



**City of
Portland, Oregon
Bureau of Development Services**

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To: Chariti Montez and Mark Lakeman

From: **Alternative Technology Advisory Committee:**
Edward Vranizan (chair) Samir Mokashi (vice-chair) Kathy Bash
Aron Faegre Ron Hays Joshua Klyber

RE: **Application #5 – Light Straw Clay – Final Recommendation**

Date: **February 20, 2011**

At the February 3, 2011 meeting, members of the Alternative Technology Advisory Committee agreed to make a final recommendation for your application with the following suggestions:

Include the following with your building code appeal:

- Your Letter of Response (including the Revised Application to ATAC) dated December 13, 2010
- U Value Wall Calculations
- Light Clay Straw Wall Diagram (provided by Ron Hays, copy attached)
- A copy of ASTM E2392 – Standard Guide for Design of Earthen Wall Building Systems. We think it is important for someone mixing LSC in the field to have this Standard because it describes the method for verifying appropriate moisture content for the clay mix. Copies are available on line for about \$40.

You may submit your building code appeal to use this technology for a site-specific project at any time by following the [instructions](#) found on the BDS website. A building code appeal must be approved by BDS to be able to use this technology in a project. Please submit a copy of this committee recommendation with your appeal application. Please contact the Appeal Board Secretary at (503) 823-7335 if you have any additional questions about the appeal process.



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RE: **Application #5 – Light Straw Clay – Final Recommendation**

Date: **February 20, 2011**

Summary of Proposal: The applicants have requested that the Committee review a proposal to install use light straw clay (LSC) as part of a non-structural exterior wall insulation and finish system for a new single-family dwelling or heated accessory structure. LSC is a mixture of clean dry straw, soil with 50% clay content, and water, with an estimated insulation value of R-2 per inch. A weather resistant coating is applied over the exterior side. The applicants claim the benefits of LSC include its low cost, low toxicity, reduced need for vapor barrier, its “flywheel” capacity to absorb the sun’s warmth during the day and release it at night, and its use of sustainable, native and locally available materials. LSC technology has been used for centuries.

Applicable Building Codes and Standards

2008 Oregon Residential Specialty Code: R703 Exterior Wall Covering;
N1104.2 Insulation Materials; N1104.9 Moisture Control; Appendix R Straw-Bale Construction
ASTM E2392 – Standard Guide For Design of Earthen Wall Building Systems

Committee Findings:

1. Since the LSC walls are non-load-bearing, the key building code issues are the durability of LSC and the insulation characteristics of the material. (These findings do not address the building structural design which in some cases may require an analysis for lateral wind or earthquake forces on the LSC elements.)
2. Because the LSC is made on site from local materials, there must be a way for those who are building and those who are inspecting to determine whether the mix will end up with the desired qualities. Moisture content of the mix is key and varies with the type of clay available, and therefore we agreed that the ASTM E2392 – Standard Guide for Design of Earthen Wall Building Systems provides appropriate guidance for determining soil adhesion.
3. A thicker LSC wall correlates positively with desirable insulation, but it correlates inversely with drying characteristics. Therefore, we agree that the nominal 12” wall (actual 11.25”) is a part of the guide that should be followed. In other words, this is a case in which thicker insulation may not be better. Just as with wood frame construction, it is imperative for durability that the wall be ‘dry’ before being closed up.
4. The nominal 12” wall is the thinnest LSC wall that will still meet the overall U value for above grade walls per Table N1101.1(1). The LSC wall does not qualify for Table N1101.1(2).3 High efficiency building envelope.
5. The Applicants have asked us to review LSC as an insulation material.. Attached to this letter is an illustration of LSC used in conjunction with Larson trusses as framing members. This was the basis of calculating the overall U value. Also attached is a copy of the Applicant’s proposed system which includes specific finishes that are important for durability. A subsequent Building Code Appeal application will require a complete wall system description.
6. Attachments:
 - Applicants Letter of Response (Revised Application) dated December 13, 2010
 - U Value Wall Calculations
 - Light Clay Straw Wall Diagram

Final Committee Recommendation:

Based on these findings the Alternative Technology Advisory Committee recommends approval of this technology. The Bureau of Development Services' Administrative Appeal Board is encouraged to approve subsequent building code appeals based on the information provided in this application.

