1997 Uniform Administrative Code Amendment for Earthen Material and Straw Bale Structures
Tucson/Pima County, Arizona

"APPENDIX CHAPTER 71 - EARTHEN MATERIAL STRUCTURES

SECTION 7101 - GENERAL

7101.1 Purpose. The purpose of this chapter is to establish minimum standards of safety for the construction of earthen material structures, collectively known as adobe, rammed earth, puddled earth, hydraulic pressed earth construction, pneumatically applied earthen construction, or other methods of construction utilizing earth as a structural material.

7101.2 Scope. The provisions of this chapter shall apply to all earthen material structures not includin concrete as defined by Chapter 18 of this Code or masonry as defined by Chapter 21 of this Code.

7101.3 Definitions. For the purpose of this chapter, certain terms are defined as follows:

ADOBE is a wet molded earthen unit which is air dried to form a masonry unit which is laid into the structure after the unit is dried. The units shall be fully cured before being laid in the wall. Adobe masonry units shall comply with UBC Standard 71-1, Part I.

BURNT ADOBE is a low-fired adobe material.

HYDRAULIC PRESSED UNIT is a compacted earthen unit which is molded under pressure and air drie to form a masonry unit which is then laid into the structure.

MONOLITHIC EARTHEN ASSEMBLY is a constructed earthen structural system in which earthen materials are formed in place.

PUDDLED EARTH is a method of constructing a structure by molding saturated earth into place.

RAMMED EARTH is a Monolithic Earthen Assembly constructed by placing earthen materials in a form and compacting to form the structure.

STABILIZATION is the process of modifying the reaction of earthen materials to water, through the introduction of agents, as described in UBC Standard Sec. 71-1.

SECTION 7102 - MATERIALS

7102.1 General. The quality, testing, and design of earthen materials used structurally shall conform to the requirements specified in this chapter and in accordance with UBC Standard 71-1.

7102.2 Earthen Masonry Units. Masonry Units shall conform to the requirements specified in UBC Standard No. 71-1.

7102.3 Mortar. Mortar in assemblies utilizing Earthen Masonry Units shall be of the same material as the Masonry Unit, M or S type mortar, as specified in Chapter 21, or mortar that when formed into samples conforms to the requirements of paragraph (b) above.

7102.4 Monolithic Earthen Assemblies Materials used in Monolithic Earthen Assemblies shall, wher formed into sample cubes or cylinders, conform to the requirements specified in UBC Standard No. 71- Such assemblies shall be field tested, as determined by the Building Official, to assure compliance witl the UBC Standards.

7102.5 Stabilized Earthen Materials Stabilized earth materials shall meet the requirements of Sectio 71.1009.1 or 71.1009.2 of U.B.C. Standard 71-1 to be used in all locations of an earthen structure.

EXCEPTION: Materials not meeting the requirements of Section 71.1009.1 or 71.1009.2 of U.B.C. Standard 71-1 may be used when, in weather-exposed surfaces, moisture protection is provided by the equivalent of 3/4-inch portland cement plaster in accordance with Chapter 25 of this code. However, materials meeting the requirements of Section 71.1009.1 shall be used in at least the following locations

1. Within 4 inches of the floor of the structure.

2. At the top 4 inches of parapet walls.

3. Around roof drains or other areas where the probability of moisture is significant, as determined by the Building Official. At sites where the 50-year average rainfall is less than 6 inches per year, plaster protection may be omitted from weather-exposed surfaces.

SECTION 7103 - ALLOWABLE STRESSES

7103.1 General. Stresses in earthen material structures under service loads shall not exceed the valu given in Table 71-B.

EXCEPTION: The allowable stresses for the design of earthen material structures may be determined by testing in accordance with the following procedure.

1. A set of three prisms shall be tested in accordance with UBC Standard No. 21-19 prior to the start of construction.

2. During construction, a set of three prisms shall be built and tested in accordance with UBC Standard No. 21-19 for each 5000 square feet of wall area, but not less than one set of three prisms for the proje

3. The average ultimate strength of each set of prisms determined in accordance with UBC Standard 21-19 shall be not less than 8 times the compressive design stress used in the structure. Shear testing shall be performed in accordance with accepted engineering practices as approved by the Building Official.

