

INTERDISCIPLINARY DESIGN PROJECTS IN THE EDUCATION OF CIVIL ENGINEERS

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ABSTRACT: The education of civil-engineers at Universities in Germany has often been criticized to be too theoretical and to be too detached from practice, often disregarding the fundamental relations to adjacent domains. In this paper an educational approach is illustrated that combines theoretical lectures with extensive project work. These projects begin at the third semester with a simple structural design task, increase successively in complexity and thematic range over the years and end with an inter-disciplinary design project in the last semester. To illustrate this, the way of the students that started their Civil Engineering education in 2004 and who did not only take part in the final inter-disciplinary design project but even erected it with their own hands is being traced in this paper.

KEYWORDS: education, civil engineering, architecture, design projects, inter-disciplinarity

1 INTRODUCTION

This paper will present the educational approach taken by the Chair for Timber Structures and Building Construction at the Technische Universität München as part of the education of future Civil Engineers. It will follow the steps of the students that started their civil engineering courses in 2004 and who were lead from the basic courses to the final design-build-project in South Africa.

2 BASIC EDUCATIONAL CONCEPT

The Chair for Timber Structures and Building Construction has two focuses. One is the general Building Construction education which is material-unspecific and covers a number of basics necessary for every Civil Engineer, no matter what she/he will specialize on in the future. These courses start during the very first semesters, however, extend to the mid-semesters and finally students can also specialize in this subject during their Master studies. The courses "Methods of Representation" and "Design of Structures" are also part of the Building Construction education and are held in the early semesters.

On the other side the chair has a strong focus on Timber Structures. Courses covering this subject are started during the late Bachelor programme, but predominantly it is a subject students can specialize in during their Master.

Throughout the entire time of the courses, a simple but consequent principle is being followed: as few exams and as much practical design work as possible. Subject matter is taught in lectures, but only the basic part of it is tested in exams. The reason is that preparation for exams produces skills that are often different from the skills needed in real life. In real life, young professionals need the ability to analyze problems, to separate complex matters into sub-problems and to solve these problems without losing sight of the whole picture. They need the ability to articulate themselves, either by traditional means like sketches and plans or by written reports, oral presentations or posters. Problem analysis, i.e. being confronted with a generally formulated task that has to be transformed into solvable sub-tasks instead of having a concrete exam question, turns out to be a major problem for Civil Engineering students regularly. Imitating real life design processes is a way to test the fact knowledge of the students but more importantly offers the opportunity to provide them with the skills described above.

There is no doubt, that the complexity of the problem setting has to be carefully adjusted to the momentary level of the student group. Otherwise, if the difference between complexity and student ability is too large, the learning effect is likely to be negative. Therefore, there is a process behind these design processes, i.e. the starting point is a very simple design task in the early semesters, but over the years the complexity and the difficulty of the following projects are successively increased. This happens by slowly widening the thematic

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width of the task, by increasing the depth to which a problem has to be solved and/or by mixing students with different thematic background and therefore a different perspective on the problem in one group.

The following chapters will briefly summarize the subjects that are taught by the Chair for Timber Structures and Building Construction. Thereafter the process of the 2004 students mentioned above will be illustrated, starting from a simple structural project the students had to solve in their third semester until the final, inter-disciplinary design-build-project during the last semester. The first part is subsumed under “acquisition phase” and the second part under “application phase”.

3 ACQUISITION OF KNOWLEDGE

3.1 BACHELOR LEVEL - BASICS

“Building Construction” is very intensively present during the first semesters. The portfolio is composed not only of lectures in “Building Construction” but also of lectures in “Methods of Representation” and “Design of Structures”.

In “Methods of Representation” the students learn different ways to produce graphical representations of technical objects. A basic knowledge they are expected to have after this course is how to transfer three-dimensional objects into a two-dimensional drawing plane and how these drawings are professionally processed, so that finally a standardized technical drawing evolves. The students had to attend this course during the second semester and it was finalized with a written exam.

