STATE OF WASHINGTON

STATE BUILDING CODE COUNCIL

May 2018

Log No. _____

1. State Building Code to be Amended:

X International Residential Code

Section(s):

AR101, AR02, AR103, AR104, AR105
AU101, AU102, AU103, AU104, AU105, AU106, AU107, AU108, AU109, AU110
AS101, AS102, AS103, AS104, AS105, AS106, AS107, AS108, AS109
BL101, BL102, BL103, BL104, BL105, BL106, BL107, BL108

Title:

Appendix BI Light Straw-Clay Construction (was Appendix AR)
Appendix BJ Strawbale Construction (was Appendix AS)
Appendix BK Cob Construction (Monolithic Adobe) (was Appendix AU)
Appendix BL - Hemp-Lime (Hempcrete) Construction (new appendix)

2. Proponent Name (Specific local government, organization or individual):

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Proponent: Cob Research Institute
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Proponent: Clay Sand Soul
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Date: 8/18/24

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Proponent: Jess Tong
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Proponent: Whatcom Waves
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4. **Proposed Code Amendment**. Reproduce the section to be amended by underlining all added language, striking through all deleted language. Insert new sections in the appropriate place in the code in order to continue the established numbering system of the code. If more than one section is proposed for amendment or more than one page is needed for reproducing the affected section of the code, additional pages may be attached.

   Clearly state if the proposal modifies an existing amendment or if a new amendment is needed. If the proposal modifies an **existing amendment**, show the modifications to the existing amendment by underlining all added language and striking through all deleted language. If a new amendment is needed, show the modifications to the **model code** by underlining all added language and striking through all deleted language.

   Code(s) _____IRC_____ **Section(s)** ____Appendices BI, BJ, BK, BL
   _____

   Enforceable code language must be used.
   Amend section to read as follows:

See Attached:

5. **Briefly explain your proposed amendment, including the purpose, benefits and problems addressed.** Specifically note any impacts or benefits to business, and specify construction types, industries and services that would be affected. Finally, please note any potential impact on enforcement such as special reporting requirements or additional inspections required.

   We are encouraging SBCC to adopt the following IRC appendices for the 2024 code adoption cycle:

   Appendix BI - Light Straw-Clay Construction [formerly Appendix AR]
   Appendix BK - Cob Construction (Monolithic Adobe) [formerly Appendix AU]
   Appendix BL - Hemp-Lime (Hempcrete) Construction [new appendix in the 2024 IRC]
   Appendix BJ - Strawbale Construction [formerly Appendix AS]

   Each one describes and regulates an alternative wall system, all of which use natural materials in various ways. In the state of Washington there are many contractors, small businesses, and individual home owners who would benefit from more accessibility to be able to build with these alternative means of construction. All of these systems can help address the increasing need to reduce our buildings' negative impacts on the environment, including the global climate, and address the impacts of a changing climate on buildings, including increased firestorms.
   All of these earthen wall systems are very fire-resistant building materials, while also having a low environmental impact. The ability to build with site- or locally-sourced materials further reduces processing and transportation impacts as well as costs.
   These appendices give the building official greater flexibility to consider empirical evidence and lifecycle impacts in meeting the intent of the code while not abridging health and life-safety requirements.
   The appendices are well-developed, comprehensive, tied directly to other requirements of the well-established IRC, and well vetted through the code development process. In addition to our core team, they received input from experienced design and building professionals, industry representatives, and building officials, in California and other states.
   Other compelling reasons for SBCC adoption of these appendices and their building systems include:
   -High resistance to fire, now a concern through much of the US due to seasonal wildfires. Cob walls earned a 2-hour fire-resistance rating with ASTM E119 tests. Light straw-clay and hemp-lime walls are inherently fire resistant by virtue of their required plaster finishes.

-Climate beneficial, with low embodied carbon and/or high carbon sequestration of the constituent materials of straw, clay, earth, hemp and lime.
-Seismic safety, by using established testing protocol such as reverse cyclic in-plane testing and out-of-plane testing in university settings (for cob construction) or by making adjustments to the IRC's lateral force- resisting system requirements by compensating for additional system weight (for light straw-clay and hemp-lime). Prescriptive structural use in Seismic Design Categories A, B, and C, and with an approved engineered design required in SDC D. All non-structural provisions apply when an engineered design is employed. All three appendices were reviewed by and received input from multiple California civil and structural engineers and representatives of FEMA.
-Ensure safe and proper use of these (and other) building systems through plan check and inspections, especially for citizens who have been known to otherwise build without permits when faced with permitting obstacles.
-Use of low-cost, locally sourced, rapidly renewable, bio-degradable materials.
-Hemp-lime (hempcrete) is a burgeoning industry, gaining popularity and use since the cultivation of hemp was legalized in the U.S. in 2018.
-Removes impediments to greater use of these building systems.

6. **Specify what criteria this proposal meets.** You may select more than one.
   X The amendment is needed to address a critical life/safety need.
   ☐ The amendment clarifies the intent or application of the code.
   ☐ The amendment is needed to address a specific state policy or statute.
   ☐ The amendment is needed for consistency with state or federal regulations.
   X The amendment is needed to address a unique character of the state.
   ☐ The amendment corrects errors and omissions.

7. **Is there an economic impact:** ☐ Yes X No

   If no, state reason:

   While these proposed changes have the potential to greatly benefit local builders and stakeholders, as well as local businesses that are emerging to supply materials and tools for these burgeoning industries, the proposed changes do not currently impact a large enough part of the industry to have a major impact.

   If yes, provide economic impact, costs and benefits as noted below in items a – f.

   a. ***Life Cycle Cost.*** Use the OFM Life Cycle Cost **Analysis tool** to estimate the life cycle cost of the proposal using one or more typical examples. Reference these **Instructions;** use these **Inputs.** Webinars on the tool can be found **Here** and **Here**). If the tool is used, submit a copy of the excel file with your proposal submission. If preferred, you may submit an alternate life cycle cost analysis.

   b. ***Construction Cost.*** Provide your best estimate of the construction cost (or cost savings) of your code change proposal.

      $Click here to enter text./square foot

      (For residential projects, also provide $Click here to enter text./ dwelling unit)

      Show calculations here, and list sources for costs/savings, or attach backup data pages

c. ***Code Enforcement.*** List any code enforcement time for additional plan review or inspections that your proposal will require, in hours per permit application:

d. ***Small Business Impact.*** Describe economic impacts to small businesses:

e. ***Housing Affordability.*** Describe economic impacts on housing affordability:

f. ***Other.*** Describe other qualitative cost and benefits to owners, to occupants, to the public, to the environment, and to other stakeholders that have not yet been discussed:

Please send your completed proposal to: sbcc@des.wa.gov

All questions must be answered to be considered complete. Incomplete proposals will not be accepted.

Appendix BI Light Straw-Clay Construction

The provisions contained in this appendix are adopted for use in the State of Washington ~~not mandatory unless specifically referenced in the adopting ordinance~~.

User notes:
About this appendix: *While heavier forms of straw-clay construction have been used in various parts of the world for thousands of years, light forms of straw-clay construction began to appear in Europe in 1950 and in the United States in 1990. These lighter forms of straw-clay construction are intended as infill materials in nonload-bearing walls. The advantages of light straw-clay construction, such as regulated by Appendix BI, include thermal performance and low environmental impact.*

Section BI 101 General

BI 101.1 Scope.
This appendix shall govern the use of *light straw-clay* as a *nonbearing* building material and wall infil system in Seismic Design Categories A and B. Use of *light straw-clay* in Seismic Design Categories C, D0, D1 and D2 shall require an approved engineered design by a registered design professional in accordance with Section R301.1.3.

BI 101.2 Flood hazard areas.
In flood hazard areas established in Table R301.2, buildings using *light straw-clay infill* shall meet the requirements of Section R306.

Section BI 102 Definitions

BI 102.1 General.
The following words and terms shall, for the purposes of this appendix, have the meanings shown herein. Refer to Chapter 2 for general definitions.

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

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

CLAY SUBSOIL.
Subsoil sourced directly from the earth or refined, containing *clay* and not more than trace amounts organic matter.

INFILL.
Light straw-clay that is placed between the structural and nonstructural members of a building.

LIGHT STRAW-CLAY.
A mixture of *straw* and *clay slip* compacted and dried to form insulation and plaster substrate between or around structural and nonstructural members in a wall.

NONBEARING.
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 wider than 1/4 inch (6 mm), greater than 2 inches (51 mm) in horizontal length and greater than 2 inches (51 mm) in depth.

Section BI 103 Nonbearing Light Straw-Clay Construction

BI 103.1 General.
Light straw-clay shall be limited to *infill* between or around structural and nonstructural wall framing members.

BI 103.2 Structure.
The structure of buildings using *light straw-clay* shall be in accordance with this code or shall be in accordance with an approved design by a registered design professional.

BI 103.2.1 Number of stories.
Use of *light straw-clay infill* shall be limited to buildings that are not more than one story above grade plane.
Exception: Buildings using *light straw-clay infill* that are greater than one story above grade plane shall be in accordance with an approved design by a registered design professional.

BI 103.2.2 Bracing.
Bracing for buildings with *light straw-clay infill* shall be in accordance with Section R602.10. Walls with *light straw-clay infill* shall use Method LIB and shall not be sheathed with solid sheathing. Walls without *light straw-clay infill* shall comply with any bracing method prescribed by this code.

BI 103.2.3 Requirements and properties of light straw-clay mixtures.
The requirements and properties of *light straw-clay* mixtures shall be in accordance with Table BI103.2.3.

TABLE BI 103.2.3 REQUIREMENTS AND PROPERTIES OF LIGHT STRAW-CLAY MIXTURES [a]

DENSITY (pcf)	STRAW (pcf)	SUBSOIL (pcf)	WATER (gal/cf)[b]	MIN. % CLAY IN SUBSOIL	MINIMUM CLAY:SILT RATIO	SUBSOIL TESTING METHOD [c, d]	MAX. WALL THICKNESS, INCHES	R-VALUE (hr/F°/cf/BTU/inch)
10	6.7	3.3	1.55	70	3.5:1	A	15	1.80
12	6.7	5.3	1.63	46	1.7:1	A	15	1.72
13	6.7	6.3	1.67	40	1.33:1	A	15	1.69
15	6.7	8.3	1.74	35	0.95:1	A	15	1.63
20	6.7	13.3	1.93	30	0.60:1	A	12	1.48
30	6.7	23.3	2.31	NA	NA	B	12	1.22
40	6.7	33.3	2.70	NA	NA	B	12	1.01
50	6.7	43.3	3.08	NA	NA	B	12	0.84

a. Interpolation permitted. Extrapolation not permitted.
b. Water mixed with subsoil equals *clay slip*.
c. Subsoil Testing Methods:
1. Lab test for percent of *clay*, silt and sand via hydrometer method.
2. The Figure 2 Ribbon Test and the Figure 3 Ball Test in the appendix of ASTM E2392/E2392M.

d. Trace amounts of organic materials are acceptable.

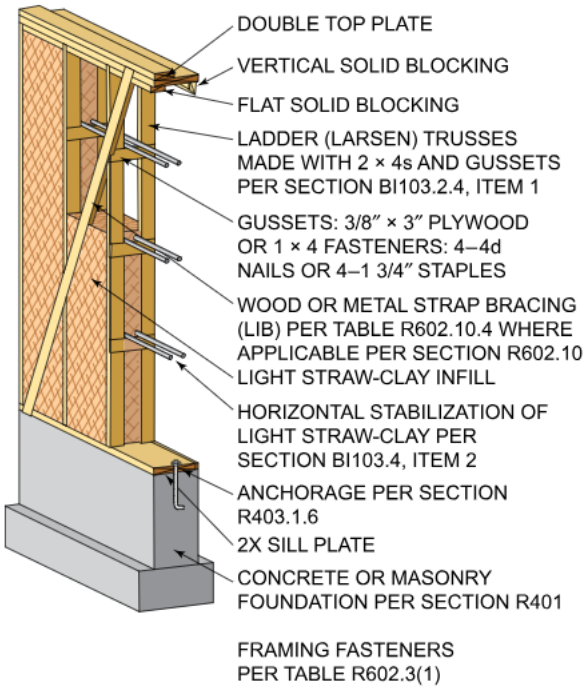
BI 103.2.4 Stabilization of light straw-clay.

Light straw-clay shall be stabilized as follows, or shall be in accordance with an approved design by a registered design professional:

1. Vertical stabilization shall be of structural or nonstructural wood framing in accordance with Figure BI103.2.4(1), BI103.2.4(2) or BI103.2.4(3). Framing members that are both load-bearing and stabilization members shall meet the requirements of Section R602 and this section. Nonstructural stabilization members shall be not more than 32 inches (813 mm) on center.

2. Horizontal stabilization shall be installed at not more than 24 inches (610 mm) on center and in accordance with Figure BI103.2.4(1), BI103.2.4(2) or BI103.2.4(3). Horizontal stabilization shall be of any of the following with the stated minimum dimensions: 3/4-inch (19.1 mm) bamboo, 1/2-inch (12.7 mm) fiberglass rod, 1-inch (25 mm) wood dowel or nominal 1-inch by 2-inch (25 mm by 51 mm) wood.

FIGURE BI 103.2.4(1) LIGHT STRAW-CLAY WALL WITH LARSEN TRUSSES



For SI: 1 inch = 25.4 mm.

FIGURE BI 103.2.4(2) LIGHT STRAW-CLAY WALL, SINGLE STUD WIDTH

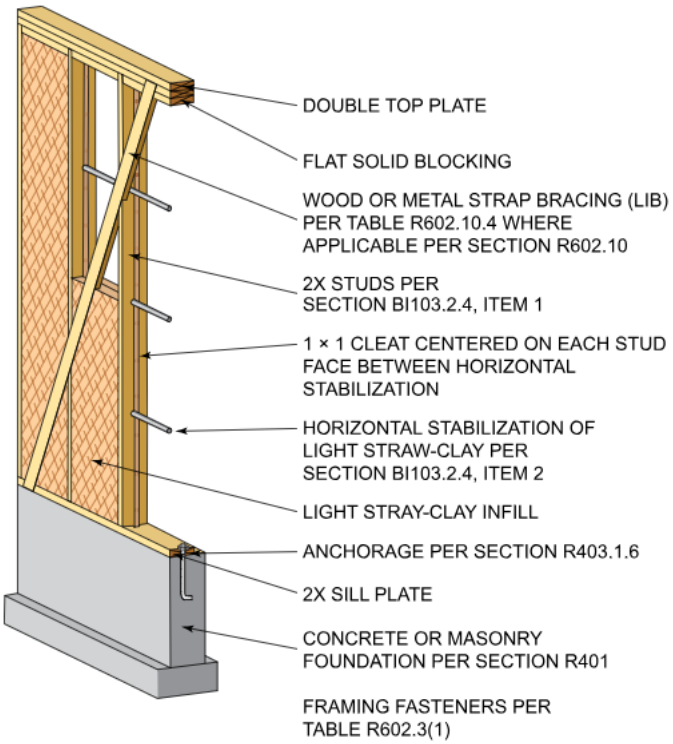
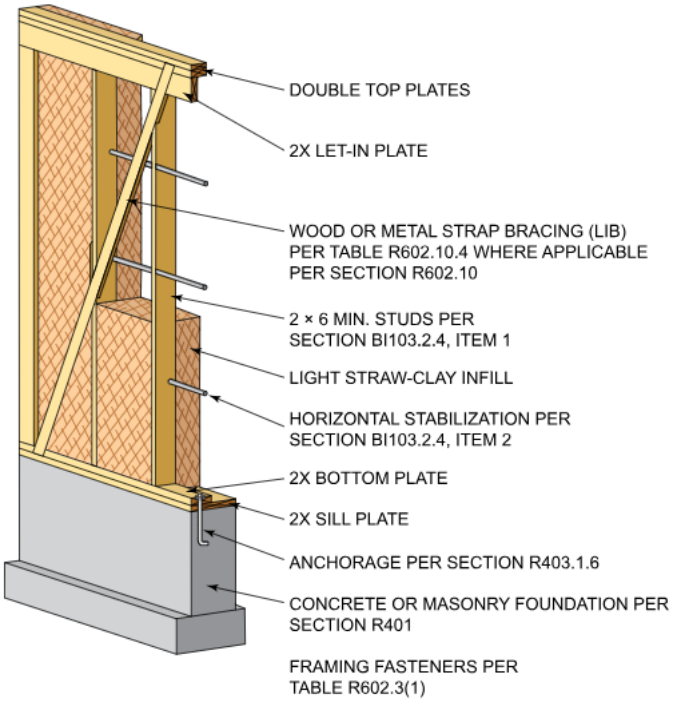


FIGURE BI 103.2.4(3) LIGHT STRAW-CLAY WALL WITH BLIND STUDS



BI 103.3 Materials.
The materials used in *light straw-clay* construction shall be in accordance with Sections BI103.3.1 through BI103.3.3.

BI 103.3.1 Straw requirements.
Straw shall be stems of wheat, rye, oats, rice or barley, and shall be free of visible decay, insects and green plant material.

BI 103.3.2 Clay subsoil requirements.
Suitability of *clay subsoil* shall be determined in accordance with Table BI103.2.3.

BI 103.3.3 Light straw-clay mixture.
A *light straw-clay* mixture shall consist of loose *straw* mixed and coated with *clay slip* such that there is not more than 5 percent uncoated *straw*, and shall be in accordance with Table BI103.2.3.

BI 103.4 Wall construction.
Light straw-clay wall construction shall be in accordance with the requirements of Sections BI103.4.1 through BI103.4.7.

BI 103.4.1 Light straw-clay maximum thickness.
The maximum thickness of *light straw-clay* shall be in accordance with Table BI103.2.3.

BI 103.4.2 Distance above grade.
Light straw-clay and its exterior finish shall be not less than 8 inches (203 mm) above exterior finished grade.

BI 103.4.3 Moisture barrier.
An approved moisture barrier shall separate the bottom of *light straw-clay* walls from any masonry or concrete foundation or slab that directly supports the walls. Penetrations and joints in the barrier shall be sealed with an approved sealant.

BI 103.4.4 Contact with wood members.
Light straw-clay shall be permitted to be in contact with untreated wood members.

BI 103.4.5 Contact with nonwood structural members.
Nonwood structural members in contact with *light straw-clay* shall be resistant to corrosion or shall be coated to prevent corrosion with an approved coating.

BI 103.4.6 Installation.
Light straw-clay shall be installed in accordance with the following:

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

2. *Light straw-clay* shall be uniformly placed into forms and evenly tamped to achieve stable walls free of *voids*. *Light straw-clay* shall be placed in lifts of not more than 6 inches (152 mm) and shall be thoroughly tamped before additional material is added.

3. Temporary formwork shall be removed from walls within 24 hours after tamping, and walls shall remain exposed until moisture content is in accordance with Section BI103.5.1. Visible *voids* shall be filled with *light straw-clay* or other insulative material prior to plastering.

BI 103.4.7 Openings in walls.
Openings in walls shall be in accordance with the following:

1. Rough framing for doors and windows shall be fastened to structural members in accordance with this code. Windows and doors shall be flashed in accordance with this code.

2. An approved moisture barrier shall be installed at windowsills in *light straw-clay* walls prior to installation of windows.

BI 103.5 Wall finishes.
The interior and exterior surfaces of *light straw-clay* walls shall be protected with a finish in accordance with Sections BI103.5.1 through BI103.5.5.

BI 103.5.1 Dimensional stability of light straw-clay prior to application of plaster finish.
Light straw-clay infill having a density of 30 pounds per cubic foot (480.6 kg/m3) or greater shall be dry to a moisture content of not more than 20 percent at a depth of 4 inches (102 mm), as measured from each side of the wall. *Light straw-clay infill* having a density of less than 30 pounds per cubic foot (480.6 kg/m3) shall be sufficiently dry such that the overall shrinkage of the *light straw-clay* is dimensionally stable.

BI 103.5.2 Plaster finish.
Exterior plaster shall be *clay* plasters or lime plasters. Interior plasters shall be *clay* plasters, lime plasters or gypsum plasters. Plasters shall be permitted to be applied directly to the surface of the *light straw-clay* walls without reinforcement, except that the juncture of dissimilar substrates shall be in accordance with Section BI103.5.4. Plasters shall have a thickness of not less than 1/2 inch (12.7 mm) and not more than 1 inch (25 mm) and shall be installed in not less than two coats. Rain-exposed *clay* plasters shall be finished with a lime-based or silicate-mineral coating.

BI 103.5.3 Separation of wood and plaster.
Where wood framing occurs in *light straw-clay* walls, such wood surfaces shall be separated from exterior plaster with No.15 asphalt felt, Grade D paper or other approved material except where the wood is preservative treated or naturally durable.
Exception: Exterior *clay* plasters shall not be required to be separated from wood.

BI 103.5.4 Bridging across dissimilar substrates.
Bridging shall be installed across dissimilar substrates prior to the application of plaster. Acceptable bridging materials include expanded metal lath, woven wire mesh, welded wire mesh, fiberglass mesh, reed matting or burlap. Bridging shall extend not less than 4 inches (102 mm), on both sides of the juncture.

BI 103.5.5 Exterior cladding.
Exterior cladding shall be spaced not less than 1/2 inch (12.7 mm) from the *light straw-clay* such that a ventilation space is created to allow for moisture diffusion. Furring strips that create this ventilation space shall be securely fastened to the stabilization members or framing. The cladding shall be fastened to the wood furring strips in accordance with the manufacturer's instructions. Insect screening shall be provided at the top and bottom of the ventilation space.

BI 103.6 Special inspections. The building official has the authority to require the owner to employ a special inspector during construction of specific types of work described in this appendix.

Section BI 104 Thermal Performance

BI 104.1 Thermal characteristics.
Walls with *light straw-clay infill* of densities greater than or equal to 20 pounds per cubic foot (480.6 kg/m3) shall be classified as mass walls in accordance with WSEC Section R402.2.5~~N1102.2.6 (R402.2.6)~~ and shall meet the above grade wall U-Factor requirement in WSEC Table R402.1.2~~R-value requirements for mass walls in Table N1102.1.3~~. Walls with *light straw-clay infill* of densities less than 20 pounds per cubic foot (480.6 kg/m3) shall meet the R-value requirements for wood frame walls in WSEC Table R402.1.3 ~~N1102.1.3~~.

BI 104.2 Thermal resistance.
Light straw-clay shall be deemed to have a thermal resistance as specified in Table BI 103.2.3.

Section BI 105 Referenced Standards

BI 105.1 General.

See Table BI105.1 for standards that are referenced in various section of this appendix. Standards are listed by the standard identification with the effective date, the standard title, and the section or sections of this appendix that reference this standard.

TABLE BI105.1 REFERENCED STANDARDS

STANDARD ACRONYM	STANDARD NAME	SECTIONS HEREIN REFERENCED
ASTM E2392/E2392M—10(2016)	Standard Guide for Design of Earthen Wall Building Systems	Table BI103.2.3

Appendix BJ Strawbale Construction

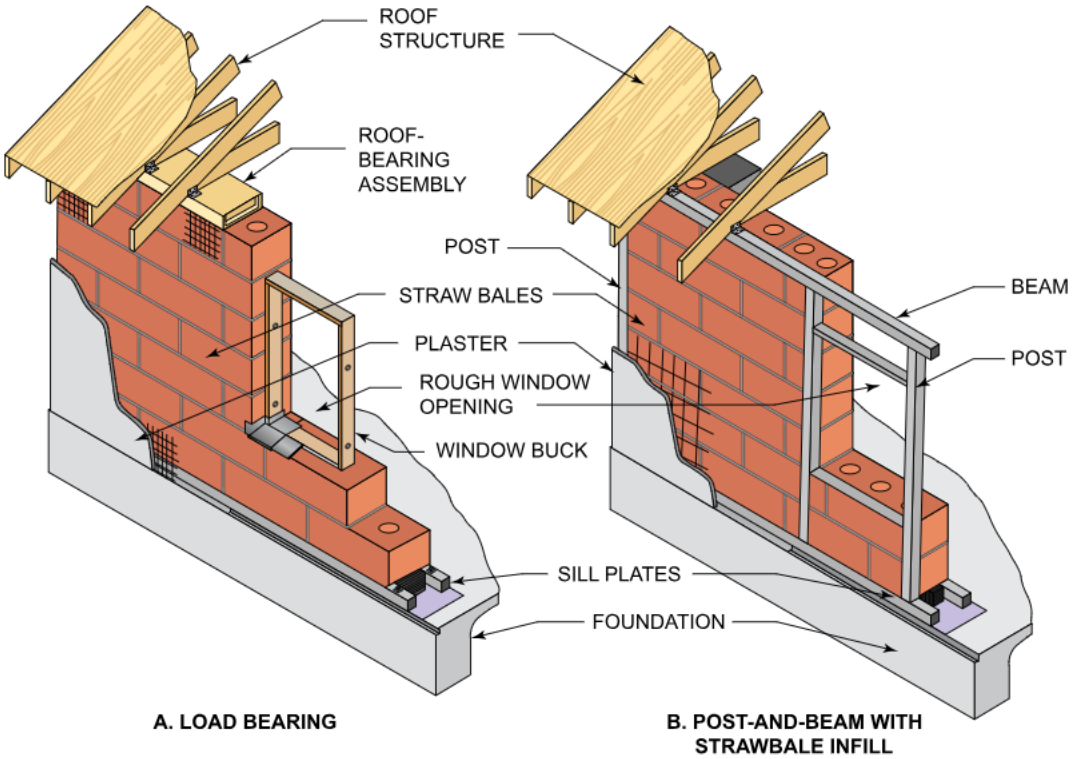
The provisions contained in this appendix are adopted for use in the State of Washington ~~not mandatory unless specifically referenced in the adopting ordinance~~.

