Computational Methods for Building Physics and Construction Materials

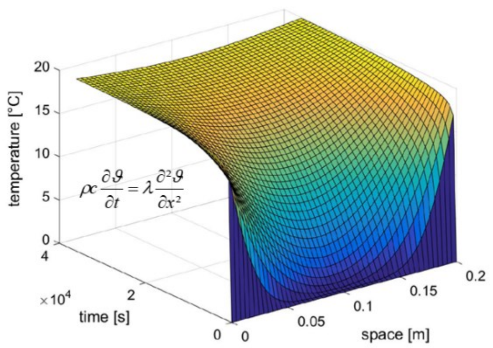
CMBPCM Course 2021
April, 12 – 16

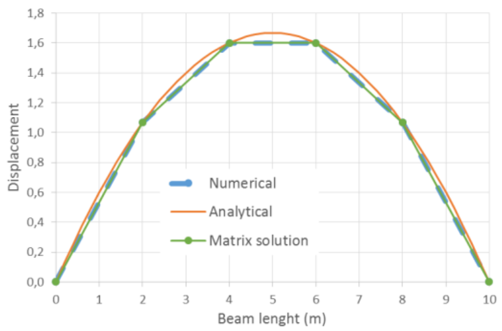
RILEM EAC Evaluation report

Organized by:
Institute of Construction and Building Materials,
Technische Universität Darmstadt, Germany

Venue:
Online course

INSTITUT FÜR WERKSTOFFE IM BAUWESEN





Computational Methods for Building Physics and Construction Materials

TU Darmstadt
May 11, 2021

unite! University Network for Innovation, Technology and Engineering

rilem

TECHNISCHE UNIVERSITÄT DARMSTADT

Subject: Evaluation report CMBPCM course 2021
Purpose: RILEM EAC feedback
Date report: 11-05-2021
Authors: Prof. E.A.B. Koenders / Dr. N. Ukrainczyk / Dr. C. Mankel / Dr. A. Caggiano

