APPROPRIATE BUILDING CODES AND SPECIFICATIONS FOR ADOBE CONSTRUCTION

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ABSTRACT

An examination of the existing regulations governing adobe construction, including the logic, shortcomings, and suggestions for appropriate change. A pragmatic approach is provided for the determination of parameters in the selection of materials, manufacturing techniques, significant testing, structural and physical requirements. These parameters recognize and are applied to meet practical economic, cultural, and social needs.

The formulation of building codes ia a perplexing task. Perhaps Hammurabi (ca 1700 B.C.) had the right idea when he wrote the first building code. It was very simple and direct. If a building collapsed and killed the owner, the builder was killed. If the collapse caused the death of the owner's son, the builder's son was likewise killed. With the limits imposed by our legal system, we cannot have such a simple solution.

Our task here is to determine what is currently required by law, what is important, and to offer acceptable practical limits for control. Building codes are formulated ostensibly for public safety and the maintainance of minimum construction quality standards. Often, however, specific details seem due to a number of other influences. Of primary importance is safety. Secondly perhaps the elusive term "quality". Other obvious input factors should include climate, local conditions, time tested local tradition, and other less clear considerations for social and economic conditions which might prevail for the area the code is to govern. When we attempt to formulate a national building code, for wide geographical use, it must necessarily ignore many of these influences. The authors of building codes frequently do not have first hand information on the practical use of locally specialized materials like adobe, little of local conditions, and logically must rely on standards for more conventional materials. Adobe does not neatly fit this pattern. The technology of adobe construction is a prime example where secondary factors assume prime importance.

Man has been using adobe for at least 10,000 years and it is currently used by a large percentage of the total population of the world today. Areas predominated by its use are more often in the underdeveloped countries of the world where its use is of vital economic importance. Very little accurate, documented, technology is available for adobe as a building material and logical reasons for these shortcomings are understandable.

For adobe to acheive its maximum effective use, the soil source must be close to the building site. The soil for the makeing of bricks and mortar must be useable as it occurs, with only minor modifications. If elaborate modifications procedures are required for its use, it then becomes too costly to consider. Consequently, standards must recognize the expected variations and determine acceptable limits. Tradition and successful use of adobe indicates very wide tolerance limits for the material, makeing the stablishment of narrow limits unrealistic.

Indigeneous builders of adobe structures historically had no access to testing laboratories we use today, but in their place developed a "seat of the pants" engineering and technology. The builder makes a value judgement based on his experience that a material was right or wrong, and what needed to be done to correct it, based on trial and error of the past. This personal judgement factor is unacceptable to the engineering community and regulatory officials, and some parameters must be established.

Building codes make use of technical engineering tests and can determine the requirements for beam strength, column size, shear value for bolts, etc., where consistency and quality control standards have been established. When we attempt to superimpose this technology on most adobe construction, it runs into serious difficulty. The soil source for bricks and mortar will vary considerably in material make-up and proportions. Tests on samples from buildings of great age (see Table A) show such a wide range of material proportions that it casts doubt on the necessity of making any tests at all. Richard Clough, in his examination of material qualities for adobe[1] concludes that "Mechanical analysis of a soil is not an infallible index to the soil's behavior in an earth wall". and quotes Schwalen that satisfactory bricks can be made from soils covering a wide range in texture and having a clay content varying between 9 and 28%. Comprehensive testing represents substantial expense, and in the light of wide tolerance limits, may have limited value. Local vernacular tradition seems to have its roots in sound practice. A common belief of worldwide scope is that adobe bricks must have straw to be sound. The mid Rio Grande valley of New Mexico, where adobe construction has been extensively practiced for centuries, has a well balanced, naturally occurring soil that requires little if any modification, and bricks are customarily made without straw. Clough further remarks that contradictory results have occurred in the testing of adobe bricks with and without straw, and that its presence does minimize shrinkage cracks during drying. It is my conclusion that straw is traditionally added to soils whose clay content is too high, a common occurrance. Shrinkage cracks result from too much clay, therefore areas with high clay soils require straw to minimize shrinkage cracks and make usable bricks.

Current building codes in various areas differ greatly in their requirements for "Unburned Clay Masonry" (adobe). The "Southern Building Code" (Southern Building Code Congress International, Inc. 1976 Ed. with 1977-78 revisions) makes no mention of this material. The "Uniform Building Code" (International Conference of Building Officials, Whittier, CA 1979 Ed.) in wide use in the western United States, recognizes the material but limits its regulation to four paragraphs, which are strongly restrictive. (see Figure 1.) The "One and Two Family Dwelling Code", 3rd Ed. 1979, a code compiled by several code authorities for residential construction makes no mention of Unburned Clay Masonry.

Various State, County, and Municipal bodies may be generally governed by the jurisdiction of one of the major codes, but add amendments or make substitutions in the light of local tradition or economic pressures. The State of New Mexico has adopted (Amendment #6, 4/15/80) the most comprehensive adobe code, which has been and is being adopted by other bodies (El Paso, TX, Tucson, AZ , and others). However, many of these bodies have modified the New Mexico Code, sometimes reflecting local climate and traditions, and sometimes adding regulations of concern to the author of the amendment. (see Appendix A for complete NM code)

Where the assumed f'_m exceeds 2600 pounds per square inch, field test in accordance with Section 2404 (c) 2 shall be required.

Unburned Clay Masonry

Sec. 2405. (a) General. Masonry of stabilized unburned clay units shall not be used in any building more than one story in height. The unsupported height of every wall of unburned clay units shall be not more than ten times the thickness of such walls. Bearing walls shall in no case be less than 16 inches. All footing walls which support masonry of unburned clay units shall extend to an elevation not less than 6 inches above the adjacent ground at all points.

(b) **Units.** At the time of laying, all units shall be clean and damp at the surface and shall have been stabilized with emulsified asphalt in accordance with U.B.C. Standard No. 24-14.

(c) **Laying.** All joints shall be solidly filled with Type M or S mortar. Bond shall be provided as specified for masonry of hollow units in Section 2411.

(d) **Stresses.** All masonry of unburned clay units shall be so constructed that the unit stresses do not exceed those set forth in Table No. 24-B. Bolt values shall not exceed those set forth in Table No. 24-C.

Gypsum Masonry

Sec. 2406. (a) **General.** Gypsum masonry is that form of construction made with gypsum block or tile in which the units are laid and set in gypsum mortar. Gypsum masonry shall not be used in any bearing wall or where exposed directly to the weather or where subject to frequent or continuous wetting.