User notes:
About this appendix:
The use of strawbale construction has steadily increased since the 1980s such that there are now buildings of strawbale construction in every state in the United States and in more than 50 countries around the globe. Estimates are that there are over 1,000 buildings of strawbale construction in California alone, including both residential and commercial buildings. Appendix BJ provides prescriptive requirements for the construction of exterior and interior walls, both structural and nonstructural, in buildings that are under the scope of this code.

Section BJ101 General
BJ101.1 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 R104.2.2 of this code. *Buildings* using *strawbale* walls shall comply with this code except as otherwise stated in this appendix.

BJ101.2 Strawbale wall systems.
Strawbale wall systems include those shown in Figure BJ101.2 and *approved* variations.

FIGURE **BJ101.2 TYPICAL STRAWBALE WALL SYSTEMS**



Note: See Figures BJ105.1(1) through BJ105.1(4) for detailed views and section references. Other strawbale wall systems or variations are permitted as *approved*.

BJ101.3 Flood hazard areas.
In flood hazard areas established in Table R301.2, *buildings* using *strawbale* wall systems shall meet the requirements of Section R306.

Section BJ102 Definitions

BJ102.1 Definitions.
The following words and terms shall, for the purposes of this appendix, have the meanings shown herein. Refer to Chapter 2 for general definitions.

BALE.
Equivalent to *straw bale*.

BRACED WALL PANEL, STRAWBALE.
A *strawbale* wall designed and constructed to resist in-plane shear loads through the interaction of the stacked *straw bales*, the reinforced *plaster* and its connections to the top plate, sill plates and foundation. The panel's length meets the requirements for the particular wall type and contributes toward the total amount of bracing required along its *braced wall line* in accordance with Sections BJ106.13 and R602.10.1.

CLAY.
Inorganic soil with particle sizes less than 0.00008 inch (0.002 mm) having the characteristics of high to very high dry strength and medium to high plasticity, used as the *binder* of other component materials in clay *plaster* and straw-clay.

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

CLAY SUBSOIL.
Subsoil sourced directly from the earth, containing *clay*, sand, silt and not more than trace amounts of organic matter.

FINISH.
Completed combination of materials on the interior or exterior face of a *strawbale* wall.

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 predominantly across the thickness of the wall. See Figure BJ102.1.

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.

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

ON-EDGE.

The orientation of a *bale* with its largest faces vertical, its longest dimension horizontal and parallel with the wall plane, its *ties* on the face of the wall and its *straw* lengths oriented predominantly vertically. See Figure BJ102.1.

ON-END.
The orientation of a *bale* with its longest dimension vertical. For use in *nonstructural strawbale* walls only. See Figure BJ102.1.

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.
Clay, soil-cement, gypsum, lime, clay-lime, lime-cement or *cement plaster*, as described in Section BJ104.

PRECOMPRESSION.
Permanent vertical compression of stacked *bales* before the application of *finish*.

REINFORCED PLASTER.
A *plaster* containing mesh reinforcement.

ROOF-BEARING ASSEMBLY.
In load-bearing *strawbale* walls, a structural assembly at the top of the wall that bears and distributes roof loads to the wall.

RUNNING BOND.
The placement of *straw bales* such that the head joints in successive courses are offset not less than one-quarter the *bale* length.

SHEAR WALL.
A *strawbale* wall designed and constructed to resist in-plane lateral seismic and wind forces in accordance with Section BJ106.13. Synonymous with "*Braced wall panel, strawbale*."

SKIN.
Plaster and its reinforcing, if any, applied to the face of a *strawbale 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.

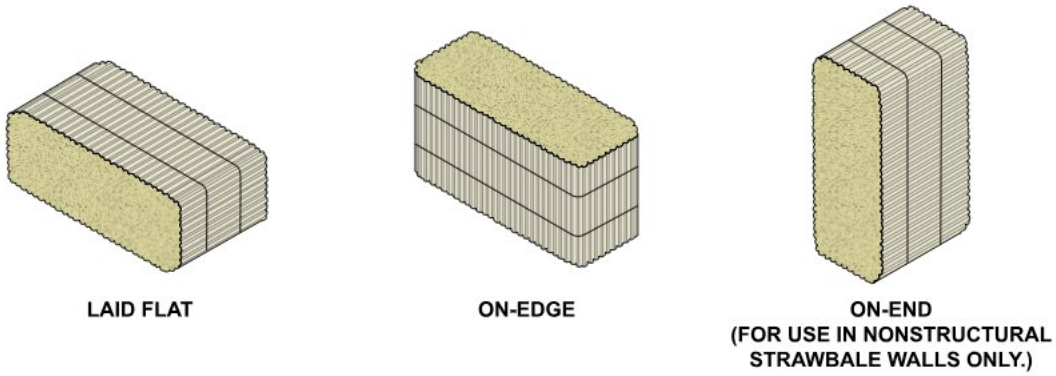
STRUCTURAL WALL.

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

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*.

FIGURE **BJ102.1 BALE ORIENTATIONS**



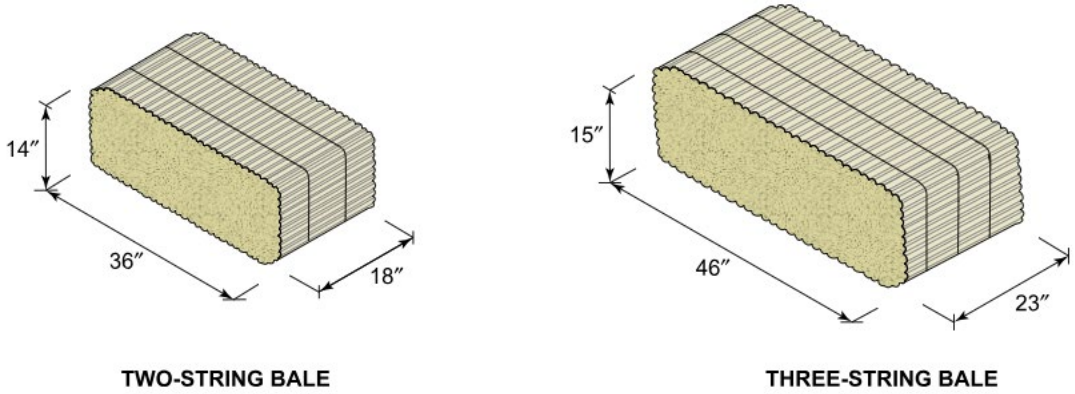
Note: Illustrations also show the predominant direction of the lengths of straw in a typical straw bale. However, some randomness of direction is normal.

Section BJ103 Bales

BJ103.1 Shape.
Bales shall be rectangular in shape, except for partial bales made to fill nonrectangular spaces in accordance with Section BJ103.6.

BJ103.2 Size.
Bales shall have a height and thickness of not less than 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. See Figure BJ103.2 for approximate dimensions of common *straw bales*.

FIGURE **BJ103.2 APPROXIMATE DIMENSIONS OF COMMON STRAW BALES**



For SI: 1 inch = 25.4 mm.

BJ103.3 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 untied faces and shall be spaced not more than 12 inches (305 mm) apart. *Bales* with broken *ties* shall be retied with sufficient tension to maintain required *bale* density.

BJ103.4 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 with 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*. Not less than 5 percent and not fewer than 10 bales shall be randomly selected and tested.

BJ103.5 Density.
Bales shall have a dry density of not less than 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). Not less than 2 percent and not fewer than five *bales* shall be randomly selected and tested on-site.

BJ103.6 Partial bales.
Partial *bales* made after original fabrication shall be retied with *ties* complying with Section BJ103.3.

BJ103.7 Types of straw.
Bales shall be composed of *straw* from wheat, rice, rye, barley or oat. The dry stems of other cereal grains or similar crops shall be acceptable where *approved* by the *building official*. Bales shall not be composed of hay.

BJ103.8 Orientation of bales.
Straw bales shall be placed *laid flat*, *on-edge* or *on end* in accordance with this appendix.

Section BJ104 Finishes

BJ104.1 General.
Finishes applied to *strawbale* walls shall comply with this section and with Chapters 3 and 7 unless stated otherwise in this section.

BJ104.1.1 Exterior wall finishes.
Exterior wall finishes shall be plasters in accordance with Section BJ104.4, or nonplaster exterior wall coverings in accordance with Section R703 and other *finish* systems complying with all of the following:

1. With *approved* specifications and details showing the *finish* system's means of attachment to the wall or its independent support, and a means of draining or evaporating water that penetrates the exterior *finish* to the exterior.

2. The vapor permeance of the combination of *finish* materials shall be 5 perms or greater to allow the transpiration of water vapor through the wall.

3. *Finish* systems with weights greater than 10 or less than or equal to 20 pounds per square foot (> 48.9 and ≤ 97.8 kg/m) of wall area require a factor of 1.2 for minimum total length of *braced wall panels* in Table BJ106.13(3).

4. *Finish* systems with weights greater than 20 pounds per square foot (97.8 kg/m) of wall area require an engineered design.

BJ104.2 Purpose, and where required.
Strawbale walls shall be finished so as to provide mechanical protection, fire resistance and protection from weather and to restrict the passage of air through the *bales*, in accordance with this appendix and this code. Vertical *strawbale* wall surfaces shall receive a coat of *plaster* not less than 3/8 inch (10 mm) thick, or greater where required elsewhere in this appendix, or shall fit tightly against a solid wall panel or dense-packed

cellulose insulation with a density of not less than 3.5 pounds per cubic foot (56 kg/m^3) blown into an adjacent framed wall. The tops of *strawbale* walls shall receive a coat of *plaster* not less than 3/8 inch (10 mm) thick or be tightly covered by *gypsum board* or a *roof-bearing assembly*.
Exception: *Truth windows* shall be permitted where a fire-resistance 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 airtight cover.

BJ104.3 Vapor retarders.
Class I and 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 5 perms, except as permitted or required elsewhere in this appendix.

BJ104.4 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).

BJ104.4.1 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.

BJ104.4.2 Lath and mesh for plaster.
The surface of the *straw bales* functions as lath, and other lath or *mesh* shall not be required, except as required for out-of-plane load resistance by Table BJ105.4 or for structural walls by Tables BJ106.12 and BJ106.13(1).

BJ104.4.3 Clay plaster.
Clay plaster shall comply with Sections BJ104.4.3.1 through BJ104.4.3.6.

BJ104.4.3.1 General.
Clay plaster shall be any *plaster* having a *clay* or *clay subsoil binder*. Such *plaster* shall contain sufficient *clay* to fully bind the sand or other aggregate, and shall be permitted to contain reinforcing fibers. Acceptable reinforcing fibers include chopped straw, sisal and animal hair.

BJ104.4.3.2 Clay subsoil requirements.
The suitability of *clay subsoil* shall be determined in accordance with the Figure 2 Ribbon Test and the Figure 3 Ball Test in the appendix of ASTM E2392/E2392M.

BJ104.4.3.3 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.

BJ104.4.3.4 Rain-exposed.
Clay plaster, where exposed to rain, shall be finished with lime wash, lime *plaster*, linseed oil or other *approved* erosion-resistant *finish*.

BJ104.4.3.5 Prohibited finish coat.
Plaster containing Portland cement shall not be permitted as a *finish* coat over *clay plasters*.

BJ104.4.3.6 Plaster additives.
Additives shall be permitted to increase *plaster* workability, durability, strength or water resistance.

BJ104.4.4 Soil-cement plaster.
Soil-cement *plaster* shall comply with Sections BJ104.4.4.1 through BJ104.4.4.3.

BJ104.4.4.1 General.
Soil-cement *plaster* shall be composed of *clay subsoil*, 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.

BJ104.4.4.2 Lath and mesh.
Soil-cement *plaster* shall use any corrosion-resistant lath or *mesh* permitted by this code, or as required in Section BJ106 where used on structural walls.

BJ104.4.4.3 Thickness.
Soil-cement *plaster* shall be not less than 1 inch (25 mm) thick.

BJ104.4.5 Gypsum plaster.
Gypsum *plaster* shall comply with Section R702.2.1. Gypsum *plaster* shall be limited to use on interior surfaces of *nonstructural* walls, and as an interior *finish* coat over a structural *plaster* that complies with this appendix.

BJ104.4.6 Lime plaster.
Lime *plaster* shall comply with Sections BJ104.4.6.1 through BJ104.4.6.3.

BJ104.4.6.1 General.
Lime *plaster* is any *plaster* with a *binder* that is composed of calcium hydroxide [$Ca(OH)_2$], including Type N or S hydrated lime, hydraulic lime, natural hydraulic lime or slaked quicklime. Hydrated lime shall comply with ASTM C206. Hydraulic lime shall comply with ASTM C1707. Natural hydraulic lime shall comply with ASTM C141 and CEN EN 459. Quicklime shall comply with ASTM C5.

BJ104.4.6.2 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.

BJ104.4.6.3 On structural walls.
Lime *plaster* on *strawbale* structural walls in accordance with Table BJ106.12 or BJ106.13(1) shall use hydraulic or natural hydraulic lime.
Exception: A nonhydraulic lime *plaster* demonstrating the minimum compressive strength in accordance with Section BJ106.6.1 and Table BJ106.6.1.

BJ104.4.7 Clay-lime plaster.
Clay-lime *plaster* shall be composed of refined *clay* or *clay subsoil*, sand and lime, and shall be permitted to contain reinforcing fibers.

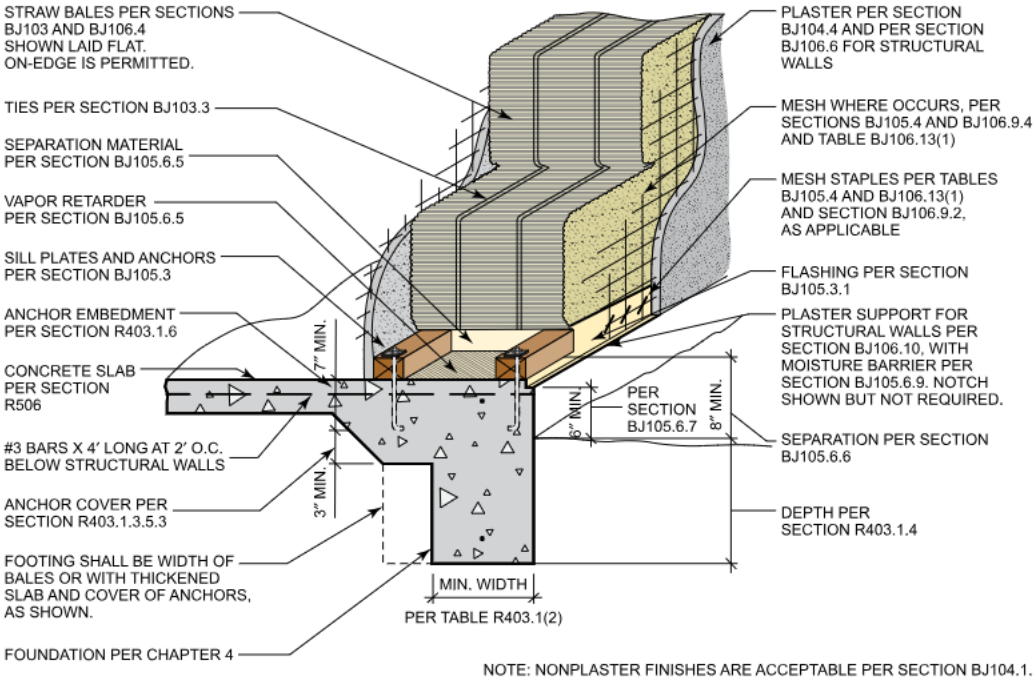
BJ104.4.8 Cement-lime plaster.
Cement-lime *plaster* shall be *plaster* mixes CL, F or FL, as described in ASTM C926.

BJ104.4.9 Cement plaster.
Cement *plaster* shall conform to ASTM C926 and shall comply with Sections R703.7.4 and R703.7.5, except that the amount of lime in *plaster* coats shall be not less than 1 part lime to 4 parts cement to allow a minimum acceptable vapor permeability. The combined thickness of *plaster* coats shall be not more than 1 1/2 inches (38 mm).

Section BJ105 Strawbale Walls—General

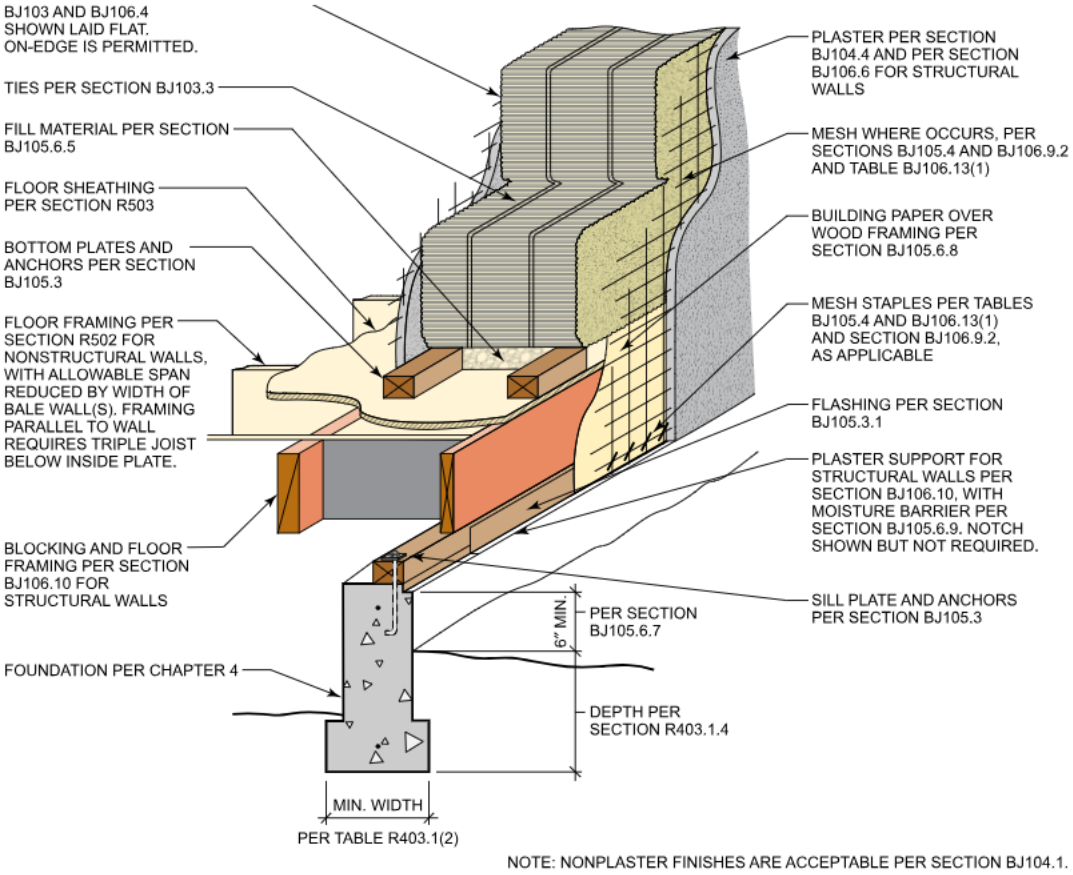
BJ105.1 General.
Strawbale walls shall be designed and constructed in accordance with this section and with Figures BJ105.1(1) through BJ105.1(4) or an *approved* alternative design. *Strawbale structural walls* shall be in accordance with the additional requirements of Section BJ106.

FIGURE **BJ105.1(1) TYPICAL BASE OF PLASTERED STRAWBALE WALL ON CONCRETE SLAB AND FOOTING**



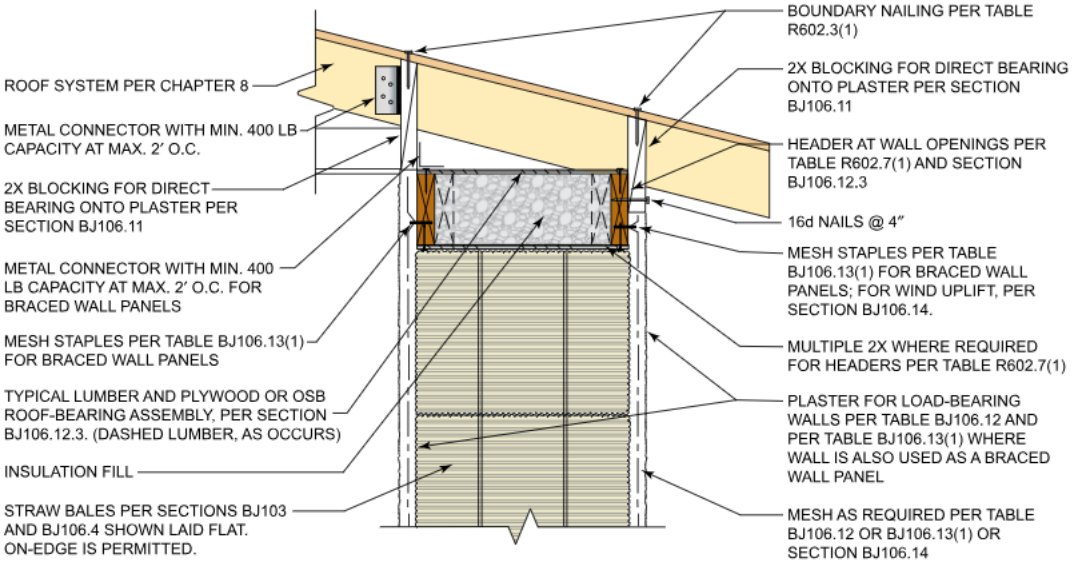
For SI: 1 inch = 25.4 mm.

FIGURE **BJ105.1(2) TYPICAL BASE OF PLASTERED STRAWBALE WALL OVER RAISED FLOOR**



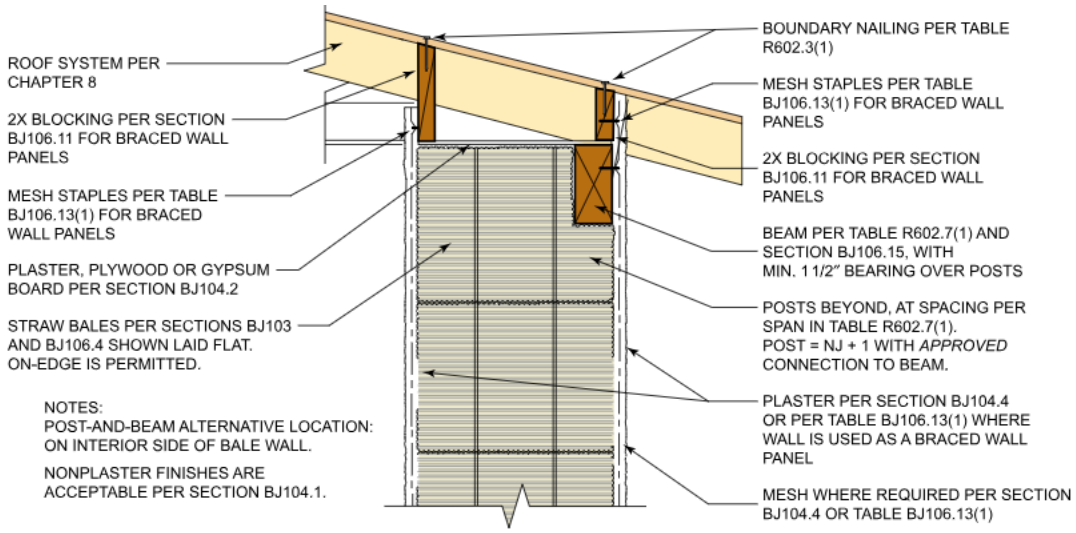
For SI: 1 inch = 25.4 mm.

FIGURE **BJ105.1(3) TYPICAL TOP OF LOAD-BEARING STRAWBALE WALL**



For SI inch = 25.4 mm, 1 foot = 304.8 mm, 1 pound = 2.2 kg.

FIGURE **BJ105.1(4) TYPICAL TOP OF POST-AND-BEAM WALL WITH PLASTERED STRAWBALE INFILL**



For SI: 1 inch = 25.4 mm.

BJ105.2 Building limitations and 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), except that greater heights shall be allowed with an *approved* engineered design.

3. Wall height: in accordance with Table BJ105.4.

4. *Braced wall panel* lengths: in accordance with Section R602.10.3, with the additional requirements that Table R602.10.3(3) shall apply to all *buildings* in *Seismic Design Category* C, and the minimum total length of *braced wall panels* in Table R602.10.3(3) shall be increased by 60 percent for *buildings* in *Seismic Design Categories* C, D_0, D_1 and D_2.

BJ105.3 Sill plates.
Sill plates shall be installed in accordance with Figure BJ105.1(1) or BJ105.1(2). 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 this 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 Table BJ105.4, where applicable, and Sections BJ106.13.2 and BJ106.13.3 for *strawbale braced wall panels*.

BJ105.3.1 Exterior sill plate flashing.
Exterior sill plates shall receive flashing across the joint between the sill plate and the slab or foundation.

BJ105.4 Out-of-plane resistance methods and unrestrained wall dimension limits.
Strawbale walls shall employ a method of out-of-plane load resistance in accordance with Table BJ105.4 and comply with its associated limits and requirements.

