Three dimensional (3D) printing is taking the world by storm. President Barack Obama recently said that “3D printing technology has the potential to revolutionize the way we make almost everything.”\(^1\) News and scientific publications have dubbed it the “second industrial revolution.”\(^2\) 3D printing used to be limited to manufacturing smaller items, such as cups, model cars, or guns. Some, however, envision 3D printing on a grander scale. Research institutions and architectural firms are developing technology that may allow the fabrication of whole buildings, or large components thereof, by printing in the not too distant future. This, they hope, will be implemented by the industry as a whole, significantly reducing the time and money needed to complete a construction project.

1. 3D Printing Technology

3D printing, or additive manufacturing, is a fully automated process for making three-dimensional, solid objects from digital designs. The process begins by digitally modeling a blueprint of the object that is to be printed in a design program. The design program then “slices” the object into layers and sequentially sends this information to the 3D printer.

Once the 3D printer has the information, it builds the object by making repeated passes, each time depositing a thin layer of material onto material previously deposited. Each layer is deposited according to a “slice” of information from the digital model. The material is applied in such a way that each layer fuses to the last. The material and precise method of application will vary depending on the item being printed and the technology being utilized. For example, 3D printers use plastic, paper, rubber, and metal, among other materials; these materials are added by spraying, extruding, or fixing them in place with a laser or electronic beam. The end result is a three dimensional object as designed by the digital model.

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2. Developments for the Construction Industry

Building on the general concept of 3D printing, innovators are working on technology that they hope will make it possible to print whole structures. Currently such technology is nascent, with progress largely being made at universities and innovative architectural firms.

Leading the charge in the United States is Behrokh Khoshnevis, an engineering professor at the University of Southern California. Khoshnevis has developed a particular iteration of 3D printing called Contour Crafting. Contour Crafting is implemented with a Contour Crafter – an extruder connected to a computer-controlled gantry on rails. The rails are placed on either side of a foundation, and the extruder, moved by the gantry, then applies layers of quick-setting concrete. The concrete is applied so as to form hollow walls, and additional concrete is added to fill the wall in varying amounts depending on whether the wall is loadbearing. The Contour Crafter is also able to install conduits for plumbing and electrical wiring, as well as leave spaces in which workers will later install windows and doors.

Using Contour Crafting, Khoshnevis reports that he has created walls that are six feet high, by adding layers of concrete six inches high and four inches thick. The walls have a compressive stress of 10,000 pounds per square inch. This technology, Khoshnevis projects, will be able to print a 2,500 square foot house in less than a day.

On the other side of the Atlantic, research institutes and architectural firms are also searching for ways to use 3D printing in the building process. A Dutch firm named Universe Architecture is planning on building a 12,000 square foot, Möbius strip shaped home by 3D printing sections on-site and then assembling them. It plans to use a printer capable of printing structures as large as 6 X 9 meters. Similarly, the Amsterdam-based firm Dus Architects is in the process of printing a canal house. Dus Architects is using a printer housed in a shipping container that makes individual rooms out of plastic and wood fibers. Those rooms will then be assembled on-site by fastening the elements together with steel cabling. Dus Architects commenced building in early 2014, and it expects to complete the project in three years.

On the other side of the Pacific, a Chinese company, WinSun Decoration Design Engineering, has also made a splash with its use of 3D printing technology. WinSun, unlike the innovators previously discussed, uses a massive printer – 490’ X 33’ X 20’ – to print pieces of houses in a factory and then assembles them on-site. WinSun makes the houses using recycled construction material, industrial waste, and tailings which are then reinforced with fiberglass. And, most impressively, WinSun has printed ten houses in less than a day, each measuring 200 square meters and costing less than $5,000. The company even constructed its own 10,000 square meter office in a month using an assembly line of four 3D printers.

3 A video of the Contour Crafter performing its basic operations may be viewed here: http://www.youtube.com/watch?v=yv-lWdSdns, and the Contour Crafting website may be viewed here: http://craft.usc.edu/CC/modem.html.


5 The project can be further explored at: http://www.3dprintcanalhouse.com/. A video for both European projects may be viewed here: https://www.youtube.com/watch?v=eu0g16SYxtQ#t=151.

6 An article further describing WinSun’s process may be found here: http://blogs.wsj.com/corporate-intelligence/2014/04/15/how-a-chinese-company-built-10-homes-in-24-hours/?mod=e2lf. And, a video may be found here: https://www.youtube.com/watch?v=SOzbNdyRTBs.

