

after thawing, of improved bond of the facing with the backup masonry and also partial hardening of the mortar during the exposure to frost and thawing of the masonry which leads to reduced shrinkage during thawing;

"(d) by application of electrical heating or steam heating to freshly laid unfrozen masonry during the time required to assure initial hardening of the mortar in the masonry up to the point of development of minimum required strength;

"(e) by application of rapidly hardening mortars having a blended cement which develops considerable strength prior to the time of thawing of masonry;

"(f) by using enclosures which insure hardening of the masonry in unfrozen condition in which the mortar develops the minimum required strength."

In the National Research Council of Canada, Technical Translation TT-583, "Winter Construction" by Bertil Naslund, "Statens Kommittee for Byggnadsforskning, Stockholm, Broschyr 5, 1952", Mr. Naslund stated: "In order to build masonry during the winter it is essential that the bricks be kept absolutely dry. Bricks must be protected against precipitation irrespective of the season. Furthermore, during the winter the mortar must be heated. Taking these measures, outdoor building can be carried out at temperatures down to -10°C " (14°F).

From these observations it is evident that research and construction requirements relating to cold weather concreting do not necessarily apply to masonry construction. Generally, concrete is placed in forms so that there is little loss of water due to absorption to the forms or evaporation to the atmosphere. In masonry construction, thin layers of mortar are placed between thicker absorbent units which, with the exception of very low suction units, quickly absorb water from the mortar, stiffening it, lowering the degree of saturation and reducing the water-cement ratio.

The Portland Cement Association's Research Department Bulletin 148 "Prevention of Frost Damage to Green Concrete", by T. C. Powers, has the following introduction:

"There are indications that to prevent damage when green concrete is exposed to frost, time must be allowed for a certain degree of hardening of the paste. Accordingly, those concerned with concrete construction during cold weather have carried out various experiments to determine the *necessary prehardening time*. It has been suggested that the necessary length of the prehardening period is fixed by the length of time required for the attainment of a certain minimum strength common to all concretes, and it is therefore a function of the characteristics of the cement, the water-cement ratio, and the prevailing temperature. Expressing the state of hardening in terms of strength seems to be based upon the belief that cement paste is able to acquire enough strength to withstand the forces associated with freezing.

"In view of the magnitude of stress that can be produced by the freezing process, we must conclude that immunity to damage after a certain time is not due to the development of strength but to absence of destructive force during freezing. Absence of destructive force can be accounted for by the decrease in the degree of saturation of the paste that occurs during the early stages of hardening."

Mr. Powers also shows that, where there is no exchange of water with environment, fresh concrete is immune to damage by freezing when the saturation coefficient of capillary spaces is below approximately 97 per cent. For most concretes this coincides with a compressive strength of about 430 psi.

RECENT RESEARCH

Although several organizations in the United States and other countries have and are conducting research on the effect on properties of masonry frozen at an early age, there is little published data at this time. The primary considerations of the effect of freezing temperatures on masonry are the influences on compressive strength, bond strength, durability and permeability. In a recent effort by the Research Department of the Structural Clay Products Institute, a program was started to define the minimum protection conditions required to prevent cold weather damage to freshly laid brickwork. Damage was detected by comparing compressive and bond strengths of frozen specimens with control specimens. The specimens were built of portland cement-lime mortars and 10,000 to 11,000 psi compressive strength brick with suction of 5 to 8 g. The variables investigated were:

Cement: Type I and type III.