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LISTEN TO THE MASON: PORTLAND CEMENT-LIME TYPE N MORTAR (1:1:6) PROVIDES THE NECESSARY WORKABILITY AND STRENGTH*

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Abstract
In the Midwest United States, portland cement-lime mortars are the most commonly used for commercial masonry projects. Type S mortars, with one part cement, one-half part lime, and four-and-one-half parts sand (by volume), are the most commonly specified. There is a perception in the engineering community that higher compressive strength mortars are required to achieve better masonry. In listening to masons, I hear their cry "THIS MORTAR IS TOO STRONG." One rarely hears a mason say they prefer Type S mortar. Given the opportunity to choose, a mason would select a Type N mortar -- one part cement, one part lime, and 6 parts sand (by volume). They choose a Type N mortar because of the workability of the mortar, not to mention the board life, yield, cleaning, and production gained with a higher lime-content mortar.

With 14 years of experience in the masonry industry, starting as a laboratory field technician and now as a pre-blended bulk mortar designer and sales representative, I cannot help but become an advocate of the "masons on the wall." The mason's most important tool is mortar and the mason should have the best tools. The compressive strength of a portland cement-lime Type N mortar is usually adequate to produce masonry that meets or exceeds the code-required masonry assemblage compressive strength and provides better workability than Type S.

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1 Introduction

My masonry career began as a laboratory and field technician in Kansas, and I am now employed as a pre-blended bulk mortar sales representative in Texas. Over the last fourteen years of being involved in commercial masonry mortar applications, I have talked to many masons about the mortar they use daily "on the wall". I have come to realize that there is a common message and it is "Type S portland cement-lime mortars are not as workable as Type N portland cement-lime mortars with their higher lime content."

The mason, while obliged to meet the requirements of the project mortar specification, is also interested in ease of use and productivity. The analogy I sometimes use is "If given a better tool, the craftsman builds a better building." Mortar is a tool that all masons use hundreds of times a day. Masons are not required to use a 10-inch, 11-inch or 12-inch trowel; their choice is the trowel that best fits their style, ability and needs. In the case of mortar, the designer or specifier should choose a mortar that meets the needs of the structure and the local code, but also accommodates the mason and the units being placed. I prefer that portland cement-lime, Type N, 1:1:6 mortars be specified for nearly all commercial masonry projects.

In support of the mason, who builds the masonry wall, I would like to discuss the following:

- the role of workability in a mortar, as viewed through the eyes of mason;
- the role of compressive strength as viewed by leading educational and masonry organizations;
- how ASTM C 270 Standard Specification for Mortar for Unit Masonry muddies the waters;
- the relationship of the compressive strength of mortar and the compressive strength of masonry as viewed through the code; and conclude with
- some thoughts on how to make everyone happy.

I am limiting this discussion to portland cement-lime mortars, which are used in the majority of commercial masonry built west of the Mississippi.

2 Workability

The Appendix of ASTM C 270, Sections X1.5.1 and X1.5.2, recognizes workability as the most important property of a plastic mortar and further recognizes its significant contribution to the desired properties of a hardened mortar.

Plastic properties of mortar include:

- spreads easily with a trowel into the separations and crevices of the masonry unit;
- supports the weight of masonry units when placed and facilitates alignment;
- adheres to vertical masonry surfaces and readily extrudes from the mortar joints when the mason applies pressure to bring the unit into alignment.

Hardened mortar properties include:

- maximum bond with masonry units, including strength, extent and durability of the bond;
- moisture penetration resistance. The spreadability and, therefore, the masonry unit surface coverage that a mortar provides are significant factors in reducing the penetration of water through the mortar joint (Borchelt *et al*., 1999)

The masons may not think about all the consequences of workability, but they sure know when a mortar is not workable. They have told me that "Type S mortars (by proportion) are 'too strong'". In further discussions, I realized they are actually saying that the mortars are "too sticky", meaning that the mortar has no "fluff". It sticks to the trowel, yet often does not stick to the unit being placed. This mortar also doesn't "strike or tool" as well as Type N mortars. With 1:1:6 Type N mortars, particularly in the heat of summer, the mortar "feels" and "flows" off of their trowels differently. Most masons also feel that they have more time to place units before the "striking" process begins.

A non-workable mortar reduces productivity and tires the masons much faster than a workable mortar. The ability of the mason to work with the mortar is essential to their job, and a mason will commonly make "adjustments" to the mortar to make it workable. Adjustments might include adding more water, reducing the amount of sand, or adding a squirt of dishwashing liquid. All of these "adjustments" change the properties of the mortar in both the plastic and hardened states, and the change is not for the better. A mason will not "adjust" a mortar that has good workability. In my experience, an ASTM C 270 Type N portland cement-lime proportioned (and I stress proportion, not property) mortar provides the workability that a mason needs. Very rarely am I made aware of "adjustments" being made to this type of mortar.

