

3D Printing Best Practices Guidance Document

Purpose Of This Guide¹

3D printing, often known as additive manufacturing, is a relatively new type of construction technology for NAHB’s members. The American Society for Testing and Materials and the International Organization for Standardization define additive manufacturing as “the process of combining materials to construct objects from 3D model data, usually layer by layer.” 3D printing is used in various trades, including, but not limited to, MEP and structural components. Industry observers estimate that the value for the concrete 3D printing market alone reached \$56.4 million in 2021.

The rise in 3D printing is due to a number of factors, including, but not limited to: (i) a push for automation to reduce labor costs in certain markets and to minimize on-site construction durations; (ii) increasing production in the construction industry; (iii) improving architectural freedom; and (iv) environmental sustainability goals. With its potential for, among other things, automation, formwork elimination, construction waste reduction, and geometrical precision enhancement, 3D printing may serve as a helpful new construction technology for NAHB’s members in certain circumstances. This document seeks to provide builders with an understanding of the challenges and basic considerations before utilizing 3D printing on their projects, as well as a series of checklists to manage potential risks stemming from the use of 3D printing.

Engagement of the 3D Printing Technology

NAHB members that are interested in using 3D printing technology may engage a company possessing 3D printing technology in several different ways, and the method chosen will, in part, impact the risk assessment.

1. Retain a construction company that has its own 3D printing technology. This might be ideal for the developer that wants to see “how” 3D printing technology differs from conventional construction without directly investing in the technology. Contracting with a vertically integrated company — to build an entire neighborhood or to construct a number of structures within a larger development – will allow the developer to see the entire process from start to finish.
2. Use a subcontractor that specializes in constructing with 3D printing technology. This might be ideal for the home builder that wants to use technology but not make the investment in purchasing the technology. For example, the builder could hire a 3D printing technology company that builds walls only, which is not much different than the general contractor hiring a framing crew or concrete masonry company.
3. Directly invest in 3D printing technology. An initial factor to consider is whether to purchase or lease your 3D printer from a 3D printing technology company. This might be ideal for the contractor that wants to own the technology and market its company as a 3D printing builder. Some leasing options may come with an option to buy.

¹ DISCLAIMER: Developed by the Construction Liability, Risk Management, and Building Materials Committee of the National Association of Home Builders with the assistance of Brenda Radmacher, John Neary, and Michelle Santos of Akerman LLP, this document is not intended to be exhaustive and all-inclusive but merely a guide to some issues and practices that builders should consider when contemplating 3D printed home construction. Satisfaction of all of the items set forth in this document is no assurance that the builder will not incur legal liability in any particular project. NAHB expressly disclaims any responsibility for any damages arising from the use, application, or reliance on recommendations and information contained herein. This publication is not intended to provide legal or other professional advice. Should you require legal advice or other expert assistance you should seek the services of a competent professional. The National Association of Home Builders expressly disclaims any responsibility for any damages arising from the use, application, or reliance on the recommendations and information contained herein.

How To Manage The Risks Of 3D Printing

This 3D printing checklist has been developed to help NAHB members evaluate and manage the risks in implementing 3D printing in their projects. This document breaks down the analysis into five primary areas for a company to evaluate before deciding to implement 3D printing:

1. Risk Transfer – including the selection of the right partners for your project, suitable insurance coverage, and warranty considerations.
2. Labor & Personnel Issues – ensuring that you have properly qualified and experienced labor who are comfortable with the technology and capable of managing the quality control process required when using 3D printing, and integrating the 3D printed elements with the other portions of your project.
3. Production Process – maintaining a plan to address the exposures for breakdowns in the equipment used in the 3D printing process.
4. Other Contractual Considerations – other terms to consider and include in your contract negotiations with 3D printing stakeholders.
5. Legal Risks – addressing the questions surrounding the lack of comprehensive regulations for 3D printing, the potential implication of product liability given the shift of work from on-site to off-site facilities, as well as understanding some of the existing legal structures that may impact your liability exposure when using 3D printing.

Each section below contains questions for evaluation, and some initial steps to consider in limiting your exposure when using 3D printing on your projects. Company leaders are encouraged to use this Pamphlet as part of the process in considering the use of 3D printing.

Risk Transfer

Risk transfer includes a variety of steps, including choosing the right partners for the project, investigating and selecting the proper insurance coverage, and establishing the best warranty procedures to address issues and replacement items, as well as ensuring that the contract terms and language are in place to provide protections. The contract language is of paramount importance and is discussed at length in the next section.

