions for future development and here are the students our biggest asset. The students will hopefully be researchers of tomorrow in the field of applied conservation and restoration and their approach to knowledge will hopefully be set already during education in those types of courses. The need for applied research within this field is immense.

4.2 **Skills and abilities**

"Use your eyes, learn to see and to understand and analyze what your eyes are seeing” is a device said by one of the teachers in conservation, Stefan Haase, to students in one of the first field excursions during the study years when they faced the problem of interpreting a building construction without previous knowledge about the specific place. Skills and abilities as well as a deeper insight of building techniques are developed through the interaction of reading, listening and doing or in other words the intersectional field between applied theory and practice. The objective of the pedagogical idea of creating reflective understanding of a phenomenon and its creation by following the material from its original state over the processing of craft to its final form are developed and implemented in the course *Traditional building techniques in stone and wood*. A skill that is specific for the course is the ability to analyse the building technique in relation to the craftsmanship and also in a deeper sense understand the importance of the craft itself.

4.3 **Values and attitudes**

The holistic understanding of the processes and parts that traditional building techniques consists of and the equal evaluation of the different knowledges needed is a carrying part of the teaching objectives in the course. The attitude toward knowledge regardless if it is the practical knowledge of persons performing craft or theoretical knowledge of persons performing science should melt together and create new perspective on knowledge in students. One of the highest ranked outcomes of the course is the students’ subtle respect for the historical, traditional skills in building technique including the craftsmanship independent of when it was performed. These learning outcomes cannot be reached without letting the students meet the bearer of knowledge in their practical work and not only as an observer but as a performer. The brain, heart and hand metaphor is sufficient when it comes to values and attitudes to-
wards built heritage and the respect for different knowledge traditions and skills of the performing of craft.

5. Conclusions

The aim and objective of this paper has been, through describing and discussing the pedagogical model and how it is performed within the course *Traditional building techniques in stone and wood*, to display the importance of a deeper understanding of a phenomenon through implemented theory and practice. The deeper understanding can not be achieved without the reading, the listening and the doing under supervision and guidance from experts in its own field regardless of this expertfield is material science, building tradition or craft. This requires a conscious attitude towards the way education is performed and how theory and practice interacts in the layout of the courses as well as how it is possible for the students to create their own knowledge and understanding of the specific field.

References

ACTIVE LEARNING STRATEGIES IN REINFORCED CONCRETE COURSES

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Abstract
Several active learning strategies were implemented in the Reinforced Concrete (RC) courses of the Integrated Master in Civil Engineering degree at Aveiro University. These strategies were implemented in the course following the application of the Bologna Process that introduced profound changes in higher education system in Europe. The purpose was to motivate students to become active participants in the learning process and promote their autonomy. There are two RC courses in the degree and different strategies have been implemented. In one of the courses a continuous assessment was implemented with four mini-tests during the semester together with a student competition where, in groups of four or five, they have to design, build and test a RC beam in order to attain a specified load. On the other course students, in groups of two, have to design the RC structure of a small house presenting the calculations, drawings and design report. The project is divided into four parts and students have to present their work to teachers. These strategies proved to engage the students with the courses. Questionnaires have been answered by students to assess their satisfaction with the method.

1. INTRODUCTION

Learning and teaching strategies are always controversial. This is an evidence since students are different and, consequently, have different learning styles and, in addition, teachers are also different, and feel comfortable with different teaching strategies. Furthermore, different courses have different objectives or different levels of abstract or practical objectives, which means that the learning/teaching strategies should be different. Moreover, attitudes of students and teachers change in time. Hence, teachers should continuously reflect, discuss and improve the strategies used in their courses.
The implementation of the Bologna Process [1] leaded to the implementation of the European Higher Education Area and profound changes in Higher Education in Europe. In Portugal this change occurred in 2007. The number of contact hours with students in classes was reduced and changes were introduced in order to turn the learning process of students more autonomous.

Active learning, although there some different definitions, can broadly be defined as an instructional process where students are actively engaged in the learning practice. This is often used as opposed to the traditional practice where students are passive receiving information from the teacher. Active learning approaches, including problem-based and project-based learning, has been used in engineering courses for a few years in a number of countries.

Reinforced concrete structures courses are, usually, considered difficult by students and have relatively high non-approval rates among students. Besides this, some students do not even show up for assessment. This pushes the use of more dynamic learning strategies that could motivate students and, simultaneously, show them that it is not so complicated to approve at these courses.

This paper describes the implementation of a series of learning/teaching activities and the results obtained in the reinforced concrete courses at University of Aveiro. The activities intend to improve the success of students at the course keeping the working load at a reasonable value. A continuous effort to amend and improve the courses has been made by the teachers with activities being revised, learning materials developed and assessment rules adjusted to university guidelines over the years.

2. THE REINFORCED CONCRETE COURSES

The reinforced concrete courses are part of the Integrated Master in Civil Engineering (IMCE). Integrated Master study cycles were introduced in Portugal with the Bologna Process and, basically, they are a Bachelor study cycle with three years followed by a Master study cycle with two years. The main difference for separated study cycles is that students do not need to complete the Bachelor degree in order to start the Master degree. This type of study cycles was implemented for courses such engineering, medicine or pharmacy, where professional associations demand five years of higher education to be a professional. Nevertheless, students can terminate the first three years and they have a Bachelor degree with reduced competencies at professional level.

In the IMCE study cycle there are two compulsory courses for reinforced and prestressed concrete: Concrete Structures (CS); and Reinforced and Prestressed Concrete Structures (RPCS). Both courses follow Eurocode 2 (EC2) design principles [2]. Concrete Structures course is at Bachelor level (third year) and Reinforced and Prestressed Concrete Structures at Master level (fourth year). Because of this division between the two study cycles, CS course deals mostly with general principles and calculation methods for elements and sections
(sections 2, 3, 4, 6, 7 and 8 of EC2), while RPCS course deals mostly with structural design of elements (sections 5 and 9 of EC2) and analysis methods for concrete structures.

CS course has 8 ECTS that correspond to 216 working hours, from which, 56 are contact hours (4 hours/week). Contact hours are divided into 2 hours/week Theoretical-Practical (TP) and 2 hours/week Practical (P). In P classes, the maximum number of students is 20, while in TP classes, the maximum number of students is 45. The number of students each year ranges from 80 to 100, meaning that there are two TP classes and three or four P classes. RPCS course has 6 ECTS that correspond to 162 working hours, from which, 56 are contact hours. Contact hours are 4 hours/week TP classes. These characteristics of the courses are the same since 2009.

It can be seen that the number of students in the course are relatively high and that it can be difficult to keep them engaged with the course throughout the semester. Moreover, reinforced concrete courses are typically considered by students as difficult.

In the CS course, the two different types of classes have different learning approaches. P classes are essentially dedicated to exercise solving. The teacher presents some exercises and students try to solve them aided by the teacher. In TP classes, the theoretical principles are explained and some basic problems are solved. In the RPCS course, classes are used to explain theoretical principles and to solve problems (either individually by students or by the teacher).

3. **ACTIVE LEARNING STRATEGIES**

It is known that learning objectives, assessments, and instructional strategies should be aligned, so that they can strengthen each other. The coherence of these three aspects is very important for the success of a particular course. Figure 1 shows the interdependence and their traditional roles. Assessment of students’ learning is, therefore, an important aspect that should be carefully planned. The key point of the assessment is what can students do with their learning, meaning that the assessment of learning is carried out through performance.
Using the Index of Learning Styles, ILS, as a reference, engineering students are typically visual, sensing, intuitive and active [3-4]. Although the ILS can be subjected to some criticism, it still provides guidance on which are the most common learning styles of students and how instructors can use this to use approaches that could match some the students’ inclinations. Thus, the use of active learning strategies seemed to be interesting to be used in the learning and teaching strategy of reinforced concrete courses.

When thinking on the activities that should be implemented, it was decided to apply a more integrated approach where assessments and instructional strategies were both tools to help students to achieve the learning objectives. This means that assessments are used as a tool to improve the performance of students. In this way, assessment can be used to change instruction from a system that transfers knowledge into students, to one that tries to develop students who are capable of learning how to learn [5].

Using these ideas as a base, some strategies were implemented in the reinforced concrete courses, both in-class and out of class. The three basic ideas behind these strategies were: i) improve the learning results of students; ii) give students the opportunity to test what they learn in classes; and iii) keep students enrolled with the course throughout the semester.

3.1 CONCRETE STRUCTURES COURSE
To provide students the opportunity to build something in reinforced concrete and, simultaneously, understand better the behaviour of concrete elements, a practical activity, in the form of a competition, where the students, in groups, have to design, construct, and test a reinforced concrete beam in order to achieve a pre-determined failure mode, have been implemented. Some active learning strategies in class were also implemented with classes being much more interactive. Finally, the number of assessment elements was also modified, with some mini-tests performed during the semester at classes. In the CS course, assessment is performed as a combination of different techniques: mini-tests (MT), the beam competition (BC) and a final exam (FE). The final mark (FM) is a weighted sum of the three components:
Students have to score at least 37.5% (7.5 out of 20) in each of the components.

Mini-tests are performed during classes. There are four mini-tests and only the best three are considered (the worst mark is discarded). Mini-tests are not scheduled with students (nevertheless they are scheduled in the department so that there is no superposition with other courses). Each mini-test relates to a part of the syllabus. Each mini-test has a duration of twenty-five minutes and a single problem. The mini-tests are important for the learning process for a number of reasons:

a) Familiarizes students with engineering problems. Although CS course is at the third year, the fact is that, until that moment, most of the courses are from base sciences (mathematics, physics, geology,…) or from Engineering Sciences (strength of materials, theory of structures, …) where little engineering judgment is needed.

b) Maintains students involved with CS course during the semester. Each test occurs every two to three weeks, so students stay tuned with the course all over the semester.

c) Familiarizes students with the exam. Although exam questions are more prone to relate different subjects, mini-tests helps in the preparation of students.