TABLE **BJ105.4 OUT-OF-PLANE LOAD RESISTANCE METHODS AND UNRESTRAINED WALL DIMENSION LIMITS**

METHOD OF OUT-OF-PLANE LOAD RESISTANCE[a]	FOR ULTIMATE DESIGN WIND 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)	
Nonplaster finish or unreinforced plaster	≤ 130	A, B, C, D_0	$H \leq 8$	$H \leq 5T$	None required
Pins per Section BJ105.4.2	≤ 130	A, B, C, D_0	$H \leq 12$	$H \leq 8T$	None required
Pins per Section BJ105.4.2	≤ 140	A, B, C, D_0, D_1, D_2	$H \leq 10$	$H \leq 7T$	None required
Reinforced[d] clay plaster	≤ 140	A, B, C, D_0, D_1, D_2	$H \leq 10$	$H \leq 8T^{0.5}$ ($H \leq 140T^{0.5}$)	≤ 6 inches
Reinforced[d] clay plaster	≤ 140	A, B, C, D_0, D_1, D_2	$10 < H \leq 12$	$H \leq 8T^{0.5}$ ($H \leq 140T^{0.5}$)	≤ 4 inches[e]
Reinforced[d] cement, cement-lime, lime or soil-cement plaster	≤ 140	A, B, C, D_0, D_1, D_2	$H \leq 10$	$H \leq 9T^{0.5}$ ($H \leq 157T^{0.5}$)	≤ 6 inches
Reinforced[d] cement, cement-lime, lime or soil-cement plaster	≤ 155	A, B, C, D_0, D_1, D_2	$H \leq 12$	$H \leq 9T^{0.5}$ ($H \leq 157T^{0.5}$)	≤ 4 inches[e]
2 × 6 load-bearing wood studs[f] at max. 6′ o.c.	≤ 140	A, B, C, D_0, D_1, D_2	H [g] ≤ 9	NA	None required
2 × 6 load-bearing wood studs[f] at max. 4′ o.c.	≤ 140	A, B, C, D_0, D_1, D_2	H [g] ≤ 10	NA	None required
2 × 6 load-bearing wood studs[f] at max. 2′ o.c.	≤ 140	A, B, C, D_0, D_1, D_2	H [g] ≤ 12	NA	None required
2 × 4 load-bearing wood studs[f] at max. 2′ o.c.	≤ 140	A, B, C, D_0, D_1, D_2	H [g] ≤ 10	NA	None required
2 × 6 nonload-bearing wood studs[f] at max. 6′ o.c.	≤ 140	A, B, C, D_0, D_1, D_2	H [g] ≤ 12	NA	None required

For SI: 1 inch = 25.4 mm, 1 foot = 304.8 mm, 1 mile per hour = 0.447 m/s.

NA = Not Applicable.

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 BJ106.13(1) for the matching plaster type, and with staple spacing in accordance with this table. Mesh shall be installed in accordance with Section BJ106.9.

e. Sill plate attachment shall be with 5/8-inch anchor bolts or approved equivalent at not more than 48 inches on center where staple spacing is required to be ≤ 4 inches.

f. Bales shall be attached to the studs by an approved method. Horizontal framing and attachment at top and bottom of studs shall be in accordance with Section R602 or an approved alternative. Table R602.7(1) shall be used to determine the top framing member where load-bearing stud spacing exceeds 24 inches o.c.
g. *H* is vertical height only.

BJ105.4.1 Determination of out-of-plane loading.
Out-of-plane loading for the use of Table BJ105.4 shall be in terms of the ultimate design wind speed and *seismic design category* as determined in accordance with Sections R301.2.1 and R301.2.2, respectively. An *approved* engineered design for out-of-plane load resistance in accordance with Section R301.2.1 shall be required where the *building* is located in a special wind region or where wind design is required in accordance with Figure R301.2(2) and Section R301.2.1.1.

BJ105.4.2 Pins.
Pins used for out-of-plane resistance shall comply with the following or shall be in accordance with an *approved* engineered design. *Pins* shall be external, internal or a combination of the two.

1. *Pins* shall be 1/2-inch-diameter (12.7 mm) steel, 3/4-inch-diameter (19.1 mm) wood or 1/2-inch-diameter (12.7 mm) 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 connected to its support and the top course shall be 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.

BJ105.5 Connection of light-frame walls to strawbale walls.
Light-frame walls perpendicular to, or at an angle to, a *strawbale* 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 this code, or the abutting stud shall be connected to alternating *strawbale* courses with a 1/2-inch diameter (12.7 mm) steel, 3/4-inch-diameter (19.1 mm) wood or 5/8-inch-diameter (15.9 mm) bamboo dowel, with not less than 8-inch (203 mm) penetration.

BJ105.6 Moisture control.
Strawbale walls shall be protected from moisture intrusion and damage in accordance with Sections BJ105.6.1 through BJ105.6.9.

BJ105.6.1 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.

BJ105.6.2 Interior 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~~WSEC R301. *Bale* walls enclosing showers or steam rooms shall be protected on the interior side by a Class I or Class II vapor retarder.

BJ105.6.3 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*. Penetrations and joints at the floor and ceiling shall be sealed on the interior side of the wall in *Climate Zones* 5, ~~6, 7, 8~~ and Marine 4, as defined in ~~Chapter 11~~WSEC R301.

BJ105.6.4 Horizontal surfaces.
Bale walls and other *bale* elements shall be provided with a water-resistant barrier at weather-exposed horizontal surfaces. The water-resistant 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*. Horizontal surfaces shall be sloped not less than 1 unit vertical in 12 units horizontal (8 percent slope) and shall drain away from *bale* walls and elements. Where the water-resistant 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 *bale* wall's vertical *finish*.

BJ105.6.5 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 (19.1 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 BJ105.3. 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.

BJ105.6.6 Separation of bales and earth.
Bales shall be separated from earth by not less than 8 inches (203 mm).

BJ105.6.7 Separation of exterior plaster and earth.
Exterior *plaster* applied to *straw bales* shall be located not less than 6 inches (152 mm) above earth or 3 inches (76 mm) above paved areas.

BJ105.6.8 Separation of wood and plaster.
Where wood framing or wood sheathing occurs at the exterior face of *strawbale* walls, such wood surfaces shall be separated from exterior *plaster* with two layers of Grade D paper, No. 15 asphalt felt or other *approved* material in accordance with Section R703.7.3, extending not less than 1 inch (25 mm) past the edges of the framing member.

Exceptions:

1. Where the wood is preservative treated or *naturally durable* and is not 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 not greater than 1 1/2 inches (38 mm) in width.

BJ105.6.9 Separation of exterior plaster and foundation.
Exterior *plaster* shall be separated from the building foundation with a moisture barrier.

BJ105.7 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.
2. *Mesh* placement and attachment, where *mesh* is required by this appendix.
3. *Pins*, where required by and in accordance with Section BJ105.4.

BJ105.7.1 Special inspections. The building official has the authority to require the owner to employ a special inspector during construction of specific types of work described in this appendix.

BJ105.8 Voids and stuffing.
Voids between *bales* and between *bales* and framing members shall not exceed 4 inches (102 mm) in width, and such *voids* shall be tightly stuffed with *flakes*, loose straw or *straw-clay* before application of *finish*.

Section BJ106 Strawbale Walls—Structural

BJ106.1 General.
Plastered *strawbale* walls shall be permitted to be used as structural walls in accordance with the prescriptive provisions of this section.

BJ106.2 Building limitations and requirements for use of strawbale structural walls.
Buildings using *strawbale structural* 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), except that greater heights shall be allowed with an *approved* engineered design.
3. Wall height: In accordance with Table BJ105.4, BJ106.13(2) or BJ106.13(3), as applicable, whichever is most restrictive.
4. *Braced wall panel* lengths: The greater of the values determined in accordance with Tables BJ106.13(2) and BJ106.13(3) for *buildings* using *strawbale braced wall panels*, or in accordance with Item 4 of Section BJ105.2 for *buildings* with *load-bearing strawbale walls* that do not use *strawbale braced wall panels*.

BJ106.3 Loads and other limitations.
Live and *dead loads* and other limitations shall be in accordance with Section R301. *Strawbale* wall *dead loads* shall not exceed 60 psf (2872 N/m^2) per face area of wall.

BJ106.4 Foundations.
Foundations for plastered *strawbale* walls shall be in accordance with Chapter 4, Figure BJ105.1(1), Figure BJ105.1(2) or an *approved* engineered design.

BJ106.5 Orientation and 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.

BJ106.6 Plaster on structural walls.
Plaster on *load-bearing* walls shall be in accordance with Table BJ106.12. *Plaster* on *shear walls* shall be in accordance with Table BJ106.13(1).

BJ106.6.1 Compressive strength.
For *plaster* on *strawbale* structural walls, the *building official* is authorized to require a 2-inch (51mm) cube test conforming to ASTM C109 to demonstrate a minimum compressive strength in accordance with Table BJ106.6.1. For natural hydraulic lime (NHL) plasters, the compressive strength in the NHL manufacturer's specifications is permitted to be used to satisfy the requirements in Table BJ106.6.1 where the *plaster* mix used for the project is identical to that in the manufacturer's specifications.

TABLE BJ106.6.1 MINIMUM COMPRESSIVE STRENGTH FOR PLASTERS ON STRUCTURAL WALLS

PLASTER TYPE	MINIMUM COMPRESSIVE STRENGTH (psi)
Clay	100
Soil-cement	1,000
Lime	600
Cement-lime	1,000
Cement	1,400

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

BJ106.7 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 all of the following:

1. As measured across the face of a *bale*, *straw* bulges shall not protrude more than 3/4 inch (19.1 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).
3. The vertical faces of adjacent *bales* shall not be offset more than 3/8 inch (9.5 mm).

BJ106.8 Plaster and membranes on structural walls.
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.

BJ106.9 Mesh.
Mesh in plasters on *strawbale* structural walls, and where required by Table BJ105.4, and where used to resist wind uplift in accordance with Section BJ106.14, shall be installed in accordance with Sections BJ106.9.1 through BJ106.9.4.

BJ106.9.1 Mesh laps.
Mesh required by Table BJ105.4 or BJ106.12 shall be installed with not less than 4-inch (102 mm) laps. *Mesh* required by Table BJ106.13(1) or in walls designed to resist wind uplift of more than 100 plf (1459 N/m) in accordance with Section BJ106.14 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).

BJ106.9.2 Mesh attachment.
Mesh shall be attached with staples to top plates or roof-bearing elements and to sill plates in accordance with all of the following:

1. **Staples.** Staples shall be pneumatically driven, stainless steel or electro-galvanized, 16 gage with 1 1/2-inch (38 mm) legs, 7/16-inch (11.1 mm) crown; or manually driven, galvanized, 15 gage with 1-inch (25 mm) legs. Other staples shall be 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 BJ106.13(1) or Section BJ106.14, as applicable.

BJ106.9.3 Steel mesh.
Steel *mesh* shall be galvanized and shall be separated from preservative-treated wood by Grade D paper, No. 15 roofing felt or other *approved* barrier.

BJ106.9.4 Mesh in plaster.
Required *mesh* shall be embedded in the *plaster* except where staples fasten the *mesh* to horizontal boundary elements.

BJ106.10 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 in accordance with Figure BJ105.1(2) and an *approved* engineered design or a steel angle anchored with an *approved* engineered design. A weep screed as described in Section R703.7.2.1 is not an acceptable support.

BJ106.11 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 in accordance with Figure BJ105.1(3) 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 in accordance with Figure BJ105.1(3) or BJ105.1(4) and to the sill plate in accordance with Figure BJ105.1(1) or BJ105.1(2) and with Table BJ106.13(1).

BJ106.12 Load-bearing walls.
Bearing capacities for plastered *strawbale* walls used as *load-bearing walls* in one-*story buildings* to support vertical loads imposed in accordance with Section R301 shall be in accordance with Table BJ106.12.

TABLE BJ106.12 ALLOWABLE SUPERIMPOSED VERTICAL LOADS (LBS/FOOT) FOR PLASTERED LOAD-BEARING STRAWBALE WALLS

WALL DESIGNATION	PLASTER[a] (both sides)		MESH[b]	STAPLES[c]	ALLOWABLE BEARING CAPACITY[d] (plf)
	Type	Thickness (minimum in inches each side)			
A	Clay	1 1/2	None required	None required	400
B	Soil-cement	1	Required	Required	800
C	Lime[e]	7/8	Required	Required	500
D	Cement-Lime	7/8	Required	Required	800
E	Cement	7/8	Required	Required	800

For SI: 1 inch = 25.4 mm, 1 pound per foot = 14.5939 N/m.

a. Plasters shall conform to Sections BJ104.4.3 through BJ104.4.9, BJ106.7 and BJ106.10.

b. Any metal mesh allowed by this appendix and installed in accordance with Section BJ106.9.

c. In accordance with Section BJ106.9.2, except as required to transfer roof loads to the plaster skins in accordance with Section BJ106.11.

d. For walls with a different plaster on each side, the lower value shall be used. For walls with plaster on only one side, half of the tabular value shall be used.

e. Shall use hydraulic or natural hydraulic lime.

BJ106.12.1 Precompression of load-bearing strawbale walls.
Prior to application of *plaster*, walls designed to be load-bearing shall be *precompressed* by a uniform load of not less than 100 plf (1459 N/m).

BJ106.12.2 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 BJ106.12 for the *plaster* type used.

BJ106.12.3 Roof-bearing assembly.
Roof-bearing assemblies shall be of nominal 2-inch by 6-inch (51 mm by 152 mm) lumber with 15/32-inch (12 mm) plywood or OSB panels fastened with 8d nails at 6 inches (152 mm) on center in accordance with Figure BJ105.1(3) and Items 1 through 6, or be of an *approved* engineered design.

1. Assembly shall be a box assembly on the top course of *bales*, with the panels horizontal.
2. Assembly shall be the width of the *strawbale* wall and shall comply with Section BJ106.11.
3. Discontinuous lumber shall be spliced with a metal strap with not less than a 500-pound (2224 N) allowable wind or seismic load tension capacity. Where the wall line includes a *braced wall panel* the strap shall have not less than a 2,000-pound (8896 N) capacity.
4. Panel joints shall be blocked.
5. Roof and ceiling framing shall be attached to the *roof-bearing assembly* in accordance with Table R602.3(1), Items 2 and 6.
6. Where the *roof-bearing assembly* spans wall openings, it shall comply with Section BJ106.12.3.1.

BJ106.12.3.1 Roof-bearing assembly spanning openings.
Roof-bearing assemblies that span openings in *strawbale* walls shall comply with the following at each opening:

1. Lumber on each side of the assembly shall be of the dimensions and quantity required to span each opening in accordance with Table R602.7(1).
2. The required lumber in the assembly shall be supported at each side of the opening by the number of jack studs required by Table R602.7(1), or shall extend beyond the opening on both sides a distance, D, using the following equation:

Equation BJ-1 $D=S\times R/2/(1-R)$

where:
D =Minimum distance (in feet) for required spanning lumber to extend beyond the opening
S =Span in feet
$R = B_L/B_C$
B_L =Design load on the wall (in pounds per lineal foot) in accordance with Sections R301.4 and R301.6
B_C =Allowable bearing capacity of the wall in accordance with Table BJ106.12

BJ106.13 Braced wall panels.
Plastered *strawbale* walls used as *braced wall panels* for one-story *buildings* shall be in accordance with Section R602.10 and Tables BJ106.13(1), BJ106.13(2) and BJ106.13(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. An *approved* engineered design in accordance with Section R301.2.1 shall be required where the *building* is located in a special wind region or where wind design is required in accordance with Figure R301.2(2) and Section R301.2.1.1, respectively.

TABLE **BJ106.13(1) PLASTERED STRAWBALE BRACED WALL PANEL TYPES**

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

For SI: 1 inch = 25.4 mm.

a. Plasters shall comply with Sections BJ104.4.3 through BJ104.4.9, BJ106.7, BJ106.8 and BJ106.12.

b. Sill plates shall be Douglas fir-larch or southern pine and shall be preservative treated where required by the ~~*International*~~ *Washington State Residential Code*.

c. Anchor bolts shall be in accordance with Section BJ106.13.3 at the spacing shown in this table.

d. Installed in accordance with Section BJ106.9.

e. Staples shall be in accordance with Section BJ106.9.2 at the spacing shown in this table.

f. Shall use hydraulic or natural hydraulic lime.

TABLE **BJ106.13(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]**		
Ultimate design windspeed (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] B, D2, E1, E2**
≤ 110	One-story building	10	6.4	3.8	3.0
		20	8.5	5.1	4.0
		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
≤ 115	One-story building	10	6.4	3.8	3.0
		20	8.5	5.1	4.0
		30	11.2	6.4	5.1
		40	14.3	7.2	5.7
		50	18.4	8.1	6.5
		60	21.4	8.8	7.0
≤ 120	One-story building	10	7.1	4.3	3.4
		20	9.0	5.4	4.3
		30	12.2	6.6	5.3
		40	16.3	7.7	6.1
		50	19.4	8.3	6.6
		60	23.5	9.2	7.3
≤ 130	One-story building	10	7.1	4.3	3.4
		20	10.2	6.1	4.8
		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
≤ 140	One-story building	10	7.8	4.7	3.7
		20	11.2	6.4	5.1
		30	16.3	7.7	6.1
		40	21.4	8.8	7.0

		50	26.5	9.8	7.8
		60	30.6	11.0	8.3

For SI: 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 BJ106.13(2).

e. Strawbale braced panel types indicated shall comply with Sections BJ106.13.1 through BJ106.13.3 and with Table BJ106.13(1).

TABLE **BJ106.13(3) BRACING REQUIREMENTS FOR STRAWBALE BRACED WALL PANELS BASED ON SEISMIC DESIGN CATEGORY**

• SOIL CLASS D[f] • 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, A3[g], 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. 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 BJ106.13.1 through BJ106.13.3 and Table BJ106.13(1).

f. Wall bracing lengths are based on a soil site class "D." Interpolation of bracing lengths between S_{ds} values associated with the seismic design categories is allowable where a site-specific S_{ds} value is determined in accordance with Section 1613.2 of the ~~*International*~~ *Washington State Building Code*.

g. Where using wall Type A3, the minimum total length of braced wall panels in this column shall be multiplied by 1.25.

BJ106.13.1 Bale wall thickness.

The thickness of *strawbale braced wall panels* without their *plaster* shall be not less than 15 inches (381 mm).

BJ106.13.2 Sill plates.

Sill plates shall be in accordance with Table BJ106.13(1).

BJ106.13.3 Sill plate fasteners.

Sill plates shall be fastened with not less than 5/8-inch-diameter (15.9 mm) steel anchor bolts with 3-inch by 3-inch by 3/16-inch (76.2 mm by 76.2 mm by 4.8 mm) steel washers, with not less than 7-inch (177.8 mm) embedment in a concrete or masonry foundation, or shall be an *approved* equivalent, with the spacing shown in Table BJ106.13(1). Anchor bolts or other fasteners into framed floors shall be of an *approved* engineered design.

BJ106.14 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 all of the following:

1. *Plaster* shall be any type and thickness allowed in Section BJ104.

2. *Mesh* shall be any type allowed in Table BJ106.13(1), and shall be attached to top plates or roof-bearing elements and to sill plates in accordance with Section BJ106.9.2.

3. Sill plates shall be not less than 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 to be 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 to be capable of resisting uplift forces of 200 plf (2918 N/m) for each *plaster* skin.

BJ106.15 Post-and-beam with strawbale infill.

Post-and-beam with *strawbale infil* systems shall be in accordance with Figure BJ105.1(4) and Items 1 through 7, or be of an *approved* engineered design.

1. Beams shall be of the dimensions and number of members in accordance with Table R602.7(1), where the space between posts equals the span in the table.

2. Beam ends shall bear over posts not less than 1 1/2 inches (38 mm) or be supported by a framing anchor in accordance with Table R602.7(1).
3. Discontinuous beam ends shall be spliced with a metal strap with not less than 1,000-pound (454 kg) wind or seismic load tension capacity. Where the wall line includes a *braced wall panel*, the strap shall have not less than a 4,000-pound (1814 kg) capacity.
4. Each post shall equal NJ + 1 in accordance with Table R602.7(1), where the space between posts equals the span in the table.
5. Posts shall be connected to the beam by an *approved* means.
6. Roof and ceiling framing shall be attached to the beam in accordance with Table R602.3(1), Items 2 and 6.
7. Posts shall be supported by the sill plate of the *bale* wall in accordance with BJ105.3 or BJ106.13.2, with fastening in accordance with Table R602.3(1), Item 16, or shall be supported and fastened at their base by an *approved* means.

Section BJ107 Fire Resistance

BJ107.1 Fire-resistance rating.
Strawbale walls shall not be considered to exhibit a fire-resistance rating, except for walls constructed in accordance with Section BJ107.1.1 or BJ107.1.2. Alternately, fire-resistance ratings of *strawbale* walls shall be determined in accordance with Section R302.

BJ107.1.1 One-hour-rated clay-plastered wall.
One-hour fire-resistance-rated nonload-bearing clay plastered *strawbale* walls shall comply with all of 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. *Bales* shall have a minimum dry density of 7.25 pounds per cubic foot (116 kg/m^3).
4. Gaps shall be stuffed with *straw-clay*.
5. Clay *plaster* on each side of the wall shall be not less than 1 inch (25 mm) thick and shall be composed of a mixture of 3 parts *clay*, 2 parts chopped straw and 6 parts sand, or an alternative *approved* clay plaster.
6. *Plaster* application shall be in accordance with Section BJ104.4.3.3 for the number and thickness of coats.

BJ107.1.2 Two-hour-rated cement-plastered wall.
Two-hour fire-resistance-rated nonload-bearing cement-plastered *strawbale* walls shall comply with all of 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. *Bales* shall have a minimum dry density of 7.25 pounds per cubic foot (116 kg/m^3).
4. Gaps shall be stuffed with *straw-clay*.
5. A single section of 1/2-inch (38 mm) by 17-gage galvanized woven wire *mesh* shall be attached to wood members with 1 1/2-inch (38 mm) staples at 6 inches (152 mm) on center. 9 gage U-pins with not less than 8-inch (203 mm) legs shall be installed at 18 inches (457 mm) on center to fasten the *mesh* to the *bales*.
6. *Cement plaster* on each side of the wall shall be not less than 1 inch (25 mm) thick.
7. *Plaster* application shall be in accordance with Section BJ104.4.9 for the number and thickness of coats.

BJ107.2 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 this code.

BJ107.3 Clearance to fireplaces and chimneys.
Strawbale surfaces adjacent to fireplaces or chimneys shall be finished with not less than 3/8-inch-thick (10 mm) *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 instructions, whichever is more restrictive.

Section BJ108 Thermal Insulation

BJ108.1 R-value.
The unit *R*-value of a *strawbale* wall with bales *laid flat* is R-1.55 for each inch of *bale* thickness. The unit *R*-value of a *strawbale* wall with *bales on-edge* is R-1.85 for each inch of *bale* thickness.

BJ108.2 Compliance with Section R302.10.1.
Straw bales meet the requirements for insulation materials in Section R302.10.1 for *flame spread index* and *smoke-developed index* as tested in accordance with ASTM E84.

Section BJ109 Referenced Standards

BJ109.1 General.
See Table BJ109.1 for standards that are referenced in various sections of this appendix. Standards are listed by the standard identification with the effective date, the standard title and the section or sections of this appendix that reference the standard.

TABLE **BJ109.1 REFERENCED STANDARDS**

STANDARD ACRONYM	STANDARD NAME	SECTIONS HEREIN REFERENCED
ASTM C5—10	*Standard Specification for Quicklime for Structural Purposes*	BJ104.4.6.1
ASTM C109/C109M—2015el	*Standard Test Method for Compressive Strength of Hydraulic Cement Mortars*	BJ106.6.1
ASTM C141/C141M—14	*Standard Specification for Hydrated Hydraulic Lime for Structural Purposes*	BJ104.4.6.1
ASTM C206—14	*Standard Specification for Finishing Hydrated Lime*	BJ104.4.6.1
ASTM C926—15B	*Standard Specification for Application of Portland Cement Based Plaster*	BJ104.4.8, BJ104.4.9
ASTM C1707—11	*Standard Specification for Pozzolanic Hydraulic Lime for Structural Purposes*	BJ104.4.6.1
ASTM E84-21a	*Standard Test Method for Surface Burning Characteristics of Building Materials*	BJ108.2
ASTM E2392/E2392M—10(2016)	*Standard Guide for Design of Earthen Wall Building Systems*	BJ104.4.3.2
CEN EN 459—2015	*Part 1: Building Lime. Definitions, Specifications and Conformity Criteria; Part 2: Test Methods*	BJ104.4.6.1

Appendix BK Cob Construction (Monolithic Adobe)

The provisions contained in this appendix are adopted for use in the State of Washington ~~not mandatory unless specifically referenced in the adopting ordinance~~.

User notes:

About this appendix:
Cob construction has been used for thousands of years around the world, notably in England and Northern Europe, the Middle East, West Africa, China and the Southwestern United States. An estimated 20,000 cob homes are still inhabited in the English county of Devon alone, some dating from the 15th century. The term "cob" derives from an Old English word for "lump," since historical structures were often constructed one handful at a time.

