The Potential of Computer Modeling Software to Support a Consideration of Building Materials in Architectural Design Education

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Most CAAD software in use for architectural education relies heavily on abstract geometry manipulation to create architectural form. Building materials are usually applied as finishing textures to complement the visual effect of the geometry. This paper attempts to investigate the limitations of commonly used CAAD software in terms of encouraging an intuitive thinking about the physical characteristics of building materials in the design studio environment. A case study involving 90 students is presented. The possibility of developing software that uses geometrical abstractions of different materials as the basis for modeling architectural form in the design studio is introduced.

Keywords: *Design, software, materials, education*

Background

Building materials: representational issues

There is an active relationship between concept making and the media of representation. The uncertainty of the design process is a primary reason for the influence of design media on conceptual design decisions (Herbert, 1992). The reflective conversation between designers and their represented materials is a key activity for learning and designing. However, the graphical medium of representation has its limitations. Students learn to "recognize these limitations" and learn to utilize different media to capture different design aspects. (Schon, 1987). Choice of media influence efficient problem solving, a point explored by Scott Johnson. He traced psychological evidence of mental creativity and its relationship with human memory (short and long term and attention). Johnson states:

"The links between representations, thought processes, and behavior are so deep that even eye movements are partly governed by representations. Choice of representations can affect limited cognitive resources like attention and short-term memory by forcing a person to try to utilize poorly organized information or perform translations from one representation to another". (Johnson, 1997)

Johnson maintains that in order to be able to solve complex problems of design, people need to develop libraries of "chunks" and "automat zed processes". These libraries are designers' internal representations and he suggests that poor external representation affect design performance. In his terms, poor external representation is one that does not match the internal representation. Johnson also refers to previous studies in the field that have shown that architects develop "libraries of partial solutions". Those libraries include elements such as "overhead plans, domes, walls, columns, half-inch trim, and so forth" and also categories of "enabling prejudices, heuristic, type, typologies, etc." (Johnson, 1997).

Building materials and CAAD modeling software

CAAD software has simulated various properties of materials through disparate packages that specialize in certain aspects of building materials (structure, thermal, acoustics, light, texture). This is specialized software that tests the performance of building materials in the context of the design. Results of these tests are usually communicated in graphical and / or numerical form. One example is the calculations related to light reflection and diffusion from a surface with defined material. The result is, in most cases, a photo-realistic image of the surface material(s). Other calculations can relate to acoustic, thermal and structural performance of building materials in design and are usually communicated in diagrammatic or numerical forms. Furthermore, there are attempts to simulate chemical or physical visual response of materials (Dorsey, 1999) while there is also some modeling software that attempts to simulate the visual effect of gravity on created bodies of geometry (Kurmann ,1995). Such specialized design support software tends to work best on the detailed design level rather than conceptual one. These are specialist packages that are not usually found in design education or practice where more generalized modeling software are used. Such software is commonly used to represent properties of building materials in two ways -texture maps and what we term a component based approach.

Photo photographic images or texture generation algorithms are included in the 'materials library'. These textures can then be mapped around the surfaces of the computer-generated model. Modeling software often allows the manipulation of brightness, transparency and other parameters of the texture maps. Therefore users could choose one material from the library and express something totally different through manipulating these parameters.

The second is through assemblies of building parts such as walls, windows, floors, etc. We will refer to software, which uses building parts for designing as 'component-based' software. An implicit way of representing building materials is through the geometry of building parts. The geometrical tool of "wall" in ArchiCAD for example, suggests particular structure, scale and material of typical wall materials. Also editing functions like twisting, bending or cutting parts of geometry in software such as 3D Studio Max simulates similar actions that a designer can take for shaping real or model materials.

Using modeling software in studio: a case study.

