Building on Material: Towards Circular Construction in the First Year Design Studio

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The construction industry requires a complete paradigm shift in the way we design, build, and manage our built environment: a shift from linear resource consumption to circular material usage. This paper describes the integration of the theory of circular construction into the curriculum of a first-year Bachelor of Architecture design studio at the Department of Architecture of Cornell University, as well as the teaching methodology developed to facilitate this paradigm shift. At the heart of the development of the syllabus is our conviction that circular design and construction requires detailed material knowledge at the earliest stage of the educational process, so that it can become an almost instinctive aspect of design consideration throughout the students' education, and one that might be further developed through electives and more advanced studios. Consequently, over the course of the semester, each student was assigned two design parameters involving (1) a raw material and (2) a reversible joint typology. The significant steps of the process are illustrated through examples of student work from the Spring 2020 design studio.

INTRODUCTION

Human influence on the socio-economic and ecologic systems of planet Earth has become so dominant that, in May 2019, the International Commission on Stratigraphy officially voted for the introduction of a new unit on the Geological Time Scale—the epoch of humans, or the Anthropocene [1]. This development is especially relevant to architects and engineers, since buildings account for more than 50% of the consumption of global finite resources, at least 39% of global carbon dioxide emissions, as well as 50% of global solid waste production, over their full life-cycles [2, 3]. All of these factors are dominant causes of climate change. We believe that the construction industry requires a complete paradigm shift in the way we design, build, and manage our built environment: a shift from linear resource consumption to circular material usage. And as architects, we must become a larger part of the solution by being more cognizant of the value chains of buildings.

"Circular construction" [4, 5] addresses both the re-activation of anthropogenic material stocks in today's already built environment as well as the design of buildings as material depots for future construction. Precise, detailed material information combined with strategies for designing for adaptability and/ or disassembly are all prerequisites for both of these aspects. At the heart of the development of this semester's syllabus is our conviction that circular design and construction require detailed material knowledge at the earliest stage of the educational process.

The overall theme of the semester as we developed it is *Material+* [6], so over the course of the semester, each of the sixty students enrolled in the first year studio was assigned two design parameters, presented in the form of two randomly-selected postcards, depicting (1) a raw material and (2) a reversible joint typology. In combination with a third postcard—the site—this technique generated sixty unique results from the same design brief: a small workshop for a craftsperson

MATERIAL RESEARCH

The first postcard began an analysis of some of the materials we work with every day in our profession: aluminium, clay, concrete, copper, iron/steel, glass, grass, loam, metamorphic rock, plastics, sedimentary rock, and timber. The goal was multifaceted, as it aimed to supply the students with all of the necessary background information to enable them to make informed decisions, but it also aimed to stimulate their creative process through the discussion and understanding of material properties, the use of materials in precedents, the discovery of the problems, limits, and barriers associated with the chosen material and—equally important—to bring forward an awareness of the visual and tactile properties that can be associated with the various materials (see *Figures 1 and 2*).

There are some general requirements we believe to be necessary in any thorough material research. The most basic and important is a physical sample of the material, as sensory research for architects is often equally important to all the other tools we have available [7]. The second element is a list of specifications such as density, fire rating, or other building-related information that may be needed in the design process or for building permit regulations. Then there are aesthetic and subjective criteria associated with the students' personal rapports to the material, as well as an analysis of how others

