RE: ASSEMBLY

MATERIAL INTELLIGENCE IN DESIGN

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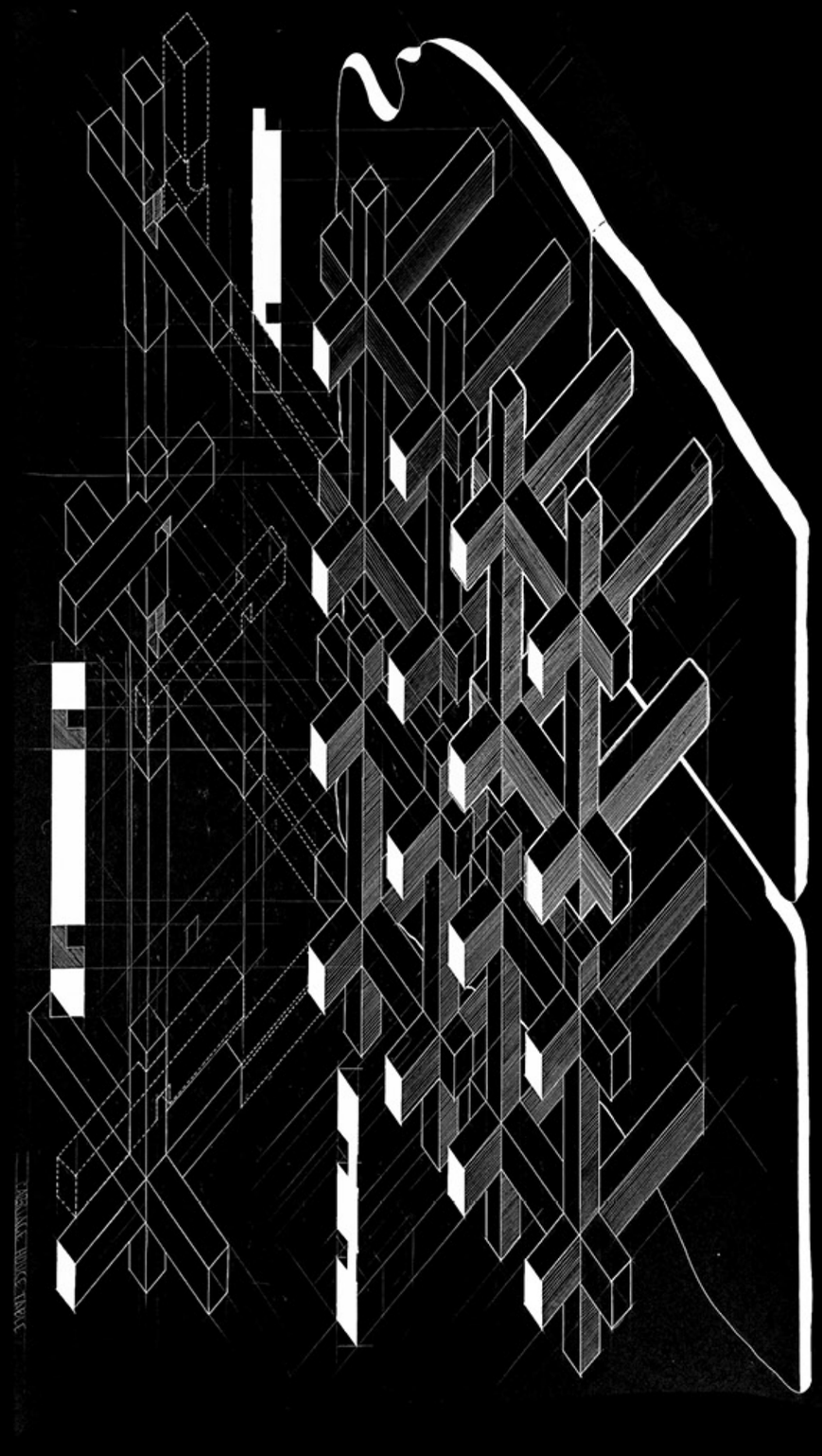

ABSTRACT /

The Architecture, Engineering, and Construction industry remains the world's largest contributor to global carbon emissions, and historical "sustainable" design responses have been reactive rather than forward thinking. However, recent strategies like Design for Disassembly and Circular Economy (CE) principles have responded to this, promoting proactive and holistic design approaches.

This thesis interrogates the growing disconnect between architecture and assembly, arguing that schools can impart foundational understandings of material that are critical to advancing sustainability and adaptation of environmentally conscious design principles in the broader discipline. Through research and prototyping of the "Carriage House Table," this study explores how construction logic and material can be reengaged as active design tools, positioning them as professional and ecological necessities. The final furniture piece utilizes found material and adaptable connections that facilitate future considerations while still being intensely responsive to a site.

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ACKNOWLEDGEMENTS /

I would like to thank my family, friends, and teachers who have supported me throughout my time at Syracuse. I am forever grateful for my parents whose immeasurable sacrifices and unwavering support for my education have allowed me to pursue my passions while working and living around the world.

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A close to home example of architecture's current state of affairs; the demolition site of Marion and Kimmel Hall on Syracuse University's campus, former home to over 300 students.

INTRODUCTION/

Architecture is complicit in the climate crisis.

The building and construction industry remains the world's largest single contributor of CO_2 emissions, with buildings and construction accounting for about 40% of total CO_2 output. Now that the United States has withdrawn again from the Paris Climate Agreement, which included an international commitment to carbon neutrality by 2050, it is even more imperative that the building industry in the U.S. takes significant strides towards sustainable practices.