This case study examines the use that first year design students made of the material representation capacity of two standard CAAD applications (ArchiCAD 5.0 and 3D Studio Max 3.1). Materiality was included as one of a number of design considerations that students were required to include. The use of a first year design class for this study allowed a large sample (90 students) who had yet to settle into habitual working approaches. The class were required to complete a two week computer module as part of a semester design paper. The module required the students design two projects: the first was to design an exhibition space for chairs using ArchiCAD 5.0 and the second was to design a chair using 3D Studio Max 3.1. Most students had no previous experience with modeling software. The first two days of each week were used to give students a working knowledge - instruction was focused only on the modeling tools and interface elements required to complete the design tasks. Material palettes and application methods were emphasized in these workshops.

The Design projects

The first project required students to utilize archiCAD to design an exhibition space for chairs.

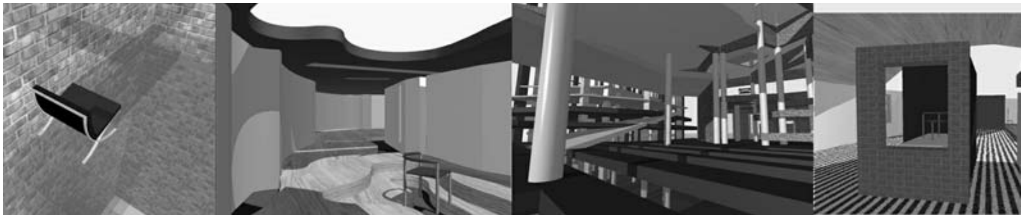

Figure 1. ArchiCAD and the emphasis on mass, transparency and structure

Students were given a file that contained a plinth on which were five 'classic' chair designs. The design focus of this project was to explore and create interior architectural spaces they considered appropriate for each chair exhibit. Typically students did not need to decide on materials early in design because such decisions were contained within the default archiCAD tool settings. Because of this students were involved in different level of decision making about materials. They addressed issues such as the transparency of these elements, visual mass and weight, the flexibility of shapes and also textures and patterns of these elements Figure (1). In the second project, the focus was shifted from the design of space to that of form. Students were asked to design a chair using 3D Studio Max. Students were asked to conceive their designs in terms of a functional and / or symbolic context of their choosing and were required to include material considerations.

Outcomes:

We have identified three groups of students in terms of how they dealt with the representation of building materials in their designs. The first group had clear intentions about what materials they wanted to use for their designs. They tended to model the geometry of the materials. One student who wanted to model a steel pipe used the loft tool to create appropriate geometry and then decided upon the tone of the metal *Figure (2-a).* In another example, a student wanted to model a stone chair. He considered the cutting difficulties of the material and used simple geometry for the purpose *Figure (2-d).* Another student tried to model an elastic rubber material that can take the shape of the body of the person that sits on it *Figure (2-c).* She tried to model a feature of material that goes far beyond geometry or texture and eventually, far beyond what modeling software offered. She struggled trying to imagine the behavior of the modeled material in order to develop her design. She received poor feedback about the rubber elasticity and distortion under body weight. In this case, modeling software limited her conceptual thinking and hindered intuitive development of creative design.

This group tended to do the following:

- Worked with rendered views early in the process.
- The selection of materials from materials library was carefully considered.
- Created geometry relevant to the perceived

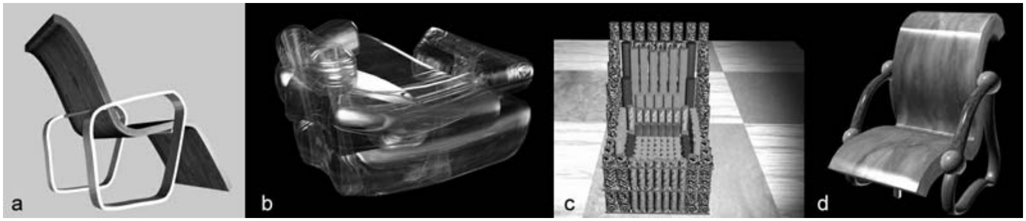

Figure 2. Group1: Decided about materials early in the design process

Figure 3. Group2: considered materials later

geometry of actual materials.

