

Approved Standard for Earthen IBC Structures

EARTHEN STRUCTURES

Rated Fire-Resistance for Earthen Walls

Material	Item	Construction	4 hour	3 hour	2 hour	1 hour
1a Earthen Walls	1a – 1.1	Solid wall construction utilizing earth as the structural wall	14	12	10	8

Section 2114.1 General. Earthen structures with any site condition may be designed with accepted engineering practice for earthen wall structures and with the provisions of this standard.

Section 2114.1.1 Earthen materials. This document shall establish minimum standards for safety for construction of earthen material structures, collectively known as adobe, burnt adobe, rammed earth, and hydraulic pressed unit construction.

Section 2114.1.2 Professional registration required. Plans and specifications designed under the provisions of this standard shall be prepared by an Arizona Registrant.

Section 2114.2. Minimum thickness. The minimum thickness of earthen structures shall be designed to limit tension to zero unless tensile reinforcement is provided. Walls shall be designed to meet forces prescribed by the *International Building Code*. The measurement of height of walls shall be the distance between points of lateral support. Wall thickness shall be measured from face to face of each wall with. The thickness of walls using raked joints shall be the surface to surface distance of the mortar joints. The withes of wall sections shall not be combined without cross bonding of the masonry units throughout the structural element. Cross bonding shall mean overlapping of not less than 1/3 of the dimension of the masonry units.

Section 2114.3 Support conditions. Earthen structures shall be supported on a solid concrete, solid masonry foundation system the width of which shall be not greater than 1/6 inch narrower than the earthen structure which it supports. Earthen structures shall not be less than 6 inches above adjacent grade.

Section 2114.4 Corbeled wall elements. The maximum corbeled projection beyond the face of the wall shall not be more than 4 inches. Such corbeled projections shall add additional thickness to the wall, the opposite face of the wall remaining plane with the primary wall plane.

Section 2114.5 Moisture barrier. A moisture barrier equal to 30 lbs asphalt impregnated building paper, or equivalent moisture resistant barrier, shall be installed between the supporting foundation and the earthen material.

Section 2114.6 Allowable stresses. Allowable compressive, tensile and shear stresses in earthen structures shall not exceed the values prescribed in Table 2114.6 A. In determining the stresses, the effects of all loads and conditions of loading and the influence of all forces affecting the design and strength of the several parts shall be considered. Bolt values shall not exceed those set forth in *International Building Code* Table 2109.3.3.1

Section 2114.6.1 Combined units. In walls composed of different kinds or grades of units, materials or mortars, the maximum stress shall not exceed the allowable stress for the weakest of the combination of units, materials and mortars of which the wall is composed. The net thickness of any facing unit of earthen materials used to resist stress shall not be less than 3 inches.

When dissimilar materials (e.g. concrete masonry or steel) is used to support earth wall construction, such elements shall be structurally isolated from other earth wall elements. The design shall recognize, with specific detailing, the effects shrinkage of the earth wall construction may have on the structural integrity of the structure.

TABLE 2114.6.A
ALLOWABLE STRESSES FOR EMPIRICAL DESIGN OF EARTHEN WALL STRUCTURES

Strength of Unit, Gross Area		Allowable Stresses, Gross Sectional Area ¹	
Compression:	300 psi	Compressive Stress:	30 psi
Modulus of rupture:	50 psi	Allowable tension w/o tensile reinforcing:	0 psi
Shear:	N/A	Shear with Special Inspection:	8 psi
		Shear w/o Special Inspection:	4 psi
Modulus of Elasticity:	60,000 psi	Allowable Deflection:	Less than 0.5%

¹ Gross cross-sectional area shall be calculated on the actual rather than the nominal dimensions

Section 2114.7 Lateral support. Earthen walls shall be laterally supported in the vertical direction and at intersection with other earthen walls. Support at the top of the wall shall in accordance with one of the methods in Section 2114.7.1 or Section 2114.7.2.