The beam competition (Figure 2) plays an important role in the course. It has multiple learning objectives, such as apply to practical situations what students learn, feel the problems that can occur in real world situations (how difficult can be to actually build what is designed), integrate knowledge from other courses (such as Construction Materials for concrete mix proportion) or reflect on the results obtained after execution. Although the competition gives some work for students, the ludic part of the competition and the moments where students have to concentrate more work (such as when they have to actually build the beam) are planned to minimize its effect on other courses (for example, the beam is built during the academic week where students have no classes). For the competition, students are divided in groups of four or five students. Each group has to design, build and test a reinforced concrete beam in order to reach a pre-determined failure load (failure mode). The winner is the group that reaches the failure load closer (on the safe side) to the prescribed failure load. The competition has four phases. In Phase 1, students have to present a preliminary design report where they justify their design in order to achieve the prescribed failure mode. This report is discussed with the teacher in order to validate the solution. In Phase 2, the groups specify concrete mix proportions and build the beam. Phase 3 is the testing of the beams. All beams are tested in a special session. Before the test, each group explains to other groups the characteristics of the beam and the expected failure load. Concrete cubes are tested at the same day to know the real concrete strength. After each test, the teacher explains the distinctive aspects of the obtained failure mode. Finally, in Phase 4, each group present a final design report where the calculations, the build process and, if failure occurs at a different load, the justification for the discrepancy of the loads. All the students get a Participation Certificate and the best three groups get a Diploma with their result.
There are some important aspects of the beam competition that should be outlined since they play an important role in keeping the students active learners during the semester:

a) Students actually participate in the course.

b) Students can visualize different failure modes and understand their differences.

c) The competition facilitates and enhances the interactions between the teacher and the students due to the different phases and need to talk to the teacher.

d) The ludic aspect of the competition (despite counting for the assessment), creates an informal environment between students and the teacher.

e) They get excited by the competition aspect and the day the beams are tested is rather animated.

3.2 REINFORCED AND PRESTRESSED CONCRETE STRUCTURES COURSE

RPCS course has a very different approach to concrete design when compares with CS course: it is much more design oriented, focused on analysis methods for concrete structures and elements and member detailing. Thus, the existence of just TP classes is better suited for this course. In order to guide students into practical design situations, there is a project work that students, in groups of two, have to perform during the semester. They have to design the RC structure of a small house presenting the calculations, drawings and design report. The project is divided into four phases and students have to present their work to teachers. The project is randomly assigned to each group from a list of available houses. They have to use a finite element program to model and calculate the structure. The four phases of the project are divided throughout the semester with defined dates for the groups to present their work: Phase 1, define the structural solution and preliminary design of cross sections; Phase 2, slab design (including design report and drawings); Phase 3, beam design (including design report and drawings); and Phase 4, column and foundation design (including design report and drawings). In Phases 2 and 4, each group must present and discuss their work with the teacher (20 minutes for each group). In the RPCS course, assessment is performed as a combination of the design project (DP) and a final exam (FE). The final mark (FM) is a weighted sum of the two components:
FM = 0.45DP + 0.55FE (2)

Again, students have to score at least 37.5% (7.5 out of 20) in each of the components. There are some important aspects of the design project that have an important role in keeping them engaged with the course during the semester:

a) Students have to perform a real design problem from scratch and get used to what a concrete structure project looks like.

b) They learn how to use analysis software and get acquainted of modelling issues.

c) The division of the work into phases, aligned with the subjects taught in classes maintains them focused with the course during the semester.

d) The discussion and presentation of the work to the teacher makes them more responsible for their work.

4. RESULTS OF QUESTIONNAIRES TO STUDENTS

A questionnaire was made to students in order to assess their satisfaction with the procedures used and their importance for the success in the course. The answers were anonymous. Students were invited to answer, in a 20-point scale, as shown, as an example, in Figure 3. In order to have a more qualitative analysis it is considered in the discussion that it is important if answer is \( \geq 10 \), very important if \( \geq 15 \) and extremely important if \( \geq 18 \).

In Table 1, some significant values are presented. It can be observed that students recognized that mini-tests and the beam competition are very important for their success at the course, with a slightly bigger importance for the mini-tests. They also say that these activities made the learning process easier for them. The slightly bigger importance that students credit to the mini-tests is probably related to the fact that mini-tests act as training tools for the examination.
Table 1: Significant values of answers (CS course).

<table>
<thead>
<tr>
<th>Activity</th>
<th>Median</th>
<th>Average</th>
<th>C.O.V.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Importance of mini-tests</td>
<td>18</td>
<td>17.3</td>
<td>0.167</td>
</tr>
<tr>
<td>Importance of beam competition</td>
<td>18</td>
<td>16.9</td>
<td>0.184</td>
</tr>
<tr>
<td>Mini-tests made learning easier</td>
<td>18</td>
<td>16.6</td>
<td>0.224</td>
</tr>
<tr>
<td>The beam competition made learning easier</td>
<td>17</td>
<td>15.9</td>
<td>0.247</td>
</tr>
<tr>
<td>The assessment method is adequate</td>
<td>17</td>
<td>16.5</td>
<td>0.227</td>
</tr>
</tbody>
</table>

A detailed distribution of answers regarding the importance that students give to these activities is presented in Figure 4. All the students considered that the activities are important and, in both cases, more than 50% of the students considered it extremely important. The most frequent answer is the maximum importance. These results indicate that the activities play an important role in the course.

Figure 4. Distribution of answers regarding the importance of assessment activities in CS.

Regarding the question of activities made easier the learning process, more than 90% of the students considered that the activities facilitate learning. Regarding mini-test, 78% considered them very or extremely useful, while 53% considered it extremely useful. When considering the beam competition, it can be observed that 67% of the students very or extremely useful, while 38% considered it extremely useful. Again, in both cases, the most frequent answer is the maximum value (25% for the beam competition and 30% for the mini-tests).

In Table 2, some significant values are presented for the RPCS course. It can be observed that students recognized the importance of the design project and that it is important in the course. They also say that these activities made the learning process easier for them. An interesting result is also observed for the importance of learning of how to use an analysis software: it
gave them lots of work to understand how to use it. Nevertheless, they recognize it as important.

Table 2: Significant values of answers (RPCS course).

<table>
<thead>
<tr>
<th></th>
<th>Median</th>
<th>Average</th>
<th>C.O.V.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Importance of the design project</td>
<td>19.0</td>
<td>17.7</td>
<td>2.96</td>
</tr>
<tr>
<td>Design project made learning easier</td>
<td>18.0</td>
<td>16.9</td>
<td>3.23</td>
</tr>
<tr>
<td>Importance of the use of analysis software</td>
<td>18.0</td>
<td>17.0</td>
<td>3.42</td>
</tr>
<tr>
<td>The assessment method is adequate</td>
<td>15.0</td>
<td>14.7</td>
<td>3.54</td>
</tr>
</tbody>
</table>

A detailed distribution of answers regarding the importance that students give to the assessment activities in RPCS course is presented in Figure 5. It can be seen that about 70% of the students considered that the activities are very important and, in both cases, approximately 50% of the students considered it extremely important. The most frequent answer is the maximum importance. The students do not consider the use of the software is as much important as the design project. Again these results indicate that the activities play an important role in the course.

Finally, a question was asked to RPCS students whether they prefer the learning methods of CS course or RPCS course (see Table 3). The answers show a rather big dispersion of results and a preference for the CS methods. This agrees with the results of the answer to the question “The assessment method is adequate”, that has a smaller median and average in RPCS than in CS course. This is not entirely surprising because it could be that students feel more comfortable doing activities that are more used to, such as mini-tests, instead of completely new to them activities, such as the design project where they have to make much more decisions on their own.
Table 3: Comparison of CS with RPCS methods.

<table>
<thead>
<tr>
<th></th>
<th>Median</th>
<th>Average</th>
<th>C.O.V.</th>
</tr>
</thead>
<tbody>
<tr>
<td>I prefer CS methods to RPCS methods</td>
<td>14.0</td>
<td>13.3</td>
<td>5.86</td>
</tr>
</tbody>
</table>

5. CONCLUSIONS

This article presents the strategies and the results of the implementation of active learning techniques in reinforced Concrete courses. Some anonymous questionnaires have been presented to students to assess their opinion regarding the methodologies. From the existence experience, it can be concluded that:

- The variety of learning activities motivated students and teacher.
- The activities bridge the gap (at least to some extent) between theoretical knowledge to practical education.
- Assessment methods can be an important learning tool.
- The method promotes autonomy and critical thinking of students.
- The teaching/learning method allowed integration of knowledge.
- Students like the active learning method used in the course.

Regardless the results obtained, there are always things to improve, things to develop that is, there is still, and always, a lot of work to do. Learning and teaching are dynamic realities: students change, teachers change, technology changes, environment changes. There is, however, one thing that does not change, the desire of professors for teaching, the wish of students to learn.

REFERENCES

TEACHING CONCRETE TECHNOLOGY TO UNDERGRADUATES:
AN INDUCTIVE APPROACH

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Abstract
Concrete science and technology is commonly taught by following the structure of a typical textbook, i.e., first discussing cement and other constituents, followed by the properties and then the applications. However, when students, in their second or third year of undergraduate studies, are presented the content in this manner, they do not understand why they are being taught the chemistry, factual matter about the cement and aggregates, etc. and often get bored or are not enthusiastic enough. For the past decade, the author has used an inductive approach for teaching concrete technology as an elective course at IIT Madras. The sequence of the course has been the discussion of applications; identification of key aspects related to concrete technology in these applications; study of unconventional concretes that could push technology further; components needed for the special concretes; properties; durability; and environmental concerns. The students also have to develop technological specifications for a structure chosen by them by first studying the constraints posed by the design, location, etc., then specifying a concrete and its mix design principles, followed by formwork, curing and final checking guidelines. In order to ensure continuous learning, many short surprise quizzes are conducted throughout the course.

1. Background
Concrete is a ubiquitous material that has undoubtedly become the backbone of today's infrastructure and the built environment. It is of considerable importance to society due to the influence it can and does have on the safety, comfort, security and economical well-being of people. Nevertheless, the science and technology of concrete is hardly ever emphasized in academic curricula or bureaucratic policies. Moreover, the general public and even some architects seem to consider concrete as an ugly unexciting material, and at best a necessary evil. Forty [1] argues that, though concrete has been called stupid, dumb, mongrel and many other derogatory names, one cannot deny that concrete is a modern material that has transformed the lives of people in the twentieth century, has a major impact on global resource consumption, and has relevance in both global and local terms.
Among academics in the civil engineering faculty, reinforced concrete design is considered essential in undergraduate curricula while the material itself is hardly addressed adequately. When concrete technology is offered as an elective or optional course, many students tend to consider it as a less challenging option or not really something that they need to learn in class. As a consequence, the graduate engineer may possess the ability to design a structure but has probably never touched fresh concrete, understood its behaviour or contemplated its environmental impact. In this scenario, it is quite challenging to keep concrete technology on the academic menu card, and to attract and to maintain the enthusiasm of students, especially undergraduates of a generation that is governed by information that can be flashed or action that can played out on the screen of a smartphone.