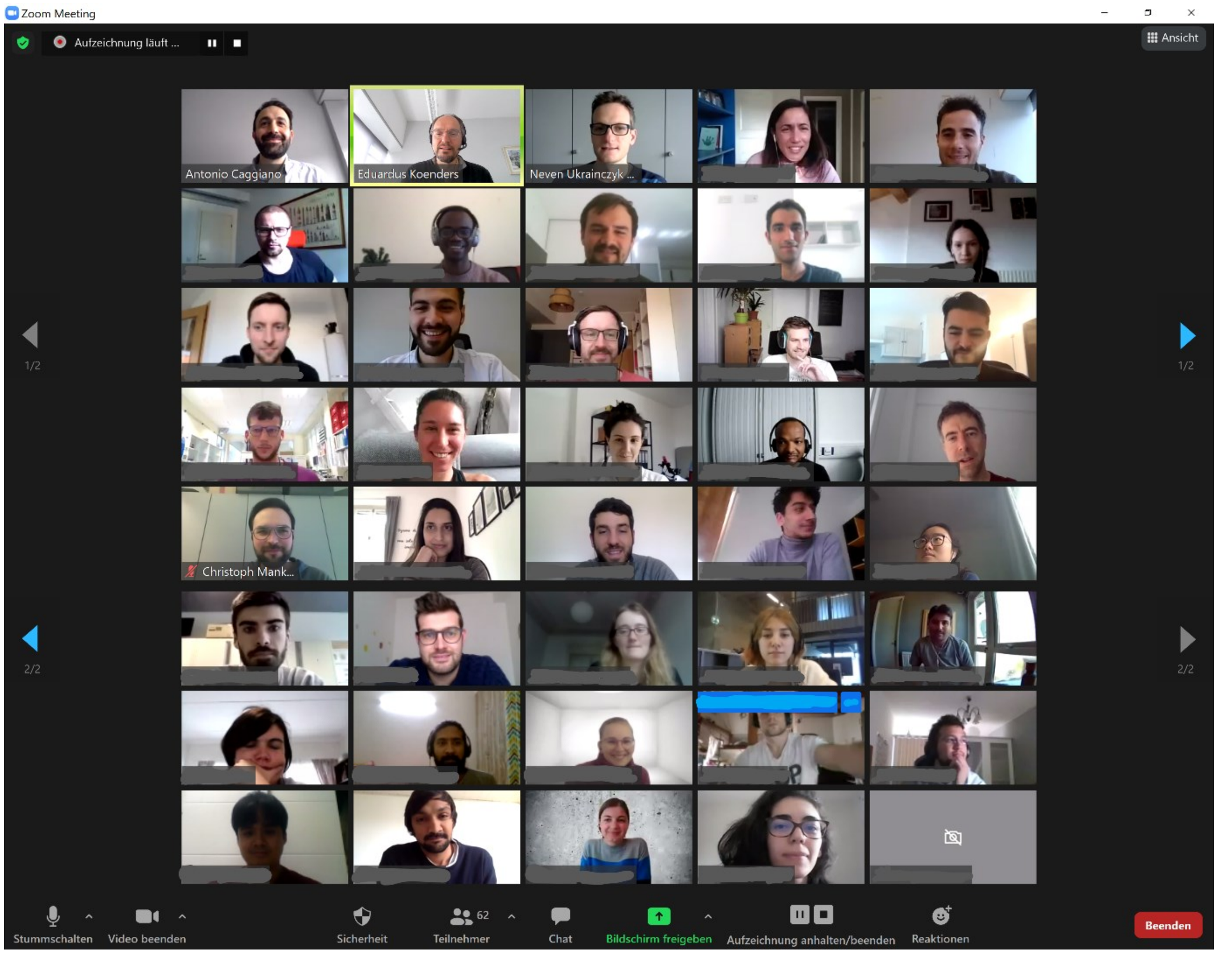


Figure 1: Online course organized by the Institute of Construction and Building Materials of the TU Darmstadt, Germany.

1. Course objective:

This year, due to the enormous interest of students, the RILEM EAC course "Computational Methods for Building Physics and Construction Materials" was organized again as an online course by employing the Zoom-platform (Figure 1). The course was organized by the Institute of Construction and Building Materials of the Technical University of Darmstadt, in Germany and was this year also supported by RILEM and UNITE!, which is an European university network on innovation, technology and engineering. The main objective of the course is to teach MSc, PhD and/or post-doctoral students, the basic principles of computational methods for differential equations employed in the field of building physics and construction materials. Due to the online limitations, the course program was party updated in comparison with previous years. This year, emphasis was on numerical solution strategies with Excel and Octave, explicit and implicit discretization with the finite difference method, method of lines, boundary conditions and implementation strategies of physical temperature and moisture processes that frequently occur in construction materials. Typical problems addressed in this course were some classical steady-state mechanics problems like a simply supported and cantilever beam problem, followed by modelling transient heat transport and chloride diffusion problems, multi-layer systems, coupled moisture – heat systems, whereas also the particle structure and kinetics of cement hydration were addressed. Similar to the last year course, this year a full day introduction to the Finite Element Method was provided as well. In total, the course was structured in a 5 full day (intensive) program, by teaching every day a different aspect of computational modelling. In the morning sessions theoretical lessens were taught and in the afternoons demonstrations and exercises. An overview of the full course program is added in Appendix 1.

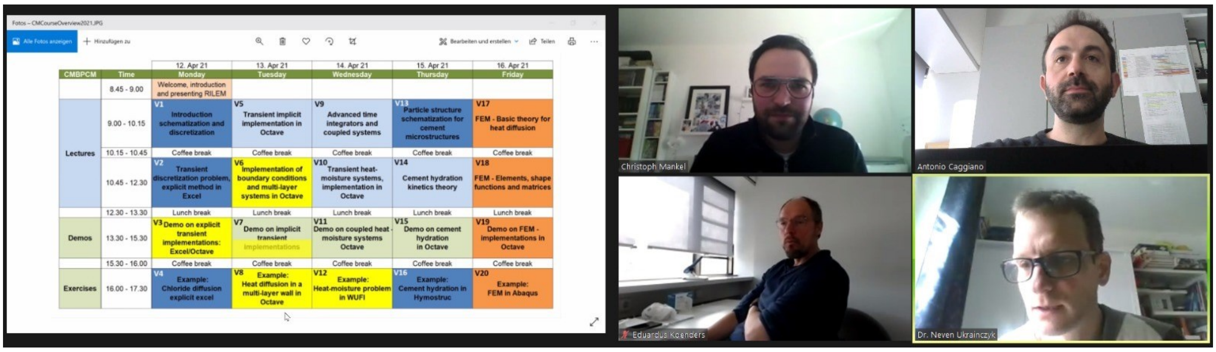


Figure 2: Teachers preparing the course.

