

Commonwealth of Kentucky  
Department of Highways

Report

on

COLD-WEATHER CONCRETING

by

Milton Evans, Jr.  
Research Engineer

Highway Materials Research Laboratory  
Lexington, Kentucky

February, 1960



COMMONWEALTH OF KENTUCKY  
DEPARTMENT OF HIGHWAYS  
FRANKFORT

December 1, 1959

ADDRESS REPLY TO  
DEPARTMENT OF HIGHWAYS  
MATERIALS RESEARCH LABORATORY  
132 GRAHAM AVENUE  
LEXINGTON 29, KENTUCKY

Ward J. Oates  
COMMISSIONER OF HIGHWAYS

C. 2. 1.

MEMO TO: T. H. Baker  
Director of Construction

ATTN: Austin Griffith  
Bridge Construction Engineer

SUBJECT: Cold Weather Concreting

As a result of Mr. Griffith's inquiries and his visit to this office, we are submitting certain information on cold weather concreting. Preliminary test of insulating materials have been conducted in the freeze-thaw equipment at the Research Laboratory. While these tests of necessity have not been all conclusive, we feel that enough data is presently available to recommend that cold weather concrete placement using insulating material be permitted.

The attached memo and special provision have been prepared by Mr. Milton Evans, Jr., head of the Concrete Section of the Research Division. We believe that adequate safeguards have been incorporated in the special provision to protect concrete placed in the insulated forms. We are most interested that adequate temperature records be maintained and have so provided in the special provision.

We would be pleased to observe a limited number of projects to further evaluate the practice of cold weather concreting and would, of course, welcome any discussion of the special provision or attachments.

A handwritten signature in cursive script that reads "W. B. Drake".

W. B. Drake  
Associate Director of Research

WBD:dl  
Encs.  
cc: A. O. Neiser  
S. T. Collier



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MEMO TO: W. B. Drake  
Associate Director of Research

SUBJECT: Cold-Weather Concreting

In order to successfully place concrete in cold weather, certain established requirements must be met. The concrete must not be allowed to freeze, it must not be overheated by artificial means in an attempt to protect it from the cold, and proper curing conditions must be maintained during the period of protection to insure sufficient moisture for the cement to hydrate. Generally, temperatures of not less than 50°F and not more than 90°F are satisfactory. These temperatures must be maintained long enough for the concrete to develop sufficient strength to withstand freezing temperatures and to support the loads. Generally, concretes made with other than Type III cement should be maintained at temperatures above freezing for at least six days, and concretes made with Type III cement should be maintained at temperatures above freezing for at least four days.

It is also important to prevent rapid or excessive temperature changes before the concrete has developed sufficient strength to resist thermal stresses. Hence, when protection is discontinued, it must

be done gradually to avert damage which might be caused by large temperature differentials in the concrete.

According to A.C.I. Standard 604-56, Recommended Practice for Winter Concreting, regardless of the method of protection used, calcium chloride and air entrainment are advantageous. For best results calcium chloride may be added in amounts of not less than 1 percent and not more than 2 percent by weight of the cement, and air contents between 3 percent and 6 percent should be obtained. Also small amounts (approximately 1 bag per cu. yd.) of additional cement are advantageous. These additions provide higher early strength and make the concrete more resistant to freezing.

Accepted methods of protecting concrete in cold weather include the use of calcium chloride, air entrainment, additional cement; the heating of materials before mixing; and the protection of the concrete with either heated enclosures or sufficient insulation. The conventional method of protecting concrete with heated enclosures is expensive, proper curing is difficult, and the hazard of fire is high. On the other hand, greater economy, better curing, and the near elimination of a fire hazard may be possible through the use of proper insulating materials.

The idea of utilizing the chemical heat of hydration of cement to warm fresh concrete in cold weather is not new. The heat produced depends, of course, on the amount of cement in the mix. Generally, most of the heat of hydration of hardening cement is developed in the first three days. If this heat and the heat originally in the mix are retained by the use of efficient insulation, the temperature of the

concrete can usually be maintained at a satisfactory level considerably beyond this time.