“Design of Structures” is also a very early course and it was held in two parts during the first two semesters. This course is the first confrontation of the students with structures. Therefore the students are first of all taught the basic technical terms that are related to structures. They then learn how to identify load bearing structures in a building, how to deduce from these structures to abstract load bearing systems and how these systems act separately or in the context of a more complex total system. Another important part of this course is the description of standardized loads, the way they act on the system and finally the material’s general reaction to the load. For each part, the students had to write an exam to finalize the course.

The „Building Construction“ education during the Bachelor is split into three parts, taking place during the second, the third and also the sixth semester. The first part covers all construction materials like timber, steel, concrete, masonry and the typical ways they are processed, built and joined. Additional lectures are held about insulation, sealing and foundations of buildings, interior work and of course about the typical planning processes. The students had to write an exam to finish this first course.

The second part during the third semester was fully spent on the first design project of the students. Lectures were

held in the beginning, but referenced directly the structure that was to be built, i.e. in this case a tower-structure (see chapter 4, “structure in a bag”).

The third part during the sixth semester, which is called “Building in the Building Stock” views “Building Construction” from another standpoint. To enable the students to analyze typical historical buildings they get a brief building and architecture history that is followed by lectures about typical historical and era-specific constructions and their weaknesses. Building damages, typical deterioration symptoms and analyzing methods like monitoring or measuring equipment are also an essential part of this course. The second half of the semester our students had to spend on a project which was the assessment of the whole course (see chapter 4, “TU Clock Tower”).

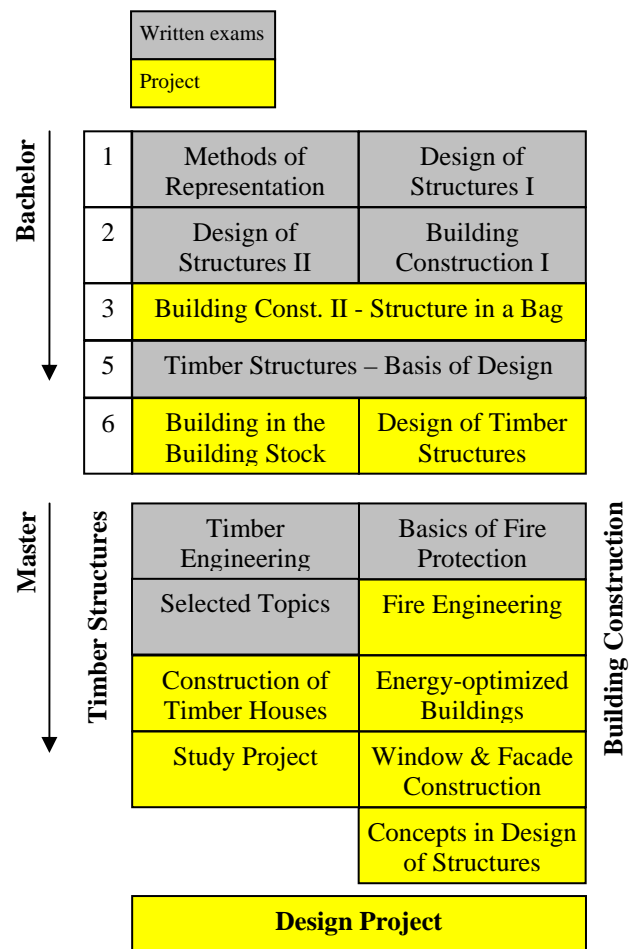


Figure 1: Flow Chart of the Courses held by the Chair for Timber Structures and Building Construction

“Timber Structures – Basis of Design” was the first course for these students with a timber focus. The objective of the introductory course into timber structures is to lay the foundation on which the students can develop knowledge towards a material appropriate design and dimensioning of timber structures. Emphasis is given to the specific properties of timber and its reaction towards environmental conditions, with special consideration of appropriate connections between timber

components. This course interlinks the knowledge in structural mechanics, acquired in the basic courses, with a code-conform design under consideration of the particular characteristics of timber as a structural material. This course was held during the fifth semester and was finished with an exam.

The scope of the course “Design of Timber Structures” is the application and expansion of the knowledge obtained in the course “Timber Structures - Basis of Design” with regard to the design of timber structures, construction methods, connection types and the detailing process. The students hear lectures on structural systems, construction types, connection details, some building physics aspects, fire protection and the issue of transportation and erection. The main focus however was an individual design project which was the basis to grade the students (see chapter 4).

