RB_____ – 13
Appendix R (New)

Proponent: Martin Hammer, representing: California Straw Building Association, Colorado Straw Bale Association, Straw Bale Construction Association – New Mexico, Ontario Straw Bale Building Coalition, Development Center for Appropriate Technology and Ecological Building Network

(Note: This code change proposal was submitted to the International Code Council on Jan. 3, 2013 to be considered for inclusion in the 2015 International Residential Code, and includes final revisions made on Feb. 27, 2013. See the Reason Statement and other information at the end of the proposed appendix text. See the code development schedule at www.iccsafe.org. Direct comments or inquiries to Martin Hammer at mfhammer@pacbell.net.)

Add new text as follows:

APPENDIX R
STRAWBALE CONSTRUCTION

The provisions contained in this appendix are not mandatory unless specifically referenced in the adopting ordinance.

SECTION AR101
GENERAL

AR101.1 Scope. This appendix provides prescriptive and performance-based requirements for the use of baled straw as a building material. Other methods of strawbale construction shall be subject to approval in accordance with Section 104.11 of the *International Residential Code*. Buildings using strawbale walls shall comply with the *International Residential Code* except as otherwise stated in this appendix.

SECTION AR102
DEFINITIONS

AR102.1 Definitions. The following words and terms shall, for the purposes of this appendix, have the meanings shown herein. Refer to Chapter 2 of the *International Residential Code* for general definitions.

BALE. Equivalent to *straw bale*.

CLAY. Inorganic soil with particle sizes less than 0.00008 in. (0.002 mm) having the characteristics of high to very high dry strength and medium to high plasticity.

CLAY SLIP. A suspension of *clay* particles in water.

FINISH. Completed compilation of materials on the interior or exterior faces of stacked *bales*.

FLAKE. An intact section of compressed *straw* removed from an untied *bale*.

LAID FLAT. The orientation of a *bale* with its largest faces horizontal, its longest dimension parallel with the wall plane, its *ties* concealed in the unfinished wall and its *straw* lengths oriented across the thickness of the wall.

LOAD-BEARING WALL. A strawbale wall that supports more than 100 pounds per linear foot (1459 N/m) of vertical load in addition its own weight.

MESH. An openwork fabric of linked strands of metal, plastic, or natural or synthetic fiber, embedded in plaster.

NONSTRUCTURAL WALL. All walls other than *load-bearing walls* or *shear walls*.

ON-EDGE. The orientation of a *bale* with its largest faces vertical, its longest dimension parallel with the wall plane, its *ties* on the face of the wall, and its *straw* lengths oriented vertically.

PIN. A vertical metal rod, wood dowel, or bamboo, driven into the center of stacked *bales*, or placed on opposite surfaces of stacked *bales* and through-tied.

PLASTER. Gypsum or cement plaster, as defined in Section R702 and in Section AR104, or clay plaster, soil-cement plaster, lime plaster, or cement-lime plaster as defined in Section AR104.

PRE-COMPRESSION. Vertical compression of stacked *bales* before the application of *finish*.

REINFORCED PLASTER. A plaster containing mesh reinforcement.

RUNNING BOND. The placement of *straw bales* such that the head joints in successive courses are offset at least one-quarter the bale length.

SHEAR WALL. A *strawbale* wall designed and constructed to resist lateral seismic and wind forces parallel to the plane of the wall in accordance with Section AR106.13.

SKIN. The compilation of *plaster* and reinforcing, if any, applied to the surface of stacked bales.

STRUCTURAL WALL. A wall that meets the definition for a *load-bearing wall* or *shear wall*.

STACK BOND. The placement of *straw bales* such that head joints in successive courses are vertically aligned.

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

STRAW BALE. A rectangular compressed block of *straw*, bound by *ties*.

STRAWBALE. The adjective form of *straw bale*.

STRAW-CLAY. Loose *straw* mixed and coated with *clay slip*.

TIE. A synthetic fiber, natural fiber, or metal wire used to confine a *straw bale*.

TRUTH WINDOW. An area of a *strawbale* wall left without its *finish*, to allow view of the *straw* otherwise concealed by its *finish*.

SECTION AR103
BALES

AR103.1 Shape. Bales shall be rectangular in shape.

AR103.2 Size. Bales shall have a minimum height and thickness of 12 inches (305 mm), except as otherwise permitted or required in this appendix. Bales used within a continuous wall shall be of consistent height and thickness to ensure even distribution of loads within the wall system.

AR103.3 Ties. Bales shall be confined by synthetic fiber, natural fiber, or metal ties sufficient to maintain required bale density. Ties shall be not less than 3 inches (76 mm) and not more than 6 inches (152 mm)

from the two faces without ties and shall be spaced not more than 12 (305 mm) inches apart. Bales with broken ties shall be retied with sufficient tension to maintain required bale density.

AR103.4 Moisture content. The moisture content of bales at the time of application of the first coat of plaster or the installation of another finish shall not exceed 20 percent of the weight of the bale. The moisture content of bales shall be determined by use of a moisture meter designed for use with baled straw or hay, equipped with a probe of sufficient length to reach the center of the bale. At least 5 percent and not less than ten bales used shall be randomly selected and tested.

AR103.5 Density. Bales shall have a minimum dry density of 6.5 pounds per cubic foot (104 kg/cubic meter). The dry density shall be calculated by subtracting the weight of the moisture in pounds (kg) from the actual bale weight and dividing by the volume of the bale in cubic feet (cubic meters). At least 2 percent and not less than five bales to be used shall be randomly selected and tested on site.

AR103.6 Partial bales. Partial bales made after original fabrication shall be retied with ties complying with Section AR103.3.

AR103.7 Types of straw. Bales shall be composed of straw from wheat, rice, rye, barley, or oat.