Concrete is all the more important in countries like India where there are major demands for new construction, as well as the need to repair aging structures. The consumption of cement in India in 2015 was about 280 million tonnes per year, which is second highest in the world, after China. Considering that that the per capita cement use is about 190 kg and can reach about 350 kg eventually, the cement production is expected to surpass 500 million tonnes by 2025 [2]. One can assume that the mortar and concrete usage in India is now in the order of 1 billion cubic metres and can become double that by 2025. Such predictions are based on the fact that per capita cement consumption in India is about 180 kg whereas it surpassed 1 tonne/capita in China during the development boom [3]. The major usage of cement in India is in infrastructure projects (about 20%), public buildings (about 18%) and housing (about 42%) [3], the demand for all of which will continue to increase over the next few decades. In addition, the usage of concrete in road construction, which is currently low, is expected to become significant in the future [3]. These statistics imply that many more civil engineers are and will be making concrete and managing its transportation, placing and maintenance than just designing structures, for which they have to adequately trained. Another obvious implication is that the cement and concrete production will have a major impact on the energy demand and green house gas emissions, and if there is wastage, improper use and compromising of the useful life, the impact will be unnecessarily higher. There are three other challenges that the Indian construction sector has, in common to some other emerging countries: (1) considerable variability of raw material (especially, sand) characteristics and quality due to scarcity, cost-cutting and inadequate knowledge; (2) severe shortage of water is, in most areas, leading to the use of brackish water and inadequate curing; and (3) an uneducated and unskilled migrant labour force that leads to improper construction, if not managed well. These aspects make it all the more important that the civil engineer is knowledgeable about the influence of raw material variations, ambient conditions, water quality, curing and construction methods on the mechanical and durability behaviour of the concrete structure.

With the above considerations in mind, the way concrete technology needs to be taught warrants a paradigm shift. The structure and delivery methods used by the author are explained and justified in the following sections. The student response to the course assessed through surveys is also reported.
2. Need to consider the student mindset

Students who opt for civil engineering can be classified into several groups: (1) those who have assessed different career options and have made the choice consciously; (2) those who wanted to be in a certain educational institution due its brand value, and qualified only for civil engineering and have accepted it though it was not a top choice; and (3) those who thought they would enjoy engineering and find out after joining that they do not but continue due to social pressure. At the Indian Institute of Technology Madras (IITM), where the author teaches, the students who enter are among the top 1% of those who take a highly competitive set of entrance exams [4]. However, most would fall in group 2 and some in group 3. They go through the coursework with an attitude that is, expectedly, not conducive to teaching with the aim of transforming them into good engineers. They prefer electives that are either so easy that they do not have to work hard, that are challenging in terms of analytical content, that discuss case studies, or that focus on global innovations.

The mindset of the students has to be kept in mind when concrete technology is taught at IITM so that they would opt to take it as an elective. Further, it should be noted that the students are taught a core or compulsory course on construction materials and methods in their first or second year. So, they have already formed an opinion on whether they know enough of concrete, whether they would like to know more or whether they would find the course beneficial.

3. How is the course taught?

The course is taught in about 40 classroom sessions of 50 minutes each, 3 to 4 per week, over a semester of about 18 weeks. Two 50-minute quizzes are scheduled during the 6th and 12th weeks, and a 3-hour final examination is held at the end of the semester. The important aspects of the course are the structure or organization of its contents, assignments, and continuous evaluation to promote out-of-class and to some extent unconditioned learning.

3.1 Course structure

The concrete technology course at IITM has been taught over the past decade with the following structure:

- Applications of concrete and case studies (6 sessions)
- Special concretes (e.g., high strength/performance, fibre reinforced, shotcrete, self compacting, ultra high performance, lightweight, pervious, heavyweight) (12 sessions)
- Constituent materials and mix design of concrete (9 sessions)
- Behaviour of concrete (e.g., fresh state, mechanical response, fracture, shrinkage, creep, durability) (9 sessions)
- Environmental concerns and life cycle assessment (1 session)
- Guest lectures by industry experts and site visits (3 sessions)

The above structure is markedly different from the organization followed in popular textbooks, including those prescribed by the author, in whose opinion it is not necessary to
adopt the organization of a textbook in the corresponding course. *Concrete* by Mindess et al. [5] has four main parts: (1) constituent materials (31% in terms of pages); (2) fresh concrete, proportioning of mixes and construction practices (18%); (3) properties of hardened concrete (35%); and (4) special concretes (16%). This book has a logical structure, is easy to follow and to find information. *Concrete: Microstructure, Properties, and Materials* by Mehta and Monteiro [6] has three parts: (1) microstructure and properties of hardened concrete (29%); (2) constituent materials and processing, including early age behaviour and non-destructive testing (36%); and (3) special topics, including special concretes, mechanics and sustainability (35%). Here, the emphasis is clearly on the relation between the microstructure and the behaviour of the concrete, followed by a description of the constituent materials and tests. The special topics seem to be meant for advanced learning after the basics have been covered. The organization of this book favours conventional structural engineering curricula, complementing the courses on reinforced concrete design.

The author chose to begin his course by discussing the historical applications, followed by pioneering and landmark cases, and some case studies in order for the student to know the range of usage of concrete and the innovations that have occurred, and to recognize the need to employ special concretes beneficially in certain circumstances and structures. During this part, the technological implications are highlighted so that the role of concrete technology in the cases studied is well understood. The collateral benefit of such a beginning is that the student gets a holistic view and is possibly inspired to pursue the course to "discover" how such applications have been achieved. This also seems to give a more "practical" flavour to the course rather than being "theoretical", similar to Aïtcin's organization of his *High-Performance Concrete* book [7].

To maintain the tempo, in a way, the discussion of applications is followed by the presentation of different special concretes, considering that conventional concretes have already been studied in the previous core course. The target applications, unconventional constituents, typical behaviour and test methods for each of these concretes are discussed.

The applications and special concretes are covered over the first half of the course, when the students are typically less occupied. This ensures that the student is exposed to the more inspiring part of the course when he/she is most amenable to learning. Also, local (in this case, Indian) examples are highlighted so that the student can relate to the applications and not feel that these innovations can happen only in more developed countries and consequently lose interest.

The latter half of the course deals with the constituents and properties. Guest lectures given by industry experts, such as project managers, designers and material manufacturers, are scheduled during the course to emphasize the practical relevance of the subjects.

One disadvantage of the structure followed is that some repetition becomes inevitable as the constituents and properties are introduced in the first half of the course but treated more in detail only in the second half. However, this repetition often serves as a revision.
The "applications first" course structure has also been used at IITM by a former colleague of the author, Prof. M.S. Mathews, over several years with great success [8]. He taught the core course on construction materials and methods in several parts, each of which consisted of a phase of construction, the relevant methods, materials used and their properties. He would start from the foundation and complete the course with the glazing, roofing, finishes, etc. He was inspired to adopt this approach by the book of Allen and Iano on *Fundamentals of Building Construction* [9], which demonstrates an effective way to organize the matter related to a very vast and complex field.

The major merit of the structure followed by the author is that it is inductive, which many experts such as Felder believe to be the best teaching method [10]. When the applications and special concretes are discussed, the student is challenged to reason how and why, enquire and resolve; for example, how to make concrete float, how to make concrete stronger, why fibres affect the post-peak response, why and how to make concrete pervious. When the constituents and properties are addressed later in the course, the student takes it as a confirmation of the "discoveries" made in the first half of the course. On the other hand, use of the more traditional teaching method of deduction [10], where the fundamentals are covered first and the applications last, would not have instilled the same enthusiasm in the student.

However, the limitation of the inductive approach is the absence of a logical structure and the need to be repetitive, as mentioned earlier. This may be confusing to some students who would prefer to be told how to solve a certain problem or list characteristics, etc. Another limitation of the course structure is that the instructor should ideally have a good knowledge of practice and not just be "theoretical". This is because the student is encouraged to enquire about the demerits and alternatives, without any bounds. The instructor needs to have the confidence to accept ignorance of certain issues queried by the students and opt to respond in the subsequent session. Obviously, such enquiries aid in the instructor's learning considerably, as experienced extensively by the author.

### 3.2 Assignments
A weightage of 30% is assigned in the grade of the student to assignments done through the course. Typically, there are 3 assignments, one leading to the other:

- In the first, given on the first day of the course, is to list any five different concrete structures existing, proposed or envisioned that the student would like to take up as a project, with at least one of them from India, and explain their characteristics (location, geography, environmental conditions, and structural and other requirements). One of the structures is selected by the instructor for the following assignments.

- In second assignment, the student has to explain the possible construction methods, and if there are many options, choose one and explain why he/she prefers it; discuss the restrictions imposed by the type of construction method on this structure; see if the structure would benefit from the use of an unconventional (special) concrete; and explain the characteristics and typical properties of the conventional or special concrete suggested. It is also required to recommend the constituents, mix design guidelines, formwork requirements and guidelines for transportation and placing of concrete. Any other specific problems to be addressed can also be listed.
In the final assignment, the student has to give the curing and formwork removal instructions. Also, the following questions have to be addressed: How can such a structure be checked finally before acceptance? What can the owner use as final acceptance criteria? How long can such a structure be expected to last?

It is expected that the student appreciates that the complete set of assignments would form the bases of the technical specifications for the concrete in the structure chosen. Moreover, the student is allowed to "discover" structures, choose freely and explain without limitations what has been discovered.

Obviously, the source of most information for the assignments comes from the Internet and published reports. However, all the required information is most often not available for the structure chosen, and the student has to read and assimilate information related to similar structures in order to complete the assignments. Nevertheless, to limit the "cut-and-copy" practices that plague the Internet-savvy generations, the assignments are submitted through a similarity checking website [11]. The students are permitted to see the similarity report and resubmit until they themselves are satisfied. This drives the student to economize in reporting, paraphrase, employ synonyms and reword sentences, all of which helps him/her tune their communication skills.

3.3 Continuous evaluation

The two scheduled quizzes and the final examination account for 55% of the grade. In addition, 15% of the weightage is given to short surprise quizzes given throughout the course. Each quiz has typically 3 questions and is expected to take about 10 minutes to answer. The intention of these surprise quizzes is to ensure that the student pays attention to aspects emphasized in class and continuously revises the lecture material.