Please note: The Bureau of Development Services (BDS) and its Administrative Appeal Board is not bound by the recommendations of the Committee. A favorable recommendation of a technology by the Committee does not guarantee approval of a building code appeal.

Further instructions for the applicant:

You may submit your building code appeal to use this technology in a site-specific project at any time by following the [instructions](#) found on the BDS website. A building code appeal must be approved by BDS to be able to use this technology in a project. Please submit a copy of this committee recommendation with your appeal application. Please contact the Appeal Board Secretary at (503) 823-7335 if you have any additional questions about the appeal process.

LIGHT STRAW CLAY

- 1. Scope.** This appendix shall govern the use of light straw clay as a non-loadbearing building material and system. Unless stated otherwise in this section, the provisions of the *International Building Code, International Mechanical Code, International Plumbing Code, and National Electric Code, and all other applicable codes* shall apply to buildings using light straw clay.
- 2. Definitions.** The following words and terms shall, for the purposes of this appendix, have the meanings shown herein.

CLAY. Add ASTM standard wording for clay.

CLAY SLIP. A suspension of clay particles in water.

CLAY SOIL. Soil containing 50% or more clay per volume.

INFILL. Light Straw Clay mixture which is placed between the structural members of a building.

LIGHT STRAW CLAY. A mixture of straw and clay compacted to form an insulated wall between or around structural members and around wall openings. Also known as Clay-Straw, Clay-Fiber, Straw-Clay, or SLC.

MONOLITHIC. A continuous wall without seams.

NON-LOAD BEARING. Not bearing the weight of the building other than the weight of the light straw clay itself and its finish.

STRAW. The dry stems of cereal grains after the seed heads have been removed.

VOID. Any space in a light straw clay wall that allows a 2" sphere to be inserted.

3. Non-loadbearing Light Straw Clay Construction.

- a. General.** Light straw clay shall not be used to support the weight of the building beyond the weight of the light straw clay material and its finish. The light straw clay either surrounds or acts as infill between the structural members.
- b. Structure.** The structural support of the building shall be designed in accordance with the *International Building Code*.

4. Material Specifications.

- a. Straw.** Straw shall be wheat, rye, oats, rice or barley, and shall be free of visible decay and insects. Alternative cellulose materials such as wood chips may be substituted for straw when approved by a building official.
- b. Clay soil.** Soil used for the clay slip in the light straw clay mix shall have a minimum clay content of 50% by volume.
- c. Light straw clay mixture.** All straw stems shall be mixed with clay slip until they are thoroughly and evenly coated so as to avoid pockets of dry straw.

5. Wall Construction.

- a. **Wall thickness.** Light straw clay walls shall be a maximum of 12 inches thick.
- b. **Distance above grade.** Light straw clay shall not be used below grade. The foundation shall be constructed so that the bottom of the light straw clay wall is at least 8 inches above final exterior grade.
- c. **Moisture barrier.** An IBC approved moisture barrier shall extend across the full width of the foundation stem wall between the light straw clay wall and the stem wall. All penetrations through the moisture barrier, as well as all joints in the barrier, shall be sealed with asphalt, caulking or an IBC approved sealant.
- d. **Sill plate.** A decay resistant sill plate shall be used over the moisture barrier and foundation stem wall, or may be untreated wood when over a framed floor. Sill plates shall be fastened in accordance with the IBC.
- e. **Overhang of light straw clay.** Light straw clay may overhang the foundation the thickness of perimeter insulation, but in no case greater than 2 inches.
- f. **Wood and light straw clay contact.** Untreated wood structural and non-structural members in exterior and interior walls may be in direct contact with light straw clay.
- g. **Non-wood structural members.** Non-wood structural members in contact with light straw clay in exterior walls shall be resistant to corrosion or coated to prevent corrosion with an approved coating.

