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## Doctoral courses in cement and concrete technology – our experience

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**Abstract:** Since 1999 we have been involved in teaching and organization of international doctoral (PhD) courses on cement and concrete technology, and since 2006 we have as founder, chair and secretary of the Educational Activities Committee in the international materials organization RILEM been responsible for the sponsorship and promotion of a large number of doctoral courses on construction materials. Events, organizers, teachers and participants have been affiliated with most parts of the world. The doctoral courses we have been directly involved in as teachers and organizers count more than 500 participants from approximately 50 countries at 20 different courses. The doctoral courses we have been responsible for have developed over the years and this paper presents their contents and structure and some of the underlying ideas behind their organization.

**Keywords:** Doctoral courses; PhD courses; Organization; Teaching

## 1 Background

In particular in the last couple of decades there has been a world-wide, strongly increased tendency towards harmonization, increased mobility, internationalization and quality assurance of the university educational systems. An example of this is the European so-called Bologna declaration which was signed in 1999 and its affiliated Bologna Process, which involves 50 participating countries, some also from Asia and the Middle East. The PhD education is part of this agreement, and though the process of implementation is long a lot of consequences in accordance with the aims of the declaration are already visible. One such element is the European Credit Transfer and Accumulation System, ECTS, which for example allows credits earned by a student to be easily transferred from one university to another<sup>[1]</sup>; The ECTS system quantifies the volume of learning, promotes a structured formulation of learning competence targets, and it ensures assessment of learning outcomes. The workload of one full-time academic year is equivalent to 60 ECTS credits, i.e. 1 ECTS credit corresponds to a workload of 25-30 hours.

Similar to many other countries it is required in Denmark that a PhD program includes a study program corresponding to 30 ECTS points. According to the Bologna declaration the duration of a PhD study is 3 years and the required study program will fill in about ½ year. PhD students need to attend doctoral courses to fulfill this requirement. Only few dedicated, international doctoral courses existed 20 years ago, whereas today many doctoral courses are offered world-wide. Despite this, it may still be a challenge for PhD students to find a sufficient number of fully relevant scientific courses for their study program. Contrary to this it has been easy for the PhD students to find so-called transferable skills courses such as entrepreneurship, innovation, intellectual property rights, research communication, and scientific writing.

## 2 Main principles behind the doctoral courses

### 2.1 Topics, participants and conference integration

In 1999 we started at the Technical University of Denmark and subsequently in other countries to offer international doctoral courses (PhD courses) on various topics within cement and concrete technology. Examples of this include: Advanced cement-based materials, Concrete curing, Shrinkage and cracking of early-age concrete, Durability of concrete, Smart concrete, Early-age concrete, Concrete construction, High-performance concrete, Service life, Supplementary cementitious materials, and concrete and radiological aspects. These courses have consisted in week-long “summer schools” where the participants through a series of lectures and exercises were given up-to-date knowledge from researchers on the individual topics. The primary aim with the courses has been to serve as an effective forum for knowledge transfer from experienced researchers to PhD students, but the benefit of the courses is more extensive. The courses support and fit very well into the desired internationalization and quality assurance of the PhD

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education, and as an additional benefit the PhD students become able to collect relevant credits for their PhD study program.

At the courses we have organized usually around 90% of the participants are PhD students and 10% come from industry, but also a university professor or a MSc student may be found among the participants. The highly specialized nature of the courses is demonstrated by the considerable international participation; in the latest round of courses with 106 participants, by host institution 31 countries were represented.

We have several times made doctoral course as pre-conference events where there has been a thematic link between these two parts. This combination seems to be quite successful and involves several advantages. For many teachers and doctoral course participants the conference may be a factor which legitimizes and potentially finances their doctoral course participation, i.e. the conference serves as a promotor of the doctoral course and vice versa for such a combined set-up. It is our experience that about 50% of the participants at the doctoral course also participate in the conference. Furthermore, conference participation may be a new, uneasy experience for some PhD students, but through the doctoral course they will be funneled into the scientific environment by practicing conference presentation at the course, and by becoming familiar with experienced researchers and fellow students who they will also be together with at the subsequent conference; they will suddenly feel integrated in such an event.

