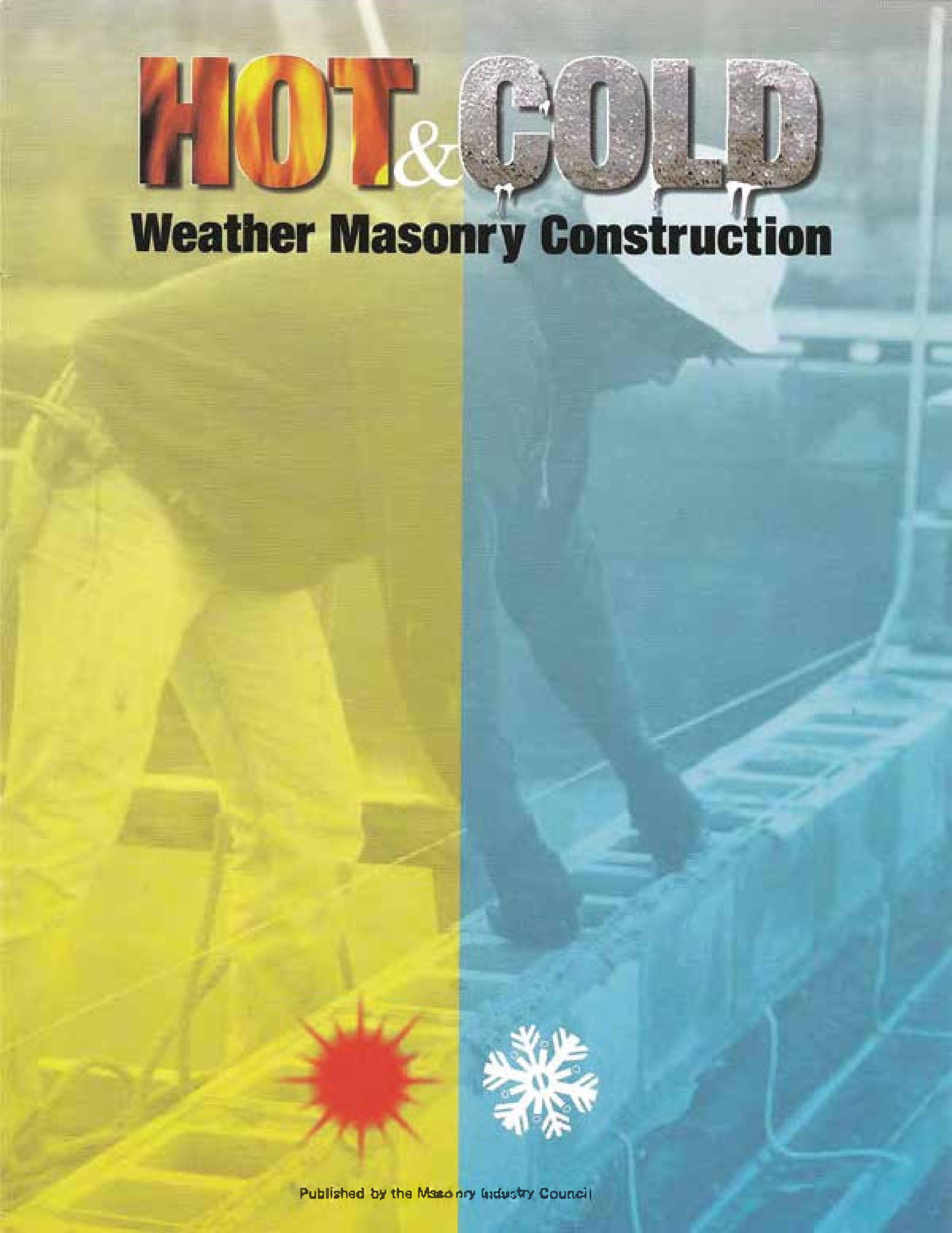
HOT & COLD

Weather Masonry Construction



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Hot & Cold Weather Masonry Construction

FOREWORD

This document was developed as a reference for the construction of masonry structures during above-normal and below-normal temperature conditions. The practices presented herein are based on criteria presented in Specification for Masonry Structures, ACI 530.1-98/ASCE 5-98/TMS 402-98, prepared by the Masonry Standards Joint Committee (MSJC).

When masonry construction is conducted under either of these conditions, it is important to have an understanding of the effects of temperature (both ambient and mean daily) and wind, as well as an understanding of the influence these environmental factors have on masonry and mortar properties, construction practices, and economics.

A knowledge of these factors provides an important tool to the designer and contractor during the early planning stages. From this knowledge, judgments may be made regarding the type and amount of protection, if any, that may be required at all stages of the construction. This also provides a sound basis for the development of construction scheduling and cost estimates. Just as importantly, this knowledge is also useful in providing guidelines to the mason contractor during the daily construction sequence to assure that the completed masonry performs to the satisfaction of the architect, designer, and owner.

The Masonry Industry Council believes that the methods and procedures recommended in this publication are important in assuring the quality and performance of masonry constructed in all types of weather.

The recommendations contained herein are the consensus of the Masonry Industry Council.

ACKNOWLEDGEMENTS

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GENERAL

Advanced planning and careful preparation are key to successful and satisfactory masonry construction of any type of weather, especially periods of relatively hot or cold weather. Construction conducted during periods of hot and cold weather involves changes in procedures that may require additional equipment and supplies.

During below-normal temperature periods (40°F and below; 4.4°C and below) and above-normal temperature periods (90°F and above; 32.2°C and above) the rate of masonry construction may be affected, since the mason must be more attentive to such things as personal comfort, materials handling, and masonry protection.

It is acknowledged that as the ambient temperature rises above 90°F (32.2°C) or falls below 40°F (4.4°C), more of the construction materials must be preconditioned to permit satisfactory masonry strength development. To successfully accomplish hot and cold weather masonry construction, a knowledge of the performance characteristics of the construction materials at above-normal and below-normal temperature conditions is essential.

WEATHER SERVICES

General. The design, planning, and execution of all-weather masonry construction requires several types of weather service data. These data fall into two general categories: climatology, which may be defined as the historic record of the average and extremes of temperature phenomena; and meteorology, which may be defined as the current state of the atmospheric conditions and their short-term projected movements and consequences.

