ICC EVALUATION SERVICE®

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November 22, 2024

TO: **PARTIES INTERESTED IN AUTOMATED 3D PRINTING CONSTRUCTION TECHNOLOGY FOR 3D PRINTED HEMPCRETE WALLS**

SUBJECT: Proposed New Acceptance Criteria for Automated 3D Printing Construction Technology for 3D Printed Hempcrete Walls, Subject AC572-0225-R1 (AV/MS)

Hearing Information:
WebEx Event Meeting
Wednesday, February 19, 2025
8:00 am Pacific Standard Time
Click the date above to register

Dear Colleague:

You are invited to comment on the enclosed proposal for a new ICC-ES Acceptance Criteria for Automated 3D Printing Construction Technology for 3D Printed Hempcrete Walls (AC572).

The proposed new criteria is applicable to automated 3D printing construction technology and 3D printed hempcrete (hemp-lime) used to construct interior and exterior, load-bearing or non-load bearing walls, in one-story structures under Seismic Design Categories A and B. 3D printable hempcrete, in this criteria, is a non-cementitious material bio-aggregate composite consisting of hemp hurd, a lime-based binder, water, and additives and admixtures, if applicable. The 3D printed hempcrete walls are constructed by depositing 3D printable hempcrete layer-by-layer to create wall configurations. This criteria contains provisions for the evaluation of the material properties of 3D printed hempcrete, as well as for the structural performance of 3D printed hempcrete walls.

You are invited to submit written comments on this or any other agenda item, or to attend the Evaluation Committee hearing and present your views in person. If you wish to contribute to the discussion, please note the following:

1. Regarding written comments and presentations:

   a. You should submit these via e-mail to es@icc-es.org by the applicable due date.

   b. Comments are to be received by **December 18, 2025.** These written comments will be forwarded to the committee before the meeting, and will also be posted on the ICC-ES web site shortly after the deadline for submission. Written comments that are not submitted by this deadline will not be considered at the meeting.

   c. Rebuttal comments, from the proponent noted in this letter, are to be received by **January 9, 2025**. They will be forwarded to the committee before the meeting, and will also be posted on the ICC-ES web site shortly after the deadline for submission. Written rebuttal comments that are not submitted by the deadline will not be considered at the meeting.

d. If you want to make a visual presentation at the hearing, it must be received in PowerPoint format. The presentation is to be received by **January 24, 2025.** These will be forwarded to the committee before the meeting, and will also be posted on the ICC-ES web site after the deadline for submission. Presentations that are not submitted by the deadline cannot be presented at the meeting. **Note:** Videos will not be posted on the web site.

   Presentations will be retained with other records of the meeting.

e. ICC-ES will post to the web site, on **February 5, 2025**, memos by the ICC-ES staff, responding to the previously received public comments.

f. If you miss the deadlines for submission of written comments and visual presentations, your verbal comments can be presented at the meeting.

g. Proposed criteria, written public comments, visual presentations, and responses by ICC-ES staff for this agenda item are all available on our website.

2. Regarding verbal comments and presentations:

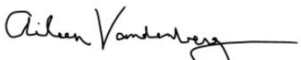
   Please plan to speak for not more than ten minutes. As noted above, visuals are to be in PowerPoint format.

3. Keep in mind that all materials submitted for committee consideration are part of the public record and will not be treated as confidential. It is the presenter's responsibility to certify to ICC-ES staff that no materials infringe copyright.

4. Please do not communicate with committee members before the meeting about any items on the agenda.

We appreciate your interest in the work of the Evaluation Committee. If you have any questions, please contact me at (562) 699-0543, extension 3256, or Melissa Sanchez, P.E, S.E. Principal Structural Engineer at extension 3230. You may also reach us by e-mail at es@icc-es.org.

Yours very truly,



Aileen Vandenberg, Ph.D.
Evaluation Specialist

AV/MS/ls

Encl.

cc: Evaluation Committee

ICC EVALUATION SERVICE, LLC, RULES OF PROCEDURE FOR THE EVALUATION COMMITTEE

1.0 PURPOSE

The purpose of the Evaluation Committee is to review and approve acceptance criteria on which evaluation reports may be based.

2.0 MEMBERSHIP

2.1 The Evaluation Committee has a membership of not fewer than nine, with one of the members named by the ICC-ES president each year to serve as the chairperson–moderator.

2.2 All members of the committee shall be representatives of a body enforcing regulations related to the built environment.

2.3 Persons are appointed to the committee by the ICC-ES president, from among individuals who have formally applied for membership.

2.4 The ICC-ES Board of Managers, using simple majority vote, shall ratify the nominations of the president.

2.5 Committee membership is for one year, coinciding with the calendar year. Members may be renominated and reappointed.

2.6 In the event that a member is unable to attend a committee meeting or complete a term on the committee, the ICC-ES president may appoint a replacement to fill in at the meeting or for the remainder of the member's term. Any replacement appointed for only one meeting must have prior experience as a member of the Evaluation Committee. Appointments under this section (Section 2.6) are subject to ratification as noted in Section 2.4.

3.0 MEETINGS

3.1 The Evaluation Committee shall schedule meetings that are open to the public in discharging its duties under Section 1.0, subject to Section 3.0.

