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WINTER CONCRETING TRENDS IN EUROPE

BY

E. G. SWENSON

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Winter Concreting Trends in Europe*

By E. G. SWENSON*

SYNOPSIS

Postwar labor and economic problems in Europe have led to governmental encouragement of winter construction. This has resulted in extensive, state-supported research on winter concreting, the progress of which is largely reflected in the papers presented by European authors at the RILEM Symposium on Winter Concreting in Copenhagen, February, 1956.

The primary consideration has been the reduction in costs of winter protection of green concrete concurrent with the achievement of better assurance of safety. Research has been directed toward methods of quantitative prediction of frost resistance and of minimum protection requirements. Methods of increasing frost resistance of green concrete have received attention.

Practical developments involve the refinement of existing methods of safe winter concreting, particularly the choice of building types most suitable for winter construction and the utilization of locally available materials.

INTRODUCTION

Because of the increasing importance of winter construction, the problems associated with winter concreting have been the subject of extensive investigation in recent years. Northern European countries appear to have taken a lead in the research field and there is much to be gained by a survey of developments in some of these countries.

The writer visited three Scandinavian countries and participated in a symposium on winter concreting held in Copenhagen, Denmark, in February, 1956. The following is a brief review of developments as gained from the papers and discussions at the symposium combined with observations of actual winter construction and talks with research workers and men on the job in Denmark, Sweden, and Norway.

The symposium on winter concreting was sponsored by the International Union of Testing and Research Laboratories for Materials and Structures, more commonly known as RILEM. The organization of the meeting was carried out by the Danish National Institute for Building Research; about 250 delegates from about 20 countries attended. Apart from small delegations from China and Japan, and one or two representatives each from Canada and the United States, the representation was predominantly northern European.

*Presented at the ACI 9th regional meeting, Montreal, P. Q., Oct. 25, 1956. Title No. 54-19 is a part of copyrighted JOURNAL OF THE AMERICAN CONCRETE INSTITUTE, V. 29, No. 5, Nov. 1957, *Proceedings* V. 54. Separate prints are available at 60 cents each. **Discussion** (copies in triplicate) should reach the Institute not later than Feb. 1, 1958. Address P. O. Box 4754, Redford Station, Detroit 19, Mich.

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Most of the papers presented, therefore, reflected European thinking and practices.*

The purpose of this symposium was to coordinate and assess present knowledge of the theoretical and practical aspects of winter concreting. Four theoretical sessions dealt with: weather and climate in relation to winter concreting; laboratory experiments on winter concreting; the hardening of concrete as influenced by temperature; and the resistance of concrete to frost at early ages. The practical sessions dealt with high concrete quality in cold weather, and winter concreting on the job site.

ECONOMIC AND SOCIAL INFLUENCES

Since the war there has been in Europe an increasing trend to year-round construction which stems from the same causes as in Canada and the United States. Expansion in housing and other construction has been encouraged by government agencies through such methods as subsidization and preferential treatment. State controls are exercised through methods such as the building permit system. State financial support and direction have been provided in many European countries for research and development in winter construction. The Danish National Institute for Building Research has, through state support, carried out comprehensive research in the last 5 to 6 years on winter construction problems, including methods of concreting in cold weather. Similar support is provided in Sweden through the State Committee on Building Research, in Norway through the Building Research Institute, and in Finland through the State Institute of Technical Research. These agencies aid builders in organization and direction of winter work, and provide recommendations and specifications as well as research information.

As an example of the methods used to encourage winter construction, the Danish National Institute of Building Research, in its early program, provided monetary aid for additional expenditures by the contractor for exceptional weather conditions. The contractor received 5 kroner per effective man-day when the temperature at 8 a.m. was below -2°C (28.4°F), or if the precipitation in the course of the day was 5 mm (0.2 in.) or more. This aid was considered a contribution to extraordinary expenditure and measures, and also a compensation to the contractors for their pioneer work, reporting, etc.² Further inducement was provided by waiving certain building code requirements. The Danish institute also provided technical inspectors to give direction and advice.

