

Material Skunkworks: Building Technology for Future Architects

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ABSTRACT: Traditionally seminar teaching of construction systems utilizes several methods to convey information: readings from established texts, topical lectures, and iconic case studies, all sequenced and formatted to follow the Construction Specification Institute's (CSI) organization of topics. While these techniques have their value, this overall method tends to arrange and prioritize information into a series of material silos; (wood, masonry, steel, etc.). This often results in an isolated, desk bound learning experience that fosters passive engagement by the student. It tends to meet NAAB's first goal of understanding a topic, but falls short of conveying an ability to apply the new ideas encountered in building technology classes. This paper outlines an adjusted approach where information is organized and taught to expose translational learning opportunities through an applied knowledge of construction materials and methods.

KEYWORDS: Architecture, Pedagogy, Materials, Construction

INTRODUCTION

The development of construction materials since the industrial revolution has exponentially expanded the palette of the architect. Today's 'material-copia' provides a broader opportunity for architectural possibility while simultaneously increasing the chances for its misappropriation. Teaching students how to take advantage of this expansion, while understanding their complex assemblage, is essential to their development as future architects. Interested organizations such as NAAB, NCARB and the AIA have differing requirements for developing architects with knowledge of building technologies and the ability to apply associated concepts. Each of these organizations establish different baselines for meeting practical objectives during one's education, internship and throughout their career, but the responsibility of establishing the foundation of this education falls on the shoulders of building technology educators in architecture programs.



Figure 1: New material catalogs compiled by architect Blaine Brownell. Source: (<http://transmaterial.net/>)

Materials and Methods of construction knowledge standards are policed through the National Architectural Accrediting Board, (NAAB), who set guidelines for all topics that lead to an accredited degree of architecture. NAAB categorizes the knowledge to be conveyed into different realms and setting student performance criteria (SPC's) for each topic within them. Schools must prove that they meet these conditions through the recurring process of accreditation. NAAB does this to ensure the public and potential students that an architecture program meets a *minimum* level of quality. There are three specific SPC's that relate directly to building technology materials in NAAB's accreditation guidelines. The first covers building envelope systems and requires that students understand their basic principles, appropriate application, and expected interior environmental performance. The second SPC, building service systems, requires students understand the basic principles related to mechanical, electrical, plumbing, fire protection, and vertical circulation systems. The last SPC, building materials and assemblies, essentially requires students to understand materials' inherent properties and their assembly.

Post-graduation the National Council of Architectural Registration Board's, (NCARB), as well as state licensure boards establish knowledge standards through the requirements needed to pass the Architectural Registration Exam (ARE). In its study guide for the exam, NCARB indicates five specific content areas related to materials and methods of construction; principles, environmental issues, codes and regulations, materials and technology, and project and practice management. The categories correspond directly to broad topics rather than specific classes taught in architecture programs, and there are overlaps across course syllabi in materials and methods, environmental controls, and professional practice. Under material properties the study guide organizes the materials and technology section in a similar way to many materials and methods classes. It distinguishes the topics similarly to their CSI classification; Masonry, Metals, Wood, concrete, other and specialties. Historically this has proven to be appropriate, as the topics are heavy on traditional materials; however as a requirement for passing the exam it tends to deemphasize innovative explorations by grouping all the remaining topics into the 'other' category.

Once interns have obtained their registration, the American Institute of Architects (AIA), establishes basic knowledge standards through continuing education guidelines in health, safety, and welfare topics (HSW). These are defined on the AIA website as 'Technical and professional subjects, that the NCARB Board deems appropriate to safeguard the public and that are within the following enumerated areas necessary for the proper evaluation, design, construction, and utilization of buildings and the built environment.' These are categorized into several sub-topics. Those that relate to building technologies are building systems, design, environmental topics, and materials and methods.

All of these organizations set their own baseline for the appropriate make-up and amount of knowledge required of architects as it relates to practice. For schools, these standards help to establish the direction and goals of their materials and methods of construction sequences. However requiring students to take courses on these topics does not necessarily guarantee an understanding of the basic knowledge required by these organizations. In the face of an ever evolving palette of available materials schools must constantly ask themselves how to develop graduates that can and adjust their courses accordingly.