3.2 All scheduled meetings shall be publicly announced. There shall be three to six meetings per year (as necessary).

3.3 More than half of the Evaluation Committee members, counting the chairperson, shall constitute a quorum. A majority vote of members present is required on any action. To avoid any tie vote, the chairperson may choose to exercise or not exercise, as necessary, their right to vote.

3.4 In the absence of the chairperson–moderator, Evaluation Committee members present shall elect an alternate chairperson from the committee for that meeting. The alternate chairperson shall be counted as a voting committee member for purposes of maintaining a committee quorum and to cast a tie-breaking vote of the committee.

3.5 Minutes shall be kept and shall be the official record of each meeting.

3.6 An electronic record of meetings may be made by ICC-ES if deemed necessary; no other audio, video, electronic recordings of the meetings will be permitted. Visual aids (including, but not limited to, charts, slides, videos, or presentation software) viewed at meetings shall be permitted only if the presenter provides ICC-ES before the presentation with a copy of the visual aid in a medium which can be retained by ICC-ES with its record of the meeting and which can also be provided to interested parties requesting a copy.

3.7 Parties interested in the deliberations of the committee should refrain from communicating, whether in writing or verbally, with committee members regarding agenda items. All written communications and submissions regarding agenda items must be delivered to ICC-ES and shall be considered nonconfidential and available for discussion in open session of an Evaluation Committee meeting. Such materials will be posted on the ICC-ES web site (www.icc-es.org) prior to the meeting. Comments and submissions not meeting the following deadlines will not be considered at the meeting:

- Initial comments on agenda items shall be submitted at least 28 days before the scheduled meeting.
- A rebuttal comment period shall follow, whereby rebuttal comments to the initial comments may be submitted by the proponent at least 21 days before the scheduled meeting.
- Those planning on giving a visual presentation at the meeting must submit their presentation, in PowerPoint format only, at least 10 days before the scheduled meeting.

The committee reserves the right to refuse recognition of communications which do not comply with the provisions of this section.

4.0 CLOSED SESSIONS

Evaluation Committee meetings shall be open except that at the discretion of the chairperson, staff counsel may be necessary. Also, matters related to clients or potential clients covered by confidentiality requirements of ICC-ES Rules of Procedure for Evaluation Reports are discussed only during closed meetings.

5.0 ACCEPTANCE CRITERIA

5.1 Acceptance criteria are established by the committee to provide a basis for issuing ICC-ES evaluation reports on products and systems under codes referenced in Section 2.0 of the Rules of Procedure for Evaluation Reports. They also clarify conditions of acceptance for products and systems specifically regulated by the codes.

Acceptance criteria may involve a product, material, or method of construction. Consideration of any acceptance criteria must be in conjunction with a current and valid application for an ICC-ES evaluation report, an existing ICC-ES evaluation report, or as otherwise determined by the ICC-ES President.

EXCEPTIONS: The following acceptance criteria are controlled by the ICC-ES executive staff and are not subject to committee approval:

- The Acceptance Criteria for Quality Documentation (AC10)
- The Acceptance Criteria for Test Reports (AC85)
- The Acceptance Criteria for Inspections and Inspection Agencies (AC304)

5.2 Procedure:

5.2.1 Proposed acceptance criteria shall be developed by the ICC-ES staff and discussed in open session with the Evaluation Committee during a scheduled meeting, except as permitted in Section 4.0 of these rules.

5.2.2 Proposed acceptance criteria shall be available to interested parties at least 30 days before discussion at the committee meeting.

5.2.3 The committee shall be informed of all pertinent written communications received by ICC-ES.

5.2.4 Attendees at Evaluation Committee meetings shall have the opportunity to speak on acceptance criteria listed on the meeting agenda, to provide information to committee members. In the interest of fairness, each speaker requesting to testify on a proposed acceptance criteria or proposed changes to an existing acceptance criteria will be given the same amount of time, as follows:

a. A 10-minute time limit applies to speakers giving their first testimony on any item, which applies to both verbal testimony and/or visual presentations.

b. A 5-minute time limit applies to speakers returning to the microphone to offer additional testimony and/or to rebut testimony given by others.

c. A 2-minute time limit applies to speakers offering testimony on the staff recommendation to criteria.

Should a company have multiple speakers, the speaker time limits above apply the company, in that multiple speakers from the same company shall share the testimony time, i.e., multiple speakers from the same company shall not each get their own testimony times. Time limits do not include time needed to answer questions from the staff and/or committee members. The chairperson–moderator shall have limited authority to modify time limitations on testimony. The chairperson–moderator shall also have the authority to adjust time limits as necessary in order to get through the hearing agenda.

An automatic timing device shall keep time for testimony and shall provide the time remaining to the speaker testifying. Interruptions during testimony will not be tolerated. It is the responsibility of the chairperson–moderator to maintain decorum and order during all testimony.

5.3 Approval of any action on an acceptance criteria shall be as specified in Section 3.3 of these rules. Possible actions made by the Evaluation Committee include: Approval; Approval with Revisions; Disapproval; or Further Study. The Evaluation Committee must give the reason(s) for any Disapproval or Further Study actions with specific recommendations.

5.4 Actions of the Evaluation Committee may be appealed in accordance with the ICC-ES Rules of Procedure for Appeal of Acceptance Criteria or the ICC-ES Rules of Procedure for Appeals of Evaluation Committee Technical Decisions.

