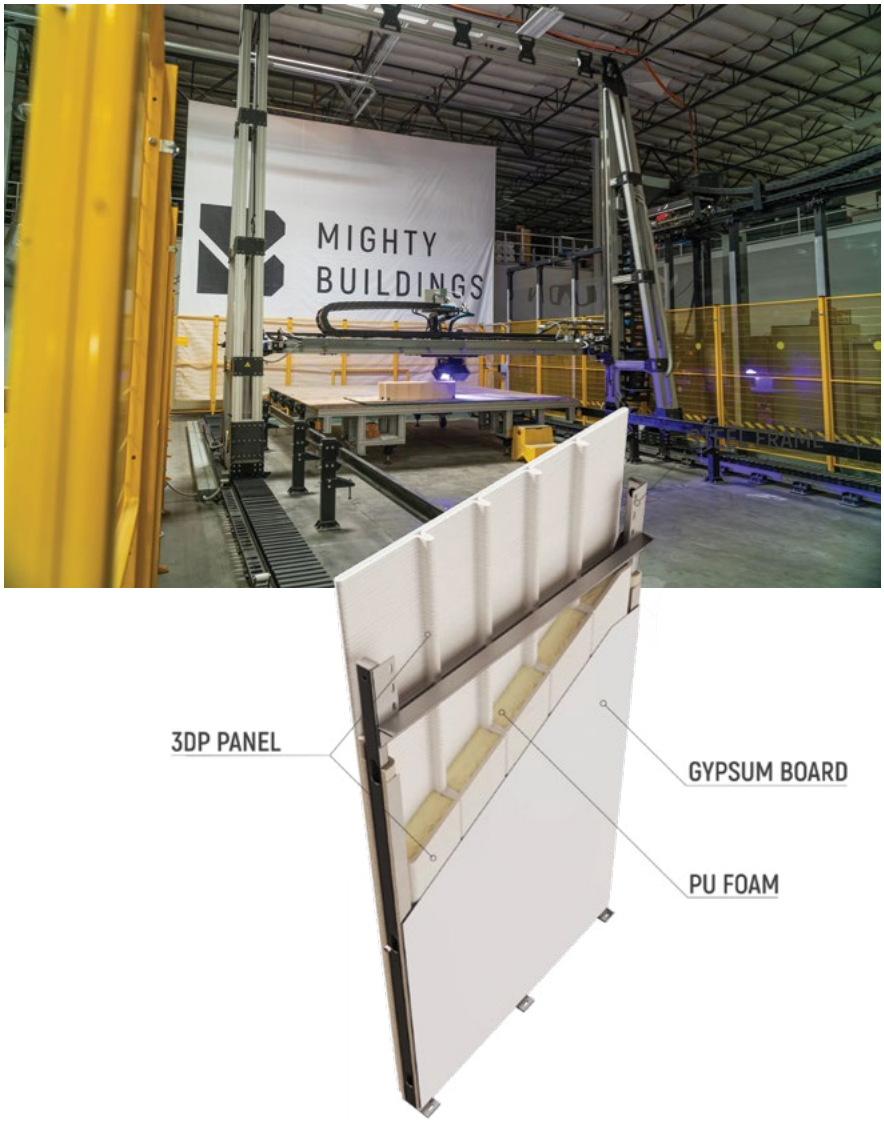
Delivering 3D printed prefabricated homes

Oakland, California based startup, Mighty Buildings, was founded in 2017 with a goal of disrupting the US construction market by coming up with innovative new materials by creating beautiful, high-quality, and sustainable homes using 3D printing and robotic automation as well as unlocking productivity gains for this mainstay industry. The founders are seeking to combine experience in 3D printing, robotics and automation, sustainability, and housing policy to develop a new construction paradigm. They are using large-format 3D printers, UV-curable resins, advanced materials, together with digital design and automation to deliver innovative sustainable homes. Traditional home construction methods in the US are often labor-intensive, materially wasteful and energy-inefficient with approaches and technologies that have been in use for the last half century without much change. Moreover, California, with its rapidly growing population has faced a long-standing housing shortage and a lack of affordable housing for both low- and middle-income families: Mighty Buildings homes currently retail for around $200k - $400k. The caveat is that they offer turnkey solutions, handling the entire process from start to finish. To date, Mighty Buildings have won multiple awards including the 2020 CAMX 'Unsurpassed Innovation' Award in the housing sector.



The 3D printing technology devised by Mighty Buildings aims at producing modular houses and building components for clients much faster than traditional construction methods. They use large 3D printers (see above) and a thermoset composite material they invented called Light Stone Material (LSM), which hardens when exposed to UV light, to make a modern, robust building material. As a sustainably focused mission driven company, they are also aiming for a near-zero waste production process, preventing 1,100 - 2,000 kg of CO_2 emission per 3D printed home and they are committed to achieving Net-Zero Carbon by 2028 (22 years ahead of the construction industry). They are also rolling out a Production-as-a-Service building model to leverage a 'digital fabrication' platform to unlock untapped productivity in the construction sector (1). Their patented and certified Mighty Kit System (MKS) made out of 3D printed panels is unlike any other wall system in the industry. Each panel uses the non-silicate LSM and steel components with these building materials providing a high-performance, sustainable, durable, and cost-efficient solution for construction across the United States.