Labor policy in these countries appears to have strongly supported winter construction in the interests of maintaining year-round employment. Observation of jobs and talks with builders indicated, however, that winter work, particularly in concreting, was usually discontinued during very cold periods, apparently for reasons of discomfort rather than danger of frost

*Six general reports were presented, one for each session, followed by some 25 supplementary papers. This writer was privileged to present the general report for the first session, on weather in relation to winter concreting. The complete record of the symposium, including discussions and summaries of conclusions for each session is available from the Danish National Institute of Building Research in Copenhagen.¹

damage to concrete. This was rather well illustrated on the last 2 days of the symposium, when scheduled visits to winter concreting jobs in Denmark and southern Sweden were cancelled because work had stopped due to cold weather. Actual temperatures were reported to range from about 10 F down to -10 F during this period, which would not be considered extreme in Canada. Some such cases were due no doubt to lack of proper protective materials and equipment on the job.

Further incentive to winter concreting is provided by the need to utilize fully the comparatively expensive equipment kept on hand, and the skills of specialized labor which the builder wishes to retain. Quantity and variety of materials are also more readily available during the winter, as is the case in North America. Also certain operations can be carried out more advantageously in winter; for example, transportation on the site may be easier when the ground is frozen.

Further encouragement to winter concreting is provided by recent research which demonstrates that fresh concrete has a considerably higher resistance to frost damage than was previously thought, thus reducing the amount and cost of protection. Simpler methods of protection have also become available. Concrete placed in winter usually receives more uniform curing than in summer, a factor also to be considered.

Certain building types are better suited to winter concreting and advantage is taken of this fact; e.g., in Sweden cellular concrete is used extensively. In one common type of construction, precast cellular concrete slabs are placed as outside insulation and bonded to the inner monolithic, load-bearing concrete. During placing of the concrete, the cellular slabs serve as the outside formwork. In this type of construction protection requirements are considerably reduced.

Economic conditions in Europe naturally engender cost consciousness especially with regard to labor, and the methods developed reflect the urgency to minimize costs of protection. Research and practice therefore have focused on reducing the amount and time of protection and increasing the frost resistance of concrete. The degree to which European practice has developed in this direction appears limited, perhaps due largely to the usual reluctance to take practical risks on the basis of theory. The discrepancy between theory and practice in Europe would appear to be as great as in Canada.

ENVIRONMENTAL CONSIDERATIONS

Influence of the various elements of weather and climate on the cooling of concrete was treated in detail at the symposium in Copenhagen.^{3,4,5} The conclusions establish that predictions based on temperature alone are inadequate. Factors of wind speed and radiation, in particular, can have proportionately as great an influence on heat losses as temperature difference alone. Local climatic factors may also modify the cooling of concrete considerably.

It was also emphasized that accurate prediction of cooling rates on any given job, taking all environmental factors into account, is extremely complicated and difficult to achieve. A reasonable estimation of conditions can be made, however, with the use of certain simplifying assumptions.

The practical, empirical methods already developed are based on outside temperatures only. Of special interest is the method proposed by the Danish National Institute for Building Research, which, for a given outside air temperature, provides for the calculation of the degree of protection required, the time when stripping of forms can be done, and the actual degree of hydration attained at any time.⁶ Thus, the various internal factors are taken into account but only the external influence of temperature.

Field application of the principles and factors of heat loss in winter concreting appears as limited in Europe as in Canada and the United States,

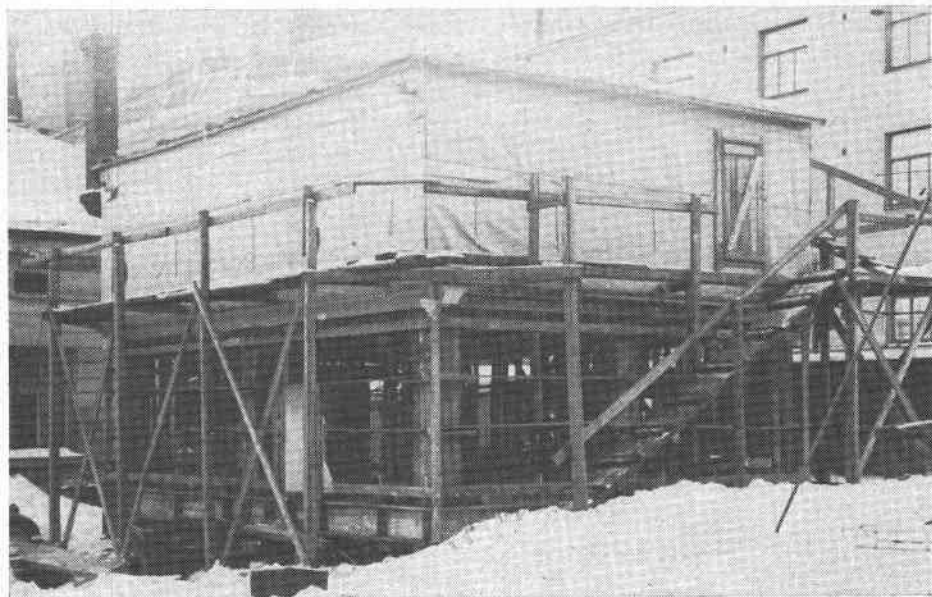


Fig. 1—Experimental house in Finland for research on winter construction; first floor enclosures removed