AR103.8 Other baled material. The dry stems of other cereal grains shall be acceptable when *approved* by the *building official*.

SECTION AR104
FINISHES

AR104.1 General. Finishes applied to strawbale walls shall be any type permitted by the *International Residential Code*, and shall comply with this section and with Chapters 3 and 7 of the *International Residential Code* unless stated otherwise in this section.

AR104.2 Purpose, and where required. Strawbale walls shall be finished so as to provide mechanical protection, fire resistance, protection from weather, and to restrict the passage of air through the bales, in accordance with this appendix and the *International Residential Code*. Vertical strawbale wall surfaces shall receive a coat of plaster 3/8" (10 m) thick, or greater where required elsewhere in this appendix, or shall fit tightly against a solid wall panel. The tops of strawbale walls shall receive a coat of plaster no less than 3/8" (10 m) thick where straw would otherwise be exposed.

Exception: Truth windows shall be permitted where a fire-resistive rating is not required. Weather-exposed truth windows shall be fitted with a weather-tight cover. Interior truth windows in Climate Zones 5, 6, 7, 8, and Marine 4 shall be fitted with an air-tight cover.

AR104.3 Vapor retarders. Class I and Class II vapor retarders shall not be used on a strawbale wall, nor shall any other material be used that has a vapor permeance rating of less than 3 perms be used, except as permitted or required elsewhere in this appendix.

AR104.4 Plaster. Plaster applied to bales shall be any type described in this section, and as required or limited in this appendix. Plaster thickness shall not exceed 2 inches (51 mm).

AR104.4.1 Plaster and membranes. Plaster shall be applied directly to strawbale walls to facilitate transpiration of moisture from the bales, and to secure a mechanical bond between the *skin* and the bales, except where a membrane is allowed or required elsewhere in this appendix.

AR104.4.2 Lath and mesh for plaster. The surface of the straw bales functions as lath, and no other lath or mesh shall be required, except as required for out-of-plane resistance by Table 105.4, or for *structural walls* by Table AR106.12 and Table AR106.13(1).

AR104.4.3 Clay plaster. Clay plaster shall comply with Sections AR104.4.3.1 through AR104.4.3.6.

AR104.4.3.1 General. Clay plaster shall be any plaster having a clay or clay-soil binder. Such plaster shall contain sufficient clay to fully bind the plaster, sand or other inert granular material, and shall be permitted to contain reinforcing fibers. Acceptable reinforcing fibers include chopped straw, sisal, and animal hair.

AR104.4.3.2 Lath and mesh. Clay plaster shall not be required to contain reinforcing lath or mesh except as required in Table AR105.4 and Table AR106.13(1). Where provided, mesh shall be natural fiber, corrosion-resistant metal, nylon, high-density polypropylene, or other *approved* material.

AR104.4.3.3 Thickness and coats. Clay plaster shall be not less than 1 inch (25 mm) thick, except where required to be thicker for *structural walls*, as described elsewhere in this appendix, and shall be applied in not less than two coats.

AR104.4.3.4 Rain-exposed. Clay plaster, where exposed to rain, shall be finished with lime wash, lime plaster linseed oil, or other *approved* erosion-resistant finish.

AR104.4.3.5 Prohibited finish coat. Plaster containing Portland cement shall not be permitted as a finish coat over clay plasters.

AR104.4.3.6 Plaster additives. Additives shall be permitted to increase plaster workability, durability, strength, or water resistance.

AR104.4.4 Soil-cement plaster. Soil-cement plaster shall comply with Sections AR104.4.4.1 through AR104.4.4.3.

AR104.4.4.1 General. Soil-cement plaster shall be comprised of soil (free of organic matter), sand, and not less than 10 percent and not more than 20 percent Portland cement by volume, and shall be permitted to contain reinforcing fibers.

AR104.4.4.2 Lath and mesh. Soil-cement plaster shall use any corrosion-resistant lath or mesh permitted by the *International Residential Code*, or as required in Section AR106 where used on *structural walls*.

AR104.4.4.3 Thickness. Soil-cement plaster shall be not less than 1 inch (25 mm) thick.

AR104.4.5 Gypsum plaster. Gypsum plaster shall comply with Section R702. Gypsum plaster shall be limited to use on interior surfaces of non-structural walls, and as an interior finish coat over a structural plaster that complies with this appendix.

AR104.4.6 Lime plaster. Lime plaster shall comply with Sections AR104.4.6.1 and AR104.4.6.3.

AR104.4.6.1 General. Lime plaster is any plaster whose binder is comprised of calcium hydroxide (CaOH) including Type N or Type S hydrated lime, hydraulic lime, natural hydraulic lime, or quicklime. Hydrated lime shall comply with ASTM C 206. Hydraulic lime shall comply with ASTM C 1707. Natural hydraulic lime shall comply with ASTM C 141 and EN 459. Quicklime shall comply with ASTM C 5.

AR104.4.6.2 Thickness and coats. Lime plaster shall be not less than 7/8 inch (22 mm) thick, and shall be applied in not less than three coats.

AR104.4.6.3 On structural walls. Lime plaster on strawbale *structural walls* in accordance with Table AR106.12 or Table AR106.13(1) shall use a binder of hydraulic or natural hydraulic lime.

AR104.4.7 Cement-lime plaster. Cement-lime plaster shall be plaster mixes CL, F, or FL as described in ASTM C 926.

AR104.4.8 Cement plaster. Cement plaster shall conform to ASTM C 926 and shall comply with Sections R703.6.2, R703.6.4 and R703.6.5, except that the amount of lime in all plaster coats shall be not less than 1 part lime to 6 parts cement to allow a minimum acceptable vapor permeability. The combined thickness of all plaster coats shall be not more than 1 1/2 inch (38 mm) thick.