In terms of quick assembly and low maintenance that impacts sustainability KPIs, a single Mighty Buildings composite panel can replace up to eight layers of traditional construction materials and associated trade coordination (see above). By printing only what they need per home, they can produce units with virtually zero waste — eliminating the 3 - 5 lbs of waste per sq. ft. generated by traditional US home construction. This panellised system is already compliant with California building codes and quality standards. And their near-zero waste technology produces savings of 2.3 tons of CO_2 emission per 3D printed home. Indeed, insurance premiums are generally 10% lower because their homes are constructed with non-combustible materials. Mighty Buildings' panels come for assembly as 100% complete panels: structure, insulation, MEP integration, air/moisture/fire barrier & interior/exterior finishes and their process supports a digital fabrication platform from design through build. Mighty Buildings' PACE (Photo-Activated Component Extrusion) 3D printing system can fully 3D print all structures for a modular ADU (Accessory Dwelling Unit) in one print.

3D printing and thermosetting composites

Mighty Buildings have created their own proprietary 3D printing technology, PACE, and developed a unique thermoset composite to 3D print the photocurable material into almost any shape and in a way that can be used for any aspect of a build. The company also delivers panel systems transported in shipping containers that require more on-site assembly but eliminate the need for cranes to install the housing modules at the building site. The company has ambitions to create a neighbourhood of 15 homes near Coachella Valley, single-family multi-story houses, as well as townhouses. Ultimately it envisions evolving into a micro-factory production platform and spawning a network of micro-factories in the United States and globally to produce prefab housing where they are most needed.

Currently, Mighty Buildings constructs its housing solutions like the Mighty Studio Accessory Dwelling Unit (ADU) product line and the Mighty House single family home product line and sells directly to customers and residential developers in California. Ultimately, the company plans to build Mighty Factories as well as its PaaS platform across the U.S. and globally. ADUs were the company's initial focus to demonstrate their technology. They offer a range of modules ranging from a 350-square-foot Mighty studio to a 700-square-foot Mighty Duo B, which are built at the

company's production space and then installed onsite via crane plus three variants of two-bedroom and three-bedroom "Mighty Houses" built as panels that are shipped and assembled at the construction site. The modular units arrive fully finished ready to move in including washer/dryer, fridge, dishwasher, etc. Depending on the model, installation usually only takes a day or two on site, with additional on-site assembly typically completed within a week, which compares favourably to the months-long process of building a home using traditional on-site construction approaches.

The original version of LSM is an unreinforced thermoset resin, i.e., a mixture of resin and a UV initiator and other proprietary materials. This unreinforced resin enables building of single-story buildings and ADUs, but ultimately, Mighty Buildings plans to go bigger and taller up to five floors with the help of fibre reinforcement. They have developed a version of LSM reinforced with continuous glass fibre and internal testing has shown that 3D printed structures made with this material are able to achieve a maximum ultimate load similar to that of a comparably sized, steel-reinforced concrete beam, a quarter of the weight and with an ultimate tensile strength that is almost 20 times higher. LSM is also water and fire resistant, highly energy-efficient and is said to be the first UL-certified 3D printed building material. The higher strength will also enable the company to scale up the process to taller structures and buildings without the need for support structures. They also foresee the printing of a roof as well as the walls and floors, opening up a new era of design possibilities.

3D printing and assembly engineering simulation challenges

Production of each prefabricated building involves 3D printing, quality control, post processing and assembly with as much automation as possible. Mighty Buildings has been working with Hexagon | e-Xstream Software to develop its own digital simulation and modelling platform using Digimat. The ultimate goal is to achieve 100% digital fabrication and then to use this platform to simulate every step of production before the building process to reduce production costs and speed the process, eliminating quality control issues and enabling late-stage changes. The PACE 3D printing process is designed for large parts, zero waste and high speed. It involves extrusion of an LSM gel at room temperature and polymerisation via UV light at the end of the printhead. The PACE system boasts a print volume of 11 x 26 x 13 feet. With the help of robotic arms, cured parts can be inspected via 3D scanning and thermography, and then each structure is moved into a robotic finishing cell for post-processing. Depending on the project, it may involve milling the exterior surface to simulate a stone-like or brick finish, spraying on paint, and pouring polyurethane insulation foam layers into wall interiors. Finished modules will then be transported and assembled at the construction site. Mighty Buildings' current process takes about two to three weeks start to finish to build a house. The company's ultimate goal is to build an entirely 3D printed module from start to finish in less than a week.

The beauty of 3D printing housing materials is that the printers in theory can produce any shape. It also offers unique flexibility options because there's a more direct link between digital design and production. Mighty Buildings can print ideas better because the design, materials and mechanical processes have been perfected beforehand. Mechanical issues such as warpage, delamination and residual stress can all be eliminated at the design stage thanks to Hexagon's simulation software's first-time-right approach such that there's no need to waste time and money printing a four-tonne prototype that's warped and not in specification.

Reference

1. "3D printed Prefab Homes aim to Disrupt Construction Market" by H. Mason, CompositesWorld Magazine, 11th December 2020, https://www.compositesworld.com/articles/3D printed-prefab-homes-aim-to-disrupt-construction-market