Occasionally, portland cement is used with sand and water only in what is called a *straight cement-sand mortar*. Mixed in proportions of 1 part cement to 3 parts sand, these mortars harden quickly and consistently, exhibit high compressive strengths, and offer good resistance to freeze-thaw cycles, but are stiff and unworkable, and have low water retention and poor bond.

Portland cement, which proved to be more stable and consistent in quality than natural cement, was first used as an additive in lime-sand mortars to provide greater compressive strength and promote faster setting. As the speed of building construction increased and portland cement gained wider acceptance, the proportion was increased until it accounted for as much as 80% of the cementitious ingredients.

Cement-lime mortars represent a compromise in the attempt to take advantage of the desirable properties of both lime-sand and straight cement-sand mortars. Workability, water retentivity, and compressive strength can be varied over a wide range of values by varying the proportions of cement and lime in the mix. Improvements in one property, however, are usually gained only at the expense of another. As workability and water retentivity increase with higher lime content, for instance, compressive strength decreases. Cement-lime mortars have a high sand-carrying capacity and generally require relatively high water content, which is beneficial in satisfying the moisture demands of unit absorption and cement hydration. During cold-weather construction, however, cement-lime mortars may be more susceptible to early-age freezing because of this high moisture content. During hot-weather construction, in dry conditions, or when highly absorptive units are used, cement-lime mortars generally perform better as their lime content increases. Board life is also extended with high-lime mortars.

Scanning electron microscopy has shown that cement-lime mortars can produce tight mechanical bonds with a continuous structure of hydration products and a low incidence of micro-cracks at the mortar-to-unit interface (*see Fig. 6-5*). Small voids at the interface, whether caused by drying shrinkage of the cement or by water or air bubbles in the mix, are often filled as the masonry ages by carbonation of the lime in the mortar. This process, known as *autogenous healing,* occurs when carbon dioxide reacts with the calcium hydroxide of the lime to form calcium carbonate. It is the same process of carbonation by which lime-sand mortars cure.

Cement-sand mortars gain about 75% of their ultimate strength in 10 to 14 days. With cement-lime mortars, ultimate strength development takes much longer, so small initial building movements can often be absorbed without breaking the bond between mortar and unit. Even after full cure, the extensibility of cement-lime mortars provides some elasticity to accommodate limited thermal and moisture movement in the masonry without cracking. Lime-rich mixes accommodate such movements more readily than the stronger and more rigid cement-rich mixes.

6.2.4 Masonry Cement Mortars

Proprietary masonry cements are widely used and are popular with masons because of their convenience, consistency, and economy (refer to Chapter 2). The first masonry cements were mixtures of portland cement and lime, preblended and prebagged to simplify job-site mixing operations and to increase batch-to-batch consistency. Other plasticizers such as ground clay, limestone,

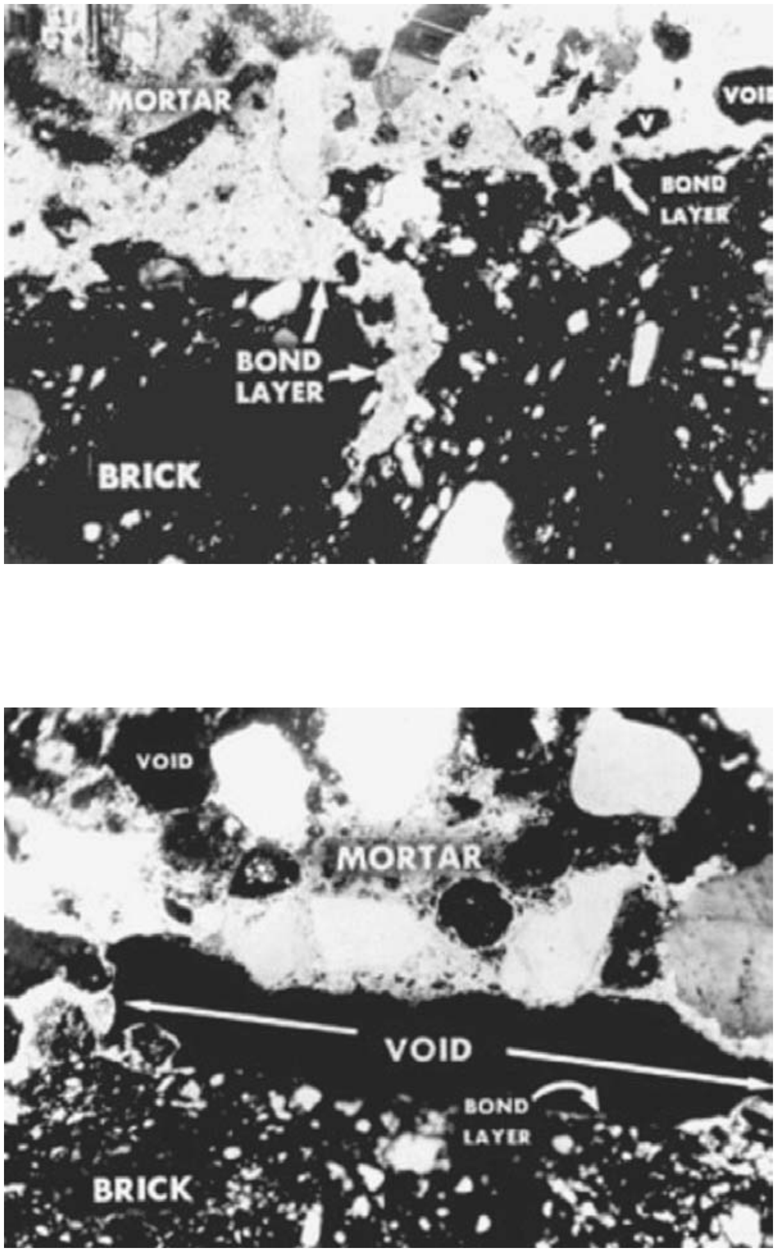

Figure 6-5 Microscopic view of mortar bond line. *(Photos courtesy National Lime Association.)*

and air-entrained cement were soon substituted for lime. Masonry cements generally contain one or more of the following materials:

- Portland cement or blended hydraulic cement
- A plasticizing material such as finely ground limestone, hydrated lime, or certain clays or shales
- Air-entraining agents
- Sometimes water-repelling agents