1.0 MODES OF TEACHING MATERIALS AND METHODS

1.1. The Traditional MasterFormat™ Model

Most of the current popular texts adopted by instructors for Materials and Methods of Construction classes organize material in a manner that roughly follows the logic set forth by the Construction Specifications Institute (CSI) in their MasterFormat system. It establishes a standardized numbering system for the organization of all specifications required to construct a project. Traditional these have numbered 16 total divisions, but they have grown recently to 50 in 2004. Many of the new divisions are left unused for future expansion of the system, as CSI also understands that the material palette is growing.

In materials and methods texts this organization has naturally and frequently followed the earlier 16 division CSI layout. For example, MasterFormat Division 2-Site Construction would correspond closely with a chapter on foundations, while broader topics like Division 06-Wood and Plastics would encompass several chapters in a text book. Instructors who closely follow these texts find themselves discussing entire topics at one time. The subject of wood is presented from its harvest, through its manipulation into a building material, and finally into its use in assemblies.

As a method of systematizing the information this is versatile yet specific, and it works for an industry that that must manage the use of virtually any material the architect may introduce to a project. However, it tends to utilize an organization of knowledge that is required in practice, rather than one which accounts for the layperson level of understanding possessed by most beginning design students unexposed to the

industry and its standards. It is possible that there is a more efficient method for teaching students, specifically those focused on Architecture.

1.2. A New Material/Assembly Model

In an attempt to streamline the teaching of materials and methods of construction, the faculty at Auburn University's School of Architecture, Planning and Landscape Architecture, (SoAPLA), has been developing an alternative method for course delivery in this sequence of class topics. Traditionally these courses followed a survey of information set forth in well-established texts that utilized several methods to convey information; readings, topical lectures, and iconic case studies that might culminate in a large scale drawing project or detailed model. The faculty recently questioned whether this model best fit the NAAB requirements for an 'understanding of' or an 'ability to apply' knowledge gained in the class, and set out to design a syllabus that ensured it.

The first major shift that occurred was at the level of the curriculum. The materials and methods topics at Auburn are taught in a pair of three hour courses. Previously, the first occurred at the beginning of second year, and it typically covered all topics on foundations, wood, and masonry. The second came later in the curriculum. Materials and Methods II was typically taken at the end of third year and covered all topics on concrete, steel, roofing, glazing and interior finishes. The faculty shifted the second class to immediately follow the first. They are now taught in consecutive semester during second year.

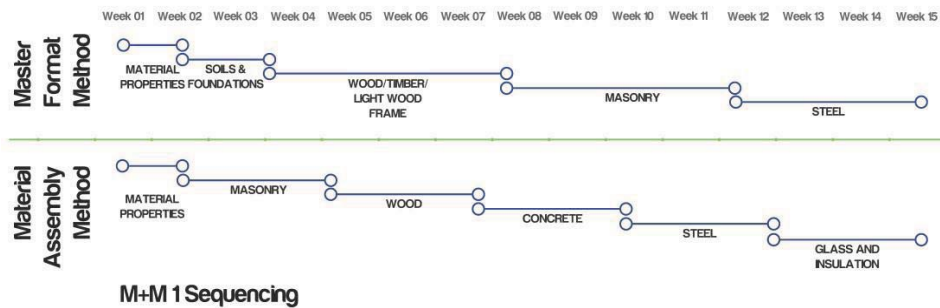


Figure 2: Comparative diagram showing two models for Materials & Methods 1. Source: (Sproull 2013)

The subsequent and more complicated shift occurred within the courses themselves. The instructors abandoned the CSI MasterFormat organizational system, instead categorizing the information into two broad topics taught in separate classes. The first course now focuses on materials while the second centers on assemblies. This configuration of information benefitted the students in two ways. First it divided the topics into processes that happen to materials before arriving on-site in M&M1 or after in M&M2. The first course now covers any transformations related to processing from raw materials to building materials including pre-fabrication of typical construction elements like trusses or open web steel joists. The second class focuses on material arrangement and connection. These differences in course foci are evident in the learning outcome strategies found in the assigned readings, course lectures, and most acutely in class projects. The new structure provides a clean divide between *learning through making* in M&M1 and *learning through drawing* in M&M2. Projects follow these methodologies on an ever increasing procession of complexity throughout the entire calendar year.