6.0 COMMITTEE BALLOTING FOR ACCEPTANCE CRITERIA

6.1 Acceptance criteria may be revised without a public hearing following a 30-day public comment period and a majority vote for approval by the Evaluation Committee (i.e., alternative criteria development process), when at the discretion of the ICC-ES executive staff, the subject is a revision that requires formal action by the Evaluation Committee.

6.2 Negative votes must be based upon one or more of the following, for the ballots to be considered valid and require resolution:

a. *Lack of clarity*: There is insufficient explanation of the scope of the acceptance criteria or insufficient description of the intended use of the product or system; or the acceptance criteria is so unclear as to be unacceptable. (The areas where greater clarity is required must be specifically identified.)

b. *Insufficiency*: The criteria is insufficient for proper evaluation of the product or system. (The provisions of the criteria that are in question must be specifically identified.)

c. *The subject of the acceptance criteria is not within the scope of the applicable codes*: A report issued by ICC-ES is intended to provide a basis for approval under the codes. If the subject of the acceptance criteria is not regulated by the codes, there is no basis for issuing a report, or a criteria. (Specifics must be provided concerning the inapplicability of the code.)

d. *The subject of the acceptance criteria needs to be discussed in public hearings*. The committee member requests additional input from other committee members, staff or industry.

6.3 An Evaluation Committee member, in voting on an acceptance criteria, may only cast the following ballots:

- Approved
- Approved with Comments
- Negative: Do Not Proceed

7.0 COMMITTEE COMMUNICATION

Direct communication between committee members, and between committee members and an applicant or concerned party, with regard to the processing of a particular acceptance criteria or evaluation report, shall take place only in a public hearing of the Evaluation Committee. Accordingly:

7.1 Committee members receiving an electronic ballot should respond only to the sender (ICC-ES staff). Committee members who wish to discuss a particular

matter with other committee members, before reaching a decision, should ballot accordingly and bring the matter to the attention of ICC-ES staff, so the issue can be placed on the agenda of a future committee meeting.

7.2 Committee members who are contacted by an applicant or concerned party on a particular matter that will be brought to the committee will refrain from private communication and will encourage the applicant or concerned party to forward their concerns through the ICC-ES staff in writing, and/or make their concerns known by addressing the committee at a public hearing, so that their concerns can receive the attention of all committee members.■

Revised May 2024

ICC EVALUATION SERVICE®

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PROPOSED ACCEPTANCE CRITERIA FOR AUTOMATED 3D PRINTING CONSTRUCTION TECHNOLOGY FOR 3D PRINTED HEMPCRETE WALLS

AC572

Proposed November 2024

PREFACE

Evaluation reports issued by ICC Evaluation Service, LLC (ICC-ES), are based upon performance features of the International family of codes, and may include other codes, as applicable.

For alternative materials, design and methods of construction and equipment, see Section 104.2.3 of the 2024 *International Building Code*® (IBC), Section R104.2.2 of the 2024 *International Residential Code*® (IRC), Section 104.11 of the 2021 IBC and earlier editions, and Section R104.11 of the 2021 IRC and earlier editions.

ICC-ES may consider alternate criteria for report approval, provided the report applicant submits data demonstrating that the alternate criteria are at least equivalent to the criteria set forth in this document, and otherwise demonstrate compliance with the performance features of the codes. ICC-ES retains the right to refuse to issue or renew any evaluation report, if the applicable product, material, or method of construction is such that either unusual care with its installation or use must be exercised for satisfactory performance, or if malfunctioning is apt to cause injury or unreasonable damage.

Acceptance criteria are developed for use solely by ICC-ES for purposes of issuing ICC-ES evaluation reports

PROPOSED ACCEPTANCE CRITERIA FOR AUTOMATED 3D PRINTING CONSTRUCTION TECHNOLOGY FOR 3D PRINTED HEMPCRETE WALLS

1.0 INTRODUCTION

1.1 Purpose: The purpose of this criteria is to establish requirements for automated 3D printing construction technology, also termed additive construction, for use with proprietary 3D printable hempcrete, also termed 3D printable hemp-lime, for the construction of 3D printed hempcrete walls in ICC Evaluation Service, LLC (ICC-ES) evaluation reports under the 2024, 2021, and 2018 *International Building Code*® (IBC), and the 2024, 2021, 2018 *International Residential Code*® (IRC). The basis of evaluation is IBC Section 104.2.3 and IRC Section R104.2.2.

The reason for the development of this criteria is because the IBC and IRC do not contain provisions for the evaluation of 3D printed hempcrete walls constructed using automated 3D printing construction technology and 3D printable hempcrete.

1.2 Scope: This criteria applies to automated 3D printing construction technology and 3D printable hempcrete used to construct interior and exterior 3D printed hempcrete walls, with or without ladder wire mesh and steel reinforced grouted cells, used as bearing walls, non-load bearing walls, and shearwalls, in one-story structures of Type V-B construction, with optional testing for Type I – IV construction. The walls are to be constructed by depositing 3D printable hempcrete layer-by-layer to create wall configurations.

This criteria contains provisions for the evaluation of the material properties of proprietary 3D printable hempcrete, and the evaluation of the structural performance of 3D printed hempcrete walls.