SECTION AR105
STRAWBALE WALLS – GENERAL

AR105.1 General. Strawbale walls shall be designed and constructed in accordance with this section. Strawbale *structural walls* shall be in accordance with the additional requirements of Section AR106.

AR105.2 Building requirements for use of strawbale nonstructural walls. Buildings using strawbale *nonstructural walls* shall be subject to the following limitations and requirements:

1. Number of stories: not more than one, except that two stories shall be allowed with an *approved* engineered design.
2. Building height: not more than 25 feet (7620 mm)
3. Wall height: in accordance with Table AR105.4
4. Braced wall panel length, and increase in seismic design categories C, D_0, D_1 and D_2: the required length of bracing for buildings using strawbale *nonstructural walls* shall comply with Section R602.10.3 of the *International Residential Code*, with the additional requirements that Table 602.10.3(3) shall be applicable to all buildings in Seismic Design Category C, and that the minimum total length of *braced wall panel*s in Table R602.10.3(3) shall be increased by 60 percent.

AR105.3 Sill plates. Sill plates shall support and be flush with each face of the straw bales above and shall be of *naturally durable* or *preservative-treated wood* where required by the *International Residential Code*. Sill plates shall be not less than nominal 2 inches by 4 inches (51 mm by 102 mm) with anchoring complying with Section R403.1.6 and the additional requirements of Tables AR105.4 and AR106.16(1) where applicable.

AR105.4 Out-of-plane resistance and unrestrained wall dimensions. Strawbale walls shall employ a method of out-of-plane resistance in accordance with Table AR105.4, and comply with its associated limits and requirements.

AR105.4.1 Determination of out-of-plane loading. Out-of-plane loading for the use of Table AR105.4 shall be in terms of the design wind speed and seismic design category as determined in accordance with Sections R301.2.1 and R301.2.2 of the *International Residential Code*.

TABLE AR105.4
OUT-OF-PLANE RESISTANCE AND UNRESTRAINED WALL DIMENSIONS

Method of Out-of-Plane Resistance[a]	For Wind Design Speeds (mph)	For Seismic Design Categories	Unrestrained Wall Dimensions, H[b]		Mesh Staple Spacing at Boundary Restraints
			Absolute limit in feet	Limit based on bale thickness T[c] in feet (mm)	
Non-plaster finish or unreinforced plaster	≤100	A, B, C, D_0	H ≤ 8	H ≤ 5T	none required
Pins per Section AR105.4.2	≤100	A, B, C, D_0	H ≤ 12	H ≤ 8T	none required
Pins per Section AR105.4.2	≤110	A, B, C, D_0, D_1, D_2	H ≤ 10	H ≤ 7T	none required

Reinforced[c] clay plaster	≤110	A, B, C, D_0, D_1, D_2	$H \leq 10$	$H \leq 8T^{0.5}$ ($H \leq 140T^{0.5}$)	$\leq$ 6 inches
Reinforced[c] clay plaster	≤110	A, B, C, D_0, D_1, D_2	$10 < H \leq 12$	$H \leq 8T^{0.5}$ ($H \leq 140T^{0.5}$)	$\leq$ 4 inches[e]
Reinforced[c] cement, cement-lime, lime, or soil-cement plaster	≤110	A, B, C, D_0, D_1, D_2	$H \leq 10$	$H \leq 9T^{0.5}$ ($H \leq 157T^{0.5}$)	$\leq$ 6 inches
Reinforced[c] cement, cement-lime, lime, or soil-cement plaster	≤120	A, B, C, D_0, D_1, D_2,	$H \leq 12$	$H \leq 9T^{0.5}$ ($H \leq 157T^{0.5}$)	$\leq$ 4 inches[e]

For SI: 1 inch = 25.4 mm, 1 foot = 304.8 mm

a. Finishes applied to both sides of stacked bales. Where different finishes are used on opposite sides of a wall, the more restrictive requirements shall apply.
b. H = stacked bale height in feet (mm) between sill plate and top plate or other *approved* horizontal restraint, or the horizontal distance in feet (mm) between *approved* vertical restraints. For load-bearing walls, H refers to vertical height only.
c. T= bale thickness in feet (mm).
d. Plaster reinforcement shall be any mesh allowed in Table AR106.16 for the matching plaster type, but with staple spacing per this table. Mesh shall be installed in accordance with Section AR106.9.
e. Sill plate attachment shall be with 5/8 inch anchor bolts or *approved* equivalent at a maximum of 48 inches on center where staple spacing is required to be ≤ 4 inches.

AR105.4.2 Pins. Pins used for out-of-plane resistance shall comply with the following or shall be in accordance with an *approved* engineered design. Pins may be external, internal or a combination of the two.

1. Pins shall be 1/2 inch (13 mm) diameter steel, 3/4 inch (19 mm) diameter wood, or 1/2 inch (13 mm) diameter bamboo.
2. External pins shall be installed vertically on both sides of the wall at a spacing of not more than 24 inches (610 mm) on center. External pins shall have full lateral bearing on the sill plate and the top plate or roof-bearing element, and shall be tightly tied through the wall to an opposing pin with ties spaced not more than 32 inches (813 mm) apart and not more than 8 inches (203 mm) from each end of the pins.
3. Internal pins shall be installed vertically within the center third of the bales, at spacing of not more than 24 inches (610 mm) and shall extend from top course to bottom course. The bottom course shall be similarly connected to its support and the top course shall be similarly connected to the roof- or floor-bearing member above with pins or other *approved* means. Internal pins shall be continuous or shall overlap through not less than one bale course.