SECTION 7104 - CONSTRUCTION AND GENERAL REQUIREMENTS

7104.1 General. Earthen material structures shall be classified in accordance with Chapter 6 of this code. Walls with a minimum thickness of 10 inches shall be deemed to have a fire resistive rating of tw hours.

7104.2 Maximum Height. Earthen material structures shall not exceed one story nor 16 feet in height unless the structure is designed in accordance with criteria as required by this code and approved by th Building Official and developed by an engineer or architect licensed by the State to practice as such.

7104.3 Allowable Loads. Earthen material structures shall be designed to withstand all vertical and horizontal loads as specified in Chapter 16.

7104.4 Construction. All earthen material walls shall be constructed in a safe and workmanlike mann for the construction method utilized. Masonry assemblies shall comply with the requirements of Sectior 2104.2 except items 3 and 4, Section 2104.3.3, and Section 2404.4.3.

7104.5 Thickness of Walls The thickness of earthen material walls shall be designed so that allowab maximum stresses specified in this chapter are not exceeded. All walls shall be designed free of uplift unless tensile reinforcement is provided. Walls meeting the height limits of Table No. 71-A and Table No.71-C may be considered to be uplift free. Reinforced earthen material walls shall be designed in accordance with acceptable engineering practice for the strengths of the materials utilized. Reinforcement used in earthen material structures shall be compatible with other materials in the assembly and protected against long term corrosive effects.

7104.6 Bracing. All earthen walls exceeding the height limits of Table No. 71-C which are part of an enclosed structure shall be laterally braced. Such bracing system shall be designed to resist the minimum lateral forces as indicated in Table No. 71-A unless other analysis is provided and approved by the Building Official.

7104.7 Lateral Support System One of the following methods shall be used to brace earthen materia walls.

1. A continuous reinforced concrete member at the top of the wall designed in conformance with Chapt 19 of this code. The concrete member shall be securely fastened to the wall when the allowable shear, as limited by Section 7104.9, is exceeded.

2. A continuous wood beam system securely fastened to the wall and designed in conformance with Chapter 23 of this code.

3. A roof diaphragm support system in conformance with Chapter 23 of this code, adequately secured to the wall.

4. Alternative lateral supporting methods properly analyzed and approved by the Building Official.

5. All earthen material walls used as part of the lateral force resisting system subject to inplane forces shall meet not less than one of the following requirements:

A. One section of the wall shall be without openings for a length of not less than 1.5 times the height.

B. One section of the wall shall be without openings for a length of not less than the height of the wall, and 9 gage horizontal reinforcing shall be provided at each course for the full height of the wall.

C. Structural calculations shall be provided which determine the tensile reinforcement requirements of the wall.

7104.8 Ledgers. Ledgers or other connections which produce moment loads on earthen material walls shall not be used without approved calculations demonstrating adequate load bearing capacity without undue deflection. Ledgers shall not be supported from bolts embedded in earthen materials.

7104.9 Shear. The allowable shear in any direction between a concrete lateral bracing member and a earthen material wall shall not exceed the following:

F_v = DL x .125 ..... (4-1)

WHERE: F_v = Allowable shear, psi.
DL = Dead load, psi.

7104.10 Bolts. Bolt values embedded in earthen materials shall not exceed those set forth in Table No 71-D.

7104.11 Flashing. When parapet walls of earthen materials are used, or when an earthen material wa extends above and is connected to a roof system, a thru-wall flashing or other positive moisture barrier shall be installed to prevent penetration of moisture into the building.

SECTION 7105 - MAXIMUM HEIGHT OF EARTHEN MATERIAL WALLS

7105.1 Laterally Supported. The maximum height of laterally supported earthen material walls shall comply with Table No. 71-A and shall be the distance between the points of horizontal lateral support.

7105.2 Other. The maximum height of earthen material walls within a structure which have no other form of support except at the base, shall be as specified in Table No. 71-C. The height of such walls sh be the distance between the top of the wall and the base.

