

clearances should be provided for snow removal. Roads are much easier to build before the ground freezes and before fall rains or early snowfalls. Good drainage is necessary to maintain a road usable and trouble-free for several months. Besides access roads from main roads to subdivisions, it is important that driveways be roughed in to carry trucking loads. Suitable culverts should be provided at ditch crossings into construction sites to ensure proper drainage during wet weather.

Availability of building materials and equipment on short notice is one of the advantages of building in winter. It is important, therefore, not only to provide roads but to keep them open and in good condition. If this is done materials can be delivered as required reducing the amount of space and shelter that would otherwise be required. Well maintained roads also ensure easy access to the site by fire-fighting equipment in the event of an emergency.

Municipal services such as electric power, water, and sewers should be arranged for well in advance of the construction starting time so that there will be no holdups due to bad weather or trenching in frozen ground. Where storm sewers are to be provided, the site should be drained before cold weather sets in. It is best to install septic tanks at the time of excavating for the foundation. A septic tank can be put in place in winter provided the ground is first covered by snow, brush or straw to prevent frost penetration and to make cold weather excavation possible.

Disposal beds should be backfilled and covered with straw or snow to prevent freezing and heaving of the tile. Workmen and vehicles should be kept away from the disposal bed area as compacted snow cover will increase frost penetration. If cold weather is expected before there is snow on the ground, the disposal area should be covered with a foot or two of straw until after the septic tank system has been in operation for several weeks.

Lot layout, surveying, excavation, staking and the establishment

of elevations can best be done before the ground freezes or before much snow has fallen. Land clearing and rough grading can normally best be done before snow has covered the site.

The items cited above fall into the category of planning the winter job. They are dealt with more easily before freeze-up or snowfall. This does not mean that they cannot be done in winter — they can, but with difficulty.

SITE ORGANIZATION

Water Supply for Construction Purposes

In winter, precautions must be taken against freezing of water pipes to ensure an adequate water supply for on-site concrete, masonry, and plaster work. In addition, water should be available for fire-fighting purposes. Water pipes can be protected against freezing by insulating or heating.

Where water under pressure is available, a frost well can be put down to the depth of the water main. The bottom of the well must be equipped to drain to a sewer or porous ground so that the service pipe can be readily emptied at night. Where necessary the valves and couplings can be protected by a layer of straw. The well should be covered to exclude snow. Rubber or plastic hoses are often used as temporary service lines. These hoses should be emptied when not in use and stored under cover. Pipes should be supported in such a way that no water can remain in them when they are drained.

Insulation for temporary service pipes can be provided by placing the pipe in a trench and backfilling before freeze-up. If trenching is not practicable then pipes can be laid in boxes filled with shavings or sawdust. Four to 6 inches of dry insulation will prevent freezing of still water in pipes for 24 hours on most construction sites. A small amount of insulation may be enough if water is being run continually through the pipe but the pipe must be drained after working hours if the water is shut off.

Electrical heating of pipes is effected by passing a low-tension current, supplied from the power lines through a transformer, through the pipe proper, or through an insulated cable passing through the pipe. There are "wrap-around" cables available that operate on normal supply voltages and these, together with some insulation, will provide enough protection for most winter jobs.

Storage and Protection of Materials on the Site

Millwork, finish flooring, asphalt shingles and cement should be stored in a warm, dry location. Lumber, plywood, insulating sheathing, gypsum board, masonry units and masonry materials must be kept dry. Certain materials such as reinforcing steel and cast-iron pipes suffer no direct damage through exposure for a few months; nevertheless, work will be slowed down if they are encrusted with snow and ice. Materials not requiring coverings should at least be stored off the ground on platforms or skids to prevent their freezing to the ground.

The Fire Problem

Make sure that salamanders and other temporary heating equipment do not set fire to formwork and tarpaulins. Fires may occur from welding and cutting operations but most of the fires in formwork have started in tarpaulins from portable heaters.