In the early planning stages of all-weather masonry construction projects, the average climatologic data is of particular importance. For example, average daytime and nighttime temperatures, average wind velocity for the expected period of construction, as well as the expected extremes for these periods, are factors that need to be considered. From such data, judgments can be made as to the amount and type of protection, if any, that may be necessary, approximate length of time each protection requirement will be in effect, and the approximate date when construction requirements must be changed. Planning and cost estimates can then be adjusted accordingly.

Sources of Information. There are several sources of climatological data and information available. The major source for this information is the National Climatic Data Center (NCDC), an agency of the U. S. Department of Commerce.

The National Oceanic And Atmospheric Administration (NOAA) Data Centers (of which NCDC is the largest) provide long-term preservation and management of, and ready accessibility to, environmental data. The combined archive includes records taken before Ben Franklin's weather observations and continues with the latest real-time satellite imagery. The centers are part of the National Environmental Satellite and Information Service (NESDIS).

Climatological Information: Data tables of meteorological elements are available that outline the climatic conditions at major weather observation stations in all 50 states. These tables contain the following information:

Observed Data

Temperature - Highest of Record
Temperature - Lowest of Record
Mean Number of Days Minimum Temperature 32°F or Less
Mean Number of Days with Precipitation 0.01 inch or More
Snowfall (Including Ice Pellets and Sleet) Average Total in Inches
Wind - Average Speed (mph)
Wind - Maximum Speed (mph)
Sunshine - Average (Average Percent of Possible)
Cloudiness - Mean Number of Days (Clear, Partly Cloudy, Cloudy)
Average Relative Humidity - Morning, Afternoon

Climatological Normals

Normal Daily Maximum Temperature
Normal Daily Minimum Temperature
Normal Daily Mean Temperature
Normal Heating Degree Days
Normal Cooling Degree Days
Normal Precipitation, Inches

On line ordering of these tables is available at:
http://www.ncdc.noaa.gov/oa/ncdc.html

Much of the information available through NCDC may also be accessed through publications, on-line services, and on CD-ROM. A complete listing of NCDC products and services may be obtained by contacting:

U. S. Department of Commerce
National Oceanic and Atmospheric Administration National Environmental Satellite, Data and Information Service
National Climatic Data Center Federal Plaza
151 Patton Avenue
Asheville, NC 28801-5001
Telephone: (704) 271-4800
Facsimile: (704) 271-4876

NCDC also maintains an Internet website which may be accessed at:
http://www.ncdc.noaa.gov/

Meteorological Information. The U. S. Weather Bureau operates or gathers data from thousands of stations all over the world, including weather photo satellites. It is on these basic data that the "forecasting" of weather is based. The Weather Bureau is, however, responsible only for specific types of short range information and forecasting. Among these are weather phenomena, which may result in disaster, i.e., loss of life or property from wind, rain, flooding, tidal disturbances, etc. Their principal services are for the use of farmers, aviation and marine interests, and the public. The public forecast usually consists of:

1. Present temperature
2. Present sky condition (clear, cloudy, etc.)
3. Present wind velocity and direction
4. Present relative humidity
5. General prediction for high daytime temperature
6. General prediction for next-day sky condition
7. General prediction for low overnight temperature
8. General prediction of next-day precipitation possibility

These data may be readily obtained in abbreviated form through daily newspapers, local radio and television broadcasts, and the cable television Weather Channel. This information, although general and for an entire metropolitan area, may be sufficient for some minor decisions, but will not suffice for critical construction decisions.

Meteorological Consultants. The basic source data and information collected by the Weather Bureau is also available to private meteorological consultants who provide specialized services. These private consultants can take the raw data and make specific forecasts for the project site area. The forecast will be for the pertinent information needed and in a language that can be interpreted by the contractor.

The American Meteorological Society has established a program for the certification of consulting meteorologists. The principal purpose of the program is to enable users of meteorological services to select consultants with greater confidence in the quality and reliability of the products and services they provide. Some of the areas of specialization include:

Applied Meteorology
Regulatory Permits and Applications Consulting Services
Forecasting and Weather Prediction Expert Testimony
Climatology

For a complete list of Certified Consulting Meteorologists and services, contact the American Meteorological Society, 45 Beacon Street, Boston, MA 02108; Phone: (617) 227-2425

Summary. *All parties involved with masonry construction should be cognizant of the construction schedule, the probabilities of cold or hot weather masonry construction being necessary, and the availability of weather data and services. If more specific interpretation is required, consideration should be given toward obtaining the services of a professional meteorologist.*

HOT WEATHER MASONRY

MORTAR AND GROUT PERFORMANCE

General. During hot weather masonry construction, the mortar's temperature and properties, the masonry unit's temperature and properties, wind velocity, and relative humidity influence the rate at which mortar sets.

As the temperature of the mortar increases, the following physical property changes take place:

a. Workability is reduced, or the addition of more water is required to maintain a given workability
b. Initial and final set occur earlier
c. Depending on the surface characteristics, temperature, and moisture content of the masonry units, moisture loss from the mortar due to suction takes place much more rapidly
d. A given amount of air-entraining agent yields less entrained air

Rapid water loss due to evaporation and suction reduces the amount of water available for hydration of the cement. Since hydration of cement is necessary for normal strength development of mortar, a reduction of strength development may occur under rapid drying conditions. Evaporation removes moisture more rapidly from the surface of mortar joints resulting in weaker mortar on the surface.

Covering the walls immediately after construction will effectively slow the rate of water loss from the masonry, while the application of a fog spray during the first 72 hours can reduce the effects of hot, dry, windy weather. Strength development in masonry subjected to early dry-out often can be reactivated by spraying the masonry with water.

Grout will also be susceptible to a rapid set at above normal temperatures. The effects are primarily influenced by the temperature of the wall into which the grout is placed. This will influence placement procedures, not final strength.

Summary. *Mortar temperatures and properties, masonry unit temperatures and properties, wind velocity and relative humidity can affect the performance of mortar. Cooling mortar materials, covering the wall immediately after construction, and the application of a fog spray to the surface of the wall in hot weather can provide needed workability in the plastic mortar and the necessary water required to provide proper strength development.*

PERFORMANCE OF UNITS

General. When considering the influence of masonry units on construction during hot weather, one should recognize that the absorption (suction) of units may vary dependent upon their exposure at the project. Units that have been heated and dried by the sun will absorb more water from the mortar than units kept shaded.