Teachers of the course were Prof. Eddie Koenders, Dr. Neven Ukrainczyk, Dr. A. Caggiano and Dr. Christoph Mankel (Figure 2), all employed at the Technical University of Darmstadt. At the end of the course students were asked to fill out a course evaluation form of which the results are attached in Appendix 2. After the course, a RILEM certificate of attendance was sent to each student individually. As the course is also an officially registered TU Darmstadt MSc course it has a value of 6 ECTS credit points. With this, all students who attended this CMBPCM course could also opt for these credit points, and use it e.g. for their graduate school program. However, for this they have to comply with the course requirements as well, meaning they have to pass the homework exercises and the exam organized by the TU Darmstadt in.

2. Course program:

The course program (see appendix 1) was designed in such a way that the core lectures addressing the theoretical backgrounds on computational modelling were scheduled in the morning sessions, while the demonstrations and practical sessions with the use of software were scheduled in the afternoon. This concept was very successful and appreciated by the students very much. However, based on the last year experience, which was the first time that the course was organized online the program was modified a bit where the in the afternoon applied demonstrations and implementations were lectured. This updated part of the program turned out to be very well accepted, but the only point of concern was the intensity of the course as a whole. In general, this turned out be almost too tough, and will therefore be reconsidered for the next year's course.

The used software was Microsoft Excel, the freeware program called Octave, the Lite version of Hymostruc, the student edition of WuFi and Abaqus. Along with these software programs, specially prepared programming codes, made by the teachers, were provided as part of the lecture material. The basic idea of the course is that after successful attendance of the course, students learned how to use these software and understand the provided codes which they can employ for their personal research interests and/or future modelling developments.

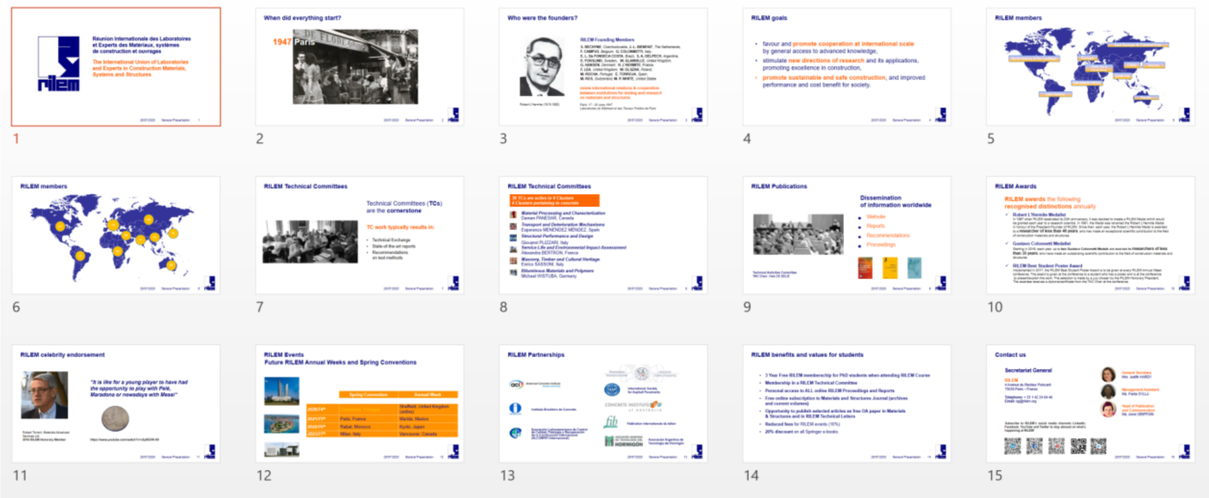


Figure 3: PPTs presented to introduce RILEM.