A flameproofing liquid for treating tarpaulins in the field was developed during the war for the armed forces. A specification for the liquid and its application is available (Canadian Government Specifications Board Specification 4-GP-56).

Salamanders should be placed on the ground or other incombustible base. If placed on wooden floors, salamanders must be insulated by at least 3 inches of incombustible material covered by sheet metal and extending 2 feet beyond all sides. There should be a clear distance of at least 30 inches in a horizontal direction from all wood construction and a clear distance of 6 feet above all salamanders.

Do not throw chunks of asphalt that are covered with ice or snow into a heating kettle. The conversion of the ice and snow into steam in the hot asphalt will cause spattering and may also cause the kettle to overflow and start a fire. Never heat asphalt cement directly over a fire; put unopened cans in hot water to warm.

Fire hoses should be kept close to all formwork and buildings when heaters are being used on the job. If there is danger of freezing, the fire main should be kept drained and controlled by a valve protected from freezing but easily accessible. Hand extinguishers are a valuable supplement to a supply of water. These should be checked periodically to determine if they are fully charged and in good working order.

EXCAVATIONS AND FOUNDATIONS

Excavating

Modern excavating machinery can readily operate in ground frozen to a depth of 1 foot. Earthwork will usually cost less, however, when it is done before or between frost periods. For a well-planned winter job it is possible that all excavating and trenching can be done before cold weather.

Earth that is to be excavated after winter sets in can be covered with brush or straw to reduce frost penetration. If heavy snows precede periods of very low temperatures, then this snow cover should be left undisturbed to provide a blanket of insulation over the area to be excavated later. Rock excavations present no particularly difficult problems at temperatures above 0°F.

Excavating is sometimes easier in winter. Drainage and well-point work is often reduced or eliminated during cold weather. Shoring, cribbing, and piling may also be reduced if the ground is frozen so as to maintain a certain stability with slopes and vertical cuts.

Frost protection inside the excavation is usually necessary. Straw should be placed in the bottom of the excavation and up the

sides for a few feet. This will reduce frost penetration and make it possible to place footings on an unfrozen base. The straw is removed immediately before placing the concrete for the footings and replaced as soon as the concrete is placed to ensure proper curing of the concrete. On a rock base, heating with steam before the footing concrete is placed will provide better curing conditions for the concrete.

Sides of excavations and embankments having a south or south-west exposure are subject to cycles of freezing and thawing with consequent sloughing and caving in. Straw placed against these sides and covered with tarpaulins will usually stop this action, and make work on the footings and foundation walls easier.

Thawing operations may be necessary where excavations must be made at the height of the cold weather.

Where frost has penetrated deep into the soil, fires can be used to thaw the ground. For sewers and water-mains this may be done by spreading approximately 1 foot of hay or straw covered with 3 inches of slack coal. When a good tight job of spreading the coal over the straw is accomplished, the ground will be thawed to a depth of as much as 3 feet by one burn. Wood scraps and petroleum products can also be set afire. Flame throwers are beginning to make an appearance for thawing small sections at a time.

Steam is sometimes used by one of the following methods:

- (1) thin coils laid on the frozen surface;
- (2) steam jets keeping water warm in a pit;
- (3) steam points melting their way into the frost crust.

The last-mentioned method has proved to be the most effective means of thawing with steam.

Foundations

Concreting against frozen ground is poor practice. Excavations should be made just before placing concrete, or so protected that the bottom and sides do not freeze. The same applies for trenches for sewers and drains.

One of the most common and serious types of frost damage is by frost heaving of foundations. It is absolutely essential to prevent freezing of the ground below the foundation when frost susceptible soils are encountered. If a basement is left open or unheated, insulation must be provided over the entire foundation, and on concrete floors. A twenty-inch layer of straw or hay will usually provide the required amount of protection for short periods.

Forms for foundations should not be placed on ice or snow. All ice or snow on the inside surfaces of forms and between forms must be removed before concrete is placed. This can readily be done by steaming. The base must be thawed before footings are placed and kept that way thereafter. Steel reinforcement and construction joints must be free of snow and ice and preferably warm.

