ABSTRACT

Title of Thesis:	DUST TO DUST, EMBRACING ENTROPY THROUGH ORGANIC BUILDING MATERIALS
	Ryan T. Muir, Master of Architecture, 2022
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Architecture has had a complicated relationship with time. Some architects have chosen to embrace time, while many have chosen to oppose it. Fearful that passing time would overcome their work, many modern architects attempted to suppress its effects. In the commercial realm of today, that fear can largely be characterized by not wanting to be "behind the times". Commercialism has bred a practice of planned obsolescence that reflects the dynamic, living organism of society, but fails to see buildings themselves as organisms. Our building practices have contributed to an immense amount of waste that is detrimental to our environment. This thesis will test architecture's ability to embrace the process of entropy through organic building materials and explore the scalability of these methods in the "res-economica" of Washington, DC. This will be applied to three different affordable housing and homeless supportive housing typologies.

DUST TO DUST,
EMBRACING ENTROPY THROUGH ORGANIC BUILDING MATERIALS

by

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Professor Brittany Williams, Chair
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“Unless the LORD builds the house, those who build it labor in vain.” Psalm 127:1

Thank you, Gabrielle for your unending support.

Thank you, to my friends who have come along for the ride.

Thank you, Britt Williams for your guidance throughout this process. It has been a pleasure.

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Suddenly then, as if seeing the single and unavoidable conclusion to all this he moved swiftly to the window before Callisto could speak; tore away the drapes and smashed out the glass with two exquisite hands which came away bleeding and glistening with splinters; and turned to face the man on the bed and wait with him until the moment of equilibrium was reached, when 37 degrees Fahrenheit should prevail both outside and inside, and forever, and the hovering, curious dominant of their separate lives should resolve into a tonic of darkness and the final absence of all motion.

Thomas Pynchon, 'Entropy' (1960)

Chapter 1: The Problem with Permanence

Introduction

For some reason, many, in western society, have been convinced (or they have convinced themselves) that 'permanence' is attainable. The unavoidable truth is that the only permanence is impermanence. Some know this better than others. Some people are left without the architectural, financial, and relational securities that lead to the perception that permanence is a reality. For these people, no day is like another, uncertainty is the only constant. Meanwhile, others chase rhythm, consistency, and stability, and ultimately only find unpredictability, inconsistency, and disorder. This is manifested in architecture, as many cultural values are. Buildings constructed out of steel and concrete; sheathed in metal and vinyl; insulated and plumbed with synthetic materials are reflections of this value of permanence.

Modernism

As a result of industrialization, western architecture was redefined in the early 20th century. Amid this revolution, architects made choices that would impact building design and function for centuries to come. The technological progress of industrialization provided architects with new structural materials, such as steel and reinforced concrete, that would carry more load, span farther, and last longer than wood. There was then a tension between utilizing architectural precedent and exploiting these materials to create a whole new era of architectural design.[1] The

[1] Brent C. Brolin, *The Failure of Modern Architecture* (New York: Van Nostrand Reinhold Co, 1976).

latter prevailed, while not entirely dismissing historical precedent as inspiration, however there was a clear shift away from the utilization of local materials as new, manufactured materials became available and transportation of materials became easier.

The rise of capitalism was another pervasive influence in architecture in the 20th century. Efficiency became one of the premier considerations in material choice, construction method, and design. The desire to maximize return on investment became a primary driver—build tall, but cheap, and fast. This was fueled by the self-righteousness and superiority that seems to be ingrained in the human condition, often gruesomely revealed during the pursuit various forms of wealth and gain.

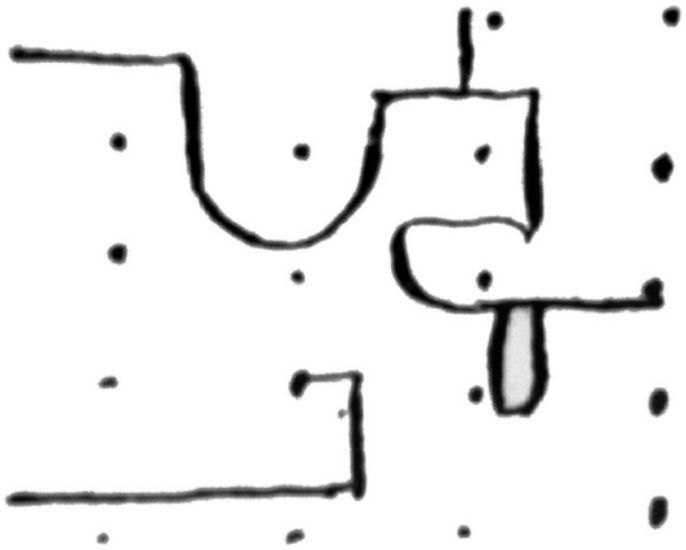

Figure 1: Sketch of "the free plan" (Le Corbusier, 1926.)

The modern architectural revolution was characterized by an attempt to suppress the effects of time. Hypocritical modernists perpetuated the unattainable idea of timelessness in an era of dramatic change and focus on the individual, straddling the line between permanence and novelty. Even the best polemical architects of the 20th century designed with concrete while preaching about adaptability. In *Toward an Architecture,* Le Corbusier famously writes that "a house is a machine for living in," the way "an armchair is a machine for sitting in."[2] This ascribed a certain replaceability to buildings. Marvin Trachtenberg writes, "Traditional buildings do not easily wear out but machines quickly do, if obsolescence does not undo them first, and so, the theory goes (or went), it will be

Figure 2: The Villa Savoye (1928-1931) designed by Swiss architect LE CORBUSIER. View from the overgrown roof garden into the salon. 1959. (Rene Burri)

[2] Le Corbusier, *Toward an Architecture* (Getty Research Institute, 2007).

with buildings if they are truly to correspond to the rationalized technological realities and spirit of modernity – to the new 'realities of the age'."[3] Due in part to the materials they were constructed out of, many examples of this modern ideology have lasted well beyond their "age". But do they still carry the "spirit of modernity"?

The intention here is not to make sweeping generalizations about modernist principles, but rather to identify the prominent ideas and philosophies that have influenced a pernicious and wasteful methodology of building today.

Machines for Profit

Today, capitalism and fashion are the demise of many buildings as they are demolished in that same "spirit of modernity" long before they succumb to erosion and degradation – or before they show hardly any wear at all. Fashion kills architecture. Stewart Brand describes buildings as being "treated by fashion as big,

Figure 3: Demolition of the Mattin Center at Johns Hopkins University began in 2021, just 20 years after its completion. (Ed Gunts, Baltimore Fishbowl)

[3] Marvin Trachtenberg, *Building-in-Time* (Yale Universtiy Press, 2010).

difficult clothing, always lagging behind the mode of the day."[4] Just like clothing, we have avoided the issue of wear and tear by simply disposing of the old and manufacturing new, again and again. Of course, this ought to be easier to do with clothing than with architecture, but modernism and capitalism have turned buildings from architecture into machines for profit, meaning that they need to be disposable to make way for the next thing. This is the definition of planned obsolescence. Some, like Thom Mayne, do not see this as a problem, so much as a reflection of the "dynamism of our cities." [5]

The problem is that buildings are still not made to be disposable. The annual production of concrete is 500 million tons in the United States and 10 billion tons globally.[6] In 2018, 600 million tons of construction and demolition debris were generated in the United States, 90 percent of which was from demolition.[7] The average lifespan of a building in America is 50 years – 35 years for commercial office buildings and only 23 years for chain drug stores.[8] The steel and concrete used to construct those buildings should be structurally viable for up to 100 years.[9] Residential homes are wrapped in vinyl siding that gets replaced every 20 to 40

[4] Stewart Brand, *How Buildings Learn: What Happens after They're Built* (Penguin Books, 2012).
[5] Arbuckle Industries, *Thom Mayne Archiculture Extras Interview*, 2015, https://www.youtube.com/watch?v=5aX-JdHk2fk.
[6] Christian Meyer, "Concrete Materials and Sustainable Development in the United States," n.d., 10.
[7] OLEM US EPA, "Sustainable Management of Construction and Demolition Materials," Overviews and Factsheets, March 8, 2016, https://www.epa.gov/smm/sustainable-management-construction-and-demolition-materials.
[8] "Research: Score Distribution; Commercial Building Age, Use, Value - Commercial Property Data," accessed October 11, 2021, https://www.commbuildings.com/ResearchComm.html.
[9] "What Is The Lifespan Of Concrete? | Razorback Concrete," accessed October 11, 2021, https://razorbackconcrete.com/what-is-the-lifespan-of-concrete/.

years.[10] These products' economic lives do not align with their material lives. The concrete, steel, vinyl, fiberglass, etc. that are used for building relatively short-term structures have long-term consequences in the landfills they end up in.[11]

Contemporary architecture is still straddling the line between permanence and change. The industry uses the same durable building materials that the industrial revolution yielded, while treating the buildings made from them as expendable. The modern principles of timelessness and permanence originated from idealized projects that were built to be lasting icons. Their monumentality was inspired by traditional architecture that lasted hundreds, sometimes thousands of years. Contemporary architecture has adopted the materials and construction methods of the modern era and left the appreciation of the actual building behind.

Chronophobia

Chronophobia is characterized by an irrational yet persistent fear of time and of the passing of time.[12]

Marvin Trachtenberg asserts that to understand the chronophobia of modern architects, one must first understand the meaning and significance of architecture. He states, "Architecture is… a primal fact of life, and long has been. Human existence is so thoroughly dependent on architecture that life without it would not only be

[10] "What Is the Lifespan of Siding & What Type Is Most Durable? | Sunshine Contracting," accessed October 28, 2021, https://sunshinecontractingcorp.com/blog/2019/05/10/what-is-the-lifespan-of-siding-and-what-type-is-the-most-durable/.
[11] "How Long Does It Take for Plastics to Biodegrade?," HowStuffWorks, December 15, 2010, https://science.howstuffworks.com/science-vs-myth/everyday-myths/how-long-does-it-take-for-plastics-to-biodegrade.htm.
[12] "Chronophobia or Fear of Passing Time: Risks, Symptoms, Treatment," Healthline, June 12, 2019, https://www.healthline.com/health/chronophobia.

impossible, but virtually unimaginable."[13] By viewing architecture as parallel to our own existence, it is easier to understand the fear of the effects of time. It is also reasonable to assume that as long as architecture has been an expression of the self, in western culture, whether as an expression or power or intellect, or something else, architects have detested watching that which is their glory dilapidate.

Today's society, in large part, has been conditioned to take architecture for granted. For many, chronophobia is characterized by not wanting to be behind trends (as Brand might suggest), rather than a fear of being without shelter. Ironically, our response to this is to tear down buildings and replace them. Trends are not necessarily a bad thing. Change is inevitable and our cities should reflect change and growth. However, the "construct for permanence" response to chronophobia mixed with the "tear it down and build something new" response makes for a dangerous and detrimental concoction.

This chronophobia predicament has three potential cures. The first is to construct buildings to last for the duration of time that corresponds with the duration of material viability and use them within society to that extent. This can be achieved, regardless of changing program or tenants, through adaptive reuse. The second is to recognize the urban fabric as something that is living and breathing, always changing, and construct buildings with materials that reflect that. The third is a combination of these.

[13] Trachtenberg, *Building-in-Time*.

Chapter 2: Embracing Entropy

Civitas

All three of the previously mentioned solutions to chronophobia are about overcoming fear and embracing entropy, the way a child must overcome their fear to embrace the freedom in riding a bicycle.

The third solution involves letting buildings age as well as anticipating change in the urban environment. One approach to this is to build for adaptability. With this, buildings are allowed to grow old and earn the admirable quality of patina. However, there is a theoretical end to the adaptability of every building. At a certain point, the adaptation is no longer rational, cost-effective, or reasonable, or the free market deems the building shell or structure not suitable for whatever program it wants to put on that lot. Another method would require a complete rethinking of our urban fabric. Per Leon Krier's diagram "Civitas" (Figure 4), a city is made up of two parts: res publica and res economica. Res publica is made up of monuments and monumental buildings. Res economica is made up of the streets and the auxiliary buildings. In other words, res publica represents the consistent nature of a city, while res economica is subject to change and adapt to the needs of the city. Each part of the city represents a different opportunity to embrace entropy. Res publica ought to be built to last and have its effect on the city for generations, slowly and subtly acquiring a patina that conveys wisdom and experience. On the other hand, Res economica could be constructed to be deconstructed, to have change affected on it, to evolve – that is if it is going to serve in its secondary role in the larger design of the city.

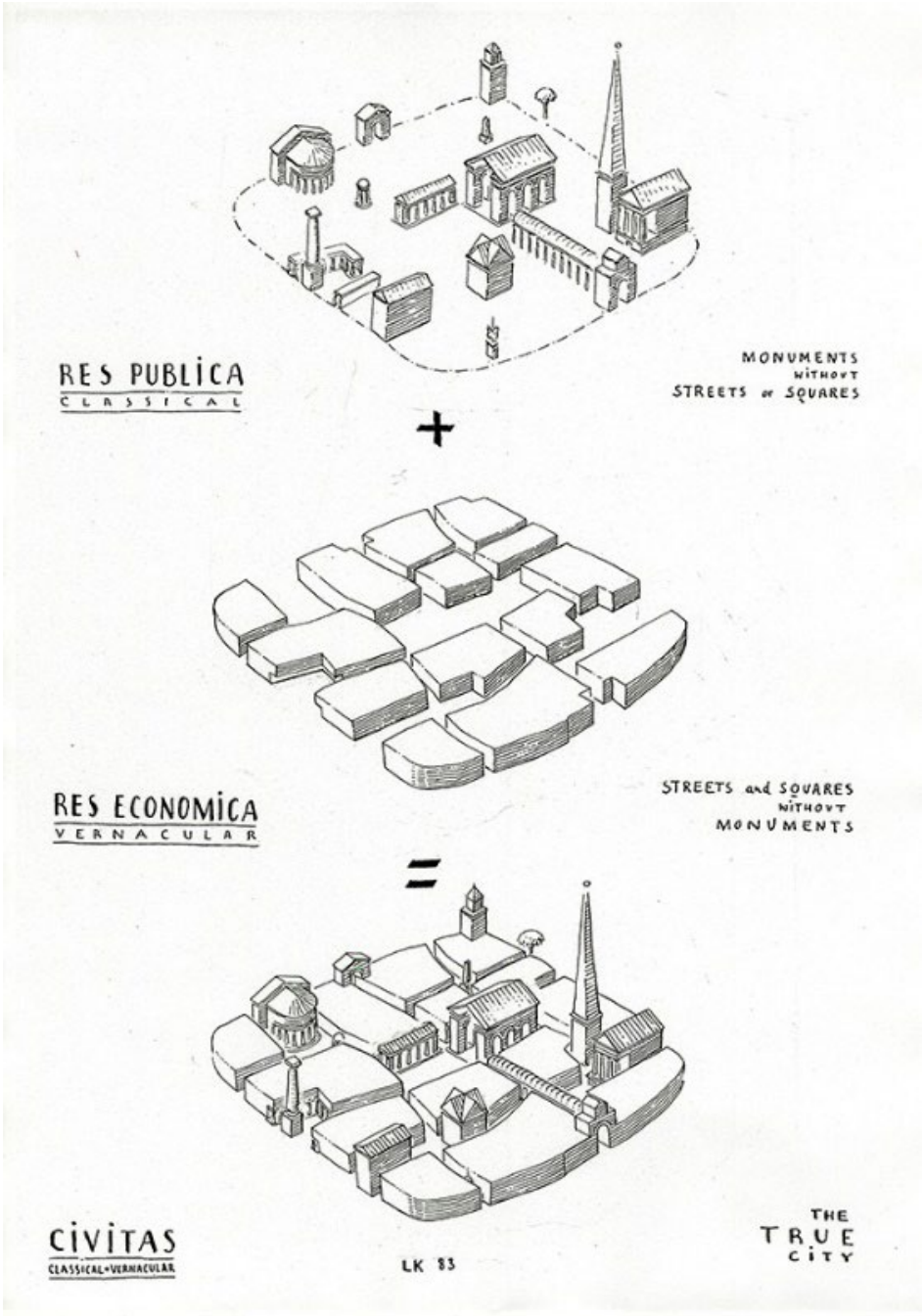

Figure 4: Civitas (Leon Krier)

Biodegradable Building Materials

To embrace the natural and inevitable degradation of matter, the truest methodology would be through biodegradable materials. Organic building materials are most effective when they are locally sourced, indigenous to the area in which they would be used for construction. The following materials are viable for construction use, able to be sourced within 100 miles of Washington, D.C., and are comparable to or perform better than their inorganic counterparts.