High absorption units can contribute to rapid dry-out of mortars in hot weather. Wetting of high absorption fired clay units prior to use will reduce this tendency to dry out the mortar. Concrete masonry units should not be wetted before use, but concrete masonry can be covered with wet burlap or water sprayed after walls are constructed to assure adequate curing moisture.

Summary. *Summary. Unit temperatures and absorption characteristics affect the properties of masonry constructed during hot weather. Shading units during storage, wetting high IRA fired clay units, and water spraying or covering clay or concrete masonry walls with wet burlap after construction are methods of compensating for the effects of hot weather on unit properties and masonry performance.*

PLANNING AND CONSTRUCTION

General. As previously noted, hot weather influences the properties of mortars and units as individual materials and it affects the interaction between mortar and units that occur in the construction of masonry. The rates of stiffening and setting of mortar are increased, while hot, dry units exhibit high suction characteristics. Relative humidity, wind velocity, and sunshine are additional factors that affect the moisture loss during and after construction. Unless proper planning, preparation, and construction procedures are used, hot weather can impede productivity and compromise the quality of masonry construction.

Planning should include a consideration of scheduling to avoid construction during hot, mid-day periods and a review of the requirements for materials. Provisions need to be made to protect and prepare masonry materials for use. Modifications to construction procedures may include wetting high absorption clay units, reducing the length of mortar spread before placement of units to minimize elapsed time between spreading mortar and placing unit, covering masonry after construction, and/or fog spraying with water.

Summary. *Planning, preparation, and procedures for hot weather masonry construction should focus on assuring that mortar remains workable from the time of mixing until placement of units, and that sufficient moisture remains in the masonry to provide for normal strength development of the mortar. Available avenues of achieving these goals include scheduling construction to avoid hot, mid-day periods, optimizing selection and preparation of masonry materials, protecting constructed masonry from sun and wind, damp curing masonry by covering with wet burlap, or fog spraying with water.*

MATERIALS

General. Hot weather construction does not require drastic changes in masonry units, mortar, or grout mixes. Materials selected for normal temperatures will generally require little if any change during construction at temperatures above normal.

Masonry Units. Masonry units should conform to the appropriate ASTM Standard for the type specified.

All masonry units used during normal temperature masonry construction may be used during hot weather construction. Absorption characteristics of units differ and may require adjustment of preparation and construction procedures. For example, clay brick units having a high initial rate of absorption (IRA) can contribute to rapid dryout of mortars in hot weather. Fired clay units that have an IRA over 30 g/min/30 in2 (30 g/min/194 cm2) should be wetted prior to use to reduce the absorption characteristics of the units when laid. Unit surfaces should not be dripping wet, since a saturated surface will inhibit development of bond between mortar and unit. A saturated, surface-dry condition is optimum.

Concrete masonry units should not be wetted before use. Concrete masonry units expand when wet and shrink as they dry. Thus, placing wet concrete masonry units in a wall contributes to increased shrinkage. A concrete masonry wall can be fog sprayed after the wall is constructed to assure the availability of adequate curing moisture.

Mortar. Requirements for mortar are contained ASTM C 270, Standard Specification for Mortar for Unit Masonry.

Mortar Selection and Preparation. Water retention and board life are the most important properties of plastic mortar in hot weather. High strength mortars tend to exhibit reduced workability, board life, and water retentivity. The specifier should consider specifying Type N mortar in hot weather, provided it is structurally adequate for the given application. ASTM C 270 specifies that mortar should be mixed in a mechanical mixer for between three and five minutes. During hot weather, improved workability will be obtained with a 5 minute mix time. Since mortar will stiffen more rapidly in hot weather, it should be mixed with the maximum amount of water consistent with workability and retempered as needed to maintain that workability. ASTM C 270 indicates that mortar can be retempered and used during the first 2-1/2 hours after mixing. During hot weather it is advisable to limit the time period to 2 hours or less.

Portland Cement. Requirements for portland cement are contained in ASTM C150 for Type I or Type II cement.

Type III, high early strength cement, is not recommended for hot weather construction. Its early strength developing characteristics may further increase the rate of stiffening of the plastic mortar in hot weather.

Blended Cements. Requirements for blended cements are contained in ASTM C 595. All of the Types listed in ASTM C 270 are considered to be acceptable for use during hot weather construction.

Masonry Cement and Mortar Cement. Requirements for masonry cements and mortar cements are contained in ASTM C 91 and ASTM C 1329 respectively. The Type designation should correspond to the mortar type specified.

Lime. Requirements for Type S hydrated lime are contained in ASTM C 207.

Lime putty prepared from slaked quicklime is also acceptable, but seldom used due to the convenience of packaged dry hydrated lime. Lime increases the water retention of mortar.

Aggregates. Requirements for sand for mortar are contained in ASTM C 144.

Evenly graded sand provides optimum workability, water retentivity, and strength development. Over-sanding or under-sanding the mortar mix should be avoided. While increasing sand content may increase board life, over-sanded mixes will have poor water retention and strength development characteristics. Conversely, undersanded mortars tend to exhibit poor board life.

Water. Mix water used in mortar and grout should be potable. Only cool water should be used during periods of above-normal temperatures. When ice is used to cool the water, it must be completely melted before mixing with other materials.

Summary. *Compliance with appropriate standards is necessary to ensure that desired properties of the materials are achieved. Avoid specifying high strength mortars when not structurally required. Wetting high-absorption fired clay units prior to use can reduce the water loss of mortars to these units. Concrete masonry units should not be wetted prior to installation, although concrete masonry walls may be fog sprayed after construction. Only cool water should be used in mortar and grout mixes.*

Admixtures. Admixtures are materials added during the initial mixing of mortar to modify one or more of the properties of the mortar in the plastic and/or hardened state. They should be used only when specified and only when their compatibility with other mortar ingredients and required mortar properties have been confirmed by laboratory tests.

Retarders. In hot weather construction, the admixtures most often considered for use are retarders. Retarders delay the set time of the mortar, but they do not reduce evaporation rates. Proper curing is still needed to develop required hardened mortar properties. Therefore, the use of retarders is not a substitute for recommended hot weather construction practices.

Pigments. Pigments are considered to have little impact on hot weather performance of mortars provided they meet the requirements for normal construction.

