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Additive manufacturing for construction — Qualification principles — Structural and infrastructure elements

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Foreword

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This document was prepared by Technical Committee ISO/TC 261, *Additive manufacturing*, in cooperation with ASTM Committee F42, *Additive Manufacturing Technologies*, on the basis of a partnership agreement between ISO and ASTM International with the aim to create a common set of ISO/ASTM standards on Additive Manufacturing and in collaboration with the European Committee for Standardization (CEN) Technical Committee CEN/TC 438, *Additive manufacturing,* in accordance with the Agreement on technical cooperation between ISO and CEN (Vienna Agreement).

Any feedback or questions on this document should be directed to the user’s national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

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Introduction

The construction sector is increasingly facing challenges with respect to labour shortages, project delays, increased lead times, excessive material use, large amounts of waste and adverse CO_2 footprint impacts. Furthermore, from a market perspective, the global construction demand is increasing especially as the housing crisis continues and infrastructure projects (whether new or sustaining existing structures) are on the increase. Additive construction (AC) also known as additive manufacturing for construction (AMC) and 3D construction printing (3DCP) has the potential to address these issues directly.

Of late, AC has made great strides. Printed elements could potentially prove to be more durable, more sustainable, more eco-friendly, cheaper (en masse), and faster to deliver than conventional construction approaches. However, without AC standards, approval, certification, and risk mitigation are unattainable.

The purpose of this document is to outline the requirements necessary as a basis for production and delivery of high quality additively manufactured structures (residential or infrastructure) in the construction sector.

Important steps of the AC process are specified. These steps will be controlled and monitored to ensure high quality printed structures for on-site or off-site use. This document is not intended to be technology- or material-specific, and therefore sub-processes are applicable depending on the approach used. However, it should be noted that printed element(s) should be approved by a locally certified engineer and adhere to both local and regional specifications and requirements.

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Additive manufacturing for construction — Qualification principles — Structural and infrastructure elements

1 Scope

This document specifies quality assurance requirements for additive construction (AC) concerning building and construction projects in which additive manufacturing techniques are used for construction. The requirements are independent of the material(s) and process category used.

This document does not apply to metals.

This document specifies the criteria for additive construction processes, quality-relevant characteristics, and factors along AC system operations. It further specifies activities and sequences within an AC cell (additive construction site) and project.

This document applies to all additive manufacturing technologies in building and construction (load bearing and non-load bearing), structural and infrastructure building elements for residential and commercial applications and follows an approach oriented to the process.

This document does not cover environmental, health and safety aspects that apply to printing facility setup, material handling, operating of robotic equipment, and packing of equipment and/or elements for shipping but material supplier guidelines, robotic solution operating guidelines, and local and regional requirements are applicable.

This document does not cover design approvals, material properties characterization and testing.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO/ASTM 52900, *Additive manufacturing — General principles — Fundamentals and vocabulary*

ISO/ASTM 52950, *Additive manufacturing — General principles — Overview of data processing*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO/ASTM 52900 and the following apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

3.1
additive manufacturing for construction
AMC
process to join materials to make structural and non-structural elements/components and systems from 3D model data usually by depositing material layer upon layer as opposed to subtractive and formative manufacturing methodologies

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3.2
additive construction
AC
term to describe all relevant disciplines and knowledge for the construction segment using additive manufacturing process categories

Note 1 to entry: The use of the technologies covers all relevant construction sectors, for example large scale real estate projects, entire buildings and building elements, civil infrastructure, and disaster relief.

Note 2 to entry: AC describes all relevant knowledge disciplines, for example: architecture, engineering, structural engineering, materials engineering, robot operator, project management, construction management, facility management, etc.

Note 3 to entry: Other terms used interchangeably are: Digital Construction (DC), Construction 4.0, Advanced Manufacturing in Construction (AMC), Construction 3D Printing (C3DP) and 3D Construction Printing (3DCP).

Note 4 to entry: Building materials include:

— cementitious variations such as concrete and mortar, polymer modified pastes,

— composite materials.

Note 5 to entry: Intrinsic to the current definition is a high degree of robotic automation, a reduced degree of human intervention during the construction process, and minimal waste due to as-needed material delivery systems.

Note 6 to entry: As of this writing in 2023, the field of AC is rapidly evolving, and novel materials and methods are very likely to become included in this definition.

Note 7 to entry: AC is used on-site or off-site (e.g. modular factory-based production).

3.3
layer deposition
application of a single layer

3.4
AC cell
printing solution deployed on site for in-situ printing (includes material mixing and placement systems)

3.5
material deposition device
numerically controlled assembly, including mixing and delivery mechanisms for raw materials, binders, and additives; places the mixture based on a digital simulation entered in the assembly's electronic programs, without the need for direct human intervention or for using moulds

3.6
physical production
physical totality of the build space, elements located on the build space, and production related support structures and plant in the build space of the system

3.7
virtual production run
computer/digital simulation of the *physical production* (3.7) run (print file)

EXAMPLE Printing simulation.

3.8
dry production run
process of running the build program with no materials to verify the first layer toolpath and other critical points of the program; and can be part of calibration process

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3.9
construction process
digital and physical AC operations, from setup of the robot through completion of the final printed element, including quality assurance testing and verification

3.10
mechanical, electrical and plumbing
MEP
building systems required for heating, ventilation, and air conditioning; electrical power and communication supply; and water supply and sewage removal, respectively

3.11
printed element
construction 3D printed component, whether constructed on-site (in-situ) or off-site, that gets incorporated into a building or structure, as a complete infrastructure component

EXAMPLE Walls, columns, beams, etc.

3.12
printability
ability of the material to be easily delivered to the print head, processed by the print head, e.g. *extrudability* (3.13), and meet consistent layer shape stability, *buildability* (3.14) requirements, and if applicable *pumpability* (3.15)

3.13
extrudability
ability of the material to smoothly be ejected through the printing nozzle without inducing any blockage of the conduits or significant damage to the material quality

3.14
buildability
ability of a print to preserve vertical and lateral stability under increasing loads coming from superposed/subsequent layers with controlled deformation

3.15
pumpability
material paste criterion that is related to the concrete extrusion and workability, as it is important to ensure that the materials have a continuous easy-flowing behaviour from the source to the printing material deposition device/nozzle

Note 1 to entry: Pumpability ensures the materials can be pumped easily and continuously without creating clogging issues inside the delivery system.

4 Constructability, assessment and review

4.1 General

The AC element requirements shall be specified and verified before the data preparation. The results shall be transferred in a definite sequence with associated production specifications including specific requirements in respect to the quality control (for load and non-load bearing elements). It is recommended that any asset monitoring and/or management be based on locally applicable standards/codes/regulations which could be based on numerical verification analysis.

If the production request is incomplete (for example missing technical drawing) or an initial commissioning is associated with restrictions, the customer shall be notified to correct the problem.

Figure 1 shows the individual steps for checking the feasibility and qualification phase as a pre-requisite for the serial production with AC.

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