Timber

Architects and engineers have been looking at timber differently over the past decade, finding ways for it to compete, structurally, with steel and concrete, which are both high in embodied carbon. There is a high volume of carbon dioxide gas in the atmosphere, naturally expelled by the human respiratory system and naturally "inhaled" by plants. In return, plants expel the oxygen that humans breathe. This is a balanced system. The system, at present, is unbalanced due to the high volume of carbon dioxide generated by our industrial practices. This imbalance is one of the root causes of climate change. Using timber as a building material stores the carbon processed by the tree for the life of the product. Only when the wood product decomposes at the end of its useful life, the exact amount of carbon dioxide that was internalized by the tree is released into the atmosphere, as part of the balanced cycle. The amount of carbon dioxide stored in construction timber can be approximated using the following values. Carbon makes up approximately 50% of the dry mass of a wood product. The rate of CO_2 recovery after processing soft wood is approximately

50%; hard wood is approximately 35%. Air-dried timber typically retains 12% moisture. The carbon figure is then multiplied by 3.67 to determine the equivalent amount of CO_2.[14]

CO2 sequestered in construction timber (kg) =

mass (kg) x 88% (dry mass) x 50% (carbon) x 3.67 x recovery rate (%)

Salvaged Wood

To extend the life of wood that has sequestered carbon, wood from old projects can be salvaged, recycled, and reused for new projects. Lumber from slow-growing, sturdy trees was commonly used for industrial and agricultural buildings prior to the industrial revolution. A few hundred years later, many of these buildings are no longer in use or are not structurally viable, making their timber parts ripe for reuse. Recycled timber can be used for decoration, flooring, furniture, partitions, or other non-structural applications.[15]

Bamboo

Bamboo grows naturally between the 46 º North and 47 º South latitudes (Washington, D.C. = 38.9 º N) and up to 14,000-foot elevation above sea level

[14] "How Carbon Is Stored in Trees and Wood Products.Pdf," accessed December 2, 2021, https://forestlearning.edu.au/images/resources/How%20carbon%20is%20stored%20in%20trees%20and%20wood%20products.pdf.
[15] "What Is Reclaimed Wood? | Why Use Reclaimed Wood?," Sustainable Lumber Company, July 8, 2019, https://www.sustainablelumberco.com/2019/07/reclaimed-wood-everything-you-need-to-know/.

(Washington, D.C. = 0 ft – 409 ft).[16] Bamboo has shallow roots and grows best in soil that is well-aerated, light in structure, and moister-retentive, but allows for proper drainage.[17] Bamboo has been compared to steel for its tensile strength, however it is not viable for the same heavy load-bearing structures in which steel is often employed.[18] Bamboo has flexural strength that is comparable to steel and could be used in its place in some roofs, partition walls, scaffolding, and other light-load construction, which could reduce construction cost by up to 25%.[19] The carbon sequestration benefit is one of the best reasons to consider bamboo as a structural alternative to steel. 100 kg of bamboo would be responsible for sequestering approximately 305.6 kg of CO_2, while 100 kg of steel would be responsible for approximately 185 kg of CO_2 emissions.[20]

Recycled Rubber

Natural rubber is produced by extracting sap, called latex, from certain trees, making it an organic and renewable material. Synthetic rubber is composed of plastic polymers that create a rubber-like substance. The largest uses of rubber worldwide are comprised of both natural and synthetic rubber, such as tires and tubes. While

[16] "Bamboo Biodiversity," accessed November 26, 2021, https://www.eeob.iastate.edu/research/bamboo/maps.html.
[17] "Bamboo Botanicals - Soil For Bamboo," accessed November 26, 2021, https://www.bamboobotanicals.ca/html/bamboo-care/soil-for-bamboo.html.
[18] "Comparative-Analysis-Of-The-Tensile-Strength-Of-Bamboo-And-Reinforcement-Steel-Bars-As-Structural-Member-In-Building-Construction.Pdf," accessed November 26, 2021, http://www.ijstr.org/final-print/nov2015/Comparative-Analysis-Of-The-Tensile-Strength-Of-Bamboo-And-Reinforcement-Steel-Bars-As-Structural-Member-In-Building-Construction.pdf.
[19] Durga G et al., "Comparison in Characteristics of Bamboo and Steel Reinforcement," April 9, 2021.
[20] Paul F. Laleicke et al., "COMPARATIVE CARBON FOOTPRINT ANALYSIS OF BAMBOO AND STEEL SCAFFOLDING," *Journal of Green Building* 10, no. 1 (April 2015): 114–26, https://doi.org/10.3992/jgb.10.1.114.

natural, non-vulcanized rubber is capable of decomposition in 50 years, vulcanization causes the rubber to resist decomposition for over 100 years. Due to its plastic properties, synthetic rubber will take centuries to decompose; and when it does, it will release harmful chemicals into the atmosphere.[21]

However, both natural and synthetic rubber can be recycled. Ecore is a Pennsylvania company that recycles 50 million pounds of rubber a year for flooring, acoustical, and industrial products. Global Environment Manufacturing (GEM) developed Euroshield, a rubber shingle roofing product that contains between 600 to 1,000 rubber tires on average and costs less than your average standing-seam metal roof. A professor and researcher at the University of Akron, named Avraam Isayev, has developed an ultrasonic devulcanization process to break the chemical bonds of vulcanized rubber, returning it to a malleable state. This would allow the rubber to be re-shaped and re-cured for alternative uses.[22]

Linoleum

Linoleum is a floor covering invented in 1860 that is composed of linseed oil, wood fibers, resin, mineral fillers, and burlap or canvas backing. It soared in popularity from the late 1800s until around 1960, when cheaper vinyl flooring began to replace linoleum in many buildings. While vinyl is slightly cheaper, easier to install, and 100% water-proof, its environmental effect has often been overlooked.

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[21] "How Long Does It Take to Degrade Rubber? – SidmartinBio," accessed November 26, 2021, https://www.sidmartinbio.org/how-long-does-it-take-to-degrade-rubber/.
[22] author/wanda-lau, "Revolutionary Building Products Made from Rubber," Architect, February 22, 2013, https://www.architectmagazine.com/technology/products/revolutionary-building-products-made-from-rubber_o.

Vinyl, or polyvinyl chloride (PVC), is a synthetic material composed of chlorine and ethylene. It is inert, meaning it will not break down or degrade. It is recyclable and partially renewable, and safe methods of incineration have been developed – but that depends on all used PVC to be filed into the proper stream of recycling to maintain a sustainable lifecycle.[23] Otherwise, the plastic that ends up in landfills or the environment is detrimental. On the other hand, when it is taken care of properly, linoleum can last up to 40 years and is completely biodegradable after it has served its purpose.[24]

Soy-based Sealants

Silicone is a synthetic material, in the plastic or rubber family, that has been widely used in the building industry for almost a century. It has been used mostly for its strong yet malleable nature as well as its humidity-resistant properties, keeping hot or cold air from passing through it.[25] Unfortunately, it poses the same issue to the environment that any other plastic does – its lifecycle is not sustainable. A series of soy-based sealants have been developed over the past few years for wood and concrete. These sealants are derived from soybean oil, which is responsible for many other bio-based products and fortunately, is abundant.[26] As of 2018, the United States

[23] "An Introduction to Vinyl," accessed November 27, 2021, https://www.azom.com/article.aspx?ArticleID=987.
[24] Marieke Gorrée et al., "Environmental Life Cycle Assessment of Linoleum," *The International Journal of Life Cycle Assessment* 7 (May 1, 2002): 158–66, https://doi.org/10.1007/BF02994050.
[25] "Building Endless Possibilities for Construction - CES - Silicones Europe," accessed November 27, 2021, https://www.silicones.eu/silicones/benefits/silicones-building-endless-possibilities-for-construction/.
[26] "Performance and Sustainability: Soy-Based Adhesives and Sealants Excel in Wide-Ranging Applications," accessed November 27, 2021, https://www.adhesivesmag.com/articles/97755-performance-and-sustainability-soy-based-adhesives-and-sealants-excel-in-wide-ranging-applications.

is the leading producer of soybeans (108 million metric tonnes).[27] A study of bio-based sealants and adhesives compared to silicone determined that soy protein and other organic matter have comparable performance to silicone's strength and water resistance. Soy protein alone has relatively low strength and is susceptible to water; but when combined with a marine adhesive protein model, its performance in these areas is significantly improved.[28]

Cellulose Insulation

Cellulose insulation is a loose, blown-in type of insulation made from post-consumer paper products, like newspaper. These paper products make up 75% to 85% of the insulation product, while the other 25% to 15% consists of fire retardants. The cost of cellulose insulation is competitive with traditional fiberglass batt insulation, with better insulation performance. The R-value of blown-in, cellulose insulation is between 3.2 to 3.8 per inch, while loose-fill fiberglass has an R-value of 2.2 to 2.7 per inch. This is in-part due to the density of cellulose insulation, which also gives it added acoustic insulating properties. Cellulose insulation is completely biodegradable, while fiberglass insulation is not. However, this means that the helpful lifespan of cellulose insulation is shorter, approximately 30 years, compared to 100 years with fiberglass, assuming no damage or exposure to moisture. [29]

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[27] "10 Countries With Largest Soybean Production," WorldAtlas, August 30, 2018, https://www.worldatlas.com/articles/world-leaders-in-soya-soybean-production-by-country.html.
[28] Solange Magalhães et al., "Brief Overview on Bio-Based Adhesives and Sealants," *Polymers* 11, no. 10 (October 15, 2019): 1685, https://doi.org/10.3390/polym11101685.
[29] Tobias Roberts Writer Rise, "Cellulose Insulation: Sustainable and High-Performance," Rise, October 5, 2020, https://www.buildwithrise.com/stories/cellulose-insulation.

Cotton Insulation

Cotton batt insulation is composed of 90% to 100% recycled material, such as denim, and a natural non-toxic fire retardant. This insulation performs better than fiberglass insulation in high wind and cold environments, and it has a better acoustic insulating performance as well. The R-value is roughly 3.4-3.7 per inch. This type of insulation requires little energy to manufacture and contains no chemical irritants, making it safe for anyone to install; however, it is more difficult to insulate attics or other tight spaces, than it would be to use loose, blown-in insulation. It is naturally resistant to mold, fungus, and pests. [30]

Slate Tile

Slate is derived from shale-type sedimentary rock of clay or volcanic ash that has undergone low-grade regional metamorphism. It requires very little processing to be used in architectural applications, minimizing CO_2 production and water consumption. Slate is naturally water-resistant, fireproof, and extremely durable, lasting well over 100 years in most applications. The applications range from roofing to flooring, siding to décor. As far as mining slate in the United States, it is most abundantly found in Vermont, New York, Virginia, and Pennsylvania. [31]

[30] "What Is the Best Insulation for a Home?," accessed November 27, 2021, https://www.ecohome.net/guides/2372/choosing-the-right-insulation-the-pros-cons-and-applications/.
[31] "Everything You Need to Know about Slate," Slateplate, accessed November 27, 2021, https://www.slateplate.com/pages/all-about-slate.

Clay

Clay is a natural rock material that has been used in construction for centuries. Brick is one of the most common clay building products. A brick is formed by mixing raw clay with water to make it malleable and shaping it into the desired form, then drying and firing it to cure and solidify the unit. [32] Brick can be expected to last 100 years or more, with minimal maintenance. When discarded, brick naturally releases its minerals, benefiting the surrounding soil. Brick can also be recycled after its original use, if still in good shape. [33] Clay is an abundant material across the globe, mostly where rocks come in contact with water or steam. [34]

Mycelium

A newer, experimental building material is the mycelium brick. Mycelium is the fibrous, vegetative root structure of fungi. A sturdy mycelium brick can be produced by combining mycelium with organic matter, such as straw, inserting the mixture into formwork, allowing the mycelium to grow, and then baking it to solidify the module. [35] As of now, mycelium bricks do not compare to the strength of clay bricks. Mycelium bricks only hold up under a compressive strength of 0.2 MPa, whereas clay bricks can withstand 28 MPa. However, they are 60 times lighter than

[32] "Manufacturing of Brick," n.d., 7.
[33] Constro Facilitator, "Use of Different Types of Clay in Construction," *Constro Facilitator* (blog), February 5, 2020, https://www.constrofacilitator.com/use-of-different-types-of-clay-in-construction/.
[34] "1999 - Information Handout.Pdf," accessed November 27, 2021, https://pubs.usgs.gov/info/clays/clays.pdf.
[35] biofilters, "Grow Architectural Models With Mushrooms," Instructables, accessed November 27, 2021, https://www.instructables.com/Grow-Architectural-Models-with-Mushrooms/.

clay bricks and have an R-value of R-4 per inch. Considering this, mycelium is more suitable for non-loadbearing and insulating structures. [36]

Indigenous Building Materials and Methods

There is a wealth of knowledge and precedents in the indigenous building practices of different cultures around the world that have been used for centuries. These principles and building strategies can be adapted and applied to modern-day building methods.