Many teachers have recognized the merits of surprise in-class quizzes for keeping the students attentive and to encourage them to come to class, especially when attendance is not taken due to practical limitations or regulations. Some instructors even have the students respond to the questions through their smartphones, upon which the corresponding App e-mails the marks directly to the instructor or stores it for the instructor to recover at his/her convenience [12]. One such App is Kahoot! [13] that is advertised as a "game-based learning platform", well adapted to the skills of today's students.
4. Student assessment of the course

Over the past decade or so (i.e., 2005-2016) of teaching the concrete technology course at IITM, it has been seen that 40-50% of the students opt for it, which can be considered as a good rate of acceptance of the teaching style and presentation. Moreover, this course has consistently been evaluated above the Institute and Department averages. Nevertheless, it is also known that some students have avoided taking this course due to the open-ended nature of the assignments and the surprise quizzes.

Recently two surveys were conducted: one among the past students through a post on Facebook and an anonymous survey among the current students towards the end of the course. In both surveys, the responses were collected through the www.surveymonkey.com website. The respondents were asked whether they supported the teaching of applications first, the scheme of assignments and the surprise quizzes. In general, the responses and comments received have been in favour of these features of the course (see Table 1).

Table 1: Responses to surveys among past and present students.

<table>
<thead>
<tr>
<th>Group surveyed</th>
<th>Responses received</th>
<th>In favour of being taught applications first</th>
<th>Found the assignments helpful</th>
<th>Found the surprise quizzes helpful</th>
</tr>
</thead>
<tbody>
<tr>
<td>Past students (2006-2015)</td>
<td>22</td>
<td>18</td>
<td>21</td>
<td>21</td>
</tr>
<tr>
<td>Present students (at the end of the 2016 course)</td>
<td>21</td>
<td>19</td>
<td>18</td>
<td>16</td>
</tr>
</tbody>
</table>

5. Concluding remarks

The author has strived, in his courses, to aid the student in developing comprehension, analysis, decision-making and communication skills, and the right attitude toward learning. To facilitate the effort, the concrete technology course has been taught to encourage learning by induction. The applications and special concretes are covered in the first half of the course whereas the second half is dedicated to the constituents, mix design, properties and environmental concerns. The response of the students taught over the past decade or so has been positive. The approach followed seems to be appropriate for emerging countries where civil engineers may be employed more for construction management, technical services and administration rather than as researchers and concrete technologists.
References

INNOVATING A CLASSIC COURSE IN CONCRETE STRUCTURES

Per Goltermann

Technical University of Denmark, Lyngby, Denmark

Abstract
A large number of changes, new activities and approaches have been tested at DTU in the teaching of concrete structures: Use of mandatory assignments, handing out solutions before or after exercises, detailed or summary solutions, brush-up teaching materials, strengthened consistency in solutions, videolectures recorded from lectures or produced from Powerpoint, electroic examples, inductive approach, repetition for reexams with or without lectures or supervisor or E-learning material, instruction videos for lab testing and many other things. The author will present his approaches and the resulting impact on the students learning – what worked very well and what had no effect. The author will also identify which of these activities, that can be implemented easily and have the largest effect - eventually with the inclusion of the students.

1. Introduction.

The author started his career as an associated professor in the summer of 2015 after 20 years as a consultant engineer. The classic course in concrete structures was first taught by the author in the autumn of 2015 as a classic course with 4 hour sessions, comprising of lectures and exercises. The student should hand in 3 assignments, (25 % weight) and attend a 4 hours written examination (75 % weight for the grade).

The approach of the teaching was from the beginning of the authors teaching changed from the classic approach to include an inductive aspect [1], so each session would start with pictures, a demonstration or a short video with the phenomena or failure, which the current session would deal with (see Figures 1 to 3).
The use of the inductive approach was very popular, but the results (see Table 1) soon revealed that not all students learned as much as they should do and that many students still fail. This sparked the development of the teaching in this course, which have by now been going on for almost 10 years and been delivered to app. 2000 BEng and BSc students.
Table 1: Performance of all students in spring semesters [3]. Note 1: Values denotes students assignments handed in. Note 2: Values in brackets are for students, actually passing the exam.

<table>
<thead>
<tr>
<th>Semester</th>
<th>Signed up for course</th>
<th>Attending at exercises</th>
<th>Signed up for exam</th>
<th>Passed</th>
<th>% Passed</th>
<th>% correct among passed</th>
</tr>
</thead>
<tbody>
<tr>
<td>S2006</td>
<td>94</td>
<td>(76)\textsuperscript{1}</td>
<td>85</td>
<td>45(62)</td>
<td>73%(53%)</td>
<td>66%(71%)\textsuperscript{2}</td>
</tr>
<tr>
<td>S2007</td>
<td>138</td>
<td>(121)\textsuperscript{1}</td>
<td>152</td>
<td>98(77)</td>
<td>64%(51%)</td>
<td>65%(72%)\textsuperscript{2}</td>
</tr>
<tr>
<td>S2008</td>
<td>177</td>
<td>No data</td>
<td>167</td>
<td>114</td>
<td>68%</td>
<td>65%</td>
</tr>
<tr>
<td>S2009</td>
<td>193</td>
<td>112</td>
<td>178</td>
<td>120</td>
<td>67%</td>
<td>66%</td>
</tr>
<tr>
<td>S2010</td>
<td>222</td>
<td>142</td>
<td>213</td>
<td>173</td>
<td>81%</td>
<td>74%</td>
</tr>
<tr>
<td>S2011</td>
<td>231</td>
<td>136</td>
<td>220</td>
<td>151</td>
<td>69%</td>
<td>73%</td>
</tr>
<tr>
<td>S2012</td>
<td>230</td>
<td>151</td>
<td>227</td>
<td>159</td>
<td>70%</td>
<td>75%</td>
</tr>
<tr>
<td>S2013</td>
<td>236</td>
<td>131</td>
<td>220</td>
<td>161</td>
<td>73%</td>
<td>72%</td>
</tr>
<tr>
<td>S2014</td>
<td>256</td>
<td>156</td>
<td>259</td>
<td>201</td>
<td>78%</td>
<td>75%</td>
</tr>
<tr>
<td>S2015</td>
<td>151</td>
<td>118</td>
<td>195</td>
<td>138</td>
<td>71%</td>
<td>70%</td>
</tr>
</tbody>
</table>

1.1. The main questions and the test program

A number of options and activities were considered and the following were found (over the years) to be the most important questions:

- Should we change the assignments and the grading approach?
- Can we do something for the less qualified students and still support and challenge the good students?
- How should we handle the solutions for the exercises? Detailed or brief solutions? Should they be handed out before or after the exercises?
- Can we facilitate the students possibilities for working independent? Could this be achieved by using some E-learning aspects?
- Can we influence the amount of work the students actually do?
- Can we support the failed students efficiently for their reexams?

The paper will focus on the teaching in the spring semester, where the largest group of students attend the course. The failed students, who study for a reexam, will be evaluated in their fall semester as this is where the largest number of failed students is observed.
2. The assignments and their use in the learning and the grading

The course was in spring 2006 and 2007 graded on a combination of a written examination (weight 75%) and three assignments for each student (weight 25%). This approach had been introduced in order to increase the number of students passing the course and also to force the students to work more during the lecture period. The work load in developing and correcting these assignments did, however, add up to a large amount of time. It was expected that this time could probably be better used in innovating the course – just as it seemed the this control of the students own planning of their work was in conflict with the university policy and the educations competence profiles of making “the students responsible for their own learning”.

The results (Figure 4) reveal that there is very little correlation between the student performance in the assignments and in the written exam. These observations lead to the opinion that, a number of students had a (too large) amount of help from other students and that the assignments did not truly represent their own contribution. It was therefore decided to cancel the assignments after 2007 as these seemed to have no relevance for the mandatory individual grading.

![Figure 4. Individual students performance at exam versus performance in their assignments in 2006 and 7 [3].](image)

The surprising effect of this chance was that not only did the number of students passing the course remain fairly constant, but the percentage of students passing the exam did actually increase substantially (Table 1). Similar observations have been reported at conferences, but have not been published as far as the author knows.
3. Upgrading the unqualified students

This course has as prerequisite certain building mechanics courses as most university course after the first semester. Not all knowledge from a prerequisite course is normally used in the next course, nor has all that students necessarily understood and remembered everything from their prerequisite courses.

It was decided to start the teaching at the level, which the students within reason should have and not lower the level to accommodate the weaker students, but identify those weak students and offer the an efficient approach to catching up.

Two “self-testing” exercises, in the beginning of the course, dealing with generalized stresses in beams and cross-sectional parameters, as these seem to be where the below average students have their weakest points in the relevant topics. These exercises are based on the required key knowledge from the prerequisite courses and provides the individual student with a clear understanding of his or hers eventual lack of proper qualifications for the concrete structures course – so the student in due time may take action and catch up with the rest of the students.

To facilitate the catching up, a “patch” was constructed and handed out in spring 2010 in the shape of a “cookbook” [4], containing a clear set of procedures and examples for determining cross-sectional parameters. This “patch” was intended for self-study and would not be a part of the teaching in the course, although all examples and solutions were rewritten to follow the approach outlined in the cookbook. The students have reported that it has been a great help for the weaker students, and as it can be seen from Table 1, this “patch” and the rewriting of examples and solutions to follow the same approach have improved the performance among the passed students with 5-10% points, corresponding to ½ to 1 grade better in average.

A second experiment in the catching up was to introduce a game based learning system (“Schnittkraftmeister” with English userinterface) for self-training in 2015 in order to train their ability to determine the cross-sectional forces. This has not lead to any significant improvement of their skills, but nor have their use of the system been registered.

4. Solutions to exercises, how and when

The exercises and their solutions are considered essential for the students learning process. It has therefore often been discussed how such solutions to exercises should be (detailed, summary, only final results or perhaps even not be exist) and also when they should be handed out or not.

Before spring 2011, solutions of varying degree of details had been used in order to force the students to find the explanations in the textbook and by doing so, also be forced to read the text. It was also organised that the student would only get access to the solutions after the end of the exercises, as the main opinion was that students would learn less after they see the solution, than before they see it. This was, however, a tiresome and timeconsuming approach.
for the teachers and against the concept of “the students being responsible for their own
learning”.