AR105.5 Connection of light-frame walls to strawbale walls. Light-frame walls perpendicular to, or at an angle to a straw bale wall assembly, shall be fastened to the bottom and top wood members of the strawbale wall in accordance with requirements for wood or cold-formed steel light-frame walls in the *International Residential Code*, or the abutting stud shall be connected to alternating straw bale courses with a 1/2 inch (13mm) diameter steel, 3/4” diameter (19 mm) wood, or 5/8” diameter (16 mm) bamboo dowel, with not less than 8 inch (203 mm) penetration.

AR105.6 Moisture control. Strawbale walls shall be protected from moisture intrusion and damage in accordance with Sections AR105.6.1 through AR105.6.8.

AR105.6.1 Water-resistive barriers and vapor permeance ratings. Plastered bale walls shall be constructed without any membrane barrier between straw and plaster to facilitate transpiration of moisture from the bales, and to secure a structural bond between straw and plaster, except as permitted or required elsewhere in this appendix. Where a water-resistive barrier is placed behind an exterior finish, it shall have a vapor permeance rating of not less than 5 perms, except as permitted or required elsewhere in this appendix.

AR105.6.2 Vapor retarders. Wall finishes shall have an equivalent vapor permeance rating of a Class III vapor retarder on the interior side of exterior strawbale walls in Climate Zones 5, 6, 7, 8 and Marine 4 as

defined in Chapter 11. Bales in walls enclosing showers or steam rooms shall be protected on the interior side by a Class I or Class II vapor retarder.

AR105.6.3 Penetrations in exterior strawbale walls. Penetrations in exterior strawbale walls shall be sealed with an *approved* sealant or gasket on the exterior side of the wall in all Climate Zones, and on the interior side of the wall in Climate Zones 5, 6, 7, 8 and Marine 4 as defined in Chapter 11.

AR105.6.4 Horizontal surfaces. Bale walls and other bale elements shall be provided with a *water-resistive barrier* at all weather-exposed horizontal surfaces. The *water-resistive barrier* shall be of a material and installation that will prevent water from entering the wall system. Horizontal surfaces shall include exterior window sills, sills at exterior niches, and buttresses. The finish material at such surfaces shall be sloped not less than 1 unit vertical in 12 units horizontal (8-percent slope) and shall drain away from all bale walls and elements. Where the *water-resistive barrier* is below the finish material, it shall be sloped not less than 1 unit vertical in 12 units horizontal (8-percent slope) and shall drain to the outside surface of the bales wall's vertical finish.

AR105.6.5 Separation of bales and concrete. A sheet or liquid-applied Class II *vapor retarder* shall be installed between bales and supporting concrete or masonry. The bales shall be separated from the *vapor retarder* by not less than 3/4 inch (19 mm), and that space shall be filled with an insulating material such as wood or rigid insulation, or a material that allows vapor dispersion such as gravel, or other *approved* insulating or vapor dispersion material. Sill plates shall be installed at this interface in accordance with Section AR105.3. Where bales abut a concrete or masonry wall that retains earth, a Class II *vapor retarder* shall be provided between such wall and the bales.

AR105.6.6 Separation of bales and earth. Bales shall be separated from earth by not less than of 8" (203 mm).

AR105.6.7 Separation of exterior plaster and earth. Exterior plaster applied to straw bales shall be located not less than 6 inches (102 mm) above earth or 3 inches (51 mm) above paved areas.

AR105.6.8 Separation of wood and plaster. Where wood framing or wood sheathing occurs on the exterior face of strawbale walls, such wood surfaces shall be separated from exterior plaster with 2 layers of grade D paper, No. 15 asphalt felt, or other *approved* material in accordance with Section R703.6.3.

Exceptions:

1. Where the wood is preservative-treated or *naturally durable* and is no greater than 1-1/2 inches (38 mm) in width.

2. Clay plaster shall not be required to be separated from untreated wood that is no greater than 1-1/2 inches (38 mm) in width.

AR105.7 Inspections. The *building official* shall inspect the following aspects of strawbale construction, in accordance with Section R109.1:

1. Sill plate anchors, as part of and in accordance with Section R109.1.1 Foundation inspection.
2. Mesh placement and attachment, where mesh is required by this appendix.
3. *Pins*, where required by and in accordance with Section AR105.4

SECTION AR106
STRAWBALE WALLS - STRUCTURAL

AR106.1 General. Plastered strawbale walls shall be permitted to be used as *structural walls* in one-story buildings in accordance with the prescriptive provisions of this section.

AR106.2 Loads and other limitations. Live and dead loads and other limitations shall be in accordance with Section R301 of the *International Residential Code*. Strawbale wall dead loads shall not exceed 60 psf (2872 N/m^2) per face area of wall.

AR106.3 Foundations. Foundations for plastered strawbale walls shall be in accordance with Chapter 4.

AR106.4 Configuration of bales. Bales in strawbale *structural walls* shall be *laid flat* or *on-edge* and in a *running bond* or *stack bond*, except that bales in *structural walls* with unreinforced plasters shall be laid in a *running bond* only.

AR106.5 Voids and stuffing. Voids between bales in strawbale *structural walls* shall not exceed 4 inches (102 mm) in width, and such voids shall be stuffed with *flakes* of straw or *straw-clay*, before application of finish.

AR106.6 Plaster on structural walls. Plaster on *load-bearing* walls shall be in accordance with Table AR106.12. Plaster on *shear walls* shall be in accordance with Table AR106.13(1).

AR106.6.1 Compressive strength. For plasters on strawbale *structural walls*, the *building official* is authorized to require a 2 inch (51mm) cube test conforming with ASTM C 109 to demonstrate a minimum compressive strength in accordance with Table AR106.6.1.