Lake Titicaca, in Peru, is home to the Uros people, who live on small islands that they have constructed out of local, organic materials such as totora reeds, peat root, and eucalyptus. The Uros people were forced to explore building and establishing their civilization on the water to protect themselves from rival tribes, including the Incan People. The Uros people have outlasted the Incans' monumental stone temples with their precarious, floating lifestyle, that is subject to and harmoniously in unison with the changing tide of Lake Titicaca. The Uros use totora

Figure 5: Traditional village on Uros Islands, general view. (Vickery, Robert L. American architect and university professor)

[36] Diederik van der Hoeven, "Mycelium as a Construction Material," Bio Based Press, April 7, 2020, https://www.biobasedpress.eu/2020/04/mycelium-as-a-construction-material/.

reed to construct the top layer matting of the islands, their houses, other structures, boats, and more. The islands and everything built on them are entirely biodegradable, capable of natural decomposition.[37]

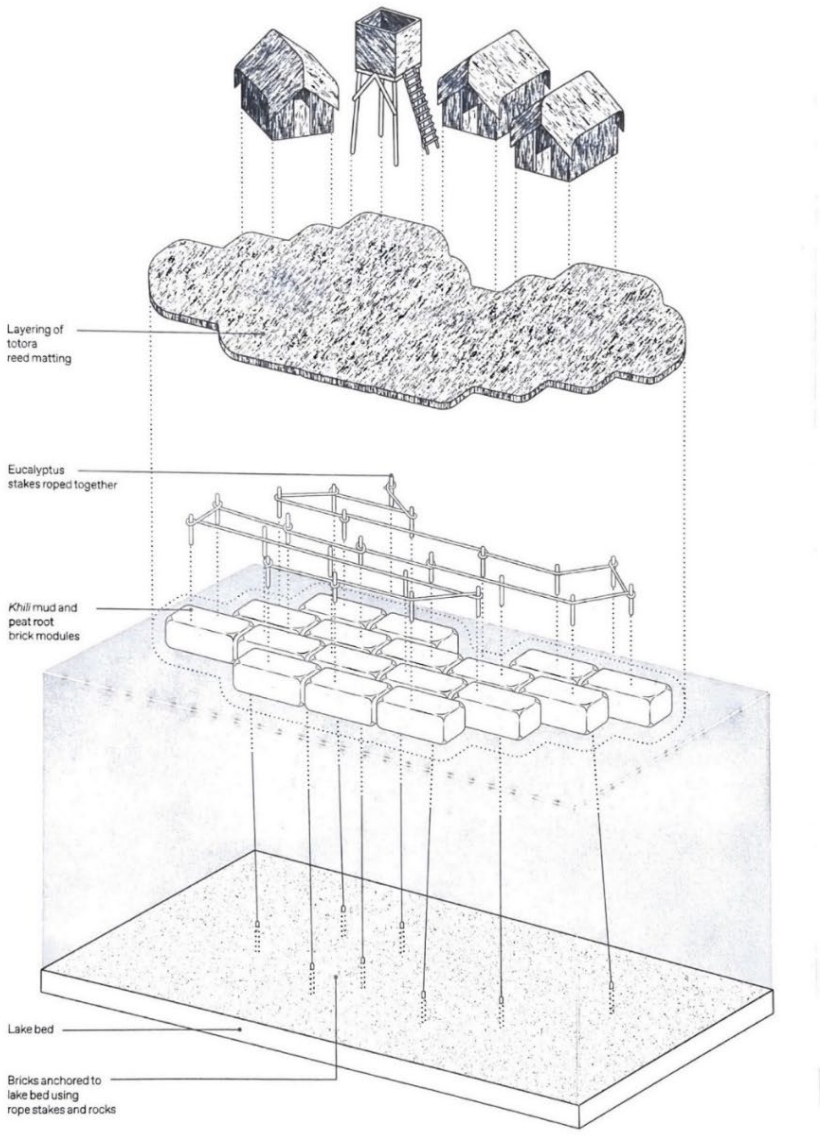


Figure 6: Diagram of the Uros' floating islands (Julia Watson, Lo-TEK)

[37] Julia Watson, *Lo-TEK: Design by Radical Indigenism* (Cologne [Paris]: Taschen, 2019).

African vernacular architecture is a diverse and beautiful array of earth-founded structures. In Africa, the most common building material is mud, which is used in a variety of ways. Mud is formed into bricks, clumped together in layers, used to fill in reed or bamboo frames, and pressed into wooden formwork to make rammed earth walls. The indigenous materials used for construction in the West African country, Ghana, include bamboo, straw, laterite, timber, and stone. The Zaina Lodge in Mole National Park was inspired by The Great Mosque of Djenne (Figures 7 and 8). This luxury lodge provides visitors a comfortable stay, while beautifully exemplifying the raw earth materials that have been used to build modest huts for centuries. The lodge also relieves visitors from having to stay at the only other accommodation at the park, a dingy, white modernist, concrete blemish in the park landscape, the Mole Motel.

Figure 8: The Great Mosque of Djenne, Exterior, Detail. (James Conlon)

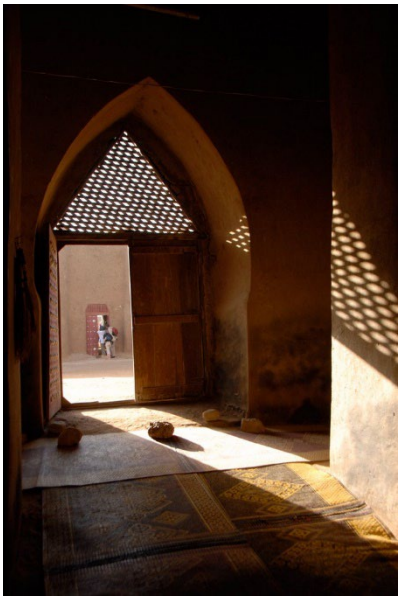


Figure 8: The Great Mosque of Djenne, Interior. (James Conlon)

Similarly, the first known inhabitants of North America used organic building materials from the earth around them. The Piscataway people, and other northeast tribes, constructed dome-shaped wigwams out of stick frames, tree bark, moss, and reed mats, or thatch.[38] When the Americas began to be colonized in the early 1600s (with Jamestown established in 1607), brickmaking followed shortly after. The colonists observed an abundance of clay and shale in the northeast, allowing them to produce bricks themselves, rather than import them from across the Atlantic. The first American brick kiln was created in 1629, in Salem Massachusetts.[39] Whether they knew it at the time or not, by introducing brick, the colonists were changing the vernacular of North American architecture.

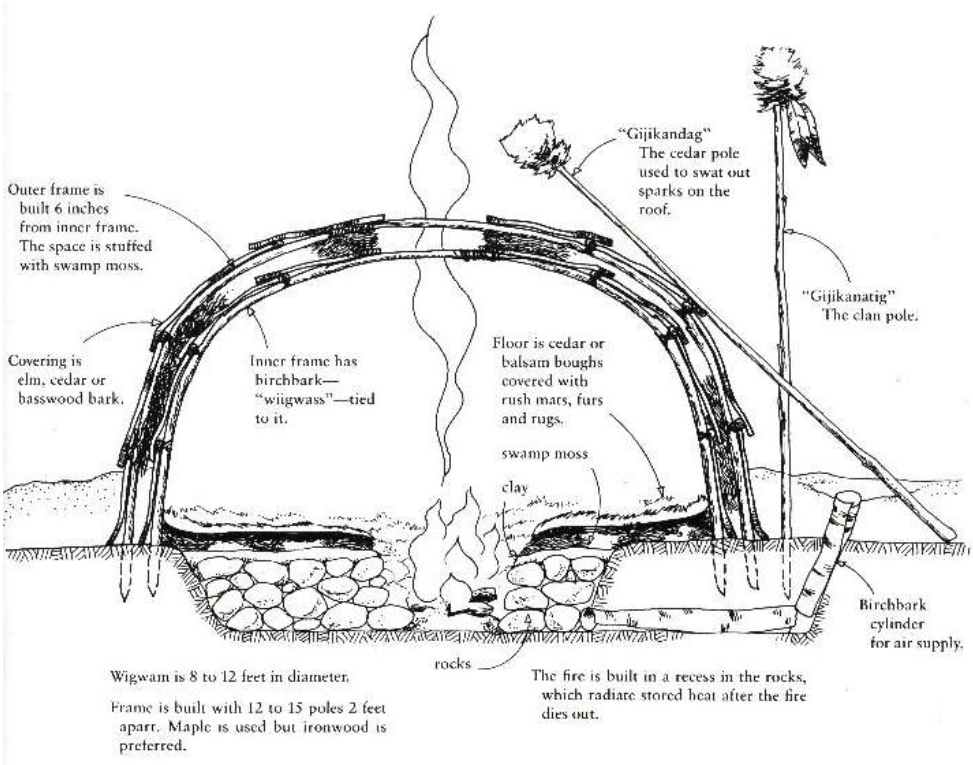


Figure 9: Inventive wigwam with double wall and radiant floor. (Nabokov and Easton, Native American Architecture.)

[38] Peter Nabokov and Robert Easton, *Native American Architecture* (New York: Oxford University Press, 1989).
[39] "Brickmaking History," accessed November 6, 2021, http://brickcollecting.com/history.htm.

Design for Disassembly

Japanese temples constructed entirely out of timber have stood for over 1000 years. Iron and other durable materials were difficult to acquire, so early Japanese builders looked beyond the material and found a method that could achieve structural longevity. These ancient temples are constructed without fasteners, like screws or nails, but by using wood joinery, the craft of connecting and securing the separate members of the wooden construction to one another by means of specific cuts on the ends or sides of the members.[40] This not only allows the wood members to expand and contract together, maintaining a secure connection, but it allows the members to be disassembled. Every 150 to 200 years, these temples undergo repair. Any parts that may be showing signs of rot or weakening is easily removed and replaced.[41]

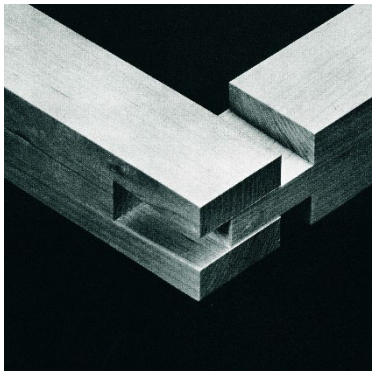


Figure 11: Open slot mortise (The Art of Japanese Joinery by Kiyosi Seike)

Figure 10: Horyuji Temple, completed in 607 AD (Bacon, Edmund Norwood)

[40] "Woodworking Joints," Craftsmanspace, accessed February 3, 2022, https://www.craftsmanspace.com/woodworking-joints.
[41] Great Big Story, *In Japan, Repairing Buildings Without a Single Nail*, 2019, https://www.youtube.com/watch?v=O-u4T13guko.

Though this practice has been in use for centuries, the phrase "design for disassembly" was only coined recently, in the 90s. It has been an important aspect of the Built Positive movement that recognizes that building systems and structure do not expire in the same time frame and allows each piece of a building to be extracted with the intention of reuse at the end of its first life. This method helps retain the value of the material, maximize carbon offset, and minimize waste.

"We currently design buildings as if they'll never be taken down. Design for disassembly is a fundamental principle that informs decisions and material choices, changing how materials are joined together and how they are layered in a way that is accessible, reversible, and robust." – Richard Boyd, Materials Consultant, and Chartered Engineer for Arup in London [42]

Designing for disassembly using natural, biodegradable building materials – so that at the end of their n^{th} life the materials can naturally and harmlessly decompose – can potentially be an extraordinarily eco-friendly building model.

The design for disassembly strategy faces a couple of valid (but surmountable) challenges. First, the strategy requires a great deal of planning, including a deconstruction plan, and choosing or designing connection details. Structural connections must be made without any chemical bonding, such as welding or glues, so that they can be easily dismantled without damaging the material that is

[42] "What Is Design for Disassembly? - News - Cradle to Cradle Products Innovation Institute," accessed November 6, 2021, https://www.c2ccertified.org/news/article/what-is-design-for-disassembly.

intended for reuse. Secondly, more research must be done on the part of the architect when selecting materials to understand their life cycles and recycling potential to ensure they are of good quality, especially after more than one use.[43]

Multipod Studio's Pop-Up House is a structure composed of prefabricated wood panels and wood fiber insulating blocks that can be erected, and likewise dismantled, with only a cordless drill.[44] The material composition makes for an easy construction process, and it has a 100% bio-based, recyclable framework.[45] The models vary in size, the smallest being just under 1,000 square feet.

Figure 12: Series showing Pop-Up House construction (Multipod Studio)

KieranTimberlake's Cellophane House was a case study in assembly, adaptability, and disassembly. Its core element was an aluminum frame that was, in

[43] "A Guide to Design for Disassembly," ArchDaily, July 10, 2020, https://www.archdaily.com/943366/a-guide-to-design-for-disassembly.
[44] "Pop-Up House / Multipod Studio," ArchDaily, March 17, 2014, https://www.archdaily.com/486587/pop-up-house-multipod-studio.
[45] "Plaquette_ossature_biosourcee_part.Pdf," accessed November 6, 2021, https://www.popup-house.com/wp-content/uploads/2014/03/plaquette_ossature_biosourcee_part.pdf.

theory, capable of housing a variety of programs, sheathed in a variety of materials to respond to a variety of climates and user needs. In the case of its realization for the Museum of Modern Art in New York, Cellophane House was sheathed in structural plastic that acted as filter for light and air. The house was made up of prefabricated "chunks", which took only six days to assemble on site. However, the true test was deconstruction. They disassembled the entire structure with basic handheld tools and removed from the site within two days, leaving no waste and retaining all of the embodied energy in the used materials. [46]

Figure 13: The Cellophane House (KieranTimberlake)

[46] Home Delivery: Fabricating the Modern Dwelling exhibit The Museum of Modern Art et al., "Cellophane House | Prefabricated Architecture & Design for Disassembly," accessed November 6, 2021, https://kierantimberlake.com/.

Chapter 3: Homelessness

"Architecture is a threshold through which we pass into the possibility of being human…" – Marvin Trachtenberg, *Building-In-Time*

The State of Homelessness

The commodification of buildings has posed a challenge to this egalitarian view of architecture. Therefore, this thesis will apply an adaptable, accessible, affordable, and eco-friendly building model to serve the homeless community.

The U.S. Department of Housing and Urban Development presented its key findings in the 2020 Annual Homeless Assessment Report (AHAR) to Congress.[47] This report is based on a point-in-time count from January 2020, reflecting the state of homelessness in America before COVID-19 interrupted the status quo and exacerbated the conditions. The key findings are as follows:

- The total number of people in the United States experiencing homelessness in 2020 was roughly 580,000. 61% of that population were staying in shelters, while 39% were unsheltered.
- National homelessness increased for the fourth consecutive year.
- More people experiencing homelessness were unsheltered than were sheltered in 2020. The number of sheltered individuals remained roughly the same, while the number of unsheltered individuals increased 7%.
- There was a 15% increase in people with chronic patterns of homelessness.

[47] "The 2020 Annual Homeless Assessment Report (AHAR) to Congress," n.d., 102.