Section 2114.7.1 Bond beams. A continuous bond beam system embedded in the earthen walls, designed to provide lateral support for the walls without the aid of additional bracing elements such as roof diaphragm. Bond beams of concrete or masonry shall be not less than the width of the wall minus 6 inches.

Section 2114.7.1.1 Bond beam anchorage. Bond beams shall be anchored to earthen walls at intervals of not over 48 inches by a connection with shear strength of not less than the shear forces in both directions. The shear between a cast in place concrete bond beam and the earthen wall shall not exceed 1/8 the dead load at the base of the bond beam unless alternate attachment is provided compatible with the allowable stresses in Table 2114.6.A or *International Building Code* Table 2109.3.3.1

Section 2114.7.2 Roof diaphragm. A roof diaphragm complying with other provisions of this code adequate to provide lateral support may be used to brace earthen walls. Anchorage shall be tie beams as specified in Section 2114.7.2.2 or other anchorage methods of equal strength.

Section 2114.7.2.1 Tie beams. A tie beam is a beam built into the earthen wall for the purpose of anchoring the roof diaphragm and transferring the lateral perpendicular and parallel forces. Tie beams shall be provided for all earthen walls laterally braced by a roof diaphragm.

Section 2114.7.2.2 Tie beam anchorage. Tie beams shall be anchored to earthen walls at intervals of not over 48 inches by a connection with shear strength of not less than the shear forces in both directions. The shear between a cast in place concrete or masonry tie beam and the earthen wall shall not exceed 1/8 the dead load at the base of the bond beam unless alternate attachment is provided compatible with the allowable stresses in Table 2114.6.A or *International Building Code* Table 2109.3.3.1.

Section 2114.8 Lintels. Earthen walls over openings shall be supported by steel lintels, reinforced concrete or masonry lintels or earthen material arches designed to support load imposed. Lintels shall not be supported by rigid structural columns, frames or posts with rigidities greater than the earthen wall unless the design allows for the potential for differential settlements. Small openings less than 12" may be constructed without structural lintels.

Section 2114.9 Shear walls. Earthen walls subject to in-plane loads shall be designed to be tension free unless tensile reinforcement is provided. Solid panels less than 4 feet shall not be considered shear walls.

Section 2114.10 Opening jambs. Portions of walls between openings shall be constructed with lengths of not less than 1 ½ times the thickness of the wall in which they occur.

Section 2114.11 Freestanding piers. Piers independent of earthen walls shall be designed to support vertical and horizontal loads unless braced by other elements of the structure. Tensile reinforcement shall be provided where tension occurs. When structural posts or columns are provided within the pier ties or attachments shall be provided to the earthen wall system to laterally secure it.

Section 2114.11.1 Pier cap. A solid concrete cap shall be provided at the top of load bearing piers under all concentrated loads. The cap shall cover not less than 50% of the top of the pier.

Section 2114.12 Chases. Chases and recesses in earthen walls shall not be deeper than one-third the thickness of the wall thickness. The maximum length of a horizontal chase or horizontal projection shall not exceed 4 feet and shall have at least 8 inches of earthen construction in back of the chases and recesses and between adjacent chases or recesses and at least 12 inches between the chase and the jambs of openings. Chases and recesses in earthen walls shall be designed and constructed so as not to reduce the required strength or required fire resistance of the wall and in no case shall a chase or recess be permitted within the required area of a pier. Earthen walls directly above chases or recesses wider than 16 inches shall be supported on noncombustible lintels.

Section 2114.13 Stack bond. When the earthen wall is constructed of units, (e.g. adobe brick), units shall not be laid in stack bond. Units shall, in all locations throughout the wall system, overlap the courses below by not less than one-third the dimension of the units.

Exception: Ornamental non-structural elements may be laid in stack bond if properly tied to the main structure.