Air Entraining Agents. The addition of air entraining admixtures is not recommended due to difficulty maintaining field control of the addition rate and subsequent mortar air content. This does not preclude the use of airentraining cementitious materials.

Summary. *Admixtures should not be included in masonry mortars unless they are laboratory tested at the temperature extremes presumably requiring their use. Further, their use should produce the desired effect while used in the construction. Specifiers should be aware of the side effects, such as corrosion and retardation, of the admixture containing mortar before selecting any admixture.*

Grout. Requirements for grout are contained in ASTM C 476 Standard Specification for Grout for Masonry. Slump should be maintained as high as possible for proper placement.

MATERIAL STORAGE

General. All masonry materials, when delivered to the job site, must be carefully stored.

Masonry sand, when bulk delivered, should be shaded, sprinkled, or covered to prevent excessive water loss from evaporation.

Bagged materials and masonry units, when delivered to the construction site, should be stored elevated to prevent moisture migration from the ground to the materials, and then protected against water penetration through the sides and the top.

Coverings should be properly installed so that all materials are completely covered. Tarpaulins, reinforced paper, or other water-repellent sheet materials may be used. Sufficient space should be provided between the materials and the covers to allow circulation to take place.

If the weather and size of the project warrant, it is recommended that a shelter be provided for the materials storage and mortar mixing areas.

Summary. *Materials delivered to the construction project need to be protected from damage and contamination. Cover sand piles and sprinkle with water as needed to maintain in damp condition. Cover or shade units from direct exposure to the sun.*

MATERIAL COOLING

General. Masonry sand comprises approximately 75% of the mortar mix. Sprinkling of masonry sand stockpiles can increase the evaporative cooling of the sand and prevent rapid absorption of the mixing water by hot, dry sand and subsequent early stiffening of the mortar.

Cool water should be used to mix mortar and grout. Ideally, the water should be stored in the shade in a lightcolored, open barrel to maximize cooling from surface evaporation. Water from long hoses exposed to the sun should not be used. When exposed to sunlight, long hoses act as water heaters. When practical, ice may be added to the mix water. Complete melting of the ice must take place before the water comes into contact with the other mortar or grout ingredients.

Equipment used to mix, transport, and store mortar and grout needs to be flushed thoroughly with water immediately before use. Mortar can absorb heat from metal mixers, wheelbarrows, and mortar pans, and lose water to the wood mortar boards.

PROTECTION

General. Increased temperatures result in a decrease in relative humidity at the surface of the masonry and an increase in evaporation rates. These conditions can lead to dry-out of the mortar and grout, which adversely affects their properties.

The use of wind screens has been shown to be effective in protecting against the drying effects of wind during extremely hot weather. Materials commonly used for protection are canvas and synthetic coverings (reinforced polyethylene and vinyl).

Under severe drying conditions, research has shown that the daily application of a fog spray to the surface of the walls for a period of about three days or covering of the walls with polyethylene plastic, or both, dramatically improves flexural bond strength over walls not similarly protected.

The tops of all walls not otherwise protected should be covered with a weather resistive membrane extending a minimum of two feet (0.6m) down on both sides to prevent water from entering the masonry.

Safety. Workers responsible for installing protection should have a full knowledge of the type of wind screen being used, and how to properly erect, adjust, brace, anchor, and dismantle the complete assemblage. Wind screens must be properly erected, braced and anchored so that the assemblage is safe from wind loads and lift. Protection should include measures to safeguard workers from injuries caused by high winds.

Summary. *The use of wind screens and moist curing of walls by the use of fog sprays and/or protective coverings, will protect against dry-out of the mortar and grout and help to improve flexural bond strength. Construction of wind screens should take into account consideration of the protection of the masonry structure and the safety of the workers.*

HOT WEATHER MASONRY CONSTRUCTION AND PROTECTION

RECOMMENDATIONS
Hot weather masonry construction and its quality control require some additional attention to construction practices and protection. Attention should be directed to the following details as well as those normally attended.

1. Implement the hot weather construction and protection requirements of this recommended practice when daytime temperatures are forecast to exceed 100°F (37.8°C) or 90°F (32.2°C) with a wind velocity greater than 8 mph (12.9km/h). Check local weather reports before the start of each day and periodically measure air temperature and wind speed during the day.

2. Receive, store, and protect construction materials in ways that prevent water from entering the materials. Cover or shade mortar materials; protect water, sand, and cement from exposure to direct sunlight. When shelters are constructed to shade materials, support covers such that they do not come into direct contact with the materials being protected and air circulation is allowed to take place.

3. Do not exceed a maximum mortar or grout temperature of 120°F (48.9°C). Check mortar temperature after mixing and before use. Use cold water to mix the mortar or grout. Ice may be added to the water, but complete melting must take place before mixing with other materials. Sand piles may be cooled by sprinkling.

4. Fog spray all newly constructed masonry until damp, at least three times a day until the masonry is three days old. Cover walls with polyethelyne plastic sheeting to prevent moisture loss from the masonry to the atmosphere.

5. At the end of the day, protect the top surfaces of all masonry to prevent moisture, as rain, from entering the masonry. Cover the top surfaces such that the protection extends down a minimum of 2 feet (0.6 m) down all sides of the masonry.

REQUIREMENTS

Table 1
Hot Weather Preparation and Construction Requirements
(ACI 530.1-98/ASCE 6-98/TMS 602-98)

Temperature Range (Ambient)*	**Preparation Requirements (Prior to Commencing Masonry Work)**	**Construction Requirements (While Masonry Work is in Progress)**
Above 115°F (46.1°C) or Above 105°F (40.6°C) with a wind velocity greater than 8 mph (12.9 km/h r)	Shade materials and mixing equipment from direct sunlight Maintain sand piles in a damp loose condition Provide necessary conditions and equipment to produce mortar and grout having a temperature below 120°F (48.9°C)	Use cool mixing water for mortar and grout Maintain temperature of mortar and grout below 120°F (48.9°C) Flush mixer, mortar and grout transport container and mortar boards with cool water before they come into contact with mortar ingredients or mortar Maintain mortar consistency by retempering with cool water Use mortar within 2 hours of initial mixing
Above 100°F (37.8°C) or Above 90°F (32.2°C) with a wind velocity greater than 8 mph (12.9 km/h r)	Maintain sand piles in a damp, loose condition Provide necessary conditions and equipment to produce mortar and grout having a temperature below 120°F (48.9°C)	Maintain temperature of mortar and grout below 120°F (48.9°C) Flush mixer, mortar and grout transport container and mortar boards with cool water before they come into contact with mortar ingredients or mortar Maintain mortar consistency by retempering with cool water Use mortar within 2 hours of initial mixing

* The surrounding jobsite temperatures when preparation activities and construction are in progress.