## 2.2 Time frame and venue

We have been involved in organization of doctoral courses of different lengths, involving course activities at the host institution of up to two weeks. For the course organization opportunities and challenges highly depend on the length of the course so this needs to be carefully considered. With course activities at the host institution of 5 days (“one week”) there is enough time for the participants to form solid professional contacts and for the organizers to establish a “full” course where very different course elements and learning principles can be included. International participants will in some cases not be interested in a longer course since it may be challenging for them to finance a longer stay, or they may not have the possibility to or be interested in investing more time in the particular course topic; when we have organized longer courses, participation in parts of the courses are frequently asked for. On the other hand, a shorter course will conflict with the international aim of the courses since it would hardly be legitimized for participants to make an intercontinental trip for a one day stay. The optimal time of the year for a course depends mainly on the venue, such as when the facilities are available to host the course and when the weather is expected to be optimal for outdoor activities which may be relevant both during course hours and outside these. At the Technical University of Denmark August is the optimal time for a doctoral course and additionally this seems to be in the least conflict with teaching periods at other universities around the world, though universities world-wide have very different teaching schedules.

## 3 Detailed course set-up

### 3.1 Overview program

The doctoral courses we have been organizing typically involve a total of 165 h of work, i.e. three weeks, or 6 ECTS credits. Two of these weeks are “home-work” and consist in preparatory readings, making a short, personal presentation, and making a scientific poster. These parts are estimated to have a workload of 50, 10 and 50 h respectively. Subsequent to these preparations one course week – 55 h of work – is spent at a host institution. The generic program for such a course week is shown in Figure 1.

### 3.2 Course modules

The program shown in Figure 1 has a number of overall course elements which are subdivided into a modular structure. The modular structure makes it easier to keep a sense of perspective in the planning, preparation and execution of the course, for organizers, teachers as well as for participants. If, for example, a teacher with a short notice is prevented from contributing, it is easier to move around lectures and to find a substitute solution when the program is modular.

The objective, contents and reasoning behind the individual modules are given in the following. A broad range of teaching forms and social elements – passive/active, classroom/lab, inductive/deductive, individual/group – are mixed in an intentional way as to create an interesting teaching environment and to support learning for every participant. The main focus of the entire course is to maximize learning for the participants. All the lecture modules obviously have this in their objective, but it is also attempted to make the social events and the assessment of learning outcomes itself contribute to the learning.



|                  | Monday                                | Tuesday           | Wednesday     | Thursday            | Friday                               |
|------------------|---------------------------------------|-------------------|---------------|---------------------|--------------------------------------|
| 8 <sup>00</sup>  |                                       |                   |               |                     |                                      |
| 9 <sup>00</sup>  | 1. Course introduct. & Personal pres. | 6. Lecture 3      | 10. Lecture 6 | 14. Lecture 10      | 19. Prep. of particip. presentations |
| 10 <sup>00</sup> | Coffee                                | Coffee            | Coffee        | Coffee              | Coffee                               |
| 11 <sup>00</sup> | 2. Lecture 1                          | 7. Lecture 4      | 11. Lecture 7 | 15. Lecture 11      | 19. Prep. of particip. presentations |
| 12 <sup>00</sup> |                                       |                   |               |                     |                                      |
| 13 <sup>00</sup> | Lunch                                 | Lunch             | Lunch         | Lunch               | Lunch                                |
| 14 <sup>00</sup> | 3. Lecture 2                          | 8. Lecture 5      | 12. Lecture 8 | 16. Lecture 12      | 20. Participant presentations        |
| 15 <sup>00</sup> | Coffee                                | Coffee            | Coffee        | Coffee              | Coffee                               |
| 16 <sup>00</sup> | 4. Lab exercise A                     | 9. Lab exercise B | 13. Lecture 9 | 17. Study tour      | 20. Participant presentations        |
| 17 <sup>00</sup> |                                       |                   |               |                     | 21. Closure                          |
| 18 <sup>00</sup> | 5. Reception dinner                   |                   |               | 18. Downtown Dinner |                                      |

Fig 1 Generic overview program for the course week at the host location of a 6 ECTS doctoral course. Prior to this course week the students need to spend an estimated 2 weeks of work by 1) reading literature, 2) making a personal presentation, and 3) making a poster presentation

*Module 1: Introduction to course and presentation of participants*

The objective is to familiarize participants and teachers with each other and to introduce the participants to the course curriculum. Practical information about the course, venue, sponsorship etc. is given and if not done on arrival, before the module starts, participants are registered and material is distributed such as name tags and ring binders. Teachers are presented and participants are practiced in giving a short oral, personal presentation of themselves and their research topic. It is important that students in due time (at least 1 month) before course start are given clear instructions for the framing of their personal presentation in this module. This may involve max. one presentation slide and max. two minutes presentation time. Their presentation should be sent to the course organizers a few days before the course starts to allow shift between student presentations without delay. The personal presentations should answer questions like: Where do you come from?, what is your background?, what is your main research topic?