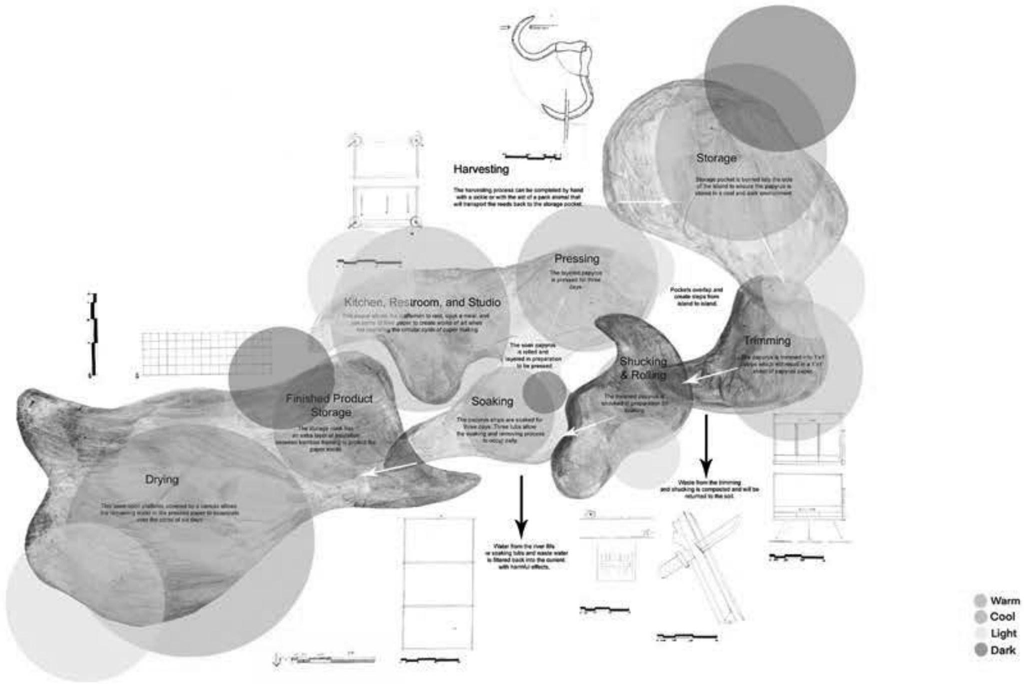

Figure 1. Life cycle drawing of the material reed, and corresponding spatial analyses of craftsperson's workshop. Image Credit: Rainey Oldfield.

have utilized the material, including historic precedents and references to contemporary buildings. These can be on very different scales, ranging from a specific detail to a building or urban design. Last but not least, this assignment also required the development of a life cycle drawing of the material and an answer to the question regarding whether and to what extent the cycle is actually closed. This research step required an investigation into how the material is made, where the resources come from, how it is used in the current building industry and what happens at the end of a building's use time. Can the material be reused or recycled, and if not—why? Researched in small groups and later presented to the entire class, these data points created the knowledge base for the semester ahead.

The second postcard initiated the next phase of material inquiries, in which the students were asked to develop – through translation and transformation—a "joint": a point of contact or connection between two or more components. If the first postcard-phase involved the investigation of a material as a class of thing (a noun; a genus); this second postcard-phase investigates the assembly of discrete components of that material as an action (a verb or present participle) dynamically capable of flexibility, variability, and multivalency: interlocking, piling, pressing, pulling, slotting, and weaving.

Figure 2. Material research on glass. Image Credit: Thena La.

One might say that conceptions of jointure are fundamental to most stages of architectural development. Through repetition and at a variety of scales, the joint can establish bounds of inside/ outside, spatial definition, functional zones, massiveness/ lightness, potential span, motion, expansion/ contraction, and so on. In this exercise, students continued their experimentation in material responsibility, while developing advanced notions of architectural space and accommodation.

It is important to note that, in terms of the studio's material theme, the second postcard described not only a concept or method of assembly, but also suggests a reciprocal process of disassembly. These cards purposefully did not define a specific technique or status quo construction detail. The reasoning behind this decision was to allow the students to develop a personal version and interpretation of the given term that could be adapted to a subjective material understanding and to the specifics discovered in the previous week.

CUBIC CONSTRUCTIONS

After this initial material research, where students aimed to understand the chemical and physical specifications of the 'chosen' material throughout several use cycles, as well as to develop a strategy for aggregation, everyone then produced a construction—a small cube, described as 'a construction-object-artifact'—using their actual materials and joint typology from the previous exercises (see *Figure 3*). This construction was required to form a 6" x 6" x 6" cube when assembled, although its disassembled dimensions could vary significantly. The cube had to be composed of at least two components with a minimum of one joint, and it had to be able to be disassembled and reassembled. Secondary materials were permitted, insofar as they were compatible with or derivative of the primary material.

MATERIAL SYSTEMS

This phase concluded the interpretive sequences of the project in relation to the material and its various precedents and extensions. The goal here was to produce instrumental models and drawings of their material systems—that is, representations that will themselves be capable of operating as vehicles of discovery throughout the design process—and that can transform in numerous, possibly unpredictable ways while constructing correlations between an origin and its derivatives, both actual and imaginable.