3D printed hempcrete walls used as the lateral-force-resisting system under this criteria are limited to Seismic Design Categories (SDC) A and B.

Anchorage of 3D printed hempcrete walls to foundations and bond beams using code-complaint anchorage provisions shall be submitted to the code official for approval and are outside the scope of this criteria.

1.3 Codes and Referenced Standards: For the applicable editions of the referenced standards, see Table 1 of this criteria.

1.3.1 2024, 2021, and 2018 *International Building Code*® (IBC), International Code Council.

1.3.2 2024, 2021, and 2018 *International Residential Code*® (IRC), International Code Council.

1.3.3 ASTM C5, Standard Specification for Quicklime for Structural Purposes, ASTM International.

1.3.4 ASTM C31/C31M, Standard Practice for Making and Curing Concrete Test Specimens in the Field, ASTM International.

1.3.5 ASTM C39/C39M, Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens, ASTM International.

1.3.6 ASTM C78/C78M, Standard Test Method for Flexural Strength of Concrete (Using Simple Beam with Third-Point Loading), ASTM International.

1.3.7 ASTM C109/C109M, Standard Test Method for Compressive Strength of Hydraulic Cement Mortars, ASTM International.

1.3.8 ASTM C141/C141M, Standard Specification for Hydrated Hydraulic Lime for Structural Purposes, ASTM International.

1.3.9 ASTM C143/C143M, Standard Test Method for Slump of Hydraulic-Cement Concrete, ASTM International.

1.3.10 ASTM C206, Standard Specification for Finishing Hydrated Lime, ASTM International.

1.3.11 ASTM C207, Standard Specification for Hydrated Lime for Masonry Purposes, ASTM International.

1.3.12 ASTM C230/C230M, Standard Specification for Flow Table for Use in Tests of Hydraulic Cement, ASTM International.

1.3.13 ASTM C469/C469M, Standard Test Method for Static Modulus of Elasticity and Poisson's Ratio of Concrete in Compression, ASTM International.

1.3.14 ASTM C1581/C1581M, Standard Test Method for Determining Age at Cracking and Induced Tensile Stress Characteristics of Mortar and Concrete under Restrained Shrinkage, ASTM International.

1.3.15 ASTM C1583/C1583M, Standard Test Method for Tensile Strength of Concrete Surfaces and the Bond Strength or Tensile Strength of Concrete Repair and Overlay Materials by Direct Tension (Pull-off Method), ASTM International.

1.3.16 ASTM C1707, Standard Specification for Pozzolanic Hydraulic Lime for Structural Purposes, ASTM International.

1.3.17 ASTM E72, Standard Test Methods of Conducting Strength Tests of Panels for Building Construction, ASTM International.

1.3.18 ASTM E84, Standard Test Methods for Surface Burning Characteristics of Building Materials, ASTM International.

1.3.19 ASTM E119, Standard Test Method for Fire Tests of Building Construction and Materials, ASTM International.

1.3.20 ASTM E136, Standard Test Method for Assessing Combustibility of Materials Using a Vertical Tube Furnace at 750 Degrees C, ASTM International.

1.3.21 ASTM E518/E518M, Standard Test Method for Flexural Bond Strength of Masonry, ASTM International.

1.3.22 UL 263, Standard for Fire Tests of Building Construction and Materials, UL, LLC.

1.3.23 UL 723, Test for Surface Burning Characteristics of Building Materials, UL LLC.

1.3.24 ISO 21930, Sustainability in Buildings and Civil Engineering Works – Core Rules for Environmental product Declarations of Construction Products and Services, International Organization of Standardization (ISO).

1.4 Definitions:

1.4.1 3D Printable Hempcrete: Hempcrete, also known as "hemp-lime", is a non-cementitious material bio-aggregate composite consisting of hemp hurd of various sizes, a lime-based binder, water and, if applicable, additives and admixtures. 3D printable hempcrete is extruded by the automated 3D printing construction technology in a layer-by-layer fashion.

1.4.2 3D Printable Hempcrete Mixture Design: Proprietary mixture design containing hemp hurd, a lime-based binder, water and, if applicable, sand, aggregates, pozzolans, and natural cements. The 3D printable hempcrete mixture design may contain water, additives and multiple admixtures to regulate flow properties, mechanical properties and durability properties.

1.4.3 3D Printed Hempcrete Walls: Walls are to be constructed with the use of automated 3D printing construction technology using 3D printable hempcrete. Walls may be printed in various configurations.

1.4.4 3D Printer: Computer-controlled equipment, which includes a delivery system used to support and control the position and orientation of a proprietary nozzle, used to construct 3D printed hempcrete walls.

1.4.5 3D Printer Software: The computer program used to control the 3D printable hempcrete flow and nozzle speed, position and orientation.

1.4.6 Automated 3D Printing Construction Technology: Construction-scale 3D printing technology, also known as additive construction or layer-by-layer automated construction technology, used in the construction of buildings or building components, consisting of a computer program (3D printer software) and computer-controlled equipment (3D printer) to create three-dimensional shapes with 3D printable hempcrete.

1.4.7 Characteristic Strength Value: 5 percent fractile (value with a 95 percent probability of being exceeded with a confidence of 90 percent).

