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Simulation of Building Physics for Beginning Design Students

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ABSTRACT
Concepts such as heat transfer, stack effect, natural ventilation, and other problems related to building physics are taught to beginning design students through architectural examples, deterministic diagrams, and rules of thumb. Unlike the approach to teaching form, which involves exploration and iteration within a studio environment, often suspending disbelief to allow exploration, these exercises see architecture through the lenses of optimization, equilibrium, and objective outcomes. They are taught as steady state concepts. Instead of leaning on teaching techniques derived from an engineering standpoint, often technocratic and deterministic, it would serve beginning design students well to explore these concepts through experimentation and scaled built models that demonstrate the intended atmosphere effect. Can we ask the students to think compositionally about an architectural atmosphere in the way we ask them to think about form, proportion, sequence, and hierarchy? The goal then is to have students learn to think about atmosphere and energy from a design standpoint. As Kiel Moe notes, this point of view comes from an understanding of architecture and energy as one of magnificence and not of management. (Moe, 2017) With the help of students at the University of Wisconsin – Milwaukee, this research looks to explore reciprocal design techniques that allow students to iterate within an open system of their design. This ongoing investigation looks to grow the rigor and accessibility of scaled physical simulation of atmosphere and energy in buildings within a beginning design student studio.

KEYWORDS
Buoyancy Ventilation, Simulation, Physical Models, Early Design Education, Design Process

INTRODUCTION

This research is focused on the physical simulation of building physics. This ongoing research attempts to balance a desire for the visual representation of building physics for use in the architectural design studio with a repeatable and measurable outcome. While the primary purpose of the model is not measurement, the various inputs of heat and matter are scaled appropriately. Using the concept of similitude, this model is scaled to allow for the building of a representational section, which can then be heated to demonstrate the flow of fluid through the section. While focusing primarily on the simulation of buoyancy ventilation in two dimensions, this project develops a working methodology that encourages iteration. Students design parts within Rhino 3D, print them with a 3D printer, test them in the rheoscopic fluid bath, document them with a long exposure camera, evaluate the results and then repeat the process. This work was completed as part of an exhibition and workshop at the University of Wisconsin – Milwaukee.

METHODS

This design exercise asked students to work through a fixed loop. Students design a section within Rhino 3D, print them with a 3D printer, test them in a rheoscopic fluid bath, document them with a long exposure camera, evaluate the results and then repeat the process. The first step is the design of an initial section in Rhino 3D, a NURBS modelling software. Students are asked to produce sectional models in which the wall thickness is fixed at .8mm. While the first section is a guess on the student's part, the next model made will be informed by the process to come. The second step is the printing of the student's design. Students print their sections 6mm thick out of PLA plastic. For the third step students place their prints into a heated bath. The parts are pinched between a piece of glass and the milled aluminium back which heats that fluid. The medium of the bath is a rheoscopic fluid that makes the flow visible. (Figure 3) A heating element is mounted to the back of the aluminium half of the tank. After this, students document the sections with a camera, make changes to their design and repeat the process. The models where scaled using similitude and the Galileo Number. (Etheridge, 2011)