The course started on Monday, early morning, by Prof Koenders, with an introduction of RILEM (Figure 3) followed by presentation of the university network UNITE! (Figure 4) and finally, a presentation of the course program and introducing the teachers. After that the official part of the course officially started. First, the basics of schematization and discretization were explained by Prof. Koenders, followed by the explicit discretization method for steady state problems and how to implement this in Excel. Main focus was on a cantilever bending beam with different types of loading, followed by an explicit schematization of a transient heat diffusion problem implemented in Excel. In the afternoon demonstrations were provided starting with an introductionary lecture on Octave followed by the explicit heat diffusion problem and implementation in Octave (Dr. Mankel). Finally, a new course module on chloride diffusion modelling was added, schematized and implemented in Excel (Prof. Koenders).

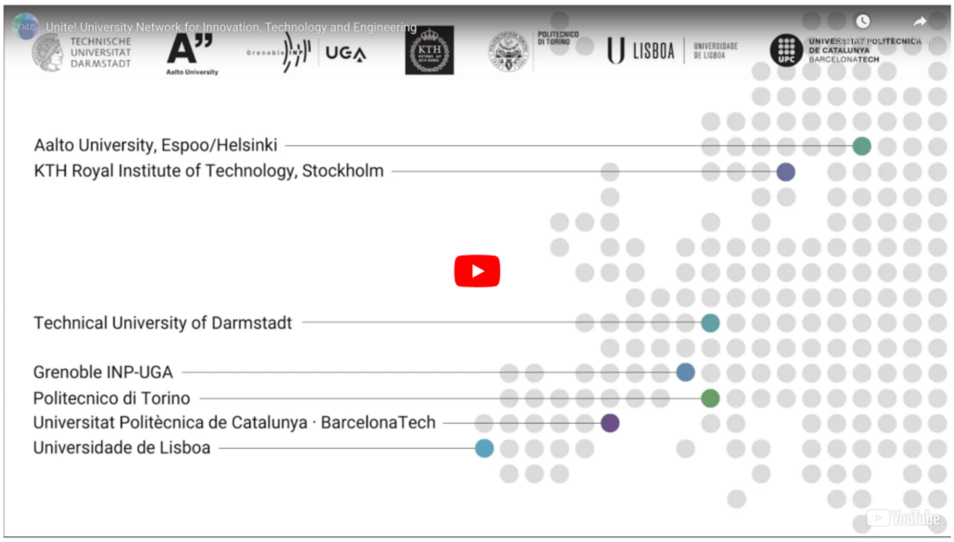


Figure 4: Screenshot of the UNITE! Website.

On Tuesday morning, the course continued with the implicit method for solving system of (discretized) algebraic equations implemented in Octave by Dr. Ukrainczyk (Figure 5). First, the focus was on of Laplace's and Poisson's (steady-state) ordinary differential equations (ode), followed by the transient heat diffusion problem, implementing backward Euler and Crank-Nicolson discretization schemes in diagonal sparse matrix representation. After that the schematization and implementation of various boundary conditions, namely the Dirichlet, the Von Neumann and the Robin boundary conditions, and multi-layer systems in Octave was explained by Dr- Mankel (Figure 5). In the afternoon, a demonstration on transient problems was lectured along with an example on the implementation of heat diffusion through a multi-layer system.

Figure 5: Dr. Ukrainczyk (left) and Dr. Mankel (Right) lecturing the course.

On Wednesday morning the course continued with lectures by Dr. Ukrainczyk. First, the theory behind higher order (e.g. Runge-Kutta) discretization was presented, followed by strategies on how to deal with non-linear ordinary and partial differential equations (ode and pde). Advanced time integrators are presented for various types of time-based solution methods for stiff ode and pde. Method of Lines (MoL) was taught as well, demonstrating the powerful and easy to use time integrator tools readily available in the Octave toolbox. The theoretical part also considered a critical overview of all different methods learnt, systematically comparing theirs's pros and cons, and concluding with a clear recommendation on which method one could use best, depending on the modeling case and its specific characteristics, such as: discretization size, desired accuracy, flexibility to adapt the code, computational cost/speed and ease of implementation. After that, an introduction to coupled pde-ode and pde-pde systems was lectured. The coupled system, which requires a predictor-corrector solution strategy, was explained in detail, along with two example implementations on heat-chemical reaction and heat-moisture demonstrated in Octave in the afternoon. The afternoon was also used to demonstrate implementation of advanced time integrators and Method of Lines examples in Octave. The last lecture of the day was on an exercise of a coupled heat-moisture problem conducted with the software WuFi. The software was explained and a typical heat-moisture problem was demonstrated by Dr. Mankel.