Students in the second group were less concerned about materials. They started with creating the geometry of their chairs and in developing the design, they chose appropriate materials that suited the created geometry Figure (3). This group tended to do the following:

- They tended not to bother about rendering because, for them, it did not serve any particular purpose, especially at early cycles of their design concepts.
- The materialistic ideas they had were vague and subject to change. However, this vague materiality was implicitly included in the created geometry.
- Adding textures was a critical stage. It involved deciding design materials for the created geometry. They tried to link the geometry of a vague materiality with textures of real materials. This stage involved the making of important decisions about materials. Textures provided by the software in the materials library were used as tools for clarifying, crystallizing and maturing students' intentions.

The third group focused on geometry and the visual composition without any consideration of materials especially in the early stages of concept formation *Figure (4).* The materiality of their design was:

- Either decided at the end in a random manner,
- Or was presented in their designs as neutral visual effect in order to not disturb their design focus on geometry.

In all three cases, geometry and texture were strongly associated with one another and to conceptual approaches of students in the three groups. This happened despite the obvious separation between geometry and texture in the software.

Learning difficulties and potentials

This section addresses the perceived difficulties and potentials of the use of the case study software to explore materials. Some comparisons is made with drawing and physical modeling.

Differculty: Forced to Perform Particular Translations

In order to model building materials, the user typically needs to perform translations of internal representations. For example in 3D Studio*,* there is a need to abstract materials into an appropriate geometrical construction first, then find appropri-

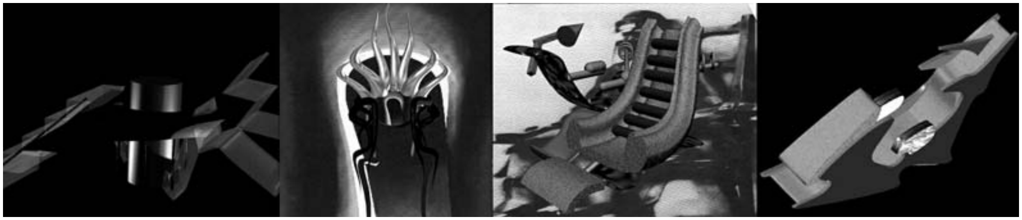

Figure 4. Group3: focused on geometry

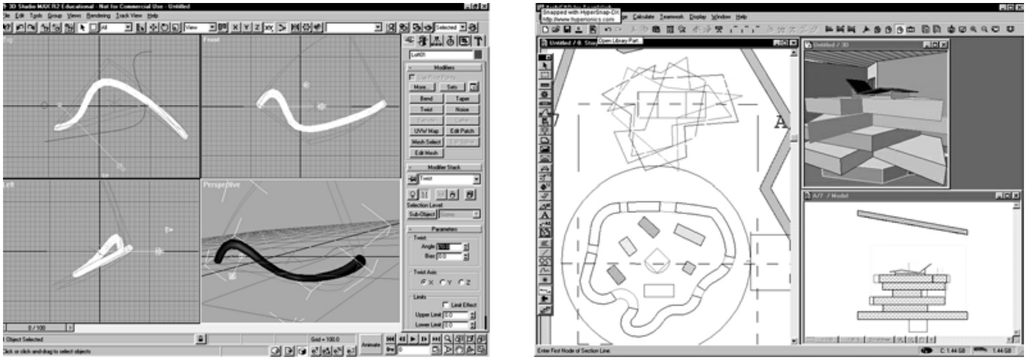

Figure 5. 3D Studio(left): abstract a steel pipe to its geometrical construction. ArchiCAD (right): build forms in 2D screen.

ate colors and maps to represent intended textures. In the case of ArchiCAD, combinations of materials are already combined with the geometry. This can ease the modeling of these particular combinations, but it would require more than one additional translation to model a single material. For example, one student wanted to model a wall of steel grid. He needed first to abstract the window tool to a square of steel bars, he then duplicated and arranged these windows in a way that represented his original intention. Students are also forced to separate the geometry and texture in both cases. As we have seen earlier, Johnson's work suggests that if the external representation medium involves translation of the internal representation, this affects negatively the creativity of the designer. *Figure (5)*.