Table 2
Hot Weather Preparation and Construction Requirements
(ACI 530.1-98/ASCE 6-98/TMS 602-98)

Temperature Range (Mean Daily)*	**Hot Weather Protection Requirements (Newly Completed Masonry Construction)**
Above 100°F (37.8°C) or Above 90°F (32.2°C) with a wind velocity greater than 8 mph (12.9 km/h r)	Fog spray all newly constructed masonry until damp, at least three times a day, until the masonry is three days old

* The temperature calculated to be the average of the extremes forecast by the local weather bureau over the next 24 hours.

COLD WEATHER MASONRY

MORTAR AND GROUT PERFORMANCE

General. As the ambient temperature falls below freezing, the individual mortar and grout ingredients become colder and their proper preparation becomes more involved. The heat-liberating reaction between cement and water is slowed or stopped when the cement paste is subjected to temperatures below 40°F (4.4°C). Hydration and strength development proceed only at temperatures above freezing and only when sufficient water is available. However, cold weather masonry construction may proceed at temperatures below freezing provided the mortar and grout ingredients are heated and, as the ambient temperature decreases, the masonry unit and the structure are maintained above freezing during the early hours after construction.

Mortars mixed using cold but unfrozen materials possess plastic properties quite different from those mixed at normal temperatures. Mortars mixed at low temperatures have a lower water demand, longer setting and hardening times, higher air contents and lower early age strength than those mixed at normal temperatures. Heated mortar materials produce mortars with performance characteristics identical to those in the normal-temperature range and, consequently, this construction practice is deemed desirable for masonry constructed during cold weather.

Mortars and grouts mixed to a particular temperature lose heat until they attain the ambient temperature. During this temperature loss, they undergo various stages of cooling, freezing, and additional cooling after freezing. They first cool to 32°F (0°C). The mortars or grouts then enter a supercooling period, where temperatures below 32°F (0°C) may be measured.

Freezing of mortars and grouts may not occur at 32°F (0°C) because dissolved cement compounds depress the freezing point of the solution in the systems. Freezing then begins, when the temperature falls below the depressed freezing point, and continues until all of the water in the mortar or grout is frozen. The temperature remains essentially constant during this stage. Once the water has frozen, the mortar or grout temperature decreases until it reaches the ambient temperature.

Increased wind velocities, combined with falling temperatures, increase the rate of cooling. Chill factor, the term relating these combined wind and temperature effects, is considered an important variable of cold weather masonry construction.

Effects of Freezing. When fresh mortar freezes, its performance characteristics are affected by many factors: water content, age at freezing, strength development prior to freezing, etc. The frozen mortar takes on an outward appearance of being hardened mortar, as evidenced by its ability to support loads in excess of its unfrozen counterpart, and its ability to bond to surfaces.

The water content of the mortar during freezing is considered a significant factor affecting its freezing characteristics. Mortars containing water in excess of 6 to 8% expand on freezing. Expansion increases as the water content increases, so cold weather practices are intended to reduce the water content from the initial 11% to 16% range to some value below 6% to avoid the disruptive expansive forces.

When grout freezes, the frozen grout may lose its ability to bond to the masonry and the reinforcement. Expansive forces can be of sufficient magnitude to fracture the masonry.

Loss of Water. Provided disruptive expansion has not occurred, the early freezing of mortars does not significantly reduce potential transverse or compressive strength. However, masonry that is subjected to freezing, where freeze-drying or evaporation reduces the water content, may be expected to suffer a strength reduction unless water is supplied to the mortar after the masonry thaws. Consequently, mortars, once frozen, should be supplied additional water or allowed to absorb natural water to reactivate the portland cement hydration process for further strength development.

Summary. *The performance characteristics of masonry mortars and grouts are influenced by temperatures below normal. The changes in the performance characteristics are predictable and quality masonry construction may proceed with only minor changes in material preparation. Heating mortar and grout materials reduces setting time, increases rate of strength development, and extends the period before freezing to permit the mortar and grout to develop hardened properties comparable to those used in normal-temperature weather.*

PERFORMANCE OF UNITS

General. While considering the influence of the masonry unit on the performance of cold weather masonry, one should distinguish between units laid cold and units that are preheated.

A cold masonry unit will exhibit performance characteristics of a heated unit, except that the volume of the unit is, or may be, the smallest it will ever be within the masonry. If the cold masonry unit is wet and frozen, the absorption characteristics may be decreased due to ice blockages in the pores and channels of the unit.

Preheated masonry units exhibit performance characteristics of units used during normal construction, except the heated unit may withdraw more water from the mortar because of the absorptive characteristics of a cooling body.

Basis of Selection. An absorptive masonry unit will withdraw water from the masonry mortar and lessen the possible disruptive expansions that may occur in the mortar on first freezing. Conversely, a very low absorption unit will not draw sufficient water to prevent mortar and masonry expansion. Auxiliary dry heat to promote mortar strength and drying may be required for very low absorptive units such as glass blocks.

Temperature Effect. The temperature of the masonry unit and the ratio of its volume and density to those of the mortar joint are further contributors to the freezing rate of masonry. Excessively cold masonry units, even when dry, may rapidly withdraw heat from the mortar and increase the rate of freezing.

Summary. *Below-normal temperatures may affect the performance of masonry units, even when dry. Wet units may freeze before use and alter the freezing characteristics of the mortar. If used, wet, frozen units need to be thawed, being careful not to over-heat the unit.*

PLANNING AND CONSTRUCTION

General. During cold weather masonry construction, the rate with which masonry freezes is influenced by the mortar's temperature and properties, the masonry unit's temperature and properties, and the severity of the temperature and wind. The difference between masonry and air temperatures affects the rate at which the masonry freezes. The mortar and masonry properties affect the possibility of damage when the masonry freezes.