1.4.8 Grouted Cells: Vertical wall framing elements consisting of a 3D printed hempcrete shell filled with conventional reinforced concrete.

1.4.9 Hemp: A class of the Cannabis sativa plant grown for industrial purposes in which the concentration of total delta-9-tetrahydrocannabinol (THC) in the flowering tops is equal to or less than the regulated maximum level established by authorities having jurisdiction.

1.4.10 Hemp Hurd: The chopped woody core of the stalks of the hemp plant, stripped of its surrounding hemp fibers. Also known as "*hemp shiv*" or "*hemp shive*" or "*hemp powder*" depending on its size.

1.4.11 Ladder wire mesh: Horizontal steel reinforcing mesh distributed over the height of the wall.

1.4.12 Lime: Lime is composed of calcium hydroxide [$Ca(OH)^2$] including Type N or S hydrated lime, hydraulic lime, natural hydraulic lime or slaked quicklime.

1.4.13 Natural Cement: Hydraulic cement made from naturally occurring limestone.

1.4.14 Pozzolan: A siliceous or alumino-siliceous material that, when finely divided and combined with hydrated lime in the presence of water, forms new chemical compounds with cementitious properties.

1.5 Nomenclature:

F_i = test results normalized to consider specified hempcrete compressive strength, lb (N).

F_k = characteristic value (5 percent fractile) from testing, lb (N).

$F_{u,test,x}$ = mean test result for test series, x, lb (N).

f'_h = manufacturer's specified compressive strength of hempcrete, psi (MPa).

$f_{h,test,x}$ = mean hempcrete compressive strength measured with standard cylinders, per Section 4.3, lb (N).

K = tolerance factor corresponding to a 5 percent probability of non-exceedance with a confidence of 90 percent derived from a noncentral t-distribution for which the population standard deviation is unknown. Values for specific sample sizes, n, are provided in Table 3.

$v_{test,x}$= the coefficient of variation of the population sample corresponding to test series x, percent.

2.0 BASIC INFORMATION

2.1 3D printed hempcrete wall configurations and 3D printable hempcrete mixture design(s) shall be submitted to ICC-ES. In addition, the ICC-ES evaluation report holder's published operation instructions shall be submitted to ICC-ES and shall include provisions for use of the automated 3D printing construction technology as well as mixing of the 3D printable hempcrete mixture. Instructions shall include set-up, operation, maintenance, quality control, and inspections of the equipment.

2.2 Automated 3D printing construction technology and packaging of 3D printable hempcrete mixture(s) evaluated under this criteria shall bear permanent identification. Product identification shall be in accordance with the product identification provisions of the ICC-ES Rules of Procedure for Evaluation Reports and shall include the report holder's company name, address, product name and the ICC-ES evaluation report number (ESR-XXXX).

2.3 Testing laboratories shall comply with Section 2.0 of the ICC-ES Acceptance Criteria for Test Reports (AC85) and Section 4.2 of the ICC-ES Rules of Procedure for Evaluation Reports.

2.4 Test reports shall comply with AC85. The test reports shall be in sufficient detail to identify specimen properties that might affect performance.

2.5 Sampling of the 3D printable hempcrete mixture(s) shall comply with Section 3.1 of AC85, and preparation of 3D printed hempcrete walls shall comply with Section 3.3 of AC85 and be constructed with the automated 3D printing construction technology to be evaluated in the ICC-ES evaluation report.

2.6 Qualification Test Plan: A qualification test plan shall be submitted to and approved by ICC-ES staff prior to any testing being performed.

3.0 TEST AND PERFORMANCE REQUIREMENTS

3.1 Material Tests: Tests shall be performed in accordance with Sections 4.1 through 4.9 of this criteria. Testing shall be performed for each 3D printable hempcrete mixture design for each automated 3D printing construction technology.

3.2 Structural Tests: Tests shall be performed in accordance with Section 4.10 of this criteria. Testing shall be performed for each automated 3D printing construction technology considering the following:

- Each 3D printable hempcrete mixture design.
- Reinforcing details (rebar size and spacing and/or ladder wire mesh), if applicable. Steel reinforcement in contact with the 3D printed hempcrete shall be stainless steel or primed and painted with an epoxy, oil, bituminous paint or other approved coating. Water-based paints shall not be used.
- Variation in geometry of the 3D printed hempcrete shells (such as thickness and width of the extrusion layers).
- Minimum and maximum time intervals between extrusion layers to be evaluated, from one extrusion layer to the next immediate extrusion layer.

3.3 Surface-burning Characteristics Tests: 3D printable hempcrete shall meet the requirements for insulation materials in IBC Section 720.2 and IRC Section R302.10.1 for flame spread index and smoke developed index as tested in accordance with ASTM E84 or UL 723.

3.4 Noncombustible Building Material (Optional): For use in Type I, II, III, or IV construction, the 3D printable hempcrete mixture(s) shall be tested in accordance with ASTM E136. The specimens of 3D printable hempcrete shall satisfy the requirements set forth in IBC Section 703.3.

3.5 Fire-Resistance-Rated Wall Test (Optional): For use as a fire resistance-rated wall assembly, a specimen of the 3D printed hempcrete wall with the minimum wall thickness, shall be tested in accordance with ASTM E119 or UL 263 and IBC Section 703.2.1. Unless the 3D printed hempcrete wall is qualified by fire-resistance testing, the scope of the evaluation report shall be limited to use in non-fire-resistance-rated construction.