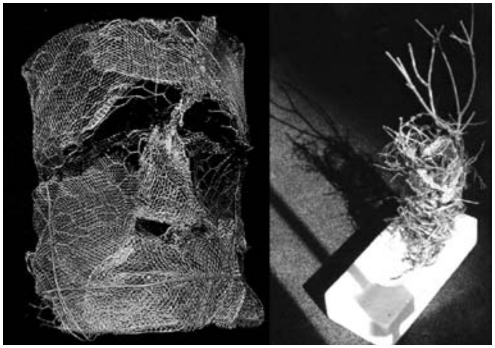

Figure 6. Physical models and the creation of natural forms.

Differculty: Modeling of Natural Forms.

It is interesting to note that materials that are formed using tools or machines are easier to model with computer software than handmade or natural forms. Apart from the technical difficulties, students need to have sufficient experience and sensitivity towards the material or the natural form they are modeling so as to be able to produce convincing models. For these purposes the chosen software is a slow, rigid, time consuming and ineffective medium. Hand drawings, photography and physical models seem to be more effective in alluding to or recording natural forms. *Figure (6)*.

Differculty: Feedback about the Response of Materials to the Physical Forces.

Materials modeled on computer do not respond to forces (internal or external). whereas in physical models, forces like gravity, loads, structure and strength of materials are present intuitively. *Figure (7)*. There is no recognition of these important physical aspects when designing with computer software (Cheng,1995).

Potential: Strong Feedback about Visual Textures of Materials

Effective computer modeling depends heavily on the visual feedback and visual judgment of the designer. Photo-realistic textures of materials are not easily achieved through any other medium

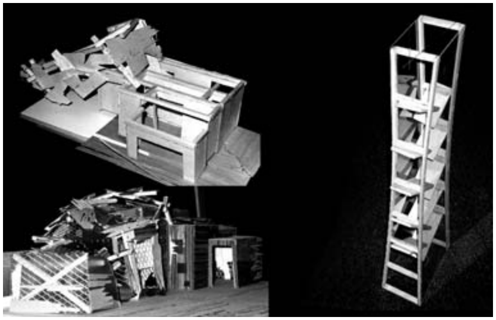

Figure 7. Physical models give intuitive feedback about internal and external physical forces.

especially at first year level. Students were more encouraged to explore the visual properties of materials than other properties when using the modeling software. Although drawing and physical modeling oblige students to develop particular craft skills, the visual feedback is highly personalized. The uniqueness of computers is revealed when attempting to experiment on a range of materials to evaluate the impact of such change on the space and form of design. Students felt that modeling software encouraged them to think about the effect of chosen materials on the designed space and also, to a certain degree, on the form of the design in the case of the chair project.

Potential: Enables Modeling Complicated Geometry and Visual Textures

Students were able to produce complicated geometry and complicated visual textures. We have shown that software such as that used in the case study has emphasis on geometry and visual texture. Therefore these properties of materials tend to be emphasized in computer models produced by students *Figure (8)*.

Potential: Facilitates Good Control in Various Scales

Modeling with computers does not require students to translate their designs in terms of scale. Students have the option to model with full-scale dimensions and zoom in and out to visualize and work on details without having to produce new representations.

The need for a decision about the full-scale dimensions early on can stimulate thinking about full-scale issues. Some students considered the constructional details of their designs despite the short period allowed for the exercise and their inexperience as designers. Textures are automatically adjusted, giving direct feedback on the active scale. One drawback is the distortion in bitmap resolution when taking a close shot of a material textures.