3.2 MASTER LEVEL – SPECIALIZATION IN BUILDING CONSTRUCTION

After the sixth semester the students continue with the Master programme during which they specialise their knowledge in four major fields. Every specialization comprises compulsory as well as a set of optional courses from which they have to choose a certain number. Half of the optional courses have to be from the related specialization, the other half can be taken from other fields, however, have to be approved by the chair that offers the specialization. Compulsory courses in “Building Construction” are the course “Basics of Fire Protection” and the participation in the final “Design Project”.

Most courses offered during the Master include individual design projects, which are, compared to the Bachelor much closer to the practice of a design engineer. During the following paragraphs the modules are briefly described.

The Module “Basics of Fire Protection” covers all major themes of fire protection as: Basics of fire origin, fire spread and fire exposure, building materials, building parts, ceilings and walls, building law and codes, fire protection concepts, cause of fire, fire behaviour of materials and constructions, preventive fire protection, fire defence and structural calculation methods for fire exposure. It is meant to be a basic course that offers the students the preparation for more conceptual work that is presented in a second, optional, course that deals with fire protection.

This second course is called “Fire engineering” and is one of four optional modules that can be chosen by the students. It covers the field of fire protection concepts, fire scenarios and design fire loads, fire protection analysis, smoke simulation, fire protection for building stocks and special types of buildings. The course has to be finalized by a project that includes a conceptualization of a fire protection plan for a building (see chapter 4).

Further modules of the specialization in “Building Construction” that can be elected by our students are “Energy-optimized Buildings”, “Window and Façade Constructions” and “Concepts for the Design of Structures”.

“Energy-optimized Buildings” is a course that deals with the modelling of transient thermal systems with the Thermal Building Simulation software TRNSYS. Students learn how to model buildings or renewable energy systems, how to define simulation domains and how to evaluate results critically. Apart from the modelling competence, they learn to judge the effects of e.g. thermal mass, the quality of the glass-sunscreen systems or night ventilation. To finish the course, our students had to simulate a building or an energy system and write a report that explains the solutions they have developed (see chapter 4).

“Facade and Window Construction” covers the technical aspects of glass, windows, facades and sun screens and teaches the students to develop facade systems with regard to the requirements of the future user and to construct them with regard to the characteristics of the materials used. This is a course that deepens the knowledge gained during the Bachelor course in “Building Construction”. The students had to individually design a façade system to finish the course successfully. Thematically, there is a close link to the course “Energy-optimized buildings” since students can work on one single project to finalize both courses: e.g. there is the possibility to optimize a façade construction thermally by TRNSYS simulations (see chapter 4).

The last module students are able to choose is „Concepts for the Design of Structures”. This course is directly based upon the Bachelor courses “Design of Structures” and continues the education in this field. The students who elected this course finished it with a detailed analysis of real-world structures and an according oral presentation.

3.3 MASTER LEVEL – SPECIALIZATION IN TIMBER STRUCTURES

The general procedure for this subject is the same as explained above for “Building Construction”. The attendance of “Timber Engineering” and the participation in the inter-disciplinary “Design Project” is compulsory whereas the students have to choose additional modules from a set of optional courses like “Construction of Timber Houses”, “Timber Structures – selected Topics” and “Study Project in Timber Construction”.

The objective of the specialization course “Timber Engineering” is to intensify the knowledge, acquired in the course “Timber Structures - Basis of Design” and give the students a deeper comprehension of the particularities in the design of wide-span timber structures including timber bridges.

Material appropriate design is demonstrated by an in-depth examination of connection types and techniques.

The ductility of connections leads to a closer examination of stability theories, concluding in practice-oriented calculation models and a compilation of possible bracing systems. The concluding section on timber bridges incorporates material specific issues on dynamics, fatigue, duration-of-load effects and durability. The structural design of a timber hall has to be worked out by the students as a prerequisite. A written exam concludes this course.