(b) **Materials.** Gypsum masonry shall be gypsum block or tile laid up in gypsum mortar composed of one part gypsum and not more than three parts sand by weight.

(c) **Stresses.** All gypsum masonry shall be so constructed that the unit stresses do not exceed those set forth in Table No. 24-B when computed on the gross cross-sectional area.

(d) **Bond.** The bond in gypsum masonry shall conform to the requirements for bond in masonry of hollow units specified in Section 2411.

(e) **Method of Laying.** All units in gypsum masonry shall be placed in side construction with cells horizontal. The entire bearing surface of every unit shall be covered with mortar spread in an even layer, and all joints shall be filled with mortar.

Reinforced Gypsum Concrete

Sec. 2407. (a) **General.** Reinforced gypsum concrete and precast reinforced gypsum shall conform to U.B.C. Standard No. 24-12.

Reinforced gypsum concrete shall develop the minimum ultimate compressive strength in pounds per square inch set forth in Table No. 24-D when dried to constant weight, with tests made on cylinders 2 inches in

FIGURE 1. Uniform Building Code, 1979 Ed.

A Cross Index Matrix is appended to this paper (Appendix B) which makes comparisons between various code provisions and authorities. For the purpose of simplification and clarification of language, individual provisions have been simplified to key words and phrases that identify the intent of the specific provisions. The areas of specific regulation are briken down into six main headings, and varying requirements within each main heading are broken down into sub heads, and summarized in the Matrix.

A. Structures
B. Specifications For Untreated Bricks
C. Specifications For Treated Bricks
D. Foundations
E. Mortar
F. Plaster and Protective Coatings

Each of the six categories will be dealt with individually, indicating current provisions, areas of greatest importance, and points for discussion. In our determination of the value for each provision, it will be necessary to recognize the basic limitations imposed by the materials and technology, and to strive for adequate minimums. The key word is "adequate" rather than "best." The use of adobe may well be an economic necessity, and if we burden its use with provisions that might seem desireable for heroic applications, we may defeat our purpose. Many geographical areas have no codes, or do not enforce them, so our purpose here may be one of establishing "guidelines" rather than regulations.

A. Structures

Building Height is limited by most codes to a maximum of one or two stories. This would seem an arbitrary provision, reflecting perhaps a suspicion of the soundness of earth materials. Buildings in the Middle East of 60-80 ft. in height are common.

Wall Height-Thickness Ratios are specified in some codes. Most restrict the unsupported height of a wall to a maximum of ten times the wall thickness. No measurements are available for Middle East structures, but lower walls for higher structures are substantially thicker.

Wall Length Without Cross Support is an important consideration, particularly when considered with wall height/thickness ratios. The seismic implication of these are significant.

Wall Thickness is related to brick size, wall height, and other factors above. Single brick walls are common, where bricks are 10" (25 cm) or more, the mass providing stability. Good masonry practice would reccomend multiple brick walls.

Brick Bonding (overlap) is specified as a minimum of 4" (10cm) in most codes, and surprisingly seems to be the standard in the Middle East as well. Efficient brick size would generate at 50% bond (one half brick).

Tie Beams are a basic part of good masonry practice. Codes vary in requirements for adobe walls, but most allow either wood or concrete, functioning doubly as a plate to support roof and floor structures, and as a "collar beam" to prevent wall separation at the corners. Another consideration not dealt with by most codes is the attachment of the tie beam to the top of the wall. Some determination of uplift wind forces acting on the roof structure and seismic forces needs be made. Some authorities accept the weight of the roof structure, tie beam, and parapet wall above the tie beam as sufficient anchorage.

Attachment of Roof Structures must be considered, possibly in conjunction with the tie beam.

Lintels are a necessary part of any masonry wall, and often the flat-arch effect is ignored in determining lintel strength requirements.

Attachment of Abutting Frame Walls requirements vary from "adequate" attachment to detailed directions specifying bolt size and spacing.

Piers and Columns of adobe brick are generally required to have minimum dimensions, reflecting multiple brick construction.

Parapet or Fire Walls are common in some architectural styles and not in others. If these are of masonry, they can act significantly to add weight anchorage for roof structures.

Earthquake Regulations are not generally delineated specifically for adobe construction, but in general structural requirements, which will vary with Earthquake Hazard Zone designation. The State of California, for example (Zone 4) enforces reinforcement requirements, while The State of New Mexico (Zone 1-2) makes no requirement.

B. Specifications for Untreated Bricks

The soil used for both bricks and mortar will be made up of five major elements: Gravel, Coarse Sand, Fine Sand, Silt, and Clay. These might be compared to concrete, with the Gravel and Coarse Sand representing the aggregate, the Fine Sand and Silt representing Sand, and the Clay representing the Cement. A major difference between adobe and concrete drying and curing however, is that where concrete represents a chemical action, adobe is purely a physical one. In the most general terms, a high percentage of clay makes the bricks less subject to water erosion, but can cause shrinkage cracks and a loss of strength. A high percentage of sand reduces cracking, increases strength, but makes the bricks more subject to erosion.

Aggregate Size might seem to be important, allthough many examples of usable adobes can be found where a large percentage of coarse gravel and stones of 1" diameter or more occur. It is common practice to remove by hand, only the large stones. Screen-

ing to control the particle size will add greatly to the cost of the bricks, and reduce the economic effectiveness of this material. A balance between quantities and proportions of gravel, sand and clay obviously must be considered, and tolerable limits, however wide, must be determined.

Clay Types are not generally noted in codes, and might seem to be a matter for concern, because some types are highly expansive when moistened, as in the case or Montmorillinite, or relatively inert as in Kaolinite clays. Determination of clay types, by X-Ray diffraction, is a costly procedure, and may not be necessary. The testing of a number of samples from obviously successful adobe buildings of considerable age was done by the National Park Service Soils Laboratory in Tucson, AZ. Table "A" indicates the wide range limits found.

Brick Size will vary with locality, local custom, and the materials available to the builder, and are seldom specified in codes. A common size for the mid Rio Grande valley is 10"x4"x14" (25 x 10 x 35 cm). Any size might be possible, determined by the curing time (thickness) and handling weight for efficient construction. Older bricks tended to be somewhat larger and current sizes in the Middle East and North Africa are somewhat smaller.

