test studies that have been performed have usually been sponsored by either the lime industry or the masonry cement industry, and the studies can easily be designed to emphasize the strong points of either mortar. In Grimm's *Conventional Masonry Mortar: A Review of the Literature* (published by the University of Texas at Arlington's Construction Research Center), conflicting research reports are numerous. As with any proprietary product, there are high-quality masonry cements and poor-quality ones. The selection or acceptance of a particular brand of cement should be based on its performance history and on independent laboratory verification of conformance to ASTM standards.

Masonry cements are more widely used than portland cement-lime for masonry mortars, and the vast majority of projects which incorporate them perform quite satisfactorily. On projects which have experienced flexural bond failures or excessive moisture penetration, the culprit is seldom found to be attributable solely to the use of masonry cement versus portland cement and lime in the mortar. Usually, there are other defects which contribute more to the problems, such as poor workmanship, inadequate flashing details, or low-strength backing walls. Both portland cement-lime mortars and masonry cement mortars allow water penetration through masonry walls. The amount of water entering the wall is generally higher with masonry cement mortars, but when workmanship is poor, joints are unfilled, and flashing and weeps are not functional, either type of mortar can produce a leaky wall. There are no industry standards or guidelines identifying varying amounts of water penetration that are either acceptable or unacceptable. A wall system with well-designed and properly installed flashing and weeps will allow tolerance of a much greater volume of water penetration without damage to the wall, the building, or its contents than one without such safeguards. Ultimately, the workmanship and the flashing and weep-hole drainage system will determine the success or failure of most masonry installations (refer to Chapter 9).

Both masonry cement mortars and portland cement-lime mortars are capable of providing what the industry considers adequate flexural bond strength when they are designed and mixed in accordance with ASTM C270, *Standard Specification for Mortar for Unit Masonry*. If specific performance characteristics need to be enhanced for a particular application, laboratory design mixes should be based on unit/mortar compatibility and testing for the desired properties.

6.3 MORTAR TYPES

ASTM C270, *Standard Specification for Mortar for Unit Masonry,* outlines requirements for five different mortar types, designated as M, S, N, O, and K. Prior to 1954, mortar types were designated A-1, A-2, B, C, and D, but it was found that A-1 carried the connotation of "best" and that many designers consistently specified this type, thinking it was somehow better than the others for all applications. To dispel this misunderstanding, the new, arbitrary letter designations were assigned so that no single mortar type could inadvertently be perceived as best for all purposes. No single mortar type is universally suited to all applications. Variations in proportioning the mix will always enhance one or more properties at the expense of others.

6.3.1 Type M Mortar

Each of the five basic mortar types has certain applications to which it is particularly suited and for which it may be recommended. Type M, for instance, is a high-compressive-strength mix recommended for both reinforced and unreinforced masonry which may be subject to high compressive loads.

6.3.2 Type S Mortar

Type S mortar produces tensile bond values which approach the maximum obtainable with portland cement-lime mortar. It is recommended for structures subject to normal compressive loads but which require flexural bond strength for high lateral loads from soil pressures, high winds, or earthquakes. Type S should also be used where mortar adhesion is the sole bonding agent between facing and backing, such as the application of adhesion-type terra cotta veneer. Because of its excellent durability, Type S mortar is also recommended for structures at or below grade and in contact with the soil, such as foundations, retaining walls, pavements, sewers, and manholes.

6.3.3 Type N Mortar

Type N is a good general-purpose mortar for use in above-grade masonry. It is recommended for exterior masonry veneers and for interior and exterior loadbearing walls. This "medium-strength" mortar represents the best compromise among compressive and flexural strength, workability, and economy and is, in fact, recommended for most masonry applications.

6.3.4 Type O Mortar

Type O is a "high-lime," low-compressive-strength mortar. It is recommended for interior and exterior non-loadbearing walls and veneers which will not be subject to freezing in the presence of moisture. Type O mortar is often used in one- and two-story residential work and is a favorite of masons because of its excellent workability and economical cost.

6.3.5 Type K Mortar

Type K mortar has a very low compressive strength and a correspondingly low tensile bond strength. It is seldom used in new construction, and is recommended in ASTM C270 only for tuckpointing historic buildings constructed originally with lime-sand mortar (refer to Chapter 15).

6.3.6 Choosing the Right Mortar Type

The Appendix to ASTM C270 contains non-mandatory guidelines on the selection and use of masonry mortars which are summarized in *Fig. 6-7*. To obtain optimum bond, use a mortar with properties compatible with those of the masonry units which will be used. To increase tensile bond in general:

- Increase the cement-to-lime ratio of the mortar within the limits established by ASTM C270.
- Keep air content within the limits established by ASTM C270.
- Use mortars with appropriate water retentivity for the absorption characteristics of the unit.
- Mix mortar with the maximum water content compatible with workability.
- Allow retempering of the mortar within recommended time limits.
- Use clay masonry units with moderate initial rates of absorption.
- Bond mortar to a rough surface rather than an extruded die skin.
- Minimize the time between spreading mortar and placing masonry units.
- Apply pressure in forming the mortar joint.