To determine the merit of the insulation method of protection several records of performance can be studied. Records available go back as far as 1952, and may be found in Journals of the American Concrete Institute, Highway Research Board Publications, and the United States Bureau of Reclamation Monographs. These accounts demonstrate that mass concrete (sections whose least dimensions are 12 in. and more) can be adequately protected with 2 in. of the efficient types of insulation in sub-zero weather. Further, it can be seen that during severe weather thin sections requiring supplemental heat can be more economically protected if insulation is used to contain the heat put in the mix initially, the heat generated, and the supplemental heat added. A.C.I. Standard 604-56 contains Tables (2a, 2b and 2c) which show the amounts of commercial blanket or batt insulation necessary for good protection for various kinds of concrete work and for several degrees of expected severity in weather.

Several tests have been run in the laboratory on small specimens at 0°F. The insulation used was chiefly balsam-wool (wood fiber) which is typical of the more efficient commercial blanket insulations. A standard 6-bag mix was used to make specimens containing one-half of a cubic foot of concrete. The specimens included 9.5-in. cubes, and 6- x 12- x 12-in. and 4- x 14.7- x 14.7-in. slabs. First, the specimens were protected with 1 in. of insulation and then with 2 in. of insulation. When placed in a deep freeze at 0°F, the 9.5-in. cubes protected by 1 in. of insulation went from a beginning temperature of 84°F to 32°F in 31 hrs. and 0 mins., and a similar specimen

protected by 2 in. of insulation went from a beginning temperature of 80°F to 32°F in 38 hrs. and 15 mins. A 9.5-in. cube, containing 2 percent calcium chloride by weight of the cement, subjected to a temperature of 0°F, and protected by 1 in. of insulation, went from a beginning temperature of 78°F to 32°F in 35 hrs. and 15 mins. The slab sections, having dimensions less than 9.5 in. and the same volume, had more surface area than the 9.5-in. cubes. Because of the greater surface area, these slab sections dissipated heat faster and cooled to freezing temperatures more rapidly. It can be seen from these data that the smaller the ratio of surface area to volume, the longer a section of concrete can be protected by insulation. The addition of calcium chloride, likewise, extends the period of protection; and 2 in. of insulation provide more lasting protection than 1 in.

The periods of protection given here for small specimens are hardly adequate, being less than two days; but the trends noted above would be the same for more massive sections which could be protected adequately. A similar test has been performed by L. H. Tuthill, R. E. Glover, C. H. Spencer, and W. B. Bierce, with a 2-ft. cube insulated with 3-1/2 in. of dry shavings. When subjected to a temperature of 20°F, the larger cube was sustained above freezing for 7 days. In this case, the temperature was higher than 0°F, but the material used for insulating was not as efficient as the commercial-type blanket. This test demonstrates that adequate protection is possible with relatively small specimens when conditions are not too severe. In actual practice, where the larger masses of concrete are involved, reliable insulation requirements for safe protection under various conditions are given in A.C.I. Standard 604-56.

Experience indicates that large sections of concrete can be adequately and economically protected from freezing in sub-zero weather if certain factors are taken into account. An efficient type of insulation having a "k" factor (thermal conductivity) of 0.27 or less, is most satisfactory. The blanket and batt insulations, including cotton fiber, rock wool, glass wool, and wood fiber, are the most common of these. Corkboard and foamed plastic are other possibilities. The characteristics of these various materials may be found in the Heating, Ventilating, and Air Conditioning Guide.

If these insulating materials are to be effective, they must be kept dry. Hence, a tough, waterproof cover is required. Heavy, asphalt impregnated papers and plastic sheets are being used with good results. Care must also be exercised to obtain a cover which is punctureproof and durable for reasons of economy. The material may then be re-used several times, making it more and more economical with each re-use.