3D printed construction involves parties that have not been traditionally involved in construction – software engineers and manufacturers of 3D printers – and requires integration of the software and manufacturing processes into the evaluation of who bears the risks of the design, building, and integration segments. The documentation of the agreement is important, but similarly, selecting the right partners who have the requisite experience, financial wherewithal, and insurance is critical. With many other types of risk, the insurance industry has years of experience, data, and metrics to understand how to price and manage the exposure. Courts have interpreted policy language and insurers afford coverage for risks based on the policy. However, the novel nature of 3D printed construction leads to new questions of liability and coverage. Folding into the pre-construction process the agreements on who is responsible for which portion of the project and how the parties will handle warranty will be paramount to an effective integration of 3D printing on your project.

Checklist for Risk Transfer:

- Selecting the Right Partners
 - The roles of the partners involved:
 - What is the role of the technology firm providing the 3D printer?
 - Is the technology firm on site or not?
 - Who is directing the 3D printer's progress?

- Is the architect or engineer of record involved in integrating the digital information into the 3D printing data (and the Building Information Modeling ("BIM") used in conjunction with the 3D printing software) under the Contract Documents?
- Who is engaging the 3D printer – will the builder engage them directly or will a subcontractor or one of the design-team members contract with the 3D printing company?
- Will there be a joint venture or partnership for the project?
- Selecting the 3D Printing Company
 - Scope of the 3D printing
 - Will there be any offsite printed materials, or will the 3D printer be on site? Or will there be “cut on-site” – where on-site printing is performed in pieces that are built and assembled as they come out of the machine?
 - Transportation arrangements and responsibilities need to be set in advance (including insurance and captured in the contract terms, as noted below).
 - Protecting the printer while it is on site – confirm a check list is provided from the 3D printing manufacturer and is followed by the team on site.
 - Installation instructions and directions for set up and dismantling the printer need to be confirmed and provided in advance to ensure the proper spacing and safety requirements are attainable.
 - Procuring the right 3D printer
 - Be aware of the availability/supply of the 3D printer well in advance during the pre-construction phase.
 - Consider any customization needs for the printer.
 - Are you renting or purchasing a 3D printer?
 - If renting:
 - Who is operating the 3D printer/what training does the 3D printing company provide?
 - What is the solution for needs for repairs?
 - Will the 3D printing company be responsible for consequential damages from delays due to equipment breakdowns or problems?
 - If purchasing:
 - How will you transport the equipment to your jobsite?
 - Who is responsible for repairs, maintenance?
 - Who provides training?
 - How long is the product warrantied for and will the seller bear responsibility for any consequential damages if there is an equipment breakdown or problem?
- Selecting the right design team
 - Ensure the architect and engineer have an understanding and experience with 3D printing.
 - Determine up front the role and design involvement of the software engineer for the 3D printer.
- Insurance Questions
 - Is a project-wide insurance program being procured for the project, through an owner or contractor-controlled insurance program? Or will each member of the construction team be procuring its own insurance?
 - What type of insurance is required?
 - In addition to standard coverages, does the 3D Printer need to have coverage for design errors & omissions?

- Who is responsible to any damage to the 3D Printer while it is transported? While it is on site?
- Carefully consider contractor's professional insurance if the builder is directly contracting with the 3D printer; require the subcontractor employing the 3D printing to have professional E&O coverage.
- Review with insurance consultant/counsel the need for cyber insurance – whether for the builder, but certainly for the 3D printer
- Review the exclusions in the policy provisions to ensure that the risks for 3D printing are not carved out from the coverage.
- Evaluate the builder's risk policy in particular for coverage for all of the 3D printing aspects of the project. Any off-site construction should be carefully evaluated.
- Warranty Issues and Procedures.
 - Did you engage in pre-construction discussions and agreements to determine who will be responsible for warranty issues for any equipment issues during the course of construction?
 - Develop and maintain a checklist for troubleshooting and addressing any issue that occur during the printing-process.
 - Have a point person set up for warranty issues and an agreed-upon process for what amount of time for any warranty response will be provided.

Labor & Personnel Issues

With the implementation of 3D printing, builders need to ensure that properly trained and qualified personnel are involved. Depending on the details of the project, the personnel associated with the 3D printing will need to be the qualified technicians and systems operators, software engineers, and the like, and may also need to understand the building codes and requirements. If the 3D printed materials are being incorporated into a larger structure, the personnel will need to be able to coordinate with the contractors handling the interface between the 3D printed and traditional elements. In addition to safety and staffing issues that apply to all construction projects, there are some unique check-list items to consider:

Checklist for Personnel Issues:

- What experience does the project superintendent/project manager have with 3D printing?
- Understand and obtain the information on the training of the personnel who are handling the on-site software and communications with the 3D printer.
- Oversight and supervision for the integration of the 3D printed elements and coordination.
- Site safety training for 3D printing issues added to the construction site.
- Ensure all personnel are wearing and using the necessary PPE.