Compressive and Tensile Strength are emphasized by current codes. Of major importance would be the compressive strength to support loads imposed by the wall and roof structure weights. Tensile strength (modulus of rupture) would represent toughness of the bricks required for handling and stacking. Most codes require a compressive strength of 300 psi, but historic examples[3] have been tested as low as 109.5 psi. Simple calculations will show that in most instances, actual compressive loadings are less than 10 psi. It might appear that compressive strength requirements are excessive. Representative testing of New Mexico adobe bricks is given in Table B.

Curing Time requirements will vary with climatic conditions. Some codes address this with minimum time requirements for cureing, but bricks that are not cured cannot be handled or stacked, so this provision may not be required.

Water For Mixing is seldom addressed by code requirements, but can be significant. Water with a high slat content (in solution) may re-crystalize during drying, causing structural damage to the bricks.

C. Specifications for Treated Bricks

In addition to the testing outlined for untreated bricks, qualifications for the designation of "treated" bricks include qualities limiting moisture absorption and resistance to erosion. Allthough some codes do not specifiy the type of stabilizer, the most successful in terms of practicality and cost considerations would seem to be asphalt emulsions. The amount of stabilizer required to meet "treated" standards will vary with the basic soil qualities, thus the test standards must be met.

TABLE A-1.

Soil Material Composition
Adobes-Mortar-Mud Plaster
Average Percent of Total Sample

	Gravel	C. Sand	F. Sand	Silt	Clay	Porosity (Mortar Samples)
TUMACACORI, AZ.[1]						
Adobes ① 10 Samples	14.4	20.2	24.8	27.8	13.9	32.3
② 8 Samples	10.7	23.7	30.1	25.8	9.7	33.1
③ 12 Samples	10.5	22.7	28.9	27.0	11.2	34.6
④ 8 Samples	12.1	24.4	29.8	24.9	9.0	31.0
⑤ 13 Samples	8.0	18.6	30.1	26.7	18.0	34.2
⑥ 10 Samples	8.22	19.7	29.4	31.1	11.5	—
GALLISTEO, NM — Soil Source	6.0	10.0	43.0	34.0	7.0	—
Fire Bricks	2.5	2.5	25.0	49.0	21.0	—
JEMEZ SPRINGS, NM — Mud Plaster	5	6	51	26	12	—
	12.5	18.6	23.2	36.1	9.6	—
TRAMPAS, NM — Mud Plaster	4.6	5.4	14.4	50.5	25.1	—
	10.6	21	23.1	28.3	17.0	—
OJO CALIENTE, NM — Mud Plaster	.3	9.0	24.9	48.1	17.7	—
GUNNISON, CO — Inter Mud Plaster	0	12	51	21	16	—
SASABE, MEXICO — (Worn Clay Used for Mixing)	1.9	23.1	28.9	16.3	29.8	—
(Std Soil/Bricks)	7.9	17.1	16	40.9	18.1	—
AVERAGE	7.2	15.8	29.6	32.1	15.4	33.0

1. TUMACACORI MISSION BUILT CA 1820 AD

NOTE: Definition of particle size not given.

TABLE A-2.

Soil Material Composition
Adobes-Mortar-Mud Plaster
High/Low percent of Total Sample

	GRAVEL		C. SAND		F. SAND		SILT		CLAY	
	Hi	Low	Hi	Low	Hi	Low	Hi	Low	Hi	Low
TUMACACORI ①	37	6	29	11	35	16	39	14	17	9
②	30	4	30	16.5	45	28	43	16	17	1
③	25	2	26.5	14	40.5	18	39	19	25	5
④	26	3	34	20	39	22	35	17	14	5
⑤	19	1	23	15	41.5	19	41	20	24	11
⑥	21.8	4.4	28	11.3	44.2	22.4	40.9	16.2	14.7	7.1
TOTAL 61 AVG	26.4	3.4	28.4	14.6	40.9	19.7	39.6	16.0	19.3	6.4

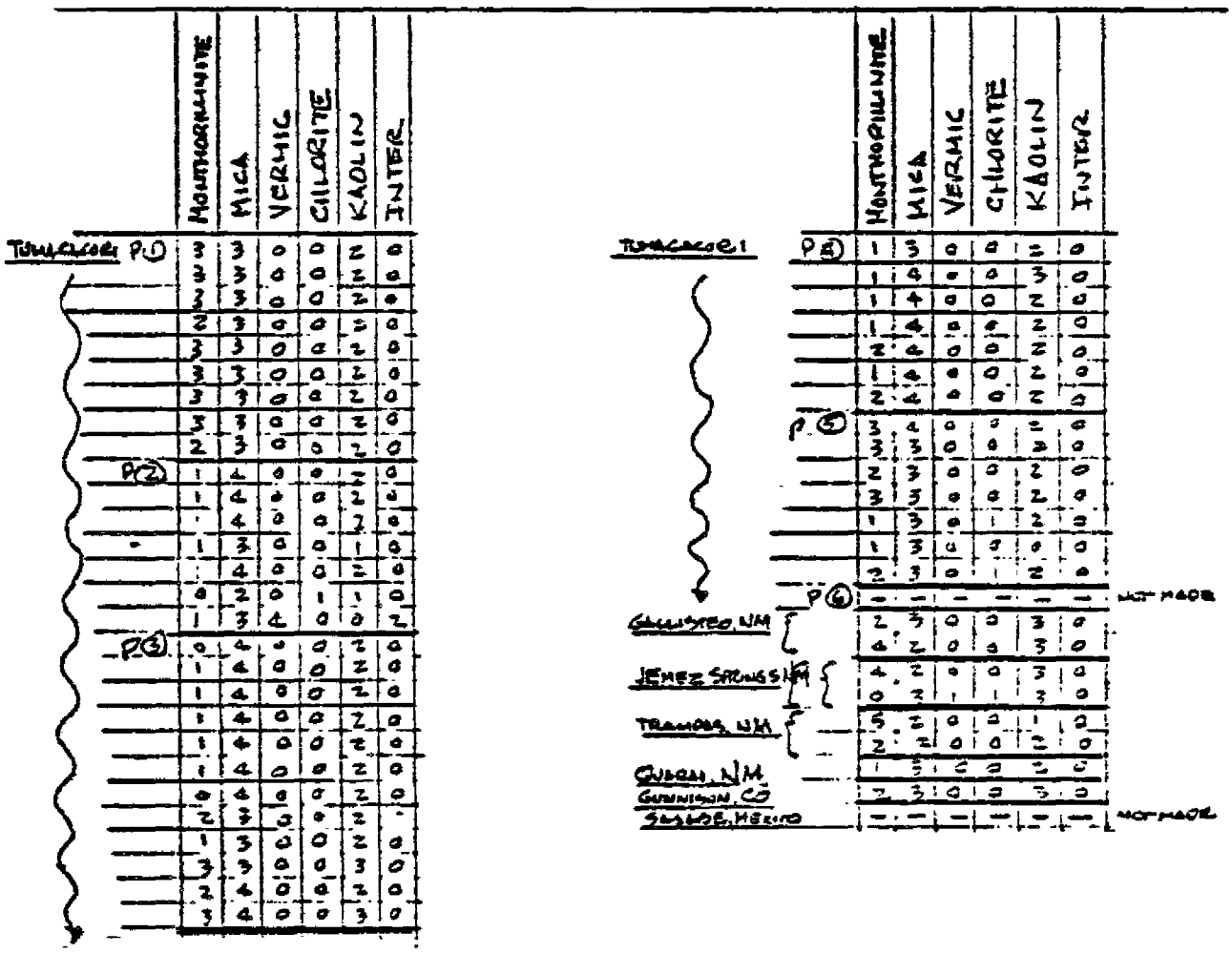
CONCLUSIONS - SOIL COMPOSITION VARIES WIDELY WITH LITTLE EFFECT
AVERAGES FROM 71 SAMPLES
Hi/LOW FROM 61 SAMPLES (TUMACACORI)