It has been established that the economy of using more than 2 in. of any of these insulations is very poor. The benefit from additional thicknesses is small, whereas the cost is high. In fact, where conditions are not severe, analysis will often show 1 in. of insulation to be sufficient.

Of course, good workmanship is necessary to insure complete coverage of the forms and slabs to be protected. Satisfactory and proven methods have already been developed.

Several states, particularly in the northern areas, and some agencies of the Federal Government have already adopted these methods. Among them are: Illinois, Indiana, South Dakota, and New York. Typical specifications are available and can be obtained on request.

Particular attention should be given in designing concrete for placement in cold weather to obtain the lowest possible water content which will still give satisfactory workability. By limiting the water content, a more rapid set is possible; and the amount of freezable water which must be maintained above freezing is decreased. Further, strict adherence to the specified slump must be maintained in the field to insure that no unnecessary water is added on the job.

In order to facilitate any proposed work of this nature, a Tentative Special Provision has been prepared and is attached hereto. This provision covers the use of insulation for the protection of concrete placed in cold weather, and is consistent with the methods and procedures developed and proved in recent years.

Milton Evans, Jr.  
Research Engineer

ME:dl  
Encs.



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Commonwealth of Kentucky  
Department of Highways

SPECIAL PROVISION

For The Use of Insulation to Protect Concrete  
Poured in Cold Weather

The following Special Provision covers the protection of concrete with commerial blanket or batt insulation whenever temperatures are below 40°F.

1. DESCRIPTION

This procedure shall include the furnishing of all the insulating materials, devices to install these materials, thermometers to check temperatures, heated enclosures and supplemental heat generators where needed, and the application of all of these items.

2. MATERIALS

- A. The insulation blanket shall meet all requirements of:

Federal Specification HH-I-571a - "Insulation (vegetable or wood fiber) Blanket, Felt and Loose Fill," Class A - Flexible Blanket,

or

Federal Specification HH-I-521c - "Insulation, Building, Mineral Wool; Batts, Loose-Fill, and Granular-Fill." Type I - Batts, Class C, with enveloping membranes.

The thermal conductivity (k) of the insulating blanket shall not exceed 0.27 Btu per sq. ft. per hr., per degree F temperature difference between the two surfaces.

- B. The insulating blanket used on vertical forms shall have a 90 lb. double creped Kraft liner on the side exposed to the weather or a polyethylene plastic liner, minimum thickness 0.004 in. or approved equal. The interior lining completing the total enclosure of the blanket shall be 40 lbs. or heavier Kraft liner or approved equal. The liners shall be securely bonded to both sides of the insulating mat. The liners shall have an extension on each side to form a flange so the blanket can be applied to the framework of the forms.
- C. Insulation used on horizontal concrete slabs shall have a polyethylene plastic liner, minimum thickness 0.004 in. or approved equal on both faces. The liner shall be securely bonded to both sides of the insulating mat. All edges shall be sealed.