In the spring semester 2011, all solutions had been changed to being detailed and to be
available before the exercises – in some cases available from the beginning of the semester.
The exam results before and after this change showed no effect in the number of students
passing the exam, or in their average performance at the exam (see Table 1). The students
were, however, naturally pleased with this change and were much easier to handle during the
exercises, as they could work more independently.

5. Establishing E-learning activities

The inductive teaching had from the beginning introduced use of videos from experiments or
demonstrations using a webcam, but it was decided to look into the e-learning possibilities,
without reducing the contact time between teacher and students. All lectures were therefore
recorded by DTU’s LearningLab in spring 2012 including the lectures presentation of slides,
demonstrations and examples on the blackboard. As an alternative to these videos, E-
 presentations were produced from the Powerpoint presentations with the same explanations as
in the lectures. All blackboard examples - both those the time permitted and those the lecturer
would have liked to present – were produced as E-examples, which could be played and
printed.

All videos were placed on Youtube, account ConStruct2800Lyngby and the course materials
were placed on a publicly available webpage www.betonkonstruktioner.byg.dtu.dk, where
overheads, exercises, solutions, and examples can be downloaded from (they are
unfortunately in Danish according to the university rules for basic courses). These materials
are not intended to replace the lectures, but to be used as an alternative and to facilitate the
students independent studying.

The Youtube records over the last 3 years shows that 60 % of the hits during the lecture
period occurs on the day, where the lecture takes place and that a large number of hits are
observed in the week just before the exam date.

Questionaires during the spring semesters showed no clear pattern in which of the different E-
learning materials the students preferred. This indicates that the E-presentations and E-
examples could replace the videorecordings of the lectures or the other way round and
provides some freedom for the teacher’s development of materials.

The experiences are that this concept has not changed the performance at the exam, nor has it
changed the student’s frequency at showing up for the exercises (see Table 1). The concept
has, however, made the students more independent during the exam period, where fewer
students feel the need to show up at the teacher’s office for asking questions.

The materials have later (2013 for IPad and 2015 for Android) become available also through
a teaching app “DTU Beton”, in order to facilitate the use of their SmartPhones as an
additional screen or to listen to the teaching during transport time.

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6. Supporting the failed students

The large number of students in this field has resulted in a number of students, who fail and need to take a reexamin. The students, who fail in the spring semester and sign up for the reexamin in the autumn have over the years been offered different types of help. In the autumn semesters in 2007, 8 and 9 the students could actually follow the lectures and the exercises in the autumn as the course was offered twice a year.

This changed in 2010, where no course was offered in the autumn, only a reexam and a “concrete café”. This café is simply a room assigned for the students exercises every Tuesday afternoon, with a teaching assistant available for two hours and offering a general question session a few days before the exam. In 2012 this offer was augmented through the developed E-learning material.

Table 2: Performance of students attending re-examination in the autumn [3].

<table>
<thead>
<tr>
<th>Semester</th>
<th>Signed up for reexam</th>
<th>Passed</th>
<th>% Passed</th>
<th>% correct among passed</th>
</tr>
</thead>
<tbody>
<tr>
<td>A2007</td>
<td>9</td>
<td>3</td>
<td>33%</td>
<td>68%</td>
</tr>
<tr>
<td>A2008</td>
<td>20</td>
<td>11</td>
<td>55%</td>
<td>58%</td>
</tr>
<tr>
<td>A2009</td>
<td>25</td>
<td>13</td>
<td>52%</td>
<td>59%</td>
</tr>
<tr>
<td>A2010</td>
<td>12</td>
<td>5</td>
<td>42%</td>
<td>59%</td>
</tr>
<tr>
<td>A2011</td>
<td>24</td>
<td>12</td>
<td>50%</td>
<td>60%</td>
</tr>
<tr>
<td>A2012</td>
<td>25</td>
<td>17</td>
<td>68%</td>
<td>65%</td>
</tr>
<tr>
<td>A2013</td>
<td>31</td>
<td>23</td>
<td>74%</td>
<td>71%</td>
</tr>
<tr>
<td>A2014</td>
<td>20</td>
<td>14</td>
<td>70%</td>
<td>64%</td>
</tr>
<tr>
<td>A2015</td>
<td>28</td>
<td>17</td>
<td>61%</td>
<td>59%</td>
</tr>
</tbody>
</table>

It can be seen from Table 2, that the concept of the “concrete café” in 2010-11 was as good for the students (60 % passing) as the option of following the full course in 2007-9 (50% passing). The experiences were, however, also that when this was combined with the E-learning material in 2010-15, the failure rates at the exam dropped further (68 % passing).

The students who fail in the spring semester are often students, who have not followed the exercises on a regular basis. The number of students, who shows up for the “concrete café” is still low, but the impression (and registrations of individual appearance at the exercises as well as responses from questionnaires) is that they use the teaching material and the E-learning materials at home and shows up for discussions with the teaching assistant, whenever they feel the need.
7. Conclusions

The approach of maximizing the students possibilities for efficient and independent learning have worked by introducing the E-learning, the consistent solutions and examples and the cookbook and have increased the “student production” substantially. The E-learning is at the moment only an alternative to the current teaching in the spring, but has shown it’s value during the autumn semester, where the failed spring students study for their reexam.

It can, however, be concluded that it has been a success to develop teaching material, which optimizes the students chances of studying independently in an efficient manner. The use of this material will be developed and tested further, although it is not the intention to reduce the number of hours contact with the students, but rather the intention to use this time more efficiently.

The future developments in this project will go into further details with the documentation of the effects of different teaching approaches. It is, however, already clear [3] that the student performance at the exam is (in average) correlated to the amount of exercises they attend to, their grades in the prerequisite course, the grade in mathematics and their average grades in their studies – with pretty much the same correlation between all these parameters. This does not mean that the teaching and learning approach do not influence the student performance, but rather that the differences in the students performances to a large extend can be explained by the traditional explanations.

References

INFLUENCE OF INTRODUCTION OF E-BASED DISTANCE LEARNING ON STUDENT EXPERIENCE AND PERFORMANCE

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(1) Technical University of Denmark, Lyngby, Denmark
(2) Aarhus University, Roskilde, Denmark

Abstract
A new project based course offered by Arctic Technology Centre, Department of Civil Engineering, Technical University of Denmark (DTU) and Department of Bioscience, Aarhus University in collaboration, targets students from the whole circumpolar area. It was developed over a three year period from being taught in class to being taught 100% online. We evaluated the results by analyzing the students’ performance and experience of the course during the three years. The students’ performance increased over the period of transforming the course. Multiple choice quizzes showed to be efficient tools for the students’ self-evaluation, while they did not contribute to their learning. Some contradiction between the group work format of the projects and the online teaching method was experienced by the students. Also student satisfaction decreased slightly - influenced by inconvenient features of the used learning management system, reduced instructor feedback and varying quality of the narration of the lecture videos.

1. Introduction
At Arctic Technology Centre, Department of Civil Engineering, Technical University of Denmark (DTU), it is our vision to develop courses and educations for students and professionals aiming at or having a career in the Arctic areas. In some cases this requires participants to meet and have practical experiences with Arctic climate, infrastructure etc. However, in other cases the topic being taught is of more a theoretical character that does not necessarily require physical presence. In those cases it could be a great benefit for participants spread over the large and sparsely populated Arctic area to be able to take courses online and asynchronous from the distance due to the large distances and span of time-zones covered of the Arctic. Together with Department of Bioscience, Aarhus University we have developed our first master level course into a 100% e-based course and tested the course for distance learning. The title of the course is Mineral resources in the Arctic: Environmental impacts.
and technologies. It is divided into two parts: one concerning land based mines, and one concerning offshore oil exploration. The main aim of the course is to teach the students to accomplish and critically evaluate an Environmental Impact Assessment (EIA) on mineral resource extraction/exploration projects in Arctic locations. To meet this aim, the students produce and evaluate EIA’s themselves the following way: In groups decided by the instructors, they produce EIA’s on fictive mineral extraction/exploration projects in arctic locations, - one for each part of the course, and they peer-review each other’s EIA’s in the format of a white-book, thereby experiencing some of the aspects in an actual hearing process. To support the students work on the EIA’s, lectures and calculation assignments are given and literature is assigned. In this work we will sum up on the student performance and feedback during the development of the course from being classroom taught into being 100 % eLearning.

2. Course setup and development

The course development is summarized in table 1. The course ran initially in fall 2013 as in-class-teaching consisting of two hours of face-to-face lectures and two hours of instructor supervised group work each week during the 13 week period of the semester. A significant number of guest lecturers from industry were contributing to the teaching. The idea of developing the course into eLearning appeared after feedback on this round.

In fall 2014 the biggest difference was the significant increase in the number of students. To be able to give the increased number of students continuous feedback on their performance combined with our goal to develop the course into being e-based, we developed electronic multiple choice quizzes (MCQs) for each lecture. We made it obligatory for the students to test themselves in the quizzes, and we cut down on the number of guest lecturers.

Table 1: Course development and number of students. * A White Book addresses concerns raised during a Public Consultation Processes.

<table>
<thead>
<tr>
<th>Teaching method</th>
<th>year</th>
<th>no of students</th>
<th>Peer review of EIA’s</th>
<th>Exam method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Classroom lecture + group work</td>
<td>2013</td>
<td>9</td>
<td>White-book* + oral presentation</td>
<td>MCQ + oral</td>
</tr>
<tr>
<td>Classroom lecture + group work + obligatory MCQs</td>
<td>2014</td>
<td>30</td>
<td>White-book* + oral presentation</td>
<td>Oral</td>
</tr>
<tr>
<td>Distance eLearning incl. voluntary MCQs</td>
<td>2015 Spring</td>
<td>5</td>
<td>White-book* + oral presentation by use of videolink</td>
<td>Oral</td>
</tr>
<tr>
<td>Distance eLearning incl. voluntary MCQs</td>
<td>2015 Fall</td>
<td>43</td>
<td>Anonymous peer review of EIA resembling white-book*</td>
<td>Oral</td>
</tr>
</tbody>
</table>
In spring 2015 the course was developed into being fully e-based. It was offered through the Learning Management System (LMS) platform Coursera on an internal DTU site only available to students whom were provided access. The course consisted of 33 narrated PowerPoint presentations on condensed topics lasting 10-20 minutes each, assigned reading material, instructions for the group EIA assignments and MCQs for each topic. Online discussion fora at the platform were used for communication between students and instructors and students among each other. The MCQs were now left voluntary and could be taken as many times as the students liked, and after having taken the quiz once, the students were able to see the correct answers. This time the course was provided as part of an Arctic semester where the students were located in Nuuk, Greenland. The instructors were placed in Denmark. The students attending the course were mostly biology students, whereas otherwise only engineering students have attended. In fall 2015 the course was again provided as 100% e-based, this time by DTU and with an increased number of engineering students, who were mostly physically present at DTU while some of them followed the course from the distance during part of the semester. In 2015 the white-book concept was implemented as much as possible into Coursera, though it was not possible to implement it as realistically, and also it was not possible for the instructors to view the comments given by the peers in a manageable manner, thus comments from the instructors were not given. On the other hand it was possible for the students to peer review as many reports as they liked, thus they could increase their learning and get substantial feedback from their peers.