SECTION 7106 - UNBURNED CLAY MASONRY (ADOBE)

7106.1 General. Adobe masonry or unburned clay units shall be classified as natural (raw) adobe and stabilized adobe and shall not be used in any building more than one story nor 16 feet in height unless design and structural calculations are submitted by an Arizona registered architect or engineer and approved by the Building Official. The unsupported height or thickness of every wall of these units shal be in accordance with Sec. 7105.

EXCEPTION. The earthen material portion of a patio wall not over 5 feet 6 inches high may be 8 inches thick.

7106.2 Foundation or Basement Walls. Adobe shall not be used for foundation (stem) or basement walls and shall have a footing complying with this code. Foundation (stem) walls which support masonry of unburned clay units shall extend to an elevation of not less than 6 inches above the adjacent ground at all points and shall be of the same thickness as the walls they support. The footing width and depth shall be governed by the allowable bearing pressure of the soil and allowable material stresses.

7106.3 Allowable Uses For Unburned Clay Masonry. Unburned clay masonry may be utilized for structures requiring seismic and lateral load resistance upon approval of submitted structural computations by an Arizona registered architect or engineer. Structures so designed shall resist all forces as determined by this code and shall not exceed the allowable stresses as provided by Tables No 71-A through No. 71-D and UBC Standard 71-1.

The minimum percentage of steel required for other masonry structures shall not be required; however, all tensile forces shall be resisted by tensile reinforcing.

7106.4 Lintels. Members supporting earthen material units shall be reinforced concrete, reinforced masonry, or steel. The wall may overhang the lintel a maximum of 2 inches on each face. Wood if used above openings, shall be for decorative trim purposes only.

Table 71-A
Maximum Allowable Height for Laterally Supported Unreinforced Earthen Walls

Wall Type	Thickness (inches)	Wind Pressure (psf) — Maximum Height of Wall Between Points of Support (feet)					
		0	14	16	18	20	22
Surcharge 0 (plf)	8	5.3	3.2	2.8	2.5	2.3	2.1
	10	5.9	5.1	4.4	3.9	3.5	3.2
	12	7.9	7.3	6.4	5.7	5.1	4.6
	14	9.2	9.2	8.7	7.7	7.0	6.3
	16	10.5	10.5	10.5	10.1	9.1	8.3
	18	11.9	11.9	11.9	11.9	11.5	10.5
	20	13.2	13.2	13.2	13.2	13.2	12.9
	24	15.8	15.8	15.8	15.8	15.8	15.8
Surcharge 100 (plf)	8	7.7	5.4	4.9	4.5	4.2	3.9
	10	8.7	7.1	6.4	5.8	5.4	5.0
	12	9.8	9.2	8.2	7.4	6.8	6.3
	14	10.9	10.9	10.4	9.4	8.6	7.9
	16	12.1	12.1	12.1	11.6	10.6	9.7
	18	13.2	13.2	13.2	13.2	12.9	11.8
	20	14.4	14.4	14.4	14.4	14.4	14.2
	24	16.0	16.0	16.0	16.0	16.0	16.0
Surcharge 200 (plf)	8	9.2	6.6	6.1	5.6	5.3	5.0
	10	10.2	8.4	7.7	7.1	6.6	6.1
	12	11.2	10.5	9.5	8.7	8.1	7.5
	14	12.2	12.2	11.7	10.6	9.8	9.1
	16	13.3	13.3	13.3	12.8	11.8	10.9
	18	14.4	14.4	14.4	14.4	14.0	13.0
	20	15.5	15.5	15.5	15.5	15.5	15.3
	24	16.0	16.0	16.0	16.0	16.0	16.0

Note: Heights above the heavy line are governed by wind.
Heights below the heavy line are governed by seismic.

Table 71-A (continued)
Maximum Allowable Height for Laterally Supported Unreinforced Earthen Walls