The second advantage of the new information configuration was its ability to emphasize the hybridity of actual construction processes, techniques, and assemblies that exist in practice. Today's assemblies typically require an understanding of many different types of materials. In this respect, covering standalone materials from beginning to end in M&M classes isolates their particular properties from all others. An example of this would be the typical residential brick wall; historically consisting of solid stacked masonry but now replaced with veneer. Where understanding masonry was previously enough to understand the assembly, one now must understand wood framing, fasteners, insulation, and thermal and vapor barriers. It has become a collection of materials, and this requires a different organization of the course information.

The rapid expansion of the architect's palette makes educating future architects a challenge. The end goal is a constantly moving target, and the body of knowledge is continuously increasing. This expansion often means architects are far less informed about what they are specifying. By focusing on materials and their properties in the first class, it sets up a methodical framework by which future architects can educate themselves about the materials they employ. They are essentially being taught how to learn. This method of

organization still meets all of the requirements set forth by NAAB, and provides knowledge required for the ARE. However, it does so by removing the silos where these topics have traditionally existed allowing an emphasis on hybridity found in typical design and construction today.

The strength of the material/assembly model is the concentrated redundancy of themes that occurs through this method. The first class covers materials, and seems to present this set of topics as isolated from assemblies with redundancy occurring in the persistent discussion of material properties found in the covered subjects. However this is actually the result of a 'planned deception'. In reality, while all the projects covered in the course focus noticeably on the materials themselves, they are carefully crafted to convey an underlying lesson regarding assemblies in the given medium.

2.0 MATERIAL SKUNKWORKS

2.1. Skunkworks in the Classroom

The Skunkworks Division of the US based Lockheed Aircraft Corporation was formed in 1943 by Kelly Johnson to directly respond to threats of a new class of German jet fighter. Johnson and his team designed and built the XP-80 in only 143 days, seven less than was required. What allowed Kelly to operate the Skunk Works so effectively and efficiently was his unconventional organizational approach. He broke the rules, challenging the current bureaucratic system that stifled innovation and hindered progress. His philosophy is spelled out in his "14 rules and practices."



Figure 3: Skunkworks team discusses XP-80. Source: (<http://www.lockheedmartin.com/us/aeronautics/skunkworks.html>)

The Material and Methods sequence at Auburn loosely employs these rules, specifically Johnson's rule #2, 4, 9, and 14. These rules and a brief explanation of their applicability to the Materials and Methods curriculum are outlined below:

2. Strong but small project offices must be provided both by the military and industry.

To this rule, the Materials and Method curriculum employs projects and assignments merging small, familiar student teams with a single invested industry partner.

4. A very simple drawing and drawing release system with great flexibility for making changes must be provided.

The Materials and Methods sequence places a heightened emphasis on planning, but not necessarily comprehensive planning, which can stifle experimentation. Lectures, case studies and students assignments all reflect the importance of iterative learning through constant drawing, making, and testing. The curriculum teaches students that making is as much working with timelines and schedules as it is working with tools.

9. The contractor must be delegated the authority to test his final product in flight. He can and must test it in the initial stages. If he doesn't, he rapidly loses his competency to design other vehicles.

Even though students are working in teams on projects, each team member is solely responsible for the work they produce, and are graded accordingly. Therefore active engagement at all levels of the curriculum is expected. Because the Materials and Methods is designed as a network of lectures, case studies, site visits, and projects, student engagement at all levels and facets is critical to student success.