3.6 Interpretation of Structural Performance Test Results: Characteristic strength values for 3D printed hempcrete walls, used in analysis and design, shall be qualified by the test data in Section 4.10.2 of this criteria. Procedures from the IBC, if applicable, along with appropriate test data, shall be used to verify characteristic strengths that provide the required level of safety. The characteristic strength value, F_k , from testing shall be calculated using the following equation:

$$F_k \leq F_i(1 - Kv_{test})$$

where,

$$F_i = F_{u,test,x}\sqrt{\frac{f'_h}{f_{h,test,x}}}$$

As a minimum, three replicate specimens shall be tested and the coefficient of variation (COV) shall be equal to or less than 10 percent. If the COV exceeds 10 percent, additional testing shall be conducted until the COV obtained from all the tests does not exceed 10 percent or until at least three additional tests have been conducted.

4.0 TEST METHODS

4.1 General: Testing shall be performed for each 3D printable hempcrete mixture design.

4.2 3D printable hempcrete material properties: Hemp hurd shall be substantially free from dust and fiber clumps such that the 3D printable hempcrete mixture maintains its integrity. Hydrated lime shall comply with ASTM C206 (or ASTM C207) and ASTM C1707. Natural hydraulic lime shall comply with ASTM C141/C141M. Quicklime shall comply with ASTM C5.

4.3 Compressive Strength: A minimum of five replicate specimens for each 3D printable hempcrete mixture design used, complying with the requirements outlined in Section 4.1 shall be tested for compressive strength.

4.3.1 Procedure: Compressive strength testing shall be in accordance with ASTM C39/39M or ASTM C109/C109M except the rate of loading shall be 1/10 of the maximum loading rate of the recommended range. The 3D printable hempcrete shall be prepared, stored and cured in accordance with ASTM C31/C31M, or following the manufacturer's recommendations. The cure procedure used shall be reported in the ICC Evaluation Service evaluation report. The ICC Evaluation Service evaluation report shall also include the minimum curing requirements recommended by the manufacturer. The average 28-day compressive strength shall be published in the ICC Evaluation Service evaluation report as the minimum compressive strength to be used for design and shall be reported for quality control purposes and used by the testing laboratory for benchmark purposes as directed in this criteria.

4.4 Slump Testing: Prior to casting test specimens for compressive strength testing, slump of 3D printable hempcrete shall be measured and reported for quality control purposes. Slump of the proprietary 3D printable hempcrete mixture(s) shall be tested in accordance with ASTM C143/C143M or ASTM C230/C230M, whichever is applicable.

4.5 3D Printable Hempcrete Density: For each 3D printable hempcrete mixture design tested; all test specimens shall result from a single batch of the hempcrete mixture design. The test specimens shall be prepared in a form of 4-inch by 4-inch by 8-inch (102 mm by 102 mm by 203 mm) prism, a 4-inch (102 mm) diameter by 8-inch (203 mm) length cylinder, a 3-inch by 3-inch by 6-inch (76mm by 76 mm by 152 mm) prism, or a 3-inch (76 mm) diameter by 6-inch (152 mm) length cylinder, and shall be removed from the form within 48-hours after the placement of the 3D printable hempcrete mixture. The test specimens shall be cured for a minimum of 28 days in indoor ambient conditions. Measurements of weights and volumes shall be taken and the average of the measured weights and volumes calculated. The dimensions of the test specimens shall be measured with a measuring device capable of reading to an accuracy of 0.002-inches (0.05 mm). The density shall be calculated by dividing the average weight of the test specimens by the average volume of the test specimens and reported.

4.6 Modulus of Rupture: A minimum of three replicate samples shall be tested.

4.6.1 Procedure: Flexural tests shall be conducted in accordance with ASTM C78/C78M. Tests shall be conducted using specimens that are 28 ± 1 days of age after the date of mixing. All test specimens shall result from a single batch of the 3D printable hempcrete mixture. Tests

shall be conducted on three tests specimens from each 3D printable hempcrete mixture design. The average modulus of rupture of the three specimens shall be published in the ICC Evaluation Service evaluation report as the minimum modulus of rupture to be used for design.

4.7 Modulus of Elasticity: A minimum of three replicate samples shall be tested.

4.7.1 Procedures: Tests shall be conducted in accordance with ASTM C469/C469M except the rate of loading shall be 1/10 of the maximum loading rate of the recommended range. Tests shall be conducted using specimens that are 28 ± 1 days of age after the date of mixing. All test specimens shall result from a single batch of 3D printable hempcrete mixture. The average modulus of elasticity (MOE) of the three specimens shall be published in the ICC Evaluation Service evaluation report as the minimum modulus of elasticity to be used for design.

4.8 Restrained Shrinkage Cracking Test: The purpose of this test is to evaluate the restrained shrinkage cracking response of 3D printable hempcrete. A minimum of three replicate specimens shall be tested for each 3D printable hempcrete mixture design.

4.8.1 Procedure: Perform tests on 3D printable hempcrete in accordance with ASTM C1581/C1581M.The average age at cracking for all samples shall be published in the ICC Evaluation Service evaluation report as the minimum age at cracking to be used for design.