Section 2114.14 Metal reinforcement. All walls shall be anchored at their intersections, at vertical intervals of not more than 16 inches with joint reinforcement of at least 9 gage when using earthen units (e.g. adobe block). Horizontal reinforcement shall be used throughout the wall system and be continuous at the intersections. Reinforcement used throughout the wall system shall be not more than 4 inches narrower than the wall thickness.

Section 2114.15 Veneer. All veneers using earthen materials shall be installed in accordance with this section. Such veneers shall be installed with a noncombustible foundation, over concrete masonry, a backing of wood or cold-formed steel and the veneer shall be not less than 4 inches or greater than 8 inches in thickness.

Section 2114.15.1 Anchorage. Earth units shall be anchored to the supporting wall with a corrosion-resistant veneer tie system mechanically attached to continuous horizontal joint reinforcement continuously installed in the veneer bed joint not less than 16 inches on center vertically. When earth mortar systems are used the tie system shall prevent the accumulation of mortar at the base of the veneer. Conventional brick ties shall not be used to anchor earth units.

Section 2114.15.2 Air space. The veneer shall be separated from the sheathing by an air space of a minimum of 1 inch but not more than 2 inches. A weather-resistant membrane or 15 lb asphalt-saturated felt by shall be provided except when veneer is applied over concrete masonry or concrete backing.

Section 2114.15.3 Flashing. Approved corrosion-resistive flashing shall be provided in the exterior wall envelop in such a manner as to prevent entry of water into the wall cavity or penetration of water into the building structural framing components. The flashing shall extend to the surface of the exterior wall finish and shall be installed to prevent water from reentering the exterior wall envelope. Flashing shall be located beneath the first course of veneer, and at other points of support, including structural floors, shelf angles and lintels. Approved corrosion-resisting flashing shall be installed at all of the following locations:

1. At top of all exterior window and door openings in such a manner as to be leak proof.

2. At the intersection of chimneys or other masonry construction with frame or stucco walls, with projecting lips on both sides under stucco copings.
3. Under and at the ends of masonry, wood or metal copings and sills.
4. Where exterior porches, decks or stairs attach to a wall or floor assembly of wood-frame construction.
5. At wall and roof intersections.

Section 2114.15.4 Weep holes. Weep holes shall be provided in the outside of masonry walls at a maximum spacing of 33 inches on center. Weep holes shall not be less than 3/16 inches in diameter. Weep holes shall be located immediately above the flashing.

Section 2114.16 Buttresses. Earthen walls used as buttresses shall not extend beyond an average length perpendicular to the wall to be braced a distance of 6 feet without consideration to out-of-plane bending of the buttress.

Section 2114.17 Gable End Walls. Gable end walls shall be constructed using veneer construction as required by Section 2114.15 or shall be provided with lateral bracing to prevent overturning.

Section 2114.18 Ledgers. Ledgers shall not be used to support vertical live and dead loads in excess of 75 lbs per lineal foot unless the tension in the wall due to bending from out-of-plane loads and the eccentric load from the ledger is zero.

Section 2114.19 Material standards. The materials used in earthen wall structures shall comply with the following material standards. For each of the tests prescribed in these standards, five full size sample units shall be selected at random from each lot of units of fraction thereof produced. Mass wall systems such as rammed earth shall provide at least five tests for each required standard test series.

Section 2114.19.1 Manufacturers of earthen materials. Established manufacturers of earthen materials shall certify compliance with these standards. Copies of their periodic testing shall be supplied to the building official when requested. Literature, advertising and other information supplied by the manufacturer to designers and users of earthen materials shall include the actual dimensions of units, not nominal dimensions.