Masonry units for foundations should be thoroughly cured. Those having a moisture content greater than 20 per cent should not be used. Blocks that have ice on them should not be used. Dry blocks permit mortar to set faster. Blocks should be warmed when temperatures fall below 40°F. These precautionary measures lessen the chances of damage by frost.

Mortar for block foundations should be prepared from warm aggregate and the mixing water must be heated when the temperature is below 40°F. Mortar should be prepared in small batches and kept warm until it is used. Mortar and masonry materials should be maintained at a temperature of not less than 40°F. during laying. The masonry should not be subjected to below freezing temperatures during the first 48 hours after laying.

Drain tile may be placed around the footings and covered with crushed rock or other granular material. Straw or hay should then be placed on top of this material to prevent frost heaving and freezing of the tile and footings. Proper outlets for the tile must be provided to take care of early spring runoff. No backfilling should be done until spring unless unfrozen material is used.

This should be placed in layers of 6 inches to one foot and compacted to prevent future settlement and subsequent ponding of water near the foundation wall.

CONCRETE

Protection for concrete is essential during placing and curing in any region where temperatures below freezing are expected. Good practice requires that the concrete be warm when placed and that it be kept above freezing until it has gained sufficient strength to prevent damage when frozen. Concrete which has attained a strength of 500 psi is considered past the danger stage, although it is still not capable of withstanding repeated cycles of freezing and thawing. Further gain in strength will depend on temperature and humidity conditions, but care must be taken to see that temperatures do not rise to a high level. It is not generally realized that concrete which is not allowed to freeze and which is placed and cured at low temperatures above freezing develops higher ultimate strength and greater durability than concrete placed and cured at higher temperatures. It is only in winter that the contractor can provide the low temperatures required for top quality concrete.

While low temperatures are desirable, fresh concrete must not be allowed to freeze. When this happens the hydration of the cement ceases and ice crystals form within the concrete. While hydration will resume with a rise in temperature, the disruption caused by the expanding ice crystals will have so damaged the concrete that it will never attain the strength of unfrozen concrete and may, in severe cases, be completely destroyed.

All necessary equipment and materials for the protection of the concrete should be on the site well in advance of freezing weather. With the concrete in place and the temperature dropping below freezing it is often too late to begin collecting protective equipment and materials.

The next step in winter concreting is to select suitable aggregate.

Soft, shaly stones are dangerous since they absorb water and may cause rupture after the concrete has hardened particularly when the concrete is subjected to cycles of freezing and thawing. Further information on the making of concrete is contained in Better Building Bulletin No. 3, "Concrete" published by the Division of Building Research.

Heating the Mix

The table below indicates, for various outside temperatures, the requirements for heating of aggregate and water and also the recommended temperature of the concrete in the mixer.

Air Temperatures	Water	Aggregates		Concrete Temp. at mixer
		Sand	Coarse	
Above 30°F.	Heated	—	—	60 to 80°F.
30 to 0°F.	"	Heated	—	65 to 90°F.
Below 0°F.	"	"	Heated	70 to 90°F.

When the air temperature is just below freezing, the required temperature for the concrete mix can be obtained by heating the water only. This assumes, however, that the aggregate is not frozen and no ice is contained in the aggregate. Later as the weather becomes colder and stockpiles freeze, heat is also applied to the sand. In severe winter weather coarse aggregate is also heated.

The temperature of the mixing water should be controlled to avoid variations from batch to batch. If either the water or the aggregate is heated to a temperature above 100°F., water and aggregate should come together first in the mixer in such a way that the temperature of the combination is reduced to below 100°F. before the cement is added. This will prevent flash set.

If water is heated to a maximum temperature of 140°F. then it should not be necessary to heat the aggregates to a temperature in excess of 60°F. even during the coldest weather.