2.1 Evaluation of students' performance

In the first round of the course in 2013 the two EIA reports counted each 25% of the individual grade, while the exam, which was a 4 hour electronic quiz counted 50% of the grade. Due to an administrative error during the exam the students were offered a chance of re-examination: They were offered an oral examination, which four of the nine students attended. Through this oral re-examination we learned that the grading based on the EIA reports did not reflect their final level. Due to this, it was decided to continue with oral exams, while keeping the EIA’s as obligatory assignments providing access to take the exam. This way we could also guarantee that the grades were given based on the student’s personal skills. The examination of the students in Nuuk in spring 2015 was done via video-conference connection. Otherwise the students were able to show up on location. The same external censor was used except for spring 2015.

2.2 Methodology

In order to evaluate the impact on teaching and students’ learning various data was collected and a series of qualitative and quantitative studies were carried out. This included:

- The examination results for each individual student: The exams were graded according to the Danish 7-step scale (which is compatible with the ECTS-scale), -3 (F) and 00 (Fx), 02 (E), 4 (D), 7 (C), 10 (B), and 12 (A) [1].
- Web-based course evaluation results for all DTU course runs. Answers to the general course evaluation were provided by 5 of 9 students in 2012, by 13 of 30 students in 2014, and by 20 of 43 students in fall 2015. The answers may be biased as students with strong opinions tend to have a higher motivation for answering evaluations.
• Web-based exam evaluation for DTU course runs in 2014 and 2015 which 12 of 30 and 13 of 43 students answered, respectively.
• MCQ pre- and post-test results from 2014. The tests were given in classroom under instructor surveillance during the first and the last lecture of the course. The tests could not be retaken, and the right answers were not revealed to the students. The two tests were identical.
• A mid-term evaluation in fall 2015 addressing the students’ perception of the eLearning and the module homepage in the learning management system (LMS).
• Statistical and access data from the Coursera platform, including the play statistics from the video server and access and usage statistics of the module homepage in the learning management system (LMS).

3 Effect of eTeaching on student performance

The grades given are shown in Figure 1. It can be seen that only very few students have failed the course and also that the average has increased from 7.2 (DTU average) in 2013 to 9.1 in 2015. It is our perception that the low number of students failing is due to the student centered active teaching method [2]. Only one student ever decided not to take the exam despite the fact the student had handed the assignments. It can be imagined that more students would have attempted to take the exam if the group assignments had not been obligatory – and that several of them would have failed or gotten a low grade. In evaluation of the effect of introducing eLearning on students’ performance we compare the two course rounds with the most comparable students in terms of number and teaching format: 2014 and fall 2015. From Figure 1 it can be seen that the GPA increased after introduction of eLearning from 8.2 in 2014 to 9.1 in fall 2015.

Figure 1: Grades given during the four runs of the course. 2013 and 2014 classroom, 2015 spring and fall: eLearning

Also the percentage of students receiving grades above 7 increased significantly (fig. 2). It may therefore be concluded that the students’ performance improved by introduction of the eLearning despite the fact that the student-instructor contact time went down to almost zero
with in most cases the first personal meeting being by the oral exam. This effect was also found by Godsk [3]. In both studies, however, the course in question was the only eLearning course in the students’ curriculum, thus other courses have provided platforms for the students’ social interaction which has been found to be particularly important for students receiving online teaching [4].

3.1 Use and usefulness of eQuizzes

Figure 3 illustrates the relation between the students’ final grade and their performance in the pre- and the post-tests in 2014. The average performance in the test increased from 42 to 70% during the course period, and a good correlation ($R^2 = 0.31$) between pre and posttest score existed. No significant correlation, however, existed ($p=0.64$) between the initial performance and the final grade, while a significant relation ($p=0.03$) was found between the post-test score and the final grade in the oral exam. In other words the course allowed for students with even very limited preconditions to raise their level and obtain a high grade.

Also it is evident that most students performed slightly better at the oral exam than at the post-test, which illustrates their increased learning during their preparations for the exam. Even better correlation ($p=0.001$) was found between the final grade and the average quiz score.
result of all quizzes (latest submission result) (fig. 4b), while there was no correlation (p=0.26) between number of quiz submissions and final grade. I.e. good grades could be obtained without handing in any quizzes, while not so good grades could be obtained even after a high number of quiz submissions. Thus the aim of the quizzes to inform the students on their individual performance throughout the course at any point of time was clearly met, while the MCQs did not in themselves improve the students learning.

Figure 4: a) correlation between final grade and no. of quiz submission in 2015; b) correlation between average quiz result and final grade in 2014.

3.2 Use and usefulness of group EIA assignments
As the aim of the group assignments was to address the core elements of the course, and the lectures, quizzes and reading material was regarded support material, it is interesting to analyze how the assignment deadline affected the student activity on the other course tools.

Figure 5: a) student activity during course period in fall 2015, b) unique number of video hours watched over a rolling 7-day period in fall 2015.

The first group assignment was to be handed in just after fall break in October (deadline A), and the other by the end of the semester – in the beginning of December (deadline B). Figure 5a with data from 2015, clearly show how both lecture watching, discussion fora browsing
and quiz submissions increased in the periods just prior to deadlines. An interesting observation is that in the second part of the course, it seems the students were initially exhausted upon handing in assignment A, while also that they had experienced the benefit of watching the lectures continuously rather than catching up just before assignment hand in, as lectures were watched more regularly during this period of the course. It is however clear from Figure 5b that the oral exam more than anything motivated the students to study. This again supports our impression that their level of knowledge had increased significantly between handing in the assignments and attending the exam (chapter 2.1).

4 Effect of eTeaching on student experience

When asked whether they felt the course was a good course (fig. 6a), the difference between the classical and eLearning versions is small, with tendency towards more satisfaction with the eLearning version. Fewer students, however, felt the eLearning encouraged their active participation (fig. 6b). No significant difference could be observed on the students’ satisfaction with regards to the teaching material (fig. 6c). In the midterm evaluation of 2015 the students were asked whether they felt the workload would have been perceived higher or lower if the course had been taught in classroom. Most students answered that they imagined either no change or that they had saved time by the eLearning (fig. 6d). According to the same evaluation 23 of 30 students had a positive or very positive experience when they first entered the course page at Coursera; while 15 tells that their ability to attend the course lectures was improved compared to if the course had been live at DTU, and 14 that it was worse.

Some positive comments were given in the final evaluation in 2015 concerned eLearning e.g.: “We did not waste time for attending to the class and we could study any time”, and “Flexibility with time is also nice”. But also several negative comments were given, - most of which concerned the quality of the sound and the speed of the narration of the PowerPoint presentations, as well as some features of the Coursera platform which was developed for (massive open online) MOOC courses, and were experienced inconvenient for a closed course like this - e.g. that the deadlines were given in North-American times, and that the flexibility for instructors to allow for extended deadlines was very low; while not the concept of the eLearning in itself. One student noted that he/she would have preferred classroom teaching, several students commented that the group forming process and necessity of physical meetings was time consuming and contradictory to the eLearning concept. The instructors had imagined the young generation being experts in meeting and communication virtually, but it seemed not to be the case.
4.1 Students perception on the use of eQuizzes as feedback tool

The purpose of the quizzes was to allow the students to evaluate themselves regarding their academic standing continually. Figure 4b and 4d showed they were a valuable tool for the purpose; still, however, less student felt the instructors “had clearly communicated their academic level of understanding” in 2015 compared to 2014 (fig. 7a). Despite the fact that the majority of the students in the midterm evaluation had expressed they experienced the quizzes to be a very good, good or satisfactory tool to inform you on your own learning (fig. 7b). This response is likely to be due to the lack of instructor feedback on the group assignments in 2015.
Figure 7: Students response in the course evaluation to the questions: a) “I think that throughout the course, the teacher/s have clearly communicated to me where I stand academically”; b) “How do you experience the quizzes as a tool to inform you on your own learning?”

4.2 Students perception of the evaluation of their performance

Figure 8 illustrates the students’ perception of the agreement between the teaching method and the examination form. It might be theorized that an oral exam after an e-based course with no personal instructor-student contact would be perceived as contradictory. However, the survey result shows that most students find the examination in good accordance with the teaching, both in 2014 in 2015.

Figure 8: Students response in the exam evaluation to the questions a) “I feel that the examination corresponded to the teaching on the course”; b) “I think that the examination form and content corresponded to the learning objectives”.

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In general the comments on the exam were positive: “We learned a lot during the courses and that we were asked” (2014 student); “oral exam is the best way to judge and check knowledge about the exam. So, I think it was very good” (2014 student); “questions focused exactly on the content of the course” (2015 student); “nice calm and good atmosphere. “Competent censors, with good questions and good guidance towards showing knowledge of an extensive area” (2015 student). Two students, however, also felt they had a bad experience: “I am little sad about the exam grade because I could not show the teachers that I really studied during the semester but because of my stress and short answer I got low grade. I think it is not fair. But actually I appreciate the way they want to explain us our assignment. It is good” and “Some of the questions asked where a bit difficult compared to what I understood were the topics” (2015 students).

5. Conclusions and future outlook

Introduction of eLearning significantly improved students learning, but also reduced satisfaction slightly. The decrease in satisfaction was not mainly due to the eLearning concept itself, but due to the reduced amount of direct feedback from instructors on group work assignments, the lecture narration quality, as well as some features of the Coursera platform. The aim of the MCQ’s, to be able inform the students on their individual performance throughout the course at any point of time was clearly met, and most students also acknowledged this source of information. The MCQ’s were, however, not a tool for learning. Many students experienced the group work as contradictory to the eLearning method. Due to Courseras closure of the platform for courses other than MOOC’s, a shift to the Blackboard platform will be made in 2016, which may solve some of the issues. E.g. this platform allows for integration of lectures recorded via iSpring software which may improve the quality of the lecture videos. The group assignments will be transferred to less comprehensive individual assignments, while the white book peer- and instructor feedback will be developed to meet the students need for feedback as much as possible by use of the new platform.