		%	NOTE
GRAVEL	Hi	26.4	
	LOW	3.4	
	AVG	7.2	- LOWER % IN PLASTERS
C. SAND	Hi	28.4	
	LOW	14.6	
	AVG	15.8	
F SAND	Hi	40.9	
	LOW	19.7	
	AVG	29.6	
SILT	Hi	39.6	
	LOW	16.0	
	AVG	32.1	
CLAY	Hi	19.3	
	LOW	6.4	ONE SAMPLE ① WITH 1% CLAY INDICATED SEVERE EROSION
	AVG	15.2	SLIGHTLY HIGHER IN PLASTERS
POROSITY	Hi	—	
	LOW	—	
	AVG	33.0	

NOTE: Definition of particle size not given.

TABLE A-3.

Soil Material Composition
Adobes-Mortar-Mud Plaster
Types of Clay Found



CODE:
5. Dominant
4. Large Amount
3. Medium Amount
2. Small Amount
1. Trace
0. Looked for, none found

TABLE B

SUMMARY OF PHYSICAL PROPERTY TESTS OF THE LARGE SCALE ADOBE PRODUCERS*

ADOBE PRODUCERS **	TYPE ADOBE BRICK	SIZE (In Inches)	AVERAGE ADOBE WEIGHT IN LBS.	COMPRESSIVE STRENGTH(psi)	MODULUS OF RUPTURE(psi)	WATER ABSORPTION (percent by weight)	MOISTURE CONTENT (percent by weight
New Mexico Earth Alameda, New Mexico	Traditional Semi-Stabilized Stabilized	10x4x14 10x4x14 10x4x10	30 30 32.4	409 499	66 89	11.6 1.3	0.9 0.6
Adobe Enterprises, Inc. Albuquerque, New Mexico	Semi-Stabilized Stabilized	10x4x14	30				
Eight Northern Indian Pueblos San Juan Pueblo, N.M.	Semi-Stabilized Stabilized	10x4x14 10x4x14	30.3 31.6	317 382	99 71	4.3 6.0	0.9 1.0
The Adobe Patch Alamogordo, New Mexico	Stabilized	10x4x14	33.8	578	157	2.2	0.6
The Adobe Farm Espanola, New Mexico	Semi-Stabilized	10x3½x14	33	322	82	2.1	1.1
Victor Montano Santa Fe, New Mexico	Traditional	10x3½x14	30	438	46	N/A	N/A
Western Adobe Albuquerque	Semi-Stabilized	10x4x14	32	456	96	N/A	1.0
Eloy Montano Santa Fe, New Mexico	Traditional	10x3 3/4x14	30	320	42	N/A	N/A
Manual Ruiz Corrales, New Mexico	Traditional	10x4x14	30	311	55	N/A	N/A
Rio Abajo Adobe Works Belen, New Mexico	Semi-Stabilized Stabilized	10x4x14 10x4x14	30 27	486	101	1.8	0.76

*- Specification requirements for U.B.C. and New Mexico State Adobe Code:

Compressive Strength: average of 5 bricks- 300 p.s.i. minimum
1 out of 5 bricks- 250 p.s.i. minimum
Modulus of Rupture: average of 5 bricks- 50 p.s.i. minimum
7-Day Water Absorption: 2.5% maximum by weight
Moisture Content: 4.0% maximum by weight

**Note: Test Results are from limited sampling of adobe bricks from each adobe yard and may not be representative of the total annual production averages. The N.M.adobe code recommends testing of samples selected at random from each 25,000 bricks produced.

D. Foundations

Basement and Foundation Walls are generally prohibited by code. Moisture infiltration into mud brick walls robs them of their compressive strength when unsupported on the sides, and can cause collapse. Below grade walls should be impervious to moisture.

Foundation Wall Height and Thickness generally are required to be the same thickness as the wall supported, and are to extend 6" - 8" above exterior finished grade. Capillary action, rain splash, and salt re-crystalization cause extensive damage at the base of adobe walls.

Footings for adobe walls are usually given the same design considerations as any other type of wall construction. Historic structures would seem to have inconsistent patterns, often using adobe bricks or stone. Current codes require steel reinforced concrete, consistent with conventional building details, but taking note of possible increased weight of the wall. It may be significant that early foundations of stone were less rigid, and could more readily absorb movements in the wall and supporting ground without extensive wall damage.

E. Mortars

Mud Mortar is most commonly made from the same soil sources used for bricks, and subject to the same criteria, with one exception. The mud mix must be free of all but the smallest stones. The presence of stones in the mortar mix will prevent the even bedding of the bricks as laid. Stones of 1/4" or larger must be removed by screening, or removed as the mortar bed is laid up. If stabilized bricks are used, it would seem desirable that the mortar be stabilized as well. Untreated mud, if of the right proportions, will adhere to the mud brick surfaces, making a homogenous mass, unlike conventional bricks and mortar. Problems of adhesion sometimes occur between stabilized surfaces, perhaps from an oxidation of the older surface.