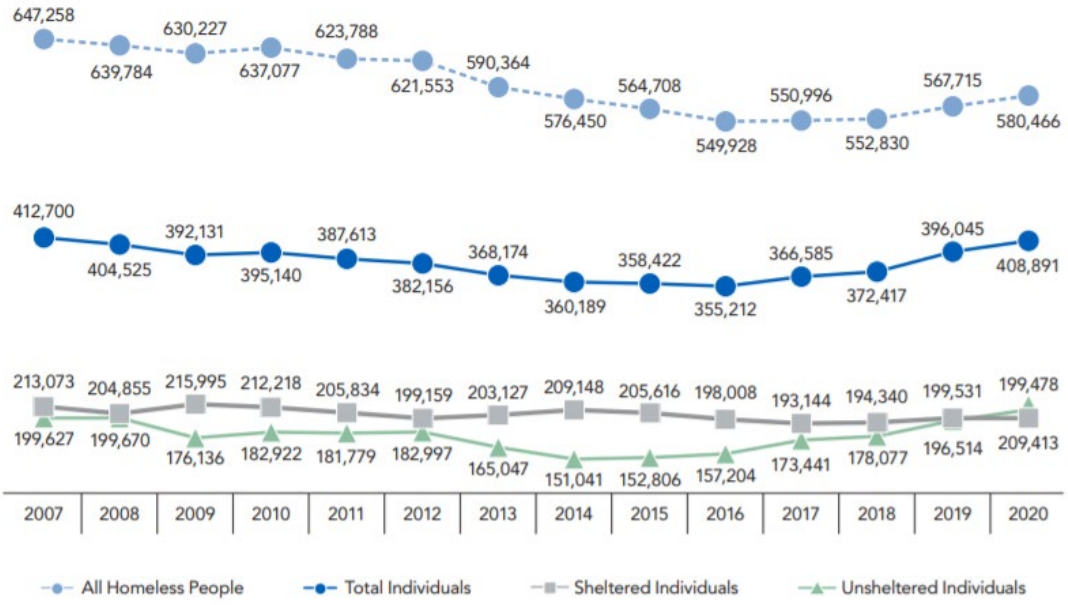


Figure 14: PIT Estimates of Individuals Experiencing Homelessness 2007-2020 (Sheltered Status)

A variety of circumstances may lead to homelessness. According to the National Law Center on Homelessness & Poverty, [48] as of 2015, the leading causes of homelessness among U.S. families were:

1. Lack of affordable housing
2. Unemployment
3. Poverty
4. Low wages

The leading causes among unaccompanied individuals similarly were:

1. Lack of affordable housing
2. Unemployment
3. Poverty

[48] "Homeless_Stats_Fact_Sheet.Pdf," accessed November 10, 2021, https://homelesslaw.org/wp-content/uploads/2018/10/Homeless_Stats_Fact_Sheet.pdf.

4. Mental illness and the lack of needed services
5. Substance abuse and the lack of needed services

These issues are magnified in certain cities where affordable housing is scarce, and cost of living is high. In 2020, the average rate of homelessness in America was 18 out of every 10,000 people. The rate in the District of Columbia was 90.4 out of every 10,000 people, which is nearly a 20% increase of the total homeless population in the city from 2007. In that same time frame, the unsheltered population rose 92% and the number of homeless families increased 52%. This issue is pervasive throughout other cities with a high cost of living and limited affordable housing. San Francisco has a homelessness rate of 92.2 per 10,000 people, equating to about 8,000 homeless. New York City has a rate of 93.5 per 10,000 people, equating to almost 78,000 homeless. [49]

The capacity to shelter the growing population of people experiencing homelessness in these cities is limited and in need of increase. New York City has beds available for 92% of the homeless population, but that still leaves 3,000 people on the street. The District of Columbia has a capacity of 87%, leaving 500 individuals unsheltered. The worst of all is San Francisco, which only has a 36% capacity, leaving nearly 5,000 people on the street.

Not only do the shelters in these cities need increased capacity, but they also need to be designed and built to a higher standard of quality. Despite the limited capacity, each city had between 100 and 1,000 empty beds throughout the course of

[49] "State of Homelessness: 2021 Edition," National Alliance to End Homelessness, accessed November 10, 2021, https://endhomelessness.org/homelessness-in-america/homelessness-statistics/state-of-homelessness-2021/.

the year. David Pirtle, a member of the Faces of Homelessness Speakers' Bureau who was once homeless himself, commented on this preference for staying on the street over staying in a shelter, "…part of the reason was, and I think this is more generally the case with people, is that you hear a lot of terrible things about shelters, that shelters are dangerous places, that they're full of drugs and drug dealers, that people will steal your shoes, and there's bedbugs and body lice. And yeah, unfortunately a lot of those things are true." [50]

Other reasons for this avoidance of shelters are cited by Jason Wasserman in his book, *At Home on the Street: People, Poverty and a Hidden Culture of Homelessness.* He writes, "Originally, we thought that the problem with homeless services was that they were not funded enough… We became more critical of the services once we started looking into them. It seemed the shelters dealt with addiction and mental illness almost exclusively. That's great if that's your problem, but alienating if it's not. One thing nearly all homeless people do want is jobs. They don't want treatment or even meals. But they will work, and they will push and shove to get a job."[51]

Bowery Residents' Committee (BRC) shares another opinion on this, related to the autonomy that living unsheltered provides as opposed to living in a shelter, "Living unsheltered isn't easy, but you're autonomous. Shelters have structure and rules: curfews, schedules, no outside food, no alcohol, limited smoking breaks, and

[50] N, P, and R, "Why Some Homeless Choose The Streets Over Shelters," *Talk of the Nation* (NPR, December 6, 2012), https://www.npr.org/2012/12/06/166666265/why-some-homeless-choose-the-streets-over-shelters.
[51] Jason Adam Wasserman and Jeffrey M. Clair, *At Home on the Street: People, Poverty, and a Hidden Culture of Homelessness* (Boulder, Colo: Lynne Rienner Publishers, 2010).

limits on visitors. This has a practical benefit; sensible from the perspective of maintaining health and safety. But it limits the freedom that comes naturally with living unsheltered, or in your own home. Living in a shelter also means living among people you don't know, may not trust, or even fear. Further, most of our clients have lived in shelters before, and often in other institutional settings as well (such as foster care, hospitals, residential treatment, jail and prison, halfway and three-quarter houses, etc.); their lack of success from these past experiences only reinforces their doubts that anyone wants to or can help them."[52] It is the architect's responsibility to respond to and consider these perspectives of architectural hostility.

[52] "Why Would a Homeless Person Not Want to Go to a Shelter? | BRC," accessed November 10, 2021, https://www.brc.org/why-would-homeless-person-not-want-go-shelter.

Homelessness in the District

Figure 15: "Homeless man sleeping in John Marshall Park, NW Washington, DC" (rjs1322 is licensed under CC BY-SA 2.0)

Washington, D.C. was chosen for this exploration due to the massive wealth disparity,[53] lack of affordable housing, high rates of homelessness and a recent government investment in addressing these issues.

In July 2021, Mayor Muriel Bowser released the FY2021-2025 plan to end homelessness, called Homeward 2.0. The major goals of the original plan were to end homelessness among veterans by the end of 2015; end chronic homelessness among

[53] "25 Richest Cities in the US: Does Your Metro Area Make the List?," accessed December 14, 2021, https://www.usatoday.com/story/money/economy/2018/05/17/25-richest-cities-in-america/34991163/.

single adults and families by the end of 2017; and reduce overall homelessness by 65% by the end of 2020. This last goal fell short about 26%, in large part due to the COVID-19 pandemic. Homeward 2.0 outlines key findings from the last five years, including that while the District has made progress in reducing the homeless population overall, that progress has not been even among individuals and families.[54]

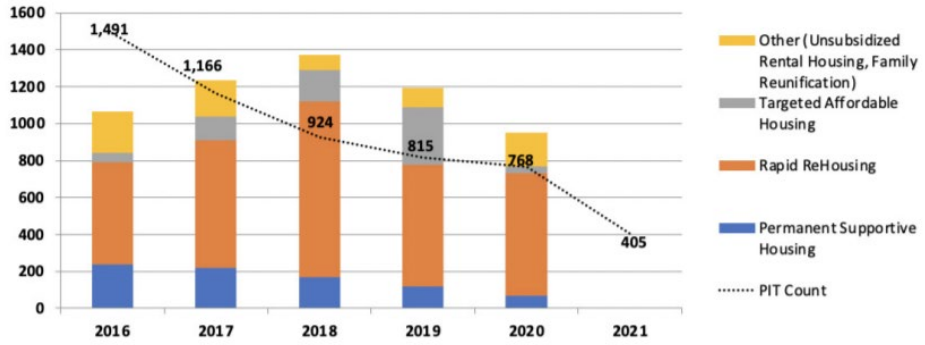


Figure 16: Number of Families Exiting to Permanent Housing (By Year) vs Changes in Family Homeless, as Measured by the PIT Count (Interagency Council on Homelessness)

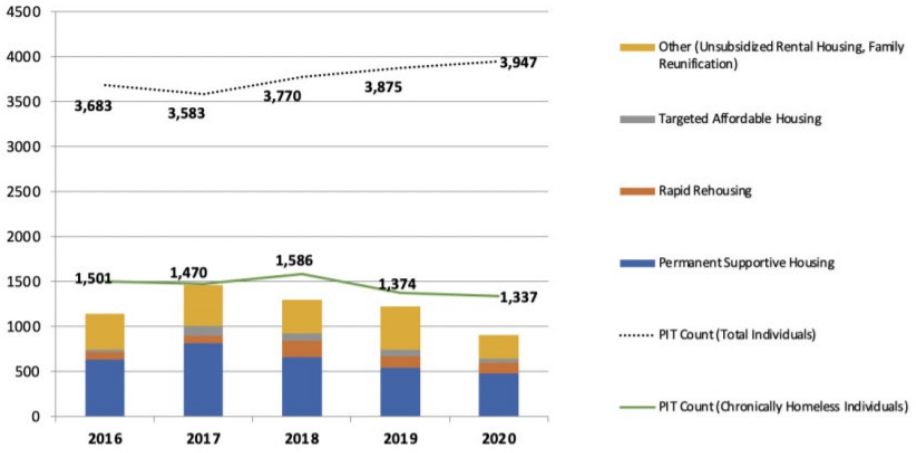


Figure 17: Figure 15: Number of Individuals Exiting to Permanent Housing (By Year) vs Changes in Homelessness Among Individuals, as Measured by the PIT Count (Interagency Council on Homelessness)

[54] "Homeward-DC-Report_FY2021-2025.Pdf," accessed November 11, 2021, https://dmhhs.dc.gov/sites/default/files/dc/sites/dmhhs/page_content/attachments/Homeward-DC-Report_FY2021-2025.pdf.

A PIT Count was completed in August 2021 for the District of Columbia. It reported that the number of families experiencing homelessness is down 49% and credited the efforts to moving families into permanent housing rather than into emergency shelters. It also reported that the number of individuals experiencing homelessness is down by 1.9%, but the number of unsheltered individuals has increased 4.3% since 2020 and is expected to increase further as the eviction moratorium expires.[55]

There is a clear problem in Washington, D.C., and the United States with the lack of affordable housing and barriers to entry for extremely low income (ELI) residents. Mayor Bowser's Homeward 2.0 plan states that the issues of affordable housing and homelessness are intrinsically related. Homelessness is fundamentally about a lack of affordable housing options; therefore, housing is the answer to the homelessness problem. The plan also identifies housing insecurity as a much larger and deeper issue, noting, "Homelessness is the tip of the iceberg with regard to housing insecurity. It is the sharply visible peak atop a submerged crisis of inequity that keeps not only housing but many other basic resources out of reach for millions of Americans." [56]

Tent Cities

Homeless encampments, known as "tent cities," have continued to spring up around Washington, D.C. While some of which have been established for years,

[55] "Homelessness In DC," *The Community Partnership* (blog), accessed November 10, 2021, https://community-partnership.org/homelessness-in-dc/.
[56] "Homeward-DC-Report_FY2021-2025.Pdf."

Figure 18: "tree — freedom plaza" (bri— hefele is licensed under CC BY-NC 2.0)

others have come about during the pandemic. Those without shelter, or avoiding shelter for personal safety or other reasons, are forced to pitch a tent and make a precarious shelter for themselves.[57] Though the shelters themselves may be precarious, the comradery, for the most part, is strong. “There is a culture within the homeless community for people to be responsible, to help each other,” says Eric Sheptock, a longtime advocate for homeless people in DC and is himself, homeless. Tent cities are located throughout Washington, D.C.: under the K St bridge, next to the Kennedy Center, under the E St Expressway, R and 7th St NW, L St NW, by

[57] “D.C.?S ?Skid Row’: Homeless Encampments Thrive amid Pandemic - The Washington Post,” accessed October 25, 2021, https://www.washingtonpost.com/local/dc-skid-row-homeless-encampment/2021/08/16/11eda0d8-fc39-11eb-b8dd-0e376fba55f2_story.html.

Union Station, across from Gonzaga High School, and more. These are micro-communities that have formed out of mutual hardship and need. Aaron Howe, a Ph.D. candidate in anthropology at American University, has been studying the encampments in NoMa for years. He advocates for the homeless community as representing a culture, not just a problem for society to solve as if they aren't a part of society themselves. "One of the narratives I'm trying to change is that homeless are a homogenous, singular group that are only victims and they only need charity and help. I'm trying to show they actually have agency and are using rational thought," says Howe. He also studied the temporary communities of 19th-century logging villages established by mostly Finnish immigrants in Michigan. The location of these communities was subject to their logging trade, meaning that they would move along Lake Michigan to different camps, redefining the notion of "home." Howe applies the principles he learned through that study to his anthropological work with the homeless community now.[58]

The effort in Washington D.C., to house the homeless involves clearing encampments all around the city, new and old. Before the bulldozers and trash compactors come through, outreach workers offer the inhabitants housing vouchers and apartments weeks ahead of time, as part of the "housing first" model. From the point of view of those who live in these encampments, there is an understandable level of distrust. Out of the 60 or so people who resided under the L St overpass, 30 people moved into apartments, 7 were transferred to hotel rooms, and 9 people left

[58] "A New Way to View Homelessness: Not as a Problem but as a Culture," *Washington Post*, accessed October 25, 2021, https://www.washingtonpost.com/lifestyle/magazine/studying-homeless-as-a-culture-not-a-problem/2021/03/19/e64df6b6-66e8-11eb-bf81-c618c88ed605_story.html.

the encampment without entering the housing program. The rest remained in their place, while the clearing began around them. The housing first model has been criticized for prioritizing housing for some, while others remain on housing waitlists[59] – and those waitlists are extremely long,[60] because the housing stock in the city is limited. Washington D.C. must increase housing capacity to keep up with encampment clearing, but it takes time build up the housing stock, and surely in that time, homelessness will continue to increase.

[59] "D.C. Clears Longtime Encampment in NoMa in Kickoff to New Program to House the Homeless," *Washington Post*, accessed November 11, 2021, https://www.washingtonpost.com/dc-md-va/2021/10/04/noma-homeless-encampment-eviction/.
[60] "Apply for Public Housing," The District Alliance for Safe Housing, accessed November 11, 2021, https://www.dashdc.org/housing-resource-center/find-safe-housing/permanent-housing/apply-public-housing/.