Wall Type	Thickness (inches)	Wind Pressure (psf) Maximum Height of Wall Between Points of Support (feet)					
		0	**14**	**16**	**18**	**20**	**22**
Surcharge 300 (plf)	8	10.5	7.7	7.0	6.5	6.1	5.8
	10	11.4	9.5	8.7	8.0	7.5	7.0
	12	12.4	12.4	10.6	9.7	9.0	8.5
	14	13.3	13.3	12.8	11.7	10.8	10.1
	16	14.4	14.4	14.4	13.9	12.8	11.9
	18	15.4	15.4	15.4	15.4	15.0	13.9
	20	16.0	16.0	16.0	16.0	16.0	16.0
	24	16.0	16.0	16.0	16.0	16.0	16.0
Surcharge 400 (plf)	8	11.6	8.5	7.9	7.3	6.9	6.5
	10	12.5	10.5	9.6	8.9	8.3	7.8
	12	13.4	12.7	11.5	10.6	9.9	9.3
	14	14.3	14.3	13.7	12.6	11.7	10.9
	16	15.3	15.3	15.3	14.8	13.7	12.8
	18	16.0	16.0	16.0	16.0	16.0	14.8
	20	16.0	16.0	16.0	16.0	16.0	17.1
	24	16.0	16.0	16.0	16.0	16.0	16.0

Note: Heights above the heavy line are governed by wind.
Heights below the heavy line are governed by seismic.

Table No. 71-B
Lateral Force on Bond Beams (plf) [1,2]

Wall Type	Thickness (inches)	Height to Bond Beam (ft)								
		8	9	10	11	12	13	14	15	16
Surcharge 0 (plf)	8									
	10									
	12	39								
	14	45	51							
	16	52	58	65						
	18	58	66	73	80	87				
	20	65	73	81	89	97	105			
	24	78	87	97	107	119	126	136	146	
Surcharge 100 (plf)	8									
	10	44								
	12	50	55							
	14	57	62	68	74					
	16	63	70	76	82	89				
	18	70	77	84	91	99	106			
	20	76	84	92	100	108	116	125		
	24	89	99	108	118	128	137	147	157	167
Surcharge 200 (plf)	8	48	52							
	10	55	59	63						
	12	61	66	71	76					
	14	68	73	79	85	90				
	16	74	81	87	94	100	107			
	18	81	88	95	103	110	117	124		
	20	87	95	103	111	120	128	136	144	
	24	100	110	120	129	139	149	158	168	178

Table No. 71-B (continued)
Lateral Force on Bond Beams (plf) [1,2]

Wall Type	Thickness (inches)	Height to Bond Beam (ft)								
		8	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
Surcharge 300 (plf)	8	60	63	66						
	10	66	70	74	83					
	12	73	77	87	87	92				
	14	82	85	90	96	102	107			
	16	86	92	98	105	111	118	124		
	18	92	99	107	114	121	128	136	143	
	20	98	107	115	123	131	139	147	155	163
	24	111	121	131	141	150	160	170	179	189
Surcharge 400 (plf)	8	71	77	77	81					
	10	77	85	85	90	94				
	12	84	89	94	98	103	108			
	14	90	96	106	107	113	119	124		
	16	97	103	110	116	123	129	136	142	
	18	103	111	118	125	132	140	147	154	161
	20	110	118	126	134	142	150	158	166	174
	24	123	132	142	152	161	171	181	191	200

[1] The bond beam of every wall shall be designed to resist the forces applied to the wall, out of plane.
[2] The combined forces from Table 71-c plusTable 71-d shall be used if greater than the forces from this table.

Table 71-c
Wind Force on Bond Beams from Parapet

Wind Force (psf)	Height above Bond Beam (ft)				
	1	**2**	**3**	**4**	**5**
14	14	28	42	56	70
16	16	32	48	64	80
18	18	36	54	72	90
20	20	40	60	80	100
22	22	44	66	88	110

Table 71-d
Wind Force on Bond Beams fromWalls

Wind Force (psf)	Height to Top of Bond Beam (ft)								
	8	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
14	42	47	53	58	63	68	74	79	84
16	48	54	60	66	72	78	84	90	96
18	54	61	68	74	81	88	95	101	108
20	60	68	75	83	90	98	105	113	120
22	66	74	83	91	99	107	116	124	132

Note: When determining wind force, all applicable factors shall be considered.