Potential: Exploration of the Time Dimension

Materials in motion are part of the real life experience. Although in the case study little time was allowed for exploring the animation features of the software, the feedback experienced when changing position and viewpoints was addressed by most of students *Figure (9)*.

Summary

The case study has highlighted the general inadequacy of software such as ArchiCAD or 3D Studio Max to consider the geometry and physical characteristics of materials. At the same time,

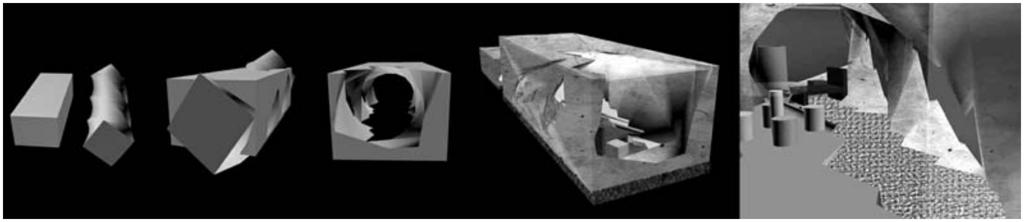

Figure 8. Computer modeling enables creating complex geometry and textures

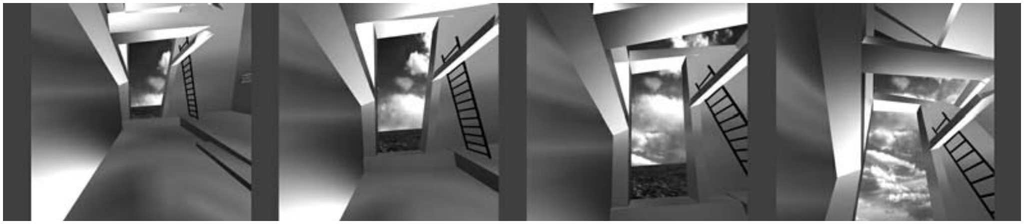

Figure 9. Exploring different view points through animation

compared to drawing or physical models, there are inherent advantages in terms of imaging visually complex materials and dealing with issues such as scale and accurate visual reproduction. There is potential to build on these strengths by considering how physical properties and geometric constraints of different materials can be used as the basis for modeling architectural form in the design studio. The aim would be to attempt to bridge the gap between the physical properties of real world materials and their representation in computer models. Poor design performance as a result of the mismatch between internal and external representations as explored by Johnson (1997) has being evidenced in relation to materials by some examples in this case study. In general students started modeling their designs using primitive or complicated geometry that has no particular consideration of the physical properties or geometry constraints of materials. We propose that students should be able to 'build' their designs with an understanding of the physical properties of materials, recognize typical manufacturing geometry such as extrusion sections, and also intuitively modify form using tools that are specific to the chosen material. The modeling of materials in this manner and its integration with design studio teaching can potentially contribute to a bridging of the gap between the virtual and the real. More research is required to identify ways of incorporating these issues into a software interface. The increasing use of library parts of building components specific to local industry is now becoming widespread. While this brings issues of scale and availability to the fore we would prefer a more abstract approach that deals with the inherent physical qualities of materials. How might we communicate tactile qualities such as surface and mass - can material sound libraries be included for example? Is there possibilities given new advances in 3D generative textures to imbue a sense of 'depth' to the often sterile computer generated surfaces that are output from industry standard software. (Legakis, 2001). However, this paper does not necessarily indicate a return to modernist dogma in terms of appropriate materials. We believe however, some redressing of the dominance of geometry over materials explicit in most software can be achieved, perhaps to the point where Scarpa's definition of architectural space can be explored with digital representation.

"What I want to say is that the sense of space is not communicated by a pictorial order but always by physical phenomena, that is by matter, by the sense of mass, the weight of the wall" (Scarpa, 1964)

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