Material Craft: An Approach to Teaching Building Materials in Architectural Education

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Abstract. Knowledge of building materials is critical for architects in order to integrate material selection and related structural thinking within the design process, rather than considering it as an after-thought. It prepares future architects to work in collaborative ways with engineering professionals and equips them to work in a field where sustainability related mandates will require them to make responsible decisions regarding material choices. However, with a packed curriculum, architecture students have limited time to acquire this knowledge and more importantly to sufficiently consider how this knowledge can be applied. Lecture-based theoretical content has limitations in the way this knowledge is transferred to design, thus curtailing innovative ideas from being generated. The paper discusses an approach towards teaching building materials, during the formative years of architectural education and has been developed through experience at teaching a first year Building Technology studio for an architectural program at a University. Details regarding the use of a design-based exercise, involving the creation of physical models, which are guided by the possibilities and limitations of the assigned materials, are presented to highlight the benefits of the approach. The use of physical models, experimentation and structural scaling methods promotes the embedding of materials knowledge in design contexts. Underlying educational value of utilizing this approach is emphasized by discussing the principles on which the exercise was based, the outcomes observed and suggestions for possible improvement. Findings from this paper are expected to be of value to those concerned with architectural education as well as built environment professionals.

1. Introduction

When architecture students develop a deep understanding of building materials, they are better able to choose, shape and scale materials in order to generate forms and to address the design program and site conditions as opposed to thinking of it as an afterthought. As future built-environment professionals, they are better able to collaborate with engineers and work effectively in a multi-disciplinary environment. In the context of sustainability, the knowledge of building materials and their responsible use becomes pertinent.

Historically, building materials and their availability have guided the evolution of the vernacular tradition in architecture. The works of Felix Candela, with his experiments in concrete; Mies van der Rohe, with his use of steel and glass buildings; Louis Baker with his architecture generated from the use
of brick are only a few examples of how a deep knowledge of building materials can guide architectural solutions and lead to a unique and expressive architectural language.

In most architectural programs, building materials feature as a part of the technology stream of courses that support the core of the program – the design studio. It is expected that students demonstrate the application of their knowledge gained from other courses to their studio designs. However, most student design studio projects often show building materials being reduced to appearing as renders in building elevations and indicate limited attention given to the importance of building materials. Less frequently, some studio exercises, demanding long-spans or other structural thinking may offer greater opportunity to develop this knowledge. Even so, various parameters such as site, program and architectural form gain precedence over the building material. While lecture-based theoretical courses are better able to pack more content, they are faced with limitations regarding transfer of knowledge to design situations [1]. Design-build projects hold great potential in requiring students to consider Building Materials while proposing architectural solutions. However, such projects require great resources of time, funding and co-ordination [2]. Hence students of architecture have limited time to develop an understanding of the substance with which they can craft their designs and educators are faced with several challenges in their attempt at preparing architecture professionals. Also pertinent is the importance of cultivating this deeper understanding of building materials during the early years of the architectural program so students are habituated in using this knowledge and are more sensitive towards their role.

In an attempt to embed knowledge of building materials, to develop intuitive understanding and to facilitate its integration in design, this paper discusses the experience of a Building Technology I studio taught at an architecture program at a University. A design-based exercise requiring the production of a model was conducted to help students develop their knowledge of the role of building materials in a design context. The goal of the exercise was to support design which is informed by knowledge of materials. Student designs were required to address the following intents: recognizes the properties of a material, its potential and limitations; explore form-making techniques which manipulate the material to advantage; develop structural solutions which bear in mind limitations and potential of the material and cultivate sensitivity to scale and proportion of the components of the proposed design.

This paper aims to report on the experience of the exercise and its outcomes, discuss the educational value that the approach holds and suggestions on possible improvements to the exercise.

2. Designing the Exercise
The exercise was a part of the Building Technology I course which is offered to second year architecture students and is the foundational course in the technology strand of the 5-year architecture program. It is offered in the same term where students commence their architectural design projects, having completed courses on design foundation and design communication. The Building Technology I course has both lecture and studio components, wherein students meet once a week for a 4-hour long session over a 13-week term. The course has a broad content covering diverse areas such as loads, stresses, structural systems, building components and building materials and the overall grade is split equally between Exams and Assignments.

2.1. Pedagogic Principles
The pedagogy for the exercise was based on constructivist active learning [3] and was guided by the following pedagogic principles [4, 5]:

2.1.1. Intuitive knowledge. Intuitive knowledge of building materials is critical for students to make informed design decisions in the architectural production process [6].
2.1.2. **Concurrency with design.** Learning of material properties, structural behaviour and structural systems should be concurrent with designing [7, 8]. Many studies have been published regarding the design education as a reflective practice [9], and the logic of the architectural design process [10].