*Modules 2-3, 6-8 and 10-16: Lectures with individual contents*

The lecture modules constitute the core of the course. Their general objective is to present to the participants in a structured and condensed manner a specific scientific topic; the sum of the individual lecture topics forms the theme of the course. Depending on the theme of the course there may be a logic order of the lecture modules so that the first lecture modules have a more theoretical or generic content, and that the last ones are more oriented towards practice. Each lecture module may involve one or more different teaching elements such as a scientific talk, small class-room demonstrations, video clips, written exercises and computer exercises. It may be considered to include a brief break within a module, in particular if the module is filled-in with talking only. For each lecture module the participants may

be asked to study preparatory readings before the course. It may be 1 to 2 scientific papers, book chapters or a standard (code or norm) relevant for the specific module. Some of the preparatory readings may be common for several course modules, including lab modules. In the full course program each teacher may be responsible for example for three lecture modules. It may be nice both for the students and for the teachers if the modules alternate between the different teachers.

#### *Modules 4 and 9: Lab exercises*

The inclusion of lab exercises is indisputably the most challenging part of a doctoral course to organize. They require a good lab infrastructure, a lot of equipment, manpower, considerable preparations, finances, potentially there may be safety concerns, and the course program may become less flexible. On the other hand lab exercises are also highly valuable for the participants, and have manifold objectives. Through the lab exercises the participants will familiarize themselves with relevant experimental methods, they will acquire a “hands-on” experience with the challenges faced in producing experimental data, they will get to know each other through group work, and they will be forced to be actively involved in the learning process as opposed to the potentially more one-way lecture modules. The lab exercises also serve as a data source for implementing the learning from the lecture modules, for making the student presentations in Module 20 and as a possibility for assessment of learning outcomes. Potentially, the theoretical background or methods used in the lab exercises can be presented in the lecture modules prior to the lab exercises – some instructions for the labs are also more conveniently given in the lecture room than in the lab. The lab exercises are positioned in the beginning of the course week. This allows students to start analyzing and discussing their measurement results during the following course days. Also, if needed, this allows further measurement results to be collected in the following couple of days from experiments they have initiated during the lab exercises. The lab exercises are positioned in the last module of the day where the students are mentally and physically optimally motivated for this kind of learning. The group size should be kept low as to promote active involvement of all participants.

#### *Module 5 – Reception dinner*

It may be useful to arrange a relaxed social event – e.g. a barbecue – in the first evening to further “break the ice”. Several other course elements also indirectly serve this purpose, and at this point the participants have seen each other’s personal presentations (Module 1) and posters, and they have worked together in the lab. For the subsequent evenings the participants are thus prepared for making their own evening arrangements.

#### *Module 17 – Study tour*

The objective of the study tour is to let the participants gain the impression of challenges and possibilities experienced with concrete materials in practice. The visit may go to places like a cement factory, a ready-mix concrete plant, a construction site, or a major concrete structure. As much as possible, technical elements at the study tour should have specific relations to course elements e.g. in the lecture modules. In addition to this, the study tour also serves as a “social” tour for the course participants, and it may conveniently be combined with transport further on to the Module 18 Dinner.

#### *Module 18 – Downtown dinner*

The downtown dinner – or wherever it takes place – is the farewell dinner of the event. It is the time for a relaxing but still official gathering where speeches and greetings can be passed on. During the dinner a prize ceremony for the poster competition can be organized – see section 3.3.

#### *Module 19 – Preparation of participant presentations*

The objective of the module is to practice the participants in preparing an oral, scientific presentation through work in the groups already established for the lab exercises, Module 4&9. It should be emphasized to the participants that the allocated time will be quickly spent, so they have to work structured and goal-oriented and not the least be well-prepared in advance to this module. This includes making a preliminary analysis of the results in the spare time – Tuesday and Wednesday evenings and during the breaks – and within the groups to coordinate who should prepare what tasks for this module. Participants should be encouraged to bring their own laptop with their favorite programs installed for data analysis and visualization, and perhaps from home to have prepared a presentation slide design.

#### *Module 20 – Participant presentations*

The objective of the module is to practice the participants in giving an oral, scientific presentation and to comment on presentations by others. It is expected that the participants in a “conference” setting present selected results from the lab exercises and that these are framed with the learnings they have achieved through the lecture modules. From an organizational point of view this module also serves as a structured possibility for assessment of learning outcomes by

the students. For each group a time slot of e.g. 25 minutes may be allocated and perhaps split in halves between the oral presentation and the plenum discussion. All teachers and participants should be present and participants should be encouraged to ask questions to their fellow presenters.