Immediately after masonry is laid during cold weather, at least two counteracting forces begin. Absorptive masonry units draw water from the mortar and the mortar, through its water-retentive characteristics, holds the water within the mortar. At the same time, the surrounding air may be chilling the masonry and withdrawing water through evaporation. The balancing of these forces governs the masonry strength development, and the degree of disruptive expansion accompanying freezing.

When masonry freezes, two conditions are identifiable: (1) masonry frozen while the mortar is in the wet condition (moisture content greater than 6%); and (2) masonry frozen while the mortar is in the dry condition (moisture content less than 6%).

Masonry frozen while the mortar is in the wet condition (greater than 6% moisture) contains enough water to cause disruptive expansion because of the 9% increase in volume that occurs when the water is converted to ice. The expansion upon freezing is related to the mortar water content. In the frozen condition the masonry develops high bond and compressive strengths - both the hydrated cement and ice contribute to these properties. Upon thawing, the masonry returns to its pre-frozen state except for damage caused by expansion, which may tend to reduce the bond and compressive strength.

Masonry frozen while the mortar is in the dry condition (less than 6% moisture) undergoes freezing without disruptive forces. As the mortar freezes, the unfrozen water moves to allow for the freezing water expansion. Cement hydration slows and stops. The frozen water contributes to the load carrying and tensile bond strengths of the masonry. Upon thawing, the masonry returns to its pre-frozen state.

Although a few researchers have related the performance characteristics to freezing, their findings are too general to warrant specific conclusions.

Summary. *When construction takes place at below-normal temperatures, masonry needs to be constructed in such a manner that it will develop sufficient strength so the mortar will lose enough water to prevent expansion of the masonry upon freezing. Further, all masonry frozen during the early periods after construction should subsequently be moistened either naturally or artificially after thawing to reactivate the cement hydration process, which in turn will promote further strength development of the masonry.*

MATERIALS

General. Cold weather construction does not require drastic changes in mortar mixes or masonry units. Materials selected for normal temperatures will generally require little if any change during construction at temperatures below normal.

Masonry Units. Masonry units should conform to the appropriate ASTM Standard for the type specified.

All masonry units used during normal temperature masonry construction may be used during cold weather construction. Low absorption clay brick units (IRA of less than 5 or 6 g/min/30 in2) (5-6 g/min/194 cm2) remove less water from the mortar and may necessitate extending protection requirements for a longer period of time until mortar water content is sufficiently low to prevent expansion on freezing. Units with a higher IRA are advantageous in some instances because they remove more water from the mortar and reduce the possibility of damage by early freezing.

Concrete masonry units should not be wetted before use. Concrete masonry units expand when wet and shrink as they dry. Thus, placing wet concrete masonry units in a wall contributes to increased shrinkage.

Mortar. Requirements for mortar are contained ASTM C 270, Standard Specification for Mortar for Unit Masonry.

Mortar Selection and Preparation. The increased strength gain of high strength mortars and reduced water retentive properties may be desirable, particularly in combination with low absorption masonry units. The specifier may wish to consider use of a Type S mortar under such circumstances. ASTM C 270 indicates that mortar should be mixed in a mechanical mixer for between 3 and 5 minutes. During cold weather, avoid extended mixing times which can increase air contents. A 3-minute mix is adequate to achieve uniform dispersion of mortar ingredients within a batch.

Portland Cement. Requirements for portland cement are contained in ASTM C 150 for Type I , Type II, or Type III cement.

Type III, high early strength cement, may provide some benefit in cold weather construction due to its more rapid strength development. Its use can be considered in mortars made by mixing portland cement and lime, however it is not a substitute for other cold weather recommendations. Hydration of cement contained in mortar is greatly reduced when mortar temperatures are below 40°F(4.4°C) regardless of whether the cement used is Type I, II, or III.

Blended Cements. Requirements for blended cements are contained in ASTM C 595.

Although all of the types listed in ASTM C 270, except slag cement (Type S or SA), are considered to be acceptable during cold weather construction, the specifier should be aware that blended cements often have slower strength development characteristics than portland cement. Slag modified portland cement and pozzolan-modified portland cement will generally more closely approximate the strength development characteristics of portland cement.

Masonry Cement and Mortar Cement. Requirements for masonry cements and mortar cements are contained in ASTM C 91 and ASTM C 1329 respectively.

The Type designation should correspond to the mortar type specified.

Lime. Requirements for Type S hydrated lime are contained in ASTM C 207.

Lime increases the water retention of mortar. Lime putty prepared from slaked quicklime possesses a slightly greater water content than the dry hydrate and is not recommended for cold weather construction.

Aggregates. Requirements for sand for mortar are contained in ASTM C 144. Evenly graded sand provides optimum workability, water retentivity, and strength development. Over-sanding or under-sanding the mortar mix should be avoided. While increasing sand content may increase board life, over-sanded mixes will have poor water retention and strength development characteristics. Conversely, under-sanded mortars tend to exhibit poor board life. Avoid the use of sands containing a large fraction of fine particles (minus #50 mesh) that increase mortar water demand.

Water. Mix water used in mortar and grout should be potable. Heated water should be used to produce mortar and grout temperatures above 40°C (4.4°C).

Summary. *Compliance with appropriate standards is necessary to ensure that desired properties of the materials are achieved. Prior to commencing construction, clay brick masonry units with suction rates greater than 5 to 6 grams of suction per minute per 30 square inches (194 square centimeters) should be selected, especially if prolonged periods of below normal temperature construction are predicted. Concrete masonry units should not be wetted prior to installation. Mortars should meet the requirements of ASTM C 270 for the Type designated. During cold weather, the use of Type III cement in portland cement-lime mortars mixed at the jobsite may be beneficial. The specifier should consider the use of Type S mortars rather than Type N mortars when low absorption units are used. Sand should not contain a high fraction of fine particles.*

Admixtures. Admixtures are materials added during the initial mixing of mortar to modify one or more of the properties of the mortar in the plastic and/or hardened state. They should be used only when specified and only when their compatibility with other mortar ingredients and required mortar properties have been confirmed by laboratory tests. In cold weather masonry construction the admixtures most often encountered are anti-freezes and accelerators.