The course “Construction of Timber Houses” shall give the students an understanding of the particularities in the design and planning of timber houses. Apart from the structural calculations, the course will cover appropriate detailing with respect to building physics and construction. Within the course, the students conduct multiple workshops in detailing (see Chapter 4), a written exam concludes this course.

„Timber Structures - Selected Topics“ shall present a link between education and the state-of-the art in research. A bow is drawn from the raw wood material via the development of a structural timber product to the acquisition of a building approval. Within this scope, special developments like composite structures or laminar structures (CLT) are presented as well as approaches to the inspection and rehabilitation of existing timber structures. This course is finalized by a written exam.

The “Study project in Timber Construction” aims at enabling the students to individually develop a seminar paper in the field of timber engineering. This paper has to be presented in front of fellow students and lecturers (see Chapter 4).

4 APPLICATION OF KNOWLEDGE – DESIGN PROJECTS

In the previous chapters it was tried to impart an overall picture of the lectures that are held by the Chair for Timber Structures and Building Construction at the Faculty of Civil Engineering. The following chapters will now focus on those courses of the program that include design projects as an integral part of the course or its finalization. The aim of these chapters is to highlight the process of increasing proximity to real life planning processes and the qualification the students got while being lead through this process.

4.1 BACHELOR LEVEL

The starting point for all the projects was the so called “structure in the bag” which was the main part of the “Building Construction” course in the third semester. Generally, students work in a group of four to six individuals and are asked to design a structure according to a number of specifications, like height, span-width or similar. The students’ task is to design this structure, to make the detailing, approximate calculations of the maximum failure load and finally to build the structure physically. A special issue is the requirement that all the materials used for the structure have to fit into a usual

rubbish-bag even though the total dimension of the structure exceeds the dimensions of the bag by far. Consequently, there is a strong focus on joining techniques. Finally, all the structures are erected by the students and tested in our testing laboratory, typically until failure. The evaluation of the project depends – next to common criteria like e.g. quality of the drawings – on the ratio of failure load to weight to the power of two.



Figure 2: Assembly of Towers prior to Testing



Figure 3: Different Tower-Constructions



Figure 4: Unorthodox pre-testing

The structure that has to be built by the students, changes annually. In the case of the students of 2004, it was a tower that had to be designed and built. Figures 2 to 4 give some impressions of that year's erection and testing event, figures 5 to 7 show examples of previous or subsequent years.



Figure 5: Student Project "Bridge in the Bag"



Figure 6: Student Project "Bridge in the Bag" – Testing in front of student audience



Figure 7: Student Project "Crane in the Bag" – Testing of Tower Crane

This was the first, rather simple design project, the students had to tackle. It was simple in terms of the scope of problems they had to solve. Apart from that, the whole, rather large group was focussed on the same problem, so no conflicting interests had to be balanced against each other. The students were supervised regularly, i.e. three to four times during the semester they had to present their results to the supervisors. Supervisors were always teams of two persons, one being a Civil Engineer and the other an Architect. Thus, right from the beginning, the students got an interdisciplinary input.

During the sixth semester, the students have to face two parallel courses that are both finalized with a project. In the field of "Building Construction" this is "Building in the Building Stock" and in the field of "Timber Structures" it is "Design of Timber Structures".

The design task in "Building in the Building Stock" changes regularly over the years. For the 2004 students it was the renovation and modernisation of the TU Clock Tower in such a way, that the renovated structure would comply with modern energy requirements and that an alteration of the type of usage was possible. The existing rooms are rather inferior and very seldom occupied and were hypothetically to be used as café and exhibition space in the future.

Basically, the students are given three steps to follow: Firstly they are asked to analyze the existing building by classifying it historically, by measuring and drawing the existing structure and by assessing its quality in comparison with a modern standard and with regard of the future hypothetical use. In a second step, the students have to conceptualize ways to modernize the building. At the end of this stage, the future renovation concept has to be qualitatively clear and well distinguishable from alternative concepts. The third step obviously is a detailed planning of the steps that have to be followed, both in terms of the demolition of parts of the structure and in terms of new-built parts.

