White and colored masonry cements containing mineral oxide pigments are available in many areas.

Air-entraining agents contribute to mortar workability by introducing millions of tiny air bubbles which act as lubricants in the mix. While the voids created by these bubbles usually reduce bond strength and increase water permeability, they also increase freeze-thaw durability by providing interstitial spaces which accommodate the expansion of ice crystals without damage to the structure of the mortar. To provide effective freeze-thaw resistance, the air content in masonry cement mortars ranges from 12% to 22%, compared to only 3% to 10% typically found in cast-in-place concrete mixes. ASTM standards limit the air content of masonry cement mortars which will contain structural reinforcement to a maximum of 18%. Air-entrained masonry cement mortars can provide a needed measure of protection against freeze-thaw deterioration in rigid masonry paving. The trade-off of reduced bond strength can usually be tolerated in paving applications because flexural stresses are carried by the supporting slab.

Masonry cement mortars generally require less mixing water to produce good workability than cement-lime mortars. The lower water content is advantageous during winter construction, and also reduces volume shrinkage and the potential for cracking in the wall. It also means that less water is available for cement hydration. In hot, dry weather and with highly absorptive units, loss of mixing water to evaporation or suction can be sufficient to stop the hydration process and impair the bond between unit and mortar. Such *dry-outs* can be avoided by moist curing the masonry, or by rehydrating the wall with a water fog spray (see Chapter 15).

Masonry cement mortars are less alkaline than cement-lime mortars. While this reduces the hazards of workers receiving burns to the skin, it also means the mortar will carbonate more rapidly. Carbonation is the process of chemical weathering in which the calcium hydroxide in hydrated portland cement reacts with atmospheric carbon dioxide to form calcium carbonate. Mortar that is carbonated is no longer alkaline, and no longer provides corrosion protection for embedded metal ties and reinforcing. Porosity affects the surface depth of carbonation. Porous mortars take carbon dioxide deeper into the joint to activate the process. Cracks or leaks in the construction will also increase carbonation, and water in sufficient quantity may contribute to calcium carbonate stains on the surface of the masonry.

6.2.5 "Mortar Cement" Mortars

A relatively new classification of masonry mortar is called *mortar cement mortars*. The physical requirements for mortar cement are covered in ASTM C1329, *Standard Specification for Mortar Cement* (*see Fig. 6-6*). Air content is limited based on the reduction in bond strength which it causes. Mortars with low flexural bond strength can crack under lateral loading, allowing water to penetrate and corrode reinforcing steel. Values for minimum flexural bond strength were established by testing cement-lime mortars and concrete brick (which develops lower bond strength than clay brick) in standard bond wrench tests, so ASTM C1329 also limits or excludes certain harmful or deleterious materials as mortar cement ingredients.

ASTM C1329 essentially sorts out masonry cements with high flexural bond strength capabilities from those which can only provide lower bond strengths. The mortar cements which meet ASTM C1329 are capable of producing mortars with flexural bond strengths equivalent to those of portland cement-lime mortars under identical laboratory test conditions. When high

	Physical Requirements		
	Masonry Cement Type		
Property	Type N	Type S	Type M
Fineness, residue on a No. 325 sieve (maximum %)	24	24	24
Autoclave expansion (maximum %)	1.0	1.0	1.0
Time of setting, Gillmore method (minutes)			
initial set not less than	120	90	90
final set not more than	1,440	1,440	1,440
Compressive strength (psi), average of 3 cubes,§ equal to or higher than the values specified for the ages indicated below:			
7 days	500	1,300	1,800
28 days	900	2,100	2,900
Flexural bond strength, 28 days, minimum (psi)	70	100	115
Air content of mortar, prepared and tested in accordance with requirements of ASTM C91			
minimum (% volume)	8	8	8
maximum (% volume)	16	14	14
Water retention value (minimum % of original flow)	70	70	70

§ Mortar cubes composed of 1 part cement and 3 parts blended sand (half graded standard sand and half standard 20-30 sand) by volume, prepared and tested in accordance with ASTM C91.

Figure 6-6 Minimum requirements for ASTM C1329 mortar cements and mortar cement mortars. (*Copyright ASTM, 100 Barr Harbor Drive, West Conshohocken, PA 19428. Reprinted with permission.*)

flexural bond strengths are required on a project and it is also desirable to use a masonry cement for its advantageous properties, a mortar cement conforming to ASTM C1329 should be specified.

6.2.6 The Portland-Lime Mortar versus Masonry Cement Mortar Controversy

For years there has been controversy over the relative merits of mortars made with portland cement and lime versus masonry cement. The preponderance of industry literature advocates the use of portland cement-lime mortars, and architects and engineers usually have a greater level of confidence in their performance. On the other hand, masons tend to prefer masonry cements because of their excellent workability, batch consistency, and easy mixing. In a survey conducted by *Aberdeen's Magazine of Masonry Construction* (February 1991, Vol. 4, No. 2), it was reported that the responding architects specified portland cement-lime mortars about 80% of the time on both commercial and residential projects. Responding masonry contractors indicated that they use masonry cement mortars nearly 70% of the time on residential projects and only about 50% of the time on commercial projects. For water leakage, bond strength, and durability, both the contractors and the architects preferred portland cement-lime mortars.

Historically, portland cement-lime mortars have exhibited higher flexural strengths than masonry cement mortars. Higher flexural strengths increase not only resistance to lateral wall loads, but resistance to moisture penetration as well. It is difficult to assess the scientific data objectively. Most laboratory