3 The role of compressive strength – a mixed message

Structural engineers are taught that Type N mortars are for lightly-loaded or non-load-bearing masonry, and Type S mortars are for load-bearing or engineered masonry structures (Drysdale et al., 1999, p. 154). The Masonry Standards Joint Committee Code (MSJC, ACI 530-02/ASCE 5-05/TMS 402-02) stipulates that Type M and Type S portland cement-lime and mortar cement mortars (proportion or property) are permitted in areas of the country that have a high risk of earthquakes. Type N mortars of any type are not permitted, nor are Type S masonry cement mortars in those regions. The message here is that higher compressive strength mortars, Type S and Type M, are required for seismic resistance.

The Appendix to ASTM C 270-04, Table X1.1 Guide for the Selection of Masonry Mortars, recommends Type N mortar for exterior and above-grade load-bearing masonry walls. A Type O mortar is recommended for above-grade, non-load-bearing masonry walls. Type S mortar is recommended only for foundation walls, retaining walls, manholes, sewers, pavements, walks, and patios. Confusingly, the table provides an alternative mortar for each of these applications. For above-grade load-bearing masonry walls, the alternatives are Type S or Type M, which are higher compressive strength mortars. In effect, the appendix, which is non-mandatory, says you can use a Type N, S or M mortar for load-bearing, above-grade masonry walls.

The message is mixed. There are clear statements in most masonry guidelines that a strong mortar does not equate to good masonry. Drysdale et al. (1999) states, "*workability, in fact, is generally more important than compressive strength, and the general rule is not to choose* *a mortar with a higher compressive strength than is required. This is so for several reasons: first, high strengths exceeding say 3000 psi are not required even in high-rise load-bearing masonry structures; second, there is no proportionate increase in masonry compressive strength with increasing mortar strength*." Davison (1974) adds, "*Mortar strength should never be greater than the masonry unit's strength.*" (p 2 of 6). The Portland Cement Association states, "*It is not always necessary to use Type M mortar for high-strength masonry, because Type S can provide comparable strength of masonry. Moreover, 'Type S' and 'Type N' generally have greater workability, water retention and extensibility*." (PCA, 2004, p. 8 of 20). The Brick Industry Association (BIA, 2000) adds, "*Do not use a mortar stronger in compression than is structurally really required by the project*." Christine Beall (2003) recommends that designers, "*always select the mortar type with the lowest compressive strength appropriate to its location and use - almost always a Type N*."

Compressive strength of a portland cement-lime mortar is greatly influenced by the ratio of cement and lime. It is also influenced by water-to-cementitious ratio and the nature of the sand. Davison (1974) states, "*Portland cement contributes strength to masonry mortar, particularly early strength… Portland cement mortars lack plasticity, have poor water retentivity, and are 'harsh' to work with. Lime, the traditional mortar material, has excellent plasticity and water retentivity, but it is low in strength and slow to cure.*" Figure 1 schematically shows the relationship between compressive strength, water retentivity and cement-to-lime ratio. Davison points out, "*The point at which the two curves cross, designating the mortar with the highest compressive strength compatible with optimum water retentivity lies within the boundaries of a proportion Type N mortar*." (p 5 of 6).

The MSJC limits the use of Type N mortars in high seismic zones, yet the guidance for mortar choice is to use a workable mortar, and that mortar is generally considered to be a Type N portland cement-lime mortar.

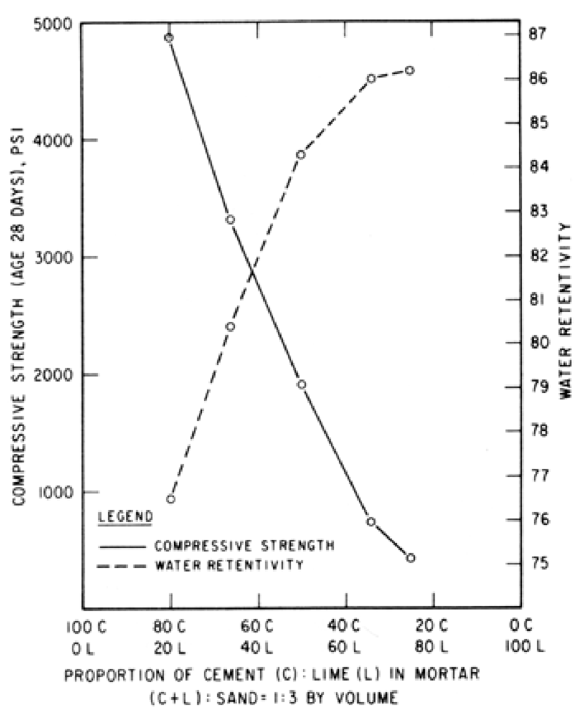

Figure 1. Relationship of cement and lime ratio to compressive strength and water retentivity. (Davison, 1974.)