Chapter 4: Housing Solutions

There are multiple homeless housing support models that have proven effective in reducing the number of unsheltered individuals and families. There is not one model that is the answer to everyone's housing needs, but different housing types are suited for different people.

Typical Shelters

Early homeless shelters were characterized by high density, uniformity, rigidity, and a lack of consideration of design. They were unsanitary and afforded people little to no privacy. Shelters presented a form of institutionalization that posed a threat to the individual dignity. [61] Today, shelters face some of the same challenges, however the typical shelter today is built to an intended capacity, rather than adapting a space that was never intended for habitation and cramming in as many people as possible. The issues of crime and lack of autonomy are still cited as reasons for not wanting to go to a shelter and choosing to instead stay on the street.[62] When shelters are done properly, they provide warm and dry living conditions, a shower, meals, clothes, and other services to assist with and reduce their guest's time on the street.

Emergency Shelters

An emergency shelter is an emergency housing option for people in crisis situations. Emergency shelters are like the typical shelter in many ways. The main difference between the two is that an emergency shelter will allow guests to stay

[61] Sam Davis, *Designing for the Homeless: Architecture That Works* (Berkeley: University of California Press, 2004).
[62] "Why Would a Homeless Person Not Want to Go to a Shelter?"

during the day, whereas the typical shelter closes its doors to guests during the day, making room for new guests the following night. An emergency shelter may also not have all the same resources that a typical shelter may have, such as job search assistance.

Transitional Housing

Transitional housing is an enrollment program that provides temporary housing for up to 24 months. In that time, the client engages in supportive services that improve their employability and help them find a permanent housing solution as quickly as possible.[63] The typical transitional house is a regular home that has been designated to support a small number of individuals (generally fewer than 10). This way, the available resources and support are focused and specifically tailored to the needs of those individuals.

Skidmore Owings and Merrill completed a transitional housing project for the City of New York in 1989. The intention was to maximize occupancy, while creating smaller communities within, to avoid the institutionalization effect that is common in typical shelters. This was achieved by organizing the building into "houses" with eight bedrooms each. A pair of houses share hygienic facilities, and four pairs are arranged around kitchen, living, and dining spaces. The 'house' module was stacked and repeated on four different sites.[64]

[63] "Types of Housing Support for the Homeless," *United To End Homelessness* (blog), January 31, 2019, https://unitedtoendhomelessness.org/blog/types-of-housing-support-for-the-homeless.
[64] "David Walker Architects," accessed November 11, 2021, http://davidwalkerarchitects.com/projects/transitional-housing.

Other forms of transitional housing have resulted from innovative responses to the housing crisis. Dignity Village began as an encampment underneath a bridge, in Portland, Oregon, where roughly 70 people had been relocated multiple times over the course of a year. In fall 2001, the city allowed the community to settle on a paved lot at the edge of town.[65] Since then, the community has established its own articles of incorporation, bylaws, and even a contract with the city of Portland. The following are three selections from the eight points in section 1.03 of the Dignity Village bylaws. These points begin to illustrate who they are and what their primary purposes are:[66]

> (1) To create a safe, clean, self-governed community environment for economically distressed residents of the State of Oregon… until they are able to access another form of housing more in keeping with said resident's personal goals and aspirations.
>
> (2) To promote community wide interest and concern for homeless and other economically distressed residents of the State of Oregon, to the end that: (a) their quality of life may be improved, (b) their educational and economic opportunities may be improved, (c) sickness, poverty and crime may be lessened, (d) all constitutional and human rights of all people are respected and protected, (e) mutual interdependence of all people may be recognized, and (f) the mutual aid among, by and for poor people may be facilitated.

[65] Davis, *Designing for the Homeless*.
[66] "Bylaws," *Dignity Village* (blog), April 21, 2015, https://dignityvillage.org/governance/bylaws/.

(3) To provide basic living facilities for otherwise homeless individuals, using temporary, semi-permanent and/or permanent structures, and to engage in alternative, sustainable, earth-friendly housing development and production and related activities in order to improve the living conditions and economic well-being of said individuals.

Figure 19: "Dignity Village house" (enough is licensed under CC BY-NC-ND 2.0)

Rapid Re-Housing (RRH)

The Rapid Re-Housing model is a “housing first” strategy that targets non-chronically homeless individuals and families, assisting them in finding housing as soon as possible. The individual or family rents the property at a temporary rate that meets their financial capabilities, while they receive financial and community support services. The Rapid Re-Housing strategy is responsible for the 49% decline in homeless families in DC, between 2020 and 2021.

Permanent Supportive Housing (PSH)

Permanent Supportive Housing is a long-term "housing first" program to house chronically homeless individuals, often with physical or mental disabilities that make it difficult for the person to work. The program involves intensive support services to respond to each individual's varied needs.

La Casa is a Permanent Supportive Housing project in Washington, D.C. that is designed to "inspire pride and a sense of community membership in its residents." La Casa introduced a new typology of shelter to D.C. in 2014, giving people, struggling with chronic homelessness, private units with all the necessary amenities, while providing them with the resources, support, and rehabilitation they need. The crucial aspects of this model are autonomy, stability, and a sense of home, rather than institution.

Supportive Housing projects often commit to one of the above types, serving the needs of the demographic best suited for the program. That could be individuals or families, chronically homeless or those in crisis, those seeking regular care or those looking for their own house and a job. However, grouping housing types together, sharing resources and social services, could result in a functionally interdependent, supportive community.

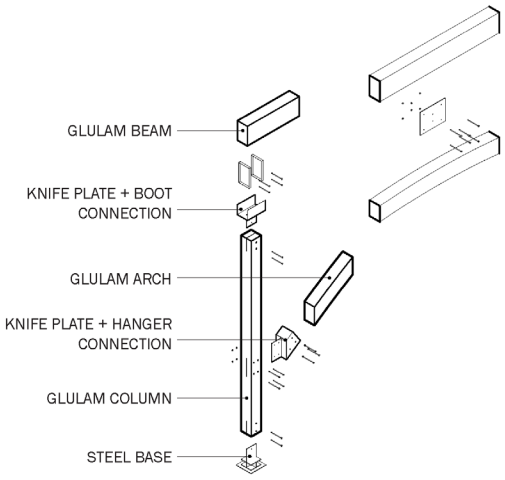
Chapter 5: The Design Solution

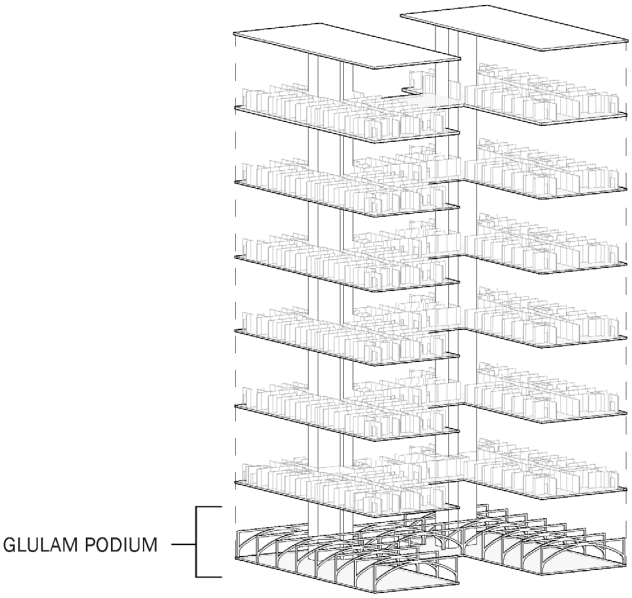
I have developed 3 models to test this theory and these materials at different scales within the “res economica” of DC - A mid-rise, a townhome, and an accessory dwelling unit. My approach to these different scales was to determine the viable materials, design each wall section assembly, design the exterior expression and the interior expression of these materials at the human scale. Then I dove into greater detail, beginning with the smallest scale as the furthest potential adoption of this theory.

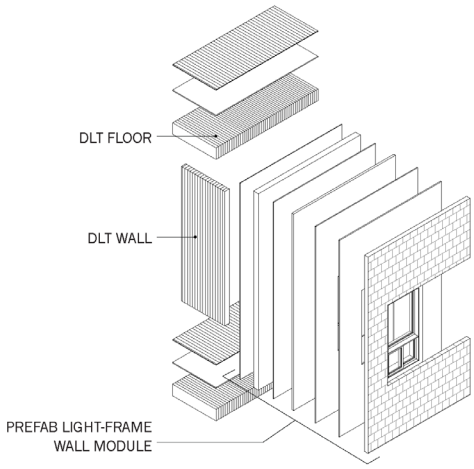
Large Scale: Mid-rise

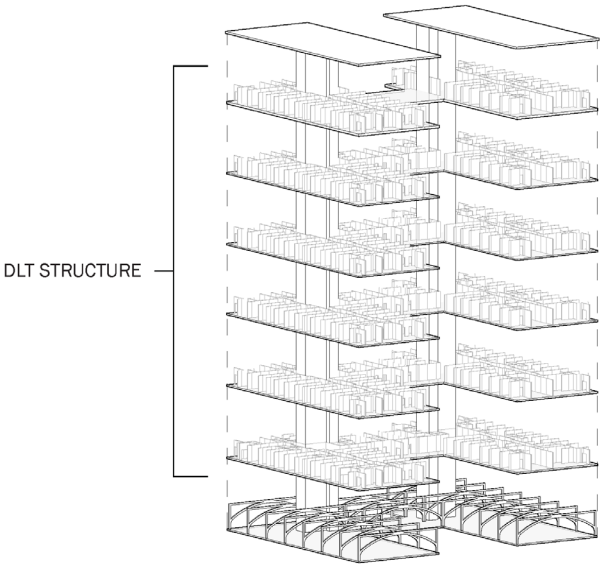
The first of these three scales is the Mid-Rise. The key materials here are Dowel-Laminated Timber, Glue Laminated Timber, Copper, Terracotta, hemp, and Wood Fiber. The building has two wings, one for multi-family with 2 and 3 bedroom units and the other is Permanent Supportive Housing with mostly 1 bedroom units. The building is constructed atop a glulam podium. The glulam arches span over large areas for commercial or public use. Above that are load bearing DLT walls. DLT panels make for good shear walls, party walls, and insulated partitions between units. Dowel laminated panels are comprised of 2x softwood lumber pressed and drilled, then a hardwood dowel is inserted. The differing moisture content of the woods causes the dowel to expand and creates a tight friction fit. Because DLT is an all-wood assembly, it can be CNC routed for utilities, acoustics, or aesthetics. And aesthetically speaking, DLT creates unique and beautiful interior spaces. Prefabricated light frame panels are fixed to the DLT structure to enclose the building. Those light frame panels are filled with hemp wool insulation. Hempwool is a plant-based product, therefore it is carbon-storing. It is safe to handle and contains zero toxins unlike fiberglass, and it is comparable in its efficiency with an R-value of 3.5 per inch. Outboard of that is a continuous wood fiber rigid insulation board, copper, and terracotta cladding. Terracotta is quite literally “cooked earth”, and we have an abundance of raw clay to source from. Non-combustible, beautifully aged, easily recyclable, and capable of natural degradation, releasing nutrients back into the environment, terracotta was an easy choice here.

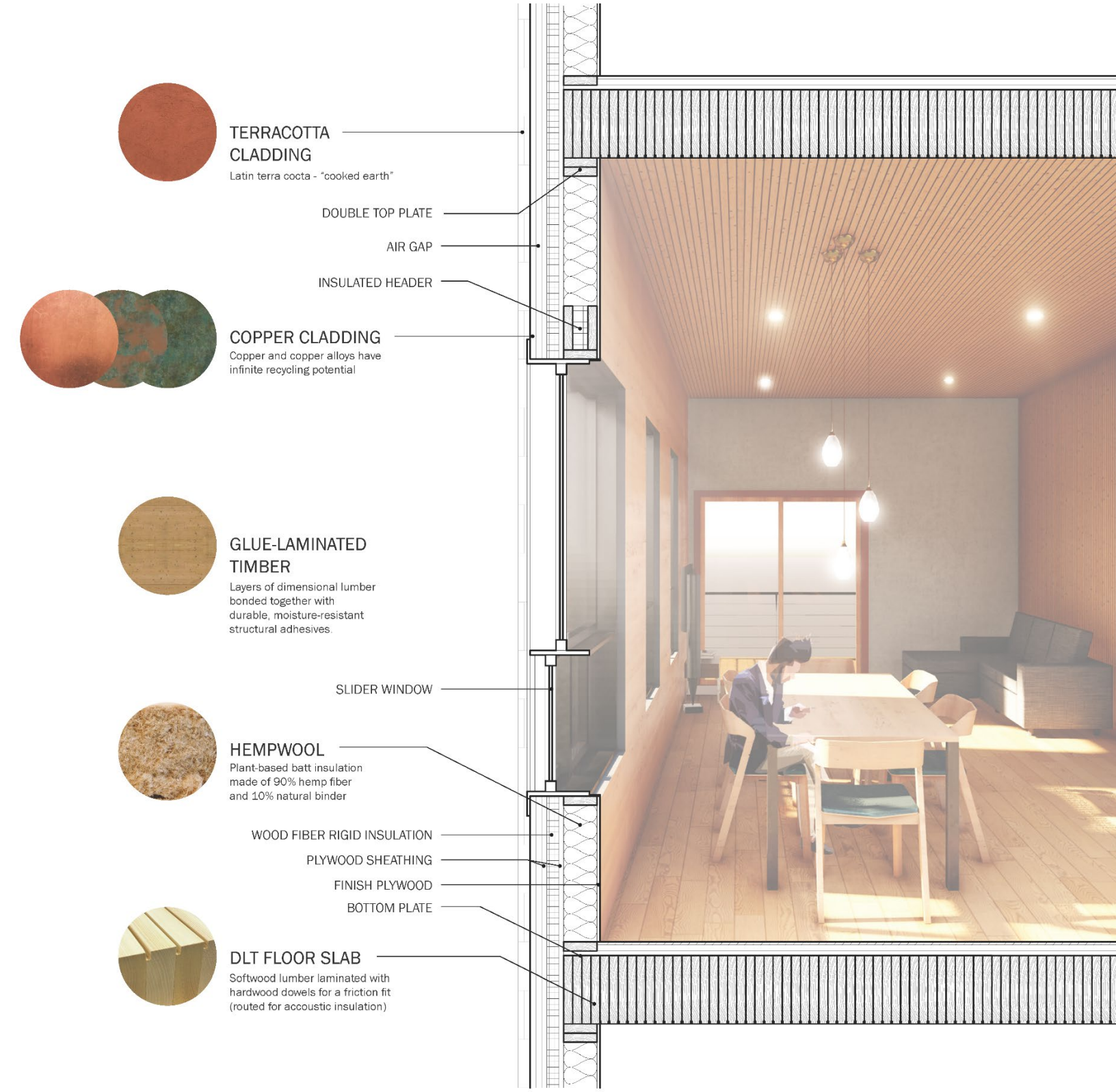
LARGE SCALE: MID-RISE


GLULAM BEAM
KNIFE PLATE + BOOT CONNECTION
GLULAM ARCH
KNIFE PLATE + HANGER CONNECTION
GLULAM COLUMN
STEEL BASE


GLULAM PODIUM


DLT FLOOR
DLT WALL
PREFAB LIGHT-FRAME WALL MODULE


DLT STRUCTURE


TERRACOTTA CLADDING
Latin terra cocta - "cooked earth"
DOUBLE TOP PLATE
AIR GAP
INSULATED HEADER
COPPER CLADDING
Copper and copper alloys have infinite recycling potential
GLUE-LAMINATED TIMBER
Layers of dimensional lumber bonded together with durable, moisture-resistant structural adhesives.
SLIDER WINDOW
HEMPWOOL
Plant-based batt insulation made of 90% hemp fiber and 10% natural binder
WOOD FIBER RIGID INSULATION
PLYWOOD SHEATHING
FINISH PLYWOOD
BOTTOM PLATE
DLT FLOOR SLAB
Softwood lumber laminated with hardwood dowels for a friction fit (routed for accoustic insulation)