In practice, sustainability evaluation frameworks like LEED and BREEAM were designed to respond to the environmental negligence of buildings, but until very recently have only served as prescriptive checklists for energy efficiency. While energy use is a crucial consideration of integrated design, its benefit is negligible when contextualized against the holistic environmental impact of a building.

Approaches like Design for Disassembly (DfD) or Circular Economy (CE) principles can provide guidance for constructing buildings in a way that displays knowledge of both aesthetics and environmental impact.

These represent much more integrated and holistic approaches to construction, ones that consider environmental impact from before material sourcing to after deconstruction. . It is here where architecture can achieve a beautiful balance, not blindly committed to design intent or functionalism but instead a harmony of diverse considerations.

Current architectural pedagogy does not forefront considerations of sustainability or construction knowledge; it privileges aesthetics above all. In most architecture curricula, education on structure and material are separated from design studio, further increasing their disparity. Furthermore, in architectural practice, these considerations are dismissed to be the responsibilities of consultants and engineers, discouraging interdisciplinarity. Design education must include more comprehensive education of building logistics in order to more adequately prepare individuals for impactful work in professional practice.

This study argues that the act of making is not just an outcome but an aspect of research itself. The physical artifact for this research is "Carriage House Table," designed for the Carriage House on Syracuse University's South Campus, home to the office of Sustainability Management and the South Campus Food Pantry. This final object is a coffee table that provides an adaptable work surface in the pantry's shared sitting room, a space used by students, staff, and community members. The table's role as a shared resource makes it an especially appropriate medium to research the sustainably conscious design concepts. Fabricated from found and reused materials, the process of its making speaks to the goals of both the Carriage House and this research. As an artifact, the furniture represents the continued life of its materials and serves as tangible evidence of the possibilities that emerge when design engages with future-oriented, sustainable thinking. ■

01

"A balanced design approach must give equal weight to material life cycles and embodied carbon considerations, not just operational efficiency."

The intersection of sustainability and construction requires analysis of historical building approaches and relationships to nature, practices lost in the rapid industrialization of the built environment. Americans now spend over 90% of our time living and working within our buildings, and our building practices have followed an equal departure away from nature. This separation and lack of awareness of impact both contribute to an unconscious abuse of the natural environment. Buildings designed with restorative and regenerative approaches have the potential to become part of the climate solution instead of perpetuating the problem.

Being "sustainable" can no longer only mean not harming future generations: it needs to mean proactively serving them. A more balanced approach must give equal weight to material life cycles and embodied carbon considerations, not just operational efficiency. While a design process that emphasizes performance or economics can be "efficient" in the short term, a lack of acknowledgement of material's complete life cycle is inefficient when considering long-term environmental impact.

Many cultures have historically embedded material intelligence into vernacular construction methods, building spaces that are not only functional but deeply contextual. These approaches reveal an inherent connection between materiality, scale, and assembly within their ecological and social contexts. American building practices must adopt these self-sustaining circular and adaptive models, rather than depending on lengthy and less reliable supply chains. By integrating these approaches, architects can provide more catered and conscious designs.

In East Asian architecture, particularly in Japan and Korea, contemporary firms demonstrate how deep material knowledge and craftsmanship from thousands of years of building culture can coexist with contemporary form-making.

The Ise Jingu grand shrine in Japan, deconsructed and rebuilt every 20 years for the last 1,500 years is a well known example.. The process of rebuilding the wooden structure helps to preserve the original design, function and also serves as a learning opportunity to pass down cultural bullding techniques, in direct response to the larger industyr shfit away from them.

JOHO Architecture in Seoul, South Korea, approaches design as a choreography between materiality, craft, and spatial experience. Their philosophy, rooted in both historical precedent and modern techniques, emphasize materials and local knowledge of artisans and construction workers in order to achieve contemporary design intent from an integrated perspective. The principal of Joho, Jeong Hoon Lee, describes his methodology through a concept called "material-metry." This concept is one where form is derived from material units and properties instead of forcing arbitrary materials to fit a form; in this way it is a methodology in line with CE principles that minimize waste and maximize recoverability. Understanding limitations can foster greater creativity, generating more innovative approaches that are born from the material itself. ■

The Ise Jingu grand shrine in Mie Prefecture, Japan a well known design for disassmbly precedent.

02

"Being "sustainable" can no longer only mean not harming future generations: it needs to mean proactively serving them."

RE/ ASSEMBLING CONNECTIONS

Contemporary architectural practice is often constrained by a heavy reliance on digital media and compartmentalized methods of working. This research responds to these constraints by reengaging full-scale making and joinery logic as active design tools in education. Design for Disassembly (DfD) provides a compelling framework for this kind of thinking: it prioritizes modular and reversible connections over permanent ones, enabling adaptability across time and use. The detailing and assembly methodologies of the design object of this study were informed by a range of precedents.

The first is a series of temporary mass timber sports facilities designed by Iten+Brechbühl, built in 2024 for the University of Zurich. The building uses prefabricated cross-laminated timber panels, untreated virgin lumber, and structural units based on transport constraints to reflect a response to project needs and educational concepts. The University required a temporary structure to relocate their athletics facilities during construction of a larger, longer lifecycle building. Full scale module mockups were crucial in testing feasibility of assembly techniques and informed the design process. While wall section mockups are a relatively common occurrence in construction, they are typically created post-design to test performance, rather than integrated into the design process itself.