#### *Module 21 – Closure*

The course week is concluded with a brief summary of the course and signed certificates for course participation are handed over. Participants who do not fulfil the requirements for the ECTS credits may receive a certificate which states that they have “participated in the course”, but with no mentioning of course credits. Participants who have fulfilled the course goals may receive a certificate with mentioning of the involved workload in hours and the corresponding ECTS course credits. To further develop the doctoral course concept, the participants are kindly asked to comment on the course. In particular the participants should fill in a Course Evaluation Form – a box is set up for anonymous posting of the form to the course organizer. Participants may also fill in other forms. For example RILEM has for many years granted a free 3-years membership to PhD student participants at these courses and to initiate this, they need to fill in a form and return it to the organizers.

### **3.3 Posters**

Participants are asked to bring a printed poster, size A1 in portrait layout, with them for the course. All posters are on arrival put on display for example in the coffee room as to allow participants to study them during breaks or at the end of the days. The poster should – in English – present each participant’s research project or their research interest to the teachers and to the rest of the participants. The design and contents of the poster may be freely selected by the participant, i.e. it may show finalized results, or it may be a description of research intended to be done. The contents may be from an ongoing PhD project or from a project the participant has accomplished or is involved in. For time reasons, no specific time slot for oral presentation of the posters are arranged, but of course poster authors will be asked questions from interested teachers and other course participants during the breaks. To encourage diligent work with the posters and to promote interaction and professional discussions among the participants a “best poster” prize competition is established. Assessment is done by a teacher’s jury and additionally a special prize, based on votes from all participants, are given (a “student prize”). The official course dinner (Module 18) is a convenient time for announcing the prize winners of the poster competition. The jury should explain to all the participants what elements in the winning posters made them particularly successful. In this way this ceremony also becomes part of the learning. Usually several posters are very well made and to distribute the well-deserved honor it may be considered to give several prizes, e.g. “gold”, “silver” and “bronze”, and perhaps in two categories: 1) The “format” of the poster, i.e. how well the poster presents its contents: clarity, structure and balance. Is the poster easy to read, is the poster logically structured, is there a relevant use of graphs and photos, is there a suitable amount of information on the available space, is the layout clean, is there an appropriate balance between the different parts of the poster?, etc. 2) The “technical content” of the poster, i.e. the quality of the scientific elements in the poster: Novelty, relevance and ingenuity. Is the research idea interesting and relevant, are the materials and methods well-chosen and described, are the results properly analyzed, are the conclusions appropriately based on the contents of the research?, etc.

## **4 Comments on course layout**

### **4.1 Optimal number of participants**

The optimal number of participants depends on the type of course. In principle, the more participants the better, since “social dynamics” among the participants is improved, and the efforts in organizing the course and preparing the teaching are better legitimized. For a course consisting purely of lectures the participant capacity may only be limited by the size of the auditorium. However, when other course elements are introduced more serious constraints will arise. For a course of the type described in Figure 1 the constraints include:

1) Each individual presentation in Module 1 cannot be done meaningfully in less than 1 minute, and for the participants and teachers it is anyway difficult mentally to room more than 60 presentations. So from this point of view 60 participants may perhaps be considered a maximum.

2) The lab exercises are also a limiting factor. For our ordinary course in construction materials at the bachelor program of the Technical University of Denmark we teach up to approx. 120 students in the laboratory at the same time, but this requires an extremely detailed planning, very large room facilities, a lot of equipment, and some previous course rounds with upscaling of the number of participants. Courses, made “individually” with laboratory tutorials – such as the doctoral courses described in this paper – become organizationally quite challenging with more than 40 participants.

3) Within Module 20 a maximum of 3 hours is allocated for the participant presentations and associated discussion. Certainly 60 participants is also a limit for this time slot.

In summary, courses of the described type may work optimally with 20-40 participants, though we have organized

doctoral courses with more than 100 participants. Such a number of participants can be handled in a rational way by making clusters of courses where one or more of the course elements are shared by the individual courses. Obviously the Module 5 and 18 dinners can be common for several parallel running courses, and depending on the similarity of the course topics also the study tour and some of the lectures may be joint.