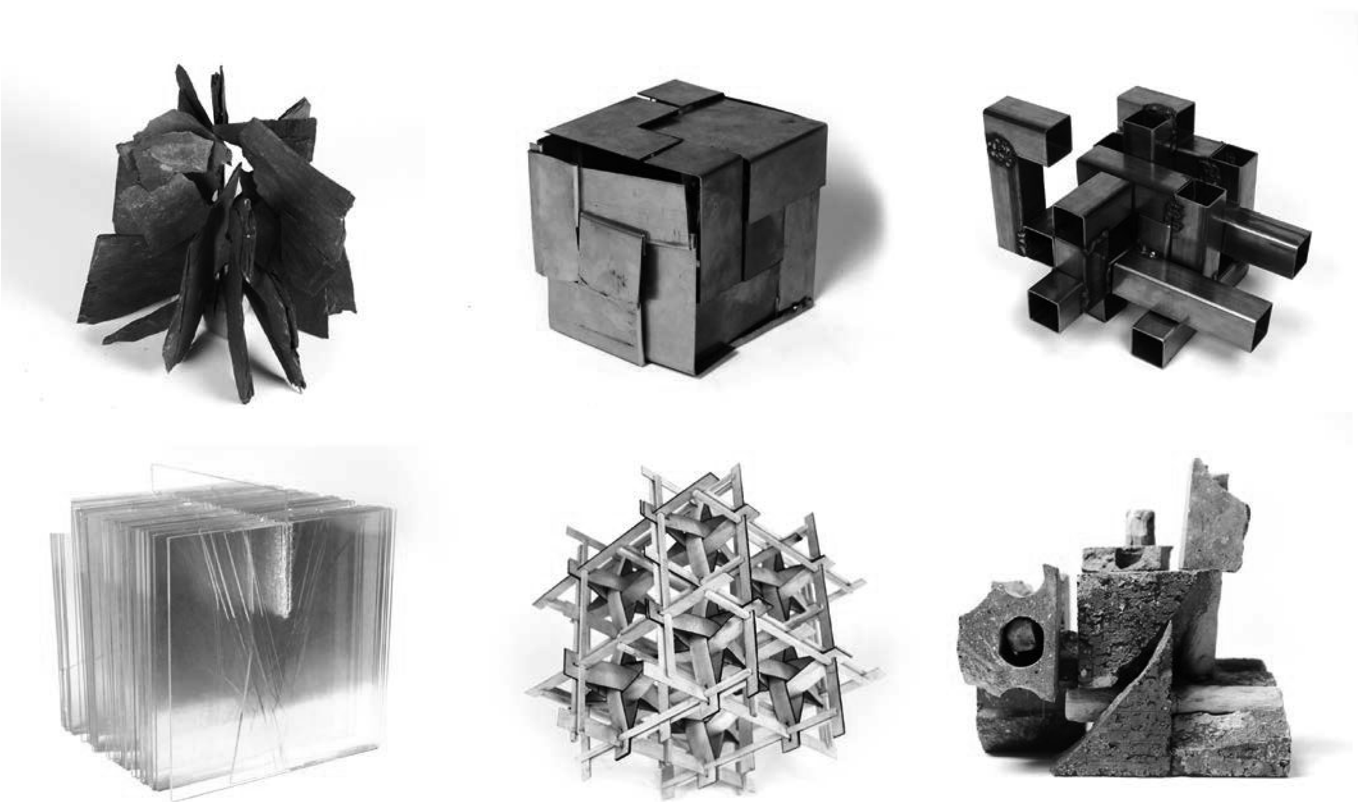

Figure 3. Representative student work of assignment 3 which asked students to develop a 6" cube from a given pairing of material and joint. Image Credit: Eva Standorf, Jonathan Wells, Desai Wang, Fangfang Zhang, Yu Da, and Tan Holocuglu.