14. Because only a few people will be used in engineering and most other areas, ways must be provided to promote good performance not based on the number of personnel supervised.

This final rule is arguably the most integral to the Materials and Methods curriculum. Many of the projects delivered in Materials and Methods I require an applied understanding of both materials and assemblies. However, given the limited structure of the class, the lectures can only feasibly elaborate on the topic of material properties and not material assemblies. The second class in the series, Materials and Methods II covers assemblies more thoroughly in lectures. However, one cannot logically separate materials from assembly and vice versa in reality. For that reason, although material properties is foregrounded in the first class, a discussion of material assemblies is actively backgrounded in all aspects of the course, most notably through the projects and workshops. The following outlines the project sequence for Materials and Methods I, and in particular how a Skunkwork method of operation functionally translates to students in the course.

2.2. The Three Little Pigs

Materials and Methods I focuses on the basic materials that architects specify and build with today and have used throughout history. While lectures and readings play a significant role in student understanding, hands-on exercises make up an important part as well. As a requirement for student's final grade, students are asked to complete a series of projects centered on the production of materials, namely masonry, wood, and concrete, or affectionately dubbed "The Three Little Pigs". The investigations take the form of a uniform 5" cube, and specific requirements vary by the material being used.

Craftsmanship of the final product is of utmost importance; as is an understanding of the process the students utilize to produce the objects. In this regard, for all of the investigations, the students are required to document all of their work. This includes not only study models and prototypes, but also photographs, videos, sketches, calculations, tools, formwork, etc. Each material study culminates in student presentations made to the class and critics, and the documentation serves to support the student work.

The three focus areas (masonry, wood, concrete) correlating to a specific cube project are sequenced such that they contain approximately 3-4 lecture classes, 2 workshops, and one site visit per material topic. The order of the lectures, site visits, and workshops are sequenced such that they are ultimately in support of the assigned material project which directly relates to the material topic.

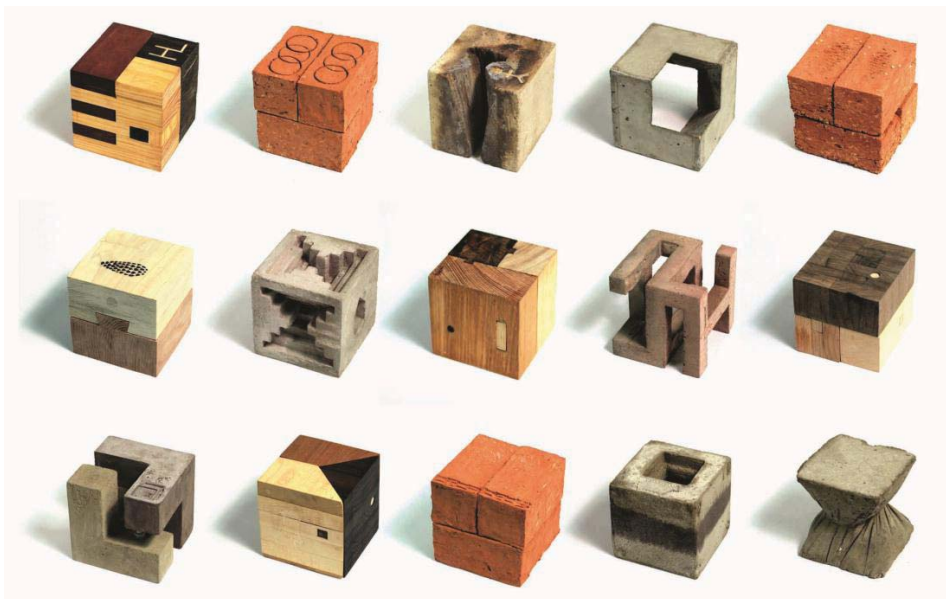


Figure 4: Examples of student work from *Three Little Pigs*. These projects teach an understanding of assemblies through a directed study of specific materials. Source: (Sproull/Salvas 2012)

2.3 The Masonry Cube

The first material cube in the series is masonry - specifically the brick. Each student group is asked to produce four stackable clay masonry units precisely measuring 5" long x 2 1/2" wide x 2 1/2" tall, when stacked

produce a cube that is a uniform 5". The student bricks must be well crafted objects, and must possess an identifiable pressed mark that is unique to the group.

