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CODES AND SPECIFICATIONS UNDERSTANDING AND WORKING THROUGH THE MAZE

MATERIAL AND PRODUCT STANDARDS PART I

This is Part I in a series of three articles to understand and locate codes and specification provisions related to concrete masonry design and construction. The purpose of these articles is not so much to provide specific design guidance, but to direct a design engineer to various provisions, primarily in the 1998 California Building Code. Many other codes and standards such as ASTM, UBC-Standards and Masonry Standards Joint Committee (MSJC) provisions are also referenced where appropriate.

Provisions in 1998 California Building Code are discussed, rather than 1997 UBC Provisions, because it is a document based on 1997 UBC adopted in California and also covers State of California Amendments, which are applicable to public schools, community colleges, essential services buildings, and hospitals.

The three part series is divided as follows:

Part I deals with Material and Product Standards.

Part II will address Design Provisions.

Part III covers Testing, Inspection, and Construction.

A typical concrete masonry assemblage is a complex system comprising of four primary materials; concrete masonry units, mortar, grout, and reinforcement. No unreinforced masonry is permitted in seismic zones 3 and 4 of the Uniform Building Code (1997 edition).

Each of the primary materials used has significant variability in its properties, making the entire assemblage difficult to analyze, design, construct, and inspect.

Testing and inspection functions are particularly important due to this inherent complexity and variability to deliver a high degree of quality in the final assemblage.

From a strictly definitional point of view, concrete masonry units are considered "a product," not a material. Therefore, concrete masonry units are discussed under the category of product.

MORTAR

Definition for mortar is given in Section 2103.3 of the California Building Code. It is defined as:

- A mixture of cementitious materials, aggregates, water, and approved additives to achieve workable plastic consistency.
- Mortar must conform to UBC Standard 21-15. This Standard is based on ASTM Standard C270-95, with minor modifications. As the latest version of ASTM Standard is C270-99b, we will use that as a reference Standard, because it supercedes C270-95. This Standard is meant for laboratory testing to specify mortar properties, not for field testing of mortar. Field samples of mortar are not meant to comply with this Standard.
- Cementitious materials that are allowed:
Portland cement
mortar cement

Cementitious materials not allowed:
epoxy resins and derivatives
phenols
asbestos fibers
fire clays
masonry cement
- Although four types of mortars are allowed, in Seismic zones 3 and 4, only type “M” and “S” are allowed. (Type “M” for the State of California buildings such as schools, community colleges and hospitals, must meet the proportions of type “S”)

Selection of proportions for mortar ingredients is covered in Section 2103.3.2.

Two methods are allowed for specifying mortar:

1. Proportion specifications (by volume)
– Table 21A.
2. Property specifications (by required compressive strength) – Section 2103A.3.2. (State Amendment)

Minimum required compressive strength is 1500 psi at 28 days for masonry with $f'_m = 1500$ psi.

It should be noted that this compressive strength is to be measured on a field test specimen prepared according to UBC Standard 21-16. Since the test specimen is a cylinder rather than a cube, direct comparisons of laboratory cube strength and field specimen cylinder strength should not be made. Generally, the cylinder strength is 85% of the cube strength.

Typical mortar proportions are as follows:

	Type “S”	Type “M”
Portland cement	1 part	1 part
Lime	½ part	¼ part
Sand	4½ parts	3½ parts

Addition of lime to mortar improves:

- a. Workability
- b. Water penetration resistance
- c. Water retentivity (usable life of mortar)

Please note, “lime” is a cementitious material, not an admixture or additive.

The compressive strength of mortar is sometimes used as the main requirement for selecting a mortar type. Compressive strength is easy to measure, tests are well established and reliable, and can give consistent results. The importance of compressive strength of mortar though, is overemphasized. Bond strength is generally more important. Since good bond strength is also dependent on water retentivity and workability, these properties are important.

Compressive strength is measured on cube or cylinder. However, the size effect needs to be considered. A mortar joint has very high width to thickness ratio. The ultimate compressive load carrying capacity of a 3/8-inch thick bed joint is deemed to be well over twice the compressive strength of a mortar cube. For these reasons, Type “S” mortar is preferable to type “M”, although it has lower compressive strength.

As a basic design philosophy, mortar should also be weaker than masonry units so that the cracking could occur in mortar joints instead of in the masonry units, which are repairable.

GROUT

Definition for grout is given in Section 2103.4.

It is defined as:

- *A mixture of cementitious materials, aggregates, additives, and water to allow flow without segregation of the constituents.*

Terms “Grout lift” and “Grout pour” are misused many times. We are defining them here for clarity.

Grout lift is an increment of grout height within total grout pour.

Grout pour is the total height of masonry wall to be grouted prior to erection of additional masonry. A grout pour consists of one or more grout lifts.