The thinking behind this approach echoes Dirk Hebel's concept of "Urban Mining," a Circular Economy framework that proposes cities as future material banks in response to the global resource scarcity. With raw material extraction having tripled since 1970, now exceeding over 90 billion tons annually, there is an urgent need to rethink the linear "buy, sell, dispose" lifecycle of current materials. Hebel's UMAR building in Zurich demonstrates how contemporary design can integrate recycled or biologically renewable materials through reversible connections, in its architecture and furniture.

Like the Zurich case studies, this research's approaches the physical act of building as fundamental to shaping design intent from the outset. The hands-on method not only reveals constraints and opportunities but also underscores the gap between aspirations often theorized in sustainability discourse and what is actually constructed. The precedents rely on legibility, allowances in detailing, and showcase that these material practices can effectively scale throughout a project from furniture to architecture without sacrificing expression or function. ■

A modular and disassemblable nursery by Djuric Tardio Architectes. Designed to be a nomadic building that rehouses Parisian children displaced by construction of their use places of care.

Many historical schools of architecture forefronted material and fabrication as crucial pillars of architectural design. The Bauhaus, one of the most influential design schools of the past century, exemplified this ethos. At the heart of the curriculum was a "radical" concept: a challenge to reimagine material use and emphasizing functional, object-based design influenced simultaneously by expressionism and rationalism. The school featured a reimagined studio environment that included both a "shop teacher," a craftsman skilled in materials and production, and a "master of form," a more artistically inclined teacher who stimulated creative exploration.

In 2020, architects like Bjarke Ingels and Shigeru Ban gathered some of the world's most innovative architectural minds to form the New European Bauhaus (NEB), a framework inspired by early Bauhaus principles but reimagined through the lens of contemporary discourse. The NEB aims to support the goals of the European Green Deal, the EU's own policy initiative to achieve climate neutrality by 2050. Advancing this vision will require a radical rethinking of manufacturing and construction, especially methods that promote circular processes. The framework posits that material and methodological shifts, coupled with changes in education and community engagement, can help imagine a more climate-responsive future.

Despite this, contemporary architectural education relies primarily on indirect media for ideation and representation. The convenience of digital tools, paired with logistical constraints, has widened the disconnect between the artistic and technical aspects of the discipline. Rather than learning through building, students are often confined to disciplinary literature and digital representation, prioritizing formal exploration over direct engagement with materials in a physical feedback loop. While theoretical and representational work are vital, a truly effective design education must balance those with construction and material knowledge. The importance of this approach will allow us to be innovative with reuse of our current building stock in addition to designing better systems in future new construction.

Many materials can and should be utilized with sustainable methodologies, materials and assembly methods should be selected based on client needs and life-cycle-based inputs. The Hamer Center for Community Design at Pennsylvania State University outlines a list of ten key DfD principles for this decision making across all materials, including conscious sourcing and the importance of accessible connections. The principles focus on a program-first methodology that prioritizes spatial intent followed by informed material selection.

The aforementioned mass timber sports facilities designed by Itten+Brechbühl, built in 2024 for the University of Zurich.

03

"Contemporary architecture education must shift to include a focus on innovative construction approaches for existing and new projects."

The Hammer Center's Dfd construction approach follows the logic by focusing on human scale elements that keep in mind construction and deconstruction, minimizing chemical or destructive connections. The principles educate that fabrication in raw materials like wood, stone, and concrete requires an understanding of performance and aesthetics, and the importance of documentation for deconstruction and reuse is underscored.

A few institutions have bridged the material education gap through integrated design-build programs, including Auburn's Rural Studio and Studio 804 at the University of Kansas. These schools provide immersive experiences where students engage with integrated architectural approaches from client meetings to design to construction.

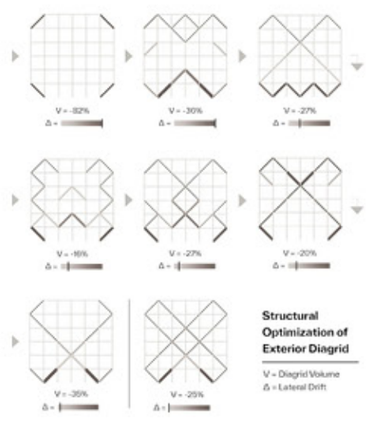
Rural Studio, as the name suggests, utilizes design approaches that work with locally available and reclaimed materials. Their work includes Masons Bend Community Center, which utilizes local dirt for rammed earth walls and salvaged car windows, exemplifies sustainable design practices within the existing built environment.

In another example, the internationally acclaimed Bjarke Ingels Group (BIG) recently completed the KUbe at the University of Kansas, an all-mass timber academic building inspired by traditional Japanese sashimono joinery. The structure eliminates all steel plates and fasteners in sashimono fashion, prioritizing reversible connections that allow for idealized disassembly processes and material expression. The KUbe serves not only as a functional extension for the program but also as a "living curriculum," where construction, technology, and design are fully expressed to students as accessible and teachable systems. Both Studio 804 and Rural Studio show sustainable building practices rooted in physical work can utilize available material in addition to providing idealized cases for the future.

Last year at the Harvard GSD Clara Mu He's prize-winning Strapped House system exemplified a full-scale case study of material-sensitive adaptability. Similar to BIG's Kube, the study exhibited an ideal integrated design process that maximized future material reuse and adaptability. Inspired by Southeast Asian bamboo construction, the system introduces non-intrusive strapping to dimensional lumber and puts forth a system that achieves sustainable goals while working within existing supply chains and contractor skillsets.

