rule, however, for converting values of compressive strength to transverse strength, or vice versa. Tensile and shearing properties of brick have not been widely tested, but data from NIST indicates that *tensile strength* normally falls between 30 and 40% of the modulus of rupture and *shear values* from 30 to 45% of the net compressive strength. Tensile strength of structural clay tile is quite low and usually will not exceed 10% of the compressive strength. The *modulus of elasticity* for brick ranges from 1,400,000 to 5,000,000.

3.4.3 Absorption

The weight of burned clay products ranges from 100 to 500 lb/cu ft. Variations may generally be attributed to the process used in manufacturing and burning. Increased density and weight result from fine grinding of raw materials, uniform mixing, pressure exerted on the clay as it is extruded, de-airing, and hard or complete burning. The extrusion process produces very dense brick and tile characterized by high strength and a small percentage of voids. Since properties of absorption are also affected by the method of manufacture and degree of burning, these factors indicate fairly close relationships among total absorption, weight, density, and compressive strengths. With few exceptions, hard-burned units are highest in strength and density and lowest in absorption.

The absorption of a brick or clay tile is defined as the weight of water taken up by the unit under given laboratory test conditions, and is expressed as a percentage of the dry weight of the unit. Since highly absorptive brick exposed to weathering can cause a build-up of damaging moisture in the wall, ASTM standards limit face brick absorption to 17% for Grade SW and 22% for Grade MW units. Most brick produced in the United States has absorption rates of only 4 to 10%.

An important property of brick that critically affects bond strength is the *initial rate of absorption* (IRA), or *suction.* High-suction brick absorbs excessive water from the mortar, which weakens bond, retards cement hydration, and results in water-permeable joints. Optimum bond and minimum water penetration are produced with units having initial rates of absorption between 5 and 25 gram/minute/30 sq in. at the time they are laid (*see Fig. 3-30*). The requirement is based on the area of the bed surface of a modular brick being approximately 30 sq in. Brick with an IRA greater than 30 gram/minute/30 sq in. should be thoroughly wetted by spray, dip, or soaker hose a day or so before installation so the moisture is fully absorbed but the surfaces are dry to the touch before the units are laid. Since IRA can be controlled by this means, it is not covered in ASTM requirements. It should, however, be included in project specifications.

Saturation coefficient, or *C/B ratio,* is a measure of the relationship of two aspects of water absorption: the amount freely or easily absorbed and the amount absorbed under pressure. The former (*C*) is determined by the 24-hour cold water absorption test, and the latter (*B*) by the 5-hour boil absorption test. For Grade SW brick, the ratio must be 0.78 or less to meet ASTM standards. The *C/B* ratio determines the volume of open pore space remaining after free absorption has taken place. This is important under severe weathering conditions when a unit has taken in water, which must have room to expand if frozen in order to avoid damage to the clay body. The theory does not apply to hollow masonry units or to certain types of de-aired products. In those cases, strength and absorption alone are used as measures of resistance to frost action.

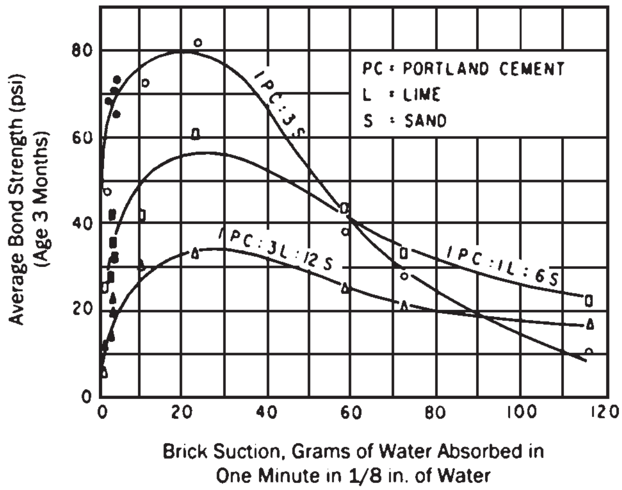

Figure 3-30 Relationship between bond strength and initial rate of absorption (IRA). (*From Ritchie and Davison,* Cement-Lime Mortars, *National Research Council, Ottawa, Ontario, Canada, 1964.*)

3.4.4 Durability

The durability of clay masonry usually refers to its ability to withstand freezing in the presence of moisture, since this is the most severe test to which it is subjected. Compressive strength, absorption, and saturation coefficient are evaluated together as indicators of freeze-thaw resistance, since a value cannot be assigned specifically for this characteristic.

Resistance to wear and abrasion is an important aspect of durability for brick paving, and for the lining of structures that will carry sewage, industrial waste, and so on. Abrasion resistance is closely associated with the degree of burning, and ranges from under-burned salmon brick at the low end to vitrified shale and fire clay at the high end. The stronger the unit and the lower the absorption, the greater the abrasion resistance will be. In salvaged brick or imported brick, under-burned units are easily detected without sophisticated laboratory equipment or procedures. Extremely soft units are easily scratched or scored with a coin, cut with a knife, or even broken by hand (*see Fig. 3-31*). Bricks conforming to ASTM standards, however, are high-quality products with proven records of performance in service.

3.4.5 Expansion Coefficients

Clay masonry products have *coefficients of thermal expansion* which range from 0.0000025 in./°F for fire clay units to 0.0000036 in./°F for surface clay and shale units. This minute thermal expansion and contraction is reversible. Moisture expansion, however, is not reversible. Fired bricks are at their smallest dimension when leaving the kiln. All natural moisture and the water added for forming and extrusion are evaporated during the firing process. Once fired, clay products begin to rehydrate by absorbing atmospheric moisture, causing irreversible expansion of the units. Test results have assigned a value of 0.02 to 0.07% for the *coefficient of moisture expansion.* Both vertical and horizontal expansion joints must be provided in the masonry to permit this movement. Severe problems can develop when clay masonry