with the possible exception of large and important jobs such as, those of the Hydro-Electric Power Commission of Ontario and the United States Bureau of Reclamation. It is apparent, however, that in some countries an attempt is being made to utilize more fully climatic and weather data in winter concreting.

It was reported that in Holland the meteorological service is now consulted about special forecasts and climatic data for the building industry. Although its winter climate is not severe, it is capricious. "It will be impossible to indicate the periods by degrees of temperature because in Holland it is quite a different matter to have a day of minimum -5°C (23°F) with a depression coming from the west, or to have a minimum -5°C with a Siberian cold

coming from the east.”⁷ In Switzerland, as another example, account is taken of the increasing frequency of temperature drops below the freezing point with increasing altitude. In Finland and Norway, the continuous frost in most areas throughout a relatively long winter requires special protective measures. Minimum temperature records are used as a guide, and weather forecasts are studied to anticipate unexpected temperature drops. Special attention is given to rock temperatures. In general, protection requirements are based on temperature ranges, for example: -5°C (23°F) and up; between -5°C and -10°C (14°F); and below -10°C .

Winters in Denmark are considered extremely unpredictable. Below-freezing temperatures may come early or late, and the length of the winter may vary considerably. Many cycles of freezing and thawing occur, and it is almost always windy. Temperatures of 23 to 18°F , along with high humidities and high winds, can present a severe condition for construction work. Thus concreting is often discontinued at temperatures not considered too severe in North America.

In Finland an experimental house has been built to aid in the research on winter construction (Fig. 1). It is reported that studies will be made of weather factors as they influence heat losses under various forms of protection. Some data already available were reported at the symposium.⁸

TECHNOLOGY OF WINTER CONCRETE

Considerable progress has been made through laboratory experiments in the determination of the frost resistance of green concrete and the factors which influence this resistance. It is now possible to estimate the degree of hardening of concrete under various temperature conditions. Acceptable theories for concrete deterioration caused by freezing and for resistance to frost damage have been developed; these provide a much clearer understanding of the problems involved in winter concreting. These points were brought out clearly in the symposium papers.

Freezing of the plastic concrete before it has begun to set does no ultimate damage provided subsequent curing conditions are favorable. A certain “prehardening” time is required, however, before the green concrete can be subjected to below freezing temperatures without damage. This period ranges from 24 to 72 hr under normal conditions according to various investigators, and is influenced by proportioning, cement type, accelerators, and entrained air. In practice, considerations of safety require a 3-day period for normal concrete, but careful execution can permit a shorter prehardening period.

Frost damage during prehardening must be distinguished from delayed hardening caused by the slowing up of hydration at low temperatures. It was also made clear that there is no direct relation between frost resistance of green concrete and subsequent durability of the mature product subjected to cycles of freezing and thawing.

The application to field practice of the time-temperature function, based on the maturity concept, is generally successful, although some minor disagreement exists over the relative merits of the Saul-Nurse and the Rastrup methods. Considerable uncertainty exists, however, in their application to hardening at below freezing temperatures. It is possible, nevertheless, to estimate the degree of hardening of concrete under various conditions, and to determine the time when the concrete has attained frost resistance and when forms can safely be removed. As mentioned previously, the Danish National Institute for Building Research has incorporated this concept into an empirical field method which, for a given cement type, a given cement content, a given initial temperature, a given cooling factor which is based on heat of hydration, degree of insulation, and the geometry of the element, and for a given outside temperature, makes it possible to calculate the time required to attain a certain degree of hydration.⁶ The Swedish Cement and Concrete Institute has conducted a program of tests to check this method.⁹

The basic research and theories of T. C. Powers on frost action and frost resistance of concrete have had great influence on European thinking and technology.¹⁰ Air entrainment is now generally accepted, not only as a means of improving the durability of mature concrete, but as a means of increasing the frost resistance of fresh concrete. Extension of these concepts has been carried out by Danish and Swedish investigators, in particular, in an attempt to correlate experimental and field evidence. Methods of testing the extent of frost damage in concrete are still those which measure strength, dynamic modulus, and volume change.