The Makers' KUbe at The University of Kansas, a 6-story mass timber student space designed by Bjarke Ingels Group in collaboration with BNIM.

The system is documented down to pieces, showing the maximum possibility of a holistic approach. It represents the case for easily adaptable housing, even from single to multifamily usage. He's thesis serves as a catalyst for possible explorations but is challenged by the constructability of the same concept at larger scale. The positive recognition of Strapped House shows a desire within academia, at the most highly regarded architectural institution in the world, for sustainable education in building and design. ■



A diagram showing modern technology hand in hand with traditional craft. (StructureCraft)

04

"Beginning with fabrication techniques and allowing them to inform design, creates a reciprocal relationship between intention and outcome."

As research shows, sustainable frameworks for design can be explored through many avenues, but human scale building provides the most opportunity for learning. Concepts like DfD and CE are often discussed at the scale of the built environment, but testing and refining through smaller interventions is a more effective way to teach.

Many design-build programs focus on complete houses or structures, but ideas are just as strongly communicated and defended through smaller scale design. Beginning with fabrication techniques and allowing them to inform design, rather than the reverse, creates a reciprocal relationship between intention and outcome. The importance of an iterative process ensures that material and construction logic are integral to the design rather than secondary and allows for many lives of a single material before it is biodegraded.

The physical research process of this study began by learning and testing joinery techniques, using reclaimed stock and leftover offcuts from the architecture woodshop. Early experiments included a variety of Japanese inspired sashimono joints: connections without nails, glue, or fasteners, chosen for their disassemblability and structural clarity. A series of six techniques were tested in full-scale sectioned prototypes to better understand process, performance, and visual expression. Joints were tested for a variety of structural applications and ease of disassembly. These joints included: shirayumi-tsugi (sunrise dovetail), hozo-shikuchi (hidden mortise and tenon), shachi-tsugi (wedged tenon), Chidori (staggered interlocking), kane-tsugi (pinned right angle miter), and shiro tsugite (castle). (see fig. 1)

Like any architectural endeavor, following the built research the design process began by identifying a client and their needs: the Sustainability Management office at Syracuse University. Recently relocated to the Carriage House on South Campus, the office is also home to the university's student Food Pantry, which combats food insecurity by making free groceries available to all students. The office's stated mission, "to reduce Syracuse University's environmental impact in a responsible manner by identifying, promoting, and implementing sustainable practices," provides fantastic evidence for the relevance of this study's explored concepts in while simultaneously serving client needs. In this space, a designed object could directly initiate a conversation about sustainable design through material expression and participatory construction, for a variety of students. The office features a shared sitting room, used for staff meetings, student gatherings, and a place for resting.

It has three loveseats, a couch, and two bar stools typically used as work surfaces, but no central element to connect them. When asked, the director stated a desire for a flexible, durable table that could anchor it, accommodating individuals and groups.

A drill press in the Syracuse Architecture's wood shop, used to drill through mortise openings for shachi-tsugi connections of the supporting structure to slab.

Figure 1

Figure 2

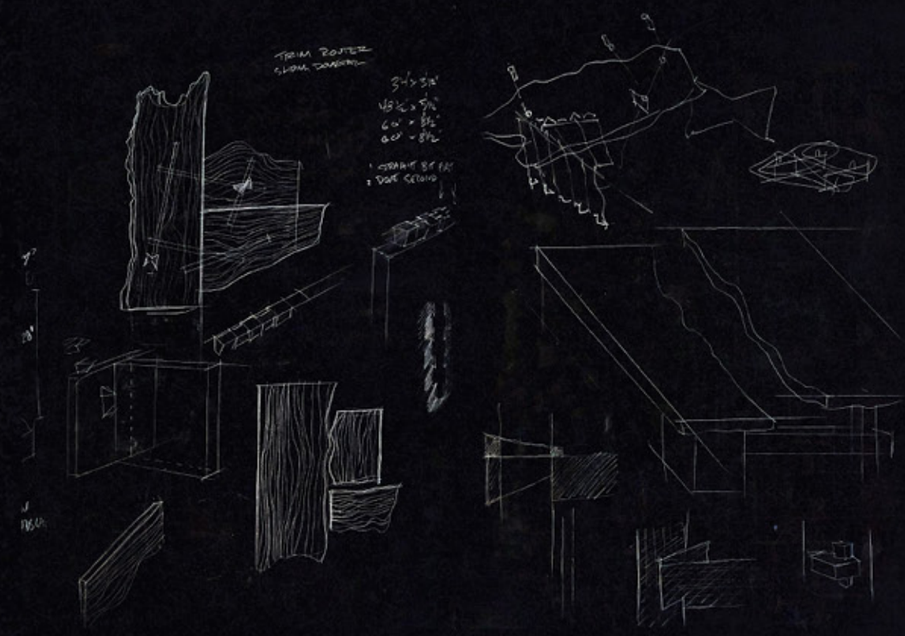


Figure 3

Once the general intent was established, the first step in the design process began with iterating through a variety of massing and arrangement studies. Following the expressed desire of the client for expressive and reporpused material, sourcing followed. Reclaimed lumber was acquired from a local craftsman who salvages fallen trees from utility companies, as well as repurposed hardwood paneling from a former Syracuse University wall system and bleacher seating from a nearby high school (see fig. 2). These materials showcase an intentional approach to CE in terms of material sourcing, and they celebrate "imperfect" natural materials instead of store-bought dimensional lumber. These physical irregularities and properties of the cherry, douglas fir, and pine wood became central design considerations. (see fig. 3)