3. Advantages and Uses of 3D Printing in the Construction Industry

The researchers and architects developing 3D printing’s use in the construction industry have identified a number of advantages associated with the technology.
a) Building in Non-Traditional Forms

3D printing has the ability to overcome obstacles in realizing architects’ and owners’ designs. Thanks in large part to highly sophisticated computer modeling, building designs are growing in geometrical complexity, but current technologies for implementing such designs, such as pouring concrete into forms, are still limited. For example, Universal Architecture envisioned building a house modeled after a Möbius strip, and its founder believes traditional construction would be ill-equipped to realize his vision. The advent of 3D printing, however, allows for more precise fabrication of such architectural components. Even in more run-of-the-mill construction projects, such as housing developments, 3D printing would increase flexibility in design. Currently, walls consist primarily of flat surfaces joined at ninety degree angles because alternate designs are more difficult to construct. 3D printing would remove this impediment, allowing owners and architects to design buildings with more curvature.

b) Time and Cost

If 3D printing allows a house, or ten houses, to be built in a day, there will be an obvious reduction in the time, and hence the money, required for construction. The condensed time frame and automation will reduce the man hours required for each project, both for direct labor and supervision. Less time will also demand less financing costs and overhead. 3D printing may replace equipment that is current used, or significantly reduce its demand due to a project’s shortened timeframe. Khoshnevis projects that a house built with Contour Crafting will be one-fifth the cost of a similar house built with conventional construction. WinSun has printed ten houses in less than 24 hours. All such savings have the potential to be boon for the industry.

The printing technology may also reduce material costs and increase flexibility with what materials may be used. On the costs front, there may be waste prevention. 3D printing is an additive technology – it only deposits material where needed in accordance with the digital model. When layering concrete, there are no scraps, as there are with traditional methods for building walls such as wood framing and drywall. Moreover the technology may provide material flexibility. WinSun, for example, plans to use recycled materials that would otherwise end up in landfills. Contour Crafting has also promised some ability to use local materials which would reduce transportation costs. Recognizing this, both the United States Navy and NASA have worked with Khoshnevis to develop the technology. For the Navy, efficient building and use of native materials means that it would be able to build outposts in warzones more quickly and safely. For NASA, the ability to use native materials brings it a large step closer to extraterrestrial construction. Khoshnevis, in fact, has come up with a proposal for a laser that would sinter moondust to form a landing station for future space crafts.

Another benefit touted is the technology’s ability to reduce injuries in the construction industry. Currently, there are approximately 800 fatalities per year in the construction industry in the United States, in addition to many more injuries. The automation of large portions of the construction process will dramatically reduce the occurrences of fatalities and injuries by removing workers from the more dangerous aspects of the process. The jobs that will be created by implementing 3D printing will be more technology focused and will shift workers to safer environments, for example to computer programming.

Both in the United States and abroad, affordable housing continues to be an issue. Technological advances that ease the costs of construction, such as 3D printing, can help. One of Khoshnevis’ goals in developing the Contour Crafter is to give more people access to low-cost housing. WinSun aims to do the same. Another particular application of these efficiencies is emergency housing. With the increased speed of construction, 3D printing may be used to build houses when natural disasters have destroyed the existing housing stock.
4. Potential Problems with 3D Printing in the Construction Industry

3D printing enthusiasts paint an exciting picture of low-cost, fast, and safe construction. Yet, from the industry’s perspective, companies will need to determine how these technologies will change the industry and what legal issues will need to be ironed out in order for them to be utilized.

a) Reduction in Workers

As with the automation of any process, if 3D printing buildings becomes reality, the technology will take the place of a portion of the current labor force. By removing studs, siding, and drywall from the construction process, there will need to be fewer boots on the ground with hammers in hand. While workers will still be needed to do other finish work, a number of workers performing shell construction will be displaced by the technology.

Khoshnevis argues that the technological advances will act to shift the kind of work to be done in the construction industry rather than simply reduce the workforce. There will be an increased demand for workers with skill sets matching the increased utilization of, for example, computer technology. These types of jobs will open opportunities for demographics not normally found in large numbers in construction industry—such as older workers or women. Yet, automation will yield a net loss in demand for construction field workers. Those affected by the shrinking workforce—one individuals and unions alike—will surely struggle in finding their place in the changed construction industry or in another industry altogether.

b) Allocating Risk

With the automation of a large part of the construction project, the legal elephant in the room is, as always, who will pick up the tab when everything does not go right? This question will need to be answered before architects, contractors, or owners reasonably will embrace these technologies, even if they are available. Few people want to take on a budding technology only to be left with the liability when it does not work out as promised. Therefore, it is necessary to put the technology in the appropriate legal framework and appropriately allocate risk.

