Choosing the Right Mortar for the Job

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Modern material technology has given us strong mortars which permit construction to proceed at a rapid pace. But occasionally we still see problems with masonry cracking and water penetration. The masonry industry has experienced it all before: soon after the introduction of cement to the mortars in the late 1800's pure sand/cement mortars were often specified in the belief that "stronger is better." Many buildings of this era experienced cracking and water leakage, prompting a number of investigations. In the 1920's and 1930's the National Bureau of Standards identified that using mortars with high cement content resulted in leaky walls. Repeating the mistakes of history, we are again seeing too much emphasis on strength at the expense of other very important and desirable mortar functions, namely bond, durability, and weather resistance.

Today's mortars are a combination of sand along with either masonry cement or Portland cement and lime. Each component contributes important properties to the end product. Cement is added to mortar mainly to provide a rapid strength gain to speed construction sequences. Increasing cement content increases mortar compressive strength but also increases shrinkage, rigidity, and cost. Lime, on the other hand, is a relatively inexpensive material and provides workable mortar that weathers well. It is important to balance strength, workability, and weathering resistance for each application to provide functional, durable masonry structures.

Strength

With more and more load bearing and reinforced masonry construction, masonry strength is an important consideration. But what part does mortar play in contributing to strength? Mortar has actually been shown to be a relatively unimportant factor in determining overall wall strength. Research by Davey showed that mortar strength has practically no effect on masonry strength for mortars as weak as 400 psi (Figure 1). Priestley also determined that, in studying results of several research projects, mortar contributes only 2 to 5 percent of masonry strength. In calculation of design strengths he recommends neglecting mortar strength altogether. These studies and others point towards using more economical mortars with low cement content for most cases.

Consider *strength compatibility* when choosing mortars: in no case should the mortar be stronger than the units. Very high strength mortars have a tendency to delaminate at the mortar/unit bond line or force cracks through the units themselves. When specifying masonry based on properties, rather than proportions, the Brick Institute of America (BIA) also recommends values generally as a lower bound estimate of expected properties for evaluation of laboratory prepared specimens. Use Table 1 for an idea of compressive strength provided by different types of mortar, and make sure the mortar is not too strong for your application.

As far as the building codes are concerned, there is no great benefit gained from using high strength mortars. When using the unit strength method, the Uniform Building Code (UBC) does not even differentiate between masonry strengths provided by Type M and S mortars, and has only a 17 to 20 percent reduction for Type N mortars. Type M or S is, however, required for use in foundation walls and in high seismic zones.

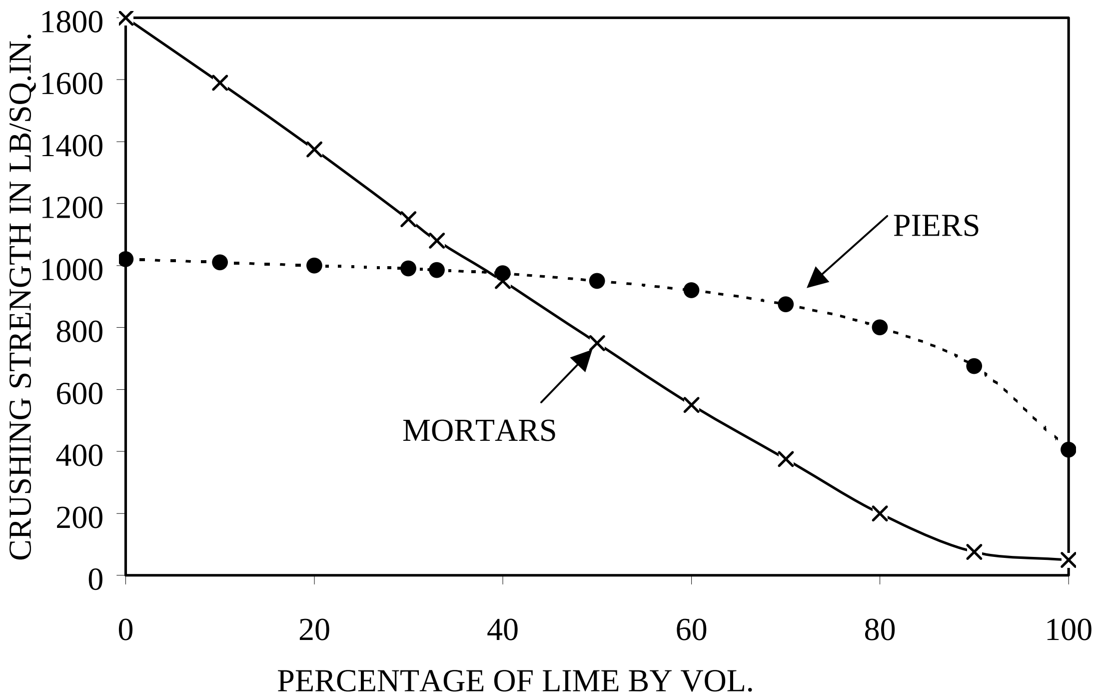

Figure 1. Mortar compressive strength has little effect on masonry assemblage strength except in extreme cases (adapted from Davey).

Table 1. Typical mortar compressive strength values.