Section BK101 General

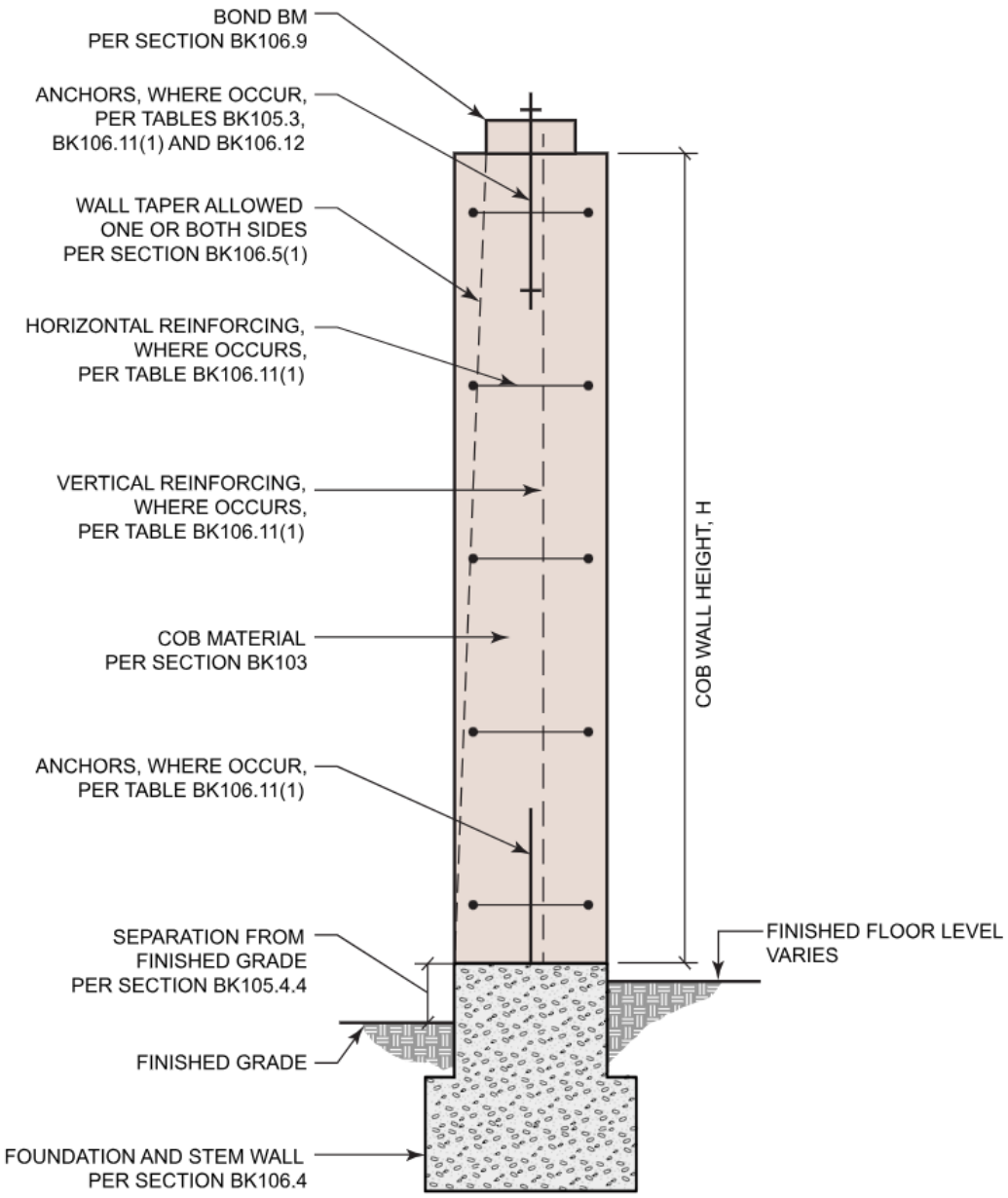
BK101.1 Scope.
This appendix provides prescriptive and performance-based requirements for the use of *natural cob* as a building material. *Buildings* using *cob* walls shall comply with this code except as otherwise stated in this appendix.

BK101.2 Intent.
In addition to the intent described in Section R101.3, the purpose of this appendix is to establish minimum requirements for *cob* structures that provide flexibility in the application of certain provisions of the code, to permit the use of site-sourced and local materials, and to permit combinations of historical and modern techniques.

BK101.3 Tests and empirical evidence.
Tests for an alternative material, design or method of construction shall be in accordance with Section R104.2.2.5, and the *building official* shall have the authority to consider evidence of a history of successful use in lieu of testing.

BK101.4 Cob wall systems.
Cob wall systems include those shown in Figure BK101.4 and *approved* variations.

FIGURE **BK101.4 TYPICAL COB WALL**



Section BK102 Definitions

BK102.1 Definitions.
The words and terms in this section shall, for the purposes of this appendix, have the meanings shown herein. Refer to Chapter 2 for general definitions.

BRACED WALL PANEL. A *cob* wall designed and constructed to resist in-plane shear loads through the interaction of the *cob* material, its reinforcing and its connections to its *bond beam* and foundation. The panel's length meets the requirements for the particular wall type and contributes toward the total amount of bracing required along its *braced wall line* in accordance with Sections BK106.11 and R602.10.1.

BUCK. A frame, typically wood, anchored in a wall system, that creates the rough opening into which a window or door frame is installed.

BUTTRESS. A mass set at an angle to or bonded to a wall that it strengthens or supports.

CLAY. Inorganic soil with particle sizes less than 0.00008 inch (0.002 mm) and having the characteristics of high to very high dry strength and medium to high plasticity, used as the *binder* of other component materials in a mix of *cob* or of clay plaster.

CLAY SUBSOIL. Subsoil sourced directly from the earth, containing *clay*, sand and silt, and containing not more than trace amounts of organic matter.

COB. A composite building material consisting of refined *clay* or *clay subsoil* wet-mixed with loose straw and sometimes sand.

COB CONSTRUCTION. A wall system of layers or lifts of moist cob placed to create monolithic walls, typically without formwork. Also known as "*Monolithic adobe.*"

DRY JOINT. The boundary between a layer of moist *cob* and a previously laid and significantly drier, nonmalleable layer of *cob* that requires wetting to achieve bonding between the layers.

FINISH. Completed combination of materials on the face of a *cob* wall.

LIFT. A layer of installed *cob*.

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

MONOLITHIC ADOBE. See "*Cob construction.*"

NATURAL COB. Cob not containing admixtures such as Portland cement, lime, asphalt emulsion or oil. Synonymous with "*Unstabilized cob.*"

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

PLASTER. Clay, soil-cement, gypsum, lime, clay-lime, cement-lime or *cement plaster* as described in Section BK104.

SHEAR WALL. A *cob* wall designed and constructed to resist in-plane lateral seismic and wind forces in accordance with Section BK106.11. Synonymous with "*Braced wall panel.*"

STABILIZED. *Cob* or other earthen material containing admixtures, such as Portland cement, lime, asphalt emulsion or oil, that are intended to help limit water absorption, stabilize volume, increase strength and increase durability.

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

STRUCTURAL WALL. A wall that meets the definition for a "*Load-bearing wall*" or "*Shear wall.*"

UNSTABILIZED. Cob or other earthen material that does not contain admixtures such as Portland cement, lime, asphalt emulsion or oil.

UNSTABILIZED COB. See "*Natural cob.*"

Section BK103 Materials, Mixing and Installation

BK103.1 Clay subsoil.
Clay subsoil for a *cob* mix shall be acceptable if the mix it produces meets the requirements of Section BK103.4.

BK103.2 Sand.
Sand or other aggregates such as, but not limited to, gravel, pumice and lava rock, when added to *cob* mixes, shall yield a mix that meets the requirements of Section BK103.4.

BK103.3 Straw.
Straw for *cob* mixes shall be from wheat, rice, rye, barley or oat, or similar reinforcing fibers with similar performance. Before mixing, the straw or other reinforcing fibers shall be dry to the touch and free of visible decay.

BK103.4 Mix proportions.
Cob mixes shall be of any proportions of refined *clay* or *clay subsoil*, added sand (if any) and straw that produce a dried mix that passes the shrinkage test in accordance with Section BK103.4.1, complies with the compressive strength requirements of Section BK106.6 and complies with the modulus of rupture requirements of Section BK106.7.

BK103.4.1 Shrinkage test for cob mixes.
Each proposed *cob* mix of different mix proportions shall be placed moist to completely fill a 24-inch by 3 1/2-inch by 3 1/2-inch (610 mm by 89 mm by 89 mm) wooden form on a plastic or paper slip sheet and dried to ambient moisture conditions, or oven dried. The total shrinkage of the length shall not exceed 1 inch (25 mm), as measured from the dried edges of the material to the insides of the form. Cracks in the sample greater than 1/16 inch (1.5 mm) shall first be closed manually. The shrinkage test shall be shown to the *building official* for approval before placement of the *cob* mix onto walls

BK103.5 Mixing.
The *clay subsoil*, sand and straw for *cob* shall be thoroughly mixed by manual or mechanical means with water sufficient to produce a mix of a plastic consistency capable of bonding of successively placed layers or *lifts*.

BK103.6 Installation.
Cob shall be installed on the wall in *lifts* of a height that supports itself with minimal slumping.

BK103.7 Dry joints.
Each layer of *cob* shall be prevented from drying until the next layer is installed, to ensure bonding of successive layers. The top of each layer shall be kept moist and malleable with one or more of the following methods:

1. Covering with a material that prevents loss of or holds moisture.
2. Covering with a material that shades it from direct sun.
3. Wetting.

Where *dry joints* are unavoidable, the previous layer shall be wetted prior to application of the next layer.

BK103.8 Drying holes.
Where holes to facilitate drying are used, such holes shall be permitted to be of any depth and shall not exceed 3/4 inch (19 mm) in diameter. Drying holes shall not be spaced closer than 10 hole-diameters and shall not be placed in *braced wall panels*. The design load on *load-bearing walls* with drying holes shall not exceed 90 percent of the allowable bearing capacity as determined in accordance with Section BK106.8. Drying holes shall be filled with *cob* before final inspection.

BK103.9 Adding roof loads to walls.
Roof and ceiling loads shall not be added until walls are sufficiently dry to support them without compressing.

Section BK104 Finishes

BK104.1 General.
Cob walls shall not require a *finish*, except as required by Section BK104.2. *Finishes* applied to *cob* walls shall comply with this section and Chapters 3 and 7 unless stated otherwise in this section.

BK104.1.1 Interior wall finishes.
Where installed, interior wall *finishes* and interior fire protection shall comply with the applicable provisions of Section R302, and shall be *plasters* in accordance with Section BK104.4 or nonplaster wall coverings in accordance with Section R702.

BK104.1.2 Exterior wall finishes.
Where installed, exterior wall *finishes* shall be *plasters* in accordance with Section BK104.4, nonplaster exterior wall coverings in accordance with Section R703, or other *finish* systems in accordance with the following:

1. Specifications and details of the *finish* system's attachment to the wall or its independent support and of its means of draining or evaporating water that penetrates the exterior *finish* shall be approved.
2. The vapor permeance of the combination of *finish* materials shall be 5 perms or greater to allow the transpiration of water vapor from the wall.
3. *Finish* systems with weights greater than 10 pounds per square foot (48.9 kg/m) and less than or equal to 20 pounds per square foot (97.8 kg/m) of wall area shall require that the minimum total length of *cob braced wall panels* in Table BK106.11(3) be multiplied by a factor of 1.2.
4. *Finish* systems with weights greater than 20 pounds per square foot (97.8 kg/m) of wall area shall require an engineered design.

BK104.2 Where required.
Cob walls exposed to rain due to local climate, building design and wall orientation shall be *finished* or clad to provide protection from excessive erosion.

BK104.3 Vapor retarders.
Class I and II vapor retarders shall not be used on *cob* walls, except at *cob* walls surrounding showers or as required or addressed elsewhere in this appendix.

BK104.4 Plaster.
Plaster applied to *cob* walls shall be any type described in this section. *Plaster* thickness shall not exceed 3 inches (76 mm) on each face except with an *approved* engineered design.

BK104.4.1 Plaster and membranes.
Plaster shall be applied directly to *cob* walls to facilitate transpiration of moisture from the walls and to secure a mechanical bond between the *plaster* and the *cob* and shall comply with Section BK105.4.1.

BK104.4.2 Plaster lath.
The surface of *cob* walls shall be permitted to function as lath for *plaster*, with no other lath required. Metal, plastic and natural fiber lath shall be permitted to be used to limit *plaster* cracking, increase the *plaster* bond to the wall or to bridge dissimilar materials.

BK104.4.3 Clay plaster.
Clay plaster shall comply with Sections BK104.4.3.1 and BK104.4.3.2.

BK104.4.3.1 General.
Clay plaster shall be any *plaster* having a *clay* or *clay subsoil binder* . Such *plaster* shall contain sufficient *clay* to fully bind the sand or other aggregate and any reinforcing fibers. Reinforcing fibers shall be chopped straw, sisal, *hemp*, animal hair or other similar *approved* fibers.

BK104.4.3.2 Clay subsoil requirements.
The suitability of *clay subsoil* shall be determined in accordance with the Figure 2 Ribbon Test and the Figure 3 Ball Test in the appendix of ASTM E2392/E2392M.

BK104.4.4 Soil-cement plaster.
Soil-cement *plaster* shall be composed of *clay subsoil*, sand, not more than 7 percent Portland cement by volume and, where provided, reinforcing fibers.

BK104.4.5 Gypsum plaster.
Gypsum plaster shall comply with Section R702.2.1 and shall be limited to interior use.

BK104.4.6 Lime plaster.
Lime *plaster* is any *plaster* with a *binder* composed of calcium hydroxide including Type N or S hydrated lime, hydraulic lime, natural hydraulic lime or slaked quicklime. Hydrated lime shall comply with ASTM C206. Hydraulic lime shall comply with ASTM C1707. Natural hydraulic lime shall comply with ASTM C141 and EN 459. Quicklime shall comply with ASTM C5.

BK104.4.7 Clay-lime plaster.
Clay-lime *plaster* shall be composed of refined *clay* or *clay subsoil*, sand, lime and, where provided, reinforcing fibers.

BK104.4.8 Cement-lime plaster.
Cement-lime *plaster* shall be *plaster* mix types CL, F or FL, as described in ASTM C926.

BK104.4.9 Cement plaster.
Cement plaster shall have not less than 1 part lime to 4 parts cement and be not thicker than 1 1/2 inches (38 mm), to ensure minimum acceptable vapor permeability.

Section BK105 Cob Walls—General

BK105.1 General.
Cob walls shall be designed and constructed in accordance with this section and Figure BK101.4 or an *approved* alternative design. In addition to the general requirements for *cob* walls in this section, *cob structural walls* shall comply with Section BK106.

BK105.2 Building limitations and requirements for *cob* wall construction.
Cob walls shall be subject to the following limitations and requirements:

1. Number of *stories:* not more than one.
2. *Building height:* not more than 20 feet (6096 mm).
3. *Seismic design categories:* limited to use in *Seismic Design Categories* A, B and C, except with an *approved* engineered design.
4. Wall height: in accordance with Table BK105.3, and with Table BK106.11(1) for *braced wall panels*.
5. Wall thickness, excluding *finish*, shall be not less than 10 inches (254 mm), not greater than 24 inches (610 mm) at the top two-thirds, not limited at the bottom third and, for structural walls, shall comply with Section BK106.2, Item 2. Wall taper is permitted in accordance with Section BK106.5, Item 1.

6. Interior *cob* walls shall require an *approved* engineered design that accounts for the seismic load of the interior *cob* walls, except in *Seismic Design Category* A for walls with a height to thickness ratio less than or equal to 6.

BK105.3 Out-of-plane resistance methods and unrestrained wall height limits.
Cob walls shall employ a method of out-of-plane load resistance in accordance with Table BK105.3, and comply with its associated height limits and requirements.

TABLE BK105.3
OUT-OF-PLANE RESISTANCE METHODS AND UNRESTRAINED WALL HEIGHT LIMITS

WALL TYPE[a, g, h] AND METHOD OF OUT-OF-PLANE LOAD RESISTANCE	FOR ULTIMATE DESIGN WIND SPEEDS (mph)	FOR SEISMIC DESIGN CATEGORIES	UNRESTRAINED COB WALL HEIGHT H[b, c, h]		TOP ANCHOR[e] SPACING (inches)	TENSION TIE[f] SPACING (inches)
			Absolute Limit (feet)	Limit Based on Wall Thickness T[d] (feet)		
Wall 1[i]: no anchors, no steel wall reinforcing	≤ 110	A	$H \leq 8$	$H \leq 6T$	None	48
Wall 2: top anchors[j], continuous vertical 6- inch × 6-inch × 6-gage steel mesh in center of wall embedded in foundation 12 inches	≤ 140	A, B, C	$H \leq 8$	$H \leq 8T$	12	24
Wall A[i]: top anchors, no vertical steelreinforcing	≤ 120	A, B	$H \leq 8$	$H \leq 6T$	12	48
Wall B[i]: top and bottom anchors, no vertical steel reinforcing	≤ 130	A, B	$H \leq 8$	$H \leq 6T$	12	48
Wall C: top and bottom anchors, continuous vertical threaded rod at 4 feet on center embedded in foundation and connected to bond beam	≤ 140	A, B, C	$H \leq 8$	$H \leq 8T$	12	24
Wall D: continuous vertical threaded rod at 1 foot on center embedded in foundation and connected to bond beam	≤ 140	A, B, C	$H \leq 8$	$H \leq 8T$	N/A	24
Wall E: top anchors, continuous vertical 6-inch × 6-inch × 6-gage steel mesh 2 inches from each face of wall embedded in foundation	≤ 140	A, B, C	$H \leq 8$	$H \leq 8T$	12	24
Wall F: top anchors, continuous vertical 6- inch × 6-inch × 10-gage steel mesh 2 inches from each face of wall embedded in foundation	≤ 140	A, B, C	$H \leq 8$	$H \leq 8$T	12	24

For SI: 1 inch = 25.4 mm, 1 foot = 304.8 mm, 1 mile per hour = 0.447 m/s.
N/A = Not Applicable

a. See Table BK106.11(1) for reinforcing and anchorage specifications for wall Types A, B, C, D and E.
b. H = height of the cob portion of the wall only. See Figure BK101.4. The maximum H is the absolute limit or the limit based on wall thickness, whichever is more restrictive.
c. Bond beams or other horizontal restraints are permitted to divide a wall into more than one unrestrained wall height with an approved engineered design.
d. T= Cob wall thickness (in feet) at its minimum, without plaster.
e. 5/8-inch threaded rod anchors at prescribed spacing with 12-inch embedment in cob, full embedment in concrete bond beams or full penetration in wood bond beam with a nut and washer.

f. Attach rafters to bond beam with 4-inch by 3-inch by 3-inch by 18-gage tension tie angles at prescribed spacing. See Figure BK106.9.5. Where rafters are attached to tension ties, roof sheathing shall be edge nailed.
g. All walls shall be tested for compressive strength in accordance with Section BK106.6.
h. For curved walls with an arc length (ARC_c) to radius (R_c) ratio of 1.5:1 or greater, the *H/ T* factor shall be increased by 1, and the absolute height limit by 1 foot. See Section BK106.11.3.
i. Wall type requires a modulus of rupture test in accordance with Section BK106.7.
j. See wall Type A in Table BK106.11(1) for top anchor requirements.

BK105.3.1 Determination of out-of-plane loading.
Out-of-plane loading for the use of Table BK105.3 shall be in accordance with the ultimate design wind speed and *seismic design category* requirements of Sections R301.2.1 and R301.2.2, respectively.
An *approved* engineered design shall be required where the *building* is located in a special wind region or where wind design is required in accordance with Figure R301.2.1.1.

BK105.3.2 Bond beams for nonstructural walls.
Nonstructural *cob* walls shall be provided with a *bond beam* at the top of the wall that complies with Section BK106.9, except for requirements relating to roof and/or ceiling loads or *braced wall panels*.

BK105.3.3 Lintels in nonstructural walls.
Door, window and other openings in nonstructural *cob* walls shall require a lintel in accordance with Section BK106.10, except for requirements relating to roof and/or ceiling loads or *braced wall panels*.

BK105.3.4 Reinforcing at wall openings.
Reinforcing shall be installed at window, door, and similar wall openings and penetrations greater than 2 feet (610 mm) in width in accordance with Sections BK105.3.4.1 through BK105.3.4.3. Surface *voids* deeper than 25 percent of the wall thickness shall be considered an opening.

BK105.3.4.1 Opening size limit.
Openings shall not exceed 6 feet (1829 mm) in width, and the height of the *cob* wall below openings shall not exceed 6 feet (1829 mm) above the top of the foundation.

BK105.3.4.2 Horizontal reinforcing.
Two-inch by 2-inch (51 mm by 51 mm) 14-gage galvanized steel mesh shall be embedded 4 inches (102 mm) in the *cob* below the rough opening for windows and shall extend 12 inches (305 mm) beyond the sides of the opening. Walls below rough window openings greater than 4 feet 6 inches (1372 mm) in height shall be provided with additional horizontal reinforcing at midheight.

BK105.3.4.3 Vertical reinforcing.
Full-height 5/8-inch (16 mm) threaded rod shall be installed 4 inches (102 mm) from each side of the opening, centered in the thickness of the *cob* wall. The threaded rods shall be embedded 7 inches (178 mm) in the foundation and 4 inches (102 mm) in concrete *bond beams* or shall penetrate through wood *bond beams* and be secured with a nut and washer. The threaded rods shall be embedded in concrete lintels or pass through a drilled hole in wood lintels.

BK105.3.5 Minimum length of cob walls.
Sections of *cob* walls between openings shall be not less than 2 feet 6 inches (762 mm) in length. Wall sections less than 4 feet (1219 mm) and not less than 2 feet 6 inches (762 mm) in length shall contain vertical reinforcing in accordance with Section BK105.3.4.3.

BK105.4 Moisture control.
Cob walls shall be protected from moisture intrusion and damage in accordance with Sections BK105.3.4.1 through BK105.4.5.

BK105.4.1 Water-resistive barriers and vapor permeance.
Cob walls shall be constructed without a membrane barrier, except as otherwise required elsewhere in this appendix. Where a water-resistive barrier is placed behind an exterior *finish*, it shall be considered part of the *finish* system and shall comply with Item 2 of Section BK104.1.2 for the combined vapor permeance rating.

BK105.4.2 Horizontal surfaces.
Cob walls and other *cob* elements shall be provided with a water-resistive barrier at weatherexposed horizontal surfaces. The water-resistive barrier shall be of a material and installation that will prevent erosion and prevent water from entering the wall system. Horizontal surfaces, including exterior windowsills, sills at exterior niches and exterior *buttresses*, shall be sloped not less than 1 unit vertical in 12 units horizontal to drain away from *cob* walls or other *cob* elements.

BK105.4.3 Separation of cob and foundation.
A liquid-applied or bituminous Class II vapor retarder shall be installed between *cob* and supporting concrete or masonry.
Exception: Where local climate, site conditions and foundation design limit ground moisture migration into the base of the *cob* wall, including but not limited to the use of a moisture barrier or capillary break between the supporting concrete or masonry and the earth.

BK105.4.4 Separation of cob and finished grade.
Cob shall be not less than 8 inches (203 mm) above finished *grade*.
Exception: The minimum separation shall be 4 inches (102 mm) in *climate zone* 5B as noted in WSEC Table R301.1 ~~dry *climate zones*, as defined in Section N1101.7.2~~, and shall be 2 inches (51mm) on walls that are not weather exposed.

