before it stiffens, these specially blended admixtures expand the grout, retard its set, and lower the water requirements. Admixtures can also be used to accelerate set in cold weather or retard set in hot weather. Superplasticizers may also be used in hot weather to increase slump without adding water or reducing strength. All grout mixes that contain admixtures should be tested in advance of construction to assure quality. Grout mix designs that meet project requirements and ASTM guidelines can be determined in the laboratory by preconstruction testing of trial batches.

The table in *Fig. 2-18* lists the types of admixtures most commonly used in masonry grout. Air-entraining admixtures for increased freeze-thaw durability are used less frequently because the grout is normally not exposed to moisture saturation.

2.4 ENVIRONMENTAL IMPACT

Environmental issues are a growing concern in the construction industry. New terms like "green buildings," "sustainable architecture," "embodied energy," and "building ecology" have crept into the vocabularies of architects, owners, and contractors alike. Ecological issues are being driven beyond the philosophical and ideological into the mainstream of business economics. The cost of energy, the cost of raw materials, and the cost of solid waste and hazardous waste disposal are directly linked to profitability in any industry. The operational efficiency of buildings and occupant productivity also have a direct effect on overhead and profit as well as health.

ASTM's Subcommittee E50.06 on Green Buildings defines that term as "building structures…that are designed, constructed, operated and demolished in an environmentally enhanced manner." That means using recycled materials wherever possible, and avoiding materials that create the clinical symptoms of "sick building syndrome." Areas of particular concern include resource efficiency, energy efficiency, pollution control, waste minimization, and indoor air quality.

The concepts of green buildings and sustainable architecture are so new that guidelines are only now being developed. Generally, a building is evaluated throughout its life cycle, from construction through operation and demolition. The amount of energy consumed and the amount of waste generated at each phase, as well as the building's internal environment and its relationship to the external global environment, should enter into site considerations, design decisions, and product selections.

Type of Admixture	Uses
Shrinkage compensating	Expands grout to compensate for moisture shrinkage
Set retarding	Delays set during hot weather, long transit, or time delays
Set accelerating (noncorrosive)	Accelerates set during cold weather
Corrosion inhibiting	Reduces corrosion in harsh environments
Superplasticizing	Increases slump without additional water and without strength reduction
Antifreeze compound	THERE IS NO SUCH THING AS AN "ANTIFREEZE" ADMIXTURE

Figure 2-18 Chemical admixtures for masonry grout.

The green building movement seeks to identify building materials that minimize environmental impacts in their creation and use, and minimize health risks to building occupants. But there is no such thing as an environmentally perfect material. Product selection for green buildings is therefore a process of evaluation and compromise, seeking the best overall solution for a given program and budget. For example, steel may have more embodied energy than wood, but steel framing is more efficient and can produce smaller structural members and longer spans. Ceramic tile is more energy intensive than hardwood for flooring, but requires no finish coatings and no chemical cleaners for maintenance. By the same token, masonry products may require more energy to produce than some other building materials, but their performance characteristics, durability, and chemical stability usually justify similar trade-offs.

Masonry's multi-functional properties have always made it an attractive choice as a building material. From an environmental standpoint, this ability to serve more than one purpose is a particular bonus. Coatings are generally not required because most types of masonry already have a finished surface. Sound batts are not required because the masonry has inherent sound-damping capacity. Fireproofing is not required because masonry is non-combustible. And structural framing is eliminated in buildings where loadbearing systems can be used. The thermal mass of masonry can reduce the amount of insulation material required in some climates. It can also, when properly integrated with passive solar design techniques, reduce total energy consumption and reduce utility service demand through off-peak loading. Such multi-functional applications, as well as the long service life and low maintenance traditionally associated with masonry buildings, mean that the energy embodied in the materials goes further, and delivers more than many other materials.

Two of the premier examples typically cited for their environmentally responsible design are the Audubon Society Headquarters in New York and the Natural Resources Defense Council Building in Washington, both designed by the Croxton Collaborative architects. One thing the two have in common is their adaptive reuse of historic masonry buildings. The rehabilitation of historic buildings, many of which are masonry, conserves the embodied energy already invested in such structures.

Products and systems must demonstrate reduced life-cycle energy consumption, increased recycled content, and minimal waste products in manufacture, construction, use, and demolition. Such requirements may result in the introduction of mortarless interlocking masonry systems, a renewed interest in "bio-bricks," or the successful reintroduction of autoclaved cellular concrete block from Europe.

2.4.1 Resource Management, Recycled Content, and Embodied Energy

The raw materials for making clay brick are an abundant resource that is easily acquired and produces little waste. Clay-mining operations are regulated by the Environmental Protection Agency, and dormant pits have been reclaimed as lakes, landfills, and nature preserves. Recycled materials are not often used in the manufacture of clay brick, but additives such as oxidized sewage sludge, incinerator ash, fly ash, waste glass, paper-making sludge, and metallurgical wastes have been incorporated with varying degrees of success. The waste materials are either burned to complete combustion at the high kiln temperatures needed to bake the brick, or encapsulated within the clay body where they cannot leach out. The primary energy cost associated with brick manufacturing is the fuel burned in the firing process.