Section 2114.19.2 Onsite earthen materials. Earthen units, mortar, rammed earth wall materials mined, mixed, formulated, and or molded on site shall be tested for compliance with these standards. For individual structures, a set of tests shall be provided for the first 2500 square feet of wall and an additional test for each additional 2500 square feet or portion thereof in the structure. At least one set of tests shall be made for each structure and for each 2500 square feet of patio wall. The fabricator of the materials used in the project shall certify in writing to the building official compliance with these standards. The certification shall include the number of units site molded, size of the units, volume of material used as mortar, dates of fabrication, and results of testing of the material. If materials from established manufacturers and onsite materials are used in the project, copies of records including sources, quantities, and location of use within the structure shall be provided to the building official upon request.

Section 2114.19.3 Categories of earthen materials. Type I, II, III, and IV earthen materials are approved for use.

Exception: Type I adobe shall only be used for repairs and small additions in which new walls do not exceed 10% of the surface area of existing walls of Type I construction and for structures constructed of a similar material system and for projects requiring this class of materials to meet historic guidelines.

Required plaster veneer. Adobe of Type I and II shall be protected on the exterior with exterior plaster meeting the requirements of *International Building Code* Section 2512 applied over wire lath. Type I and II adobe shall not be used within 4 inches of the floor or at the top of parapet walls or near potential sources of water which may effect the stability of the earth wall system. Other Types of adobe may be left unplastered and may be used without separation from the floor.

Adobe units and mortar. Moisture resistant stabilized adobe units and mortar shall meet the following testing standards as indicated in Table 2114.19. Type S Portland cement mortar may be used for Type II, III, and IV adobe in lieu of earth mortar.

Table 2114.19 Required Tests by Material Type

Material Type	Dry Compression	Wet Compression	Modulus of Rupture	Absorption <2.5%	Absorption <5.0%	Moisture Content
I	X		X			X
II	X		X		X	X
III	X		X	X		X
IV		X	X			X

X Indicates that material must pass the test standards prescribed in this Section.

Section 2114.19.4.1 Dry compression strength. Determine the compressive strength of the required number of samples in accordance with the following:

1. Dry the specimen. Dry the specimen at a temperature of 85° F+-15° F in an atmosphere having relative humidity of not more than 50 percent. Weigh the specimen at one-day intervals until constant weight is attained.
2. Cap the specimen. The specimen may be suitably capped with calcined gypsum mortar or the bearing surfaces may be rubbed smooth and true. Then calcined gypsum is used for capping, conduct the test after the capping has set and the specimen has been dried to constant weight in accordance with item 1 of this section.
3. Test the Specimen. Test the specimens in the position in which the earthen unit is designed to be used. And bed on and cap with a felt pad not less than 1/8 inch or more than ¼ inch in thickness.
4. Testing equipment. The loading head shall completely cover the bearing area of the specimen and the applied load shall be transmitted through a spherical bearing block of proper design. The speed of the moving head of the testing machine shall not be more than 0.05 inch per minute.
5. Reporting results. Calculate the average compressive strength of the specimens tested and report this as the compressive strength of the block. Units shall have an average dry compressive strength of 300 psi and no individual unit may have a strength of less than 250 psi.

Section 2114.19.4.2 Wet compression strength. Determine the compressive strength of the required number of specimen in accordance with the following:

1. Wetting the specimen. Submerge the specimen under water for not less than 8 hours or longer as required until fully saturated.
2. Test the specimen. Immediately test the specimen in the position in which the earthen unit is designed to be used. And bed on and cap with a felt pad not less than 1/8 inch or more than ¼ inch in thickness.
3. Testing equipment. The loading head shall completely cover the bearing area of the specimen and the applied load shall be transmitted through a spherical bearing block of proper design. The speed of the moving head of the testing machine shall not be more than 0.05 inch per minute.
4. Reporting results. Calculate the average compressive strength of the specimens tested and report this as the compressive strength of the block. Adobe units shall have an average wet compressive strength of 300 psi. Five samples shall be tested and no individual unit may have a wet compressive strength of less than 250 psi.