Surfaces to receive a mortar bed should be solid, free of dust and friable particles, and perhaps damp. Most codes specify that the surface be "clean and damp", but the common practice of spraying stacks of bricks of conventional masonry would not be suitable for adobe. Common practice avoids the dampening step and uses a slightly wetter mortar.

Types S and M Mortar may also be used, but it increases the cost and the wall loses its homogenuity. An advantage of conventional mortars is the increased laying speed, as mud mortar requires more drying time, restricting the number of courses laid up each day in one location.

Joints are differentiated in some codes between adobe walls that are to be plastered, and those to be left exposed. If the wall is to be plastered, open or partially filled head joints are allowable and desirable to offer a key for supporting the plaster

coat. Joints in walls to be unplastered need to be carefully filled and smoothed, with solid head joints. All codes specify, if mentioned, that bedding joints shall be full slush (solid) joints.

F. Plastering

Exposed Adobe Walls, even though unprotected, are resistant to rainfall. It has been measured[4] at approximately 1" per 20 years, in areas where rainfall is 10" to 20" per years. Exposed brick walls or mud plaster are viable as an economic alternative, where little possibility for flooding exist.

Cement Stucco is required by most codes. It is normally applied over galvanized stucco netting, attched to the wall at specific intervals. The cement stucco provides a waterproof coating that limits erosion of the mud surface. It also has the negative effect of concealing any moisture and erosion of the wall from leaking roofs and scuppers which allow water seepage into the wall underneath the stucco. If these leaks go undetected, damage can occur to the wall that can lead to structural collapse without warning. In flood prone locations, cement stucco and interior cement or gypsum plaster is a desirable treatment. Severe flooding and standing water will immediately destroy most unprotected adobe walls, while waterproof plaster will save the structure.

Mud Plaster is a traditional treatment that functions well except in areas prone to flooding mentioned above. It is not allowed by most codes, which insist on cement stucco, or stabilized bricks and mortar.

Stabilized Plaster is not mentioned in existing codes, but may offer a viable exterior wall finish. Problems with existing applications sometimes occur in terms of lack of adhesion between subsequent layers.

Motel shall mean hotel as defined in this code.

Sec. 420. "S"

Sec. is the abbreviation for Section as referred to in this code.

TELEPHONES

Sec. 1713. Where public telephones are provided, at least one shall be installed so that the handset, dial and coin receiver are within 48 inches of the floor. Unobstructed access within 12 inches of the telephone shall be provided. Such access shall be not less than 30 inches in width.

AMENDMENT 6: CHAPTER 24 - MASONRY

UNBURNED CLAY MASONRY

Sec. 2405. (a) General. Masonry of unburned clay units shall not be used in any building more than (2) stories in height. The height of every laterally unsupported wall of unburned clay units shall be not more than 10 times the thickness of such walls. Exterior walls, which are laterally supported with those supports located no more than 24 feet apart, are allowed a minimum thickness of 10 inches for single story and a minimum thickness of 14 inches for the bottom story of a two story with the upper story allowed a minimum thickness of 10 inches. Interior bearing walls are allowed a minimum thickness of 8 inches.

(b) Compressive Strength. The units shall have an average compressive strength of 300 pounds per square inch when tested in accordance with ASTM C-67. One sample out of five may have a compressive strength of not less than 250 pounds per square inch.

(c) Module of Rupture. The unit shall average 50 pounds per square inch to modulus of rupture when tested according to the following procedure:

PROCEDURES:

(1) A cured unit shall be laid over (cylindrical) supports two inches (2") in diameter, located two inches (2") from each end, and extending across the full width of the unit.

(2) A cylinder two inches (2") in diameter shall be laid midway between and parallel to the supports.

(3) Load shall be applied to the cylinder at the rate of 500 pounds per minute until rapture occurs.

(4) The modulus of rupture is equal to $\frac{3WL}{2Bd^2}$

W = Load of rupture
L = Distance between supports
B = Width of brick
d = Thickness of brick

(d) Soil. The soil used shall contain not less than 25 percent and not more than 45 percent of material passing a No. 200-mesh sieve. The soil shall contain sufficient clay to bind the particles together and shall not contain more than 0.2 percent of water-soluble salts.

Most clayey loams, except those with a high clay content, are suitable, but it is not practicable to make a selection on the basis of soil analysis only. Soil having a high clay content shrink or crack badly when drying, and sandy soils do not have sufficient banding material to prevent crumbling. Neither of these soils should be used alone for brick, but a very good building material can be obtained by mixing the two soils together in proportions that will overcome the undesirable qualities of each. The best way to determine the fitness of a soil is to make a sample brick and allow it to cure in the open, protected from moisture. It should dry without serious warping or cracking.

(e) Classes of Adobe

ADOBE TYPES: (1) Treated Adobes. The term "treated" is defined to mean adobes made of soil to which certain admixtures are added in the manufacturing process in order to limit the adobe's water absorption in order for it to comply with paragraph (h) below. Exterior walls constructed of treated adobe require no additional protection. Stucco is not required. In order for the wall to so comply, the mortar must be of Type S of adobe soil treated with an additive to make the mortar comply with the same water absorption requirement in paragraph (h) below.

(2) Untreated Adobes. Untreaded adobes are adobes which do not meet the water absorption specifications of paragraph (h) below. This shall hold even if some water absorption protection agent has been added. The determination as to whether an adobe is treated or untreated is to test for compliance with paragraph (h) below. Exterior walls of untreated adobe are allowed but must comply with paragraphs (o) requiring Portland cement plaster applied to the outside. Use of untreated adobes is prohibited within 4 inches above the finished floor grade. Treated adobes may be used for the first 4 inches above finished floor grade. Mortar must be Type S (or masonry mortar) or adobe soil (either treated or untreated.

(f) **Sampling.** Each of the tests prescribed in this Section shall be applied to five sample units selected at random from each 25,000 bricks to be used.

(g) **Moisture Content.** The moisture content of the unit shall be not more than four percent by weight.

(h) **Absorption.** A dried four-inch (4") cube cut from a sample unit shall absorb not more than two and one-half percent moisture by weight when placed upon a constantly water saturated porous surface for seven (7) days.