Anti-freeze. Most of the commercially available "antifreeze" mixtures for mortar are misidentified. They are accelerators rather than mortar freezing point depressants. Some actual antifreeze admixtures are available, which include several types of alcohol. If used in quantities that will significantly lower the freezing point of the mortar, the compressive and bond strengths of the masonry may decrease rapidly. Since antifreeze compounds have little benefit, they are not recommended.

Accelerators. The primary purpose of an accelerator is to hasten the hydration of the portland cement in the mortar. As such, they do not eliminate the need to protect mortar from freezing, but they may limit the length of time protection is required. The compounds commonly used as accelerators are: calcium chloride, soluble carbonates, silicates and fluosilicates, aluminous cements, calcium aluminate, and other organic compounds such as triethanolamine and calcium formate.

Calcium Chloride (CaCI,) is the most commonly used accelerator. It is also the main ingredient in most proprietary cold weather admixtures. Calcium chloride should not be classified as an antifreeze, because the amount required to significantly lower the freezing point of mortar would be so large as to have deleterious effects on mortar properties.

Calcium chloride is an effective accelerator, but may produce undesirable side effects, such as corrosion failures of joint reinforcement, door bucks, metal ties, and anchors in masonry. Also, excessive salts can contribute to efflorescence and may cause spalling of the masonry.

Calcium chloride should not be permitted in masonry containing metal (ties, anchors, and reinforcement). If calcium chloride is used, it is recommended that it be limited to amounts not to exceed 2% of the portland cement, and 1 % of the masonry cement, by weight.

Corrosion Inhibitors. Because accelerators are associated with corrosion failures of metal embedded in masonry, many commercial accelerators now contain corrosion inhibitors. These are usually found in proprietary compounds. Their effect on masonry and cold weather masonry construction has not been evaluated. For these reasons, the use of accelerators containing corrosion inhibitors cannot be recommended.

When accelerators are desired for use in masonry, use only non-chloride based accelerators, as certified by the admixture manufacturer.

Pigments. The possible effect of coloring agents on the performance of both fresh mortar and masonry should be considered. Mortar colors should meet the requirements for normal construction.

Some coloring agents contain dispersing agents to speed the distribution of the color throughout the mortar mixture. These dispersing agents may act as cement retarders and, consequently, affect the early strength gain of the masonry during cold weather masonry construction. During cold weather, this retarding effect may result in slow-setting, slow-strength-developing mortar, and masonry with a tendency toward efflorescence.

Air-Entraining Agents. Air-entraining admixtures are sometimes used in mortar to increase workability. Data suggest that laboratory air-entrained mortar specimens are less susceptible to deterioration due to freezing and thawing in the presence of moisture. However, excessive airentrainment in mortar will result in lower compressive and lower bond strength in masonry. Therefore, air-entraining admixtures should not be used in cold weather masonry construction. This recommendation does not preclude the use of air-entraining cementitious materials.

Summary. *Accelerators, if specified and used, should be nonchloride based. Their use does not eliminate the need to implement recommended cold weather practices.*

MATERIAL STORAGE

General. All masonry materials, when delivered to the job site, must be carefully stored.

Bagged materials and masonry units, when delivered to the construction site, should be stored elevated to prevent moisture migration from the ground to the materials, and then protected against water penetration through the sides and the top.

Coverings should be properly installed so that all materials are completely covered. Tarpaulins, reinforced paper, or other water-repellent sheet materials may be used. Sufficient space should be provided between the materials and the covers to allow circulation to take place.

If the weather and size of the project warrant, it is recommended that a shelter be provided for the materials storage and mortar mixing areas.

Summary. *Accelerators, if specified and used, should be nonchloride based. Their use does not eliminate the need to implement recommended cold weather practices.*

Grout. Requirements for grout are contained in ASTM C 476 Standard Specification for Grout for Masonry. Slump should be maintained as high as possible for proper placement.

MATERIAL HEATING

General. Heating mixing water is typically the easiest and most cost effective method of increasing mortar and grout temperatures. Heating only the water will be satisfactory if the other construction materials are unfrozen. Water may be heated using a 55-gallon drum with a fire or heat source below, or with immersion heaters, flame guns, or steam probes. Any method that does not add deleterious matter to the water is acceptable. This mixing water should be heated sufficiently to produce mortar temperatures between 40°F (4.4°C) and 120°F (48.9°C). Once a mortar temperature has been selected in this range, every effort should be made to maintain this temperature for consecutive batches.

Heat masonry sand when the temperature of the sand is below 32°F (0°C). A simple method for heating sand for mortar is to heap sand over a section of a large diameter pipe (such as a culvert or smokestack) in which a slowburning fire is built. Any device that allows the thawing of the ice without scorching the sand is satisfactory. Whenever wood fires are used for heating the sand, care should be taken to prevent the wood ash from contaminating the sand and mortar.

When the temperature of dry masonry units is below 20° F (-6.7°C) they should be heated so they are above 20°F (-6.7°C) at the time of their use. Wet frozen masonry units should be thawed without overheating. These heating requirements prevent rapid cooling of the heated mortar as it comes into contact with the masonry unit. Even when the temperature is above 20°F it may be advantageous to heat the units for greater mason productivity.

Summary. *As the temperature falls below normal, the total number of construction materials requiring heating increases. Water is the most logical first material to heat. Masonry sand will have to be thawed, if frozen, and may have to be heated additionally to produce mortars with the desired temperature.*

Wet, frozen masonry units must be thawed. Dry units, colder than 20°F (-6.7°C) should be heated, being careful not to overheat them.

HEATERS

General. There are many types of equipment available to use as sources of heat. The choice of the type of heating unit depends upon many factors. They are:

1. Availability of equipment
2. Fuel source and economics
3. Safety
4. Size of the project
5. Severity of the weather
6. Degree of comfort to be provided within enclosure
7. Protection that will be provided for the structure

The availability of various heating sources should be investigated by contacting the local gas and electric companies.

To protect both the personnel and the masonry, precautions against fire and noxious fumes should be taken when using heating devices.

Summary: *Properly vented oil or gas-burning heaters, with blowers, are recommended for projects where complete enclosure of the work is provided and where a source of heat is not available from a stationary heating plant.*

CURING

In order for masonry to cure properly, the required temperatures must be maintained for a sufficient length of time. The enclosure used to provide protection can be left in place with heaters used to maintain temperatures at or above the required minimum. When using heaters that blow hot air, be careful that the wall temperature does not rise above 120°F (48.9°C). Increased evaporation may prevent proper curing and may result in color variations. Blanket type heaters that cover the wall are viable options.