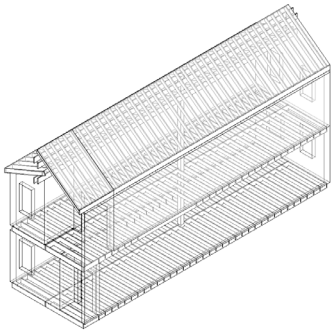

TERRACOTTA + COPPER CLADDING
WOOD FIBER INSULATION
PREFABRICATED LIGHT-FRAME
FINISHED PLYWOOD

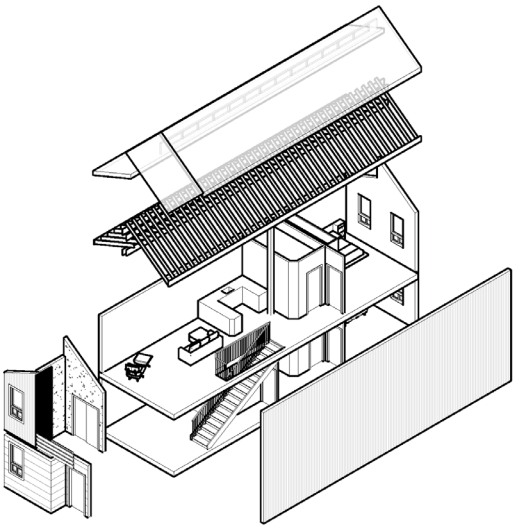
Medium Scale: Townhouse

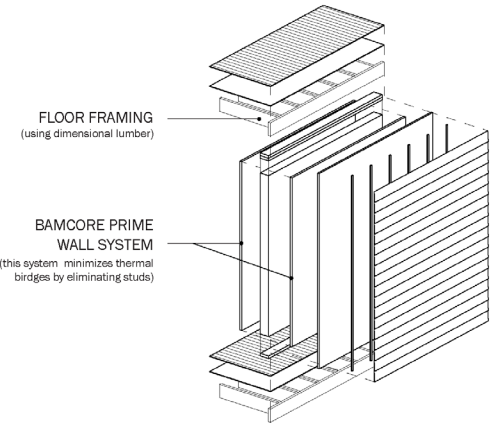
The next scale approach is the townhouse. Key materials are bamboo, yakisugi wood, cork, pine, sheep's wool, and rubber. This is a two-level townhome with two bedrooms, two bathrooms, living, kitchen, dining, and a flex space for work at home, raising children, or whatever the needs of the tenant might be. The construction method utilizes the Bamcore wall system, typical joist framing using dimensional lumber, and rafters that sit on a dual ridge beam, giving the roof its distinct profile. The Bamcore wall system is stud-less, using 1 1/4" thick bamboo sheathing attached to top and bottom plates. This minimizes thermal bridging and maximizes the insulative properties of the wall. I've chosen to use sheep's wool to insulate the Bamcore wall cavity. Sheep's wool can filter and improve air quality, manage moister, and absorb sound. Outboard of the Bamcore wall system is Thermacork, an alternative to rigid insulation. In a denser form it can also serve as the exterior cladding, as long as it can breathe and properly dry out after getting wet. The cork is steam-heated and binds to itself with natural resins and no added chemicals to form these panels. To protect the cork in more vulnerable areas, it is clad in yakisugi siding. Yakisugi is a traditional Japanese method of charring cedar or accoya wood to make it rot and insect resistant. It is often finished with tung oil. The roof is a rubber shingle roofing product that contains between 600 to 1,000 rubber tires per home and costs less than your average standing-seam metal roof. The amalgamation of these materials should be understood like this, the charred wood is the armor to the cork, which is the skin wrapping the timber frame, the bones. This design began with the roof profile. The structure is shifted to reveal a clerestory that runs the whole length

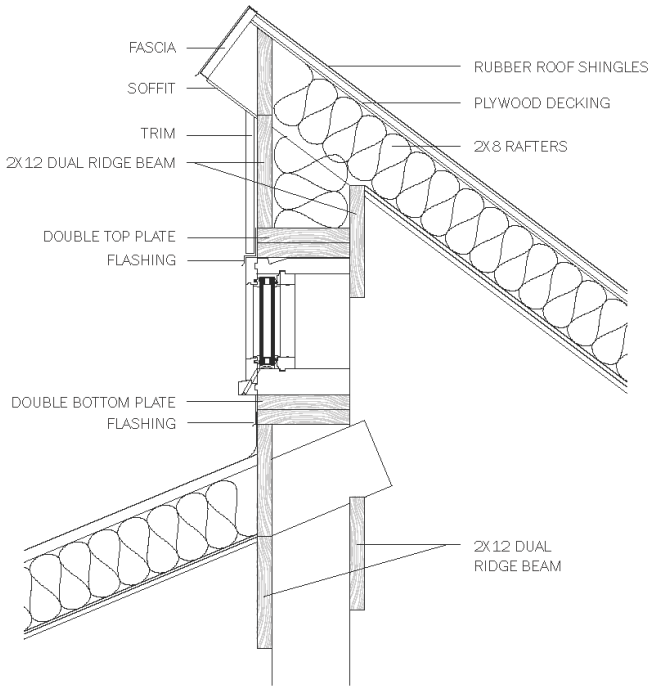
of the house. This is the reason that the main living and dining spaces were placed on the second level.

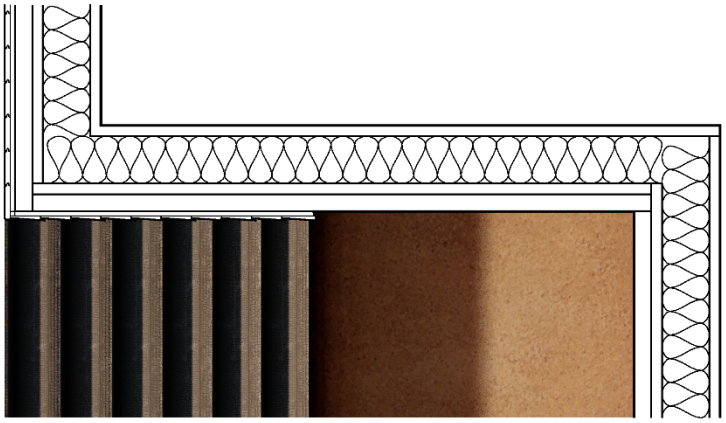
MEDIUM SCALE: TOWNHOUSE

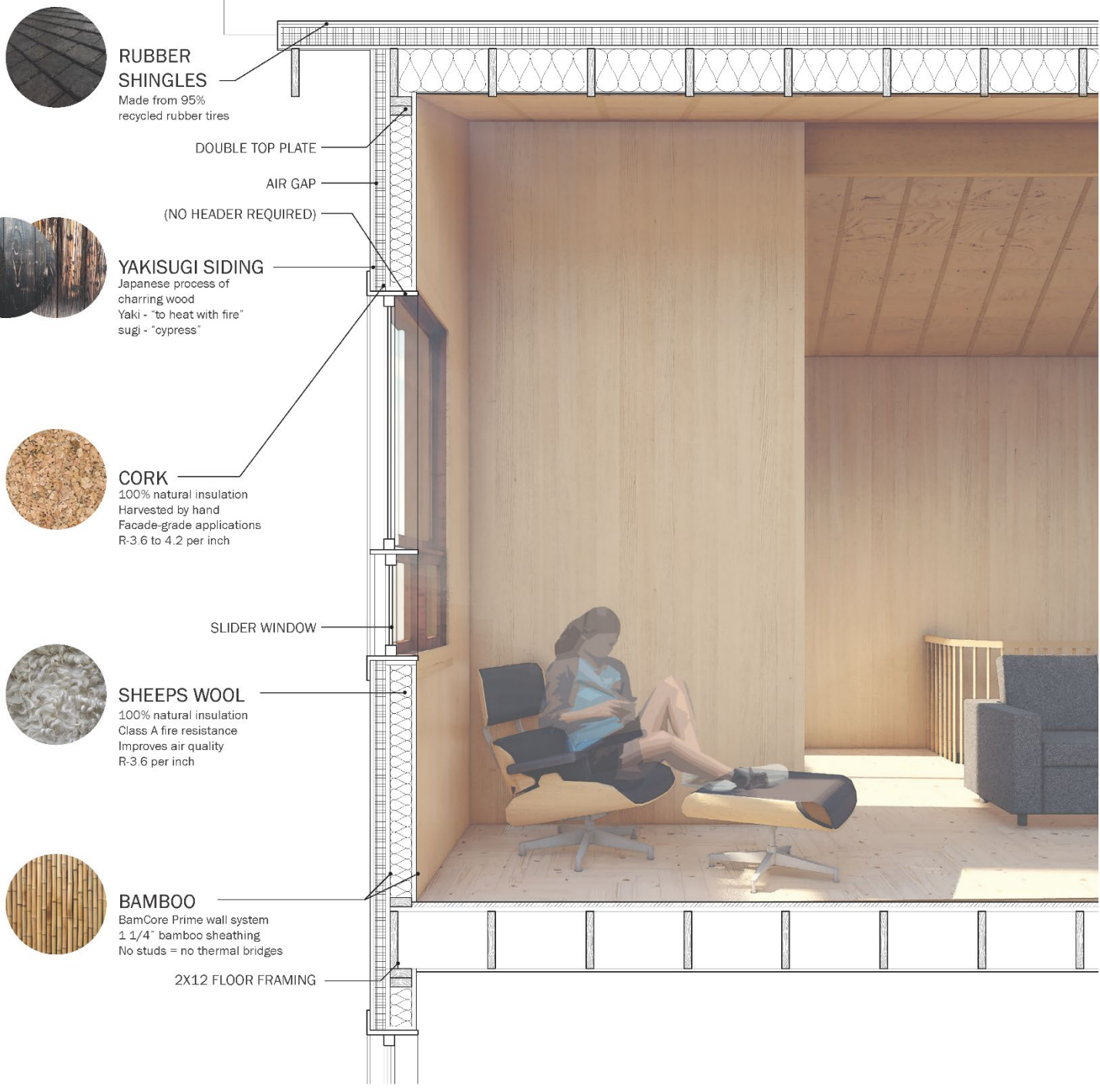





FLOOR FRAMING
(using dimensional lumber)
BAMCORE PRIME
WALL SYSTEM
(this system minimizes thermal
birdges by eliminating studs)


FASCIA
SOFFIT
TRIM
2X12 DUAL RIDGE BEAM
DOUBLE TOP PLATE
FLASHING
DOUBLE BOTTOM PLATE
FLASHING
RUBBER ROOF SHINGLES
PLYWOOD DECKING
2X8 RAFTERS
2X12 DUAL
RIDGE BEAM



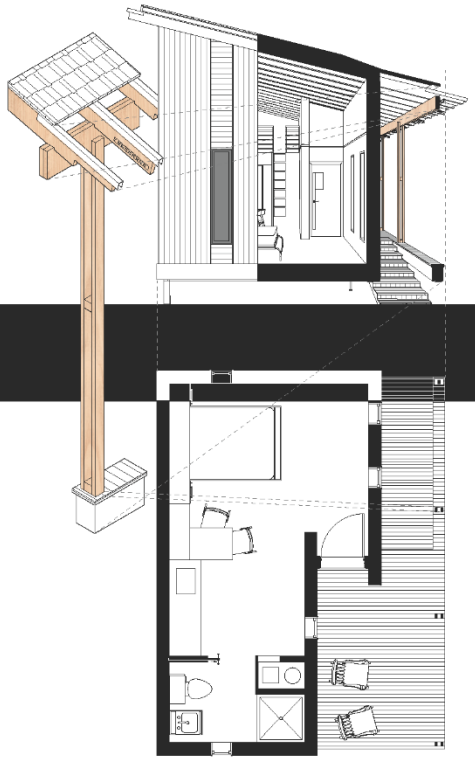

RUBBER SHINGLES
Made from 95% recycled rubber tires
DOUBLE TOP PLATE
AIR GAP
(NO HEADER REQUIRED)
YAKISUGI SIDING
Japanese process of charring wood
Yaki - "to heat with fire"
sugi - "cypress"
CORK
100% natural insulation
Harvested by hand
Facade-grade applications
R-3.6 to 4.2 per inch
SLIDER WINDOW
SHEEPS WOOL
100% natural insulation
Class A fire resistance
Improves air quality
R-3.6 per inch
BAMBOO
BamCore Prime wall system
1 1/4" bamboo sheathing
No studs = no thermal bridges
2X12 FLOOR FRAMING