#### 4.2 Assessment of learning outcomes

Appropriate use of the ECTS credit system requires an assessment of the student achievements. For the course structure described in this paper, different types of assessment are possible, including written exercises, oral tests and reports. The described set of oral “conference” presentations made by the participants at the end of the course is one possible point of oral assessment. However, as time within the Module 20 is limited it may be useful to combine it with other types of assessment, such as e.g. a few multiple choice questions at the end of each lecture module or a full test at the end of the course. We have through approx. 10 years asked the participants to deliver written reports after the courses, but the workload on the teachers was massive and apparently with a disproportional outcome for the participants. In contrast to this the oral presentations are completely interactive and all participants seem very much to learn from and become inspired by each other in parallel to this type of assessment. The oral presentations are also very efficient in binding together the different course elements – lab exercises, lecture modules, and study tour – and it also promotes a strong interaction between participants. The poster competition contains similar elements though the posters are “home-made” before the week at the host institution, and in a context of learning assessment they can, therefore, at maximum show understanding of the course readings. But their display among all participants and the setting with both teacher’s jury assessment and the fellow participant assessment also bring in a very interactive element of learning from and becoming inspired by peers. The personal presentation by the participants in the introduction module is also a required delivery from the participants, and though it may be to a lesser extent, it can also be taken into account in the assessment of the individual performance.

#### 4.3 Course evaluation

At the end of each course participants are asked to express their anonymous opinion about the course. In particular they have the option of ticking a grade on a scale “unsatisfactory, bad, satisfactory, well, very well” for every module of the course as well as giving written, supplementary comments. Usually  $\frac{1}{2}$ - $\frac{2}{3}$  of the participants take this opportunity. For the majority of the responses we have received are “well” or “very well”, and many participants express that they have found the courses very good and useful for their PhD studies, see Figure 2.

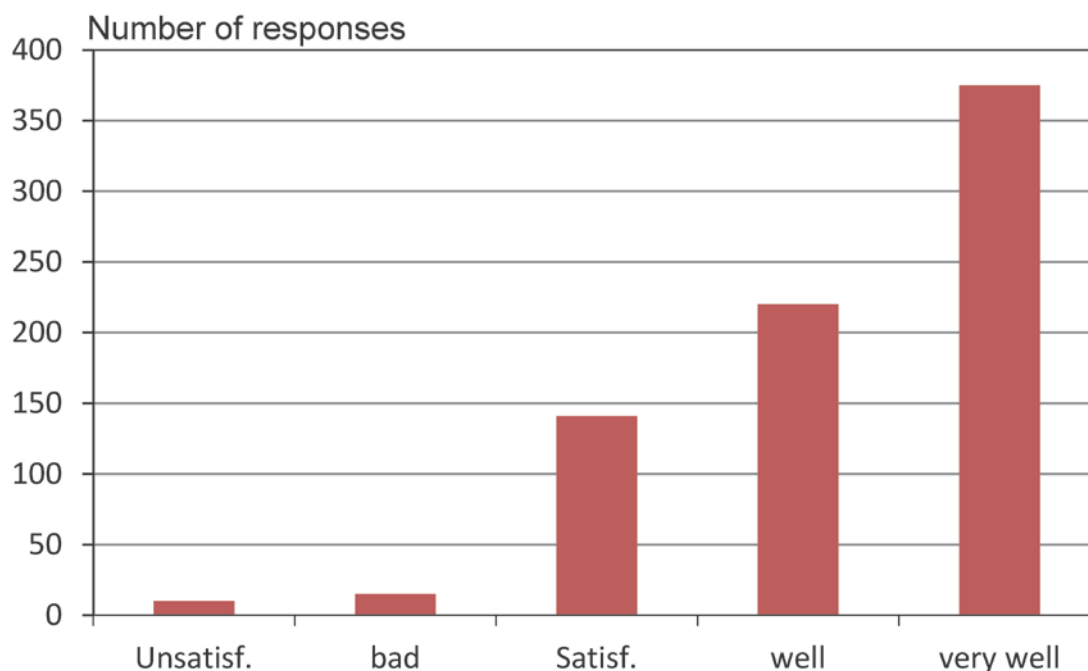


Fig 2 Evaluation responses by the participants at our 2016 international doctoral courses

#### 4.4 Final comments

We have been very happy for the cooperation with colleagues around the world in organizing and teaching at these



courses. Since colleagues around the world have started to copy this concept, even in detail, we found it useful to bring it to the attention of a broader public; Though the concept is under constant development we feel it is sufficiently well-working so that others may find inspiration in it.

**Reference:**

[1] ECTS Users' Guide 2015, On-line 19.05.2017: [http://ec.europa.eu/education/ects/users-guide/docs/ects-users-guide\\_en.pdf](http://ec.europa.eu/education/ects/users-guide/docs/ects-users-guide_en.pdf).