This project benefits from collaboration with the Department of 3D Arts at Auburn University who provides the students with an introductory workshop on clay forming and rules of thumb, and at the end of the four week project timeline fires all of the student bricks in their kiln. The project also benefits from a relationship with Jenkins Brick in Montgomery, Alabama, which operates as a brick manufacturing plant. After the students are given the assignment, and have enough time to contemplate all of the issues and opportunity the project provides them, they are asked to formulate all of their questions and direct them toward the professionals at Jenkins Brick.

While at Jenkins Brick students are exposed to the full process of brick making, from clay extraction, material mixing, forming, pressing, drying, firing, all the way to project management and design. The students are witnessing a production scale version of the process they are currently being asked to enter. The students understand the many benefits of the experience and are eager to ask questions, both broad and pointed relative to their brick assignment and the role of materials in design and architecture. The site visit ends with Jenkins Brick donating a 5 gallon bucket of raw material to each student team for use in their brick project.

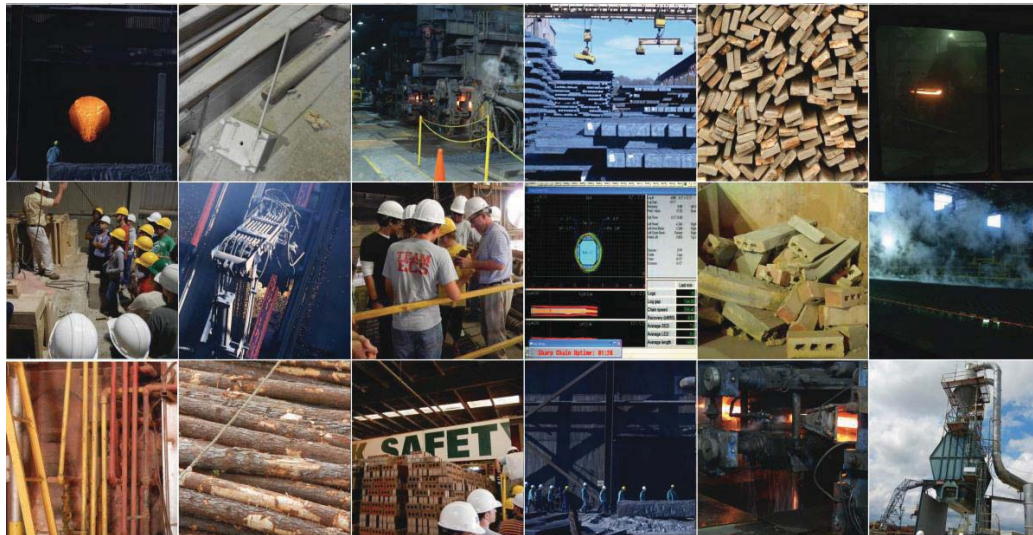


Figure 5: Montage of images from student field trips to industry collaborators. These provide a industrial scale comparison to the small hand-crafted blocks produced by students. Source: (Sproull/Salvas 2012)

2.4 The Wood Cube

The next installment in the investigation of materials deals with wood. In this study each student team is asked to design and precisely make a solid 5" cube. Each cube must be made up of three separate major pieces of wood connected with friction joints. The students are not allowed the use of any type of mechanical fasteners or glue in their production of these joints (glues are only permitted in the lamination of wood). The joints must be designed such that the constituent pieces remain together no matter how one holds the cube. On any given project no joint type may duplicate another. Each block must possess the same identifying mark that was used on the bricks.