BK105.4.5 Installation of windows and doors.
Windows and doors shall be installed in accordance with the manufacturer's instructions to a wooden *buck* of not less than nominal 2-inch by 4-inch (51 mm by 102 mm) wood members. The installation of windows and doors and their bucks shall prevent the passage of air and water into or through the wall system. Windowsills shall comply with Section BK105.4.2.
Window and door bucks shall be installed in accordance with Figure BK105.4.5 and one of the following methods:

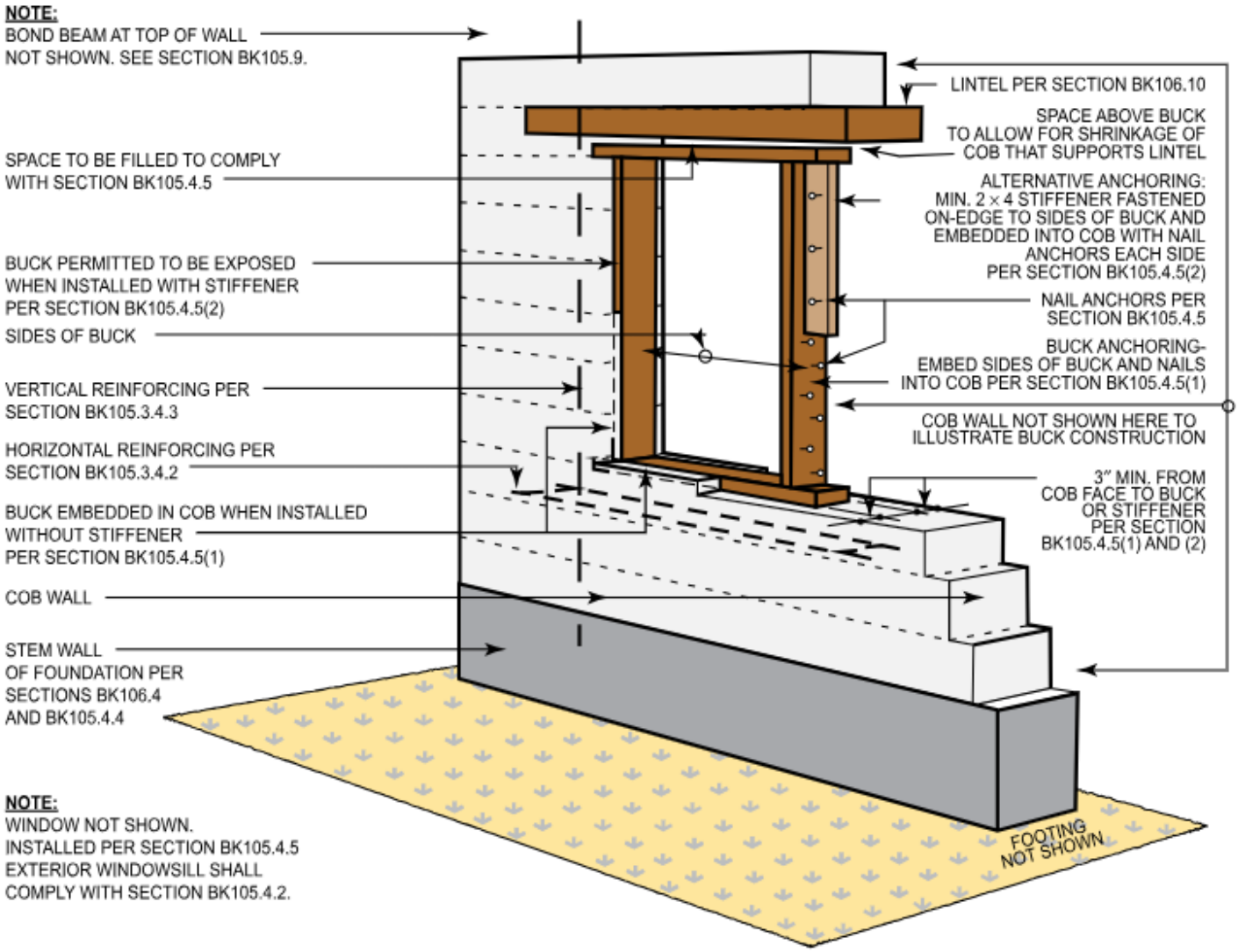
1. Side members of the bucks shall be anchored into the cob wall by embedding the protruding end of half-driven 16d galvanized nails at a maximum 6-inch (152 mm) spacing. The buck shall be embedded into the cob not less than 1 1/2 inches (38 mm) and set in from each face of the wall not less than 3 inches (76 mm).

2. Wood stiffeners not less than nominal 2-inch by 4-inch (51 mm by 102 mm) shall be attached on-edge to the sides of the buck and embedded in the cob wall a minimum of 31/2 inches (89 mm). Stiffeners shall anchor into the cob wall with the protruding end of half-driven 16d galvanized nails at a maximum 6-inch (152 mm) spacing. Stiffeners shall be set back not less than 3 inches (76 mm) from each wall face. Bucks are permitted to be exposed and do not require anchoring nails where stiffeners are used with this method.

3. Other approved methods satisfying the performance requirements of Section BK105.4.5.

Exception: Windows and unframed glass shall be permitted to be embedded directly into a cob wall with an approved design.

FIGURE BK105.4.5
WINDOW INSTALLATION (DOOR INSTALLATION SIMILAR)



BK105.5 Inspections.
In addition to ensuring compliance with Section R109.1, the *building official* shall inspect the following aspects of *cob* construction:

1. Anchors and vertical and horizontal reinforcing in *cob* walls, where required in accordance with Tables BK105.3 and BK106.11(1) and Sections BK105.3.4 through BK105.3.5.
2. Reinforcing in any concrete *bond beams* or lintels, in accordance with Section BK106.9.2 and Table BK106.10.

BK105.5.1 Special inspections. The building official has the authority to require the owner to employ a special inspector during construction of specific types of work described in this appendix.

Section BK106 Cob Walls—Structural

BK106.1 General.

Cob structural walls shall be in accordance with the prescriptive provisions of this section. Designs or portions of designs not complying with this section shall require an *approved* design by a *registered design professional*, except where an engineered design is required.

BK106.2 Requirements for cob structural walls.
In addition to the requirements of Section BK105.2, *cob* structural walls shall be subject to the following:

1. Wall height: shall be in accordance with Table BK105.3 for load-bearing *cob* walls or Table BK106.11(1) for *cob braced wall panels*, as applicable and most restrictive.
2. Wall thickness: shall be in accordance with Sections BK105.2, Item 5 and Section BK106.8.1 for loadbearing *cob* walls or Table BK106.11(1) for *cob braced wall panels*, as applicable and most restrictive.
3. *Braced wall panel* lengths: for *buildings* using *cob braced wall panels*, the greater of the values determined in accordance with Table BK106.11(2) for wind loads and Table BK106.11(3), BK106.11(4) or BK106.11(5) for seismic loads shall be used.

BK106.3 Loads and other limitations.
Live and *dead loads* and other limitations shall be in accordance with Section R301, except that the *dead load* for *cob* walls shall be determined by Equation BK-1.

Equation BK-1 $CW_{DL}=(H\times T_{avg}\times D)$

CW_{DL} = Cob wall dead load (in pounds per lineal foot of wall).
H = Height of cob portion of wall (in feet).
T_{avg} = Average thickness of wall (in feet).
D = Density of *cob* = 110 (in pounds per cubic foot), unless a lesser value at equilibrium moisture content is demonstrated to the *building official*.

BK106.4 Foundations.
Foundations for *cob* walls shall be in accordance with Chapter 4. The width of foundations for *cob* walls shall be not less than the width of the *cob* at its base, excluding *finish*.

BK106.5 Wall taper, straightness and surface voids for cob walls.
Cob walls shall be in accordance with the following:

1. *Cob* structural and *nonstructural walls* shall be vertical or shall taper from bottom to top with the wall thickness in accordance with Section BK105.2, Item 5 and the wall height in accordance with Section BK105.2, Item 4.
2. *Cob* structural and *nonstructural walls* shall be straight or curved. Curved *braced wall panels* shall be in accordance with Sections BK106.11.2 and BK106.11.3.
3. Niches and other surface *voids* in *load-bearing walls* are limited to 12 inches (305 mm) in width and height and 25 percent of the wall thickness, and shall be located in the top two-thirds of the wall. Surface *voids* that exceed these limits shall be considered wall openings, and shall receive a lintel in accordance with Section BKr106.10 and be reinforced in accordance with Section BK105.3.4. Surface voids are prohibited in *braced wall panels*.

BK106.6 Compressive strength of cob structural and *nonstructural walls*.
All *cob* walls shall have a minimum compressive strength of 60 psi (414 kPa), and *cob* in walls used as *braced wall panels* shall have a minimum compressive strength of 85 psi (586 kPa), except with an *approved* engineered design.

BK106.6.1 Demonstration of compressive strength.

The compressive strength of the *cob* mix to be used in structural walls and *nonstructural walls* as required in Section BK106.6 shall be demonstrated to the *building official* before the placement of *cob* onto walls, with compressive strength tests and an associated report by an *approved* laboratory or with an *approved* on-site test as follows:

1. Five samples of the proposed *cob* mix shall be placed moist to completely fill a 4-inch by 4-inch by 8-inch (102 mm by 102 mm by 203 mm) form and dried to ambient moisture conditions.
2. Samples shall not be oven dried.
3. The 4-inch by 4-inch (102 mm by 102 mm) faces shall be capped with *plaster* of paris to achieve smooth, parallel faces, after which the sample shall reach ambient moisture conditions before testing.
4. Samples shall be constructed, dried and tested with the long dimension vertical.
5. The horizontal cross section of the dried sample as tested, and the maximum applied load at failure shall be used to calculate the sample's compressive strength.
6. The fourth-lowest value shall be used to determine the mix's compressive strength.

BK106.7 Modulus of rupture of cob structural walls.
Cob in walls used as *braced wall panels* shall have a minimum modulus of rupture of 50 pounds per square inch (345 kPa).

BK106.7.1 Demonstration of modulus of rupture.
The modulus of rupture of *cob* used in structural walls shall be demonstrated to the *building official* before the placement of *cob* onto walls, with modulus of rupture tests and an associated report by an *approved* laboratory or with an *approved* on-site test as follows:

1. Five samples of the proposed *cob* mix shall be placed moist to completely fill a 6-inch by 6-inch by 12-inch (152 mm by 152 mm by 305 mm) form and dried to indoor ambient moisture conditions.
2. Samples shall not be oven dried.
3. Each sample shall be tested with the 12-inch (305 mm) dimension horizontal.
4. The fourth-lowest value shall be used to determine if the mix meets the minimum required modulus of rupture.

BK106.8 Bearing capacity.
The allowable bearing capacity for *cob load-bearing walls* supporting vertical roof and/or ceiling loads imposed in accordance with Section R301 shall not exceed 2,200 pounds per linear foot (plf) and shall be determined by Equation BK-2. Use of bearing capacities determined with Equation BK-2 exceeding 2,200 plf requires an *approved* design prepared by a *registered design professional* that accounts for buckling.

Equation BK-2 $BC=(C\times T_{min}\times 12)/3-(H\times T_{avg}/12\times D)$

BC = Allowable bearing capacity of wall (in pounds per lineal foot of wall).
C = Compressive strength (in psi) as determined in accordance with Section BK106.6.
T_{min} = Thickness of wall (in inches) at its minimum.
H =Height of *cob* portion of wall (in feet).
T_{avg} = Average thickness of wall (in inches).
D = Density of *cob* = 110 (in pounds per cubic foot), unless a lesser value at equilibrium moisture content is demonstrated.

BK106.8.1 Support of uniform loads.
Uniform roof and/or ceiling loads shall be supported by *cob load-bearing walls* not exceeding their allowable bearing capacity, as demonstrated in accordance with Equation BK-3.

Equation BK-3 $BL\leq BC$

BL = Design load on the wall (in pounds per lineal foot) determined in accordance with Sections R301.4 and R301.6.

BC = Allowable bearing capacity of wall (in pounds per lineal foot of wall) determined in accordance with Section BK106.8.

BK106.8.2 Support of concentrated loads.
Concentrated roof and ceiling loads shall be distributed by structural elements capable of distributing the loads to the *cob load-bearing wall* and within its allowable bearing capacity as determined in accordance with Section BK106.8. Concentrated loads over lintels or over *bond beams* spanning openings shall require an *approved* design by a *registered design professional*.

BK106.9 Bond beams.
Cob structural walls shall require a *bond beam* at the top of the wall in accordance with Section BK106.9.1, BK106.9.2 or BK106.9.3, and shall be anchored to the *cob* below in accordance with Tables BK105.3, BK106.11(1) and BK106.12, as applicable and most restrictive. *Bond beams* spanning openings shall be in accordance with Section BK106.9.4.

BK106.9.1 Wood bond beams.
Wood *bond beams* shall be not less than nominal 4 inches (102 mm) high by 8 inches (203 mm) wide and shall comply with Sections BK106.9.1.1 through BK106.9.1.3.

BK106.9.1.1 Wood species and grade.
Wood *bond beams* shall be of a species with an extreme fiber in bending (F_b) of not less than 850 psi (5.9 MPa), a modulus of elasticity (E) of not less than 1,300,000 psi (8964 MPa), and No. 2 grade or better. Composite lumber *bond beams* shall have an F_b of not less than 850 psi (5.9 MPa), and an E of not less than 1,300,000 psi (8964 MPa).

BK106.9.1.2 Discontinuity.
Discontinuous wood *bond beams* shall be spliced on top with a metal strap with not less than the allowable wind or seismic load tension capacity in accordance with the following, whichever is more restrictive:

1. For *seismic design categories*: A, 2,500 pounds (11 kN); B, 4,500 pounds (20 kN); C, 6,000 pounds (26.7 kN).

2. For *braced wall line* lengths, when wind governs: 10 feet, 2,500 pounds (11 kN); 20 feet, 3,400 pounds (15.1 kN); 30 feet, 5,000 pounds (22.2 kN).

BK106.9.1.3 Corners and curved walls.
Wood *bond beams* at corners and discontinuities atop curved walls shall be connected across their exterior faces with a metal strap with a capacity of not less than that determined in accordance with Section BK106.9.1.2.

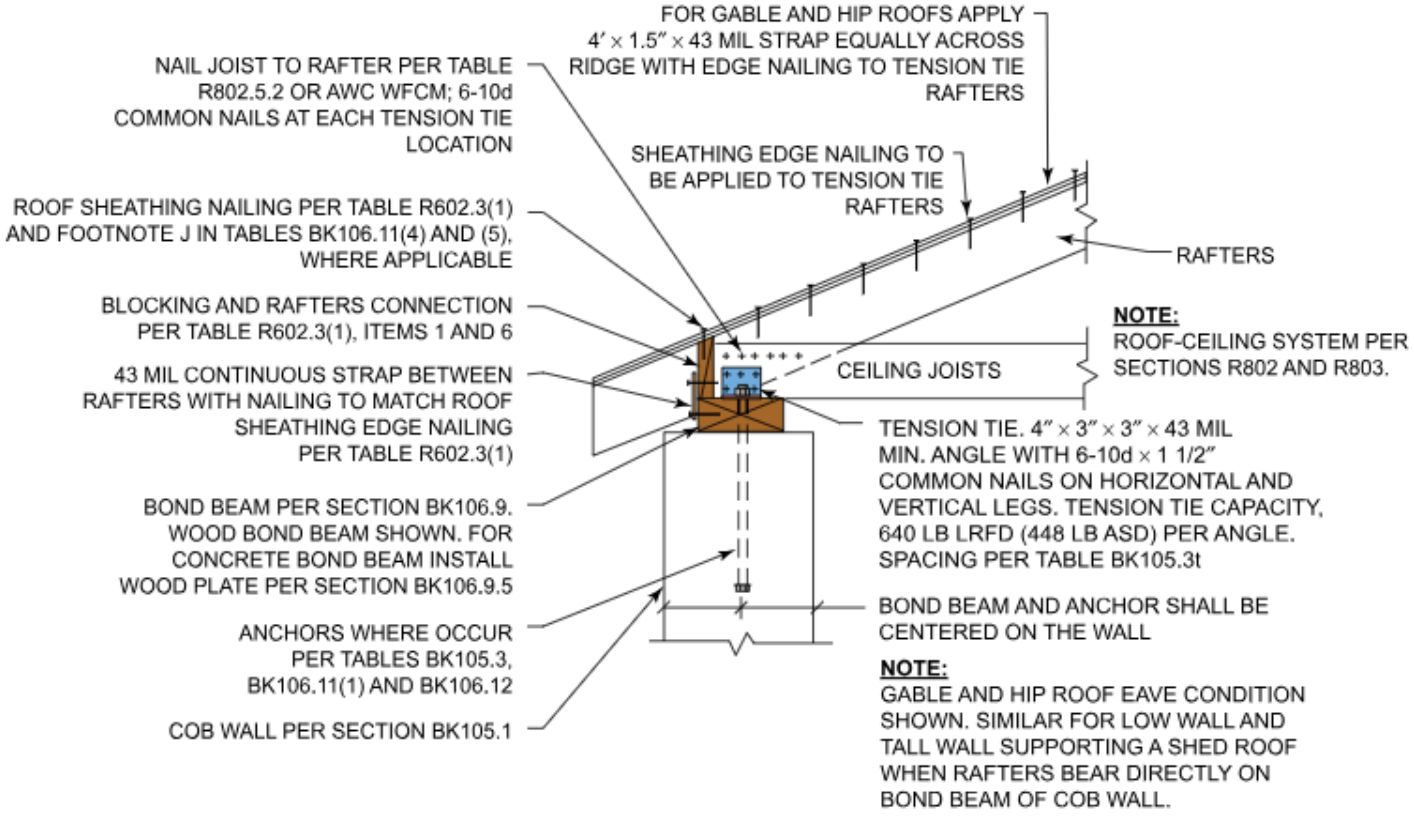
BK106.9.2 Concrete bond beams.
Concrete *bond beams* shall be not less than 6 inches (152 mm) high by 8 inches (203 mm) wide. Concrete *bond beams* shall be reinforced with two No. 4 bars, 2 inches (51 mm) clear from the bottom and 2 inches (51 mm) clear from the sides. Lap splices shall comply with Table R608.5.4(1). Reinforcing at corners shall be in accordance with the horizontal reinforcing requirements in Section R608.6.4. The concrete shall have a compressive strength of not less than 2,500 pounds per square inch (17.2 MPa) at 28 days.

BK106.9.3 Other bond beams.
Bond beams of other materials, including earthen materials, require an *approved* engineered design.

BK106.9.4 Bond beams spanning openings.
Bond beams that support uniform roof and/or ceiling loads and span openings in *cob* walls shall be in accordance with Table BK106.10. Bond beams shall be continuous across the opening and not less than 1 foot (305 mm) beyond each side of the opening.

BK106.9.5 Connection of roof framing to bond beams.
Roof and ceiling framing shall be attached to *bond beams* in accordance with Table R602.3(1), Items 2 and 6, and Figure BK106.9.5. Roof sheathing shall be attached to roof framing in accordance with Figure BK106.9.5. A minimum nominal 2-inch by 6-inch (51 mm by 152 mm) wood plate shall be installed on concrete bond beams with 5/8-inch (16 mm) diameter anchor bolts with 5-inch (127 mm) embedment at 2 feet (610 mm) on center to allow the required fastening of roof and ceiling framing, including tension ties and straps.

FIGURE BK106.9.5
CONNECTION OF ROOF FRAMING TO BOND BEAMS

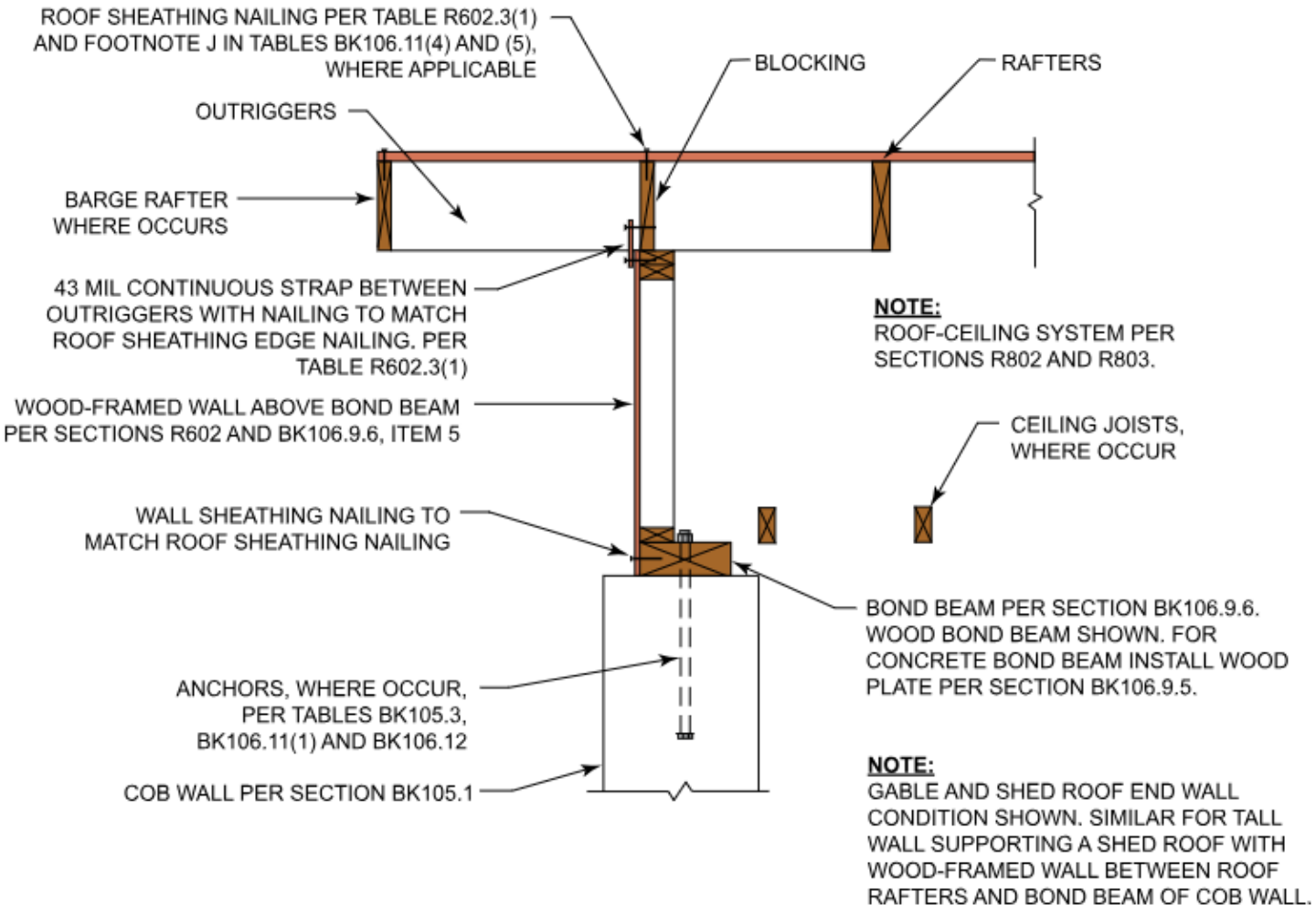


BK106.9.6 Bond beams and connections at gable and shed roof end walls.
Bond beams and connections at end walls of *buildings* with gable or shed roofs shall comply with Figure BK106.9.6 and the following:

1. End walls shall not exceed 20 feet (6096 mm) in length.
2. *Bond beams* shall be continuous and straight for the entire wall line.
3. Wood *bond beams* shall comply with the following:
3.1. Not less than nominal 4 inches by 8 inches (102 mm by 203 mm) where wind design governs in accordance with Table BK106.11(2) and where seismic design governs in accordance with Table BK106.11(3), BK106.11(4) or BK106.11(5) for wall lengths less than or equal to 20 feet (6096 mm) in *Seismic Design Category* A or wall lengths less than or equal to 10 feet (3048 mm) in *Seismic Design Categories* B and C.
3.2. Not less than nominal 4 inches by 10 inches (102 mm by 254 mm) for wall lengths less than or equal to 20 feet (6096 mm) in Seismic Design Category B.
3.3. Not less than nominal 6 inches by 12 inches (152 mm by 305 mm) or 4 inches by 16 inches (102 mm by 406 mm) for wall lengths less than or equal to 20 feet (6096 mm) in Seismic Design Category C.
3.4. Corners shall be connected in accordance with Section BK106.9.3.

4. Concrete *bond beams* when used shall be in accordance with Section BK106.9.2 in *Seismic Design Categories* A, B and C and for ultimate design wind speeds less than or equal to 140 mph (63.6 m/s).
5. Walls between the *bond beam* and roof shall be of wood-framed construction in accordance with Section R602. The ratio of its greatest height to its length shall not exceed 1:2. The wall shall not contain openings.

FIGURE BK106.9.6
CONNECTIONS AT GABLE AND SHED ROOF END WALLS



BK106.10 Lintels.
Door, window and other openings in load-bearing *cob* walls shall be provided with a lintel of wood or concrete in accordance with Table BK106.10.

TABLE **BK106.10 LINTELS AND BOND BEAMS SPANNING OPENINGS**

GROUND SNOW LOAD ≤ 30 PSF	**WOOD:** • $F_b \geq 850$ psi • $E \geq 1{,}300{,}000$ psi • No. 2 Grade or better • Oriented flat • 1 piece or 2 equal-width pieces • Extend 1 foot beyond opening sides	**CONCRETE:** • 2500 psi compressive strength • Height = 6 inches • Extend 1 foot beyond opening sides • Reinforcement two No. 4 bars[a] • 2 inches clear from bottom • 2 inches clear from sides[a]

Building width (feet)	Cob above lintel (feet)	Total cob wall and plaster thickness (inches)	Size of wood lintel or bond beam—*H* × *W* (nominal inches)		Width of concrete lintel or bond beam (inches)	
			For span ≤ 4 ft	For span ≤ 6 ft	For span ≤ 6 ft	For span ≤ 8 ft
10	0	≤ 27	4 × 8	4 × 8	8	8
10	1	15	4 × 12	4 × 12	12	12
10	1	19	4 × 16	4 × 16	16	16
10	1	27	4 × 24	4 × 24	24	24
10	2	15	4 × 12	6 × 12	12	12
10	2	19	4 × 16	6 × 16	16	16
10	2	27	4 × 24	4 × 24	24	24
20	0	≤ 27	4 × 8	6 × 8	8	8
20	1	15	4 × 12	6 × 12	12	12
20	1	19	4 × 16	6 × 16	16	16
20	1	27	4 × 24	4 × 24	24	24
20	2	15	4 × 12	6 × 12	12	NP
20	2	19	4 × 16	6 × 16	16	NP
20	2	27	4 × 24	6 × 24	24	NP
30	0	≤ 27	4 × 8	6 × 8	8	NP
30	1	15	4 × 12	6 × 12	12	NP
30	1	19	4 × 13	6 × 16	16	NP
30	1	27	4 × 24	6 × 24	24	NP
30	2	15	4 × 12	6 × 12	12	NP
30	2	19	4 × 16	6 × 16	16	NP
30	2	27	4 × 24	6 × 24	24	NP

For SI: 1 inch = 25.4 mm, 1 foot = 304.8 mm, 1 pound per square inch = 6.895 kPA.
NP = Not Permitted.

a. Concrete bond beams spanning openings, and lintels greater than 16 inches in width, shall have an additional No. 4 bar in the center of their width.