One risk to consider are contractual warranties. AIA Document A201, for example, contains warranties assuring the owner that 1) the materials and equipment furnished will be of good quality and new unless otherwise required, 2) the work will be free from defects not inherent in the quality required or permitted, and 3) work will conform with the requirements of the contract documents. And, if the project is for residential construction, there are statutory warranties. In Minnesota, for example, Minn. Stat. § 327A provides certain statutory warranties for homeowners. For goods sold by commercial suppliers or manufacturers, the Uniform Commercial Code’s (“U.C.C.”) warranties are applicable. These include warranties of fitness for a particular purpose and merchantability, and, if provided, other express warranties.

Similarly, parties to a construction contract utilize indemnity for allocating liability. Construction contracts contain indemnification provisions and flow-down clauses which funnel liability down the contractual chain. In the absence of such clauses, the common law will often still allow recovery if one is forced to pay for the mistakes of another. These warranty and indemnity concepts can be applied to 3D printing, though the nuances for each particular technology and building method need to be worked out.

If the component pieces are printed off-site and sold to the owner, as in WinSun’s vision, there should be little difference between 3D printing and any other form of manufacturing. The printed component will arrive and be incorporated into the structure, just as any other manufactured component. If the component fails, the owner may be able to recover from the manufacturer based on the U.C.C. warranties (building components are generally “goods” covered by the U.C.C.) or its indemnity agreement. The contractor may want to pay special attention to the manufacturer’s express warranties or demand an express indemnity agreement given the novelty of the manufacturing process, but the incorporation of the component into the whole project will be similar to a component manufactured in a more traditional manner.
Similarly, if the 3D printer is used on a much larger scale on the job site, such as Khoshnevis’ vision of printing the structural portions of a house with one large machine, familiar concepts should apply. In effect, the contractor will be using one large piece of construction equipment to complete a large portion of the project instead of smaller pieces of equipment and labor. While this is a large technological shift, it should not be a great leap for the legal concepts undergirding allocation of liability. The contractor is still providing services, namely constructing the building, and the same common law, contractual, and statutory warranties and indemnity provisions may be applied.

Where the points of contention will likely evolve are in the specific allocation of risk between those using the technology and those providing the design, equipment, and materials. All of these elements are currently being developed, but current design-build and integrated project deliver methods should provide useful models to guide parties’ contracts. When implementing such a new technology, the owner, designer, and contractor will want assurances that every part will perform as advertised. And, they will want to account for design, manufacturing, and contracting contingencies and draft contract language that addresses them. This is especially true for 3D printing. The technology itself is still being developed—the Contour Crafter, for instance, is obviously new and lightly tested—and any errors will likely occur the highly orchestrated, integrated, and short printing process.

5. Conclusion

The potential of 3D printing technology for the construction industry is significant. If it continues to be developed, it may well revolutionize the construction process, resulting in more speed and less expense. However, as described above, implementing the technology will not be without its challenges. Before incorporating these cutting-edge manufacturing methods, participants should consider how the technology changes their exposure to risk and consult with knowledgeable counsel and insurance professionals.

Announcements

Fabyanske, Westra, Hart & Thomson, P.A. welcomes its newest shareholder, Tom Vollbrecht. Tom, a graduate of St. John’s University and Harvard Law School, has over 27 years experience as an attorney, primarily in construction, surety and fidelity law. He is a Vice Chair of the ABA Fidelity & Surety Law Committee, the Editor-in-Chief of its Newsletter and a frequent author and speaker on construction, surety and fidelity law topics. He has been recognized multiple times as a Minnesota “Super Lawyer” and previously was a partner at Faegre & Benson, LLP and Hammargren & Meyer, P.A. His contact information is tvollbrecht@fwhtlaw.com and 612.359.7659.

Matthew Collins will be speaking on Bonds, Liens, Insurance & Indemnity at the Concentrated Course in Construction Contracts in Las Vegas, NV on May 20, 2014. The annual Course is hosted by Thomson Reuters and Mr. Collins will discuss key concepts in suretyship and insurance law, the protections provided to contractors by mechanic’s liens, and common law and contractual indemnity. For additional information, contact Mr. Collins at 612.359.7610 or mcollins@fwhtlaw.com.

Mark Becker, Luke Clayton, Julia Douglass, and Nathan Sellers will be giving a seminar on June 10, 2014 titled: Construction Management/Design-Build in Minnesota. The seminar will start at 8:30 a.m. and will end at 4:30 p.m. Continuing Education credit is available. The seminar will be hosted by Lorman, and will be held at the Holiday Inn Bloomington, I-35, 1201 W. 94th Street, Bloomington, Minnesota. For information please contact Mr. Becker at 612.359.7620. Friends of Fabyanske, Westra, Hart & Thomson, P.A. may be eligible for a discount of up to 50%. Registration can be accomplished through Lorman’s website at www.lorman.com, please mention priority code 15999 and discount code E4267574. We look forward to seeing you at this seminar!