Actual application of these principles and concepts to job work, as judged from limited observation of winter concrete work and talks with builders, appears to be limited. Extensive use is made of accelerators, entrained air, and high-early-strength cements. Considerable use is apparently made of the maturity function in estimating the strength development of winter concrete. In the opinion of the writer the practical field man in Europe is kept better informed of research developments and is perhaps better equipped to judge job situations, even though it may be in a qualitative way only, than his counterpart in North America. There is apparently closer collaboration between research and practice, probably for reasons of geography as well as through the obviously concerted efforts of research institutions and government agencies.

The development in the Soviet Union of the so-called "cold" concrete method is of special interest. Some discussion of this technique was given at the symposium but, unfortunately, there appears to be no complete translation into English of the published papers on the method. From available information, the following description can be given.¹⁸ A mixture of calcium and sodium chlorides, up to 20 percent by weight of the mixing water, is incorporated in the concrete; the actual amount is determined by the outside temperature conditions. The concrete will harden satisfactorily at mix temperatures down to -10°C (14°F). It is possible, therefore, to use un-

heated materials for the mix, and protection can be disregarded or reduced to a minimum. It is necessary, however, to maintain the temperature, for the first 10 days, above the freezing point of the salt solution in the mix. It is claimed that in 90 days such concretes develop 90-100 percent of the strength of normally cured 28-day concrete. Bond strength with reinforcement is said to be high but frost resistance is lower than for normal concrete, and is lowered further with increasing water-cement ratio and when the concrete surface is exposed. Water impermeability of such concretes is said to be higher than for normal concrete. Added danger of corrosion of reinforcement is accentuated by thin concrete covering and by exposure to relative humidities between 60 and 90 percent. Care must be taken to obtain good compaction. It is claimed that costs of winter concreting can be considerably reduced by the use of this method as compared with the conventional "thermos" and heating methods.

The government sponsored investigation into winter concreting in Finland, carried out by the State Institute for Technical Research, included a study of methods employed and results achieved on a number of actual building sites, construction of an experimental house (already mentioned), and laboratory investigations. The various questions investigated have included: effectiveness of various methods and materials; relative costs; distribution of heat losses; suitability of building types; heat consumption; tightness of different enclosures; and the effect of various weather conditions. Preliminary results were reported at the symposium.⁸

PRIMARY METHODS OF PROTECTION

In Europe, monolithic and precast concrete find use in a wider range of building elements than in North America. Improved concrete technology has also resulted in the use of more slender elements. Consequently, extra emphasis has been given to methods of protection. Some countries provide specifications for winter concreting but these are admittedly treated in a qualitative way because of the variability of site conditions. Such specifications and recommendations, in general, cover: (a) methods of protection for various arbitrarily selected outside temperature ranges based on field experience; (b) methods of insulation and utilization of heat of hydration of the cement; (c) selection of suitable cement type; (d) use of admixtures; and (e) types of enclosures and methods of heating them.

As an example of detailed recommendations for minimum protective measures to be taken at different air temperatures within the first week after placing, the following is quoted from a Swedish source:¹¹

"At temperatures:

+5 to 0 C
(41 to 32 F)

When no CaCl_2 is added the water should be heated.

When CaCl_2 is added no special measures are required, but the forms should be removed after approximately the same time as during the summer.

0 to -5 C
(32 to 23 F)

The water should be heated and preferably CaCl_2 added. If CaCl_2 is added, the concrete may be placed without heating the water. The sand should be heated and frozen lumps thawed. The freshly placed concrete should be covered during the first night with tarpaulins or cardboard on a framework, or at least with cement bags.

-5 to -10 C
(23 to 14 F)

The water should be heated and preferably CaCl_2 added. The sand should be heated and frozen lumps thawed. The freshly placed concrete should be insulated for 3 days with straw, straw mats, or similar insulating materials. Gaps in the story below should be covered and the temperature in the room under the concrete slab should be kept above 0 C (32 F) for 3 days.

