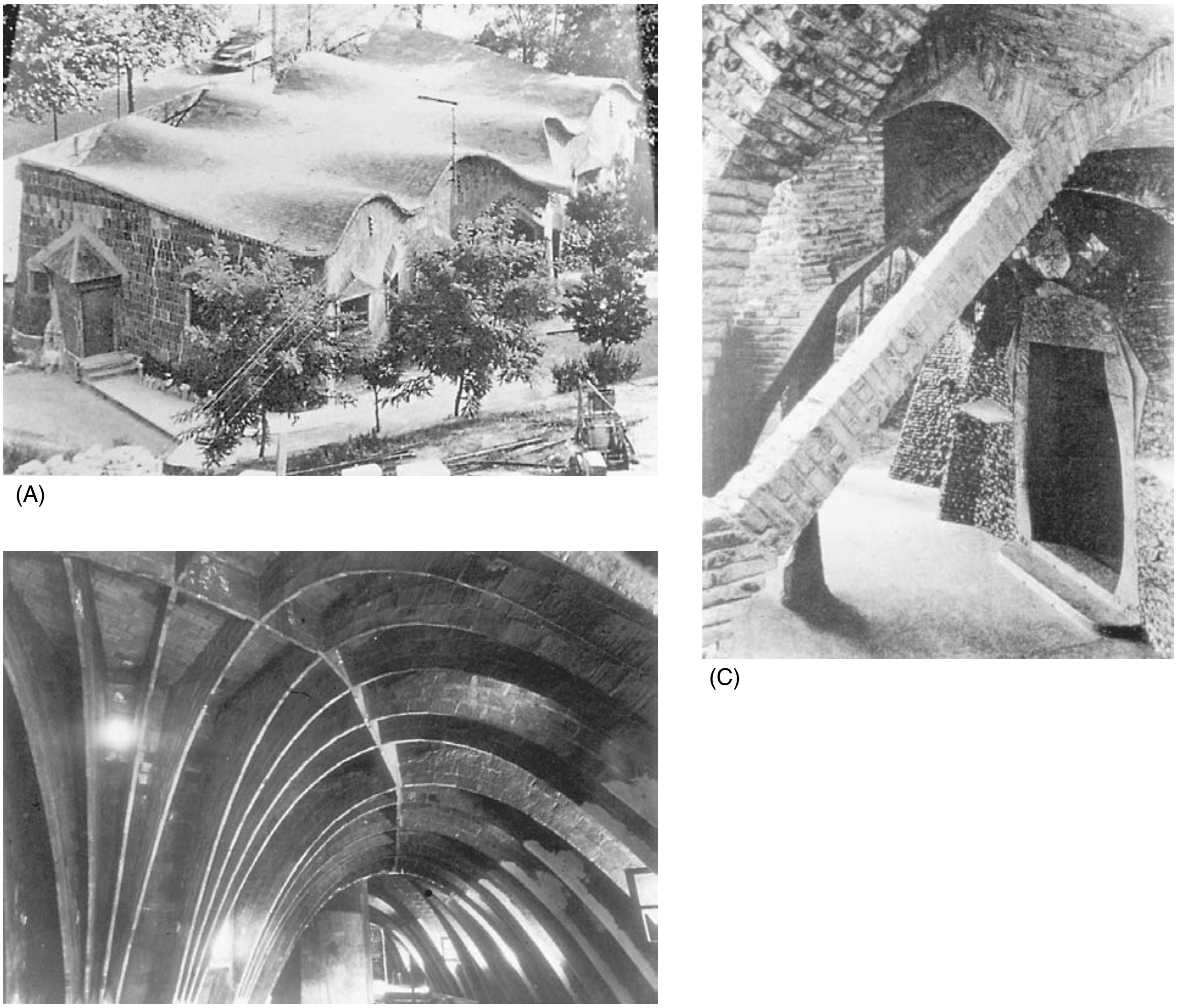

(A) (B) (C)