Placing the Concrete

The temperature of the concrete when placed should be between 60°F. and 80°F. This applies winter or summer. There is nothing to be gained and damage can result if concrete is placed at too high a temperature.

Before concrete is placed, all ice, snow and frost must be removed from forms, reinforcement and other contact surfaces. The temperature of surfaces in contact with the concrete should be above 40°F. No concrete should be placed on a frozen sub-grade or on one that contains frozen materials.

Curing

As soon as the concrete is placed, steps must be taken to ensure that the temperature of the concrete at all surfaces does not drop below 50°F. for a period of 5 days or below 70°F. for 3 days. In either case, the concrete after the initial curing period should be kept at a temperature above freezing until it has reached an age of 7 days. When high early strength cement is used or an additional 20 per cent of cement is added to the mix, the protection period may be reduced to 3 days at 50°F. or 2 days at 70°F.

Higher curing temperatures than those indicated may result in reduced strength and durability of the concrete. Rapid changes in temperature are also undesirable. At the end of the protection period, the temperature of the concrete should be gradually reduced at a rate of 20°F. per day until the outside air temperature has been reached.

During the initial curing period, the concrete must be kept damp as well as warm. At the lower wintertime temperatures, the forms will usually retain sufficient moisture to ensure adequate curing. They may, therefore, be left in place for as long a period

as possible. This is contrary to good practice during hot weather, when the forms are stripped as soon as possible to permit proper curing of the concrete. Large exposed surfaces of concrete such as floor slabs must, however, be kept damp if dry heat is used. Often heaters blow hot dry air directly over a freshly placed concrete surface. Concrete cured under these conditions will not be durable and will often have a weak chalky surface with little resistance to abrasion.

During the hardening of the concrete and especially in the first few days, considerable heat is developed. If this heat is conserved, no heat from outside sources will be necessary to ensure good curing conditions. This heat may be conserved by covering the concrete surface with insulating blankets or insulated forms. The amount of insulation for various kinds of concrete work at different outside temperatures is given in the following tables which have been taken from ACI Standard 604-56, "Recommended Practice for Winter Concreting."

**INSULATION REQUIREMENTS FOR CONCRETE
WALLS AND FLOOR SLABS ABOVE GROUND**
Concrete placed at 50°F.

Wall thickness, ft.	Minimum air temperature allowable for these thicknesses of commercial blanket or batt insulation, deg. F.			
	0.5 in.	1.0 in.	1.5 in.	2.0 in.
Cement content — 300 lb. per cu. yd.				
0.5	47	41	33	28
1.0	41	29	17	5
1.5	35	19	0	-17
2.0	34	14	-9	-29
3.0	31	8	-15	-35
4.0	30	6	-18	-39
5.0	30	5	-21	-43
Cement content — 400 lb. per cu. yd.				
0.5	46	38	28	21
1.0	38	22	6	-11
1.5	31	8	-16	-39
2.0	28	2	-26	-53
3.0	25	-6	-36	—
4.0	23	-8	-41	—
5.0	23	-10	-45	—
Cement content — 500 lb. per cu. yd.				
0.5	45	35	22	14
1.0	35	15	-5	-26
1.5	27	-3	-33	-65
2.0	23	-10	-50	—
3.0	18	-20	—	—
4.0	17	-23	—	—
5.0	16	-25	—	—
Cement content — 600 lb. per cu. yd.				
0.5	44	32	16	6
1.0	32	8	-16	-41
1.5	21	-14	-50	-89
2.0	18	-22	—	—
3.0	12	-34	—	—
4.0	11	-38	—	—
5.0	10	-40	—	—

INSULATION REQUIREMENTS FOR CONCRETE SLABS PLACED ON THE GROUND

Concrete at 50°F. placed on ground at 40°F.