Lower than -10 C
(Below 14 F)

It would be preferable to postpone the placing of the concrete, but if the concrete must be placed the same measures as at temperatures between -5 and -10 C (23 to 14 F) should be taken. The insulation should not be removed until the temperature stays above -10 C (14 F)"

Practices involving standard materials

Storage protection and preheating of materials are generally practiced according to conventional methods. High-early-strength cement is widely used in winter concreting although it is reported to cost 50 to 70 percent more than normal portland cement.¹¹ High alumina cements, however, appear to be used only to a limited extent. It is recognized that in normal portland cement certain compositional factors are favorable: high tricalcium silicate and tricalcium aluminate, high silica, and low free lime. Low-heat-producing cements are usually avoided: slag, pozzolan and supersulfated cements.* Good practice requires the use of fresh cement since long storage appears to decrease the rate of heat development. Cement is not preheated, except indirectly through the usual dry storage protection. In some cases reduced relative humidities are obtained through slight heating by kerosene lamps.

The quality of the aggregates used appears to be generally based on the usual durability tests, but evaluation specifically based on frost resistance is being carried out, for instance, in Switzerland.¹² Here aggregate is classified as "generally suitable," "conditionally suitable," and "mostly unsuitable." Those considered unsuitable are high suction rocks and those containing clayey or humus-bearing ingredients because of high water absorption properties. Rounded particles are preferred because of their lower water requirements.

Aggregates are protected by storage in pits or silos. Preheating is done by heating truckloads in sheds or by steam heating through perforated pipes. An effort is made to control the steam heating of aggregate to avoid variation in the water-cement ratio. The low-pressure, mobile steam boiler is sometimes used. Ice crusting of aggregate is eliminated by various heating methods, including gas flames.

*Cements of this type produced in the United States have been used successfully during cold weather when protection measures have been taken which are recommended for portland cement.

Heating of the mixing water is the first step taken to raise the temperature of the concrete mix. For example, a recommended practice in Norway involves heating of water and aggregates for temperatures down to -5°C (23°F); preheating of all materials, and the insulation of forms for temperatures between -5°C and -10°C (14°F); and below -10°C , all precautions, including heated enclosures. Care is taken to provide controlled heating of the mixing water in order to eliminate variation in the initial concrete temperatures. The maximum temperature to which the ingredients may be heated is limited by the danger of premature hardening and varies with each cement. The Swedish Cement Association recommends a maximum temperature to which water or sand are to be heated, of 60°C (140°F) for normal cements, and 35°C (95°F) for rapid-hardening cements.¹¹ The sand rather than the coarse aggregate is heated because heated stone does not so rapidly provide equalization of heat, and excessive shrinkage may occur in the concrete. Sand braziers and hot metal plates are often used for heating the sand in the pile which, admittedly, may affect adversely the moisture condition of the material. Simple protection of aggregate piles by the use of tarpaulins is considered good economy since tarpaulins can be rented at low cost. Danish experience suggests that heating of aggregate is excessively expensive and should be avoided except where absolutely necessary.²

Admixtures

Acceleration of hardening with 1 to 2 percent additions of calcium chloride is frequently practiced. Entrained air is used primarily to reduce the water requirement and increase the workability of the mix. Its added value in increasing frost resistance is now being recognized. Favorable results using plasticiser admixtures are reported from Switzerland.¹² "Cold" concrete developed in the Soviet Union and mentioned earlier, in which high salt concentrations are used, appears applicable primarily to massive foundation-type elements. Alcohol and other anti-freeze agents are not generally used, although some instances were reported.¹²

Proportioning and mixing conditions

A recognized requirement for a winter concrete mix is a low water-cement ratio. This is variously accomplished by reducing the fine fraction in the sand, lowering the sand content of the mix, using rounded aggregate, or by admixtures such as the air-entraining ones to improve workability. Some practices require an increased cement content to obtain higher hydration heat.

Loss of heat during mixing is minimized by the usual method involving enclosure and organization for speed of operation. The initial temperature of the mix is maintained at some maximum depending on the quick-setting properties of the cement used. Initial mix temperatures as high as 50°C (122°F) have been used,¹³ but the usual range is from 20 to 30°C (68 - 86°F).¹⁴



Fig. 2—Covering green concrete with knot pulp board and straw mats

Concrete bed, forms, and reinforcement

Protection against heat loss to the ground generally takes the form of covering excavations or preheating. One Norwegian practice consists of using a higher initial temperature of the mix in contact with rock, as well as preheating the rock.¹⁴ In Norway and Switzerland, for example, special precautions are taken when preheating ground on slopes because of the effect on soil stability.¹² Formwork is designed to guard against moisture loss as well as heat loss. Jointed formwork is recommended, with form oil or chlorinated rubber varnish. Forms are often preheated with hot water or steam; the latter method is also used to remove ice crusts. Formwork is also preheated by electric heaters in Norway. Reinforcing is preheated by blow torch and flame thrower.