TABLE AR106.6.1
MINIMUM COMPRESSIVE STRENGTH FOR PLASTERS ON STRUCTURAL WALLS

PLASTER TYPE	MINIMUM COMPRESSIVE STRENGTH (psi)
Clay	100
Soil-cement	1000
Lime	600
Cement-lime	1000
Cement	1400

For SI: 1 pound per square inch = 6894.76 N/m^2.

AR106.7 Straightness of plaster. Plaster on strawbale *structural walls* shall be straight, as a function of the bale wall surfaces they are applied to, in accordance with the following:

1. As measured across the face of a bale, straw bulges shall not protrude more than 3/4 inch (19 mm) across 2 feet (610 mm) of its height or length,
2. As measured across the face of a bale wall, straw bulges shall not protrude from the vertical plane of a bale wall more than 2 inches (51 mm) over 8 feet (2438 mm), and
3. The vertical faces of adjacent bales shall not be offset more than 3/8 inch (10 mm).

AR106.8 Plaster and membranes. Strawbale *structural walls* shall not have a membrane between straw and plaster, or shall have attachment through the bale wall from one plaster *skin* to the other in accordance with an *approved* engineered design.

AR106.9 Mesh. Mesh in plasters on strawbale *structural walls*, and where required by Table AR105.4, shall be installed in accordance with Sections AR106.9.1 through AR106.9.4.

AR106.9.1 Mesh laps. Mesh required by Tables AR106.12 or Table AR105.4 shall be installed with not less than 4-inch (102 mm) laps. Mesh required by Table AR106.13(1) or in walls designed to resist wind uplift of more than 100 plf (1459 N/m), shall run continuous vertically from sill plate to the top plate or roof-bearing element, or shall lap not less than 8 inches (203 mm). Horizontal laps in such mesh shall be not less than 4 inches (102 mm).

AR106.9.2 Mesh attachment. Mesh shall be attached with staples to top plates or roof-bearing elements and to sill plates in accordance with the following:

1. **Staples.** Staples shall be pneumatically driven, stainless steel or electro-galvanized, 16 gauge with 1 1/2-inch (38 mm) legs, 7/16-inch (11 mm) crown; or manually driven, galvanized, 15 gauge with 1-inch (25 mm) legs. Other staples shall be permitted to be used as designed by a *registered design professional*. Staples into preservative-treated wood shall be stainless steel.
2. **Staple orientation.** Staples shall be firmly driven diagonally across mesh intersections at the required spacing.
3. **Staple spacing.** Staples shall be spaced not more than 4-inches (102 mm) on center, except where a lesser spacing is required by Table AR106.13(1) or Section AR106.14 as applicable.

AR106.9.3 Steel mesh. Steel mesh shall be galvanized, and shall be separated from preservative-treated wood by grade D paper, 15# roofing felt, or other *approved* barrier.

AR106.9.4 Mesh in plaster. Required mesh shall be embedded in the plaster except where staples fasten the mesh to horizontal boundary elements.

AR106.10 Support of plaster skins. Plaster *skins* on strawbale *structural walls* shall be continuously supported along their bottom edge. Acceptable supports include: a concrete or masonry stem wall, a concrete slab-on-grade, a wood-framed floor blocked with an *approved* engineered design, or a steel angle anchored with an *approved* engineered design. A weep screed as described in R703.2.1 is not an acceptable support.

AR106.11 Transfer of loads to and from plaster skins. Where plastered strawbale walls are used to support superimposed vertical loads, such loads shall be transferred to the plaster *skins* by continuous direct bearing or by an *approved* engineered design. Where plastered strawbale walls are used to resist in-plane lateral loads, such loads shall be transferred to the reinforcing mesh from the structural member or assembly above and to the sill plate in accordance with Table AR106.13(3).

AR106.12 Load-bearing walls. Plastered strawbale walls shall be permitted to be used as *load-bearing walls* in one-story buildings to support vertical loads imposed according to Section R301, in accordance with and not more than the allowable bearing capacities indicated in Table AR106.12.
AR106.12.1 Pre-compression of load-bearing strawbale walls. Prior to application of plaster, walls designed to be *load-bearing* shall be pre-compressed by a uniform load of not less than 100 plf (1459 N/m).

AR106.12.2 Concentrated loads. Concentrated loads shall be distributed by structural elements capable of distributing the loads to the bearing wall within the allowable bearing capacity listed in Table AR106.12 for the plaster type used.

TABLE AR106.12
ALLOWABLE SUPERIMPOSED VERTICAL LOADS (LBS/FOOT)
FOR PLASTERED LOAD-BEARING STRAWBALE WALLS

WALL DESIGNATION	PLASTER[a] (both sides) Minimum thickness each side	MESH[b]	STAPLES[c]	ALLOWABLE BEARING CAPACITY[d] (plf)
A	Clay 1-1/2”	None required	None required	400
B	Soil-cement 1”	required	required	800
C	Lime 7/8”	required	required	500
D	Cement-lime 7/8”	required	required	800
E	Cement 7/8”	required	required	800

For SI: 1 inch=25.4mm, 1 pound per foot = 14.5939 N/m.
a. Plasters shall conform with Sections AR104.4.3through AR104.4.8, AR106.7, and AR106.10.

b. Any metal mesh allowed by this appendix and installed in accordance with Section AR106.9.
c. In accordance with Section AR106.9.2, except as required to transfer roof loads to the plaster skins in accordance with Section AR106.11.
d. For walls with a different plaster on each side, the lower value shall be used.

AR106.13 Braced panels. Plastered strawbale walls shall be permitted to be used as *braced wall panels* for one-story buildings in accordance with Section R602.10 of the I*nternational Residential Code,* and with Tables AR106.13 (1), AR106.13(2) and AR106.13(3). Wind design criteria shall be in accordance with Section R301.2.1. Seismic design criteria shall be in accordance with Section R301.2.2.