Mortar Type	Proportions (cement: lime:sand)	Typical Compressive Strength Values	Recommended by BIA*
M	1:1/4:3	3000-3800	2500
S	1:1/2:4½	2300-3000	1800
N	1:1:6	1500-2400	750
O	1:2:9	750-1200	350

*From BIA Technical Note 8, Mortars for Unit Masonry

Cement provides high compressive strengths, but bond strength relies more upon mortar workability and its ability to flow and, at the microscopic level, to form a completely bedded surface. This reliance upon both flow and cement content leads to Type S mortar typically providing the greatest bond strength, if all other parameters such as surface texture, suction, and workmanship are held constant. For cases where high flexural stresses are expected, use Type S mortar. Another case where high cement mortars are preferred is with dense brick, with an initial rate of absorption less than about 3 or 4 g/30in^2/min. In this case use Type M or S mortar to provide adequate bonding.

Workmanship

The key to providing strong, durable masonry depends more upon workmanship than any other single factor. Don’t underestimate the mason’s skill: whereas mortar strength contributes 2 to 5 percent of wall strength, studies have shown workmanship to be responsible for up to 40 percent of wall strength! One of the keys to good workmanship is mortar workability - a term which embodies water retention, flow, and segregation resistance. Mortar gains most of its workability properties by lime. The plasticity provided by lime results in a mortar which flows into the texture of the unit to provide good bond contact and also makes it easier to apply head joints. Workable mortar has a longer board life, is easier to spread, and less likely to form bond line delaminations upon curing. Easy to use Type N and O mortars will usually result in better built walls.

Weathering

Resistance to moisture penetration and long-term durability are also very important considerations when choosing masonry mortars. Wall leakage is not usually due to poor bond strength, but rather to a poor contact surface between unit and mortar, termed the *extent of bond*. High cement content mortars, such as Types M and S, are stronger but also more rigid. The have less flow and a tendency to shrink after hardening, which tends to reduce the extent of bond and leads to potential moisture pathways. Mortars with less cement (Type N and O) are more flexible and able to better accommodate movements due to shrinkage, building movement, and thermal strain. Research studies have shown that, in general, walls built with Type M or S mortar will leak more than those built with Type N mortar.

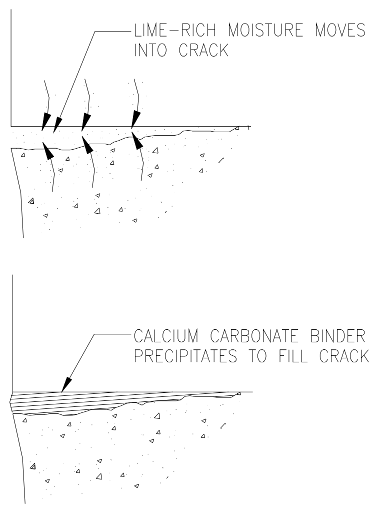

Figure 2. Lime in mortar provides autogenous healing capabilities – the ability to self-seal small cracks and voids.

The high lime content of Type N and O mortars also contributes to long-term masonry weather resistance through a process of autogenous healing, where cracked mortar actually reconstitutes itself to seal small cracks and voids (Figure 2). Uncombined free lime in the mortar (calcium hydroxide) dissolves in water where it is carried into the crack or void. There the lime combines with atmospheric carbon dioxide to form a calcium carbonate binder within the crack. After several wetting and drying cycles, small delaminations and voids are sealed by this process. This may explain, in part, the excellent long-term behavior of many historic structures which were built without any cement whatsoever. One prime example of this longevity is Massachusetts Hall at Harvard University (Figure 3), where its sand/lime mortar has survived New England weather for over 275 years without being repointed.

Where masonry can be expected to freeze while saturated, such as in parapets and retaining walls, moderate strength Type N mortar is required for resistance to freezing damage. Use Type S mortar in extreme freeze-thaw situations.

Figure 3. Historic Massachusetts Hall at Harvard University was built in 1720 with straight lime/sand mortar, and has never needed re-pointing [photo from Speweik].

Summary

With mortar we have one of the few building materials where stronger is not necessarily better. One of the most important mortar concepts is that no single type of mortar is good for all purposes. Some mortars are more economical, others may be better for high loads or for weather resistance. Relative properties of mortar Types M, S, N and O are summarized in Table 2.

Table 2. Relative Mortar Properties (adapted from Boynton)

Mortar Type	28-day Cube Strength (psi)	Water Retention	Tensile Bond Strength	Extent of Bond	Bond Durability	Permeability in Wall Tests (Leakage)	Cost
M	Very High	Low	High	Low	Very Low	High	High
S	High	Mod.	High	High	Mod.	Mod.	Mod.
N	Moderate	High	Mod.	High	High	Low	Low
O	Low	Very High	Low	Very High	Very High	Very Low	Low

What is the best way to choose mortars? For load bearing masonry, look at what the engineer requires in terms of masonry strength, following Chapter 21 of the Uniform Building Code. Remembering that *masonry strength* is very different from *mortar strength*. A good general rule for all-around performance is to specify mortar with merely adequate, but not excessive, compressive strength for the job. For situations where strength is not an issue, choose the most durable, weather-resistant mortar. Don't waste money on strength where it isn't needed.

Table 3. Recommended Mortar Usages (from BIA Technical Note 8)

Type M	high compressive strength, use for masonry below grade, in contact with earth, retaining walls, sewers, and manholes
Type S	provides maximum flexural bond strength, use in reinforced masonry and unreinforced masonry where strength is an issue
Type N	good mortar for general, all-around use and repointing, recommended for severe weathering exposure above grade, parapets, chimneys, external walls, and masonry veneer
Type O	cost-effective, use with solid units on interior, non-weathering, applications, or as general repointing mortar for pre-1890 masonry.

Additional Information

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