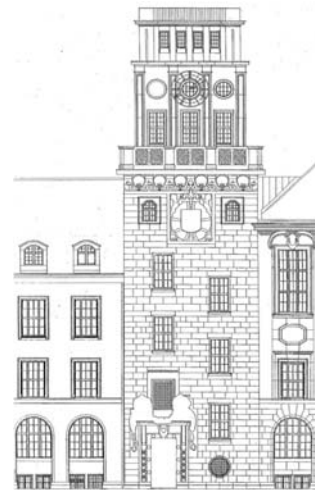


Figure 8: Historical drawing of the TU-Clock-Tower

In comparison with the first project, the students have to face a clearly more complex planning situation. Even though detailed calculations regarding structural design and building physics are not asked for, they have to balance the different requirements at least qualitatively. A major point is the restrictions that are characteristic for the planning with existing buildings, i.e. the degree of freedom during the planning is reduced. Again, the participating students are supervised by a mixed team of Civil Engineer and Architect.

In the second course “Design of Timber Structures”, the students shall apply their knowledge by means of a design project to be realized in groups of two. Over the course of the semester, the students shall develop a design for a roof structure with a free span of approximately 20 m. After having individually developed one alternative, the students are required to decide on one design which shall subsequently be worked out in form of a model, structural drawings, the dimensioning of primary structure and bracing system and the design and calculation of connections. The finalized design has to be presented and defended in front of the responsible lecturers and fellow students.

The development of the individual designs is supported by accompanying lectures which shall demonstrate the wide range of structural systems, construction types and connection details possible in the design of engineered timber structures. Subject-related lectures on building physics, fire protection and transport and erection shall demonstrate further relevant topics to be considered during the design of a structure. The individual planning processes are supported by introductory hands-on courses in computer-aided analysis, design and manufacturing.

The course “Design of Timber Structures” addresses individual creativity, solution-oriented thinking and the ability to integrate acquired theoretical knowledge into the individual detailing process. It thereby presents an important methodical preparation towards the final (interdisciplinary) design project in which the students shall incorporate their knowledge in the design of timber structures into the whole project.

4.2 MASTER LEVEL SPECIALIZATION AREA: BUILDING CONSTRUCTION

Until this point of their education, planning has always been more general than specific for the students. Now, during the first step of their specialisation they get the possibility to focus on one design requirement, regardless of other requirements from other fields in engineering or architecture. The aim during this phase is, to give them the opportunity to penetrate one theme as much as possible without being too much “distracted”.

In “Energy-optimized Buildings” the students are confronted with a way of approaching a problem they are not familiar with. A characteristic of modelling in thermal building simulations is the non-existence of rules, codes or standards. Students have to learn that they themselves have to decide on the degree of detail of their

simulation based on the design task and a judgement of the ratio of exactness and effort. Also they have to be sensitized for the responsibility they have as a planner to check results according to their plausibility.

Due to the complexity of thermal building simulations, the design tasks for the students are normally small and straightforward. I.e., in most cases they are asked to model a single zone and to optimize a certain structure regarding its heat losses in winter or its heat peaks in summer. However, they have to quantify the advantages and disadvantages of different strategies and have to find ways to argue for one or the other design option. This includes a comprehensible presentation of the numerical results and a written report. The design task for the 2004 students who had elected this course was the thermal renovation of a part of the façade of the Chair for Timber Structures and Building Construction in order to minimize the heat losses and especially to minimize heat peaks of these highly glazed rooms.

The course “Window and Façade Construction” also has to be finalized with a project. The students have to design a façade construction for either an existing building or a new building that has to be designed by them. Civil Engineers do not learn the principles of architectural design, thus, these aspects are usually ignored in the assessment of their work. However, the point in doing so is, to give the students as much freedom as possible, without constraining them by any constructional boundary condition.

The focus of this project is not on the building physics or the structural design aspects but on the correct detailing of the construction and the clear presentation of the details. Nevertheless, the students have to translate the requirements that are formulated in the written task into the choice of appropriate constructions. Thus, again, they are confronted with a more or less colloquial formulated task that has to be transformed into concrete requirements which then have to be met. Parallel to the above mentioned thermal simulation project, the 2004 students had to develop constructional solutions for the thermal renovation of the institute’s façade.

