

Additive Construction with Cement-based Materials

Objective

Develop the measurement science tools and scientific knowledge base for performance-based standards for Additively Constructed (3-D printed) concrete structures.

Business as usual.....?



3D Printing in mainstream construction

- What are some of the challenges for design and construction

Variability

Standards

Joints -
Connections

Perception



CODES

The Path to Standardization...

Acceptance and
Utilization

Design Criteria

Performance
Assessment

Field Tests

Standards

**Test
Methods**

Fundamental
Mechanics



What is required for a standard test method?

Standard tests provide a basis for establishing characteristics of material in a manner that is universal and consistently understood by practitioners – a *lingua franca* of sorts.

Test methods must be reliable, repeatable and transferable.

For nontraditional construction systems using “new” materials, this requires that a method have utility in “less than optimal” field environments.

Approach

Connecting the structural performance and failure modes to material properties requires a multi-scale research approach. The approach should be organized into three tracks:

- Fundamental studies of the relationship between hydration product formation and the setting cementitious slurries,
- Understanding the relationship between material properties and printing performance,
- Testing of the response of 3-D printed concrete structures to engineering design loads.

One thing is not like the other....

Lab vs Field

Paste vs Mortar vs Concrete

Additives and

Reinforcements

Test specimen geometry

Specimen production

Test parameters

Curing



ACI 564

Committee Mission: Develop and report information on three-dimensional printing (3-D) printing, or additive manufacturing with inorganic cementitious materials.

Goals:

1. Develop publications relating to additive manufacturing with cement-based materials. One focusing on “big picture” impact and challenges and the other focusing on construction applications.
2. Collaborate with ACI committees to disseminate AM information and determine ways AM may be integrated into the concrete community.
3. Collaborate with technical organizations outside of ACI, e.g., RILEM, ASTM, PCI (pre-cast), ISO, ASCE (SEI, EMI) to facilitate and coordinate information sharing. Foster discussion on research needs and challenges preventing AM from wide adoption in the concrete construction community.
4. Develop guidelines to evaluate materials and technology for AM.

564-0A - Emerging Technology Report

564-0B - Structural Design and Testing

564-0C - Material Testing and Formulation

ASTM F42.07.07

WK74302 - (Specification) Additive Manufacturing for construction – Process characteristics and performance – Specification for manufactured polymeric UV cured structures for residential applications

WK78110 - (Guide) Additive Manufacturing – General Principles – Development and Roadmapping of Additive Construction Standards

WK81114 - New Practice for Additive Manufacturing -- General Principles -- Design Process of Additively Manufactured Building Elements. This work item will be considered as a joint effort under ISO/ASTM 52962

WK84415 - New Practice for - Additive Construction – General Principles – Standard Practice for the Evaluation of Structural Printed Elements. This work item will be considered as a joint effort under ISO/ASTM 52963

WK89299 - **new for 2024** - (Specification) Additive Manufacturing for construction – Qualification principles – Structural and infrastructure elements. Revision of ISO/ASTM 52939 published in December 2023

WK89706 - **new for 2024** - Standard Practice for Additive Manufacturing -- Fresh and Very Early Age properties of concretes used for Additively Constructed Concrete by Means of Extrusion

WK89707 - **new for 2024** - Standard Practice for Additive Manufacturing -- Construction and Documentation of Additively Constructed Concrete and Mortar Components

WK89801 - **new for 2024** – Standard Practice Additive Manufacturing -- Curing and Extraction of Sample from Additively Constructed Concrete and Mortar Components

WK89802 - **new for 2024** - Standard Test Method Additive Manufacturing -- Determination of Hardened Mechanical Properties of Additively Constructed Concrete and Mortar

Code/ Standard Development

- Tech notes (ACI 564)
- ITG-12 Code Requirements Construction of Additively Constructed Walls
- IBC 104.11
- ICC-ES AC 509

Thank You!