Transportation and placing

Heat loss during transportation and placing of concrete is kept to a minimum by organizing the work for maximum speed of handling. Protection in transport is usually achieved by short hauls, large loads, insulated containers, and protected conveyors. Formulas have been devised, for example in German directives, for calculating such heat losses.¹⁵ Placing is done as rapidly as possible; compaction by vibration is preferred to hand tamping because of the low water-cement ratios used. Insulation and covering are provided immediately. Various methods are used to prevent direct contact of protective covering with the fresh concrete surface.

Insulated coverings

Choice of cover protection for fresh concrete is governed by cost and availability of materials, and also by local weather conditions. For example, paper covering is avoided when high winds are prevalent because of the risk

of tearing. Loose insulation cannot be used where rains and sleet are frequent, unless it is covered.

Straw, straw matting, and knot pulp are commonly used in Norway and Finland (Fig. 2). When wood products are available, as in most parts of the Scandinavian countries, cardboard and wood wool are used. The fire risk involved is considered. Materials such as glass wool, rock wool, and tarpaulins are less frequently used because of the higher cost. Glass wool is sometimes wrapped around slender elements. Empty cement bags are used for covering or plugging openings left by protruding reinforcement. Plywood panel formwork which can be used over again is quite common.

Special attention is given edges and corners where heat losses are highest due to greater surface in relation to volume. Form insulation is usually done with plywood paneling which provides an air space between it and the formwork (Fig. 3). Continuity of air gaps is interrupted to prevent heat loss by convection. The special problem of heat loss through protruding parts, such as reinforcing rods, is recognized and taken into account. Considerable data are available on the conductivities of these materials but, in nearly all cases, for the dry state only. Moisture loss from the newly placed concrete is counteracted by wide use of oiled paper and sealing compounds, presumably the same as American curing compounds. In many cases, however, reliance is placed on the insulation cover and formwork being left on as long as possible.

Enclosures and heating

Enclosures are generally considered too expensive to employ in most winter concrete work and are usually restricted to special structures and elements. Exceptions are structures where partial enclosure is already present in a building. Unless continuation of work is urgent, some recommendations suggest that concreting be stopped when temperatures fall below -10°C (14°F) or -15°C (5°F), rather than allow for the use of full enclosure as in North America.

Choice of materials for heated enclosures is again governed by cost and availability. In the Scandinavian countries, paper and cardboard are fre-

