applied by vacuum pressure to simulate the absorption of the masonry units, and the mortar is tested a second time on the flow table.

Although they accurately predict the water-retention characteristics of mortar, laboratory values differ significantly from field requirements. Construction mortars need initial flow values of the order of 130 to 150%, while laboratory mortars are required to have an initial flow of only 105 to 115%. The amount of mixing water required to produce good workability, proper flow, and water retention is quickly and accurately adjusted by experienced masons. Results produced from masonry assemblages prepared in the field reliably duplicate the standards set by laboratory researchers. Dry mixes lose too much water to the masonry units and will not cure properly. Excessively wet mixes cause units to float, and will decrease bond strength. The "proper" amount of mixing water is universally agreed upon as the maximum compatible with "workability," and workability is best judged by the mason. Project specifications should not dictate water/cement ratios for masonry mortar or grout.

Mortar is subject to water loss by evaporation, particularly on hot, dry days. *Retempering* (the addition of mixing water to compensate for evaporation) is acceptable practice in masonry construction. Since highest bond strengths are obtained with moist mixes having good flow values, a partially dried and stiffened mortar is less effective if the evaporated water is not replaced. Mortar which has begun to harden as a result of cement hydration, however, should be discarded. Since it is difficult to determine by either sight or touch whether mortar stiffening is due to evaporation or hydration, it is customary to determine the suitability of mortar based on the time elapsed after initial mixing. Evaporative drying is related to both time and temperature. When ambient temperatures are above 80°F, mortar may be safely retempered as needed during the first 1½ to 2 hours after mixing. When temperatures are below 80°F, mortar may be retempered for 2½ to 3 hours after mixing before it should be discarded. ASTM C270, *Standard Specification for Mortar for Unit Masonry,* requires that all mortar be used within 2½ hours without reference to weather conditions, and permits retempering as frequently as needed within this time period. Tests have shown that the decrease in compressive strength is minimal if retempering occurs within recommended limits, and that it is much more beneficial to the performance of the masonry to maximize workability and bond by replacing evaporated moisture.

6.1.3 Bond Strength

For the majority of masonry construction, the single most important property of mortar is bond strength and integrity. For durability, weather resistance, and resistance to loads, it is critical that this bond be strong and complete. The term *mortar bond* refers to a property that includes

- Extent of bond or area of contact between unit and mortar
- Bond strength or adhesion of the mortar to the units

Bond strength can be tested as tensile bond or flexural bond. The mechanical bond between the mortar and the individual bricks, blocks, or stones unifies the assembly for integral structural performance, provides resistance to tensile and flexural stress, and resists the penetration of moisture. The strength and extent of the bond are affected by many variables of material and workmanship. Complete and intimate contact between the mortar and the unit is essential, and the mortar must have sufficient flow and workability to spread easily and wet the contact surfaces. The masonry units must have surface irregularities to provide mechanical bond, and sufficient absorption to draw the wet mortar into these irregularities (*see Fig. 6-4*). The moisture content, absorption, pore structure, and surface characteristics of the units, the water retention of the mortar, and curing conditions such as temperature, relative humidity, and wind combine to influence the completeness and integrity of the mortar-to-unit bond. Voids at the mortar-to-unit interface offer little resistance to water infiltration and facilitate subsequent disintegration and failure if repeated freezing and thawing occur.

Investigations have shown that bond strength derives primarily from the mechanical interlocking of cement hydration crystals formed in the unit pores and on its surface. Higher bond strengths result if the extent of bond is good and the network of hydration products is complete. Although a certain amount of unit suction is desirable to increase the depth of penetration of the mortar paste, excessive suction reduces the amount of water available for hydration at the unit surface. *Moist curing* of masonry after construction assures complete hydration of the cement and improves mortar bond to high-suction brick and to dry, absorptive concrete masonry units (see Chapter 15). Clay brick with high initial rates of absorption (IRA) can leave the mortar without enough water for complete cement hydration. Clay brick with low IRA and non-absorptive units such as glass block provide little or no suction of the mortar paste into surface pores. These types of units require a relatively stiff, low-water-content mortar.

Unit texture also affects bond. Coarse concrete masonry units and the wire-cut surfaces of extruded clay brick produce a better mechanical bond than molded brick or the die-formed surfaces of extruded brick. Smooth glass block and smooth stone surfaces provide little or no mechanical bond with the mortar. Loose sand particles, dirt, coatings, and other contaminants also adversely affect mortar bond.

All other factors being equal, mortar bond strength increases slightly as compressive strength increases, although the relationship has no direct proportions. Mortar with a laboratory compressive strength of 2500 psi develops tensile bond strength of the order of 50 to 100 psi. Although higher cement ratios in the mix increase both compressive and bond strength, high cement–low lime mortars are stiff and do not readily penetrate porous unit surfaces. This leaves voids and gaps which disrupt the bond and decrease bond strength. Increasing air content, or adding air-entraining ingredients,

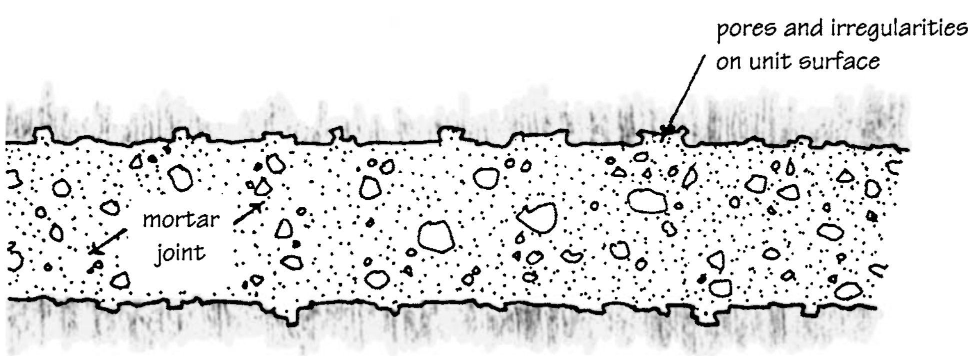

Figure 6-4 Exaggerated section showing increased mechanical bond between mortar and porous or rough unit surface.