BK106.11 Cob braced wall panels.

Cob braced wall panels shall be in accordance with Section R602.10 and Tables BK106.11(1), BK106.11(2), BK106.11(3), BK106.11(4) and BK106.11(5). Wind design criteria shall be in accordance with Section R301.2.1. Seismic design criteria shall be in accordance with Section R301.2.2. An *approved* engineered design shall be required in accordance with Section R301.2.1 where the *building* is located in a special wind region or where wind design is required in accordance with Figure R301.2.1.1.

TABLE BK106.11(1) COB BRACED WALL PANEL TYPES

WALL TYPE[a] DESIGNATION	ANCHORS TO FOUNDATION[b]	ANCHORS TO BOND BEAM[c]	VERTICAL STEEL REINFORCING[b, c]	HORIZONTAL STEEL REINFORCING	MAXIMUM HEIGHT *H*[d] (in feet)	MAXIMUM ASPECT RATIO (*H*:*L*)

A	none	5/8″ threaded rod @ 12″; 4″ from wall ends; 12″ embedment in cob	none	none	7[e]	1:1
B	#5 bar @ 12″; 16″ embedment in cob	5/8″ threaded rod @ 12″; 4″ from wall ends; 16″ embedment in cob; 2″ × 2″ × 1/4″ washer and nut at cob end	none	2″ × 2″ × 14 gage welded wire mesh[f] @ 18″; 6″ from foundation and bond beam	7[e]	1:1
C	#5 bar @ 12″; 16″ embedment in cob	5/8″ threaded rod @ 12″; 16″ embedment in cob	5/8″ threaded rod; 4″ from each end of braced wall panel; continuous from foundation to bond beam	2″ × 2″ × 14 gage welded wire mesh[f] @ 18″; 6″ from foundation and bond beam	7[e]	2:1
D	(see vertical steel reinforcing)	(see vertical steel reinforcing)	5/8″ threaded rod; 4″ from each end of braced wall panel and @ 12″; continuous from foundation to bond beam	2″ × 2″ × 14 gage welded wire mesh[f] @ 18″; 6″ from foundation and bond beam	7[e]	2:1
E	6″ × 6″× 6 gage welded wire mesh; 12″ embedment in foundation	5/8″ threaded rod @ 12″; 4″ from wall ends; 12″ embedment in cob	6″ × 6″ × 6 gage welded wire mesh; 2″ from each wall face	none	7.5	1:1

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

a. Braced wall panel *T*ypes A, B, C and D shall be not less than 16 inches thick. Braced wall panel Type E shall be not less than 12 inches thick. All braced wall panels shall be not greater than 24 inches thick.

b. Not less than 8-inch embedment into foundation, unless otherwise stated.

c. Not less than 4-inch embedment into concrete bond beams. Full penetration through wood bond beam, secured with nut and washer.

d. *H* = height of the cob portion of the wall only. See Figure BK101.4.

e. Maximum height shall be 8 feet when wall thickness is increased to 18 inches.

f. Galvanized mesh.

TABLE BK106.11(2)
BRACING REQUIREMENTS FOR COB 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 COB BRACED WALL PANELS REQUIRED ALONG EACH BRACED WALL LINE[a, b, c, d]**			
Ultimate design wind speed (mph)	**Story location**	**Braced wall line spacing (feet)**	**Cob braced wall panel[e] A; (aspect ratio *H*:*L* ≤ 1:1)**	**Cob braced wall panel[e] B; (aspect ratio *H*:*L* ≤ 1:1)**	**Cob braced wall panel[e] C, D; (aspect ratio *H*:*L* ≤ 2:1)**	**Cob braced wall panel[e] E; (aspect ratio *H*:*L* ≤ 1:1)**
≤ 110	One-story building	10	6.0	6.0	3.7	6.0
≤ 110	One-story building	20	7.9	7.4	7.4	6.0
≤ 110	One-story building	30	11.8	11.0	11.0	6.9
≤ 115	One-story building	10	6.0	6.0	4.1	6.0
≤ 115	One-story building	20	8.7	8.1	8.1	6.0
≤ 115	One-story building	30	13.0	12.1	12.1	7.6

≤ 120	One-story building	10	6.0	6.0	4.4	6.0
≤ 120	One-story building	20	9.4	8.8	8.8	6.0
≤ 120	One-story building	30	14.1	13.1	13.1	8.3
≤ 130	One-story building	10	6.0	6.0	5.1	6.0
≤ 130	One-story building	20	11.0	10.3	10.3	6.5
≤ 130	One-story building	30	16.5	15.4	15.4	9.7
≤ 140	One-story building	10	6.0	6.0	5.9	6.0
≤ 140	One-story building	20	12.7	11.9	11.9	7.5
≤ 140	One-story building	30	19.1	17.8	17.8	11.2

For SI: 1 foot = 304.8 mm, 1 mile per hour = 0.447 m/s.

a. Linear interpolation shall be permitted.

b. Braced wall panels shall be without openings.

c. Braced wall panel Types A, B and E shall have an aspect ratio (*H*:*L*) ≤ 1:1. Braced wall panel Types C and D shall have an aspect ratio (*H*:*L*) ≤ 2:1.

d. Subject to applicable wind adjustment factors associated with Items 1 and 2 of Table R602.10.3(2).

e. Cob braced wall panel types indicated shall comply with Section BK106.11 and Table BK106.11(1).

TABLE BK106.11(3)
BRACING REQUIREMENTS FOR COB BRACED WALL PANELS BASED ON SEISMIC DESIGN CATEGORY A

• SOIL CLASS D[f] • TOTAL WALL HEIGHT = 10 FEET (INCLUDING STEM WALL AND BOND BEAM) • COB WALL HEIGHT PER TABLE BK106.11(1) • 15 PSF ROOF-CEILING DEAD LOAD[d] • STORY LOCATION: ONE-STORY BUILDING • SEISMIC DESIGN CATEGORY A • 1.5″ PLASTER THICKNESS EACH SIDE[g]			MINIMUM TOTAL LENGTH (feet) OF COB BRACED WALL PANELS REQUIRED ALONG EACH BRACED WALL LINE[a, b, c, d, e]			
Braced wall line spacing (feet)	**Braced wall line length (feet)**	**Min. braced wall line % openings**	**Min. perpendicular braced wall line % openings**	**Cob braced wall panel[e] A, B**	**Cob braced wall panel[e] C, D**	**Cob braced wall panel[e] E**
10	30	0	0	—	3.4	6.0
20	20	0	0	—	3.5	6.0
20	30	0	0	—	4.5	6.0
30	30	0	0	—	5.6	6.0

For SI: 1 inch = 25.4 mm, 1 foot = 304.8 mm, 1 pound per square foot = 0.0479 kPa.

a. Interpolation is not permitted.

b. Braced wall panels shall be without openings.

c. Braced wall panel Types A, B and E shall have an aspect ratio (*H*:*L*) ≤ 1:1. Braced wall panel Types C and D shall have an aspect ratio (*H*:*L*) ≤ 2:1.

d. Subject to applicable seismic adjustment factors associated with Item 5 in Table R602.10.3(4).

e. Cob braced wall panel types indicated shall comply with Section BK106.11 and Table BK106.11(1).

f. Wall bracing lengths are based on a soil site class D. Interpolation of bracing lengths between S_{DS} values associated with the seismic design categories is allowable where a site-specific S_{DS} value is determined in accordance with Section 1613 of the ~~*International*~~ *Washington State Building Code*.

g. For total plaster thickness between 3 inches and 6 inches, the minimum total length of braced wall panels shall be multiplied by 1.2.

TABLE BK106.11(4)
BRACING REQUIREMENTS FOR COB BRACED WALL PANELS BASED ON SEISMIC DESIGN CATEGORY B

• SOIL CLASS D[f] • TOTAL WALL HEIGHT = 10 FEET (INCLUDING STEM WALL AND BOND BEAM) • COB WALL HEIGHT PER TABLE BK106.11(1) • 15 PSF ROOF-CEILING DEAD LOAD[d] • STORY LOCATION: ONE-STORY BUILDING • SEISMIC DESIGN CATEGORY B • 1.5″ PLASTER THICKNESS EACH SIDE[g]				MINIMUM TOTAL LENGTH (feet) OF COB BRACED WALL PANELS REQUIRED ALONG EACH BRACED WALL LINE[a, b, c, d, e]		
Braced wall line spacing (feet)	**Braced wall line length (feet)**	**Min. braced wall lines % openings**	**Min. perpendicular braced wall line % openings**	**Cob braced wall panel[c] A, B**	**Cob braced wall panel[c] C, D**	**Cob braced wall panel[c] E**
10	10	0	0	6.0	3.2	6.0
10	20	0	0	6.0	4.9	6.0
10	20	50	0	6.0	3.5	6.0
10	30	0	0	7.1	6.6	6.0
10	30	50	0	6.0	4.5	6.0
20	10	0	0	6.0 h	4.9 h	6.0
20	10	0	50	6.0	3.5	6.0
20	10	50	0	NP	4.2	NP
20	10	50	50	NP	3.0	NP
20	20	0	0	7.4	6.9	6.0
20	20	0	50	6.0	5.5	6.0
20	20	50	0	6.0	5.5	6.0
20	20	50	50	6.0	4.1	6.0
20	30	0	0	9.4	8.8	6.0
20	30	0	50	7.9	7.4	6.0
20	30	50	0	7.2	6.7	6.0
20	30	50	50	6.0	5.3	6.0
30	10	0	0	7.1	6.6	6.0
30	20	0	0	9.4	8.8	6.0
30	20	0	50	7.2	6.7	6.0
30	20	50	0	7.9	7.4	6.0
30	30	0	0	11.8	11.0	6.0
30	30	0	50	9.5	8.9	6.0
30	30	50	0	9.5	8.9	6.0
30	30	50	50	7.3	6.8	6.0

For SI: 1 inch = 25.4 mm, 1 foot = 304.8 mm, 1 pound per square foot = 0.0479 kPa.
NP = Not Permitted.

a. Interpolation is not permitted.

b. Braced wall panels shall be without openings.

c. Braced wall panel Types A, B and E shall have an aspect ratio (H:L) ≤ 1:1. Braced wall panel Types C and D shall have an aspect ratio (H:L) ≤ 2:1.

d. Subject to applicable seismic adjustment factors associated with Item 5 in Table R602.10.3(4).
e. Cob braced panel types indicated shall comply with Section BK106.11 and Table BK106.11(1).
f. Wall bracing lengths are based on a soil site class D. Interpolation of bracing lengths between S_{DS} values associated with the seismic design categories is allowable where a site-specific S_{DS} value is determined in accordance with Section 1613 of the ~~*International*~~ *Washington State Building Code*.
g. For total plaster thicknesses 3 inches to 6 inches, the minimum total length of braced wall panels shall be multiplied by 1.2.
h. Total plaster thicknesses shall be not greater than 3 inches. Substitute 15/32″ roof sheathing and 10d at 6″ edge nailing for requirements in Table R602.3(1).

TABLE BK106.11(5)
BRACING REQUIREMENTS FOR COB BRACED WALL PANELS BASED ON SEISMIC DESIGN CATEGORY C

• SOIL CLASS D[f] • TOTAL WALL HEIGHT = 10 FEET (INCLUDING STEM WALL AND BOND BEAM) • COB WALL HEIGHT PER TABLE BK106.11(1) • 15 PSF ROOF-CEILING DEAD LOAD[d] • STORY LOCATION: ONE-STORY BUILDING • SEISMIC DESIGN CATEGORY C • 1.5″ PLASTER THICKNESS EACH SIDE[g]				MINIMUM TOTAL LENGTH (feet) OF COB BRACED WALL PANELS REQUIRED ALONG EACH BRACED WALL LINE[a, b, c, d, e]		
Braced wall line spacing (feet)	**Braced wall line length (feet)**	**Min. braced wall line % openings**	**Min. perpendicular braced wall lines % openings**	**Cob braced wall panel[e] A, B**	**Cob braced wall panel[e] C, D**	**Cob braced wall panel[e] E**
10	10	0	0	8.3[h]	7.8[h]	6.0
10	10	0	50	6.5	6.1	6.0
10	10	25	0	7.4[h]	6.9[h]	6.0
10	10	50	50	NP	4.4	6.0
10	15	0	0	10.6	9.9	6.0
10	15	0	50	8.7	8.2	6.0
10	15	50	0	NP	7.3	6.0
10	15	50	50	6.0	5.6	6.0
10	20	0	0	12.8	11.9	6.0
10	20	0	50	11.0	10.2	6.0
10	20	50	0	9.1	8.5	6.0
10	20	50	50	7.3	6.8	6.0
15	10	25	0	NP	NP	6.0[h]
15	10	0	50	7.8	7.3	6.0
15	10	50	0	NP	NP	NP
15	10	50	50	NP	NP	NP
15	15	0	0	12.9	12.1	6.0
15	15	0	50	10.2	9.5	6.0
15	15	50	0	NP	NP	6.0
15	15	50	50	7.5	7.0	6.0
15	20	0	0	15.3	14.3	6.0
15	20	0	50	12.6	11.7	6.0
15	20	50	0	NP	NP	6.0
15	20	50	50	8.9	8.3	6.0
20	10	25	0	NP	NP	NP
20	10	0	50	9.1	8.5	6.0
20	10	50	0	NP	NP	NP

20	10	50	50	NP	NP	NP
20	15	0	0	NP	14.3[h]	6.0[h]
20	15	0	50	11.7[h]	10.9[h]	6.0
20	15	50	0	NP	NP	6.0[h]
20	15	50	50	NP	NP	6.0
20	20	0	0	17.8	16.7	6.9
20	20	0	50	14.2	13.3	6.0
20	20	50	0	NP	NP	6.0
20	20	50	50	NP	9.9	6.0

For SI: 1 inch = 25.4 mm, 1 foot = 304.8 mm, 1 pound per square foot = 0.0479 kPa.
NP = Not Permitted.

a. Interpolation is not permitted.
b. Braced wall panels shall be without openings.
c. Braced wall panel Types A, B and E shall have an aspect ratio (H:L) ≤ 1:1. Braced wall panel Types C and D shall have an aspect ratio (H:L) ≤ 2:1.
d. Subject to applicable seismic adjustment factors associated with Item 5 in Table R602.10.3(4).
e. Cob braced panel types indicated shall comply with Section BK106.11 and Table BK106.11(1).
f. Wall bracing lengths are based on a soil site class D. Interpolation of bracing lengths between S_{DS} values associated with the seismic design categories is allowable where a site-specific S_{DS} value is determined in accordance with Section 1613 of the ~~*International*~~ *Washington State Building Code*.
g. For total plaster thicknesses 3″ to 6″, multiply the minimum total length of braced wall panels by 1.2.
h. Total plaster thickness shall not be greater than 3 inches. Substitute 15/32″ roof sheathing and 10d at 6″ edge nailing for requirements in Table R602.3(1).

BK106.11.1 Nonorthogonal braced wall panels.
Braced wall panels at an angle to the orthogonal *braced wall lines* shall be considered to contribute to the minimum total braced wall lengths in Tables BK106.11(2), BK106.11(3), BK106.11(4) and BK106.11(5), as follows:

1. A *braced wall panel* not more than 45 degrees and greater than 30 degrees to an adjacent orthogonal *braced wall line* shall contribute 50 percent of its length to that line.
2. A *braced wall panel* not more than 30 degrees to an orthogonal *braced wall line* shall contribute 65 percent of its length to that line.
3. A *braced wall panel* greater than 45 degrees and not more than 60 degrees to an orthogonal *braced wall line* shall contribute 35 percent of its length to that line.
4. The angle of a curved *braced wall panel* to a *braced wall line* shall be determined with the chord of that section of wall, connecting the end points of the arc at the center of the wall.

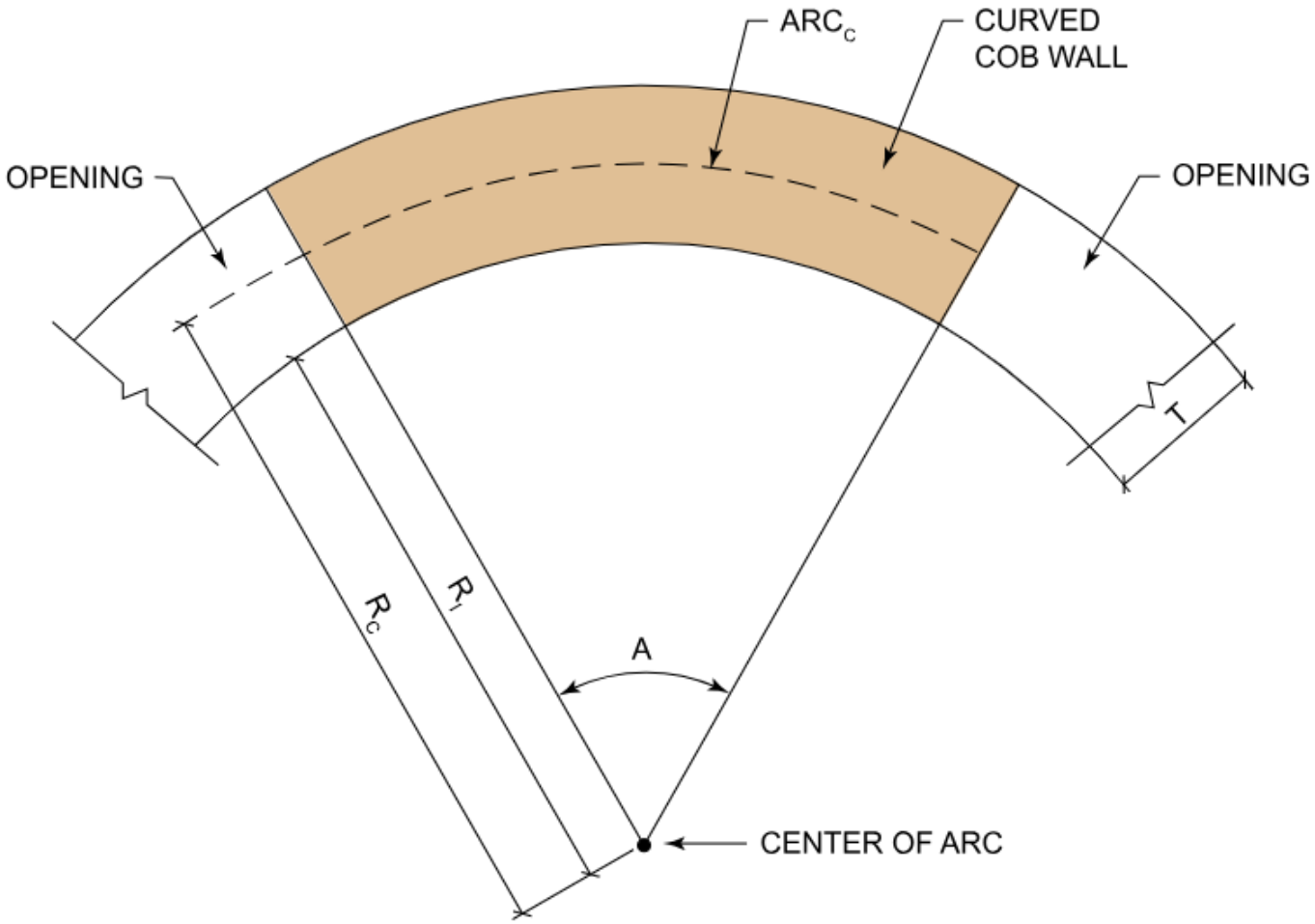
BK106.11.2 Braced wall lines for buildings with curved walls.
Buildings with curved *cob* walls shall contain two *braced wall lines* in two orthogonal directions. The spacing of the *braced wall lines* for wind design in Table BK106.11(2) and the spacing and length of the *braced wall lines* for seismic design in Tables BK106.11(3), BK106.11(4) and .11(5) shall be the maximum widths of the *building* in the two orthogonal directions.

BK106.11.3 Radius, thickness and length of curved braced wall panels.
Cob curved *braced wall panels* shall have an inside radius of not less than 5 feet (1524 mm), shall be of the thickness required in Table BK106.11(1) and of the length determined in accordance with Section BK106.11. The length of the curved wall shall be considered to be the length of the arc at the center of the wall, in accordance with Figure BK106.11.3 and determined by Equation BK-4.

Equation BK-4 $ARC_c = 0.0175R_c \times A$

ARC_c = Length of arc at center of wall (in feet).
R_c = Radius at center of wall = $R_i + 0.5T$ (in feet).
R_i = Inside radius of wall (in feet).
T = Thickness of wall without *finish* (in feet).
A = Angle of extent of *braced wall panel* from the center of the arc (in degrees).

FIGURE BK106.11.3
CURVED BRACED WALL PANEL



BK106.12 Resistance to wind uplift forces.
Cob walls that resist uplift forces from the *roof assembly*, as determined in accordance with Section R802.11, shall be in accordance with Table BK106.12.

TABLE BK106.12
ANCHORAGE OF BOND BEAMS FOR WIND UPLIFT

ANCHORS: **• 5/8″ ALL THREAD AT 12″ O.C.[a, b]** **• 2″ × 2″ × 1/4″ WASHERS AND NUT AT END IN COB** **• 4″ EMBEDMENT IN CONCRETE BOND BEAMS** **• FULL PENETRATION THROUGH WOOD BOND BEAMS WITH 2″ × 2″ × 1/4″ WASHER AND NUT**			
WIND UPLIFT FORCE FROM TABLE R802.11 **(plf)**	**ANCHORAGE DEPTH IN INCHES, PER WALL WIDTH AND WIND UPLIFT FORCE**		
	≤ 12″ wall width[c]	**≤ 16″ wall width[c]**	**≤ 24″ wall width[c]**

< 75	16	12	12
< 100	24	16	12
< 150	48 o.c. continuous from foundation to bond beamd	24	16
< 200	48 o.c. continuous from foundation to bond beamd	48 o.c. continuous from foundation to bond beamd	24

For SI: 1 inch = 25.4 mm.

a. For wood bond beams a maximum of 6 inches from bond beam ends.

b. For minimum 6-inch by 8-inch concrete bond beams, at 18″ o.c. for wind uplift forces less than 75 pounds per linear foot, and at 16″ o.c. for wind uplift forces less than 100 pounds per linear foot.

c. Excluding finishes.

d. With 7-inch embedment in foundation, 4-inch embedment in concrete bond beam or full penetration through wood bond beam with 2-inch by 2-inch by 1/4-inch washer and nut.

BK106.13 Post-and-beam with cob infill.

Post-and-beam with *cob infill* wall systems shall be in accordance with an *approved* engineered design.

BK106.14 Buttresses.

Cob buttresses that are intended to provide out-of-plane wall bracing or additional capacity for *braced wall panels* shall be in accordance with an *approved* engineered design.

Section BK107 Cob Floors

BK107.1 Cob floors.

Cob floors supported by grade shall be in accordance with an *approved* specification. Straw shall not be required in the material mix.

Section BK108 Fire Resistance

BK108.1 Fire-resistance rating.

Cob walls that comply with Table BK108.1 have a 2-hour fire-resistance rating.

TABLE BK108.1
TWO-HOUR FIRE-RESISTANCE-RATED COB WALLS

ALLOWABLE SUPERIMPOSED LOAD (plf)	DENSITY[a, d] (pcf)	MINIMUM COMPRESSIVE STRENGTH PER SECTION BK106.6.1 (psi)	WALL-TYPE REINFORCEMENT PER TABLE BK105.3	MINIMUM THICKNESS[c, e, f] AT TOP OF WALL (inches)	MINIMUM THICKNESS[c, e, f] AT BOTTOM OF WALL (inches)
1,200	100	85	E	9	12
475	≥ 50 pcf: less than 40 inches from top of wall	40[b]	E or F	8	12
	≥ 70 pcf: from 40 inches to 80 inches from top of wall	55[b]			
	≥ 90 pcf: more than 80 inches from top of wall	85			
Nonload bearing	50 to 100	≥ 60 psi < 60 psi[b]	E or F	9	9

For SI: 1 inch = 25.4 mm, 1 foot = 304.8 mm, 1 pound = 0.45 kg, 1 pound per cubic foot = 16.02 kg/m^3.

a. Density is to be measured at equilibrium moisture content. Average wall density shall be within ±5 pcf of the tabulated value.

b. Requires an approved engineered design per Section BK106.6.

c. Cob thickness only. The interior and exterior cob faces shall be permitted to be unfinished or receive any plaster finish allowed by this appendix.

d. Cob walls with more than one density shall be built with heavier densities below lighter densities.

e. Minimum cob wall thickness shall be whichever is greater in Tables BK105.3, BK106.11(1) and BK108.1.
f. Wall thicknesses less than 10 inches require an engineered design.

BK108.2 Clearance to fireplaces and chimneys.
Cob walls or other *cob* surfaces shall not require clearance to fireplaces and chimneys, except where clearance to noncombustibles is required by the manufacturer's instructions.

Section BK109 Thermal Performance

BK109.1 Thermal characteristics.
Cob walls shall be classified as mass walls in accordance with WSEC Section R402.2.5 ~~Section N1102.2.6~~ and shall meet the U-factor requirements for above-grade walls in WSEC Table R402.1.2 ~~*R*-value requirements for mass walls in Table N1102.1.3~~.