AR106.13.1 Bale wall thickness. The thickness of the stacked bale wall without its plaster shall not be less than 15 inches (381mm).

AR106.13.2 Sill plates. Sill plates shall be in accordance with Table AR106.13(1).

AR106.13.3 Sill plate fasteners. Sill plates shall be fastened with not less than 5/8-inch (16 mm) diameter steel anchor bolts with 3-inch by 3-inch by 3/16-inch steel washers, with not less than 7-inch embedment in a concrete or masonry foundation, or shall be an *approved* equivalent, with the spacing shown in Table AR106.13(1). Anchor bolts or other fasteners into framed floors shall be of an *approved* engineered design.

TABLE AR106.13(1)
PLASTERED STRAWBALE BRACED WALL PANEL TYPES

WALL DESIGNATION	PLASTER[a] (both sides)		SILL PLATES[b] (nominal size in inches)	ANCHOR BOLT[c] SPACING (on center)	MESH[d]	STAPLE SPACING[e] (on center)
	TYPE	THICK-NESS (minimum, each side)				
A1	Clay	1.5”	2 x 4	32”	None	None
A2	Clay	1.5”	2 x 4	32”	2” x 2” high-density polypropylene	2”
A3	Clay	1.5”	2 x 4	32”	2” x 2” x 14ga[i]	4”
B	Soil-cement	1”	4 x 4	24”	2” x 2” x 14ga[i]	2”
C1	Lime	7/8”	2 x 4	32”	17 ga woven wire	3”
C2	Lime	7/8”	4 x 4	24”	2” x 2” x 14ga[i]	2”
D1	Cement-lime	7/8”	4 x 4	32”	17 ga woven wire	2”
D2	Cement-lime	7/8”	4 x 4	24”	2” x 2” x 14ga[i]	2”
E1	Cement	7/8”	4 x 4	32”	2” x 2” x 14ga[i]	2”
E2	Cement	1.5”	4 x 4	24”	2 “ x 2” x 14ga[i]	2”

SI: 1 inch=25.4 mm
a. Plasters shall conform with Sections AR104.4.3 through AR104.4.8, AR106.7, AR106.8, and AR106.12.
b. Sill plates shall be Douglas fir-larch or southern pine and shall be *preservative-treated* where required by the *International Residential Code*.
c. Anchor bolts shall be in accordance with Section AR106.13.3 at the spacing shown in this table.
d. Installed in accordance with Section AR106.9.
e. Staples shall be in accordance with Section AR106.9.2 at the spacing shown in this table.

TABLE AR106.13(2)
BRACING REQUIREMENTS FOR STRAWBALE BRACED WALL PANELS BASED ON WIND SPEED

• EXPOSURE CATEGORY B[d] • 25 FOOT MEAN ROOF HEIGHT • 10 FOOT EAVE-TO-RIDGE HEIGHT[d] • 10 FOOT WALL HEIGHT[d] • 2 BRACED WALL LINES[d]			MINIMUM TOTAL LENGTH (FEET) OF STRAWBALE BRACED WALL PANELS REQUIRED ALONG EACH BRACED WALL LINE[a, b, c, d]		
Basic Wind Speed (mph)	**Story Location**	**Braced Wall Line Spacing (feet)**	**Strawbale Braced Wall Panel[e] A2, A3**	**Strawbale Braced Wall Panel[e] C1, C2, D1**	**Strawbale Braced Wall Panel[e] D2, E1, E2**
–		10	6.4	3.8	3.0
		20	8.5	5.1	4.0
≤ 85	One-story building	30	10.2	6.1	4.8
		40	13.3	6.9	5.5
		50	16.3	7.7	6.1
		60	19.4	8.3	6.6
		10	6.4	3.8	3.0
		20	9.0	5.4	4.3
≤ 90	One-story building	30	11.2	6.4	5.1
		40	15.3	7.4	5.9
		50	18.4	8.1	6.5
		60	21.4	8.8	7.0
		10	7.1	4.3	3.4
		20	10.2	6.1	4.8
≤ 100	One-story building	30	14.3	7.2	5.7
		40	18.4	8.1	6.5
		50	22.4	9.0	7.1
		60	26.5	9.8	7.8
		10	7.8	4.7	3.7
		20	12.2	6.6	5.3
≤ 110	One-story building	30	17.3	7.9	6.3
		40	22.4	9.0	7.1
		50	26.5	9.8	7.8
		60	31.6	11.4	8.5

For SI: 1 inch = 25.4 mm, 1 foot = 305 mm, 1 mile per hour = 0.447 m/s.

a. Linear interpolation shall be permitted.

b. All braced wall panels shall be without openings and shall have an *aspect ratio* (H:L) ≤ 2:1.

c. Tabulated minimum total lengths are for braced wall lines using single braced wall panels with an *aspect ratio* (H:L) ≤ 2:1, or using multiple braced wall panels with *aspect ratios* (H:L) ≤ 1:1. For braced wall lines using two or more braced wall panels with an *aspect ratio* (H:L) > 1:1, the minimum total length shall be multiplied by the largest *aspect ratio* (H:L) of braced wall panels in that line.

d. Subject to applicable wind adjustment factors associated with “All methods” in Table R602.10.3(2)

e. Strawbale braced panel types indicated shall comply with AR106.13.1 through AR106.13.3 and with Table AR106.13(1)