(i) **Shrinkage Cracks.** No units shall contain more than three shrinkage cracks, and no shrinkage crack shall exceed three inches (3") in length or one-eighth inch (1/8") in width.

(j) **Use.** No adobe shall be laid in the wall for at least three (3) weeks after making, dependent on weather conditions.

(k) **Foundations.** Adobes shall not be used for foundation or basement walls. All adobe walls, except as noted under Group M Buildings, shall have a continuous concrete footing at least eight inches (8") thick and not less than two inches (2") wider on each side than the foundation walls above. All foundation walls which support adobe units shall extend to an elevation not less than six inches (6") above the finish grade.

Foundation walls shall be at least as thick as the exterior wall as specified in Section 2405 (1). Where stem wall insulation is used, a variance is allowed for the stem wall width to be two inches (2") smaller than the width of the adobe wall it supports.

(l) **Exterior Walls.** All walls of adobe (treated or untreated) shall not have thicknesses less than that allowed in paragraph (a) above. Mortar shall be in accordance with paragraph (e1) and (e2) above depending on the class of adobe being used. All adobe brick shall be laid up with full slush (bed) joints and shall be bonded (overlapped) not less than 4 inches. Walls of treated adobe which do not require a protective outer coating must also be laid up with full head (end) joints. All exterior adobe walls shall be topped with a continuous belt course or tie beam (except patio walls less than 6' high above stem). At the time of laying, all units shall be clean and damp at the surface.

(m) **Concrete Tie Beam.** Shall be minimum size six inches (6") by width of wall up to a ten inch (10") width. For walls thicker than ten inches, a ten inch (10") tie beam will suffice. All concrete tie beams shall be reinforced with a minimum of two No. 4 reinforcing rods each floor and ceiling plate line.

(n) **Wood Lintels or Tie Beams.** Shall be minimum size six inches (6") by wall width up to a ten inch (10") width. For walls thicker than ten inches, a tie beam of ten inch (10") thickness shall suffice. The wooden tie beam shall be overlapped, or spliced, at least six inches (6") at all joints. All joints shall have a wall bearing of at least twelve inches (12"). Wood tie beams may be solid in the six inch (6") dimension or may be less than one inch (1"). Wood joints, vigas or beams shall be spiked to the wood tie beam with large nails or large screws. All lintels, wood or concrete, in excess of nine feet (9') shall have specific approval of the building official.

(o) **Plastering.** All untreated adobe shall have all exterior walls plastered on the outside with Portland cement plaster, minimum thickness ¾" in accordance with Chapter 47. Protective coatings other than plaster are allowed provided such coating is equivalent to Portland cement plaster in protecting the untreated adobes against deterioration and/or loss of strength due to water. Metal wire mesh minimum 20 gauge by one inch (1") opening shall be securely attached to the exterior adobe wall surface by nails or staples with minimum penetration of one and one-half inches (1½"). Such mesh fasteners shall have a maximum spacing of sixteen inches (16") from each other. All exposed wood surfaces in adobe walls shall be treated with an approved wood preservative before the application of wire mesh. No adobe bricks shall be used for isolated piers, porch columns or wall section of less than 25" x 10". A minimum twelve inch (12") wall section will be permitted between openings provided a continuous lintel of concrete or timber be installed spanning both openings and wall section.

EXCEPTION:

(1) Exterior patio, yard walls, etc., need not have Portland cement coating.

(p) **Floors and Roofs.** Floors and roofs may be constructed of wood, the sizes and spans to be in accordance with Chapter 25.

(q) **Floor Area.** Allowable floor area shall not exceed that specified under Occupancy (Part III). Adobe construction shall be allowed the same area as given in Table No. 5-C, Type V construction, Column N.

(r) **Wood Partitions.** Partitions of wood shall be constructed as specified in Chapter 25, wood partitions shall be nailed to nailing blocks laid up in the adobe wall or bolted through the adobe wall the height of the partition with ⅛" bolts @ 24" on center with large washers or plates.

(s) **Stop work.** The Building Official shall have the power to stop work whenever adobes have not been thoroughly cured and shall give prior approval to the use of any hardeners, stabilizers or other so-called preservatives.

ANALYSIS AND COMPARISON OF BUILDING CODES FOR UNBURNED CLAY MASONRY (ADOBE)

CODE MATRIX

In order to make a more useful comparison, the building codes governing adobe construction have been synopsized to managable phrases or short descriptions. State, County and community variations are codified in a matrix code, so that comparisons may be more easily made. As the structures of most building codes are complex and differ in organization, the matrix code is broken down into six parts:

A. Structures
B. Specifications for bricks, general
C. Specifications for Treated Bricks
D. Foundations for adobe structures
E. Mortars for adobe bricks
F. Plastering of adobe structures

Certain portions of each code are similar, and perhaps some sub-categories might be unneccesary, but an effort was made to make fine distinctions where it seemed pertinent. The matrix code definitions follow, and the comparison sheets refer to matrix code designations. For a precise interpretation, it is suggested that the appropriate specific building code for the State, County, or cummunity be carefully examined. It should also be noted that in many instances, variations and exceptions to the code may be allowed, if sufficient justification can be shown.

A. STRUCTURES

A. 1. ...not to be used for more than 2 stories.

1.a....not to be used more than one story.

2. ...wall height not more than 10 times wall thickness (laterally unsupported)

2.a....wall height or length not more than 10 times wall thick.

3. ...exterior walls not more than 24 ft long (without cross wall)

3.a....when supported at ceiling line by joists or rafters. (wall length of 24 ft. is allowed)

4. ...minimum wall thickness 10 in. for single or upper story.

4.a....minimum exterior wall thickness not less than 10 in.

4.b....bearing wall not less than 16 in. thick.

5. ...minimum wall thickness 14 in.(lower wall of 2 story)

6. ...minimum wall thickness 8 in. for interior bearing walls.

7. ...not used

8. ...not used

9. ...brick bonding not less than 4 in.

9.a....brick bonding provided per Sec. 2104.7 or 2104.8

9.b....brick bonding as specified for hollow units (Sec. 2411 = 4")

9.c....brick bonding to be "running bond", 50% lap.

10. ...tie beams required for all exterior walls more than 6 ft. high.

10.a....Bond beams provide support and anchorage for roof structure. If of adobe, use continuous rows of joint re-inforcement between "required" number of courses to resist uplift forces.