On Thursday morning the course continued with hydration modelling, starting with a lecture on particle structure generation for cement/binder based systems (Prof. Koenders). The lecture is on providing the students insights on how to setup a basic particle structure that complies with the particle grading and water/binder ratio of systems, and forms the starting point of the hydration kinetics modelling, which was the next lecture, provided by Dr. Ukrainczyk. This lecture was on how to model the volume changes and rate of hydration driven by the chemical cement reactions. Main hydration rate mechanisms are introduced for single particle dissolution, nucleation and diffusion, followed by theory on integrated multi-particle (Hymostruc) approach. In the afternoon, Dr. Ukrainczyk demonstrated how this theory can be implemented in Octave and showed a few examples on the developed basic cement hydration model as well as on how to generate and visualize 3D particle structure. The last lecture was on an example and demonstration with the software Hymostruc Lite, provided by Prof. Koenders (Figure 6). During this lecture the model possibilities and simulation options were explained and the graphical output and 3D visualizations explained and the output possibilities of the model were demonstrated.


Figure 6: Dr. Caggiano (left) and Prof. Koenders (Right) lecturing the course.

This year, Friday was fully allocated for lectures on FEM provided by Dr. Caggiano (Figure 6). The course started with a brief lecture on the basic theory of the Finite Element Method, addressing at a glance the theoretical backgrounds, implementation and a solution strategies, followed by a lecture on various elements, shape functions and how to compose matrices. After lunch, a demonstration session was prepared showing the implementation of the heat diffusion equation in Octave, where the code files were also provided to the students. The final lecture was on an FEM example in Abaqus, where Dr. Caggiano showed in detail the implementation and calculation of a full FEM problem. Finally, the students were asked to fill out the online evaluation form (Appendix 2) and a “group photo” was made (Figure 1).

3. Number of persons:

The official number of registered participants for the full online CMBPCM course was 118 (excluding teachers), 104 full week students and 14 for one or more days. From these students were 8 from the UNITE! University network.

4. Target group:

The target group was as expected, i.e. MSc students predominantly from TU Darmstadt, as well as mostly PhD students, some Postdocs, a few Professors, and a few researchers from the Industry. The course structure enables all educational levels to learn from the provided content.

5. Country of participants:

The attendees of the CMBPCM course were from 29 different countries. From these, Argentina 2x, Belgium 3x, Brazil 2x, Canada 2x, China 7x, Croatia 1x, Czech 3x, Estonia 1x, France 9x, Finland 4x, Germany 31x, Greece 2x, India 2x, Iran 1x, Italy 11x, Japan 1x, Netherlands 1x, Norway 1x, Pakistan 1x, Poland 3x, Portugal 3x, Singapore 1x, Spain 4x, South Africa 2x, South Korea 1x, Turkey 3x, UK 7x, and USA 8x.

6. Teachers:

The teachers; Prof. Dr. Eddie Koenders (TU Darmstadt, course responsible), Dr. Neven Ukrainczyk (senior scientist), Dr. Christoph Mankel (senior scientist) and Dr. Antonio Caggiano (senior scientist). All teachers showed professional skills and all were very much able to present inspiring lectures to the students during the theoretical morning sessions as well as during the practical afternoon sessions. The different backgrounds (Koenders and Mankel are Civil Engineer and Ukrainczyk a Chemical Engineer and Caggiano Computational Mechanics Engineer) and the wide research and educational experiences of all teachers is considered very important to achieve a divers and comprehensive program of lectures, examples and exercises, and to provide a broad vision on the various aspects of computational modelling and implementation to the students.

7. Frequency and co-organization:

The CMBPCM course is an annual EAC supported RILEM Educational Course and an official TU Darmstadt course, which was this year organized for the fifth time, and (because of the corona situation), for the second time as an online course. Next year the CMBPCM course will be organized again by the Institute of Construction and Building Materials, maybe with a slightly revised program adapted for online education.

8. Date:

The course will be organized every year in the spring. The date for the next year CMBPCM course will be in or around the second week of April 2022. The course will be offered as an on-line course again.

