SPEAKING IN CODE

The Lowdown on Testing and Special Inspection Topics *September 2024*

QUALITY MASONRY MORTAR - ACCORDING TO ASTM C270

Producing quality, durable, and code-compliant masonry mortar on project work is important for many reasons. ASTM C270, "*Standard Specification for Mortar for Unit Masonry*," along with ASTM C144, "*Standard Specification for Aggregate for Masonry Mortar,*" contain most of the pertinent code compliance criteria governing the production of masonry mortar used in the construction of non-reinforced and reinforced unit masonry structures. ASTM C144 sets forth compliance criteria for the aggregate used to make the mortar, and ASTM C270 sets forth compliance criteria for proportioning the various materials used to produce the mortar, as well as minimum compressive strength criteria and other minimum property requirements. C270 also addresses laboratory and field testing methods to perform quality assurance duties, construction practices, and project special inspections.

C270 includes two consequential tables: Table 1, "*Property Specification Requirements*," and Table 2, "*Proportion Specification Requirements*." C270 is adopted by the International Building Code (IBC), and all of the statistical data comprised in these two tables is code compliance criteria.

TABLE 1 Property Specification Requirements[A]

Mortar	Type	Average Compressive Strength at 28 days, min, psi (MPa)	Water Retention, min, %	Air Content, max, %[B]	Aggregate Ratio (Measured in Damp, Loose Conditions)
Cement-Lime	M	2500 (17.2)	75	12	
	S	1800 (12.4)	75	12	
	N	750 (5.2)	75	14[C]	
	O	350 (2.4)	75	14[C]	
Mortar Cement	M	2500 (17.2)	75	12	Not less than 2 ¼ and not more than 3 ½ times the sum of the separate volumes of cementitious materials
	S	1800 (12.4)	75	12	
	N	750 (5.2)	75	14[C]	
	O	350 (2.4)	75	14[C]	
Masonry Cement	M	2500 (17.2)	75	18	
	S	1800 (12.4)	75	18	
	N	750 (5.2)	75	20[D]	
	O	350 (2.4)	75	20[D]	

[A]Laboratory prepared mortar only (see Note 5).
[B]See Note 6.
[C]When structural reinforcement is incorporated in cement-lime or mortar cement mortar, the maximum air content shall be 12 %.
[D]When structural reinforcement is incorporated in masonry cement mortar, the maximum air content shall be 18 %.

It should be emphasized that C270 Table 1 criteria are absolutely invoked whenever the masonry sand used on the project does not comply with C144 grading specifications. C144, Section 4.4 states, "*When an aggregate fails the gradation limits specified in 4.1 and 4.2, its use is permitted provided the mortar can be prepared to comply with the aggregate ratio, water retention, air content and compressive strength requirements of the property specifications of ASTM C270.*" This code language basically requires that a laboratory mortar mix design be performed on any masonry sand that does not comply with the grading requirements of ASTM C144. The mortar developed from the noncompliant sand must comply with C270, Table 1 requirements.

It is essential to understand that Note 5 of Table 1 addresses laboratory-prepared mortar mixes. While laboratory mortar mix designs must comply with the property requirements of Table 1 of ASTM C270, it would be wrong to expect mortar specimens produced in the field to comply with Table 1 properties (especially compressive strength). Here's why: Compressive strength values obtained from field testing of masonry mortar can be expected to be lower and less consistent than values obtained in the laboratory. Laboratory mortars are mixed with water to produce a 110 ± 5 percent flow. This water quantity is insufficient to make a mortar with consistent **workability*** for laying masonry units in the field.

Mortar for use in the field must be mixed with the maximum amount of water (higher flows than 110) to satisfy the suction of the masonry units (when they are laid in the mortar bed). The properties and flow rates (110) of the laboratory-prepared mortar are intended to approximate the flow and properties of the field-prepared mortar AFTER it has been in contact with the masonry units during construction. Masonry inspection and testing, in the field, are provided in general accordance with ASTM C780, "*Standard Test Method for Construction Evaluation of Mortars.*" However, C780 compressive strength results are not expected or required, by code, to meet the minimum compressive strength values of the ASTM C270 property specification. ASTM C1586, "*Standard Guide for Quality Assurance of Mortars*," contains an excellent narrative that guides the proper use of Specification C270 and Test Method C780 for evaluating masonry mortar produced in the laboratory and at the construction site.

***Workability** is the result of a ball-bearing effect of aggregate particles lubricated by the cementing paste. Although largely determined by aggregate grading, material proportions, and air content, the final adjustment to workability depends on water content. This can be, and usually is, regulated on the mortar board by the mason.

Laboratory Mortar Flow Table

Let's shift the discussion, for a moment, to ASTM C270 Table 2, "*Proportion Specification Requirements*." This table addresses mortar mixtures consisting of cementitious material, aggregate, and water, all conforming to Section 4 of C270 and proportions specification requirements of Table 2. To comply with C270 Table 2 criteria, the mortar producer must only comply with the proportioning criteria stipulated in Table 2 and any required proportion and materials criteria outlined in the project specifications. In the final analysis, all that you know about a mortar that is mixed by the C270 Table 2 proportion method is that the quantities of materials mixed are the ones that are required by Table 2 (if those quantities can be accurately verified). You certainly do not know the compressive strength, water retention qualities, air content, and workability qualities that are paramount to producing quality mortar in the field under job site conditions.

The very existence of C270 Table 2 deserves more commentary to add some context as to why Table 2 is even a part of C270. Seventy-plus years ago, when ASTM C270 was approved in 1951, the original authors of this ASTM standard agreed to develop a property specification based on the many desirable and necessary qualities of masonry mortar. They invested a great deal of time exploring various mortar properties and created specific test methods to measure those properties so that a property specification could be written. At some point, it became pretty clear (to the authors) that to get an ASTM specification approved

by consensus, a proportion table (recipe) would have to be added. All of us associated with the masonry industry have lived with this confusing compromise ever since.