No ground temperature gradient assumed

Slab thickness, ft.	Minimum air temperature allowable for these thicknesses of commercial blanket or batt insulation, deg. F.			
	0.5 in.	1.0 in.	1.5 in.	2.0 in.
Cement content — 300 lb. per cu. yd.				
0.333	—	—	—	—
0.667	49	47	44	42
1.0	43	33	22	12
1.5	33	12	-10	-33
2.0	24	-9	-43	-77
2.5	14	-31	-76	—
3.0	5	-52	—	—
Cement content — 400 lb. per cu. yd.				
0.333	—	—	—	—
0.667	46	40	32	26
1.0	37	22	5	-12
1.5	25	-5	-37	-68
2.0	13	-32	-78	—
2.5	1	-59	—	—
3.0	-11	—	—	—
Cement content — 500 lb. per cu. yd.				
0.333	—	—	—	—
0.667	42	32	21	10
1.0	32	10	-13	-35
1.5	17	-23	-63	-103
2.0	3	-55	—	—
2.5	-12	—	—	—
3.0	-27	—	—	—
Cement content — 600 lb. per cu. yd.				
0.333	50	50	48	48
0.667	39	24	9	-5
1.0	27	-1	-31	-59
1.5	10	-40	-90	-139
2.0	-8	-78	—	—
2.5	-25	—	—	—
3.0	-43	—	—	—

INSULATION EQUIVALENTS*

Insulating material	Equivalent thickness, in.
1 in. of commercial blanket or batt insulation	1.000
1 in. of loose fill insulation of fibrous type	1.000
1 in. of insulating board	0.758
1 in. of sawdust	0.610
1 in. (nominal) of lumber	0.333
1 in. of dead-air space (vertical)	0.234
1 in. of damp sand	0.023

*The tables are calculated for the stated thicknesses of blanket-type insulation with an assumed conductivity of 0.25 Btu. per hr. per sq. ft. for a thermal gradient of 1 deg. F. per in. The values given are for still air conditions and will not be realized where air infiltration due to wind occurs. Close-packed straw under canvas may be considered a loose-fill type if wind is kept out of the straw. The insulating value of a dead-air space greater than about $\frac{1}{2}$ in. thick does not change greatly with increasing thickness. Textbooks or manufacturers' test data should be consulted for more detailed data on insulations.

Accelerators

The hardening of concrete will be accelerated if small amounts of additional cement are added to the mix. Use of 1 per cent of calcium chloride by weight of the cement is often recommended in cold weather for the same purpose. An exception to this is when sulphate-resisting concrete is required; in this case, an extra bag of cement per cubic yard should be used rather than calcium chloride. The calcium chloride, when it is used, should be dissolved in a portion of the mixing water.

Salts or other chemicals must not be used as antifreeze agents. In the quantity that is safe to use, calcium chloride will only lower the freezing point by 2 or 3 degrees. Too much salt may reduce the durability of concrete, intensify the destructive reaction between the alkalis in portland cement and certain susceptible aggregates, and promote the corrosion of metal reinforcement

and ducts imbedded in the concrete. It is generally agreed that calcium chloride must not be used in amounts in excess of 2 per cent by weight of the cement.

MASONRY

While much is known about winter concreting, little study has been devoted to cold weather masonry construction. Regulations which have been in use are based on the results of work done about thirty years ago on concrete since it was considered that the mortar would react to cold weather in much the same way as does concrete. Many masonry buildings have been constructed, however, without protection and, even under severe winter conditions, these structures have shown remarkable durability. This has led to some relaxation of the regulations regarding winter masonry construction, but this does not mean that masonry can take care of itself in cold weather. Failures are still reported and are no doubt due to inadequate supervision on the site.

Storage of Materials

The first step in preparing for winter masonry construction is to provide a storage space where masonry units and mortar materials can be kept on a platform raised to prevent wetting from ground moisture. The materials must be covered with tarpaulins, building paper or plastic film to keep them dry and free of ice or snow. Space located in an area where the temperature is above freezing is desirable but not essential.