4 Confusion about ASTM C 270 proportion and property mortars

ASTM C 270, Standard Specification for Mortar for Unit Masonry, is the cornerstone specification for mortar. There is considerable confusion in the design community as to its use. There are two “Specification Requirement” tables. Table 1 is by proportion, or more commonly referred to as the “Recipe Table”. This table addresses how to make mortar by volumetric proportions. When using this table, ASTM C-270 (Para 8.2) states “*Compliance with Table 1 proportion mortars is obtained in the field by verifying that the required proportions of the specified materials are added to the mixer.*” There are no required properties, because there is a sufficient history of use to have confidence that the resulting mortar will achieve the needed properties.

Table 2, (Property Specification Requirements) lists the performance requirements for mortar, including minimum compressive strength, water retention, maximum air content, and range of aggregate-to-binder ratio. There is no requirement for how much of each cementitious material is to be used to achieve these properties. Mortar compliance with Table 2 properties is established by completing laboratory tests. Table 2 property mortars are reproduced in the field by mixing mortar according to the proportions established in the laboratory. Property testing is completed by the owner, designer or contractor for each job for which this type of mortar is specified.

The problem comes from the common assumption that mortars derived by volume proportioning and those derived by properties established in a laboratory have the same compressive strength ranges. They do not. Portland cement-lime proportioned mortars typically have a higher compressive strength range then the minimum strength value of same letter designation property mortars. A Type N portland cement-lime proportioned mortar (1:1:6) typically has compressive strength in the range of 1800 to 2200 psi, which would classify it as a Type S portland cement-lime property mortar. I spend a lot of time trying to explain this to specifiers, but it can be quite confusing to them.

5 Relationship of compressive strength of masonry and compressive strength of mortar

The net area compressive strength of the masonry assembly (f'_m) is the basis for most of the design considerations in the Masonry Standards Joint Committee code (ACI 530-02/ASCE 5-05/TMS 402-02). Compressive strength of masonry is determined by the unit strength method or by the prism test method. It is my experience that unit strength method is commonly used, because the prism test method requires pre-construction laboratory testing. Figure 2 shows data (NCMA 2002) of the relationship between masonry compressive strength and concrete masonry unit strength. The curves are the predicted strengths based on mortar types, which are proportioned portland cement-lime mortars. Figure 2 and Drysdale *et al*. (1999, and quoted above) show that f'_m is not related to compressive strength of the mortar but rather to compressive strength of the masonry unit. The difference in f'_m between Type S and Type N mortars is not significant.

I have experienced only three situations where the $f'_{m,}$ using a Type N portland cement-lime mortar, was called into question and masonry prisms were actually cut out of the wall for testing using ASTM C 1532. In each case, the compressive strength of the masonry prism exceeded the specified 1500 psi. It is not uncommon for specifiers to think that there is a need for higher mortar compressive strength in order to achieve high masonry compressive strength.

6 Conclusion

A portland cement-lime Type N proportioned mortar has been called the workhorse of mortars. I believe that it provides the workability that a mason needs and satisfies the masonry compressive strength values required by the engineering community. It is a message that I consistently deliver in my work. Unfortunately, masonry specifiers have moved toward even stronger mortars, at the expense of the mason and good performing masonry structures. This trend needs to be reversed.

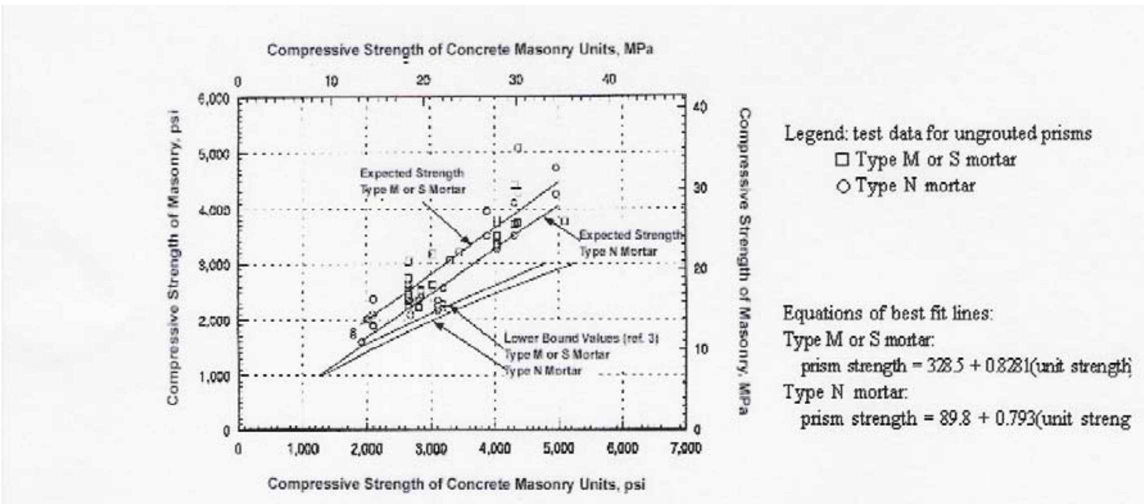

Figure 2. Compressive strength of masonry versus concrete masonry unit strength and mortar type. (NCMA, (2002) TEK Notes, T18-9F)

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