2.1.3. **Model-making for visualization.** Experience and visualization of structural behaviour of building materials through appropriate model-making promotes learning [11].

2.1.4. **Experimentation and feedback.** Experimentation and feedback are important predecessors to discussions on formal theory. Design tasks supporting exploration and experimentation facilitate integration of knowledge, even in projects which have short durations.

2.2. **Details of the exercise**

The exercise spanned a duration of 5 weeks during the 13-week term and required students to work collaboratively to facilitate peer to peer learning and discussion and to also share the workload involved in preparing multiple experimental models. The class was divided into groups of 3 – 4 students and each group were assigned a particular material such as barbecue sticks, sugar cubes, toothpicks, fabric, foam cups, paper etc. The materials were such that they were simple, easily available and inexpensive, demonstrated diverse material behaviour and properties and could also serve as analogies for real construction materials in their structural behaviour.

The groups were asked to prepare a model of a pavilion / roof structure / enclosure out of these materials which was expected to span over area of about 30cm x 30 cm. The students were required to ‘build’ with these materials as opposed to preparing models which relied extensively on adhesives or were representational models and not truly structural ones. While the brief was deliberately kept simple so as to encourage free exploration of material possibilities, they were still expected to deal with architectural issues relating to scale, form, spatial quality, light, texture etc. A great emphasis was laid on experimentation as the means to ideate and develop the final model. Students were reminded that discarded models and experiments also played an important role in the final solution.

Students worked over 5 studio sessions during which they were provided with feedback in over-the-table discussions as well as interactive lectures. To guide students and provide scaffolding, the exercise was divided into stages which are summarised in Table 1. Details of the activities conducted during these stages and related theoretical concepts covered have also been included.

Since the assigned material was really the starting point for the project, students investigated the material properties to shortlist possibilities. Theory regarding loads and stresses was introduced through discussion and self-study conducted by students themselves. Next, students explored manipulating the material through form-making techniques. This stage supported creative solutions and allowed architectural vocabulary regarding tectonics to be blended with knowledge of materials. This stage naturally led students to incorporate structural systems and develop more theory on the same. While preparing their final models they had the chance to make deliberate decisions which considered very critical issues of scale and proportion to the model. Finally, students reflected upon and documented their process and the findings from their self-study on building material.

3. **Results and discussions**

At the end of 5 weeks, students shared their final work with the class through a presentation. Students final work which included both the experimental models as well as the Final model. In addition, students prepared posters which documented the process, articulated the relevant theory related to their solution and shared it with other class members. Student submissions included several deliverables which are summarized in Table 2 and illustrated with a sample poster in Fig. 1.
Table 1. Stages of the Exercise.

| Stage | Theoretical concepts covered | Activity                                                                                                                                                                                                 | Session |
|-------|------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------|
| I     | Types of loads, forces, Building components | Students form groups and begin basic studies with the material assigned to their group, investigating the properties of the material, types of forces it could handle, how it failed, what were its limitations due to available physical dimensions etc. Using students’ study models, Instructor introduces concepts of span and bay, types of forces observed (compression, tension, bending, shear, torsion) and types of building components involved (beam, column, girder etc.) | 1       |
| II    | Building Materials and their behaviour | Students explore various techniques to use and manipulate the material – folding, curving, stretching, stiffening, connecting (bundling, trussing, creating panels, creating a membrane / shell surface) etc. Discussions are conducted on how the form-making technique affects the material behaviour and real building materials and their properties are introduced as analogies to the assigned material. | 2, 3    |
| III   | Structural Systems and solutions | Students ideate on possible structural solutions. Instructor uses students’ models to discuss theory related to structural systems and suitability of material for the system. Students also conduct self-study by collecting data on real building materials which could replace the materials of the model in a building scenario. Work on developing the Final Model begins after discussion with instructor. Discussions involve both technical as well as artistic aspects of the proposal. | 3, 4    |
| IV    | Advanced theory / filling gaps in theory. | Students complete final model and prepare posters. Posters required students to document the results of the investigations, evolution of the proposed solution, details of the proposed system and the theory developed by the students which was related to the model. Student groups share findings with the class. | 4, 5    |

The ‘making’ aspects of the exercise and the highly interactive environment of the class were well-received by students and they demonstrated high levels of enthusiasm and motivation in their attempts. A large number of experimental models were presented in addition to the final model. Models were also quite diverse with varying techniques being adopted to manipulate the material while working with its properties (Fig. 2.). Preparing the poster presentations offered students the opportunity to discuss and evaluate new developments, examples of similar systems and also relate the assigned project materials to real building materials.
A pivotal component of the exercise was the use of the physical models as a learning tool. Though computer-based technologies and virtual modelling have several advantages, they do not always adequately substitute for the experience that real physical models can provide for learners, particularly...
those at a foundation level. The physical models help visualize abstract theoretical concepts related to forces and material behaviour and have a great advantage in comparison to written or verbal explanations. When students observe the behaviour of the material components, they also develop their intuitive knowledge of the subject, a critical requirement for comprehensive architectural design. Students demonstrated a sensitivity towards these aspects when scaling the individual components of their model to suit both functional as well as artistic requirements.