Preparation of Mortar

When the temperature falls below 40°F., the water for the mortar should be heated to provide a mortar with a temperature between 60°F. and 80°F. The water must not be heated to a temperature higher than 150°F. In very cold weather, the sand also may require to be heated, but again care must be taken to avoid overheating. All that is required is that the temperature

of the sand be above freezing and that it is free of snow or ice. Sand can be heated by piling it around a metal pipe in which a slow fire is built.

Mortar Mixes

In mild weather, a suitable mix is one part portland cement, two parts lime putty and eight or nine parts of sand (1:2:8 or 9) all by volume.

In cold weather, more cement is used to accelerate the hardening of the mortar. A 1:1:5 or 6 mix is suggested.

Mixes stronger than 1:1:5 such as 1:3 (cement:sand) are only recommended where a dense, strong mortar is required in engineering construction or for masonry construction below grade. These strong mortars should not be used, however, with masonry units which have a high drying-shrinkage, since the brick or block may be cracked during the drying out period.

A weaker mortar will accommodate the movement of those concrete blocks and concrete or sand-lime bricks which have higher shrinkage values.

Heating of Masonry Units

Bricks must be heated when the temperature falls below 32°F. Not only will this ensure that the temperature of the masonry is above freezing but will also permit the establishment of a good bond between the mortar and the brick. When the suction of the brick must be controlled, this can only be done when the brick is at a temperature above freezing. The brick must not be overheated, a temperature of 40 to 50°F. being quite adequate.

Laying Precautions

Block and brick must never be laid on a snow- or ice-covered base. The tops of unfinished walls must be covered at the end of the day's work to keep the masonry dry and free from ice or snow. Bricks must be supplied in a dry condition.

Bricks with initial rates of absorption above 20 grams per minute should be sprinkled with warm water just before laying. The brick must not be saturated since they may disintegrate on freezing.

Masonry Protection

After the masonry walls are laid up, they should be kept at a temperature above freezing for at least 48 hours. Tarpaulins are usually sufficient for this purpose for temperatures down to 25°F. At lower temperatures artificial heat inside temporary enclosures is required. Care must be taken to prevent heating of one side of a wall only.

PLASTER

Fresh plaster must not be allowed to freeze since this will result in damp, dark-coloured walls with inadequate strength. During the first twenty-four hours the plaster should be kept warm and moist. After plaster has hydrated, which will be within the 24 hours, ventilation must be provided to permit drying of the plaster. High humidity conditions, particularly at temperatures of 40°F. to 50°F., may prevent drying of the plaster; this greatly weakens the bond of the plaster to the base. If outside temperatures are below 40°F., heat must be introduced to supplement ventilation. The temperature should be controlled, however, to prevent too rapid drying of the plaster which often results in the formation of shrinkage cracks. A temperature of 65°F. could be considered a desirable maximum level. Ventilation should be so arranged that air currents do not impinge on a freshly plastered surface. In very cold weather air for ventilation should be introduced at some point away from the area to be dried.

Since in most cases the permanent heating system is in operation when the plastering is started, no trouble is found in maintaining proper temperatures. Warm air heating systems also permit the introduction of fresh air directly to the furnace. When temporary

heaters are used, care must be taken to provide careful supervision since smoke or fumes may stain the plaster.

Condensation on windows is a problem during the first 24 hours on a winter plastering job. Water dripping from windows may cause permanent damage to the plaster or to woodwork. If condensation cannot be controlled during this period, then ventilation must be provided.

STUCCO

Stucco is usually a cement plaster and requires curing conditions similar to those for concrete. Stucco should not therefore be applied at below-freezing temperatures unless adequate protection in the form of heated enclosures is available.

ROOFING

Water trapped under or between the plies of built-up roofing will invariably give trouble. It is important, therefore, that the roof deck is dry when the roofing is applied and that no water gets between the layers of roofing felt.

Asphalt and tar are often heated to higher temperatures than normal to compensate for the lower winter air temperatures. This is not good practice since overheating changes the physical properties of these materials and will reduce roof life. The temperature recommended by the manufacturer must not, therefore, be exceeded.