Using knowledge gained working with mortise and tenon and wedged connections, joints conducted in the previous studies were connected into a simple Douglas Fir sitting stool (repurposed from the reclaimed bleacher seating, see fig. 4), which helped generate and test potential dimensions, tolerances, and finishes for the main table. Cutoffs were used to fabricate tenons, wedges, and support elements, minimizing waste and maintaining material continuity across the pieces. As material testing progressed, the natural edge cherry slabs were planed, sanded, and selectively trimmed to remove rot while retaining as much usable mass as possible. A benefit to utilizing live edge pieces is that unusual growths or knots central to the design instead of trash. This hands-on process of preparing and experimenting with the wood also helped understand how the wood would respond to chiseling, hand, and machine tools. (see fig. 5) Following this experimentation, the two primary slabs were identified as

Figure 4

suitable for the sitting room, and the design of the full assembly began. The design process oscillated between physical mockups of assemblies and clearly articulated drawings that communicated process.

The final table employs two traditional joinery systems: the shachi-tsugi joint and the Chidori system. The Chidori joint, derived from Japanese sashimono woodworking, allows three intersecting members to meet with hidden interlocking joinery which comprise the base. The sachi-tsugi, composed of through mortise openings for the table structure and small walnut wedges that are removeable and yet provide a strong mechanical connection (see fig. 8). Kengo Kuma, the world renowned Japanese architect, is well known for utilizing traditional joints in construction and create adaptable systems that inspired the use of traditional Japanese methods in this study. Crafted from Douglas fir, the intersecting sashimono elements form a modular framework that supports the table and allows for simple disassembly and reconfiguration (see fig. 7). The tabletop is composed of three live-edge slab sections. When separated, they function as smaller surfaces for individual use; when joined, they form a unified centerpiece capable of anchoring the room. This modularity allows the table to adapt to varying users without establishing a visual or spatial hierarchy. Its flexibility mirrors the mission of the Food Pantry: accessible, non-prescriptive, and centered on community needs. During the design process, a section of the table was also brought into the pantry and left for people to interact with and critique which yielded the desire for separability and finish options (see fig. 6).

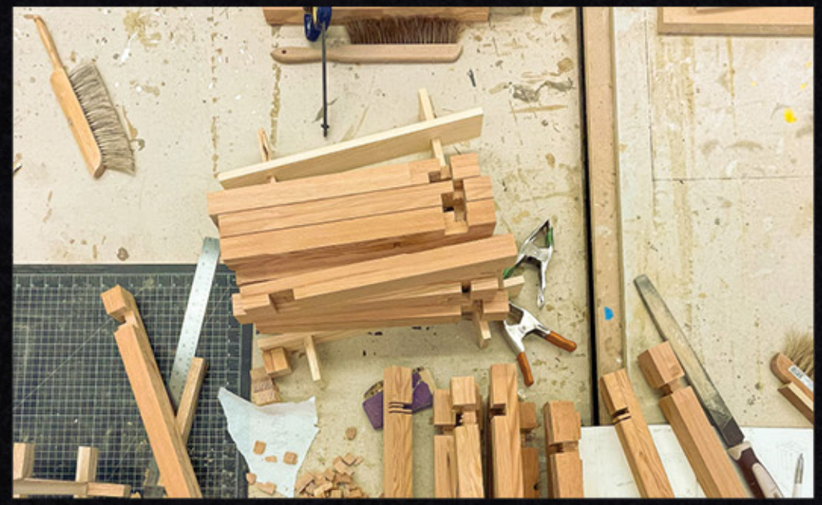


Figure 5

Figure 6

The final piece is finished with Danish Oil, an all-natural, biodegradable product that enhances grain expression while offering protection for interior applications. The expressed joinery communicates the table's logic of assembly and invites users to recognize its construction as both functional and educational.

The table is not delivered as a finished object, but rather as a set of components to be assembled by the future users and myself, through an instruction booklet (see fig. 9).

Figure 7

Figure 8

This participatory act transforms the furniture from static product to an interactive experience, embedding as much value into the understanding of its creation as its function. Not only did the table elicit immediate responses but its expressed material and natural characteristics allowed for a harmony within the setting of the Carriage House and Sustainability Management's mission.

The table serves both as a prototype for sustainable design and an educational tool, one that invites dialogue and challenges the conventional separation between designer, constructor, and user. By embedding disassembly into both its construction process and user experience, the table becomes an artifact of how circular design principles can be meaningfully implemented at a manageable scale in an educational setting and by extension, inform larger architectural practices. ■

Figure 9

This research demonstrates that the future of architecture lies both in technology and in re-engaging with environmental responsibility. The case study used wood and related methods of working because of its accessibility and site-related decision making but is not advocating for one material; rather, it speaks to more conscious considerations of material selection and usage at large.

As part of a Syracuse Architecture Directed Research group led by Tim Stenson that focused on reintegrating fabrication into architectural education, the table takes the argument a step further to claim that sustainability awareness is equally as significant of an omission. This research interfaces with many emerging (and established) voices in the field of architecture and furniture, inspired by architects like Kengo Kuma and George Nakashima among others for their interdisciplinary work but reintroduced into contemporary sustainability discourse. Much of the experience that has culminated in this research has resulted from professional work, conversations with architectural professionals, and off-campus study in Italy and Japan. While technology increases the gaps between representation and reality in other fields, architecture has the opportunity to channel these advances into becoming a global role model in championing sustainable practices.