BK109.2 Thermal resistance.
The unit *R*-value for *cob* walls with a density of 110 pounds per cubic foot (1762 kg/m^3) shall be *R*-0.22 (RSI 0.0387) per inch of *cob* thickness. The unit *R*-value for *cob* walls with a density of 75 pounds per cubic foot (1201 kg/m3) shall be *R*-0.54 (RSI 0.095) per inch of *cob* thickness. Linear interpolation is permitted. Extrapolation is not permitted. Walls that vary in thickness along their height or length shall use the average thickness of the wall to determine its *R*-value. The thermal resistance values of air films and *finish* materials or additional insulation shall be added to the *cob* wall's thermal resistance value to determine the *R*-value of the wall assembly. *Cob* density shall be measured at equilibrium moisture content.

BK109.3 Additional insulation.
Where insulating materials are added to the face of a *cob* wall, the combination of additional insulation and any associated connecting, weather-resisting or protective materials shall comply with Section BK104.1.2, Items 1 through 4.

Section BK110 Referenced Standards

BK110.1 General.
See Table BK110.1 for standards that are referenced in various sections of this appendix. Standards are listed by the standard identification with the effective date, the standard title and the section or sections of this appendix that reference the standard.

TABLE BK110.1
REFERENCED STANDARDS

STANDARD ACRONYM	STANDARD NAME	SECTIONS HEREIN REFERENCED
ASTM C5—10	*Standard Specification for Quicklime for Structural Purposes*	BK104.4.6
ASTM C141/C141M—14	*Standard Specification for Hydrated Hydraulic Lime for Structural Purposes*	BK104.4.6
ASTM C206—14	*Standard Specification for Finishing Hydrated Lime*	BK104.4.6
ASTM C926—21	*Specification for Appliance of Portland Cement-Based Plaster*	BK104.4.8
ASTM C1707—11	*Standard Specification for Pozzolanic Hydraulic Lime for Structural Purposes*	BK104.4.6
ASTM E2392/E2392M—10(2016)	*Standard Guide for Design of Earthen Wall Building Systems*	BK104.4.3.2
ASTM BS1, ASTM BS EN 459—15	*Building Lime—Part 1: Definitions, Specifications and Conformity Criteria; Part 2: Test Methods*	BK104.4.6

Appendix BL Hemp-Lime (Hempcrete) Construction

The provisions contained in this appendix are adopted for use in the State of Washington ~~not mandatory unless specifically referenced in the adopting ordinance~~.

User notes:

About this appendix:
Hemp-lime, commonly referred to as hempcrete, is a nonstructural, bio-composite insulation infill material composed of hemp hurd and a lime-based binder. The benefits of hemp-lime include high thermal performance, low embodied carbon emissions in production, high carbon sequestration in service, healthy living environments and high fire-resistance. These benefits, along with the 2018 United States legalization of hemp as a commercial crop, are driving rapid growth in interest and projects across the US.

Section BL101 General

BL101.1 Scope.
This appendix shall govern the use of *hemp-lime* as a nonstructural building material and wall infill system. *Townhouses* in *Seismic Design Categories* C, D0, D1 and D2 and one- and two-family dwellings in *Seismic Design Categories* D0, D1 and D2 shall require an *approved* engineered design by a *registered design professional* in accordance with Section R301.1.3.

Section BL102 Definitions

BL102.1 General.
The following words and terms shall, for the purposes of this appendix, have the meanings shown herein. Refer to Chapter 2 for general definitions.

BINDER.
The material that binds the *hemp hurd* in a *hemp-lime* mix.

BONDING COAT.
The initial thin layer of binder-rich granulated *plaster* used in *lined applications* of *hemp-lime* construction to ensure adhesive and/or mechanical bonding. Also known as “gobetis.”

CASTING.
Placing wet *hemp-lime* into forms.

CAST-IN-PLACE.
Installation of *hemp-lime* mix by hand or by spraying into forms in its permanent location.

CLAY.
Inorganic soil with particle sizes less than 0.00008 inch (0.002 mm) and having the characteristics of high dry strength and medium to high plasticity, used as a *binder* of other component materials in clay *plaster*.

CLAY SUBSOIL.
Subsoil sourced directly from the earth, containing *clay*, sand and silt, and containing not more than trace amounts of organic matter.

FIBER CLUMPS.
Long fibers that are attached to hemp hurd, or for other reasons, cause clumping of fibrous balls when agitated.

FINISH.
Exposed surface material on the interior or exterior face of a *hemp-lime* infill wall.

FORM.
The material into which *hemp-lime* infill, panels or blocks are cast.

FORMWORK.
The system of forms, their bracing and fasteners assembled for casting of *hemp-lime* infill.

HAND-CAST.
Hemp-lime infill cast by placing *hemp-lime* mix into formwork and evenly tamping by hand or with a tool.

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.

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."

HEMPCRETE.
Common usage term for *hemp-lime* .

HEMP-LIME.
A bio-aggregate composite consisting of *hemp* hurd and a lime-based *binder*. Also known as "*hempcrete*."

INFILL.
Hemp-lime placed between or around the structural or nonstructural framing of a building as insulation, thermal mass and a substrate for finish.

LIFT.
A horizontal layer of *hemp-lime* infill.

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.

LINED APPLICATION.
Installation of a vertical hemp-lime layer, lining a masonry or concrete wall.

NATURAL CEMENT.
Hydraulic cement made from naturally occurring limestone.

NONBEARING.
Not bearing the weight of the building other than the weight of the *hemp-lime* infill and its finish.

PLASTER.
Lime, clay, clay-lime or *hemp-lime plaster* as described in Section BL104.3, applied to the interior or exterior face of *hemp-lime* walls.

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.

PRECAST.
Blocks or panels of *hemp-lime* formed and cured before installation.

REED MAT.
A mat consisting of reed, cane, bamboo or other similar plant material.

SCREEDING.
Removal of excess material to form a planar surface.

SPRAY-APPLIED.
A method of mechanical projection of *hemp-lime* applied onto or into a form using compressed air.

TADELAKT.
A lime-plaster which is compressed, polished and treated with oil-based soap to make it water-repellent.

UNIT WALL WEIGHT.
The *unit wall weight* is the calculated weight of a 1-foot by 1-foot (305 mm × 305 mm) section of wall surface area times the full wall thickness, including finishes. The *unit wall weight* is the sum of the weight of each constituent material times its volume, expressed as pounds per square foot (psf).

VOID.
Any space in a *hemp-lime* wall greater than 1/4 inch (6 mm) wide, 2 inches (51 mm) long and 2 inches (51 mm) deep.

Section BL103 Hemp-Lime Construction

BL103.1 General.
Hemp-lime construction shall be limited to the nonstructural, solid infill mix of *hemp hurd* and its *binder* between or around structural and nonstructural wall framing. *Hemp-lime* infill shall have a density ranging from 12.5 lb/ft^{3}to 25 lb/ft^3(200 kg/m^{3}to 400 kg/m^3). *Hemp-lime* walls shall be designed and constructed in accordance with Section BL103 and with Figures BL103.1(1) through BL103.1(4) or an *approved* alternative design.

FIGURE BL103.1(1)
TYPICAL HEMP-LIME WITH INTERIOR STUD FRAMING

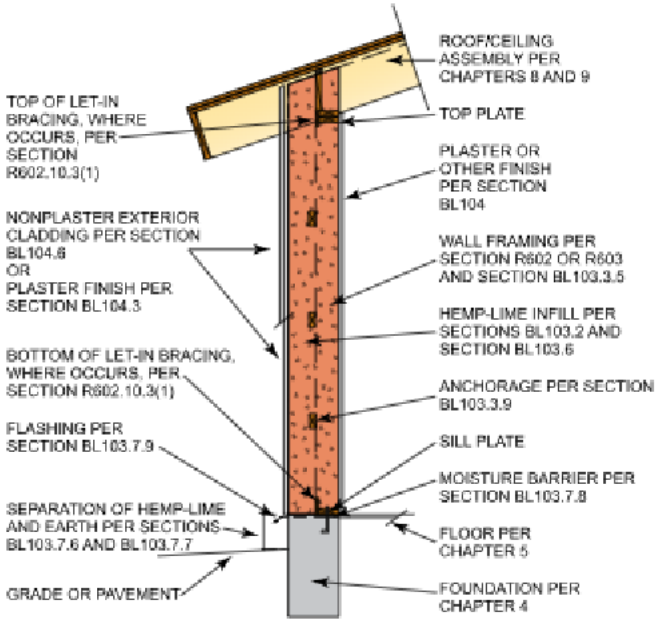


FIGURE BL103.1(2)
TYPICAL HEMP-LIME WITH CENTER STUD FRAMING

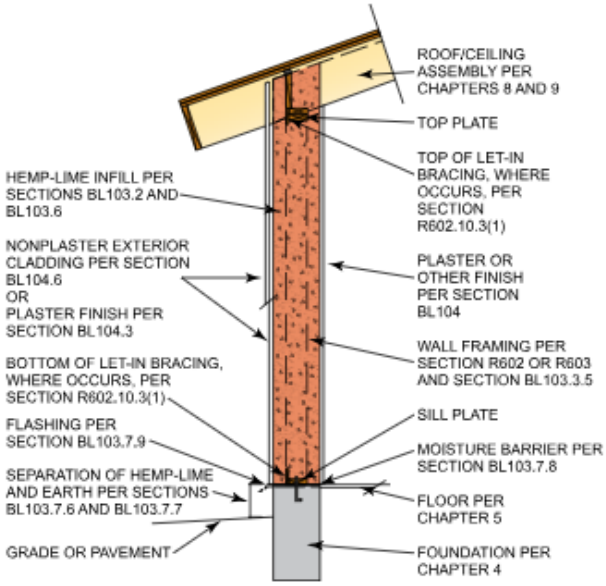


FIGURE BL103.1(3)
TYPICAL HEMP-LIME WITH EXTERIOR STUD FRAMING

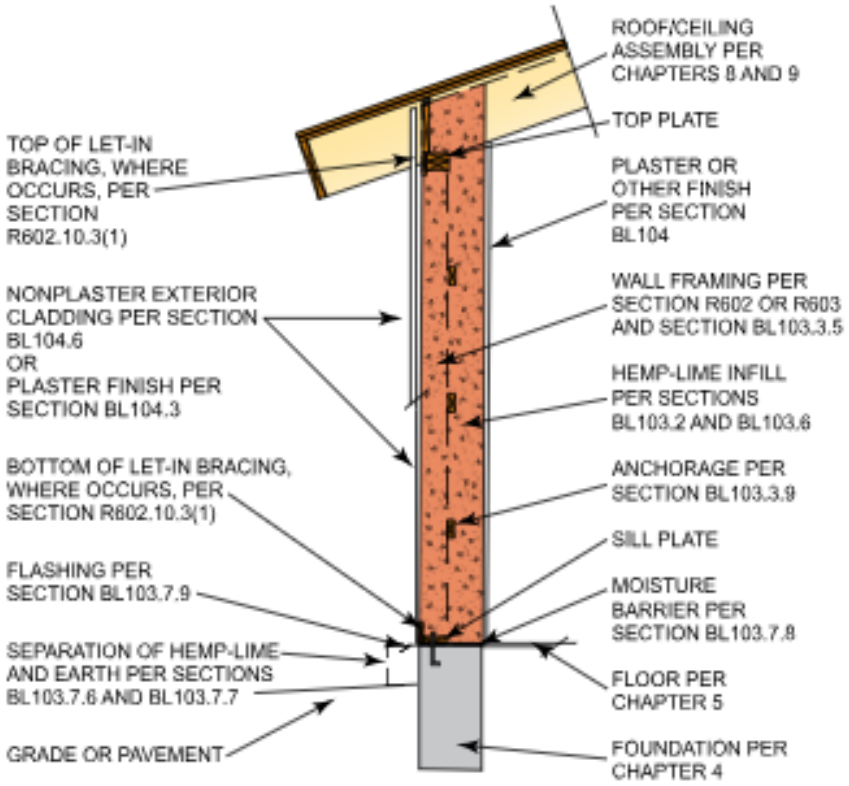
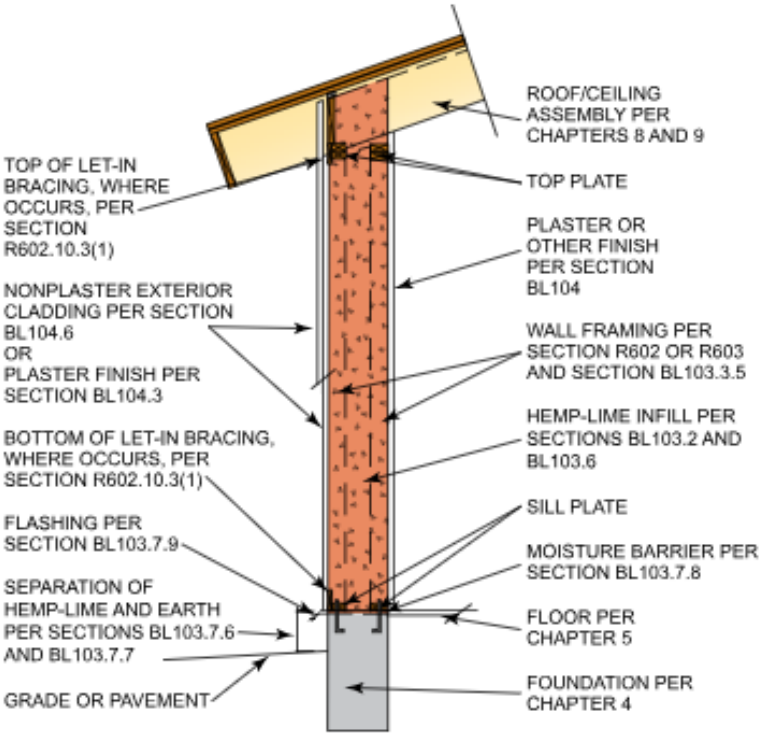


FIGURE BL103.1(4)
TYPICAL HEMP-LIME WITH DOUBLE STUD WALL FRAMING



BL103.2 Materials.
Materials to be used in *hemp-lime* construction shall be in accordance with Sections BL103.2 through BL103.2.3.

BL103.2.1 Hemp hurd.
Hemp hurd shall match the specifications of the *approved* test samples in Sections BL106.3 and BL107.1. *Hemp hurd* shall be substantially free from dust and *fiber clumps* such that the installed *hemp-lime* maintains its integrity.

BL103.2.2 Binders.
Acceptable binders, singular or in combination, include hydraulic lime, hydrated lime, *pozzolans*, *natural cements* or other binders that match the specification of the *approved* test samples in Sections BL106.3 and BL107.1.

BL103.2.3 Water and water additives.
Water and any water additives shall match the specifications of the *approved* test samples in S ections BL106.3 and BL107.1.

BL103.3 Structure.
The structure of buildings using *hemp-lime* infill shall be in accordance with this code and Sections BL103.3.1 through BL103.3.9 or with an *approved* engineered design by a *registered design professional*.

BL103.3.1 Limitations and requirements for buildings using *hemp-lime* infill.
Buildings using *hemp-lime* infill shall be subject to the following limitations and requirements:

1. Number of *stories*: not more than one *story above grade plane*.
2. The *building height* shall not be more than 25 feet (7620 mm).
3. Braced wall panel lengths: in accordance with Sections R602.10.3 and BL103.3.2.
4. *Unit wall weight*: *Hemp-lime* walls shall not exceed an average *unit wall weight* of 65 psf (317 kg/m^2).

BL103.3.2 Bracing.
Bracing for buildings with *hemp-lime* infill in *Seismic Design Categories* A, B and C shall be in accordance with Section R602.10 and in accordance with the following. Walls with *hemp-lime* infill shall use Method LIB and shall not be braced with solid sheathing. *Hemp-lime* infill walls utilizing Method LIB shall not require *gypsum board* to be installed and shall use the minimum braced wall lengths listed in Section R602.10. Adjustment factors in Table R602.10.3(4) shall be used as applicable. Alternatively, *hemp-lime* infill walls shall comply with Section R301.1. Walls or wall sections without *hemp-lime* infill shall be permitted to use any bracing method allowed in Section R602.10.

BL103.3.3 Connection of light-frame walls to hemp-lime walls.
Light-frame walls perpendicular to, or at an angle to, a *hemp-lime* wall assembly shall be fastened to the *hemp-lime* wall in accordance with Section R602 or R603.

BL103.3.4 Hemp-lime thickness.
Hemp-lime infill shall be not less than 3 inches (76 mm) thick between face of framing and *finish*. Maximum *hemp-lime* wall thickness is limited by the average *unit wall weight* limit of 65 psf (317 kg/m^2) in Section BL103.3.1, Item 4.

BL103.3.5 Contact with structural metal.
Structural metal members and components in contact with *hemp-lime* shall be protected in accordance with Section BL103.4.

BL103.3.6 Contact with wood members.
Hemp-lime shall be permitted to be in contact with untreated wood members.

BL103.3.7 Openings in walls.
Doors, windows and similar openings in *hemp-lime* walls shall be in accordance with the following:

1. Rough framing for doors and windows shall be part of, or be fastened to, the wall framing in accordance with this code.

2. An *approved water-resistive barrier* shall be installed at openings in *hemp-lime* walls in accordance with Sections BL103.7.4 and BL104.5.1.

3. Header size and their maximum span above openings in bearing walls with *hemp-lime* infill shall be determined with Tables R602.7(1) and BL103.3.7 or an *approved* design by a *registered design professional*.

4. Cast-in-place *hemp-lime* over and overhanging the face of a header more than 3 inches (76 mm) shall require an *approved* design of its support by a *registered design professional*.

5. *Hemp-lime* blocks overhanging headers shall require an *approved* design of their support by a *registered design professional*.

TABLE BL103.3.7
ALLOWABLE HEADER SPAN MULTIPLIER[a]

WALL HEIGHT ABOVE HEADER	UNIT WALL WEIGHT (psf)			
	15	30	45	65
1'-0″	1.00	1.00	1.00	1.00
1’-6″	1.00	1.00	0.90	0.90
2’-0″	1.00	0.90	0.90	0.85
2’-6″	1.00	0.90	0.90	0.85
3’-0″	1.00	0.90	0.90	0.80

For SI: 1 foot = 304.8 mm, 1 pound per square foot = 4.882 kg/m^2.

a. Multiply the maximum allowable spans from Table R602.7(1) by the applicable factor to determine the adjusted maximum allowable header span.

BL103.3.8 Voids.
Voids shall be filled with *hemp-lime* or other *approved* material before application of *finish*.

BL103.3.9 Anchorage of hemp-lime.
Hemp-lime for interior and exterior stud walls shall be anchored or shall be in accordance with an *approved* design by a *registered design professional*. Horizontal anchorage rails shall be installed at not more than 24 inches (610 mm) on center and in accordance with Figures BL103.1(1) and BL103.1(3). Horizontal anchorage rails shall be no less than 1 inch by 2 inches (25 mm by 51 mm). Anchorage rails shall be wood, metal per Section BL103.4, or other *approved* material. Anchorage rails should be attached to the side of the stud facing the interior of the wall with one 8d box nail to each stud and run the entire length of the wall.

BL103.4 Contact with metal.
Metal in contact with *hemp-lime* shall be stainless steel or primed and painted with a coating in accordance with Section BL103.4.1.

BL103.4.1 Protective coatings.
Metal shall be painted with an epoxy, oil, bituminous paint or other approved coating. Waterbased paints shall not be used.
Exception: Heads of pneumatically driven hot-dip galvanized nails.

BL103.5 Mechanical, electrical and plumbing in hemp-lime infill.
Electrical and telecommunication wiring, panels and boxes, mechanical ducts, plumbing pipes and other mechanical, electrical and plumbing components in or in contact with *hemp-lime* infill shall be isolated in sleeves, pipes, conduits or tubing made of plastic, or of metal in accordance with Section BL103.4, or separated from *hemp-lime* with an *approved* alkaline-resistant material.

BL103.6 Hemp-lime installation methods.
Hemp-lime shall be installed in accordance with Sections BL103.6.1 and BL103.6.2, and one of Sections BL103.6.3 through BL103.6.7.

BL103.6.1 Mix and mixing.
The materials and ratio of *hemp hurd* to *binder* to water shall match the specifications of the *approved* test samples in Sections BL106.3 and BL107.1. The water-to-*binder* ratio shall be not less than 1:1 and not greater than 2:1 by weight or by *binder* manufacturer's recommendations. The *hemp hurd*, *binder* and water shall be thoroughly and uniformly mixed by manual or mechanical means.

BL103.6.2 Formwork for hand-cast and spray-applied methods.
Forms shall be removable or permanent and shall not deform under the lateral pressure of the installed wet *hemp-lime* .

BL103.6.2.1 Permanent forms.
Permanent forms shall be permitted to be installed on only one side. Permanent forms shall be *reed mats* or other approved materials with an open weave. Sheet materials shall not be used as permanent forms. Permanent forms remain after curing as a *finish* or substrate for another *finish*.
Exception: Permanent forms of any material shall be permitted at the jambs, heads and sills of openings.

BL103.6.2.2 Removable forms.
Removable forms shall be removed within 24 hours after *hemp-lime* placement or per the binder manufacturer's specifications.
Exception: Removable forms temporarily supporting *hemp-lime* infill above wall openings shall not be removed for a minimum of 3 days or per binder manufacturer's specifications.

BL103.6.3 Hand-cast.
Hand-cast hemp-lime infill shall be installed in uniform lifts not greater than 4 inches (102 mm) in height. Each lift shall be tamped to achieve stable walls free of *voids*.

BL103.6.4 Spray-applied.
Spray-applied hemp-lime infill shall be installed in accordance with Sections BL103.6.4.1 through BL103.6.4.4.

BL103.6.4.1 Forms.
Forms shall be installed on one side in accordance with Section BL103.6.2 or BL103.6.7.2 for *lined applications*.

BL103.6.4.2 Mixing.
Mixing shall be in accordance with Section BL103.6.1 or the spray equipment manufacturer's instructions.

BL103.6.4.3 Installation.
Hemp-lime shall be sprayed from the base up and per the spray equipment manufacturer's and/or *binder* manufacturer's instructions.

BL103.6.4.4 Screeding.
Excess *hemp-lime* shall be removed by *screeding* per the spray equipment manufacturer's and/or *binder* manufacturer's instructions.

BL103.6.5 Precast blocks.
Precast hemp-lime blocks shall be cast and installed in accordance with Sections BL103.6.5.1 through BL103.6.5.5 or per manufacturer's specifications.

BL103.6.5.1 Block dimensions.
Hemp-lime blocks shall be a minimum thickness of 3 inches (76 mm) in all dimensions and shall not exceed the maximum thickness in accordance with Section BL103.3.4.

BL103.6.5.2 Casting.
Hemp-lime blocks shall be cast in accordance with Sections BL103.6.1 through BL103.6.6, as applicable, or by other means that produce *approved* blocks.

BL103.6.5.3 Mortar.
Mortar shall consist of lime and sand or other aggregate with a ratio of not less than 1:1 and not greater than 1:3, or other *approved* mortar. The lime shall be hydrated Type N or S, or hydraulic lime.

BL103.6.5.4 Installation.
Hemp-lime blocks shall be installed in a *running bond* between and around wall framing members. Mortar shall fill all *voids* between blocks and shall be not less than 1/8 inch (3 mm) thick. Spaces between blocks and framing shall be not more than 3/4 inch (19 mm) and shall be filled with mortar.

BL103.6.5.5 Hemp-lime block veneer.
Hemp-lime block veneer shall not exceed 50 psf (244 kg/m^2) of veneer only *unit wall weight* , shall be limited to 5-inch (127 mm) thickness, and shall be anchored to the supporting wall studs in accordance with Section R703.8.4 or secured with *approved* ties and fasteners to an *approved* backing. Metal ties and fasteners shall be protected in accordance with Section BL103.4.

BL103.6.6 Hemp-lime panels.
Hemp-lime panels shall require an *approved* design by a *registered design professional*.

BL103.6.7 Lined application.
Interior and exterior *hemp-lime lined applications* shall be installed in accordance with Sections BL103.6.7.1 through BL103.6.7.6 and Sections BL103.6.3 through BL103.6.6, as applicable.