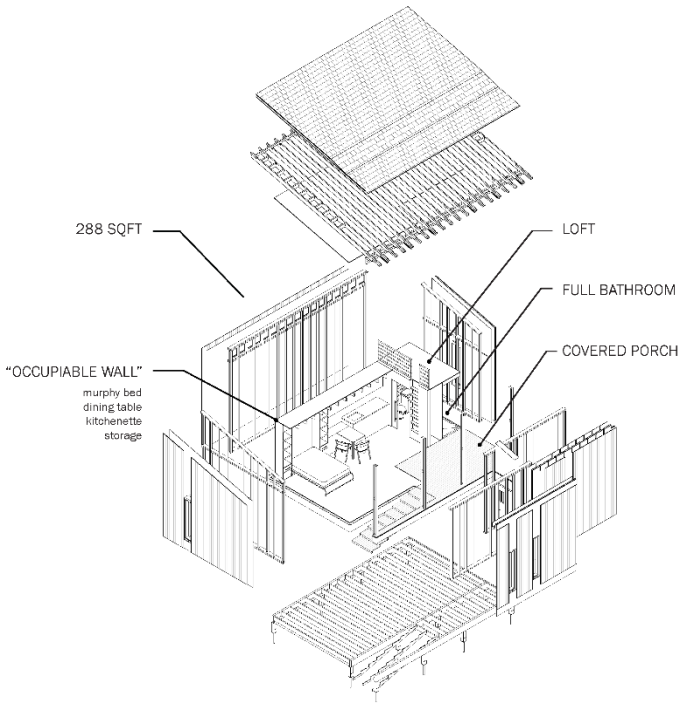

BAMCORE
SHEEPS WOOL
BAMCORE
CHARRED WOOD
CORK

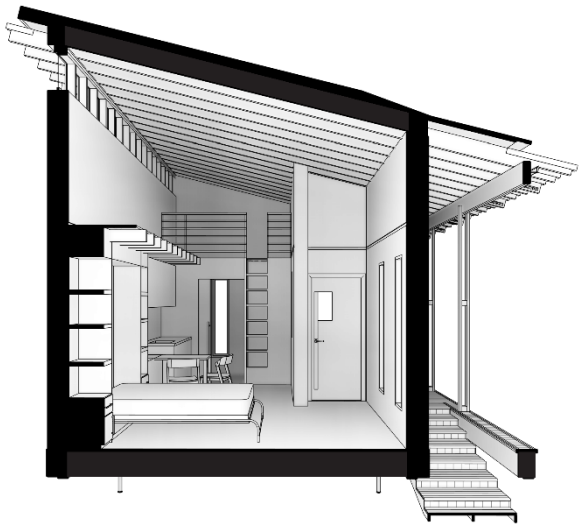
Small Scale: Accessory Dwelling Unit

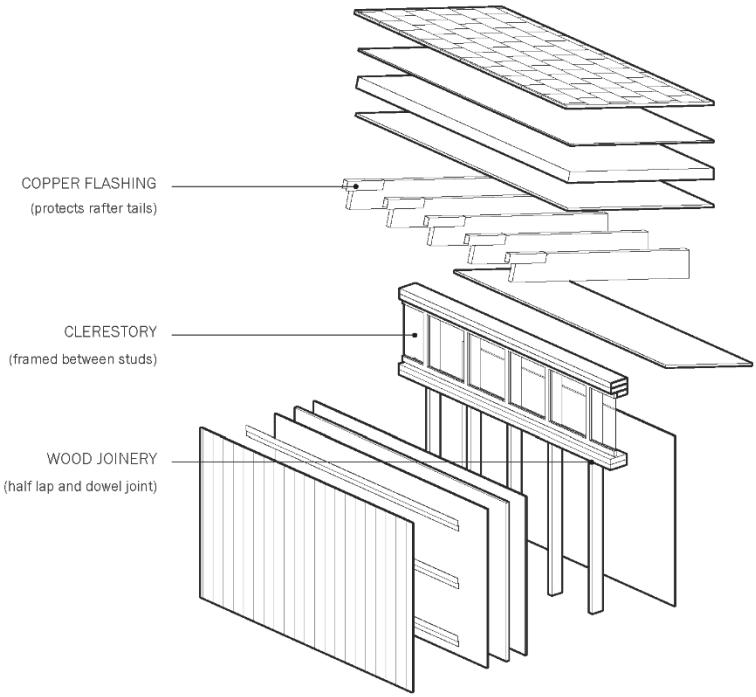
The final scale is the accessory dwelling unit. The key materials here are pine, cedar, cork, mycelium, cellulose, slate, and copper. This is a 12x24' unit, designed for a backyard or really any unused space in the city as other cities/organizations have implemented as a homeless housing strategy. It offers a lot for its compactness. Full bathroom, kitchenette, murphy bed, a loft, and a front porch. It is a light frame structure, with staggered studs for continuous cellulose insulation. This model is designed to be disassembled, whether it be for transitional housing relocation or for proper degradation at the end of its useful life. The framing uses half lap and dowel wood joinery techniques and the interior cladding, insulation panel, and exterior cladding are all attached with screws or hung without nails or adhesives. A mycelium panel is fixed to the frame for extra insulation, then clad in cedar, cork floors, and a slate roof. And it is delaminated wherever possible to show off all these materials. Rafters and copper flashing are extended to give the roof a unique profile, studs are used to frame a clerestory and support blocking that doubles as a ladder. Siding is reoriented and bordered with trim wherever openings occur, and the porch columns are given a lighter presence, made from 2x6s and blocking rather than one solid piece of timber.

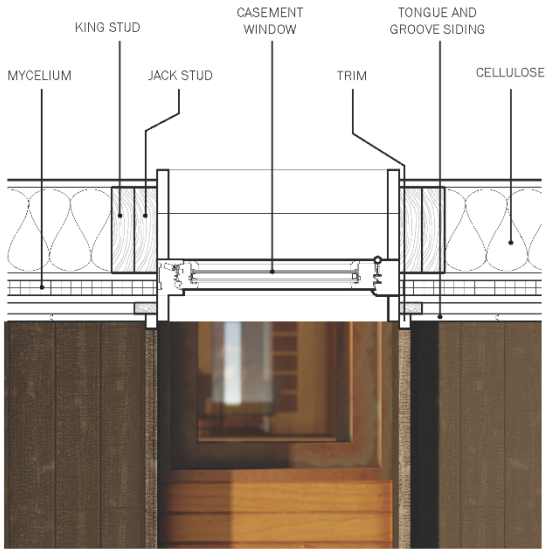
SMALL SCALE: ACCESSORY DWELLING UNIT




288 SQFT
LOFT
FULL BATHROOM
COVERED PORCH
"OCCUPIABLE WALL"
murphy bed
dining table
kitchenette
storage




COPPER FLASHING
(protects rafter tails)
CLERESTORY
(framed between studs)
WOOD JOINERY
(half lap and dowel joint)


KING STUD
CASEMENT WINDOW
TONGUE AND GROOVE SIDING
MYCELIUM
JACK STUD
TRIM
CELLULOSE

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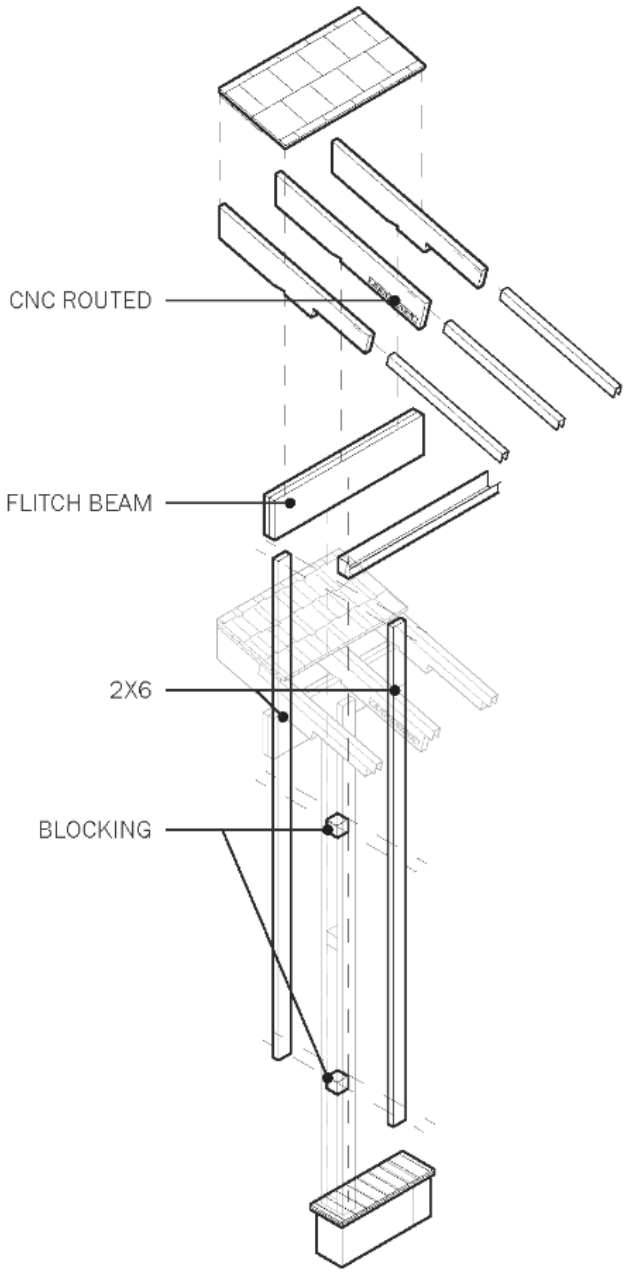
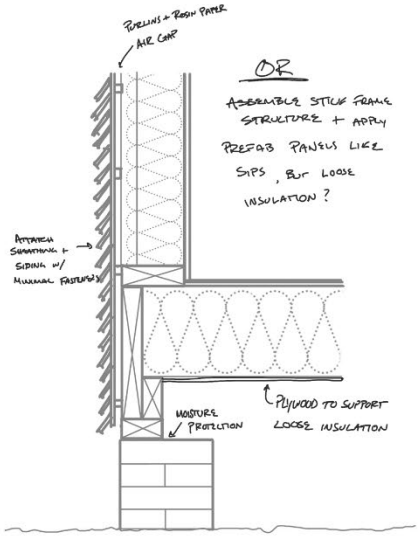
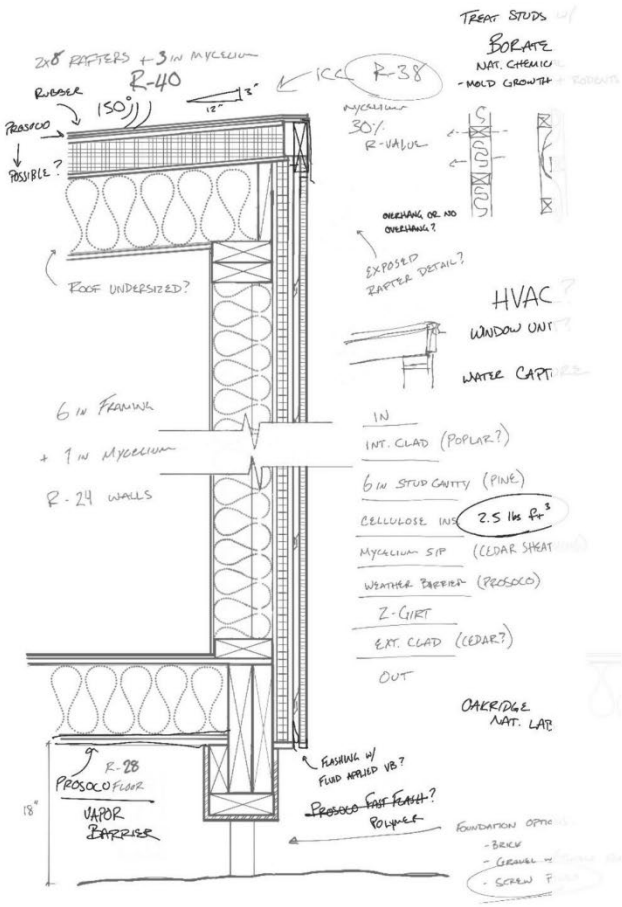
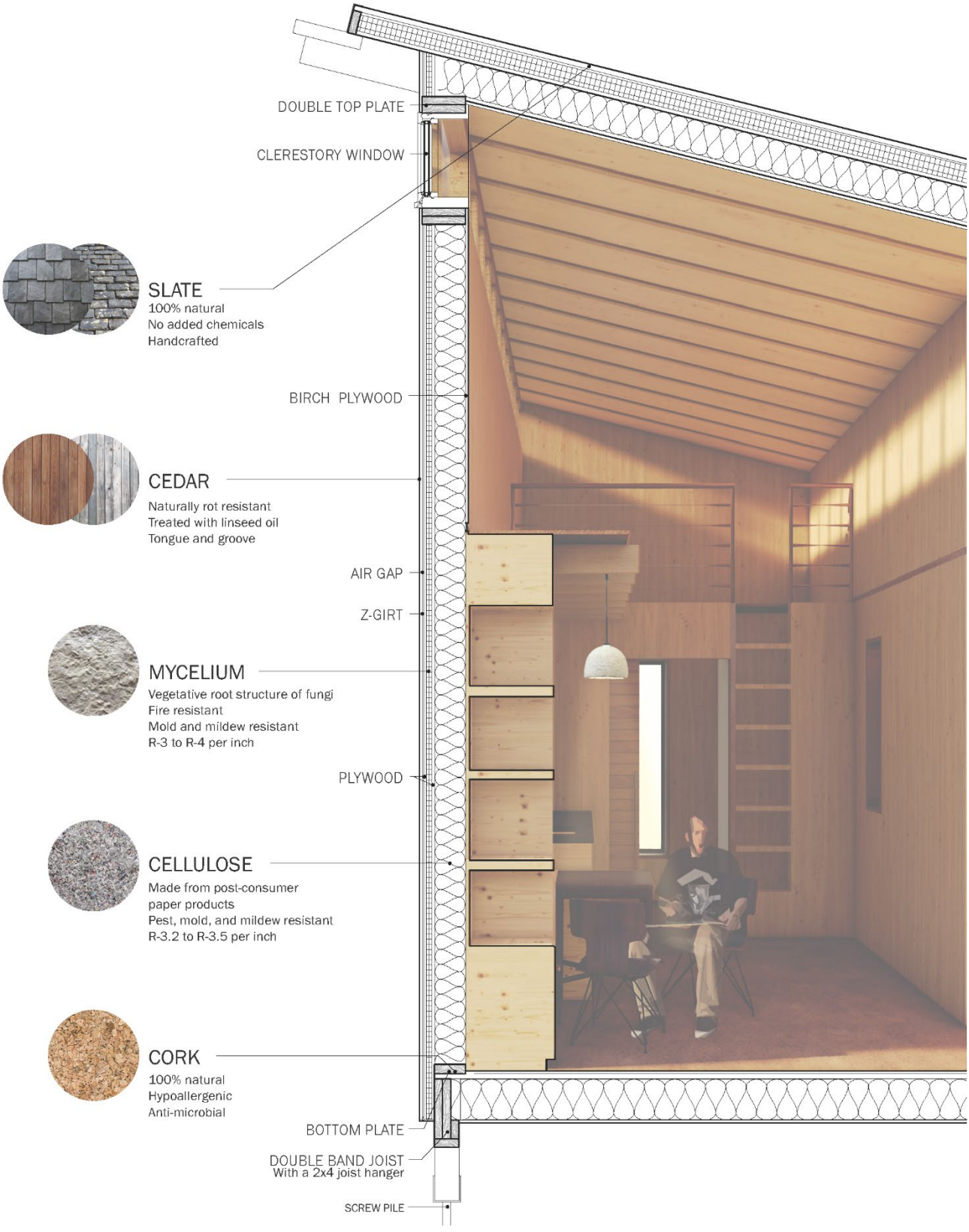

CNC ROUTED
FLITCH BEAM
2X6
BLOCKING


PURLINS + ROOF PAPER
AIR GAP
OR
ASSEMBLE STICK FRAME STRUCTURE + APPLY PREFAB PANELS LIKE SIPS, BUT LOOSE INSULATION?
ATTACH SHEATHING + SIDING W/ MINIMAL FASTENERS
MOISTURE PROTECTION
PLYWOOD TO SUPPORT LOOSE INSULATION