4.9 Test for Minimum and Maximum Extrusion Time Intervals: The purpose of this test is to demonstrate the effect of minimum and maximum time intervals of continuous extrusion of 3D printed hempcrete layers on the bond between the extrusion layers. The test shall be performed on specimens representative of the layered, 3D printed shells. The specimens shall be 3D printed with the automated 3D printing construction technology under evaluation.

4.9.1 Procedure: Flexural bond tests shall be in accordance with Section 5.2 (Method A) of ASTM E518/E518M on three replicate sets of specimens cast at both minimum and maximum extrusion time intervals between layers.

4.9.2 Conditions of Acceptance: The tested flexural bond strengths at minimum and maximum extrusion time intervals shall be statistically equal. Otherwise, any deviation shall be reported in the ICC-ES evaluation report. Average flexural bond strength and acceptable extrusion time intervals shall also be reported in the ICC-ES evaluation report.

4.10 Structural Performance: The following structural performance tests shall be in compliance with Section 3.6 of this criteria:

4.10.1 Test Specimens and Reports of Tests:

4.10.1.1 Types of Tests: For each 3D printed hempcrete wall configuration and for each combination of 3D printable hempcrete mixture designs to be used, the number of specimens as outlined in Sections 4.10.1.1.1 to 4.10.1.1.3 shall be tested. Testing shall continue until the ultimate load in each case is achieved. Where applicable, effect of buckling and/or outer face spalling of 3D printed hempcrete shall also be considered in the analysis.

4.10.1.1.1 Wall Axial Compression Test: A minimum of three specimens, shall be tested per wall height for two different wall heights, if applicable. One set of specimens shall be of the maximum wall height with the minimum wall thickness to be evaluated.

4.10.1.1.2 Wall Flexure Test: A minimum of three specimens shall be tested per wall height for two different wall heights, if applicable. The specimen preparation and dimensions shall be the same as those used in the wall axial compression test.

4.10.1.1.3 Wall Static In-Plane Shear Test: A minimum of three replicate specimens shall be tested for the thinnest wall width to be evaluated. If multiple wall thicknesses are to be included in the evaluation report, an additional three replicate specimens of the maximum wall thickness to be considered shall be tested.

4.10.1.2 Companion Material Testing: 3D printable hempcrete compression test cylinders shall be prepared of the 3D printable hempcrete used in each of the wall test specimens at the time the wall test specimens are constructed. The cylinders shall be prepared, stored and cured in accordance with ASTM C31/C31M, or according to the manufacturer. Within 24 hours after the wall tests, three replicate cylinders shall be compression tested in accordance with ASTM C39/C39M for each wall specimen for correlation of results with the wall tests. The minimum design compressive strength published in the ICC-ES evaluation report shall not exceed the average compressive strength of the 3D printable hempcrete used in the 3D printed hempcrete wall.

4.10.1.3 Reporting: In addition to the standard reporting and certification of test results, observations, deflections, and loads shall be reported and photographs taken and submitted, of specimen response at significant stages of the loading process.

4.10.2 Test Procedures:

4.10.2.1 Wall Axial Compression Tests: Wall axial compression specimens, with a minimum eccentricity of $t/6$ from the center plane of the wall, where t is the wall thickness, shall be tested in accordance with the general guidelines of ASTM E72 until ultimate load is reached.

4.10.2.2 Wall Flexure Tests: Wall flexural specimens shall be tested in accordance with the general guidelines of ASTM E72.

4.10.2.3 Wall Static In-plane Shear Tests: Shear tests shall be performed based on the racking load procedure described in Section 14 of ASTM E72. For these tests, the loading procedure shall be modified to apply the lateral racking through a continuous, reinforced concrete or steel member. The attachment to the specimen shall be designed so that applied loads are uniformly distributed along the specimen length. The specimen shall be mounted on a base in a manner equivalent to the method commonly used in the field. In this regard, the attachment of the specimen to the base shall be constructed to avoid concentrated reaction. In addition, where the vertical load is not sufficient to resist the overturning moment, anchorage shall be incorporated to prevent premature failure due to this action. The procedures and details of the specific test setup will depend on the product or system being tested, and these procedures and details shall be fully described in

the test plan. Calculations and reporting shall be in accordance with Section 14.5 of ASTM E72.

5.0 QUALITY CONTROL

5.1 The automated 3D printing construction technology shall be labeled and maintained under an approved quality control program with inspections twice annually by ICC-ES or by a properly accredited inspection agency with a contractual relationship with ICC-ES on behalf of ICC-ES in accordance with AC304.

5.2 The 3D printable hempcrete mixture design(s) shall be manufactured under an approved quality control program with annual inspections by ICC-ES or by a properly accredited inspection agency with a contractual relationship with ICC-ES.

5.3 Quality documentation, complying with the ICC-ES Acceptance Criteria for Quality Documentation (AC10) shall be submitted for both the automated 3D printing construction technology and the 3D printable hempcrete mixture design(s).

5.4 A qualifying inspection shall be performed at each automated 3D printing construction technology facility and each 3D printable hempcrete mixture manufacturing facility in accordance with the requirements of the ICC-ES Acceptance Criteria for Inspections and Inspection Agencies (AC304).