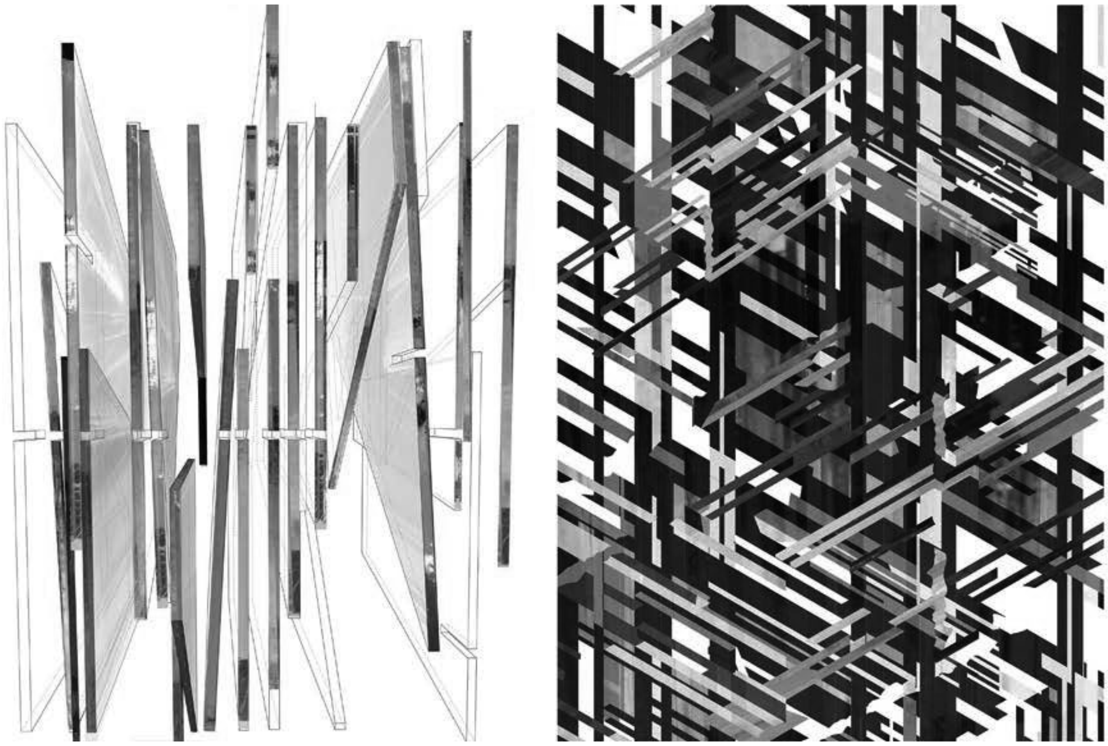

Figure 4. Student work representing the zoom-in and zoom-out of an interlocking glass cube. Image Credit: Desai Wang.

Using the cube as a given, the studio next repeatedly shifted in scale, from 10:1 to 1:500, thereby challenging while investigating the spatial and constructive qualities of the given joint typology, observing various material behaviors as the cube was alternately considered to be a detail or fragment of a larger construction, a building, and eventually assuming an almost 'urban' scale. The project brief suggested the students consider their "cube as a building, with a small scale figure in the size of less than 1" walking through the spaces created by your material: a brick might be understood as a room, a hinge as a door or a window. Maybe you can actually stand *inside* a bolt, experiencing the curved surfaces on a very different scale." In the second phase, the close-up drawings were to be suggestive of much larger scale constructions. This "zooming-in" and "zooming-out" facilitated an awareness of the spatial potentials of each material and its various concepts of jointure (see *Figure 4*).

Over the two week duration of this phase, the investigations primarily took on the form of large (scale) drawings. While hand drawings were definitely welcome, in the interest of the density and accuracy of information, students were encouraged to consider utilizing all the tools at their disposal in creating these drawings. (This included photomontage, photo editing software, and even basic three-dimensional modeling; hybrid presentations were most welcomed.) Students worked toward 'dense' presentations showing materiality, contrasting textures, light and shade, details, and whatever else they could consider as relevant and unique to their specific material and methods of combined assembly/ disassembly.

Through the next series of exercises, the concept of 'program' was introduced, not simply as the traditional inventory of required areas, but as a construct that incorporates elements of site, structure, spatial configurations, and narrative as they might be revealed through the materials' aptitudes. Through a rapid series of assignments, the relationships between each system's implicit site as program, its spatial capabilities as program, its structural capabilities as program, and its formal/ conceptual capabilities were investigated and strengthened – all as suggestives of various programmatic applications.