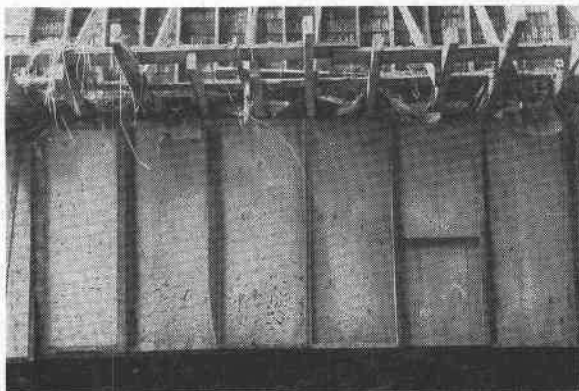


Fig. 3—Framed plywood covering. Note protruding formwork

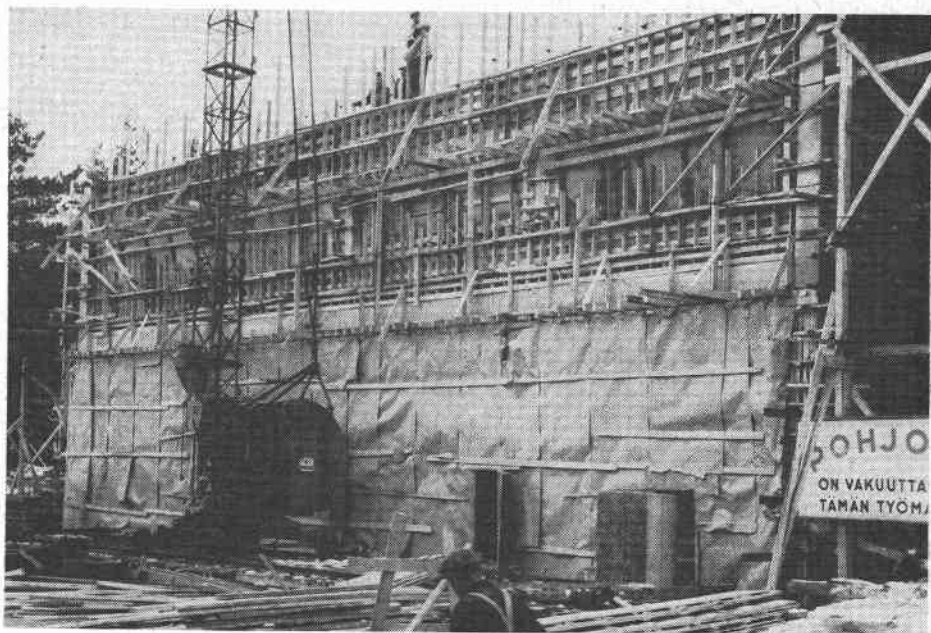


Fig. 4—Enclosure of knot pulp board fastened with waste board on skeleton framework

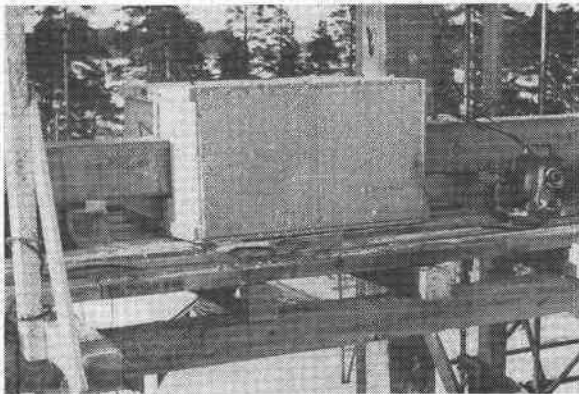
quently nailed over waste wood framing (Fig. 4). Wood slabs are also in common use. In Finland paper is used for covering windows in a building. In countries where wood products are limited, canvas and various other readily available materials are employed. Steel tube framing is sometimes used where canvas covered enclosures are employed.

Certain features in the design of enclosures are favored because of convenience and low cost. Enclosures are restricted to the smallest volume possible to conserve heat. Small movable shelters are used where continuity of operation make it possible (Fig. 5). Special attention is given to protruding parts, scaffolding arrangement, elimination of convection, and arrangement for temporary openings. Overlapping canvas hoods are sometimes employed.

Sources of heat include wood and coke burners, oil burners, electric heaters, and mobile steam boilers such as the Swedish Osby, or the "Jokke 2" oil heater (Fig. 6). The latter two types are noteworthy for the rapidity with which they can develop steam pressure. Special attention is given to uniform distribution of heat sources because of the danger of local overheating, particularly at edges and corners. Where hot air is used, as is common in Switzerland, pans of water or similar devices are used to prevent excessive drying of the concrete.

As far as possible the same heat source is used for heating aggregate and water as for heating the concrete. Centralized heating systems are used extensively. These consist of boiler plants for high or low pressure steam heating. Oil heating is becoming common but waste wood materials are still

Fig. 5—Portable wallboard enclosure for joint of a pre-fabricated beam, heated by electric bulbs



the principal fuel. Common procedure in Switzerland is to place perforated steam pipes in stockpiles or to place heating grills under them. Infra-red radiation heaters have been employed successfully. Electro-curing has been developed and used successfully in Switzerland, but the higher cost has prevented any extensive use of this method. Radiation heating by placing heating coils in concrete ceiling slabs was reported.⁸

Inspection and control

Inspection and control of operations appear to be of a more positive type in European practice than is usually the case in North America. For example, some Swiss recommendations require daily casting of test specimens, part of which are stored under normal conditions, and part under the same exposure as the structural elements.¹² A consulting engineer in Norway showed the writer a method of control which he followed on his jobs. Flexural and compressive strengths were taken on specimens from the job concrete and plotted during the progress of the job. By agreement with the contractor, any concrete below a specified quality was not paid for. The writer was told that in Sweden a contractor is held legally responsible for a building for 2 years.

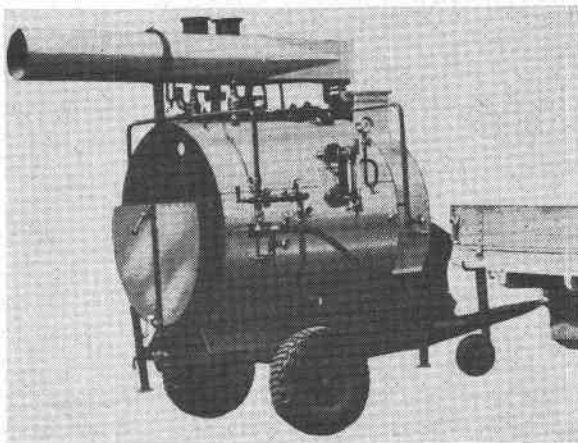


Fig. 6—A mobile steam boiler used on winter construction jobs

JOB PRACTICES

Certain site practices are being recognized as aids to more efficient protection during winter concreting, i.e., winter work techniques are being developed as distinct from conventional practices.