9. RILEM support:

RILEM guidelines are followed and a presentation about RILEM is provided during the introduction session of the course. The RILEM presentation was given by Prof. Eddie Koenders. Students are informed about the general RILEM activities and also about the three year free membership.

10. Flyer:

A flyer has been made in paper and PDF form and was distributed actively among potential participants via the RILEM website, the TU Darmstadt website and other online platforms.

11. Evaluation:

After the course, students were asked to fill in an evaluation form. The results of this evaluation will be used to improve the course for the forthcoming year. An overview of the results is provided in Appendix 2.

APPENDIX 1

Course program 2021

Program of the CMBPCM 2021 course

CMBPCM	Time	Monday 12. Apr 21	Tuesday 13. Apr 21	Wednesday 14. Apr 21	Thursday 15. Apr 21	Friday 16. Apr 21
	8.45 - 9.00	Welcome, introduction and presenting RILEM				
Lectures	9.00 - 10.15	**V1** Introduction schematization and discretization	**V5** Transient implicit implementation in Octave	**V9** Advanced time integrators and coupled systems	**V13** Particle structure schematization for cement microstructures	**V17** FEM - Basic theory for heat diffusion
Lectures	10.15 - 10.45	Coffee break	Coffee break	Coffee break	Coffee break	Coffee break
Lectures	10.45 - 12.30	**V2** Transient discretization problem, explicit method in Excel	**V6** Implementation of boundary conditions and multi-layer systems in Octave	**V10** Transient heat-moisture systems, implementation in Octave	**V14** Cement hydration kinetics theory	**V18** FEM - Elements, shape functions and matrices
	12.30 - 13.30	Lunch break	Lunch break	Lunch break	Lunch break	Lunch break
Demos	13.30 - 15.30	**V3** Demo on explicit transient implementations: Excel/Octave	**V7** Demo on implicit transient implementations	**V11** Demo on coupled heat - moisture systems Octave	**V15** Demo on cement hydration in Octave	**V19** Demo on FEM - implementations in Octave
	15.30 - 16.00	Coffee break	Coffee break	Coffee break	Coffee break	Coffee break
Exercises	16.00 - 17.30	**V4** Example: Chloride diffusion explicit excel	**V8** Example: Heat diffusion in a multi-layer wall in Octave	**V12** Example: Heat-moisture problem in WUFI	**V16** Example: Cement hydration in Hymostruc	**V20** Example: FEM in Abaqus

APPENDIX 2

Evaluation results CMBPCM 2021

Online Evaluation Questions and Results CMBPCM 2021

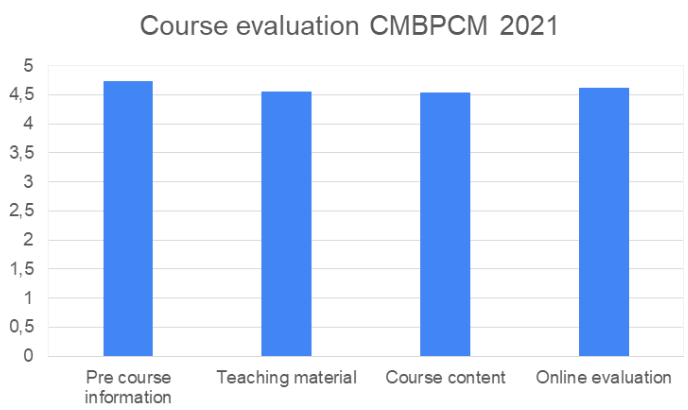
Questions asked:

Pre-course information:
Was the pre-announcement (flyer) of the course clear enough?
Was the E-mail contact appropriate?
Was the registration form appropriate?
Was the (RILEM) Website information appropriate?

Teaching material:
Providing PDFs of the lecture notes was sufficient?
Quality of the lecture notes?
Quality of the exercises?
Quality of the demonstrations?

Course content:
What is your opinion about the quality of the lectures in general?
What is your impression about the quality of the whole course?
Was the teaching level appropriate?

Online evaluation:
Was the quality of the online platform sufficient?
The possibility for asking questions was enough?
Were the questions satisfactory answered?
Were the hand-notations by iPad tablet clear enough?
Would you be interested in an advanced course?
Offering streaming of the recordings for one week after the course is a good idea?



(Average results of 63 students, with 5 = the highest grade)