Figure 1-3 Gaudi's innovative masonry structures: (*A*) warped masonry roof, Schools of the Sagrada Familia Church; (*B*) thin masonry arch ribs, Casa Mila; and (*C*) inclined brick column, Colonia Guell Chapel. (*Photos courtesy of the School of Architecture Slide Library, the University of Texas at Austin.*)

By that time, manufacturers were producing brick with compressive strengths in excess of 8000 psi, and portland cement mortars had strengths as high as 2500 psi. Extensive testing of some 1500 wall sections generated the laboratory data needed to develop a rational design method for masonry. These studies produced the first reliable, mathematical analysis of a very old material, freed engineers for the first time from the constraints of empirical design, and allowed formulation of rational structural theories. It was found that no new techniques of analysis were required, but merely the application of accepted engineering principles already being used on other systems.

The development of recommended practices in masonry design and construction in the United States took place during the decade of the 1950s, and resulted in publication of the first "engineered masonry" building code in 1966. Continued research throughout the following two decades brought about refinements in testing methods and design procedures, and led to the adoption of engineered masonry structural systems by all of the major building codes in the United States. Laboratory and field tests have also identified and defined the physical properties of masonry and verified its excellent performance in fire control, sound attenuation, and thermal resistance.

Masonry construction today includes not only quarried stone and clay brick, but a host of other manufactured products as well. Concrete block, cast stone, structural clay tile, terra cotta, glass block, mortar, grout, and metal accessories are all a part of the mason's trade. In various definitions of masonry, this group of materials is often expanded to include concrete, stucco, or precast concrete. However, the most conventional application of the term "masonry" is limited to relatively small building units of natural or manufactured stone, clay, concrete, or glass that are assembled by hand, using mortar, dry-stacking, or mechanical connectors.

1.4 CONTEMPORARY MASONRY

Contemporary masonry may take one of several forms. Structurally, it may be divided into loadbearing and non-loadbearing construction. Walls may be of single- or multi-wythe design. They may also be solid masonry, solid walls of hollow units, or cavity walls. Finally, masonry may be reinforced or unreinforced, and either empirically or analytically designed. Loadbearing masonry supports its own weight as well as the dead and live loads of the structure, and all lateral wind and seismic forces. Non-loadbearing masonry also resists lateral loads, and veneers may support their own weight for the full height of the structure, or be wholly supported by the structure at each floor. Solid masonry is built of solid units or fully grouted hollow units in multiple wythes with the collar joint between wythes filled with mortar or grout. Solid walls of hollow units have open cores in the units, but grouted collar joints. Cavity walls have two or more wythes of solid or hollow units separated by an open collar joint or cavity at least 2 in. wide (*see Fig. 1-4*). Masonry veneers are applied over non-masonry backing walls.

Empirical designs are based on arbitrary limits of height and wall thickness. Engineered designs, however, are based on rational analysis of the loads and the strength of the materials used in the structure. Standard calculations are used to determine the actual compressive, tensile, and shear stresses, and the masonry designed to resist these forces. Unreinforced masonry is still sometimes designed by empirical methods, but is applicable only to low-rise structures with modest loads. Unreinforced masonry is strong in compression, but weak in tension and flexure (*see Fig. 1-5*). Small lateral loads and overturning moments are resisted by the weight of the wall. Shear and flexural stresses are resisted only by the bond between mortar and units. Where lateral loads are higher, flexural strength can be increased by solidly grouting reinforcing steel into hollow unit cores or wall cavities wherever design analysis indicates that tensile stress is developed. The cured grout binds the masonry and the steel together to act as a single load-resisting element.

Contemporary masonry is very different from the traditional construction of earlier centuries. Its structural capabilities are still being explored as continuing research provides a better understanding of masonry structural behavior. Contemporary masonry buildings have thinner, lighter-weight, more efficient structural systems and veneers than in the past, and structures designed in compliance with current code requirements perform well, even in cases of significant seismic activity and extreme fire exposure.

1.5 COMMON CONCERNS

Although there is continuing structural research aimed at making masonry systems stronger, more efficient, and more economical, many of the concerns