This project benefits from a heavy dependence on SoAPLA's Wood Shop, and in particular its custodian Steve Protzman. Students are required to pass a series of design sign-offs before they are allowed to begin wood working. They must first obtain approval of their design from the Materials and Methods instructors, at which time they can then approach Steve Protzman for design sign-off. Only after both endorsements may that student manipulate the raw materials. In addition, the woodshop requires careful coordination and no more than two student groups are allowed to work in the woodshop at any one time. This ensures the appropriate amount of instructor to student attention and that all safety measures are followed.

The wood cube assignment also greatly benefits from a collaboration with Frasier Lumber and Van Nostrand

Custom Cabinets, both located in Opelika, Alabama 15 minutes east of Auburn University. The first year of the material cube assignments, faculty and students visited Frasier Lumber at the onset of the wood cube assignment. Although it was incredibly informative and insightful, their focus in the wood industry was more removed from the student assignments and it was more difficult for the students to engage. Therefore the year after the faculty decided to partner instead with Van Nostrand Cabinets. Their focus was more on material connections and less on material processing. The students were able to see first-hand the process of taking raw materials and transforming them into a finished product through the utilization of both digital and manual processes. Like Jenkins Brick, Van Nostrand Cabinets donated off-cut hardwoods to the students for free, eliminating or greatly reducing the cost that the students had to pay out of pocket for the assignment.



Figure 6: Example of documentation by students working on a concrete cube project. To complete this project it essential for the students to understand how to assemble the elements of their design. Source: (Sproull/Salvas 2012)

2.5 The Concrete Cube

The final installment of the material cubes deals with concrete’s versatility relative to form making. It may be used to create both straight edges and organic curves. Using this as provocation student teams are asked to create a single monolithic 5” cube with a visible void or multiple voids within it. Students are allowed to remove up to two corners from the cube however they may not be adjacent to each other.

Primarily, the cube must demonstrate the plastic nature of concrete. Although the final cube foregrounds the use and mastery of concrete, equally integral to the success of the project is the craft and precision used in the formwork, which is primarily made of wood. The final project is the synthesis of the two previous cube assignments, merging the careful understanding of the manipulation of a plastic building material, as in the brick cube, paired with the precision and craft learned in the wood cube. This final cube is a complex assembly, deconstructed to leave only the concrete artifact. Due to the complexity of the assignment, and the emphasis on innovation, experimentation is expected and accounted for in the duration of the project. The students are given approximately 8 weeks to complete the concrete cube assignment, twice as long as either the brick or the wood block assignments.

The concrete cube project again benefits from an orchestrated collaboration with SoAPLA’s Architecture Wood Shop and Steve Protzman. At this point in the semester, the students have had sufficient exposure to the woodshop, and the students are able to work more freely without as much instructor supervision. Their concrete formwork reflects their experiences in the last two material cube projects, and is better for it. Industry collaboration on this cube comes from Castone Corporation, a precast concrete fabricator in Opelika, Alabama. Similar to the past collaborations with industrial partners, Castone allowed faculty and students to take a tour of their facility as well as ask questions. They also provided the students with a variety of aggregate sizes and concrete dyes to use should they desire to. In more complex designs Castone worked side by side with the students to with specialized concrete mixtures.

CONCLUSION

In schools nationwide, there are many new building technologies education models being explored – especially as they relate to materials and methods. The premise for the variation on the traditional version presented here stems from the idea that a better understanding of course material is a result of applied and

theoretical student work. For materials and methods this involves both hands-on and paper assignments that balance between the big ideas and smallest particulars of any given project. Auburn's modification to its more traditional model is unique in that while it re-organizes the course material completely it simultaneously manages to emphasize all the same topics as well. By focusing the first class on the materials, it allows the faculty to covertly teach lessons about assembly; a topic that is hierarchically more complex than the topic directly foregrounded in the investigation.

Materials and Methods 2, while not covered in this paper, will continue this trajectory. It too clandestinely conveys idea about more complex subjects while focusing on a seemingly obvious topic. While folding in discussions regarding materials, the second course, again through carefully crafted projects, uses assemblies to covertly teach spatial and formal relationships as they relate to material properties. This is done with the intent of seeing that the principles covered in class are understood as well as applied in other studio based classes.