5

NATURAL STONE

The earth's hard crust has undergone many changes throughout the millennia of geologic history. The stress and strains, the wearing away by atmospheric forces, by rain, wind, and heat, have produced a great variety of stones differing widely in appearance, but sharing some similarities of composition. All stone is made up of one or more minerals of specific crystalline structure and definable chemical makeup. No two blocks of stone, however, even if quarried side by side, are identical in internal structure or physical and chemical composition.

5.1 GEOLOGICAL CHARACTERISTICS

As a natural, inorganic substance, stone can be categorized by form and geological origin. *Igneous rock* is formed by the solidifying and cooling of molten material lying deep within the earth or thrust to its surface by volcanic action. Granite is the only major building stone of this origin. *Sedimentary rock* such as sandstone, shale, and limestone is formed by waterborne deposits of minerals produced from the weathering and destruction of igneous rock. The jointed and stratified character of the formation makes it generally weaker than igneous rock. *Metamorphic rock* is either igneous or sedimentary material whose structure has been changed by the action of extreme heat or pressure. Marble, quartzite, and slate are all metamorphically formed.

Stone may also be classified by mineral composition. Building stone generally contains as the major constituent (1) silica, (2) silicates, or (3) calcareous materials. The primary silica mineral is quartz, the most abundant mineral on the earth's surface and the principal component of granite. Silicate minerals include feldspar, hornblende, mica, and serpentine. Feldspar may combine with lime or potash to produce red, pink, or clear crystals. Hornblende, combining often with lime or iron, appears green, brown, or black. Mica, with iron or potash, produces clear crystals. Serpentine, in combination with lime, is generally green or yellow in color. The most common silicate building stone is also called serpentine after this mineral. Calcareous minerals include carbonates of lime and magnesia, such as calcite and dolomite, forming limestone, travertine, and marble.

5.2 PROPERTIES

Prior to the twentieth century, stone was the predominant material used in major building construction. It was not only the structural material, but also the exterior and interior finish, and often the flooring and roofing as well. The term "masonry" at one time referred exclusively to stonework, and the "architects" of medieval castles and cathedrals were actually stone masons. Because of its massive weight and the resulting foundation requirements, stone is seldom used today as a structural element in contemporary architecture. It is, however, still widely used as a facing or veneer; in retaining walls, steps, walks, paths, and roads; and as a floor finish, and is enjoying renewed popularity as a roofing material.

Despite their abundant variety, relatively few types of stone are suitable as building materials. In addition to accessibility and ease of quarrying, the stone must also satisfy the requirements of *strength, hardness, workability, porosity, durability,* and *appearance.*

The strength of a stone depends on its structure, the hardness of its particles, and the manner in which those particles are interlocked or cemented together. Generally, the denser and more durable stones are also stronger, but this is not always true. A minimum *compressive strength* of 5000 psi is considered adequate for building purposes, and the stones most often used are many times stronger in compression than required by the loads imposed on them. Failures from bending or uneven settlement are not uncommon, however, since stone is much stronger in compression than in flexure or shear. Stones of the same type may vary widely in strength, those from one quarry being stronger or weaker than those from another. Thus, the average crushing strength of any type of stone may be misleading because of the wide variation in test results produced by stones within the same classification. The table in *Fig. 5-1* illustrates the ranges typical for several major types of stone. In modern building construction, *shearing strength* in stone is not nearly so important as compressive strength. The allowable unit stress of stone in shear should not be taken at more than one-fourth the allowable compressive unit stress. In *tension,* a safe working stress for stone masonry with portland cement mortar is 15 psi.

Hardness of stone is critically important only in horizontal planes such as flooring and paving, but hardness does have a direct influence on workability. Characteristics may vary from soft sandstone, which is easily scratched, to some stones which are harder than steel. Both strength and hardness are proportional to silica content. *Workability* in this instance refers to the ease with which a stone may be sawed, shaped, dressed, or carved, and will directly affect the cost of production. Workability decreases as the percentage of siliceous materials increases. Limestone, for instance, which contains little silica, is easily cut, drilled, and processed. Granite, however, which consists largely of quartz, is the most difficult stone to cut and finish.

Porosity, the percentage of void content, affects the stone's absorption of moisture, thus influencing its ability to withstand frost action and repeated freeze-thaw cycles. Pore spaces are usually continuous and often form microscopic cracks of irregular shape. The method of stone formation and the speed of cooling of the molten material influence the degree and structure of these voids because of compaction and the possibility of trapped gases. Thus, sedimentary rock, formed in layers without high levels of pressure, is more porous than rock of igneous or metamorphic origin. Closely linked to this characteristic are grain and texture, which influence the ease with which stones may be split, and for ornamental purposes contribute to aesthetic effects as much as color.