A WORKSHOP

Bringing together the lessons learned, the final project involved workshops or ateliers for artisans who would work with the given materials in producing some manner of artifacts or components for larger assemblies (see *Figure 5*). These workshops were designed to be constructed for adaptability and disassembly, utilizing throughout—and at every scale, from furnishings to overall structure—aspects of their design's material circularity and reversible connections [8].

In the third postcard that was distributed, fragments of a general, abstract 'site' were presented. These site fragments could be interpreted in a number of different ways: as forested, as quarried, as a lagoon, as a desert, and so on. The variability of the sites was intended to assist in developing the specific

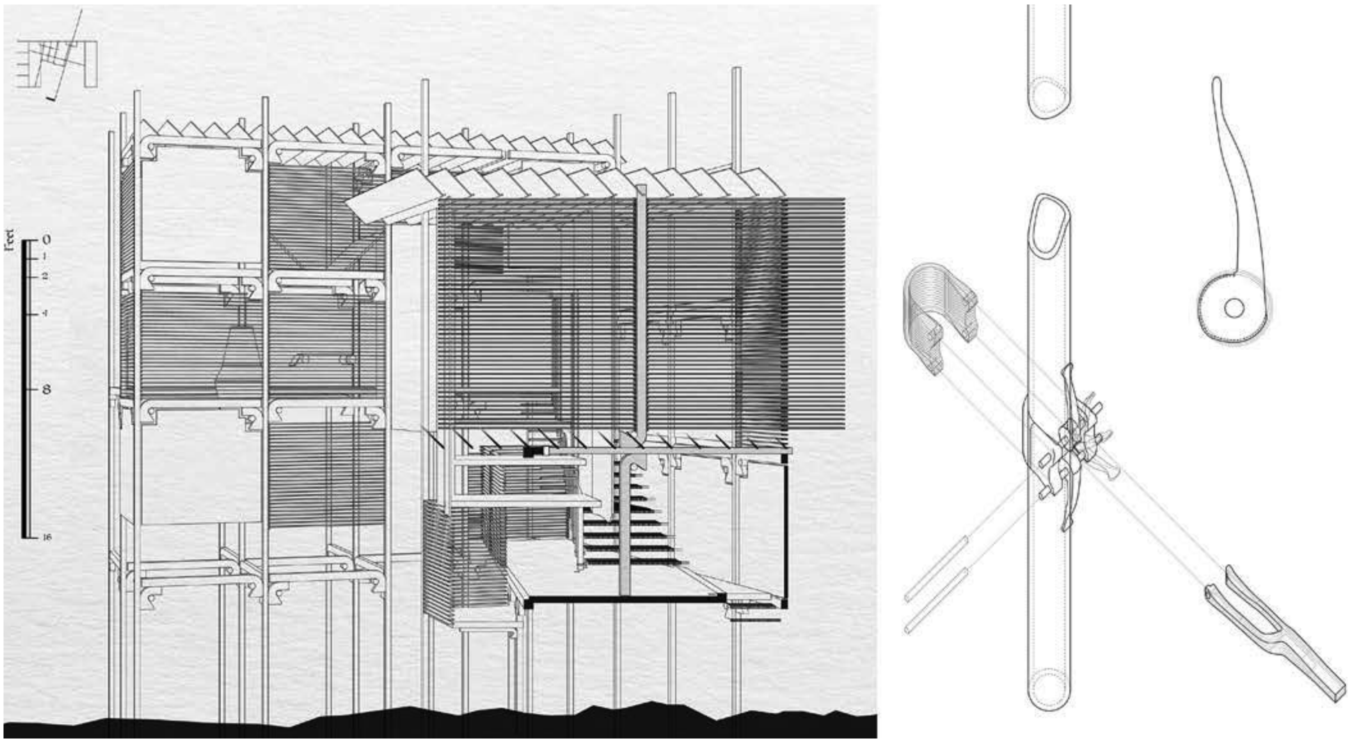

Figure 5. Representative student work of an aluminum craftsperson's workshop and design for assembly/ disassembly. Image Credit: Cook Shaw.

narratives each student would develop for their artisan and for the material cycle to be employed. For example, the designs of the sites might answer relevant questions such as: where does the artisan get their materials?—where might the artisan store for recycling various leftover materials?—could the waste material from a nearby industry be incorporated as the base material for the artisan? The first phase of the final project involved the sharpening of their materials' spatial capabilities in alignment with the programmatic inventions necessary for the specific artisans' accommodations.