TABLE AR106.17.4(2)
BRACING REQUIREMENTS FOR STRAWBALE BRACED WALL PANELS BASED ON SEISMIC DESIGN CATEGORY

• SOIL CLASS D[d] • WALL HEIGHT = 10 FEET[d] • 15 PSF ROOF/CEILING DEAD LOAD[d] • BRACED WALL LINE SPACING ≤ 25 FEET[d]			MINIMUM TOTAL LENGTH (FEET) OF STRAWBALE BRACED WALL PANELS REQUIRED ALONG EACH BRACED WALL LINE[a, b, c, d]	
Seismic Design Category	**Story Location**	**Braced Wall Line Length (feet)**	**Strawbale Braced Wall Panel[e] A2, C1, C2, D1**	**Strawbale Braced Wall Panel[e] B, D2, E1, E2**
C	One-story building	10	5.7	4.6
		20	8.0	6.5
		30	9.8	7.9
		40	12.9	9.1
		50	16.1	10.4
D_0	One-story building	10	6.0	4.8
		20	8.5	6.8
		30	10.9	8.4
		40	14.5	9.7
		50	18.1	11.7
D_1	One-story building	10	6.3	5.1
		20	9.0	7.2
		30	12.1	8.8
		40	16.1	10.4
		50	20.1	13.0
D_2	One-story building	10	7.1	5.7
		20	10.1	8.1
		30	15.1	9.9
		40	20.1	13.0
		50	25.1	16.3

For SI: 1 inch = 25.4 mm, 1 foot = 305 mm, 1 pound per square foot = 0.0479 kPa.

a. Linear interpolation shall be permitted.
b. All braced wall panels shall be without openings and shall have an *aspect ratio* (H:L) ≤ 2:1.
c. Tabulated minimum total lengths are for braced wall lines using single braced wall panels with an *aspect ratio* (H:L) ≤ 2:1, or using multiple braced wall panels with *aspect ratios* (H:L) ≤ 1:1. For braced wall lines using two or more braced wall panels with an *aspect ratio* (H:L) > 1:1, the minimum total length shall be multiplied by the largest *aspect ratio* (H:L) of braced wall panels in that line.
d. Subject to applicable seismic adjustment factors associated with "All methods" in Table R602.10.3(4), except "Wall dead load".
e. Strawbale braced wall panel types indicated shall comply with Sections AR106.13.1 through AR106.13.3 and with Table AR106.13(1)

AR106.14 Resistance to wind uplift forces. Plaster mesh in *skins* of strawbale walls that resist uplift forces from the roof assembly, as determined in accordance with Section R802.11, shall be in accordance with the following:

1. Plaster shall be any type and thickness allowed in Section AR 104.
2. Mesh shall be any type allowed in Table AR106.13(1), and shall be attached to top plates or roof-bearing elements and to sill plates in accordance with Section AR106.9.2.
3. Sill plates shall be a minimum nominal 2-inch by 4-inch (51 mm by 102 mm) with anchoring complying with Section R403.1.6.
4. Mesh attached with staples at 4 inches (51 mm) on center, shall be considered capable of resisting uplift forces of 100 plf (1459 N/m) for each plaster *skin*.
5. Mesh attached with staples at 2 inches (51 mm) on center, shall be considered capable of resisting uplift forces of 200 plf (2918 N/m) for each plaster *skin*.

SECTION AR107
FIRE RESISTANCE

AR107.1 Fire-resistance rating. Strawbale walls shall be considered to be non-rated, except for walls constructed in accordance with Section AR107.1.1 or AR107.1.2. Alternately, fire-resistance ratings of strawbale walls shall be determined in accordance with Section R302 of the *International Residential Code*.

AR107.1.1 1-hour rated clay plastered wall. 1-hour fire-resistance-rated non-load-bearing clay plastered strawbale walls shall comply with the following:

1. Bales shall be *laid flat* or *on-edge* in a *running bond*;
2. Bales shall maintain thickness of not less than 18 inches (457 mm);
3. Gaps shall be stuffed with *straw-clay*;
4. Clay plaster on each side of the wall shall be not less than 1 inch (25 mm) thick and shall be comprised of a mixture of 3 parts clay, 2 parts chopped straw, and 6 parts sand, or an alternative *approved* clay plaster; and
5. Plaster application shall be in accordance with AR104.4.3.3 for the number and thickness of coats.

AR107.1.2 2-hour rated cement plastered wall. 2-hour fire-resistance-rated non-load-bearing cement plastered strawbale walls shall comply with the following:

1. Bales shall be *laid flat* or *on-edge* in a *running bond*;
2. Bales shall maintain a thickness of not less than 14 inches (356 mm);
3. Gaps shall be stuffed with *straw-clay*;
4. 1 1/2 inch (38 mm) by 17 gauge galvanized woven wire mesh shall be attached to wood members with 1 1/2 inch (38 mm) staples at 6 inches (406 mm) on center. 9 gauge U-pins with minimum 8 inch (203 mm) legs shall be installed at 18 inches (457 mm) on center to fasten the mesh to the bales;
5. Cement plaster on each side of the wall shall be not less than 1 inch (25 mm) thick; and
6. Plaster application shall be in accordance with Section AR104.4.8 for the number and thickness of coats.

AR107.2 Openings in rated walls. Openings and penetrations in bale walls required to have a fire-resistance rating shall satisfy the same requirements for openings and penetrations as prescribed in the *International Residential Code*.

AR107.3 Clearance to fireplaces and chimneys. Strawbale surfaces adjacent to fireplaces or chimneys shall be finished with a minimum 3/8 inch (10 mm) thick plaster of any type permitted by this appendix. Clearance from the face of such plaster to fireplaces and chimneys shall be maintained as required from fireplaces and chimneys to combustibles in Chapter 10, or as required by manufacturer's installation instructions, whichever is more restrictive.

SECTION AR108
THERMAL INSULATION

AR108.1 R-value. The unit R-value of a strawbale wall with bales laid flat is R-1.3 per inch of bale thickness. The unit R-value of a strawbale wall with bales on-edge is R-2 per inch of bale thickness.