5.5 Special inspection shall be required in accordance with Sections 1705.1.1 and 1705.3 of the IBC during the mixing, printing, and placing of the 3D printable hempcrete. In addition, the report applicant shall submit inspection procedures to verify proper usage. The inspection shall include verification that the hempcrete compressive strength and flexural bond strength is in compliance with ICC-ES evaluation report. Hempcrete cylinders are to be field cured in accordance with ASTM C31/C31M and tested in accordance with ASTM C39/C39M. Testing of flexural bond strength in accordance with ASTM E518/E518M shall be compared with published values in the ICC-ES ESR report with maximum variability of 10 percent.

6.0 EVALUATION REPORT REQUIREMENTS

The evaluation report shall include the following information:

6.1 Product description, operation instructions and product identification, as required in Section 2.1 and 2.2. In addition, the minimum hempcrete compressive strength as outlined in Section 4.3, and acceptable slump range shall be reported in the evaluation report.

6.2 Design loads and deflections for each assembly, based on testing and analysis of data in Sections 4.10.2 and 3.6, respectively.

6.3 The 3D printed hempcrete walls are limited to use in one-story structures of Type V-B construction in dry service conditions, unless protected with code-compliant exterior wall coverings. For Type I, II, III, or IV construction, compliance with Section 3.4 of this criteria is required.

6.4 Where fire-resistance ratings for the 3D printed hempcrete have been established in accordance with Section 3.5, the evaluation report shall contain the details of the tested wall assembly and the associated fire resistance rating. Otherwise, the scope of the evaluation report will be limited to use in non-fire-resistance-rated construction.

6.5 The 3D printed hempcrete walls used as the lateral-force-resisting system are limited to Seismic Design Categories (SDC) A and B only.

6.6 Anchorage of 3D printed hempcrete walls to foundations and bond beams are outside the scope of this report and must comply with applicable sections of the IBC and IRC.

6.7 The use of reinforcement in 3D printed hempcrete walls must comply with Section 3.2 of this criteria. Otherwise, the evaluation report shall include a statement that the use of reinforcement in 3D Printed Hempcrete walls is outside the scope of this report.

6.8 The evaluation report shall include a statement that post-installed anchors in 3D printed hempcrete walls are outside the scope of this report.

6.9 Structural design calculations and details of the 3D printed hempcrete walls must be prepared by a registered design professional and submitted to the code official for approval. The structural calculations must also address the design and detailing of openings and loads on headers. Exterior envelope requirements of the applicable codes have not been evaluated and are outside the scope of the report.

6.10 The evaluation report shall include the special inspection provisions of Section 5.5 of this criteria.

6.11 The evaluation report shall include a statement that pauses in printing longer than the published extrusion time interval outlined in Section 4.9 shall be reported to the code official and registered design professional in charge of construction. If requested by the code official and/or registered design professional, evidence of equivalent bond strength between printed layers before and after the pause shall be provided to the satisfaction of the code official using the direct tension test method of ASTM C1583/C1583M or ASTM C78/C78M.

6.12 The evaluation report shall include a statement that use of bonding agents between printed layers is beyond the scope of this report.

7.0 ENVIRONMENTAL PRODUCT DECLARATION (Optional)

Environmental impacts shall be assessed via an Environmental Product Declaration (EPD) based on a Life Cycle Assessment (LCA). The LCA and EPD shall be conducted in accordance with ISO 21930 and the appropriate Product Category Rule(s) for the product type. ■

TABLE 1—REFERENCE STANDARD EDITIONS

STANDARD	2024 IBC	2021 IBC	2018 IBC
ASTM C5	2018	2018	2010
ASTM C31/31M	2021a	2018b	2015
ASTM C39/39M	2018	2018	2014a
ASTM C78/C78M	2022	2021	2018
ASTM C109/C109M	2023	2021	2016a
ASTM C141/C141M	2014	2014	2014
ASTM C143/143M	2020	2020	2015a
ASTM C206	2014	2014	2014
ASTM C207	2024	2018	2018
ASTM C230/C230M	2023	2021	2014
ASTM C469/C469M	2014	2014	2014
ASTM C1581/C1581M	2024	2018a	2018a
ASTM C1583/C1583M	2020	2020	2013
ASTM C1707	2018	2018	2018
ASTM E72	2022	2015	2015
ASTM E84	2021a	2018b	2016
ASTM E119	2020	2018b	2016
ASTM E136	2022	2019	2016
ASTM E518/E518M	2022	2021	2015
UL 263	2011	2011	2011
UL 723	2018	2018	2008
ISO 21930	2017	2017	2017

TABLE 2 – REFERENCED SECTIONS OF THE IBC AND IRC

2024 IBC	2021 IBC	2018 IBC	2024 IRC	2021 IRC	2018 IRC
104.2.3	104.11		R104.2.2	R104.11	
703.3		703.5	N/A		
703.2.1		703.2	N/A		
720.2			R302.10.1		
1705.1.1			N/A		
1705.3			N/A		

TABLE 3—K VALUES FOR 5 PERCENT PROBABLITY OF NON-EXCEEDANCE WITH A CONFIDENCE OF 90 PERCENT

Number of tests, n	K
3	5.311
4	3.957
5	3.400
6	3.092
7	2.894
8	2.754
9	2.650
10	2.568