This work is as much a critique of architectural education as it is a proposal for larger shifts in building and design methods, arguing that the two are inextricably related. In order to foster a professional discipline capable of impacting positive environmental change, education on the means and methods building must begin in schools. While the table is a small artifact, it reflects a broader dialogue interrogating how we build, what we build with, and what happens after. It is important to acknowledge that the required education regarding sustainable design practices goes much further than what is explored in this body of work. The final creative object of this study serves as a conversation piece, a provocation for deeper consideration of process and impacts at large in processes of design. Although not all joints in the final assembly are directly translatable to larger scale building, the sentiment remains: Sustainability and beauty are not oppositional, and the constraints posed by environmental responsibility, paired with functional needs, lead to more intentional, meaningful, and ultimately more architectural outcomes.

To design with disassembly is *not* to design less, but to design with greater intention, toward architecture that is dynamic, adaptable, and holistically responsive.

-DAH

Bell, Victoria Ballard, and Patrick Rand. Materials for Architectural Design. London: Laurence King; New York: Princeton Architectural Press, 2006.

Bjarke Ingels Group. "U of Kansas School of Architecture and Design." 2024. https://big.dk/projects/university-of-kansas-school-of-architecture-and-design-18157

Brown, Martin, Edeltraud Haselsteiner, Diana Apró, Diana Kopeva, Egla Luca, Katri-Liisa Pulkkinen and Blerta Vula Rizvanolli. Sustainability, Restorative to Regenerative. 2018.

European Commission. New European Bauhaus: Concept Paper. July 2021. https://new-european-bauhaus.europa.eu/system/files/2021-07/2021-06-30_New_European_Bauhaus_Concept_Paper_HLRT_FINAL.pdf.

Ferreira, Ana, Manuel Pinheiro, Jorge Brito, and Ricardo Mateus. "A Critical Analysis of LEED, BREEAM and DGNB as Sustainability Assessment Methods for Retail Buildings." Journal of Building Engineering 66 (2023): 105825. https://doi.org/10.1016/j.jobe.2023.105825.

Guy, Brad, and Nicholas Ciarimboli. "Design for Disassembly: A guide to closed loop design and building." 2018.

He, Clara Mu. "How to (Un)build a House? A Reinvention of Wood Framing." Thesis, Harvard Graduate School of Design, Spring 2024. https://www.gsd.harvard.edu/project/how-to-unbuild-a-house-wood-framing-mu-he/.

Interview with Jeong Hoon Lee. Interview by Donovan Hernandez. Seoul, South Korea, September 12, 2024.

Lerner, Fern. "Foundations for Design Education: Continuing the Bauhaus Vorkurs Vision." Studies in Art Education 46, no. 3 (2005): 211–26. http://www.jstor.org/stable/3497081.

Paris Agreement. United Nations Framework Convention on Climate Change. 2015.

Peacock, Amy. "Itten+Brechbühl creates demountable timber sports hall for University of Zurich," Dezeen, November 11, 2024, https://www.dezeen.com/2024/11/11/sporthallenprovisorium-gloriarank-itten-brechbuhl-sports-hall-zurich/.

Riskiyanto, Resza. "Material-Based Learning in Architecture Design Studio: From 'Beaux-Arts' to 'Bauhaus' into Current Educational Era." 2023.

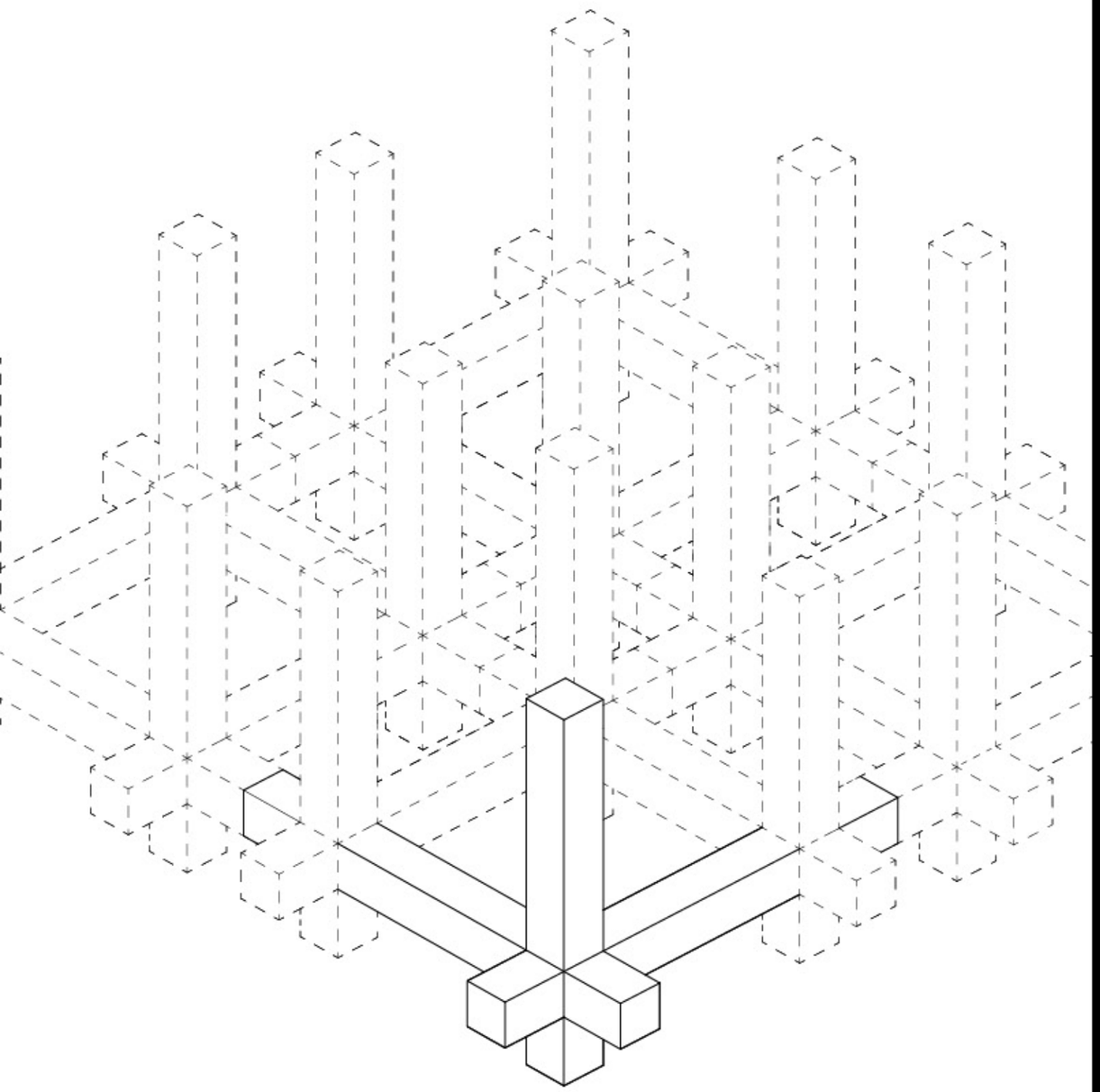
Seike, Kiyosi. The Art of Japanese Joinery. Shambhala Publications, 1977.