A. STRUCTURES (cont.)

A. 10.b....all adobe walls to contain continuous tie beam at point of bearing.

11. ...tie beam of concrete 6 in. x wall thickness(to 10 in.) with 2 each #4 rebar at plate line.

12. ...tie beam of wood 6 in x wall thickness (to 10 in.) solid or spliced, 1 in. laminations, minimum over-lap 6 in.

12.a....protect all wood tie beams with preservative.

12.b....joists, vigas or beams spike or screw to tie beam.

13. ...lintel wall bearing not less than 12 in.

13.a....all lintels of wood or concrete over 9 ft. long require specific approval.

13.b....lintels to be of reinforced concrete, masonry or steel, an adobe overhang of not more than 2 in. each side is permitted.

13.c....all lintels to be designed in accordance with city code.

14. ...wood partitions to be attached to adobe walls with nailing blocks laid up with the wall, or through bolts, 1/2" D., 24 in. o.c. with large washers or plates.

14.a....ledgers and partitions bolt through wall with plate washers 1/8 in. x 4 in. x 4 in., Table 24-C for shear values.

14.b....Interior stud partitions to be adequately secured.

14.c....Bolt values not to exceed Table 24-C

15. ...inspector has power to stop work if bricks not cured and shall have power to approve stabilizers or so called preservatives.

16. ...not used

17. ...units must be stabilized with emulsified asphalt.

18. ...adobe not to be used for piers or columns in bearing capacity less than 24 in.

18.a....no isolated piers or columns less than 28 in. x 10 in. or a minimum of 12 in. is premitted if lintel over is continuous.

19. ...all adobe parapet walls shall be waterproofed.

A. STRUCTURES

A. 20. ...masonry wall shall comply with empirical requirements designed in conformance with approved requirements of Sec. 2106.

A. 21. ...top wall plates and anchor bolts designed to resist uplift forces, minimum 1/2"D x 20" imbedment, with 1/8" x 4" x 6" plates in adobe, 2"D washers on wood plates.

A. 22. ...fireplaces and chimneys of adobe shall be lined with firebrick not less than 4" thick.

A. 23. ...Floors and roofs of wood permitted, sizes and spans in accordance with Chap. 25

A. 24. ...allowable floor area not to exceed occupancy Part III, adobe allowed same area in Table 5-C, Type IV, Col.N

A. 25. ...Do not lay more than 10 courses per day with mud mortar.

A. 26. ...Every structure designed to resist seismic stresses (UBC Section 2312. (Earthquake Regulations)

B. SPECIFICATIONS FOR BRICKS

B. 1. ...compressive strength average 300 PSI (ASTM C-67)

B. 1.a....unit stresses not to exceed Table 24-B (30 PSI)

B. 2. ...one sample of 5 may have minimum 250 PSI

B. 2.a....one sample of 5 may have minimum 200 PSI

B. 2.b....five samples per 25,000

B. 2.c....five samples per 5,000

B. 3. ...Modulus of rupture average 50 PSI ($3WL/2Bd^2$)

B. 4. ...soil not less than 25% or more than 45% pass through a #200 mesh screen.

B. 4.a....soil to pass through a 1/4" screeen (100%) free from deleterious matter.

B. SPECIFICATIONS FOR BRICKS (cont.)

B. 5. ...soil to have sufficient clay to bind

B. 5.a....suitable mixture of soil, clay and stabilizing agent

B. 6. ...soil to contain not more than .20% water soluble salts.

B. 6.a....soil to contain not more than .10% water soluble salts

B. 7. ...most clayey loams suitable, not practical to make soil tests only.

B. 8. ...high clay or unsufficient clay soils may be mixed.

B. 9. ...make test bricks, to dry without serious warping or cracking.

B. 10. ...moisture content maximum 4% by weight

B. 11. ...not more than 3 shrinkage cracks 1/8" x 3"

B. 12. ...Minimum curing time 3 weeks

B. 12.a....sun baked 1 week, stack 2 weeks before use, or longer

B. 13. ...use potable water

B. 14. ...protect from moisture

B. 15. ...all units clean and damp for laying

C. SPECIFICATIONS FOR TREATED BRICKS

C. 1. ... certain admixtures to limit water absorption

C. 2. ...certain admixtures or emulsified asphalt to limit water absorption, to comply with Sec. 2405.(c)

C. 3. ...emulsified asphalt mixed to provide required resistance to moisture.

C. 4. ...a dried 4" cube, cut from brick, shall not absorb more than 2-1/2% moisture by weight when placed on a constantly water-saturated porous surface for 7 days.

C. 4.a....if sample absorbs more than 2-1/2%, are to be classified "unstabilized"

C. 5. ...soil must be compatible with stabilizing material

D. FOUNDATIONS FOR ADOBE STRUCTURES

D. 1. ...adobes not to be used for foundations or basement walls,except Group M buildings (garages, outbuildings,et

1.a....adobes not to be used for foundation or basement walls.

2. ...continuous concrete footing 8 in. thick x wall thickness plus 2 in. on each side.

2.a....continuous footing, width and depth governed by allowable soil bearing pressures and concrete strength.

3. ...foundation wall to extend 6 in. above finish grade.

3.a....foundation wall to extend 8 in. above adjacent ground.

4. ...foundation wall to be as thick as wall above, except may be reduced by 2 in. for perimiter insulation.

4.a....foundation wall to be as thick as wall above.

5. ..."treated" adobes to be used for 4 in. above finish floor.

5.a....no "raw" adobes used within 4 in. of finish floor.

E. MORTARS FOR ADOBE BRICKS

E. 1. ...for treated bricks, type S or treated mortar, with full slush bedding and head joints.

1.a....treated exterior walls without plaster are to have full head joints.

2. ...for untreated bricks use type S or untreated mortar with full slush bedding joints.

3. ...all joints solid with mortar

4. ...mud mortar to be the same as units, type M or S and acheive bond.

5. ...mortar type O or adobe soil mortar, treated or untreate

6. ...mortar type N or treated adobe soil mortar

7. ...mortar in accordance with adobe type.