The Production Process

Even if the production process has been delegated to others, the builder must consider and implement a plan to address the exposures for issues that may arise during the production process.

Checklist for the Production Process:

- Constructability Considerations:
 - Ensure the size of the 3D printer can manage and cover the scope and scale of the project.
 - Ensure that the design of the project is able to be achieved by the 3D printer.
 - Confirm the software platform being utilized will coordinate with any other digital processes used on the project.
 - Coordinate with the necessary structural engineers to evaluate the quality of the printed parts for load-bearing capacity; evaluate the specific concrete or polymers being used for proper products for the ultimate printed material and its usage.

- Determine the necessary nozzle shape and size for the extrudability of the mix by the 3D printer to meet relevant construction standards and design criteria.
- Pre-construction needs must be evaluated for transportation and set up of the equipment at the project site, and any needs for adaptability during the course of construction.
- Emergency contact information if there is a problem during the 3D printing process.
- Have a troubleshooting outline and plan in place before problems occur; a backup plan should be discussed and documented to address breakdowns in the 3D printer, material or supply issues or impacts, and weather impacts.
- Have a safety and preparedness plan in place including utilities and emergency generators to ensure the printing process can continue.

Contract Language

All contracts involving construction that utilize 3D printing must include the standard provisions for all other types of construction; however, there are some unique issues that require special consideration in the terms of the agreement. There are multiple types of contracts that will require consideration of how the 3D printing integrates into the project and they will depend on the delivery mechanism for the project. Some of the following issues should be considered and negotiated in the contracting stage when a 3D printing company is involved. In addition, the agreements with the architect and engineer require close examination to ensure a proper allocation of responsibility for the design portion of your project. Additionally, subcontractor and supplier agreements require coordination with other project elements to avoid gaps in scope and to confirm the nuances associated with 3D printed construction work.

Checklist for Contract Language:

- Scope.
 - What are the boundaries of what the 3D printer must do as part of its scope of work:
 - What design confirmation must be made?
 - Who designates the materials to be made and to ensure the printer can accurately generate the consistency of the product (whether it be concrete, plastic, etc.)?
 - Identify the required physical properties of the 3D printed elements.
- Roles and responsibilities of the parties.
 - State and describe the role and responsibility of each of the parties to the project.
 - Clearly identify what contracts and agreements establish the details of each party's responsibilities.
 - Quality control over off-site production.
 - Details regarding interfacing with other construction materials and building elements.
- Deliverables.
 - Define the specific deliverables for each of the parties.
 - Specify the printed objects' intended application, desired detail level, and any specific requirements, and requirements for the 3D printer to comply with project specifications.
- Project timeline, including milestones.
 - Tie in the 3D printed work with the overall project timeline.
 - Define milestones and delay issues.
 - Risk of loss (e.g., delay of delivery, or damage or destruction while in transit from the manufacturing site to the project site).
- Materials and Allocation of Responsibility for the Materials.
 - The agreement must have a delineation of responsibility for compliance with the specifications, in particular, whether the supplier of the concrete mix (or polymers/metals being used for the composite printed material) will bear responsibility to meet the requirements or whether this responsibility sits with the 3D printer or other inspector.

- Also, does the agreement include designation of who is the designer of the concrete mix and if that is the same designer of the overall construction project?
- Terms also must be considered for how to address problems with the printer hardware or software.
- Indemnity.
 - Ensure the indemnity provision provides the builder indemnity by the 3D printer regardless of whether the contract is direct or via a subcontractor.
 - Ensure that the indemnity language is consistent throughout the contracts between the builder, subcontractor, designer, and 3D printer.
 - Verify that the indemnity provision is enforceable under the relevant state law.
 - Confirm the indemnity provision is connected with how the scope of work is divided and that the 3D printing company has agreed to indemnify the necessary upstream parties.
 - Include a separate express defense obligation.
 - Carefully look at the scope of design work and ensure that you can legally obtain the necessary indemnity and defense associated with the design elements.
- Warranty & Repairs.
 - Who is responsible for “rework” costs? Address and consider how the builder will recover “rework” costs if the project owner does not approve of the 3D-printed aspects of the build.
 - What notice and right to cure, if any, will be provided?
 - Consider carefully the timing that needs to be stated and required for warranty work.
 - Disclaimer of warranties – consider the language and ensure that it meets the overall allocation of the parties’ roles and risk transfer.
 - Include a provision that the builder is not responsible for any misuse, modification, or negligence of the 3D printer, engineers, and/or suppliers.
 - Confirm and delineate the allocation of fault if 3D-printed work products cause harm to someone or damage property and how claims are to be addressed.
- How is warranty/repair work going to be accomplished once the 3D printer is off site?
- Cyber Security.
 - Confirm in the contract with the 3D printer that any files used are clearly designed for the subject project and are not procured from any sharesite, opensource, or internet source.
 - Inquire regarding the security for the CAD files and software for the 3D printing.
- Payment terms. What is the timing for payment related to the delivery of any 3D printed equipment and materials? If the project is a hybrid of 3D printed components and traditional construction, when is payment to the 3D printer issued?
- Intellectual Property.
 - Clearly identify who owns the copyright, trademark, patent, or other rights to the 3D printing designs, models, files, and products for the project.
 - Is a license needed/granted for the use, modification, or distribution of any of the 3D printed work, and if so, under what conditions?
 - What Confidentiality or Non-Disclosure provisions are needed?

