

3D printed building construction: Evaluating code compliance and safety.

Session overview

- UL Solutions profile
- 3D printed building construction
- Thought leadership
- UL 3401* fabrication process evaluation
- Construction document review
- Testing
- UL 3401 report of findings
- Plan submittals and inspections
- International Residential Code (IRC)

3D printed construction considerations.

Demand drivers

- Less expensive than traditional construction
- Economies of scale
- Less manual labor
- Reduced construction times
- Affordable housing
- Custom designs and shapes
- Global expansion
- Buildings and structures
- Dubai futures – 25% of buildings by 2025

UL Solutions involvement in 3D printed building construction.

- Started in 2017
- Published UL 3401, the Outline of Investigation for 3D Printed Building Construction
- UL 3401 referenced in the 2021 IRC
- Coordinated efforts with AHJs
- Evaluates fabrication processes

Material property reproducibility

- Long history of testing polymeric material properties
- Research into the impact of 3D printing
- Varying 3D printing parameters can greatly affect mechanical, flammability and electrical properties
- Blue Card program established in 2017

Gaps to be addressed.

- Consistent reproducibility

- Fabrication process
- Additive manufacturing materials
- Code compliance determination
- Design and construction factors
- Quality control and documentation

Developing program requirements

Involved UL Solutions subject matter experts in:

- Material performance
- Additive manufacturing
- Building materials testing
- Building/residential codes
- Industrial machinery safety

UL 3401 scope

Evaluation of building elements fabricated using an additive manufacturing or 3D printing process

UL 3401 3D printed building construction.

- Evaluates 3D printed building elements
- Verifies that the 3D printing equipment, materials, and fabrication process produces building elements with equivalent properties

Types of additive manufacturing materials (AMM)

- Cementitious-based
- Polymeric-based
- Cellulosic fillers

UL 3401 fabrication process evaluation

Covers factors critical for consistent builds

- 3D printing equipment
- Fabrication (3D printing) process
- Quality control procedures
- Production records
- Additive manufacturing materials

Documented in proprietary report

3D printing equipment

- Listed to UL 2011, the Outline of Investigation for Machinery
- Printer and ancillary equipment
- Described in fabrication process description

Fabrication process

- Nozzle diameter
- Flow rate and print speed
- Deposition width and layer thickness
- Curing, post-curing finishing
- Ambient temperature and humidity limitations
- Software, firmware and controllers

Quality control (QC)

- Calibration procedures
- In-process QC
- Milling, cutting, finishing
- Post-processing inspection
- Repairing defective builds

QC manual retained on-site

Production records

- Automatically record production parameters
- Information saved for each build

AMM

- Proprietary AMM covered by third-party material traceability program
- Containers include a certification mark
- Instructions provided for on-site AMM mixing

UL 3401 construction documents review

Representative construction documents provided by the fabricator

- Typically cover an individual assembly, e.g., wall
- Identify insulation and finish materials
- Evaluated against identified building codes
- No code conflicts
- Identify applicable code-required testing
- Assembly produced with the same process and AMM

UL 3401 code-based tests.

Tests identified during the code review

- Surface burning characteristics (UL 723/ASTM E84)
- Fire Resistance (UL 263, ASTM E119)

- Thermal barrier (NFPA 275)
- Air and water leakage (ASTM E331, E283)
- Thermal performance (R-value ASTM C1363)

Samples produced with the documented fabrication process and AMM

UL 3401 durability and integrity tests.

Develops performance data for this new construction

- Tensile, compressive strength, slump
- High/low ambient temperature
- UV* exposure, freeze-thaw, water absorption
- Dimensional stability/shrinkage
- Interlayer adhesion

Regulatory compliance challenges.

- Building codes don't cover construction
- Lack of regulatory expertise
- Allowed under alternate materials and methods
 - properties equivalent to code requirements
- UL 3401 report of findings - technical report and test results that demonstrate equivalency
- Contractors' expertise and reproducibility produced with the same process and AMM

UL 3401 report of findings

(For review by the regulatory authority)

- Building element description, e.g., wall, roof, column
- Building regulations or codes evaluated
- Test results and certifications
- Identification of:
 - 3D printer
 - Fabrication process
 - UL Certified AMM

Example report of findings.

- 2021 IBC and IRC
- Type VB wall assembly
- Material property test data (comparison)
- Code-based tests
- Class A UL 723*/ASTM E84
- Foam plastic Class A
- Air and water leakage (ASTM E331 and E283)
- R-value 38 (ASTM C1363)
- Hourly fire resistance rating — not established

2021 International Residential Code

Appendix U includes:

- **U103.1 Design organization.** 3D printed building elements shall be designed by an organization certified per UL 3401 by an agency approved by the building official.
- **U103.2 Design approval.** The structural design, construction documents, and UL 3401 report of findings shall be submitted for review and approval in accordance with Section 104.11.
- **U104.1 Construction.** 3D printed building elements shall be constructed in accordance with this section.

U105.1 Initial inspection. An initial special inspection is required after the equipment is on site but before fabrication begins.