Types of structures

Considerable attention is now being given in Europe to the suitability of structures for winter construction. In Finland buildings with masonry supporting walls and reinforced concrete floors are increasingly not considered for winter construction.¹⁶ This is largely because the "mixed character" of the work involved can complicate protective measures. Buildings with supporting concrete partition walls and reinforced concrete floors are simpler and easier to rationalize from the point of view of winter construction and protection. Reinforced skeleton frame structures are also favored in Finland, with brickwork or precast wall sections put up under more favorable conditions.

A large proportion of apartment buildings in Sweden are built with exterior concrete walls having outside insulation of cellular concrete. Protection for such structures is relatively simple since the exterior walls, apart from window and door openings, are already insulated. A variation of this method is developing in Finland where the sliding-form technique is used. It is considered particularly suited to winter construction.

The use of prefabricated concrete elements is used widely in winter construction work in Europe, particularly in the Soviet Union. The advantages are evident, especially for large structures. Care has to be taken, however, in protecting the necessary grouting operations.

General organization

Relatively mild and variable winters in many parts of Europe permit planning of construction so that concreting can be carried out during the most favorable weather. This is done to avoid expensive enclosures and heating. The starting date of construction is an important factor in these cases. Advance arrangements for materials can therefore be made.

The actual concreting itself is usually begun in the morning in order to finish a particular section before the onset of lower night temperatures. It is reported that preliminary "drills" of construction crews have shown good results in speeding up operations, such as transportation and placing of the concrete, and providing covering. Speed is also important to avoid later delay in permitting follow-up work.

Scaffolding is arranged to minimize interference with protective coverings. The installation and removal of forms is considered in connection with speed of operation. Organization for rapid removal of snow is also taken into account. A definite effort is made to plan reasonably comfortable conditions for workmen. This applies to eating and clean-up quarters as well as working

places. Government agencies have encouraged manufacturers to design clothing particularly suited to winter construction work.

Considerable use is made of the "Hico" system for supporting floor slab and wall forms. This involves the use of adjustable steel girders resting on wall forms and bracing, permitting placing of a floor slab without interfering with the area below which can then be used for various job operations. Basement areas are usually used for storage purposes as well as for small jobs.

As far as is possible heat sources for enclosures are used which can be employed for other purposes. Steam can be used to heat living and office quarters, for example. Wood-burning, mobile boilers, called locomobiles, are used widely since they are available as cheap surplus from agricultural agencies following electrification of rural areas in parts of Scandinavia.

Forecast weather data are utilized in conjunction with long term average minimum temperatures. On most of the larger jobs, thermometers and thermocouples are placed in the concrete and a record is kept of the progress of cooling. Extra covering material is usually provided in case of sudden drops in temperature.

Ready-mixed concrete is considered an important factor in winter concreting in Denmark.¹⁷ Provision for storage and preheating of materials on the job is eliminated. The thawing of snow and ice around formwork can be done by flame throwers. This procedure is particularly suited to conditions where the placed concrete is sufficiently protected by unheated covering.

CONCLUSIONS

In Europe, special efforts are made to encourage and promote winter construction. Research on winter concreting has been pursued intensively with the help of state funds, particularly in the Scandinavian countries.

The primary concern for added costs of winter work has directed investigations into developing methods for increasing the frost resistance of concrete and determining the minimum protection requirements. Progress has been made in developing quantitative methods for predicting the maturity of the concrete, taking into account the material properties and the geometry of the elements, but only for variations in outside temperature conditions. The influences of the different climatic elements and factors however, have received little attention. The development of the "cold" concrete technique in the Soviet Union is of special interest.

A direct consequence of the increasing trend to winter construction is the growing tendency to choose those types of structures most amenable to winter protection. This is reflected in the wider use of prefabricated elements and the Swedish techniques involving cellular concretes.

It is evident, however, that progress in the application of technical advances to field practice is retarded by conservative attitudes in the building industry, a situation similar to that in North America.

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