Acknowledgements
We thank Frank Farsø Rigét for guidance with the statistical analysis: We thank Capricorn 2011 Impact Benefit Agreement Education Fund as well The Danish Ministry of Higher Education and Science through UARCTIC for financial support for development of the course and development of the course into eLearning, respectively.

References
[1] [http://eng.uvm.dk/Education/General/7-point-grading-scale](http://eng.uvm.dk/Education/General/7-point-grading-scale)
"FROM MICROSTRUCTURE TO SERVICE LIFE DESIGN", A THEORETICAL-PRACTICAL RILEM INTERNATIONAL WORKSHOP

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Abstract
The paper presents the evolution from a first PhD Course "From Microstructure to Performance Testing", held in English in Barcelona in 2012, consisting exclusively of lectures, to the Workshop "From Microstructure to Service Life Design", held in Spanish in México in 2013 and in Argentina in 2015, including lectures, testing and case study-solving. The Workshop was oriented to university students and lecturers, as well as to practitioners.

In its final version, the Workshop involves 2½ days of lectures, 1 day of testing (laboratory and site) and ½ day of resolution of a case study.

The testing module consists of the preparation of four reinforced concrete slabs made: two with w/c=0.40 and two with w/c=0.65. For each w/c ratio, one slab is moist cured 7 days and the other 0 day. Companion specimens, moist-cured 28 days, are used for laboratory standard tests (gas and water permeability and migration) to characterize the concretes and feed the service-life prediction (SLP) models. The slabs are used for site testing (air-permeability and cover depth), serving also for SLP.

The feedback from participants and lecturers indicates a high degree of satisfaction, in particular for the active parts of the Workshop and supplied documentation, pinpointing improvement opportunities.

1. Origin and Evolution of the Course

1.1 Origin: “From Microstructure to Performance Testing”, Barcelona, Spain, 2012
This 3-day Marie-Curie course was held in Barcelona, Spain in June 25-27, 2012.
The main organizers were Mette Geiker, DTU, Denmark/NTNU, Norway, Karen Scrivener, EPFL, Switzerland, and Ignasi Casanova, UPC, Spain.

The course was aimed at PhD students and practicing engineers dealing with cementitious materials and with a basic knowledge of cement chemistry. Its main objective was to introduce the participants to performance testing of concrete and to discuss their application in practice in relation to current knowledge on the microstructure and properties of cementitious materials.

The course consisted of 12 lectures of 1.5 hours duration each, according to the schedule shown in Table 1.

<table>
<thead>
<tr>
<th>Day 1</th>
<th>Day 2</th>
<th>Day 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Microstructure of concrete</td>
<td>Science and engineering of accelerated</td>
<td>Application to engineering problems</td>
</tr>
<tr>
<td>(K. Scrivener/Switzerland)</td>
<td>testing (I. Casanova/Spain)</td>
<td>(J. Marchand/Canada)</td>
</tr>
<tr>
<td>Structure of C-S-H (K.</td>
<td>Performance site testing (R. Torrent/</td>
<td></td>
</tr>
<tr>
<td>Scrivener/Switzerland)</td>
<td>Argentina)</td>
<td></td>
</tr>
<tr>
<td>Interaction of concrete with</td>
<td>Durability design in China,</td>
<td>Application to engineering problems</td>
</tr>
<tr>
<td>environment (M. Thomas/</td>
<td>approaches and methods (Li Kefei/China)</td>
<td>(M. Boutz/Netherlands)</td>
</tr>
<tr>
<td>Canada)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Performance lab testing (M.</td>
<td>Standards, guidelines and specifications</td>
<td>Service life prediction for sustainability</td>
</tr>
<tr>
<td>Thomas/Canada)</td>
<td>(J. Gulikers/Netherlands)</td>
<td>assessment (M. Geiker/Denmark)</td>
</tr>
</tbody>
</table>

A total of 40 participants registered for the course, the large majority of them PhD students of European Universities (a couple from N. America and one from Japan), 5 from the cement industry and 1 from a precast company in Uganda.

Based on the successful experience of this course, conversations were started between Roberto Torrent (lecturer) and Prof. Fernando Martirena from Cuba (invited attendant) about the possibility of running this course in Latin America, an initiative that was warmly encouraged by Prof. Karen Scrivener.

1.2 Evolution towards a Workshop designed for Latin America

From the beginning, it was recognized that the structure of the new course had to be adapted to the conditions in Latin America, widely different to those prevailing in Europe.

In Latin America there are less PhD students than in Europe and, more important still, they do not normally have access to funds to attend courses beyond the national boundaries.

Hence, the focus of the course had to be shifted from PhD students to lecturers of universities, practitioners and testing organizations, covering both the public and private sector.

Now, to make the course more attractive to these potential “customers”, more emphasis had to be placed on practical aspects, without neglecting or minimizing the knowledge on
fundamental matters that helps in understanding the complex phenomena associated with performance testing and service life modelling.

The design of the new course implied an extra day, the inclusion of practical work with test methods and the explanation and supply of tools allowing the participants to solve a case study.

Under these principles, a Workshop rather than a course was designed involving:

- 2 days of fundamental lectures, including presentation of a case study to be solved by participants
- 1 day of practical work, involving execution or observation of key processes of laboratory and site durability test methods
- 1 day of presentation of real cases by lecturers and presentation and discussion of solutions of a case study solved by participants divided into groups

2. “From microstructure to service life design”, Latin America Workshop 2013 & 2015

The structure of the new course was completed in February 2013 and submitted to RILEM Educational Activities Committee (EAC) for approval as RILEM official educational activity. The approval was given on March 11, 2013 for the Workshop, due to be delivered in Mexico and Argentina.

2.1 Programme

Table 2 presents the programme of lectures of the Workshop that, with few variations, was run in México City and Toluca (12-15 November 2013) and in Buenos Aires, Argentina (2-5 November 2015):

Table 2: Programme of Lectures of the Latin American Workshop
Table 3: Programme of Tests and Applied Lectures of the LatAm Workshop

<table>
<thead>
<tr>
<th>Laboratory and Site Testing</th>
<th>Keynote Lectures and Real Cases</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Day 3</strong></td>
<td><strong>Day 4</strong></td>
</tr>
<tr>
<td>Lab Station 1: Gas- and Water-Permeability:</td>
<td>What is RILEM?</td>
</tr>
<tr>
<td>• O₂ Permeability (RILEM 116 PCD)</td>
<td>• K. Scrivener: &quot;The Future of Cementitious Materials and Durability Implications&quot;</td>
</tr>
<tr>
<td>• Water Penetration under Pressure (EN 12390-8)</td>
<td>• O. Gjørv: &quot;Durability Design and Quality Assurance of Major Concrete Infrastructure&quot;</td>
</tr>
<tr>
<td>• Capillary suction (ASTM C1585)</td>
<td></td>
</tr>
<tr>
<td>Lab Station 2: Migration:</td>
<td>Port of Miami Tunnel: Service Life Assessment of Extrados (chlorides) and Intrados (Carbonation)</td>
</tr>
<tr>
<td>• “Rapid Cl⁻ Permeability” (ASTM C1202)</td>
<td>Yucatan Progreso Viaduct, México</td>
</tr>
<tr>
<td>• Rapid Chloride Migration (NT BUILD 492)</td>
<td>• Museum of Western Art, Tokyo (Carbonation)</td>
</tr>
<tr>
<td>• Electrical Resistivity (AASHTO TP95)</td>
<td>Hong Kong-Zhuhai-Macao Link, China (Chlorides)</td>
</tr>
<tr>
<td>Site Station 1: Penetrability of Covercrete</td>
<td>Real Cases:</td>
</tr>
<tr>
<td>• ISAT (BS 1881-208)</td>
<td>• Real cases from Brazil</td>
</tr>
<tr>
<td>• Air-Permeability (SIA 262/1-E)</td>
<td>• Real cases from USA</td>
</tr>
<tr>
<td>• Surface moisture (SIA 262/1-E)</td>
<td>• Comprehensive approach of service life design of marine structures, Chile</td>
</tr>
<tr>
<td>Site Station 2: Cover depth</td>
<td>Resolution of Case Study Discussion of Case Study Solutions</td>
</tr>
<tr>
<td>• Electromagnetic covermeters (BS 1881-204, RILEM 189 NEC)</td>
<td></td>
</tr>
<tr>
<td>• Ground Penetrating Radar</td>
<td></td>
</tr>
</tbody>
</table>

2.2 Lecturers

A careful selection of lecturers was made, including local and foreign experts (Table 4). In particular, care was taken to include people with experience and holding different views of such an elusive topic as Service Life prediction, which accepts a wide variety of viewpoints.

Table 4: Lecturers of both Workshops

<table>
<thead>
<tr>
<th>México 2013</th>
<th>Buenos Aires 2015</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alejandro Durán Herrera (México)</td>
<td>Alberto Sagüés (USA)</td>
</tr>
<tr>
<td>Andrés Antonio Torres Acosta (México), Carlos Juárez (México)</td>
<td>Alejandra Benítez (Argentina)</td>
</tr>
<tr>
<td>Daniel Dámaso Juárez (México)</td>
<td>Edgardo Fabián Irazar (Argentina)</td>
</tr>
<tr>
<td>Eric Ivan Moreno (México)</td>
<td>Enio Pazini Figueiredo (Brazil)</td>
</tr>
<tr>
<td>Karen Scrivener (Switzerland)</td>
<td>José Fernando Martirena (Cuba)</td>
</tr>
<tr>
<td>Luis Fernández Luco (Argentina)</td>
<td>Karen Scrivener (Switzerland)</td>
</tr>
<tr>
<td>Mario Paredes (USA)</td>
<td>Luis Ebensperger Morales (Chile)</td>
</tr>
<tr>
<td>Pedro Castro Borges (México)</td>
<td>Luis Fernández Luco (Argentina)</td>
</tr>
<tr>
<td>Roberto Torrent (Argentina)</td>
<td>María Victoria Altinier (Argentina)</td>
</tr>
<tr>
<td>Rosa Bibiano Guerrero (México)</td>
<td>Odd Gjørv (Norway)</td>
</tr>
<tr>
<td></td>
<td>Roberto Torrent (Argentina)</td>
</tr>
<tr>
<td></td>
<td>Yury Villagrán (Argentina)</td>
</tr>
</tbody>
</table>
Except for the Keynote Lectures, delivered in English without translation, all lectures were delivered in Spanish, language in which the lecturers were proficient.

