carbon dioxide to reconstitute or reknit itself if small cracks develop. Some manufacturers preblend portland cement and lime, and sell bagged mixes that require only the addition of sand and water at the job site.

2.3.3 Masonry Cements and Mortar Cements

Proprietary mixes of cement and workability agents, or "masonry cements," are popular with masons because of their convenience and good workability. However, ASTM C91, *Standard Specification for Masonry Cement,* places no limitations on chemical composition, and the ingredients as well as the properties and performance vary widely among the many brands available. Although the exact formula is seldom disclosed by the manufacturer, masonry cements generally contain combinations of portland cement, plasticizers, and air-entraining additives. Finely ground limestone, clay, and lime hydrate are often used as plasticizers because of their ability to adsorb water and thus improve workability. Air-entraining additives protect against freeze-thaw damage and provide some additional workability. ASTM C91 limits air content to a range of 8 to 21% (*see Fig. 2-11*), and sets water retentivity at a minimum of 70%.

Like all proprietary products, different brands of masonry cements will be of different qualities. Because of the latitude permitted for ingredients and proportioning, the properties of a particular masonry cement cannot be accurately predicted solely on the basis of compliance with ASTM standards. They must be established through performance records and laboratory tests.

Mortar cements are also proprietary products, but they must meet higher performance standards than masonry cements (*see Fig. 2-12*). ASTM C1329, *Standard Specification for Mortar Cement,* permits a maximum air content of 16% for mortars made with mortar cement, and also prescribes minimum flexural bond strength (refer to Chapter 6).

	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
	900	2,100	2,900
Air content of mortar, prepared and tested in accordance with requirements of ASTM C91			
minimum (% volume)	8	8	8
maximum (% volume)	21	19	19
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 2-11 ASTM C91 requirements for masonry cements. (*Copyright ASTM, 100 Barr Harbor Drive, West Conshohocken, PA 19428. Reprinted with permission.*)

2.3.4 Sand

Sand aggregate accounts for at least 75% of the volume of masonry mortar and grout. Manufactured sands have sharp, angular grains, while natural sands obtained from banks, pits, and river beds have particles that are smoother and more round. Natural sands generally produce mortars that are more workable than those made with manufactured sands.

For use in masonry mortar and grout, sand must be clean, sound, and well graded according to requirements set by ASTM C144, *Standard Specification for Aggregate for Masonry Mortar* (*see Fig. 2-13*), or ASTM C404, *Standard Specification for Aggregates for Masonry Grout* (*see Fig. 2-14*). Sand particles should always be washed and treated to remove foreign substances. Silt can cause mortar to stick to the trowel, and can impair proper bond of the cementitious material to the sand particles. Clay and organic substances reduce mortar strength and can cause brownish stains varying in intensity from batch to batch.

The sand in masonry mortar and grout acts as a filler. The cementitious paste must completely coat each particle to lubricate the mix. Sands that have a high percentage of large grains produce voids between the particles, and will make harsh mortars with poor workability and low resistance to moisture penetration. When the sand is well proportioned of both fine and coarse grains, the smaller grains fill these voids and produce mortars that are more workable and plastic. If the percentage of fine particles is too high, more cement is required to coat the particles thoroughly, more mixing water is required to produce good workability, and the mortar will be weaker, more porous, and subject to greater volume shrinkage.

	Physical Requirements		
	Mortar 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 2-12 ASTM C1329 requirements for mortar cements. (*Copyright ASTM, 100 Barr Harbor Drive, West Conshohocken, PA 19428. Reprinted with permission.*)