Legal Risks

3D printing is still being developed and the careful builder will ensure that it is aware of the potential legal risks involved before jumping in. As discussed above, having clear delineation of role and responsibilities, thought-through contract terms (do not use something “off the shelf”), selection of qualified personnel, and careful consideration of the production process are all important issues to consider in evaluating the legal risks for builders. In addition, builders must be aware and vigilant that the current building codes, permit requirements, and quality assurance standards are potential additional obstacles as 3D printing may not completely address or comply with these issues.

Increased prevalence of this emerging technology will also have an impact on material suppliers. If 3D printers will be used in a specific project, designers and contractors should provide proper specifications for material compatible with the specific 3D printer. Material suppliers will also have to certify their materials as compatible with the printers. The developer must be aware and understand who has the responsibilities for these designations and comport these responsibilities with carefully crafted contract terms. Failure to do so could open designers and material suppliers to liability for construction defects resulting from the incompatibility of the material with the specific 3D printer.

The use of 3D printers in construction projects may pose conflicts with current licensing and permit regulations. The increased speed with which 3D printers can complete projects could be slowed down by current inspection requirements and inspection scheduling procedures. That said, there is a move toward enacting regulations, with the International Code Council's recent introduction of Appendix AW to the International Residential Code regarding 3D printing.² Appendix AW provides guidance for the 3D printed construction industry, using the Underwriters Laboratories' UL 3401 to set forth guidelines for officials' evaluation of 3D printed construction regarding both building elements and structures. Builders must be vigilant to check in with the jurisdiction to determine whether the locale has adopted this section.

It is notable that an acceptance criterion for 3D concrete walls (AC509) has been developed under International Building Code ("IBC") Section 104.11, which allows for alternative materials, design, and construction methods provided that such alternatives meet the intent of the IBC. However, again, local building codes will need to be modified to accommodate 3D printing, and local building and code compliance departments must become conversant in this new building method.

As the use of 3D printers becomes more common, government agencies in charge of inspecting construction projects will have to adapt to the faster-paced construction offered. In the ideal scenario, governmental agencies would embrace the new technologies in the construction industry and, for example, invest in automated scanner drones that could inspect an automated 3D printer's work and, immediately thereafter, send the inspection's result to the governmental agency for certification.

Finally, the advent of 3D printing potentially implicates manufacturing defects, and ensuing product liability. For example, some 3D printing companies sell prefabricated homes and others sell prefabricated kits of parts to developers, who then use such kits to construct residential structures. This hybrid environment with 3D printing and modular construction has the potential to complicate a builder or developer's risks and how they should assess their respective insurance needs.

NAHB's members should carefully assess their contracts and insurance policies to protect themselves from issues stemming from potential product liability risks. NAHB's members may need to modify their purchase order terms and conditions, as well as their insurance policies, including, but not limited to, builder's risk, and product liability provisions, whether as a stand-alone policy or as part of a general liability policy.

Checklist for Assessing Legal Risks:

- Verify what regulations may have been adopted in your jurisdiction. Meet with and discuss any issues with the building inspector at the outset of the project.
- Discuss with the supplier, 3D printer, subcontractors, and design team how the regulations have been considered in the development of the 3D printed elements to ensure compliance.
- Obtain necessary licenses and certifications for use of the 3D printed elements and designs.

² Appendix AW 3D-Printed Building Construction, 2021 International Residential Code (IRC), <https://codes.iccsafe.org/s/IRC2021P2/appendix-aw-3d-printed-building-construction/IRC2021P2-AppxAW>, (last visited Dec. 11, 2023).

- Review and confirm material compatibility.
- Assess any intellectual property issues and releases.
- Confirm the contract terms have been addressed and are coordinated.
- Determine what insurance and risk transfer is required and ensure that these mechanisms have been documented in the contracts.
- Identify the responsibility and evaluation criteria for the 3D-printed work products meeting aesthetic and engineered expectations.

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