In México, out of the 11 lecturers selected, 7 were local and 4 came from abroad. In Buenos Aires, out of the 12 lecturers selected, 6 were local and 6 came from abroad (Table 4).

### 2.3 Laboratory and Site Testing

The preparation of this aspect of the Workshop required strict planning and execution efforts from the labs involved. They had to prepare, about 45 days in advance, two concrete mixes A and B as follows:

- A with w/c ratio 0.40 and 400 kg/m² of cement
- B with w/c = 0.65 and 280 kg/m² cement

Both mixes reached a plastic/soft consistency, achieved with varying dosages of water reducers. With each concrete, the following specimens were cast about 45 days before the initiation of the Workshops, for the purpose indicated in Table 5.

<table>
<thead>
<tr>
<th>Specimens</th>
<th>Curing</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 cylinders Ø150x300 mm</td>
<td>28 d. in water</td>
<td>3 for Compressive strength and 1 for electrical resistivity</td>
</tr>
<tr>
<td>6 discs Ø150x50 mm</td>
<td>28 d. in water + 6 d. drying 50°C</td>
<td>Permeability to O₂, to Air and capillary suction</td>
</tr>
<tr>
<td>6 discs Ø100x50 mm</td>
<td>28 d. in water</td>
<td>Rapid Cl⁻ Permeability</td>
</tr>
<tr>
<td>6 discs Ø100x50 mm</td>
<td>28 d. in water</td>
<td>Rapid Cl⁻ Migration</td>
</tr>
<tr>
<td>2 reinforced concrete slabs (1.00x0.60x0.10 m). The bars protruded few mm to verify accuracy of cover estimates, see Image 6.</td>
<td>Water-cured: one 7 days, the other 0 day. Nominal cover of bars: 25, 50, 75 mm</td>
<td>ISAT, Air-Permeability, Surface Moisture and Cover depth</td>
</tr>
</tbody>
</table>

The concrete properties were measured on the lab specimens at 28 days (i.e. about two weeks before starting the Workshop) to provide data for the analytical Service Life prediction methods (Life 365, Duracrete, EHE-08). During the Workshop, companion specimens were tested by the participants (or demonstrated) at the resulting age (around 45 days).

The measurements on the slabs (cover permeability and depth) were used for the experimental Service Life prediction method “Exp-Ref”.

### 2.4 Case Study: Service Life Prediction

Each Group (eventually split into subgroups) was given the task of estimating the service life of one of the four slabs, assuming them placed in a marine environment (C2 ACI 318 or XS3 EN 206-1) and in a tropical environment (C1 ACI 318 or XC4 EN 206-1). Typical locations of the country were given, with monthly average data of T, RH and Rainfall.

The Service Life prediction had to be performed applying:

- For chlorides: Life 365, Duracrete, EHE-08 and Exp-Ref
• For carbonation: Duracrete, EHE-08 and Exp-Ref

For Life 365, participants were given the link to download the free software; for the other methods, non-commercial Excel sheets were provided to facilitate the calculations.

2.5 Local Support
For both Workshops, counting with local support was essential for the success of the events.

In México, the organization of the event was in charge of IMCYC (Mexican Institute for Cement and Concrete). The preparatory work and testing was held at CITEC (Holcim Research Center for Construction Technology).

In Argentina, the organization of the event was in charge of AATH (Argentine Association of Concrete Technology). The preparatory work and testing was held at INTI (National Institute of Industrial Technology).

All parties involved did a great job and should be acknowledged for their efforts.

2.6 Participants
In México, 27 participants registered, 25 local and two foreigners (Colombia and Panamá). In Argentina, 61 participants registered, 46 local and 15 foreigners (4 Chile, 1 Cuba, 1 Panamá, 1 Perú and 8 Uruguay).

Fig. 1 shows the similar distribution by professional activity for both countries.

Fig. 1 – Distribution of participants by professional activity

2.7 Financing
Due to the characteristics of the event, involving travelling and accommodation expenses of the lecturers, financial aspects were important for the success of the Workshops. None of the lecturers charged professional fees for their participation.
Fees were relatively high for Latin-American conditions (USD 640 in México and USD 500 in Argentina). Fees reduction of 20% was offered to members of RILEM and AATH and grants were offered to students.

Platinum sponsors were Holcim in México and Sika in Argentina; in the latter, the local cement industry and the Civil Engineering Council also contributed.

Nanocem covered the transatlantic flights of Karen Scrivener.

The Workshop in México roughly broke even, whilst the one in Argentina left some surplus for the organization body AATH, due to the larger amount of participants.

In both events, the laboratory work was not charged to the organization; in Argentina, INTI received free registrations in exchange for their preparatory and practical work.

3. Evaluation by participants and lecturers

3.1 Evaluation by participants

There was unanimous response from participants of both Workshops about the high quality and usefulness of the event. Fig. 2 shows the evaluation of the Buenos Aires Workshop, based on replies of about 50% of the participants.

The aspects evaluated are: Content and Presentation of the lectures, Workshop Quality, Documentation provided, Usefulness for Professional Activity and Value/Cost ratio.

As can be seen the large majority of the responses correspond to an Excellent or Very Good assessment, even for the Value/Cost ratio. The latter means that people are prepared to pay relatively (for the region) high fees for high quality events.
3.2 Room for Improvement
Some participants expressed their opinion on what they liked most, less and provided useful suggestions for improvement, summarized in Table 5.

Table 5 - Specific comments by some participants

<table>
<thead>
<tr>
<th>Best</th>
<th>Worst</th>
<th>Suggestions</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Quality of presentations</td>
<td>• Shortage of time</td>
<td>• Cracking, Dimensional Stability</td>
</tr>
<tr>
<td>• Access to methods, experiences and applications</td>
<td>• Last minute changes in the programme</td>
<td>• Cracking, Methods and materials for Protection, Repairs and Strengthening. The room for microscopy demo too small</td>
</tr>
<tr>
<td>• Academic quality of lecturers</td>
<td>• Shortage of time to to better understand the methods</td>
<td>• Pavements, Industrial Floors, Repairs of Structures</td>
</tr>
<tr>
<td>• Very good structure and sequence of lectures. Care in the preparation of the presentations. For those initiating R&amp;D in materials, information and tools provided</td>
<td>• Lack of time to show the use of the different methods/software presented</td>
<td>• Relation prescriptive - performance specifications</td>
</tr>
<tr>
<td>• Real Cases</td>
<td>• More detailed treatment of cement hydration. Possibility of team work with models, solving case studies, preferably working on real cases.</td>
<td>• Repairs</td>
</tr>
<tr>
<td>• Very pleased with lab demos</td>
<td></td>
<td>• Despite the large attendance, introduction of participants would have helped interaction. Practical work very important (seats should be provided)</td>
</tr>
<tr>
<td>• Change of meeting room helped concentration</td>
<td></td>
<td>• Complement the analysis with other deterioration mechanisms (cracking, sulphates, ASR)</td>
</tr>
</tbody>
</table>

The Practical Work on durability test methods was highly appreciated; given that it takes one day, optimum planning and comfortable settings with seats should be attempted.

One aspect of the Workshop that requires full revision is the resolution of the Case Study. It definitely cannot be accommodated within the 4 days of the course, due to lack of time and opportunity for the Groups to meet and work and to insufficient digestion of the concepts and tools provided during the lectures. Hence, it should be given as an (optional/mandatory?) post-Workshop task, with a standard template to present the solutions and facilitate their evaluation. Perhaps a web session could be organized, say one month after the Workshop, to discuss the solutions provided by the Groups and present the experts' solutions. Alternatively, it can also be handled by e-mail.

3.3 Evaluation by lecturers
Most of the lecturers expressed their satisfaction in participating in the Workshops. Some comments:
“A very generous Workshop” (Enio Pazini Figueiredo).
“Congratulation for a very interesting and successful Workshop, and again, thank you very much for all great hospitality.
By coming home again, I would just like to thank you so much for all great hospitality during our staying in Buenos Aires. Also, it was very nice and interesting to meet so many colleagues both from Argentina and other Latin-American countries during the Workshop.
By the end of the year, it is nice to look back on the very nice and interesting days we had together in Buenos Aires.” (three messages from late Odd Gjørv†).
“I want to express my gratitude and great satisfaction for the experience of having co-participated in the RILEM Workshop last week. It pleased me not just cooperating with you but also see the talent, enthusiasm and appreciation of the students, many of whom will doubtless be part of the new generation of professionals following our steps. I see also good potential for future cooperation, both educational and professional, with the other lecturers; it was good to have also the participation of European lecturers. I plan to extend the durability course I run here, inspired by the Workshop” (Alberto Sagüés).
4. Conclusions
The RILEM Workshop "From Microstructure to Service Life Design" has been a successful initiative, enjoyed by participants and lecturers alike.
Given the worldwide relevance of the topic it could be replicated in almost any country. Key success factors are the selection of competent and experienced lecturers and the availability of well-equipped laboratory(es), capable of handling most standardized durability test methods.
The fact that two Workshops have been approved by RILEM EAC facilitates achieving future RILEM sponsorship, which certainly adds value to the event and helps promoting RILEM.
In that respect, the support and encouragement of then EAC Chairman, Prof. Ole Jensen, to carry forward the initiative, is greatly appreciated.
The contribution of co-organizers in México (Eng. Donato Figueroa) and Argentina (Prof. Edgardo F. Irassar) and, especially, the generous efforts of all lecturers are to be acknowledged.
5. Images
The following page shows some pictures taken from the Workshops held in Mexico and Argentina.
1 - K. Scrivener's keynote lecture
2 - What is RILEM? Presentation
3 - Electrical resistivity test
4 - ND Assessment of cover depth
5 - O₂ Permeability Test
6 - Air-permeability and depth of cover concrete on site (notice wooden tablet at the extreme of slabs hiding actual position of protruding steel bars)
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Materials, Systems and Structures in Civil Engineering 2016

Innovation of Teaching in Materials and Structures

Edited by
Per Goltermann

RILEM Proceedings PRO 108

This volume contains the proceedings of the MSSCE 2016 conference segment on “Innovation of Teaching in Materials and Structures”. The conference segment is organized by DTU Byg and deals with innovation and development within the field of teaching in a number of fields, dealing with materials and structures. All contributions have been peer reviewed.

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