Roofing felts and asphalt shingles during cold weather should be kept at a temperature of 70°F. until they are ready to be used. Gravel or slag used to surface built-up roofs must be dry and should be heated when the air temperature is below 40°F. to ensure proper penetration into the bitumen.

Every effort should be made to construct a built-up roof in warm dry weather. When this is not possible, then precautions must be taken to keep water, snow and ice off the roof deck and the roofing.

PAINTING AND DECORATING

Do not apply exterior paint at temperatures below 50°F. Paint applied in cold weather will not dry properly and will lose its durability and resistance to weathering. For winter work it is best to pre-prime outside trim and millwork in a heated and ventilated building and finish the painting in warm weather.

Control of temperature for interior painting presents no problem if the heating system is operating. Ventilation is desirable not only to assist in the drying of the paint, but also to remove the solvents which are sometimes toxic.

Fresh plaster should not be painted. This retards the drying of the plaster and may result in fading of the pigments in the paint. Taping of joints in dry wall construction should not be done at temperatures below 50°F.

Wallpaper should not be applied at low temperatures. If heat is not provided freezing and souring of paste can readily occur. If the paste sours it will spoil the paper. Wet conditions inside the house or papering over fresh plaster will also cause paste souring. A tablespoon of carbolic acid to a bucket of paste reportedly will keep paste good for three or four days. If paper will not dry in this time, increase the heat in the building or use a dehumidifier.

PROTECTION OF WINTER WORK

Winter in most of Canada is severe and the majority of building operations can carry on only when protection in the form of insulation or shelters is provided. In house building many builders find that the use of insulated forms to protect concrete foundations and steam to prevent the entry of frost into the ground is all the protection that is required. As soon as the foundation is in place, the wood frame and exterior cladding can be put in place in all but the most severe weather. Quality of such work is often better in winter since the frame is not subjected to

wetting by rain as so often occurs in summer. Temporary shelters do provide good working conditions for house builders, but so far a light, portable shelter designed for repeated re-use has not been developed. Shelters which can only be used once or which must be dismantled and then re-erected have been found too expensive for general use.

On other projects including larger residential units, shelters are widely used. The great advantage of using a shelter to enclose all or a portion of the work is that it permits the contractor to carry on without interruption under conditions selected to ensure maximum quality and productivity.

Most enclosures make use of transparent plastic films. Sometimes the plastic is used only as temporary hoarding for door and window openings or as window strips, but often the whole enclosure is covered with polyethylene. Other enclosures use panels of plywood or building board which are later recovered and used in construction. Tarpaulins are still widely used. Recently, plastic tarpaulins have been introduced which have the great advantage of remaining flexible at low temperatures. The transparent plastics also have the great advantage of trapping solar heat so that the temperature inside enclosures covered with polyethylene may be as much as 45 degrees above outside air temperatures during sunny weather. This often provides all the heat that is required during the daytime. In very cold areas, additional insulation may be obtained with two layers of plastic to provide an air space to reduce heat loss during cloudy, windy weather and at night.

Shelters can be grouped in two general classifications. There are those which are self-supporting such as the laminated-arch plastic-covered enclosures. The second type of shelter uses the existing frame of the building for support. The most common type is the enclosed scaffold suspended from outriggers on the roof. This external working platform is raised from one story to the next as work progresses. Another method of enclosing the

skeleton makes use of standard sections of tubular scaffolding and is generally most economical for buildings under four or five stories in height. The scaffold is braced against the frame and covered with plywood, tarpaulins or plastic attached to a light frame wired to the outer members of the scaffold.

HEATING EQUIPMENT FOR WINTER WORK

Steam boilers are recognized as an economical source of heat for winter jobs. On the average job, the capacity of a boiler should be from 2 to $2\frac{1}{2}$ boiler horse power per yard of concrete per hour of maximum demand. Steam from the boilers may be used to:

- (1) heat the various buildings used;
- (2) heat the concrete aggregates and mixing water;
- (3) thaw out forms;
- (4) protect the concrete after placement.