- Minimum specified compressive strength to be 2000 psi at 28 days – section 2103.4.1.
- Antifreeze compounds or air-entraining agents are not allowed.
- Additives and admixtures can be used only when approved by the building official or enforcing agency.
- Grout must conform to UBC Standard 21-19, which is based on ASTM C476-99.

Selecting proportions for grout ingredients is covered in Section 2103.4.2.

Grout can be specified by one of the three methods:

1. Proportion specifications (by volume) – Table 21-B.
2. Minimum compressive strength, which will produce required specified prism strength.
3. Laboratory or field experience with grout ingredients and masonry units. Grout to be proportioned by parts by volume of its constituents.

When specified by proportion of ingredients, typical proportions by volume are as follows:

Fine Grout

Portland cement	1	part
Lime	Max 0.1	part
Fine aggregates	3	parts
Coarse aggregates	-----	

Coarse Grout

Portland cement	1	part
Lime	Max 0.1	part
Fine aggregates	3	parts
Coarse aggregates	1 ½	parts

Specifying grout by compressive strength at 28 days is common. Many times minimum specified compressive strength is far in excess of masonry unit strength or prism strength. This is not necessary if adequate data exists. Code allows the grout to be specified based on the data. In that case, the proportion of ingredients needs to be specified by volume.

CONCRETE MASONRY UNITS (CMU'S)

Primarily four types of CMU's are available; *load bearing, non-load bearing, concrete brick, and segmental retaining wall units*. Each conforms to a different Standard of ASTM. Our focus in this article is “**load bearing units,**” as it is the predominant product used in structural masonry.

- Must conform to ASTM C90-01. UBC Standard 21-4 is still applicable, but is based upon ASTM C90-95 version. One of the prime changes in the latest ASTM Specification is that differentiation of masonry units as type I or type II has been eliminated.
- Concrete masonry units are classified as; normal weight, medium weight, and light weight.

Classification	Density	Maximum Water Absorption
Light weight	< 105 pcf	18 pcf
Medium weight	105 to < 125pcf	15 pcf
Normal weight	≥ 125 pcf	13 pcf

- All units have to meet a minimum compressive strength calculated on average net area.

Individual unit	-	Minimum 1700 psi.
Average of 3 units	-	Minimum 1900 psi.
- Permissible variations in dimensions for standard units are set as ± 1/8 inch. For special units different standards may be applied.
- Relationship between unit strength of CMU and f'_m of masonry assemblage varies because of variability in mortar strength and grout strength, and their interaction with the masonry unit in generating compressive strength. When unit strength of CMU is specified for a desired f'_m , California Building Code requires following minimum unit strengths, based on Table 21D:

For Type M or S Mortar

Specified f'_m (psi)	Required Unit Strength (psi)
1000	1250
1500	1900
2000	2800
2500	3750
3000	4800 or more

As one can see, the multiplier for required unit strength varies from 1.25 at the low end to 1.60 at the high end of f'_m . Linear interpolation for values of f'_m not listed in the table is allowed.

REINFORCEMENT

Reinforcement that is unique to concrete masonry construction is joint reinforcing made from cold drawn steel wire. This reinforcing consists of deformed longitudinal wires welded to cross wires. The joint reinforcing is placed in mortar joints between masonry courses.

- Joint reinforcing must conform to UBC Standard 21-10 part I.
- Some of the basic requirements are:
 1. Longitudinal wires to be minimum 0.148 inches in diameter (9 gage), but not more than one-half the mortar joint thickness, which is typically 3/8 inch.
 2. Cross wires to be minimum 0.148 inches (9 gage) in diameter, but not greater than longitudinal wire diameter. Cross wires not to project more than 1/8 inch beyond longitudinal wires.
 3. Width of joint reinforcement is defined as out to out distance between longitudinal wires. 1/8 inch variation in width is permitted.
 4. Length of pieces of joint reinforcement not to vary by more than 1/2 inch or 1% of the length, whichever is smaller.
- 5. Minimum required yield strength of wires is 60 ksi with a minimum tensile strength of 75 ksi.

FINISH AND APPEARANCE

It is common to have minor cracks, minor chipping, or minor imperfections in masonry walls. These should not be considered as basis for rejection of work. ASTM C90-01 Standard requires that when viewed from a distance of not less than 20 feet under diffused lighting, exposed wall construction shall not show imperfections, chipping, or cracking. This is considered a general criterion for accepting appearance.

This issue of Masonry Chronicles was written by Vilas Mujumdar, Executive Director of Concrete Masonry Association of California and Nevada.

Masonry Chronicles is a publication of the Concrete Masonry Association of California and Nevada. Please contact the Association Executive Director, Dr. Vilas Mujumdar, with any comments or suggestions for future issues.

The Masonry Chronicles may also be seen on our website.

CMACN's web address is <http://www.cmacn.org>

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