In the second phase, students were asked to verify the constructability of their fundamental designs. They were encouraged to focus on selective details of their buildings (for example, the connection to the ground, the connection between vertical and horizontal elements, the roof, structural elements, material aesthetics and waterproofing) and to zoom in on the specific layers of exterior, interior, and furnishing, and on their various connections and disconnections. They were asked to determine the kind of fasteners—reversible, flexible, standard, custom—needed to affect the eventual disassembly of their constructions; to evaluate the possible necessity of a secondary material that might be necessary to accomplish the artisans' work (and how might that material factor into the life cycle diagram).

The third phase was essentially a reminder of the ubiquitous principle of the semester—indeed of the entire first year—since its inception: while the material circularity of the project is the subject of the semester, it is the spatial quality of the design that elevates the building above its rudimentary conceptual, functional, and efficient attributes. And that it is often a negotiation between all of these aspects with the overall concept that allows one to define the priorities necessary to develop a unique version of these qualities in respect to the site, the material, and the program brief, not to mention the phenomenal aspects of light, sound, climate, texture, and so on. (In one's first year, we suggest that it might be a good idea to be bold in these negotiations.)

CONCLUSION

The goal of our experiment involves bringing to the forefront an awareness of the critical dilemma of linear material consumption as well as a mindfulness of our responsibilities as problem solvers, thereby helping us in making decisions regarding materiality, structure, and detailing. Since the first year generally provides the occasion when architectural education focuses on issues considered to be fundamental to the education of an architect—issues such as space, organization, the manipulation and transformation of forms, critical discourse, collaboration, and so on—and introduces a proficiency in the skills required to represent these issues for oneself as well as to present them to others, it seems imperative that confronting the realities of this dilemma should be among those issues.

For this reason, while we always emphasized the fact that the creation of an architecture that is functional, healthy, and resilient, while also being aesthetically, spatially, and intellectually satisfying is central to the role of an architect, and that circularity in construction can never be the goal in itself, it is nevertheless one very important scale against which we must measure our decisions.

Developed then, from intrinsic material specifications and capabilities as well as from a life cycle perspective, the final design proposals seemed ultimately to be both oddly familiar and excitingly innovative, while introducing each student to a strong conceptual vector that should propel their awareness of environmental responsibility throughout their educational and professional careers.

ENDNOTES

1. Anthropocene Working Group. "Results of the Binding Vote by AWG." Subcommission on Quaternary Stratigraphy, 2019.
2. Architecture 2030. "The Carbon Issue." *ARCHITECT*, January 2020.
3. Transparency Market Research. "Construction Waste Market - Global Industry Analysis, Size, Share, Growth, Trends, and Forecast 2017 - 2025." Pre-Book Report. Albany, NY, 2020.
4. Circular Construction Lab, 2021. http://ccl.aap.cornell.edu.
5. Heisel, Felix, and Dirk E. Hebel. *Urban Mining und kreislaufgerechtes Bauen: Die Stadt als Rohstofflager.* Stuttgart: Fraunhofer IRB Verlag, 2021.
6. Heisel, Felix, and Val Warke. *Material+ PLATE B1_20s*. Ithaca: Cornell University, 2021. https://aap.cornell.edu/plate-publication.
7. It should be noted that, in our attempt not to strain the financial resources of the students, as well as to reinforce the interests of the studio, we make every attempt to utilize materials that are either naturally available in abundance, or that have been salvaged from the models, constructions, installations, and so on from the studios of the previous semester.
8. Due to the sudden change to on-line education, necessitated by the global pandemic, the final five weeks of the concluding exercise were conducted remotely. Thanks to our resourceful and passionate staff of teaching associates, a number of workshops and tutorials regarding various digital and representational strategies were rapidly compiled and made available, so that there was surprisingly little negative impact on the final results or on the enthusiasm of the students. These teaching associates included: Jordan Berta, Hallie Black, Madeleine Eggers, Evan McDowell, and Alexandre Mecattaf.