RESULTS

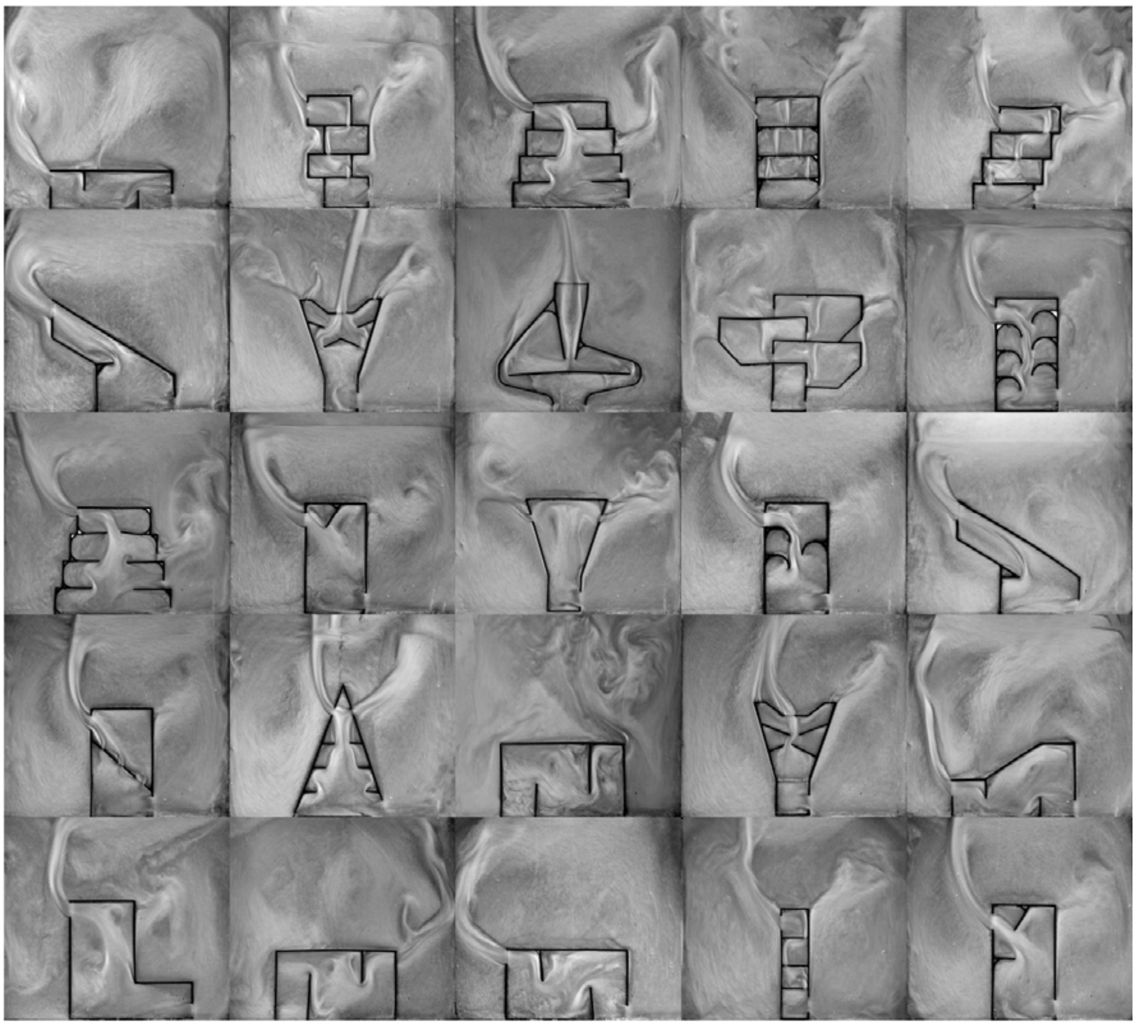

Figure 1. Iterations produced by the students.

The students produced a wide range of examples. (Figure 1,2) The studies often led to a series of variations in which each student explored the role of shape, form, and proportion in the flow of fluid by buoyancy ventilation. The more successful explorations used simple forms to better understand the effects of their design decisions. While the models are essentially two dimensional, they offer a way into the process of natural ventilation from the point of view of a designer. The work was exhibited and functioned as a workshop to introduce the students to the concept of buoyancy ventilation. (Figure 4, 5, 6)