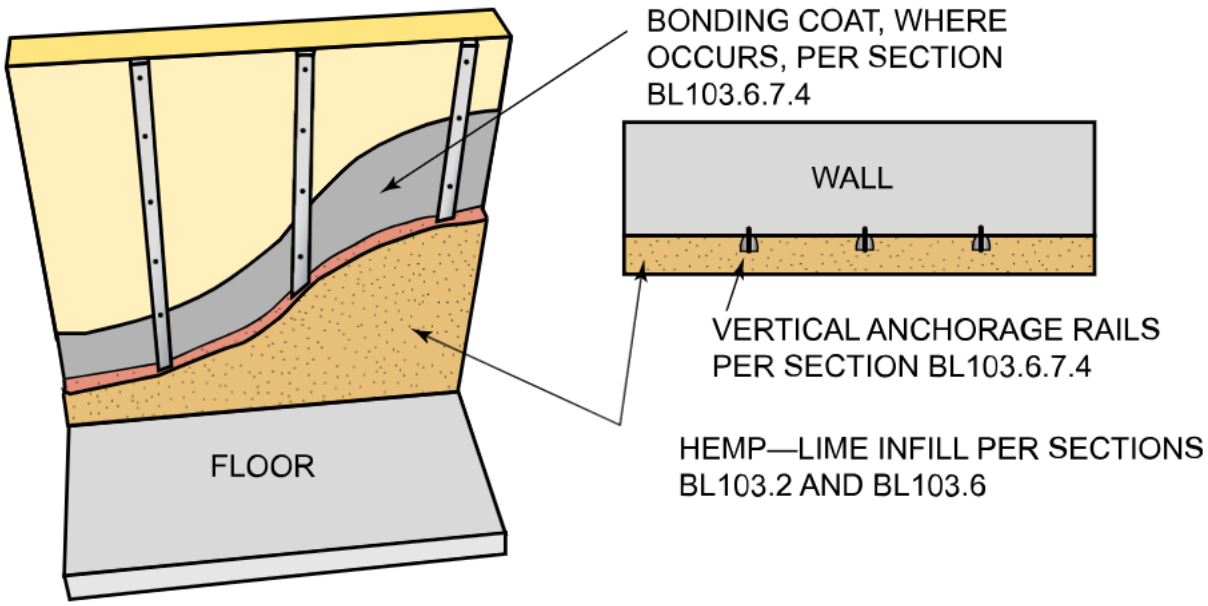
BL103.6.7.1 General.
Prior to installation, the concrete or masonry walls receiving the installation shall be clean and free of loose mortar. Lined installations on basement walls shall require an *approved* design by a registered design professional. Exterior applications shall be in accordance with Section BL103.7.6. Attachment of precast blocks to the receiving wall shall be in accordance with Section BL103.6.5.5. Attachment of hemp-lime panels to the receiving wall shall be in accordance with Section BL103.6.6.

BL103.6.7.2 Formwork.
Forms shall be in accordance with Section BL103.6.2. Permanent *formwork* shall not be allowed on the nonreceiving wall side.

BL103.6.7.3 Thin lining.
Thin linings are from 3 inches to 4 3/4 inches (76 mm to 121 mm) thick. Hand troweled *hemp-lime* shall be installed over a *bonding coat* .

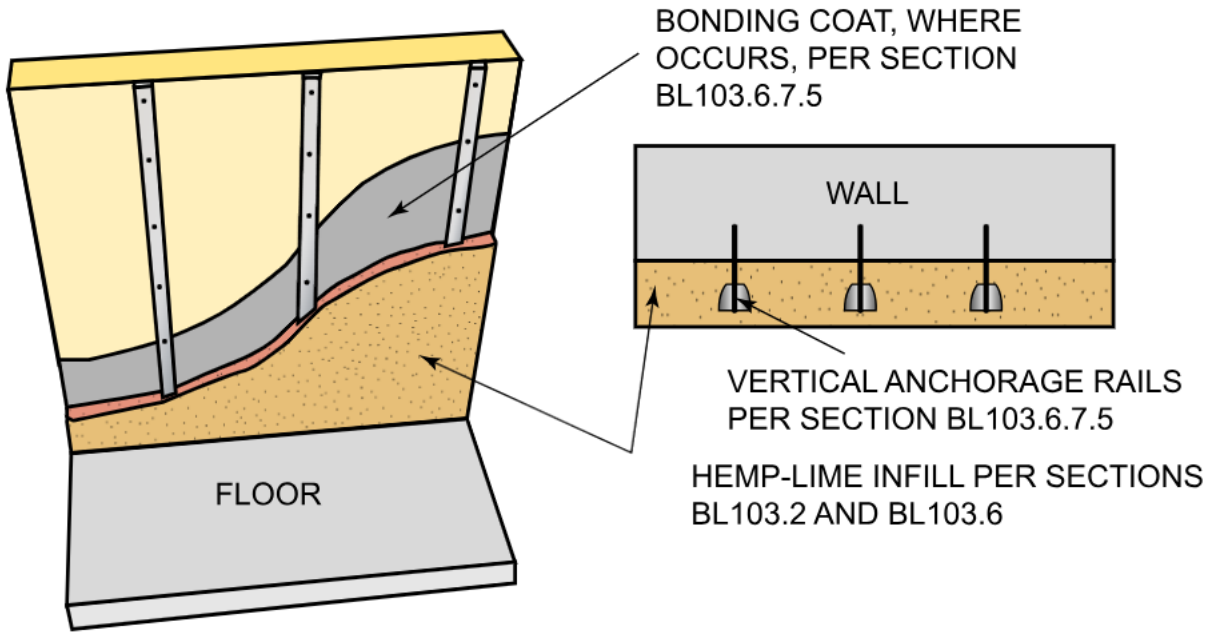
BL103.6.7.4 Medium lining.
Medium linings exceed 4 3/4 inches (121 mm) and are not greater than 6 1/2 inches (165 mm) thick. For *hand-cast* or *spray-applied*, 1 1/2-inch by 1 1/2-inch (38 mm × 38 mm) dovetail-shaped vertical anchorage rails shall be attached with the narrowest face to the receiving wall, spaced not less than 20 inches (508 mm) and not greater than 32 inches (813 mm), with fasteners not less than 2 feet (610 mm) and not greater than 3 feet (914 mm) apart. *Hand-cast* medium linings shall be installed over a *bonding coat* on the receiving wall. See Figure BL103.6.7.4.

FIGURE BL103.6.7.4
TYPICAL HEMP-LIME MEDIUM LINING



BL103.6.7.5 Thick lining.
Thick linings exceed 6 1/2 inches (165 mm) and shall not be greater than 8 inches (203 mm) thick or per the *binder* manufacturer's specifications. For *hand-cast* or spray-applied, 1 1/2-inch by 2 1/2-inch (38 mm × 64 mm) vertical anchorage rails shall be attached with the 2 1/2-inch (64 mm) face parallel to the receiving wall and spaced not less than 20 inches (508 mm) and not greater than 32 inches (813 mm). The anchorage rails shall be fastened to and separated from the receiving wall with 2-inch (51 mm) spacers not less than 3 feet (914 mm) and not greater than 4 feet (1219 mm) apart. *Hand-cast* thick linings shall be installed over a *bonding coat* on the receiving wall. See Figure BL103.6.7.5.

FIGURE BL103.6.7.5
TYPICAL HEMP-LIME THICK LINING



BL103.6.7.6 Minimum thickness at anchorage rails.
The minimum thickness of *hemp-lime* between the exterior face of vertical anchorage rails and the finished face of *hemp-lime* shall be 3 inches (76 mm) or in accordance with the *binder* manufacturer's specifications.

BL103.7 Moisture control.
Hemp-lime assemblies shall be protected from water intrusion and damage in accordance with Sections BL103.7.1 through BL103.7.9.

BL103.7.1 Water-resistive barriers.
Water-resistive barriers are prohibited on *hemp-lime* walls, except as permitted or required elsewhere in this appendix.

BL103.7.2 Vapor retarders.
Vapor retarders are prohibited on *hemp-lime* walls, except as permitted or required elsewhere in this appendix.

BL103.7.3 Penetrations in hemp-lime walls.
Penetrations in exterior *hemp-lime* 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~~WSEC R301.

BL103.7.4 Horizontal surfaces.
Hemp-lime walls and other *hemp-lime* assemblies shall be provided with a *water-resistive barrier* at 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 and sills at exterior niches. Horizontal surfaces shall be sloped not less than 1 unit vertical in 12 units horizontal (8 percent slope) and shall drain away from *hemp-lime* walls and other assemblies. 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 exterior surface of the *hemp-lime* wall's vertical *finish*.

BL103.7.5 Air barrier.
Exterior *hemp-lime* walls shall have a *vapor-permeable air barrier* on all exterior and interior surfaces, except as permitted or required elsewhere in this appendix. *Plaster* in accordance with Section BL104.3 shall be acceptable as an *air barrier*.

BL103.7.6 Separation of hemp-lime and earth or paved areas.
Hemp-lime shall be not less than 8 inches (203 mm) above exposed earth or paved areas.

BL103.7.7 Separation of exterior plaster and earth or paved areas.
Exterior plaster applied to *hemp-lime* shall be not less than 8 inches (203 mm) above exposed earth or paved areas.

BL103.7.8 Separation of hemp-lime and exterior plaster from foundation.
Hemp-lime and exterior *plaster* shall be separated from the foundation with an *approved* moisture barrier.

BL103.7.9 Base of wall flashing.
The outer face of exterior walls shall be flashed to prevent water intrusion at the base of the wall.

BL103.8 Special inspections. The building official has the authority to require the owner to employ a special inspector during construction of specific types of work described in this appendix.

Section BL104 Finishes

BL104.1 General.
The interior and exterior surfaces of *hemp-lime* walls shall be protected with a *finish* in accordance with Section BL104. Finishes shall have a vapor permeance rating of 5 perms [285 mg/(s × m^2× Pa)] or greater tested in accordance with Procedure B of ASTM E96.

BL104.2 Moisture content prior to application of finish.
Hemp-lime infill shall have an average moisture content of no more than 20 percent at a depth of 1 1/2 inches (38 mm), as measured from the face of the wall to which the *finish* will be applied for each wall. Moisture content shall be measured with a probe-style wood moisture equivalent (WME) meter.

BL104.3 Plaster finish.
Exterior plaster shall be lime *plaster*, clay *plaster* in accordance with Section BL104.3.6.3, or other *approved plaster*. Interior plasters shall be any *plaster* permitted in Sections BL104.3.1 through BL104.3.9. Plasters shall be permitted to be applied directly to the surface of the *hemp-lime* infill without reinforcement, except that the juncture of dissimilar substrates shall be in accordance with Section BL104.5. Plasters shall have a thickness of not less than 1/2 inch (13 mm) on the interior and 3/4 inch (19 mm) on the exterior and shall be installed in not less than two coats, or per *binder* manufacturer's instructions. Not less than 3/8 inch (10 mm) exterior *plaster* is permitted behind exterior *cladding* in accordance with Section BL104.6.

BL104.3.1 Membranes.
Membranes are prohibited between *plaster* and *hemp-lime* , except where a membrane is allowed or required elsewhere in this appendix.

BL104.3.2 Lath and mesh for plaster.
The surface of the *hemp-lime* functions as lath, and other lath or mesh shall not be required, except as required in Section BL104.5.

BL104.3.3 Plaster additives.

Additives shall be permitted to increase *plaster* workability, durability, strength or water resistance. Additives shall not reduce the *plaster* vapor permeance rating to less than 5 perms [285 mg/(s × m^2× Pa)]. Additives containing polymers are prohibited.

BL104.3.4 Plaster reinforcing fibers.
Reinforcing fibers shall be permitted in *plaster*. Acceptable reinforcing fibers include hemp fiber, chopped straw, sisal, animal hair and fiberglass.

BL104.3.5 Lime plaster.
Lime *plaster* is any *plaster* with a binder primarily composed of calcium hydroxide [$Ca(OH)^2$], including Type N or S hydrated lime, hydraulic lime, natural hydraulic lime or slaked quicklime. Hydrated lime shall comply with ASTM C206. Hydraulic lime shall comply with ASTM C1707. Natural hydraulic lime shall comply with ASTM C141 and CEN EN 459. Quicklime shall comply with ASTM C5. Lime *plaster* shall contain sufficient lime to fully bind the sand or other aggregate and shall be permitted to contain *pozzolans*.

BL104.3.6 Clay plaster.
Clay *plaster* shall be any *plaster* having a *clay* or *clay subsoil binder* . Such *plaster* shall contain sufficient *clay* to fully bind the sand or other aggregate.

BL104.3.6.1 Clay subsoil requirements.
The suitability of *clay subsoil* shall be determined in accordance with Figure 2, Ribbon Test, and Figure 3, Ball Test, in the appendix of ASTM E2392/E2392M.

BL104.3.6.2 Thickness and coats.
Clay *plaster* shall be not less than 3/4 inch (19 mm) thick and shall be applied in not less than two coats.

BL104.3.6.3 Rain-exposed.
Clay *plaster*, where exposed to rain, shall be finished with an *approved* erosion-resistant *finish*.

BL104.3.6.4 Prohibited finish coat.
Plaster containing Portland cement shall not be permitted as a *finish* coat over clay plasters.

BL104.3.7 Clay-lime plaster.
Clay-lime *plaster* shall be composed of refined *clay* or *clay subsoil*, sand and lime.

BL104.3.8 Hemp-lime plaster.
Hemp-lime plaster shall be composed of *hemp hurd* and lime and shall be permitted to contain sand or other aggregate, and *pozzolans*.

BL104.3.9 Hemp-clay plaster.
Hemp-clay *plaster* shall be composed of *hemp hurd* and *clay* or *clay subsoil* and shall be permitted to contain sand or other aggregate.

BL104.4 Separation of wood and plaster.
Wood framing at the exterior surface of *hemp-lime* walls shall be separated from exterior *plaster* with Grade D paper or other *approved* material, except where the wood is naturally durable.
Exception: Exterior *clay plaster* shall not be required to be separated from wood.

BL104.5 Bridging across dissimilar substrates.
Bridging shall be installed onto and across dissimilar substrates prior to the application of *plaster* on the interior or exterior. Acceptable bridging materials include expanded metal lath, woven wire mesh, welded wire mesh,

fiberglass mesh, *reed mat*, burlap or other *approved* materials. Bridging shall extend not less than 3 inches (76 mm) on both sides of the juncture.

BL104.5.1 Returns on recessed openings.
Plaster or other exterior *finish* returns at recessed windows and doors shall require an *approved* design that prevents the intrusion of moisture.

BL104.6 Nonplaster exterior cladding.
Nonplaster exterior *cladding* shall be spaced not less than 1 inch (25 mm) from the face of the *water-resistive barrier* or *air barrier* to the back of the *cladding* to allow for *ventilation*. The ventilation space shall be open at the top and bottom and be provided with insect screening.

BL104.6.1 Water-resistive and air barriers.
Water-resistive barriers and air barriers, when *vapor permeable*, are permitted to be applied directly to the *hemp-lime* when exterior *cladding* is installed in accordance with Section BL104.6.

BL104.7 High moisture interior environments.
Exterior *hemp-lime* walls enclosing showers or steam rooms shall be lined on the interior side with ceramic tiles on an *approved* tile backer board, ceramic tiles on a lime plaster, or a *tadelakt finish*.

Section BL105 Fire Resistance

BL105.1 Fire-resistance rating.
Hemp-lime walls do not have a fire-resistance rating, except for walls constructed in accordance with Sections BL105.1.1, BL105.1.2, or BL105.1.3. Fire-resistance ratings for other *hemp-lime* wall assemblies shall be determined by testing in accordance with ASTM E119 or UL 263, or an analytical method in accordance with Section 703.2.2 of the Washington State Building Code.

BL105.1.1 One-hour rated hemp-lime wall with center stud framing. One-hour fire-resistance rated load-bearing hemp-lime center stud walls shall comply with all of the following:

1. Shall be constructed with center stud framing per Figure BL103.1(2) with 2x4 studs at 16 inches (406 mm). The framed wall height shall not exceed 10 feet (3.05 m). Staggered 2x4 blocking shall be installed at mid-height between the studs.
2. Hemp-lime complying with Sections BL103.6.1, BL103.6.2 and BL107.1 shall be spray applied in accordance with Section BL103.6.4 to a thickness of 12 inches (305 mm).
3. Exterior and interior plaster shall be lime plaster complying with Section BL104.3.5, and shall be applied with 1/4-inch (6.4 mm) coats to a thickness of 3/4 inch (19 mm) on the exterior and 1/2 inch (12.7 mm) on the interior. Fiberglass stucco lath shall be embedded in the first exterior and interior coats.

BL105.1.2 One-hour rated hemp-lime wall with exterior stud framing. One-hour fire-resistance rated load-bearing hemp-lime exterior stud walls shall comply with all of the following:

1. Shall be constructed with exterior stud framing per Figure BL103.1(3) with 2x6 studs at 16 inches (406 mm). The framed wall height shall not exceed 10 feet (3.05 m). 2x4 on-edge blocking shall be installed at 5 feet (1.52 m) and 9 feet (2.74 m) between the studs and flush with their exterior face. 2x2 anchorage at 16 inches (406 mm) shall be fastened horizontally to inside face of the studs with 16d nails, and vertically at 16 inches (406 mm) to the horizontal anchorage.
2. A vapor permeable combined water-resistive and air barrier shall be stapled with lapped and taped joints at the 2x4 on-edge blocking.
3. A .06 inch x 2 3/8-inch (1.5 mm x 60mm) galvanized steel strap shall be installed diagonally from top plate to bottom plate and fastened to framing members per manufacturer's specifications.

4. 1x3 wood furring shall be installed vertically to each stud with 2 3/8 inch (60 mm) screws, and horizontally at 16 inches (406 mm) to the vertical furring.
5. 3/4-inch (19 mm) x 5 ½-inch (127 mm) vertical wood siding shall be fastened at each horizontal furring member.
6. Hemp-lime complying with Sections BL103.6.1, BL103.6.2, and BL107.1 shall be spray applied in accordance with Section BL103.6.4 to a thickness of 12 inches (305 mm).
7. Interior plaster shall be lime plaster complying with Section BL104.3.5, and applied with 1/4–inch (6.4 mm) coats to a thickness of ½ inch (12.7 mm). Fiberglass stucco lath shall be embedded in the first coat.

BL105.1.3 One-hour rated hemp-lime wall with double stud framing. One-hour fire-resistance rated load-bearing hemp-lime double stud walls shall comply with all of the following:

1. Shall be constructed with double stud framing per Figure BL103.1(4), with exterior load-bearing 2x4 studs at 16 inches (406 mm) and interior nonload-bearing 2x3 studs at 24 inches (610 mm). The framed wall height shall not exceed 10 feet (3.05 m). 2x4 on-edge blocking shall be installed at 5 feet (1.52 m) and 9 feet (2.74 m) between the exterior studs and flush with their exterior face. Horizontal 2x4 anchorage shall be fastened to the interior face of the 2x4 studs at 30, 60, and 90 inches (.76, 1.52, and 2.29 m).
2. A vapor permeable combined water-resistive and air barrier shall be stapled with lapped and taped joints at the 2x4 on-edge blocking.
3. A .06 inch x 2 3/8-inch (1.5 mm x 60mm) galvanized steel strap shall be installed diagonally from top plate to bottom plate and fastened to framing members per manufacturer's specifications.
4. 1x3 wood furring shall be installed vertically to each stud with 2 3/8 inch (60 mm) screws, and horizontally at 16 inches (406 mm) to the vertical furring.
5. 3/4-inch (19 mm) x 5 ½-inch (127 mm) vertical wood siding shall be fastened at each horizontal furring member.
6. Hemp-lime complying with Sections BL103.6.1, BL103.6.2, and BL107.1 shall be spray applied in accordance with Section BL103.6.4 to a thickness of 12 inches (305 mm).
7. Interior plaster shall be lime plaster complying with Section BL104.3.5, and applied with 1/4–inch (6.4 mm) coats to a thickness of ½ inch (12.7 mm). Fiberglass stucco lath shall be embedded in the first coat.

BL105.2 Clearance to fireplaces and chimneys.
Hemp-lime surfaces adjacent to fireplaces or chimneys shall be finished with not less than ⅜ 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 instructions, whichever is more restrictive.

Section BL106 Thermal Performance

BL106.1 Mass walls.
Walls with *hemp-lime* infill shall be classified as mass walls in accordance with WSEC Section R402.2.5 ~~N1102.2.5 (R402.2.5)~~ and shall meet the U-factor requirements for above-grade walls in WSEC Table R402.1.2 ~~*R*-value requirements for mass walls in Table N1102.1.3 (R402.1.3)~~, when their heat capacity (C) is greater than or equal to 6 Btu/ft^2× °F (123 kJ/m^2× K) in Equation BL-1.

Equation BL-1 $C=\rho \times t \times 0.299$ Btu/lb×°F
where:
C = Heat capacity (Btu/ft^2× °F).
ρ = Density of *hemp-lime* infill (pounds per cubic foot).
t = Thickness of *hemp-lime* infill (feet).

BL106.2 Thermal resistance.
Hemp-lime has the unit thermal resistance values in accordance with Table BL106.2. Alternatively, the unit *R*-value of *hemp-lime* shall be determined with one of the following tests by an *approved* laboratory: ASTM C177 ASTM C518, ASTM C1114 or ASTM C1363. Test results from a specific *hemp-lime* mix shall be permitted to be used for multiple projects.

TABLE BL106.2
THERMAL RESISTANCE OF HEMP-LIME[a]

DENSITY (pounds per cubic foot)	*R*-VALUE ($ft^2 \times °F \times h/Btu$ per inch of thickness)
12.5	R-2.10
15	R-1.86
20	R-1.54
25	R-1.20

For SI: 1 pound per cubic foot = 1.6 kg/m^3.

a. Linear interpolation is permitted. Extrapolation is not permitted.

BL106.3 Density measurement.
Hemp-lime density shall be measured based on *approved* test samples as follows:

1. Three samples of the proposed *hemp-lime* mix shall be placed moist to completely fill a 6-inch by 6-inch by 12-inch (152 mm × 152 mm × 305 mm) *form*, a 6-inch (152 mm) diameter by 12-inch (305 mm) length *form* or other *approved form*, following the application method and procedure that will be used during construction.

2. Samples shall be removed from the forms within 24 hours after *hemp-lime* placement or per the binder manufacturer's specifications.

3. Samples shall be cured/dried for a minimum of 14 days in indoor ambient conditions before density determination.

4. Density shall be determined by Equation BL-2.

Equation BL-2 $\rho = w/V$

where:

ρ = Density of hemp-lime infill (pounds per cubic foot).
w = Weight of hemp-lime infill sample (pounds).
V = Volume of hemp-lime sample (cubic feet).

BL106.4 Compliance with Section R302.10.1**.**
Hemp-lime infill shall meet the requirements for insulation materials in Section R302.10.1 for *flame spread index* and *smoke-developed index* as tested in accordance with ASTM E84.

Section BL107 Mechanical Performance

BL107.1 Hemp-lime infill integrity.
The integrity of *hemp-lime* infill and its ability to hold a *plaster finish* shall be demonstrated with a minimum compressive strength of 29 psi (0.2 MPa). Test results from a specific *hemp-lime* mix shall be permitted to be used for multiple projects.

BL107.1.1 Demonstration of compressive strength.

The compressive strength of the *hemp-lime* mix shall be demonstrated to the *building official* before the placement of *hemp-lime* infill, with compressive strength tests and an associated report by an *approved* laboratory tested as follows:

1. Three samples of the proposed *hemp-lime* mix shall be placed moist to completely fill a 6-inch by 6-inch by 12-inch (152 mm × 152 mm × 305 mm) *form*, a 6-inch (152mm) diameter by 12-inch (305 mm) length *form*, or other *approved form*, following the application method and procedure that will be used during construction.

2. Samples shall be removed from the forms within 24 hours after *hemp-lime* placement or per the *binder* manufacturer's specifications.

3. Samples shall be cured/dried for a minimum of 14 days in indoor ambient conditions before testing.

4. The opposite faces shall be capped with *plaster* of paris to achieve smooth and parallel faces, after which the sample shall reach ambient moisture conditions before testing.

5. The horizontal cross section of the dried sample as tested and the maximum applied load at failure shall be used to calculate the sample's compressive strength.

6. The average value of the samples shall be used to determine the mix's compressive strength.

Section BL108 Referenced Standards

BL108.1 General.

See Table BL108.1 for standards that are referenced in various sections of this appendix. Standards are listed by the standard identification with the effective date, the standard title and the section or sections of this appendix that reference this standard.

TABLE BL108.1
REFERENCED STANDARDS

STANDARD ACRONYM	STANDARD NAME	SECTIONS HEREIN REFERENCED
ASTM C5—10	*Standard Specification for Quicklime for Structural Purposes*	BL104.3.5
ASTM C141/C141M—14	*Standard Specification for Hydrated Hydraulic Lime for Structural Purposes*	BL104.3.5
ASTM C177—19	*Standard Test Method for Steady-State Heat Flux Measurements and Thermal Transmission Properties by Means of the Guarded-Hot-Plate Apparatus*	BL106.2
ASTM C206—14	*Standard Specification for Finishing Hydrated Lime*	BL104.3.5
ASTM C518—21	*Transmission Properties by Means of the Heat Flow Meter Apparatus*	BL106.2
ASTM C1114—06(2019)	*Standard Test Method for Steady-State Thermal Transmission Properties by Means of the Thin-Heater Apparatus*	BL106.2
ASTM C1363—19	*Standard Test Method for Thermal Performance of Building Materials and Envelope Assemblies by Means of a Hot Box Apparatus*	BL106.2
ASTM C1707—11	*Standard Specification for Pozzolanic Hydraulic Lime for Structural Purposes*	BL104.3.5
ASTM E84—21a	*Standard Test Method for Surface Burning Characteristics of Building Materials*	BL106.4
ASTM E96/E96M—21	*Standard Test Methods for Water Vapor Transmission of Materials*	BL104.1
ASTM E119—20	*Standard Test Methods for Fire Tests of Building Construction and Materials*	BL105.1
ASTM E2392/E2392M—10(2016)	*Standard Guide for Design of Earthen Wall Building Systems*	BL104.3.6.1
CEN EN 459—2015	*Building Lime—Part 1: Definitions, Specifications and Conformity Criteria; Part 2: Test Methods*	BL104.3.5
UL 263—2011	*Fire Test of Building Construction and Materials—with Revisions through August 2021*	BL105.1