Table 71-e
Bending Moment on Bond Beams (Ft. Kips) [1]

Bond Beam	Span (ft.)												
Load (plf)	**10**	**12**	**14**	**16**	**18**	**20**	**22**	**24**	**26**	**28**	**30**	**32**	**34**
40	0.5	0.7	1.0	1.3	1.6	2.0	2.4	2.9	3.4	3.9	4.5	5.1	5.8
50	0.6	0.9	1.2	1.6	2.0	2.5	3.0	3.6	4.2	4.9	5.6	6.4	7.2
60	0.8	1.1	1.5	1.9	2.4	3.0	3.6	4.3	5.1	5.9	6.8	7.7	8.7
70	0.9	1.3	1.7	2.2	2.8	3.5	4.2	5.0	5.9	6.9	7.9	9.0	10.1
80	1.0	1.4	2.0	2.6	3.2	4.0	4.8	5.8	6.8	7.8	9.0	10.2	11.6
90	1.1	1.6	2.2	2.9	3.6	4.5	5.4	6.5	7.6	8.8	10.1	11.5	13.0
100	1.3	1.8	2.5	3.2	4.1	5.0	6.1	7.2	8.5	9.8	11.3	12.8	14.5
110	1.4	2.0	2.7	3.5	4.5	5.5	6.7	7.9	9.3	10.8	12.4	14.1	15.9
120	1.5	2.2	2.9	3.8	4.9	6.0	7.3	8.6	10.1	11.8	13.5	15.4	17.3
130	1.6	2.3	3.2	4.2	5.3	6.5	7.9	9.4	11.0	12.7	14.6	16.6	18.8
140	1.8	2.5	3.4	4.5	5.7	7.0	8.5	10.1	11.8	13.7	15.8	17.9	20.2
150	1.9	2.7	3.7	4.8	6.1	7.5	9.1	10.8	12.7	14.7	16.9	19.2	21.7
160	2.0	2.9	3.9	5.1	6.5	8.0	9.7	11.5	13.5	15.7	18.0	20.5	23.1
170	2.1	3.1	4.2	5.4	6.9	8.5	10.3	12.2	14.4	16.7	19.1	21.8	24.6
180	2.3	3.2	4.4	5.8	7.3	9.0	10.9	13.0	15.2	17.6	20.3	23.0	26.0
190	2.4	3.4	4.7	6.1	7.7	9.5	11.5	13.7	16.1	18.6	21.4	24.3	27.5
200	2.5	3.6	4.9	6.4	8.1	10.0	12.1	14.4	16.9	19.6	22.5	25.6	28.9
210	2.6	3.8	5.1	6.7	8.5	10.5	12.7	15.1	17.7	20.6	23.6	26.9	30.3

Table 71-e (continued)
Bending Moment on Bond Beams (Ft. Kips) [1]

Bond Beam	**Span (ft.)**												
Load (plf)	10	12	14	16	18	20	22	24	26	28	30	32	34
220	2.8	4.0	5.4	7.0	8.9	11.0	13.3	15.8	18.6	21.6	24.8	28.2	31.8
230	2.9	4.1	5.6	7.4	9.3	11.5	13.9	16.6	19.4	22.5	25.9	29.4	33.2
240	3.0	4.3	5.9	7.7	9.7	12.0	14.5	17.3	2.03	23.5	27.0	30.7	34.7
250	3.1	4.5	6.1	8.0	10.1	12.5	15.1	18.0	21.1	24.5	28.1	32.0	36.1
260	3.3	4.7	6.4	8.3	10.5	13.0	15.7	18.7	22.0	25.5	29.3	33.3	37.6

[1] Assumes single span.

Table 71-f
Capacity of Concrete Bond Beams (ft Kips)[1]
4.75 inch Deep Bond Beams

Bond Beam	Number and Size of Reinforcing Bars							
Width (in)	2 - #4	2 - #5	4 - #4	2 - #6	4 - #5	4 - #6	6 - #5	6 - #6
5	0.7							
6	1.1							
7	1.5	1.7						
8	1.7	2.4						
9	2.0	3.1	3.2					
10	2.3	3.5	4.1					
11	2.5	3.9	5.1					
12	2.8	4.3	5.6	6.1	6.2			
13	3.1	4.7	6.1	6.7	7.5			
14	3.3	5.2	6.7	7.3	8.8			
15	3.6	5.6	7.2	7.9	10.3			
16	3.9	6.0	7.7	8.5	11.9			
17	4.1	6.4	8.2	9.1	12.8	13.6		
18	4.4	6.8	8.8	9.7	13.6	15.4		
19	4.7	7.2	9.3	10.2	14.4	17.3		
20	4.9	7.6	9.8	10.8	15.3	19.3		
21	5.2	8.0	10.4	11.4	16.1	21.5		
22	5.5	8.5	10.9	12.0	16.9	23.8		
23	5.7	8.9	11.4	12.6	17.7	25.2	26.1	
24	6.0	9.3	12.0	13.2	18.6	26.3	27.8	28.6