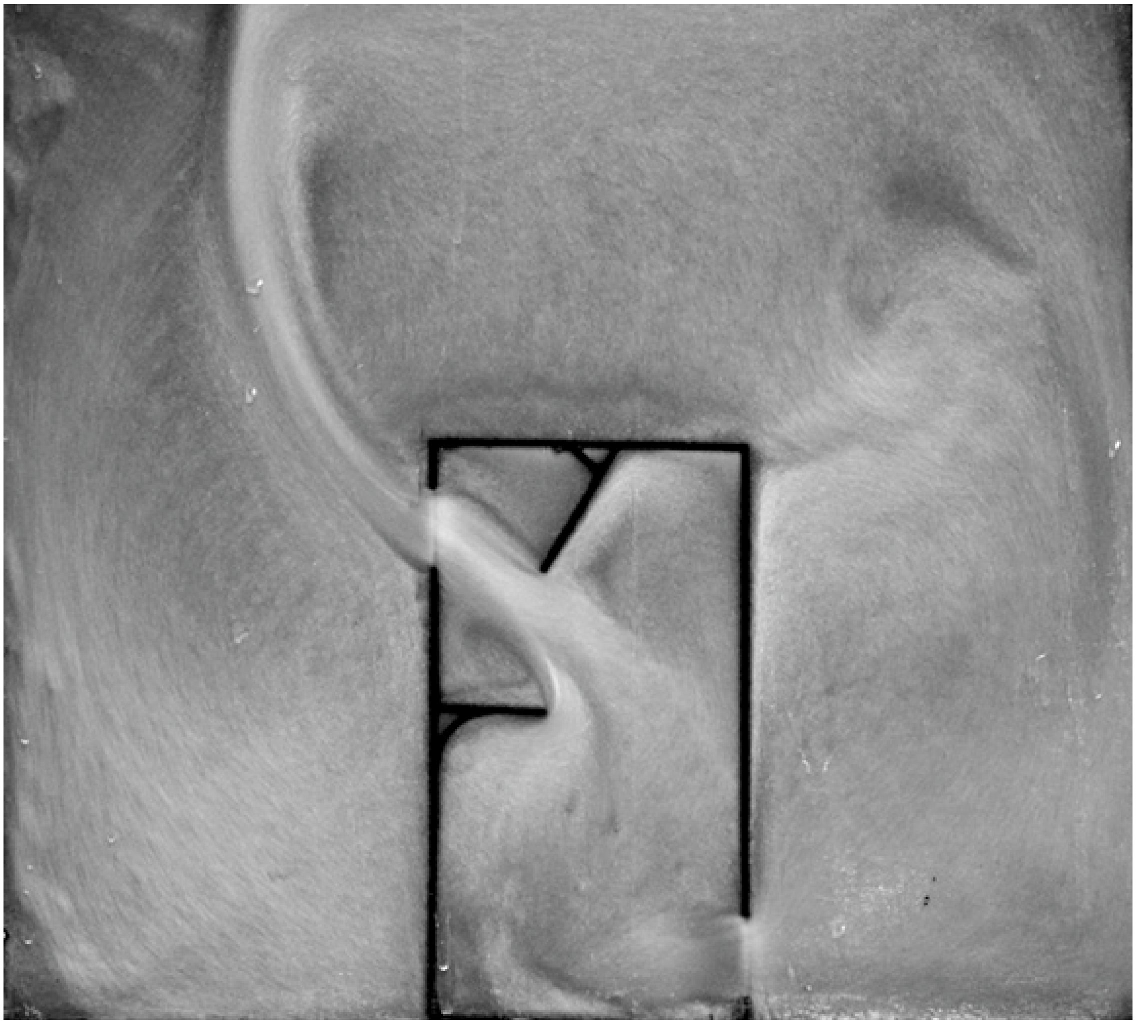

Figure 2. Long exposure documentation of rheoscopic fluid.

Figure 3. Rheoscopic fluid tank with section.

Figure 4. Exhibition and workshop.

Figure 5. Exhibition and workshop.

Equations

$$Ga_M \equiv \left[\frac{\Delta T_0}{T_0}\right]_P \left[\frac{\Delta T_0}{T_0}\right]_M Ga_P \quad (1)$$

Using dimensionless analysis similarity between the model and prototype can be achieved by increasing the ΔT_0 in the model. This equation assumes a simple single cell enclosure in which ventilation is achieved with buoyancy only. (Etheridge, 2011)

Names and units

Ga	Galileo Number
T	Temperature, C^o

DISCUSSIONS

The most problematic aspect of these models is the lack of three dimensionality. While the two-dimensional model allows students to understand some of the basic concepts of buoyancy ventilation, it lacks the complex reality of a three-dimensional model. The appropriate application of this pedagogy to the design of a building, not merely proto architectural objects, requires more research. In general, though the next steps in this research will require a transition to three dimensions. Additionally, while this modeling technique allows for the visual approximation of heat driven flows, it does not at this time allow for the measurement of the rate of flow. Although, the appropriate scaling of the model and its heat input should allow for a measurable rate of flow through the openings by mathematical means. As mentioned before, the intended goal of this exercise is the development of a pedagogy that encourages design students to explore building physics as an opportunity for design and spatial innovation.

CONCLUSIONS

When we think of architectural models, we think of them as objects, representational at best, a stand-in for a larger construct. While this has not always been the case historically, new digital measures seek to reduce the physical model further to merely the output of a printer: a stereotomic afterthought. Renaissance model makers, for example, used the model as a stand-in for construction documents that were intended to assist the builders with complex geometry, calculating structural loads, and testing the quality of light. These models participated in the construction of buildings. At the Bauhaus, making was integral to the introductory design exercises, asking students to fold the paper and imagine the spatial and sculptural qualities. The paper though was not a stand-in for another material but the material of study itself. With the advent of the digital model, and more recently the BIM model, the physical artifact has been pushed out. In its transformation, it has lost its material intelligence and its active role in the design process. It has been reduced to a representational artifact and an imperfect imitation of its digital doppelganger. What then is the role of the contemporary physical model, what could its role be in contemporary design practice?

These new operative artifacts find themselves between a study model and a finished representational model. They hang ambiguously between these two states. They are far from pristine, but they are highly rigorous and intensely participatory. They are objects that both represent a complete thought and speak to a possible future. These objects develop out of an understanding of design as an open system, a series of inputs and outputs, in which the model is understood as an active participant in the design process rather than passive byproduct.

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REFERENCES

Etheridge, D. (2011). Natural ventilation of buildings: theory, measurement and design. Retrieved from https://ebookcentral.proquest.com

Moe, K. (2017). Magnificence: On the Appearance of the Baths of Caracalla, Journal of Architectural Education, 71:2, 241-246