6. Wall Reinforcing.

- a. **Vertical reinforcing and blocking.** Vertical wall reinforcing shall be a minimum of 2x4s at 32 inches on center, secured to sill and top plates per IBC Section 2304.9.1, or per an approved design by an architect or an engineer. This vertical reinforcing shall be horizontally blocked every 8 feet with minimum 2x4 blocks.
- b. **Stabilizing bars.** Non-structural horizontal bars to stabilize the light straw clay infill shall be installed at 24 inches on center and secured to vertical members. Stabilizing bars may be of any of the following: $\frac{3}{4}$ in bamboo, $\frac{1}{2}$ inch fiberglass rod, 1 inch wood dowels, wood 1x2.

7. Monolithic Walls.

- a. **Formwork.** Formwork shall be sufficiently strong to resist bowing when the light straw clay is compacted into the forms.

- b. Installation of light straw clay.** Forms shall be uniformly loaded with light straw clay and be evenly tamped to achieve stable, monolithic walls that are free of voids. Light straw clay shall be installed in lifts of no more than 6 inches and shall be thoroughly tamped before additional material is added.
- c. Removal of formwork.** Formwork shall be removed from walls within 24 hours after tamping, and walls shall remain exposed until dry. Any visible voids shall be patched with light straw clay prior to plastering.
- d. Cold joints.** Whenever a wall is not continuously built, the top of the wall shall be thoroughly coated with clay slip prior to the application of a new layer of light straw clay in order to prevent cold joints.

8. Openings in Walls.

- a. Doors and windows.** Rough bucks and/or frames for door and window shall be fastened securely to structural members. Windows and doors shall be flashed in accordance with IBC Section 1405.3.
- b. Window sills.** A moisture barrier shall be installed at window sills in light straw clay walls prior to installation of windows.

9. Wall surfacing.

- a. General.** The exterior face of light straw clay walls shall be protected by a weather-resistant finish in accordance with this section.
- b. Moisture content of light straw clay prior to application of finish.** Light straw clay walls shall be dry to a maximum moisture content of 20% at a depth of 4 inches, as measured from each side of the wall, prior to the application of finish on either side of the wall. Moisture content is a self-certified measurement and shall be measured with an approved moisture meter or by other approved means.
- c. Vapor permeability of finish.** Finish materials on light straw clay walls shall allow for the diffusion of moisture through the wall.
- d. Plaster finish.** Acceptable plaster finishes include clay based and lime based plasters.
- e. Bridging of dissimilar substrates.** Bridging shall be installed at the juncture of dissimilar substrates prior to the application of plaster. Acceptable bridging materials include: expanded metal lath, fiberglass mesh, reed matting, or burlap. Bridging shall extend a minimum of 4 inches on either side of the juncture.

- f. Exterior siding.** Exterior wood, metal or composite material siding shall be spaced a minimum of $\frac{3}{4}$ inch from the light straw clay to allow for moisture diffusion. The siding shall be fastened to wood furring strips in accordance with manufacturer's recommendations. Furring strips shall be securely fastened to the vertical wall reinforcing or structural framing at a maximum spacing of 32 inches. An air barrier shall be applied prior to application of siding, consisting of Grade 'D' building paper or clay plaster or lime plaster.

10. Electrical.

- a. Electrical wiring.** Wiring in light straw clay walls shall be type UF or shall be installed in an approved conduit system. Wiring in light straw clay walls unprotected by conduit may be set in channels or embedded in the light straw clay maintaining a minimum depth of 1-1/4 inches from the interior and exterior surfaces of the light straw clay.
- b. Attachment.** All cable, conduit systems, and junction boxes shall be securely attached to wall framing per provisions of the NEC. Additional framing members shall be installed as necessary to meet NEC requirements.

11. Thermal Insulation.

- a. R-Value.** Light straw clay, when installed as according to this appendix, shall be deemed to have an R-value of 1.6 per inch.
- b. U-Value.** Light straw clay, when installed as according to this appendix, shall be deemed to thermally perform as well as a 2x6 wall with R-21 insulation.