8. ...all joints with type M or S mortar

9. ...fill all joints solid with type S or M mortar

F. PLASTERING FOR ADOBE STRUCTURES

F. 1. ...untreated brick exterior walls must be protected with Portland Cement plaster

F. 2. ...add to the above...3/4" thick...

F. 3. ...other treatment allowed if equivalent to Portland cement plaster

F. 4. ...stucco net required 20 ga. x 1", fastened 16" o.c. with 1-1/2" penetration of fasteners

F. 5. ...if wall 14" thick, mud plaster allowed

F. 6. ...use stucco net on wood surfaces to be plastered

F. 7. ...treat exposed wood under stucco net with preservative

F. 8. ...patio/yard walls do not require cement stucco

F. 9. ...untreated adobe exterior wall permitted without plaster if: Cornice cap drains to roof
Canales long enough to keep water off wal
Windcw sill brick or concrete with lip to prevent drip on walls.

F. 10. ...treated bricks for exterior walls with Type S or treated mortar do not require plaster protection.

PROVISIONS SUMMARY	NEW MEXICO (UBC)				ARIZONA (UBC)			TEXAS (-)		CALIFORNIA (UBC)	
	STATE CODE (UBC '79)	STATE MODIF. '76 - 1/1/80	CITY OF ALBQ (MOD)	CITY OF SANTA FE	CITY OF PHOENIX	CITY OF TUCSON (MOD.)		STATE CODE	CITY OF EL PASO (SUC. MOD)	STATE CODE (UBC-'79)	CITY OF LOS ANGELES (MOD)
(A) STRUCTURES								NO CONTRACTOR LICENSING OR PERMITS REQUIRED - CERTAIN CITIES HAVE ADOPTED BUILDING CODES		SEE CHART	
STABIL. REQD.	(A)17	–	–		–	–			–		–
BLDG. HT. ALLOWED	(A)1a	(A)1	(A)1		(A)1a, 20	(A)1a			–		(A)1a
WALL HT/THICK. RATIO	(A)2	(A)2	(A)2		(A)2	(A)2a			(A)2		(A)2
WALL LENGTH	–	(A)3	(A)3		–	(A)3a			(A)3		–
WALL THICKNESS	(A)4.4	(A)4.5.6	(A)4,5,6		(A)4.4	(A)4a			(A)4.5.6		(A)4.4
BRICK BONDING	(A)9.4	(A)9	(A)9		(A)9a	(A)9c			(A)9		(A)9.4
TIE BEAMS-CONC.	–	(A)10,11	(A)10,11		–	(A)10a			(A)10,11		–
TIE BEAMS-WOOD	–	(A)12	(A)12		–	–			(A)12,12a		–
ROOF STRUCT. ATTACH.	–	–	(A)13.4		–	–			–		–
PLATES	–	–	–		–	–			–		–
LINTELS	–	(A)13a	(A)13a		–	(A)13.4			(A)13c		–
WOOD PARTN. ATTACH.	–	(A)14	(A)14		–	(A)14a			(A)14.4		–
PIERS & COLS.	–	(A)18a	(A)18.4		–	–			(A)18		–
PARAPETS	–	–	–		–	–			(A)19		–
FIREPLACES	–	–	–		–	–			–		(A)22
MISC.	(A)14c, 26	(A)16, 23, 24	(A)16, 23, 24		(A)26	(A)21, 23, 24			(A)26		(A)26
(B) SPEC. FOR BRICKS											
COMP. STRENGTH	–	(B)1	(B)1		–	(B)1			(B)1		(B)1
MOD. OF RUPTURE	–	(B)3	(B)3		–	(B)3			(B)3		(B)3
UNIT STRESSES	(B)1a	–	–		–	(B)1a			–		–
TESTING BRICKS	–	(B)2, 2.4	(B)2		–	(B)2			(B)2a		(B)2, 2c
SOIL	–	(B)4,5,6,7,8,9	(B)4,5,6,7,8,9		–	(B)4.4a, 5, 6			–		(B)4, 5, 6
MOISTURE CONTENT	–	(B)10	(B)10		–	(B)10			(B)10		(B)10
CRACKING	–	(B)11	(B)11		–	(B)11			(B)11		(B)11
WATER FOR MIXING	–	–	–		–	(B)13			–		–
MISC.	(B)15	(B)12, 15	(B)12, 15		(B)15	(B)12a, 14, 15			–		(B)15

PROVISIONS SUMMARY	NEW MEXICO (UBC)				ARIZONA (UBC)			TEXAS (-)		CALIFORNIA (UBC)	
	STATE CODE (UBC '79)	STATE MODIF. "6-1-1/80	CITY OF ALBQ. (MOD)	CITY OF SANTA FE	CITY OF PHOENIX	CITY OF TUCSON (MOD.)		STATE CODE	CITY OF EL PASO (SBC-MIB)	STATE CODE (UBC-'79)	CITY OF LOS ANGELES (MOD.)
(C) SPEC. FOR BRICKS (masonry)											
ADDATIVES	–	(C)1	(C)1		–	(C)2			(C)1		(C)3
TESTING	–	(C)4	(C)4		–	(C)4a			(C)4		(C)4
MISC.	–	–	–		–	–			(C)5		–
(D) FOUNDATIONS											
BASEMENT/FOUND. WALLS	–	(D)1	(D)1		–	(D)1a			–		–
FOUNDATION WALL HT.	(D)3	(D)3,5	(D)3.5		(D)3a	(D)3.5a			(D)3a,5		(D)3
FOUNDATION WALL THK.	–	(D)4	(D)4		–	(D)4a			(D)4		–
FOOTINGS	–	(D)2	(D)2		–	(D)2a			–		–
MISC.	–	–	–		–	–			–		–
(E) MORTARS											
TYPE OF BRICK	–	(E)1,2	(E)1,2		–	–			–		–
JOINTS	–	(E)1,2	(E)1,2		(E)3	(E)3			–		(E)3
TYPE	(E)8	(E)1,2	(E)1,2		–	(E)4			(E)5,6,7		–
MISC.	–	–	–		–	–			–		–
(F) PLASTERING											
CEMENT STUCCO REQD	–	(F)1	(F)1,1a		–	–			(F)1		–
THICKNESS	–	(F)2	(F)2		–	(F)2			(F)2		–
STUCCO NET	–	(F)4	(F)4		–	(F)4			(F)4		–
- NOT REQD -	–	(F)8,10	(F)8,10		–	–			–		–
MUD PLASTER	–	–	–		–	–			–		–
MISC.	–	(F)3,6,7	(F)3,7		–	(F)3,9			(F)3,5,6		–

NO CONTRACTOR LICENSING OR PERMITS REQUIRED - CERTAIN CITIES HAVE ADOPTED BUILDING CODES +

MEP CAL. +

END NOTES

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