TREAT STUDS
BORATE
NAT. CHEMICAL
- MOLD GROWTH
2x6 RAFTERS + 3 IN MYCELIUM
R-40
ICC R-38
RUBBER
150°
12"
PROSOCO
POSSIBLE?
MYCELIUM
30%
R-VALUE
OVERHANG OR NO OVERHANG?
EXPOSED RAFTER DETAIL?
ROOF UNDERSIZED?
HVAC
WINDOW UNIT
WATER CAPT
6 IN FRAMING
+ 1 IN MYCELIUM
R-24 WALLS
IN
INT. CLAD (POPLAR?)
6 IN STUD CAVITY (PINE)
CELLULOSE INS
2.5 lbs ft³
MYCELIUM SIP
(CEDAR SHEAT
WEATHER BARRIER (PROSOCO)
Z-CLIRT
EXT. CLAD (CEDAR?)
OUT
CARRIDGE
NAT. LAB
R-28
PROSOCO FLOOR
VAPOR BARRIER
FLASHING W/ FLUID APPLIED VB?
PROSOCO FAST FLASH?
POLYUREA
18"
FOUNDATION OPTIO
- BRICK
- GRAVEL
- SCREW


DOUBLE TOP PLATE
CLERESTORY WINDOW
SLATE
100% natural
No added chemicals
Handcrafted
BIRCH PLYWOOD
CEDAR
Naturally rot resistant
Treated with linseed oil
Tongue and groove
AIR GAP
Z-GIRT
MYCELIUM
Vegetative root structure of fungi
Fire resistant
Mold and mildew resistant
R-3 to R-4 per inch
PLYWOOD
CELLULOSE
Made from post-consumer
paper products
Pest, mold, and mildew resistant
R-3.2 to R-3.5 per inch
CORK
100% natural
Hypoallergenic
Anti-microbial
BOTTOM PLATE
DOUBLE BAND JOIST
With a 2x4 joist hanger
SCREW PILE


CEDAR
PLYWOOD
MYCELIUM
PLYWOOD
LIGHT-FRAME
BIRCH PLYWOOD

Bibliography

WorldAtlas. “10 Countries With Largest Soybean Production,” August 30, 2018. https://www.worldatlas.com/articles/world-leaders-in-soya-soybean-production-by-country.html.

“25 Richest Cities in the US: Does Your Metro Area Make the List?” Accessed December 14, 2021. https://www.usatoday.com/story/money/economy/2018/05/17/25-richest-cities-in-america/34991163/.

“1999 - Information Handout.Pdf.” Accessed November 27, 2021. https://pubs.usgs.gov/info/clays/clays.pdf.

ArchDaily. “A Guide to Design for Disassembly,” July 10, 2020. https://www.archdaily.com/943366/a-guide-to-design-for-disassembly.

Washington Post. “A New Way to View Homelessness: Not as a Problem but as a Culture.” Accessed October 25, 2021. https://www.washingtonpost.com/lifestyle/magazine/studying-homeless-as-a-culture-not-a-problem/2021/03/19/e64df6b6-66e8-11eb-bf81-c618c88ed605_story.html.

“An Introduction to Vinyl.” Accessed November 27, 2021. https://www.azom.com/article.aspx?ArticleID=987.

The District Alliance for Safe Housing. “Apply for Public Housing.” Accessed November 11, 2021. https://www.dashdc.org/housing-resource-center/find-safe-housing/permanent-housing/apply-public-housing/.

Arbuckle Industries. *Thom Mayne Archiculture Extras Interview*, 2015. https://www.youtube.com/watch?v=5aX-JdHk2fk.

author/wanda-lau. “Revolutionary Building Products Made from Rubber.” Architect, February 22, 2013. https://www.architectmagazine.com/technology/products/revolutionary-building-products-made-from-rubber_o.

“Bamboo Biodiversity.” Accessed November 26, 2021. https://www.eeob.iastate.edu/research/bamboo/maps.html.

“Bamboo Botanicals - Soil For Bamboo.” Accessed November 26, 2021. https://www.bamboobotanicals.ca/html/bamboo-care/soil-for-bamboo.html.

biofilters. “Grow Architectural Models With Mushrooms.” Instructables. Accessed November 27, 2021. https://www.instructables.com/Grow-Architectural-Models-with-Mushrooms/.

Brand, Stewart. *How Buildings Learn: What Happens after They’re Built*. Penguin Books, 2012.

“Brickmaking History.” Accessed November 6, 2021. http://brickcollecting.com/history.htm.

Brolin, Brent C. *The Failure of Modern Architecture*. New York: Van Nostrand Reinhold Co, 1976.

“Building Endless Possibilities for Construction - CES - Silicones Europe.” Accessed November 27, 2021. https://www.silicones.eu/silicones/benefits/silicones-building-endless-possibilities-for-construction/.

Dignity Village. “Bylaws,” April 21, 2015. https://dignityvillage.org/governance/bylaws/.

Healthline. “Chronophobia or Fear of Passing Time: Risks, Symptoms, Treatment,” June 12, 2019. https://www.healthline.com/health/chronophobia.
“Comparative-Analysis-Of-The-Tensile-Strength-Of-Bamboo-And-Reinforcement-Steel-Bars-As-Structural-Member-In-Building-Construction.Pdf.” Accessed November 26, 2021. http://www.ijstr.org/final-print/nov2015/Comparative-Analysis-Of-The-Tensile-Strength-Of-Bamboo-And-Reinforcement-Steel-Bars-As-Structural-Member-In-Building-Construction.pdf.
Corbusier, Le. *Toward an Architecture*. Getty Research Institute, 2007.
“David Walker Architects.” Accessed November 11, 2021. http://davidwalkerarchitects.com/projects/transitional-housing.
Davis, Sam. *Designing for the Homeless: Architecture That Works*. Berkeley: University of California Press, 2004.
Washington Post. “D.C. Clears Longtime Encampment in NoMa in Kickoff to New Program to House the Homeless.” Accessed November 11, 2021. https://www.washingtonpost.com/dc-md-va/2021/10/04/noma-homeless-encampment-eviction/.
“D.C.?S ?Skid Row’: Homeless Encampments Thrive amid Pandemic - The Washington Post.” Accessed October 25, 2021. https://www.washingtonpost.com/local/dc-skid-row-homeless-encampment/2021/08/16/11eda0d8-fc39-11eb-b8dd-0e376fba55f2_story.html.
Slateplate. “Everything You Need to Know about Slate.” Accessed November 27, 2021. https://www.slateplate.com/pages/all-about-slate.
Facilitator, Constro. “Use of Different Types of Clay in Construction.” *Constro Facilitator* (blog), February 5, 2020. https://www.constrofacilitator.com/use-of-different-types-of-clay-in-construction/.
G, Durga, Dhilip R G, B. Prasad, and C Ujwal. “Comparison in Characteristics of Bamboo and Steel Reinforcement,” April 9, 2021.
Gorrée, Marieke, Jeroen Guinée, Gjalt Huppes, and Lauran Oers. “Environmental Life Cycle Assessment of Linoleum.” *The International Journal of Life Cycle Assessment* 7 (May 1, 2002): 158–66. https://doi.org/10.1007/BF02994050.
Great Big Story. *In Japan, Repairing Buildings Without a Single Nail*, 2019. https://www.youtube.com/watch?v=O-u4T13guko.
Hoeven, Diederik van der. “Mycelium as a Construction Material.” Bio Based Press, April 7, 2020. https://www.biobasedpress.eu/2020/04/mycelium-as-a-construction-material/.
The Community Partnership. “Homelessness In DC.” Accessed November 10, 2021. https://community-partnership.org/homelessness-in-dc/.
“Homeless_Stats_Fact_Sheet.Pdf.” Accessed November 10, 2021. https://homelesslaw.org/wp-content/uploads/2018/10/Homeless_Stats_Fact_Sheet.pdf.
“Homeward-DC-Report_FY2021-2025.Pdf.” Accessed November 11, 2021. https://dmhhs.dc.gov/sites/default/files/dc/sites/dmhhs/page_content/attachments/Homeward-DC-Report_FY2021-2025.pdf.
“How Carbon Is Stored in Trees and Wood Products.Pdf.” Accessed December 2, 2021.

https://forestlearning.edu.au/images/resources/How%20carbon%20is%20stored%20in%20trees%20and%20wood%20products.pdf.
HowStuffWorks. “How Long Does It Take for Plastics to Biodegrade?,” December 15, 2010. https://science.howstuffworks.com/science-vs-myth/everyday-myths/how-long-does-it-take-for-plastics-to-biodegrade.htm.
“How Long Does It Take to Degrade Rubber? – SidmartinBio.” Accessed November 26, 2021. https://www.sidmartinbio.org/how-long-does-it-take-to-degrade-rubber/.
Laleicke, Paul F., Alex Cimino-Hurt, Dylan Gardner, and Arijit Sinha. “COMPARATIVE CARBON FOOTPRINT ANALYSIS OF BAMBOO AND STEEL SCAFFOLDING.” *Journal of Green Building* 10, no. 1 (April 2015): 114–26. https://doi.org/10.3992/jgb.10.1.114.
Magalhães, Solange, Luís Alves, Bruno Medronho, Ana C. Fonseca, Anabela Romano, Jorge F.J. Coelho, and Magnus Norgren. “Brief Overview on Bio-Based Adhesives and Sealants.” *Polymers* 11, no. 10 (October 15, 2019): 1685. https://doi.org/10.3390/polym11101685.
“Manufacturing of Brick,” n.d., 7.
Meyer, Christian. “Concrete Materials and Sustainable Development in the United States,” n.d., 10.
Monagan, John S. *Horace, Priest of the Poor*. Washington, D.C: Georgetown University Press, 1985.
N, P, and R. “Why Some Homeless Choose The Streets Over Shelters.” *Talk of the Nation*. NPR, December 6, 2012. https://www.npr.org/2012/12/06/166666265/why-some-homeless-choose-the-streets-over-shelters.
Nabokov, Peter, and Robert Easton. *Native American Architecture*. New York: Oxford University Press, 1989.
“Performance and Sustainability: Soy-Based Adhesives and Sealants Excel in Wide-Ranging Applications.” Accessed November 27, 2021. https://www.adhesivesmag.com/articles/97755-performance-and-sustainability-soy-based-adhesives-and-sealants-excel-in-wide-ranging-applications.
“Plaquette_ossature_biosourcee_part.Pdf.” Accessed November 6, 2021. https://www.popup-house.com/wp-content/uploads/2014/03/plaquette_ossature_biosourcee_part.pdf.
ArchDaily. “Pop-Up House / Multipod Studio,” March 17, 2014. https://www.archdaily.com/486587/pop-up-house-multipod-studio.
“Research: Score Distribution; Commercial Building Age, Use, Value - Commercial Property Data.” Accessed October 11, 2021. https://www.commbuildings.com/ResearchComm.html.
National Alliance to End Homelessness. “State of Homelessness: 2021 Edition.” Accessed November 10, 2021. https://endhomelessness.org/homelessness-in-america/homelessness-statistics/state-of-homelessness-2021/.
“Sursum Corda (Washington, D.C.).” In *Wikipedia*, July 29, 2021. https://en.wikipedia.org/w/index.php?title=Sursum_Corda_(Washington,_D.C.)&oldid=1036142897.
“The 2020 Annual Homeless Assessment Report (AHAR) to Congress,” n.d., 102.
The Museum of Modern Art, Home Delivery: Fabricating the Modern Dwelling exhibit, New York New York, 800 Square Feet 1, 2008, roof deck Program: Single-

family home, Awards:AIA Philadelphia Gold MedalAIA Pennsylvania Merit AwardAIA TAP Outstanding Design for Fabrication Using BIMAIA Housing AwardBSA Sustainable Design CitationChicago Athenaeum American Architecture Award and International Architecture AwardWorld Architecture Festival Awards (Shortlisted), and Click for Project Details ». “Cellophane House | Prefabricated Architecture & Design for Disassembly.” Accessed November 6, 2021. https://kierantimberlake.com/.
Bisnow. “Toll Brothers Begins Demolition Of Sursum Corda Community, Plans 1,100-Unit Project.” Accessed December 4, 2021. https://www.bisnow.com/washington-dc/news/multifamily/toll-brothers-begins-demolition-of-sursum-corda-community-plans-1100-unit-project-95126.
Trachtenberg, Marvin. *Building-in-Time*. Yale Universtiy Press, 2010.
United To End Homelessness. “Types of Housing Support for the Homeless,” January 31, 2019. https://unitedtoendhomelessness.org/blog/types-of-housing-support-for-the-homeless.
US EPA, OLEM. “Sustainable Management of Construction and Demolition Materials.” Overviews and Factsheets, March 8, 2016. https://www.epa.gov/smm/sustainable-management-construction-and-demolition-materials.
Wasserman, Jason Adam, and Jeffrey M. Clair. *At Home on the Street: People, Poverty, and a Hidden Culture of Homelessness*. Boulder, Colo: Lynne Rienner Publishers, 2010.
Watson, Julia. *Lo-TEK: Design by Radical Indigenism*. Cologne [Paris]: Taschen, 2019.
“What Is Design for Disassembly? - News - Cradle to Cradle Products Innovation Institute.” Accessed November 6, 2021. https://www.c2ccertified.org/news/article/what-is-design-for-disassembly.
Sustainable Lumber Company. “What Is Reclaimed Wood? | Why Use Reclaimed Wood?,” July 8, 2019. https://www.sustainablelumberco.com/2019/07/reclaimed-wood-everything-you-need-to-know/.
“What Is the Best Insulation for a Home?” Accessed November 27, 2021. https://www.ecohome.net/guides/2372/choosing-the-right-insulation-the-pros-cons-and-applications/.
“What Is The Lifespan Of Concrete? | Razorback Concrete.” Accessed October 11, 2021. https://razorbackconcrete.com/what-is-the-lifespan-of-concrete/.
“What Is the Lifespan of Siding & What Type Is Most Durable? | Sunshine Contracting.” Accessed October 28, 2021. https://sunshinecontractingcorp.com/blog/2019/05/10/what-is-the-lifespan-of-siding-and-what-type-is-the-most-durable/.
Consumers’ Checkbook Magazine. “Which Grocery Stores Offer the Best Prices and Quality?” Accessed December 4, 2021. https://www.checkbook.org/national/supermarkets/articles/Which-Grocery-Stores-Offer-the-Best-Prices-7139.
“Why Would a Homeless Person Not Want to Go to a Shelter? | BRC.” Accessed November 10, 2021. https://www.brc.org/why-would-homeless-person-not-want-go-shelter.

Craftsmanspace. “Woodworking Joints.” Accessed February 3, 2022. https://www.craftsmanspace.com/woodworking-joints.
Writer, Tobias Roberts, Rise. “Cellulose Insulation: Sustainable and High-Performance.” Rise, October 5, 2020. https://www.buildwithrise.com/stories/cellulose-insulation.