Stenson, Tim. FABRICATING FORM ARC 498. Syllabus. Syracuse University, 2025.

Hebel, Dirk. "UMAR: Urban Mining and Recycling." Nest-UMAR, accessed Jan. 10, 2025. http://nest-umar.net/portfolio/umar/

Walsh, St John, and Elizabeth Shotton. "Integrating Design for Adaptability, Disassembly, and Reuse into Architectural Design Practice." Sustainability 16, no. 17 (2024): 7771. https://doi.org/10.3390/su16177771.

CARRIAGE HOUSE TABLE
MANUAL



~~DIS~~ASSEMBLE

Chidori (千鳥)is a type of joint without nails or adhesives traditionally used in the city of Hida Takayama to build children's wooden toys. Internationally renowned architect Kengo Kuma collaborated with artisans in the region to develop the popularity of the system and utilize it both in furniture and in his architecture. The following drawings indicate the assembly process of the Chidori system and the Carriage House Table, for readers of this text and users of the table itself.

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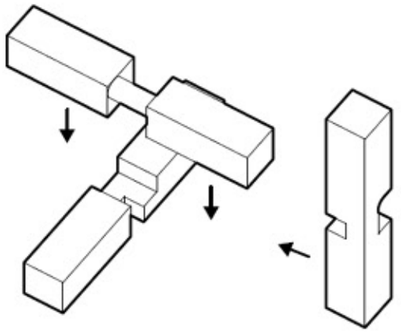

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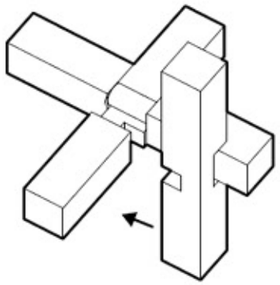

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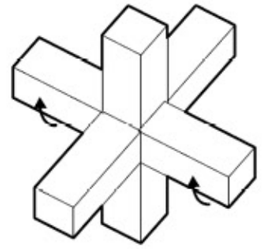

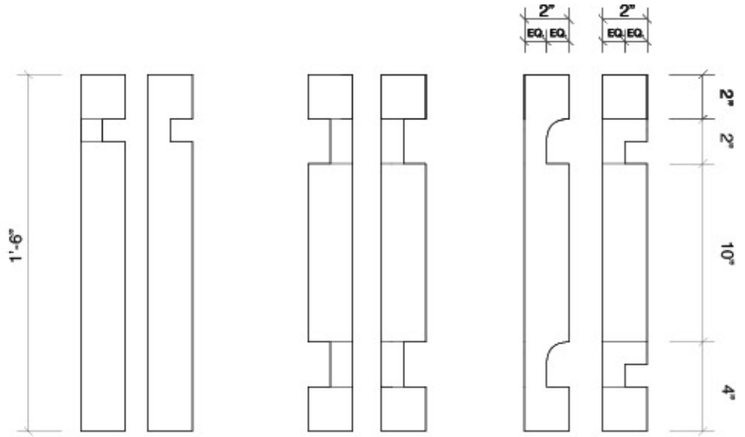

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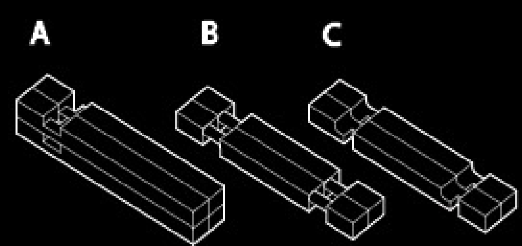