In “Fire Engineering” the students have to develop a fire protection concept by applying their knowledge to the situation of a real building. Depending on the type of the building, its use and size, they have to define the protection target and have to develop appropriate constructional, plant specific, organizational and protective measures. The results have to be documented in a written report.

4.3 MASTER LEVEL SPECIALIZATION AREA: TIMBER STRUCTURES

Within the Master courses in Timber Construction, the objective of the individual projects also shift from larger, rather basic design projects to more special topics, be it in detailing or the application of innovative developments or products in the field of timber construction.

Within the course “Construction of Timber Houses” the educational approach is changed from frontal teaching to individual exercises in detailing. In half-day workshops, the students are required to develop details for specific structural-physical problems in timber houses. The so-called “Condetti” system [1], used for these workshops has found wide acceptance and application in the education of carpenters, civil engineers and architects over the last decade. The details to be developed require the students to bring together their knowledge from the basic courses in “Building Construction” and “Timber Structures”. The realization of plausible solutions for these details from an essential base for the final year design project since a correct detailing constitutes a major part of the final grade.

The “Study Project” aims at enabling the students to individually develop a seminar paper in the field of timber engineering. This project is closely interlinked with the course “Timber Structures - Selected Topics” (see Chapter 3.3), thereby offering the students a wide range of individual topics requiring development and/or problem-solving skills in the area of timber construction, including engineered timber products. Although featuring less width of requirements as the preceding design projects is this course an important preparation towards the final year design project since latter project also requires in-depth elaboration on project-specific problems. This course is also an important component to foster the independent research-based analysis and solution of a problem, including the written elaboration and oral presentation of the results.

5 INTERDISCIPLINARY DESIGN PROJECT

The interdisciplinary design project during the ninth semester is the final and outstanding point of the contribution of the Chair for Timber Structures and Building Construction to the students’ education in Civil Engineering.

After having gone through the process of specialization described above, the students now have to widen their view again. After they had been free to concentrate on one special issue, they now have to learn to integrate their special knowledge into a whole picture.

This project is a co-operation between the Chair for Timber Structures and Building Construction at the Faculty of Civil Engineering and the Chair for Timber Structures of the Faculty of Architecture. Every participating Civil Engineering student has to work together with a student of Architecture who is responsible for the architectural design of the project. The design project is also an integral part of the education of the Architecture students and one of a number of projects these students have to finish for graduation.

The students usually work in a group of three – one Architect and two Civil Engineers – and thereby get close to a real-life planning situation. The building they have to design normally covers requirements from all fields that were dealt with during the preceding

specialization semesters, however focuses can shift, depending on the respective project.

At three stages during the design process, the students have to present their intermediate results in front of the supervisors, the professors and their fellow students. They must demonstrate that their results are coming from an integrated approach to the project and their ideas must reflect the careful process of balancing advantages and disadvantages of different strategies. The project is finalized with a fourth presentation which takes place not only in front of the university lecturers but also in front of an independent jury. This jury is the MAIV, i.e. the Munich Association of Architects and Engineers who assess the different student projects and award monetary prizes to the three best results.

Being aware of the complexity of such a design project, the students are intensely supervised. Meetings are usually held on a weekly basis throughout the whole semester. Again, one Civil Engineer and one Architect make up one supervising team.

At this final stage of their education we want the students to have internalized at least the following abilities:

- to integrate divergent requirements that come from different disciplines into a whole concept and to justify their decisions either quantitatively or qualitatively,
- to follow a process that starts at a conceptual stage, goes on to a reasonable choice of design options which are then accepted or rejected and which finishes at the thorough detailing of the final design,
- to present results precisely, be it by drawings, written reports or oral presentations.

5.1 The design projects of previous years

All design projects of the previous years had a reference to reality, be it (1) a school building, (2) a wine cellar, (3) a motorway restaurant bridging the highway or (4) temporary buildings to host two University chairs on the property of the TU München.