Summary: *Sufficient temperatures to promote continued hydration of the cement in the mortar must be maintained to provide adequate curing.*

PROTECTION

General. An enclosed construction site maintained at a temperature greater than 40°F (4.4°C) is ideal for cold weather masonry construction.

Economics, however, dictate how elaborate the protection can be, whereas ambient temperature dictates when the protection is needed or when work stoppage should be enacted. A balance between mason productivity and structure protection is required. Because each case is different, specific procedures should be designed for each particular job. The range of protection may go from a simple windbreak to a completely enclosed structure.

The tops of all walls not otherwise protected should be covered with a weather resistive membrane extending a minimum of 2 feet (0.6 m) down on both sides to prevent water from entering the masonry.

Types. Enclosures and windbreaks are temporary and therefore are designed to fit the particular job. They can range in size from a single insulation blanket to an elaborate shelter which protects the entire work area. Factors to be considered in selecting the type of protection:

1. Type of building and its design
2. Type of scaffolding used
3. Masonry work under construction 4. Severity of the weather

Materials commonly used for protection are canvas and synthetic coverings (reinforced polyethylene and vinyl).

The ingenuity of the individual contractor is exhibited by the use of other materials for protection. Such characteristics as strength, durability, flexibility, transparency, fire resistance, and ease of installation should be considered when selecting protection material.

In most instances, an unheated enclosure reduces the effects of temperature plus wind and provides the degree of protection that is adequate for masonry construction. The enclosure, heated or unheated, should protect the structure from early freezing, and if heat is applied, from rapid mortar dry-out.

Safety. Workers responsible for installing protection must have a full knowledge of the scaffolding being used, and how to properly erect, adjust, brace, anchor, and dismantle the complete assemblage. The protection must provide measures to safeguard the worker from injuries caused by high winds, fires, and air contamination. Scaffolding must be properly erected, braced and anchored so that the assemblage is safe from snow and wind loads and lift.

Summary. *Enclosures and windbreaks should be designed for the particular structure using locally available materials. For the method of installation, the contractor's* *ingenuity will generally prove adequate. Enclosures and windbreaks must be designed with consideration of both protection of the structure and safety of the individual worker.*

COLD WEATHER MASONRY CONSTRUCTION AND PROTECTION

RECOMMENDATIONS

Cold weather masonry construction and its quality control require some additional attention to construction practices and protection. Attention should be directed to the following details as well as those normally attended.

1. Implement the cold weather construction and protection requirements of this recommended practice when temperatures are forecast to fall below 40°F (4.4°C) or the temperature of the masonry units is 40°F (4.4°C) or lower. Check local weather reports before the start of each day and periodically measure air temperature during the day.

2. Receive, store, and protect construction materials in ways that prevent water from entering the materials.

3. Measure temperatures of construction materials when climatic conditions warrant. Thaw frozen sand and wet masonry units. Heat masonry units that are at or below 20°F (-6.7°C) without overheating.

4. Heat sufficient ingredients to produce mortar and grout temperatures between 40°F (4.4°C) and 120°F (48.9°C). Produce consecutive batches with nearly the same temperature. The mortar temperature after mixing and before use is required to be above 40°F (4.4°C), maintainable either by auxiliary heaters under the mortar board or by more frequent mixing of mortar batches. Heated mortar on mortar boards must not become excessively hot (greater than 120°F; 48.9°C).

5. During below normal temperatures, place masonry only on sound unfrozen foundations. Never place masonry on a snow or ice covered surface, because of the danger of movement when the base thaws and the possibility of very little bond being developed between the mortar and the supporting surface.

6. At the end of the day, protect the top surfaces of all masonry to prevent moisture, as rain, snow, or sleet, from entering the masonry. Cover the top surfaces such that the protection extends down a minimum of 2 feet (0.6 m) down all sides of the masonry.

7. Do not lay glass unit masonry when the ambient temperature falls below 40°F (4.4°C) or the temperature of the units is below 40°F (4.4°C).

REQUIREMENTS

Table 1
Cold Weather Preparation and Construction Requirements
(ACI 530.1-98/ASCE 6-98/TMS 602-98)

Temperature Range (Ambient)*	**Construction Requirements (While Masonry Work is in Progess)**
Below 40°F (4.4°C) or Temperature of Masonry Units is Below 40°F (4.4°C)	Remove visible ice on masonry units before the unit is laid in the masonry. Do not lay masonry units having a temperature below 20°F (-6.7°C) Heat sand and water to produce mortar and grout temperatures between 40°F (4.4°C) and 120°F (48.9°C) at the time of mixing Maintain mortar and grout above freezing until used in masonry
Above 25°F (-3.9°C) and above 20°F (-6.7°C)	Same as above except: Use heat sources on both sides of the masonry under construction Install wind breaks when wind velocity is in excess of 15 mph (24.1 km/h)
Below 20°F (-6.7°C)	Same as above except: Provide and enclosure for the masonry under construction Use heat sources to maintain temperatures above 32°F (0°C) within the enclosure

* The surrounding jobsite temperature while construction is in progress.

Table 2
Cold Weather Preparation and Construction Requirements
(ACI 530.1-98/ASCE 6-98/TMS 602-98)

Temperature Range (Mean Daily)*	**Construction Requirements (While Masonry Work is in Progess)**
Below 40°F (4.4°C)	Protect top of completed masonry from rain or snow by covering

and Above 32°F (0°C)	with a weather resistive membrane for 24 hours after construction
Below 32°F (0°C) and Above 25°F (-3.9°C)	Completely cover completed masonry with a weather resistive membrane for 24 hours after construction
Below 25°F (-3.9°C) and Above 20°F (-6.7°C)	Completely cover completed masonry with insulating blankets or equal protection for 24 hours after construction
Below 20°F (-6.7°C) and Above 32°F (0°C)	Maintain masonry temperature above 32°C F (0°C) for 24 hours after construction by enclosure with supplementary heat, electric heating blankets, infared heat lamps, or by other acceptable methods.

* The temperature calculated to be the average of the extremes forecast by the local weather bureau over the next 24 hours.