U-Value Calculations for Light Straw Clay

Done by Kathy Bash

For a 8' high x 8' long wall, x 12" thick, see attached wall diagram:

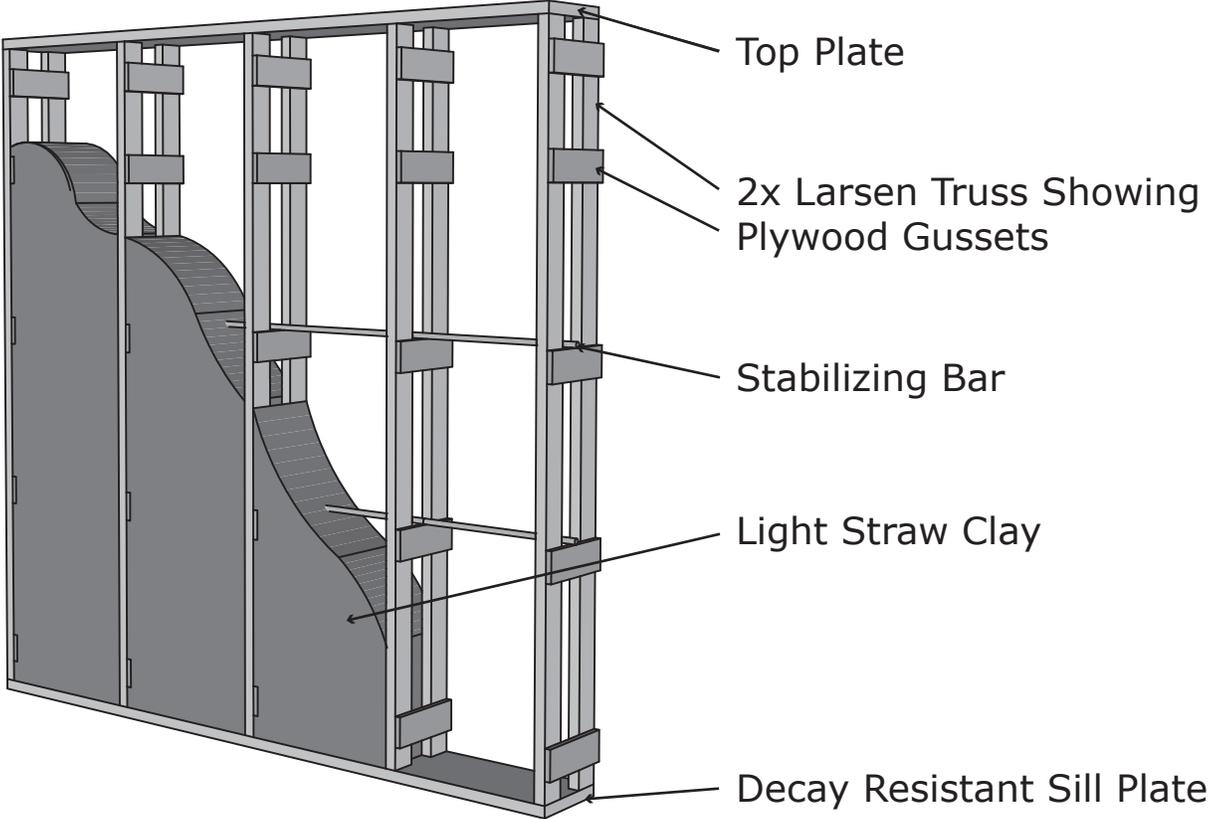
(Per Table N1101(1) Wall Unsul. Above Grade)

- Wall measured at 96" wide x 97 1/8" high
- Larson trusses @ 16" o.c.

| <u>Wall Element</u> | <u>Area of Wall</u> | <u>% of Total</u> | <u>R</u> | <u>U</u> | <u>wtd</u> |
|---|---------------------|-------------------|----------|------------------|------------|
| A) plates @ R1/in | 432 sq.inches | 4.6% | 11.5 | 0.089 | .0041 |
| B) Plywd @ R1/in | 324 sq. inches | 3.5% | 11.25 | 0.089 | .0031 |
| C) Larson Truss (Larson truss = 2x4, strawclay x 6.25 in, and a 2x2) | 972 sq. inches | 10.4% | 15 | 0.067 | .0070 |
| D) Strawclay | 7596 sq. inches | 81.5% | 18 | 0.056 | .0456 |
| | | | | Average U = 0.06 | |

***** Summary: Thermally performs as well as 2 x 6 wall w/ R-21 insulation.**

Criteria is met without adding still air boundary layers or interior and exterior finishes.



Typical Light Straw Clay Wall
(for illustration purposes only)