SECTION AR109
REFERENCED STANDARDS

ASTM

C 5 – 10	Standard Specification for Quicklime for Structural Purposes…….AR104.4.6.1
C 109/C 109M - 12	Standard Test Method for Compressive Strength of Hydraulic Cement Mortars…. AR106.6.1

C 141 / C 141M – 09	Standard Specification for Hydrated Hydraulic Lime for Structural Purposes…….AR104.4.6.1
C 206 – 03	Standard Specification for Finishing Hydrated Lime……...AR104.4.6.1
C 926 – 12a	Standard Specification for Application of Portland Cement Based Plaster……. AR104.4.7, AR104.4.8
C 1707 – 11	Standard Specification for Pozzolanic Hydraulic Lime for Structural Purposes…. AR104.4.6.1
EN	European Committee for Standardization Central Secretariat Rue de Stassart 36 B-10 50 Brussels
EN 459 – 2010	Building Lime - Part 1: Definitions, Specifications and Conformity Criteria, and Building Lime - Part 2: Test Methods ….. AR104.4.6.1

Reason: Strawbale construction has proven to be a safe, durable, resource efficient, and fully viable method of construction. However, the International Residential Code (IRC) does not contain a section on strawbale construction, which has been an impediment to this construction system's proper and broader use.

First practiced in Nebraska in the late 1800's, with buildings over 100 years old still in service, strawbale construction was rediscovered in the 1980's in the American southwest. Since then it has been further developed and explored, including considerable testing and research regarding structural performance (under vertical and lateral loads), moisture, fire, and its thermal and acoustic properties.

Currently only New Mexico and Oregon have adopted statewide strawbale building codes. California has legislated strawbale construction guidelines for voluntary adoption by local jurisdictions. In addition, nine U.S. cities or counties have adopted strawbale building codes. Three countries outside of the United States – Germany, France, and Belarus - have limited strawbale building codes.

Most of the strawbale building codes that do exist are derived from the first such code, created for and adopted by Tucson / Pima County, Arizona in 1996. Much experience, testing and research since then have proven these codes to be deficient. They are often either too restrictive, or not restrictive enough, and in some cases don't address important issues at all.

Although strawbale codes are both few and flawed, strawbale buildings are now found in 49 of the 50 United States, and strawbale construction is practiced in over 45 countries throughout the world and in every climate. There are an estimated 600 strawbale buildings in California alone. The strawbale buildings in the U.S. include residences, public and private schools, libraries, office and retail buildings, wineries, multi-story buildings, buildings over 10,000 sq.ft in floor area, load-bearing strawbale structures, and structures in areas of high seismic risk (plastered strawbale walls are particularly resistant to earthquakes because they are energy-absorbing and tough). The practice of, and the desire to utilize strawbale construction, continues to increase and promises to accelerate as increased pressure is exacted on our environment and natural resources.

There is great need for a comprehensive strawbale code, with full benefit of the experience and knowledge that has been gained to date about this method of construction. The proposed Strawbale Construction appendix for the IRC was created to fulfill this need. It is based on the collective experience of the design, construction, and testing of strawbale buildings over 25 years by architects, engineers, builders, and academics throughout the U.S., Canada, and other countries throughout the world. The testing, research, and comprehensive understanding of the performance of strawbale buildings are summarized in the book *Design of Straw Bale Buildings* (B.King, et al, 2006, Green Building Press). Testing, research reports, and other supporting documentation are available for viewing and download at: http://www.ecobuildnetwork.org/strawbale-construction-code-supporting-documentation

As lead author of the proposed appendix, and as a licensed architect for 26 years, I have been involved in the design, construction, testing, and research of strawbale buildings since 1995. In 2001 I spearheaded legislation and revisions to the current California Guidelines for Straw-Bale Structures. The proposed Strawbale Construction appendix for the IRC has benefited from numerous peer reviews by experienced, licensed design and building professionals over the course of more than five years. It has also received input from other stakeholders including the Structural Engineers Association of California (SEAOC) and the National Association of Home Builders (NAHB). The proposed appendix would serve designers, builders, owners, inhabitants, and building officials alike in the construction and utilization of strawbale buildings.

Supporting Documentation: Selected documents that are available via the above link

Answers to Common Questions Regarding the IRC Strawbale Construction Proposal – M.Hammer, Architect, et al
Load-Bearing Straw Bale Construction – A summary of worldwide testing and experience, B.King, PE

Testing of Straw Bale Walls with Out-of-Plane Loads – K.Donahue, SE
In-Plane Cyclic Tests of Plastered Straw Bale Wall Assemblies – C.Ash, M.Aschheim, PE, D.Mar, SE
Structural Testing of Plastered Straw Bale Wall Assemblies – K.Lerner, Architect, K.Donahue, SE
Basis for Prescriptive Use of Plastered Strawbale Walls as Braced Wall Panels in the IRC – M.Aschheim, PE
Shake Table Test Video of Full Scale Straw Bale Building Specimen – D.Donovan, PE
Moisture Properties of Plaster and Stucco for Strawbale Buildings – J.Straube, PE
Monitoring of Hygrothermal Performance of Strawbale Walls – J.Sraube, PE, C.Schumacher
ASTM E119 1-Hour Fire Resistance Test of a Non-Loadbearing Straw Bale Wall with Clay Plaster
ASTM E119 2-Hour Fire Resistance Test of a Non-Loadbearing Straw Bale Wall with Cement Plaster
ASTM E119 Fire Tests – Video
ASTM E84 Surface Burning Characteristics Test
Thermal Performance of Straw Bale Wall Systems (including Oak Ridge Lab test results) – N.Stone
Support Letters from Licensed Practitioners: Letters from 2 Structural Engineers, 4 Civil Engineers, 1 Professor of Civil Engineering, 7 Architects