Section 2114.19.5 Modulus of rupture. Adobe units shall have an average modulus of rupture of 50 psi when tested in accordance with the following procedure. Five samples shall be tested and no individual unit shall have a modulus of rupture of less than 35 psi.

Section 2114.19.5.1 Support conditions. A cured unit shall be simply supported by 2-inch-diameter cylindrical supports located 2 inches in from each end and extending the full width of the unit.

Section 2114.19.5.2 Loading conditions. A 2-inch-diameter cylinder shall be placed at mid-span parallel to the supports.

Section 2114.19.5.3 Testing procedure. A vertical load shall be applied to the cylinder at the rate of 500 pounds per minute until failure occurs.

Section 2114.19.5.4 Modulus of rupture determination. The modulus of rupture shall be determined by the formula:

$$Fr = 3WLs/2bt^2 \quad (\text{Equation 2114.19.5.4})$$

Where, for the purposes of this section only:

b = Width of the test specimen measured parallel to the loading cylinder, inches.

fr = Modulus of rupture, psi.

Ls = Distance between supports, inches.

t = Thickness of the test specimen measured parallel to the direction of load, inches.

W = The applied load at failure, pounds.

Section 2114.19.6 Absorption less than 2.5%. A 4-inch cube, cut from an adobe unit fired to a constant weight in a ventilated oven at 212 degrees F to 239 degrees F, shall not absorb more than 2 ½ percent moisture by weight when placed upon a constantly water-saturated, porous surface for 7 days. A minimum of five specimens shall be tested and each specimen shall be cut from a separate unit.

Section 2114.19.7 Absorption less than 5.0%. A 4-inch cube, cut from an adobe unit fired to a constant weight in a ventilated oven at 212 degrees F to 239 degrees F, shall not absorb more than 5 percent moisture by weight when placed upon a constantly water-saturated, porous surface for 7 days. A minimum of five specimens shall be tested and each specimen shall be cut from a separate unit.

Section 2114.19.8 Additional requirements. All earthen units shall meet the following requirements:

1. Moisture content requirements. Earthen units shall have a moisture content not exceeding 4 percent by weight at the time of use.
2. Shrinkage cracks. All earthen units shall not contain more than three shrinkage cracks and any single shrinkage crack shall not exceed 3 inches in length or 1/8 inch in width.
3. Soil requirements. Soil used for moisture resisting adobe units and mortar shall be chemically compatible with the stabilizing material. The soil shall contain sufficient clay to bind the particles together without the aid of stabilizers. The soil shall contain not more than 0.2 percent of water-soluble salts.

Section 2114.19.9 Cement stabilized rammed earth. Cement stabilized Rammed Earth shall meet the following standards:

1. Testing before construction. The installer of cement stabilized Rammed Earth shall provide the following testing before issuance of a building permit.
2. Materials from a licensed sand and gravel producer. A copy of Proctor ASTM D 698 shall be provided for each soil type and source or combination of sources. Periodic testing as provided by the supplier may be supplied to meet this requirement. The soil shall contain not more than 0.2 percent of water-soluble salts.
3. Material mined and mixed on site. A copy of ASTM D 698, ASTM C 117, ASTM C 136, and ASTM D 4318 shall be provide for each soil type and source or combination of sources. Such tests shall be repeated

as required to assure that all materials to be used have been tested and are represented by the tests. The soil shall contain not more than 0.2 percent of water-soluble salts.

4. Testing required during construction. The installer of cement stabilized Rammed Earth shall provide the following tests made during the construction process. A certified testing laboratory shall provide field density tests for comparison to the pre-construction Proctor ASTM D 698, percent moisture ASTM D 2216, dry density ASTM D 698, and percent moisture ASTM D 1556. Cement Stabilized Rammed Earth walls shall meet or exceed 95% maximum dry density (ASTM D 698). Samples taken from the wall shall exceed 300 psi compression (ASTM D 1633) 14 days after placement.