TABLE 2 Proportion Specification Requirements

NOTE 1—Two air-entraining materials shall not be combined in mortar.

Mortar	Type	Proportions by Volume (Cementitious Materials)							
		Cement[A]	Mortar Cement			Masonry Cement			Hydrated Lime or Lime Putty	Aggregate Ratio (Measured in Damp, Loose Conditions)
			M	S	N	M	S	N		
Cement-Lime	M	1	...	...	...	...	...	...	¼	
	S	1	...	...	...	...	...	...	over ¼ to ½	
	N	1	...	...	...	...	...	...	over ½ to 1¼	
	O	1	...	...	...	...	...	...	over 1¼ to 2½	
Mortar Cement	M	1	...	...	1	...	...	...	...	Not less than 2¼ and not more than 3 times the sum of the separate volumes of cementitious materials
	M	...	1	...	...	...	...	...	...	
	S	½	...	...	1	...	...	...	...	
	S	...	...	1	...	...	...	...	...	
	N	...	...	...	1	...	...	...	...	
	O	...	...	...	1	...	...	...	...	
Masonry Cement	M	1	...	...	...	...	...	1	...	
	M	...	...	...	...	1	...	...	...	
	S	½	...	...	...	...	...	1	...	
	S	...	...	...	...	...	1	...	...	
	N	...	...	...	...	...	...	1	...	
	O	...	...	...	...	...	...	1	...	

[A]Includes Specification C150, C595, and C1157 cements as described in 4.1.1.

As the masonry industry moves more and more toward “engineered masonry,” the need for the increased use and application of the property standard for mortar is consistent with that direction. All types of masonry units and cements are required to meet exacting property standards and be tested for compliance. The same criteria should be applied to mortar – we should specify property standards (in project specifications). It just makes sense to specify what you want a mortar to do (C270 Table 1) rather than how much of each ingredient should comprise the mortar (C270 Table 2).

ASTM C270 is a vital part of the code since the International Building Code (IBC) and the masonry code (TMS 401/602) adopts ASTM C270. The language used in ASTM C270 regarding whether to use a property spec or proportion spec is ambiguous and should be clarified. Currently, C270 requires that a laboratory mortar mix design be provided for masonry sands that do not comply with the grading requirements of ASTM C144, and the resultant mortar made from that sand must comply with the property requirements of Table 1 of C270. This requirement is made clear only due to the verbiage stipulated in section 4.4 of C144. C270 verbiage implies that all masonry sands that comply with the provisions of C144 can be used for masonry mortar using the proportioning methodology outlined in Table 2 of C270. Are all sands that comply with the grading requirements of C144 suitable for masonry mortar mixtures? No. There are masonry sands in the Mid-Atlantic region of the country whose gradation complies with ASTM C144 but should not be used to produce masonry mortar. Some of these sands have excessive amounts of deleterious and organic material, significantly decreasing mortar compressive strengths.

ASTM C270 is not perfect, but it is the primary code that addresses the acceptance criteria for masonry mortar and the code-adopted “*Standard Specification for Mortar*.” Anyone reading and reviewing ASTM C270 should spend a portion of their time also reviewing the C270 appendices, nine pages of amazing information about mortar characteristics located at the very end of the C270 standard. The verbiage expressed in the C270 appendices is an easy read and enjoyable, as compared to most technical standards. The subject matter covered in the appendices will greatly increase the reader’s understanding and

knowledge about numerous important mortar characteristics. Just a few of the salient topics addressed in the C270 appendices are:

- Good workability and how it is essential to obtain maximum bond strengths
- Difference of mortar flow rates between laboratory mortar and construction mortar
- How bond strength increases as the mortar flow rate increases
- How the bond between the mortar and masonry unit is the most single important physical property of hardened mortar
- Why the compressive strength of the mortar should be weaker than the masonry unit
- The impact of properly "tooled" masonry joints on the compressive strength of the entire masonry system
- The problems associated with mortar strengths that are too high
- How increases in sand content increases setting time of mortar
- Importance of controlling moisture contents of masonry sands at the job site
- Water evaporation from job site mortar and the necessity of mortar retempering
- Differences between masonry cement, mortar-cement, and cement-lime cement
- Absorption rate of masonry units and the vital process of "suction" by the masonry unit
- Why mortars should have high water retention qualities (especially in the summer time)
- Why the mason should NOT spread that mortar bed joint too far ahead of the mason
- Mixing masonry mortar at the job site and how wet sand bulks and increases volume
- Weather conditions and how they should be considered when selecting mortar type
- How "bond" is probably the most important single property of conventional mortar
- "Thumbprint" hard rule that governs when to tool a mortar joint during construction
- Efflorescence and how to avoid it

ASTM C270 addresses practically all of the essential properties of masonry mortar, including both plastic mortar and hardened mortar. Plastic properties (workability and water retentivity) determine a mortar's construction suitability. Hardened mortar properties help determine the finished masonry's performance, including bond, durability, and compressive strength. The C270 appendices drill down deeper into these mortar properties and qualities. While the information set forth in the appendices is non-mandatory insofar as the code is concerned, the depth and breadth of the information presented will make any reader that reviews the appendices more mortar savvy.

But wait! We have a lot more to say!

For a complete picture of the Code and how it relates to Special Inspections, F&R would love to provide a virtual AIA-accredited Lunch & Learn presentation to the professionals at your firm.

Trouble Deciphering the Code? **Call the Experts at F&R!**

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