Bond beams above line are controlled by beam size

[1] f _c = 2,500 psi
f _s = 18,000 psi
fc = 0.35 fc

n = 12
j = 0.887
k = 0.368

$M = Rbd^2$

where R = 141.2

Table 71-f (continued)
Capacity of Concrete Bond Beams (ft Kips)[1]
9.5 inch Deep Bond Beams

Bond Beam Width (in)	Number and Size of Reinforcing Bars							
	2 - #4	**2 - #5**	**4 - #4**	**2 - #6**	**4 - #5**	**4 - #6**	**6 - #5**	**6 - #6**
5	0.9	1.4						
6	1.2	1.9	2.3	Bond beams above line are controlled by beam size				
7	1.5	2.3	2.9	3.2	3.4			
8	1.7	2.7	3.5	3.8	4.8			
9	2.0	3.1	4.0	4.4	6.2	6.4		
10	2.3	3.5	4.5	5.0	7.0	8.2		
11	2.5	3.9	5.1	5.6	7.8	10.2		
12	2.8	4.3	5.6	6.1	8.7	12.3	12.5	
13	3.1	4.7	6.1	6.7	9.5	13.5	14.2	15.0
14	3.3	5.2	6.7	7.3	10.3	14.6	15.5	17.7
15	3.6	5.6	7.2	7.9	11.1	15.8	16.7	20.6
16	3.9	6.0	7.7	8.5	12.0	17.0	17.9	23.8
17	4.1	6.4	8.2	9.1	12.8	18.1	19.2	27.2
18	4.4	6.8	8.8	9.7	13.6	19.3	20.4	29.0
19	4.7	7.2	9.3	10.2	14.4	20.5	21.7	30.7
20	4.9	7.6	9.8	10.8	15.3	21.7	22.9	32.5
21	5.2	8.0	10.4	11.4	16.1	22.8	24.1	34.2
22	5.5	8.5	10.9	12.0	16.9	24.0	25.4	36.0
23	5.7	8.9	11.4	12.6	17.7	25.2	26.6	37.8
24	6.0	9.3	12.0	13.2	18.6	26.3	27.8	39.5

[1] f _c = 2,500 psi
f _s = 18,000 psi
fc = 0.35 fc

n = 12
j = 0.887
k = 0.368

$M = Rbd^2$

where R = 141.2

Table No. 71-g
Allowable Shear on Bolts Embedded In Earthen Material Assemblies
(See Section 7104.1. Ledgers shall not be supported from bolts in earthen materials)
SEISMIC ZONE 2-A

BOLT DIAMETER (inches) [1]	MINIMUM EMBEDMENT (inches)	SHEAR (pounds)
5/8	12	200
3/4	15	300
7/8	18	400
1	21	500
1-1/8	24	600

[1] Bolts smaller than 5/8" diameter shall not be used to resist shear.

Table No. 71-h
Allowable Working Stress In Earthen Material Walls [1]

SEISMIC ZONE 2-A

Compression [2]	30 ps1
Shear [3]	4 ps1
Tension or uplift	0 psi

[1] Allowable stresses may be increased by 1/3 for wind and seismic loads as provided for in Section 2303(d).

[2] Allowable axial or flexural compressive stress in pounds per square inch of gross cross sectional area. The allowable working stress in bearing directly under concentrated loads may be 50 percent greater than this value.

[3] Allowable shear stress in pounds per square inch of the gross cross sectional area.

Table No. 71-i
Maximum Allowable Height [1]

SEISMIC ZONE 2-A

Wall Thickness (inches)	8	10	12	14	16	18	20	24
Wall Height (inches)	54	54	54	54	54	54	59	71

[1] Earthen material partitions supported only at the base, within an enclosed structure shall comply with this table.