Figure 9: Students presenting their results



Figure 10: Jury discussing the Student Designs



Figure 11: Design Project “Cantina in Piemonte” - Winning Design



Figure 12: Design Project “Restaurant Bridge” - Winning Design



Figure 13: Design Project “Temporary University Facilities” - Winning Design

5.2 DESIGN PROJECT “KINDERGARTEN RAITHBY”/ SOUTH AFRICA

The design project that was carried out with the Civil Engineering students that started in 2004 has been a Kindergarten for eighty children in Raithby, a small settlement near Stellenbosch in South Africa. So far, this has been the highlight of all design projects, simply for the reason, that it has not only been a design, but a design-build project. I.e. a few weeks after completion of the Design Project the majority of the students and the supervising teams went to South Africa to erect the design of the winning team in collaboration with local workers within nine weeks.

Even apart from the fact that the students have built the Kindergarten with their own hands, this building is of a special kind. Much emphasis was laid on creating a building that has the chance to act as a “best practice” building and a prototype for future Kindergarten buildings in the Western Cape region. E.g., the energy content of the construction was minimized by using a combination of timber and unfired adobe bricks for the walls and the roof. Further on, a solar heating system was designed that is able to cover the full heating demand of the playrooms without additional electrical heating. This system is robust, easy to build, cheap and fully available in South Africa and thus can be copied easily. To make this system work, the building envelope is well insulated and even the windows are equipped with low-E glazing instead of the typical single glazing. Apart from a very few exceptions, all materials are South African products; every product however is available in the region. The main objective for the structural design was that the structure and its details could be realized by technically untrained students within the time of nine weeks.

Thus, this project perfectly implements the idea of a holistic and sustainable education that does not stop in the lecture hall but integrates practical aspects.

In detail, this educational approach, as well as the project in South Africa (covered in [2]) will be presented to an expert audience for the first time at WCTE 2010.



Figure 14: Design Project “Kindergarten Raithby” – Side view of Winning Design

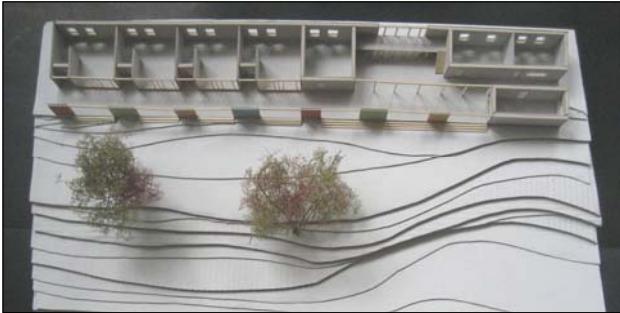


Figure 15: Design Project “Kindergarten Raithby” – Top view on model of Winning Design



Figure 16: Design Project “Kindergarten Raithby” – Student team erecting a timber frame wall



Figure 17: Design Project “Kindergarten Raithby” – Building site in wide angle



Figure 18: Design Project “Kindergarten Raithby” – View from the west side



Figure 19: Design Project “Kindergarten Raithby” – View from the east side

For the future, projects with a similar character, i.e. real projects with a social background and based on student designs, are aimed for. Currently, a number of students are preparing a fact finding mission to Ecuador to research the design conditions for a future pedestrian bridge over a side arm of the Rio Pastaza near Sharamentsa. Additionally, a Master project that will start in April this year, will deal with the development of a renewable energy system for a school building in Matola Rio, near Maputo/Mozambique. In both cases, the projects will not only be planned but finally implemented.



Figure 20: Design Project “Kindergarten Raithby” – one of the playrooms

6 CONCLUSIONS

In this paper the part of the Civil Engineering education at the Faculty of Civil Engineering of the Technische Universität München is explained which the Chair for Timber Structures and Building Construction is responsible for.

On the basis of the path taken by the group of students that started in 2004 the view on an education that links theoretical knowledge, taught in the lecture hall with practical aspects of the future professional life of the students is illustrated. The core of this idea is to place

extensive project work next to classical lectures. The project work the students were required to do has started in the third semester with the design of a simple structure that was nevertheless tested against real world requirements, i.e. weight and failure load. These projects underwent a process of successively increasing complexity, be it regarding the number and/or the depth of the thematic bandwidth, or regarding the number of different students with different views on the project that took part. Obviously, with view on the Kindergarten the students have designed and built finally, this strategy has not been without success.

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