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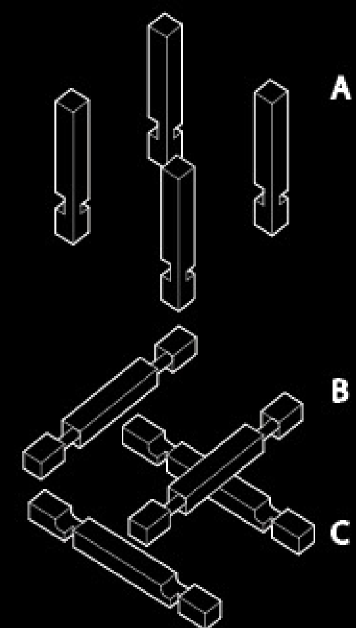

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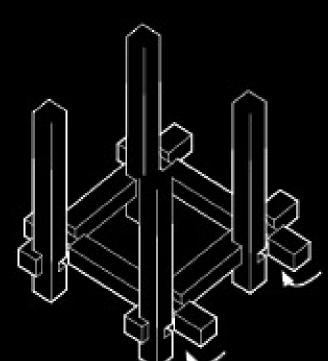

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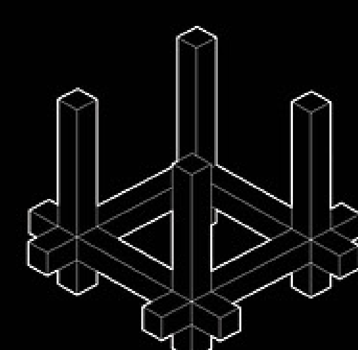

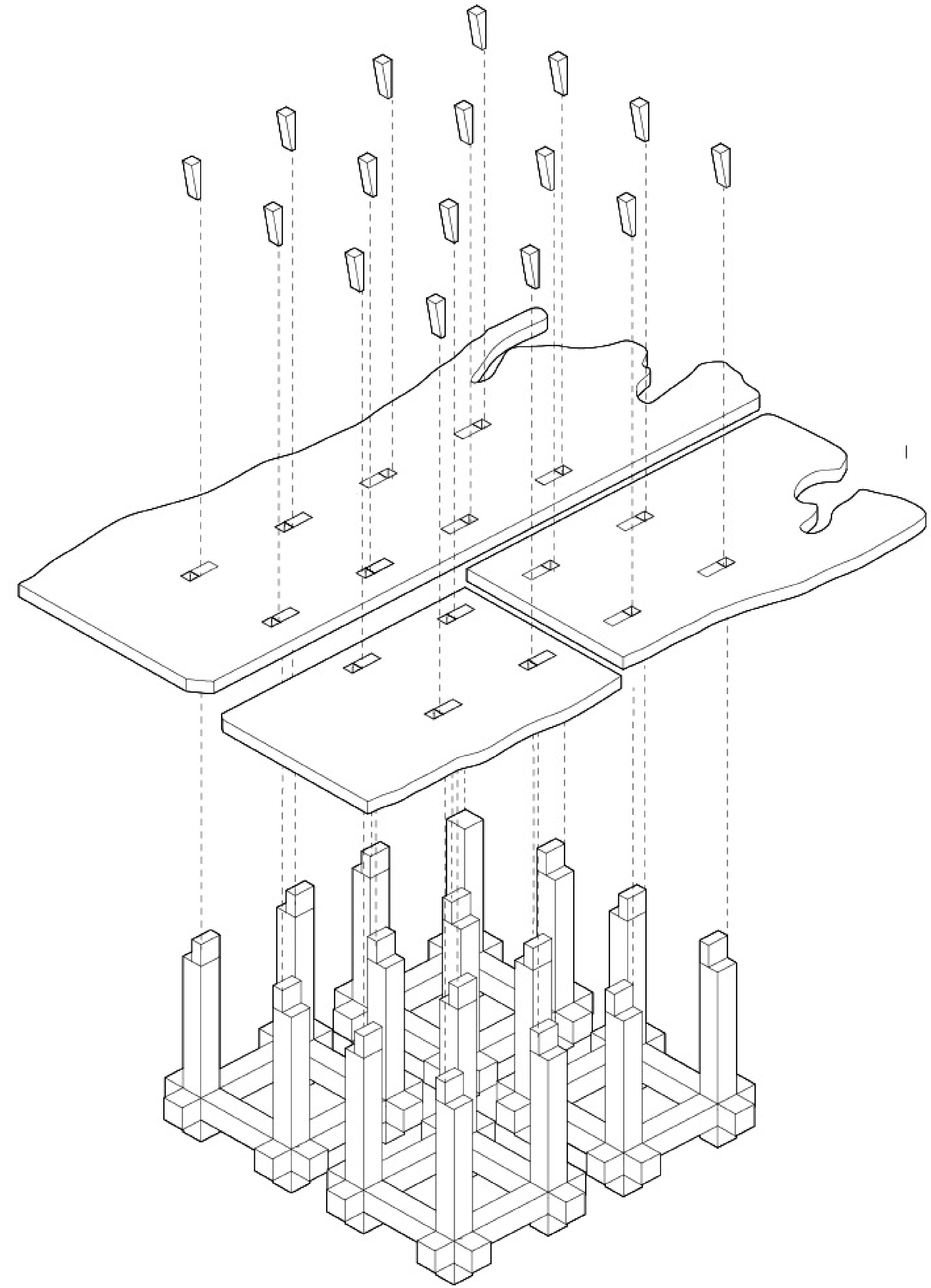

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