By the end of the exercise, students began to use vocabulary related to material properties while explaining their design decisions when they presented their projects. The assignment helped address multiple outcomes and allowed various theoretical concepts covering material properties, structural behaviour, structural systems and building components to be dealt with concurrently. Since different groups had been asked to work on different materials, they concluded with diverse contributions thus allowing the entire class to be informed of a broad theoretical base within a short duration of time.

3.1. Challenges and Obstacles
The challenges dealt with in the exercise are discussed in this section under the following headings along with suggestions to overcome them.

3.1.1. Emphasis on process over product. Once the project was introduced, many students were keen to rush into discussing their ideas for the final model. Very often these ideas were inspired by internet searches of models and buildings on image-sharing websites. Such an approach would have completely bypassed the learning process even though the end result may have been aesthetically pleasing. In order to deal with this tendency and align it properly with the learning intent, it was emphasized that the
project work follow experiments corresponding to the assigned stages. Once students followed these stages, they themselves came up with new solutions which were informed by their experiments as opposed to rigidly adhering to a fixed visual image. Reflecting upon and using the feedback from experiments to inform and guide design decisions is a useful practice for architecture students since it supports the interactive nature of the design process.

3.1.2. Value of technical aspects. At the early stages of developing their models, when students were faced with questions concerning technical aspects, a large majority expressed that these were issues to be resolved by the civil engineer and did not necessarily merit the architect’s attention. There appeared to be an understanding that addressing technical areas is not a part of the architect’s role and could possibly be at counter-purposes to the creative aspects of design. Thus it becomes pertinent to sensitize students to the crucial role that technical knowledge such as that of building materials plays in design, feeding not only the technical aspects but also the aesthetic ones relating to form and spatial quality. Small student-led critiques and case studies looking at examples from history and vernacular architecture, discussing this role, were very beneficial towards this.

3.1.3. ‘Building’ a model. The other challenge related to the idea of a structurally expressive models which needed to be explicitly discussed. Such a model was distinguished from one which is for representational purpose only and does not convey the true role of the material component. Some students tried configurations such as stacking foam cups which were not suitable either as a technique or in terms of scale and needed to be guided towards structural thinking. Also, some solutions depended excessively on adhesive which was also discouraged. A small class activity which explains to students what a true expressive model is, would be helpful in setting clear expectations right at the onset of the project. Such an exercise could also be developed as a collaborative exercise between architects and civil engineers and would help prepare future professionals and could serve as a good foundation for more advanced and empirical methods.

The students were encouraged to explore the evolution of the form (Fig 3) and embrace the open-ended nature of the project rather than work with a preconceived notion. When students felt a material had reached its limit and the overall solution could benefit with the addition of a new material with different properties, they were required to make a case for it and if found convincing, were encouraged to add a different material. This helped students understand how materials would work together thus opening up further creative possibilities. In terms of teaching too, this approach demands the instructor to also be flexible and open-minded and join the students in exploration of structural thinking.

4. Conclusions
Building materials constitute the substance of the craft that architecture students aim to develop an expertise in. Architectural educators are faced with the challenge of adequately preparing future professionals in this area. This paper presented a learning approach to embed knowledge of materials in architectural production. The paper discussed the intent and goals of the project and detailed out the exercise employed to achieve the learning intent. The results of the exercise were discussed along with shared insights on challenges and suggestions for improvements of such an activity in the future. It is hoped that the paper will be a helpful resource to those concerned with architectural education to incorporate material knowledge and structural behaviour within a design context that supports active learning and constructivism. Small exercises can have high impacts and help achieve the learning outcomes effectively without further straining an already crowded curriculum.
Figure 3. Student work showing evolution of the final form

This exercise, despite being relatively small in terms of duration and resources had a high impact on student learning such that it allowed students to explore how building materials and their structural behaviour can be important contributors to the architectural production process and that selecting building materials need not be an afterthought to the process.

Acknowledgments
The author would like to thank the students from the architecture program from the College of Engineering, Abu Dhabi University, Abu Dhabi, for their sincere efforts in participating in this exercise.

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