For the use of boilers for heating the materials used in making concrete, the following data may be useful:

- (1) One boiler h.p. (33.5 thousand B.t.u.'s per hour) will raise the temperature of 30 gallons of water about 100°F. in one hour;
- (2) One boiler h.p. will raise the temperature of 1 ton of moist unfrozen aggregate about 60 to 65°F. in one hour;
- (3) One boiler h.p. will raise the temperature of about 1 ton of the frozen aggregate about 30 to 40°F. in one hour;
- (4) When steam is used for heating aggregates and water, the required boiler capacity per yard of concrete per hour will range from about 1 h.p. for mild winter weather to about $2\frac{1}{2}$ h.p. for fairly severe winter weather. For boilers of the type and capacity discussed here, about 140 sq. ft. of steam radiation is equal to 1 boiler h.p.

Steam unit heaters, portable warm-air units equipped with blowers, coal-, coke-, and oil-fired salamanders and gas-burning units are all commonly used in present-day cold-weather work.

It is important to note that extreme care should be exercised in the handling and locating of this equipment.

Coke-burning equipment should not be left unattended and enough ventilation of enclosures should be provided to take care of harmful gases that are sometimes given off by such units. Portable coke ovens produce sulphurous acid which produces rust on hardware. Hardware should be coated therefore when these units are used.

Infra-red rays are being used on some winter concrete jobs. Banks of five 250-watt infra-red lights are used to keep fresh concrete from freezing. These are the ordinary bulbs for therapeutic heat lamps and can be bought in drug, hardware or appliance stores. Job-made troughs fitted with light sockets contain the lamp banks. The troughs are deep enough to protect the lamps and are about 20 feet long. The trough is set horizontally on the working platform and the lamps are directed at the form surfaces. These units have been used successfully for protecting concrete placed at -15°F . It is suggested that the lamps be not placed too close to wood forms or tarpaulins because of the fire hazard involved.

Natural gas, where available, is often used to supply heat for winter construction jobs. Where there is no fire hazard, it is common practice to use open flares; otherwise gas-fired unit heaters are used.

The most widely used heater is the oil-fired space heater which comes in a number of sizes up to 800,000 B.t.u. per hour. These heaters are usually located inside the enclosure and are not vented.

All heaters burning coal, coke, oil or gas which discharge the products of combustion into the heated space must be operated with care to prevent a build-up of harmful gases. While there is little danger from carbon monoxide with properly adjusted heating units, ventilation should be provided when workmen are in the enclosure. Ventilation must also be provided during the first 24 hours after placing concrete. During this period, floor slabs

or other exposed surfaces will be damaged when the carbon dioxide content reaches a high level. When carbonation has taken place, the only way to correct the damage is to grind down the soft surface of the concrete until a firm surface is reached. This is an expensive operation.

ELECTRIC LIGHTING

Because of the shorter days and cloudy weather associated with the winter months in Canada, artificial illumination must be provided on most construction jobs. It is generally considered that for construction work, a light intensity of 10 foot-candles must be provided for the ordinary construction operations. On small construction jobs this usually involves between 5 and 10 100-watt bulbs per 1000 square feet of area. Where power lines are already installed, no difficulty is experienced in obtaining a temporary power line to the job for the operation of electrical equipment as well as lighting equipment. Portable generators, of which there are a large number on the market, can be used where power lines are not available.

CONCLUSION

This bulletin has attempted to indicate some of the techniques used in Canada by contractors working throughout the winter months. There is little to be found in these pages which will be new to those familiar with winter construction but it is hoped that many contractors who in the past have stopped construction in the late fall, will be encouraged to so plan their construction that it will be possible for them to continue throughout the winter months. It should be pointed out that while many protective measures must be taken during the winter, good control can be maintained of the various jobs associated with construction work. This often results in a superior structure over one built, for example, during extremely hot summer weather when it is very difficult to provide protective measures for concrete and masonry.

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