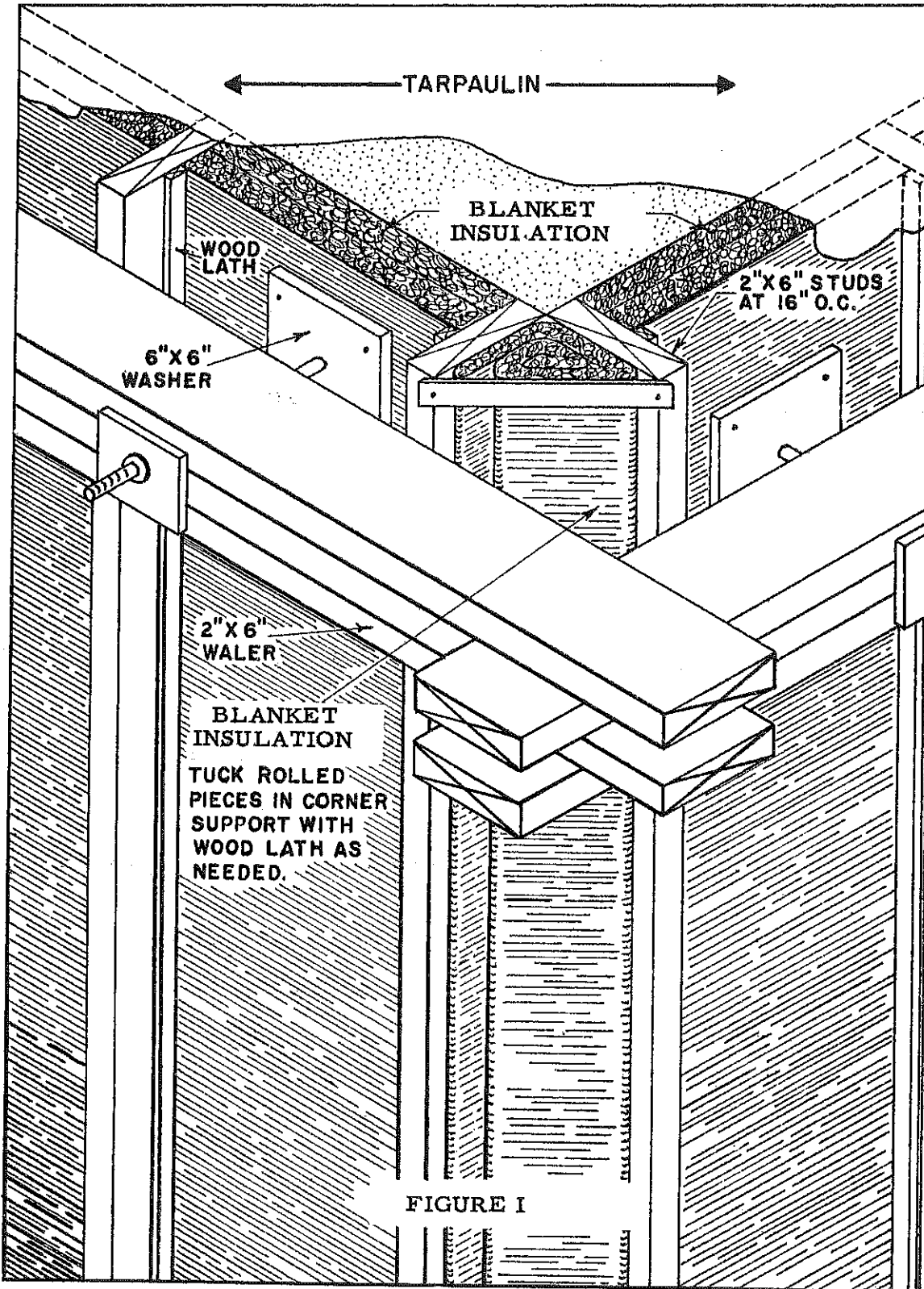
- D. If insulation furnished by the contractor has been previously used, it shall meet all requirements set forth herein and be approved by the engineer.

### 3. METHOD OF APPLICATION (Figure I)

- A. The blanket insulation shall be applied tightly against the wood form with the nailing flanges extending out from the blanket so they can be stapled or battened to the sides of the framing, which are either horizontal or vertical and spaced 12 in. to 16 in. o.c. The ends of the blanket shall also be sealed by removing a portion of the mat in order to bring the liners together and stapled or battened down to headers so as to exclude air and moisture. The corners or angles shall be well insulated and held in place.
- B. In the case of steel forms the insulating blanket shall be applied tightly against the form and held in an approved secure manner with ends sealed to exclude air and moisture.
- C. Insulation (or insulated form) shall overlap any previously placed (cold) concrete by at least one foot.
- D. Insulation of slabs on steel members shall be as indicated in Figure II.
- E. Any tears in the liner shall be patched or covered with a tacky waterproof tape or a piece of vapor barrier asphalted in place.
- F. Where tie rods extend through the insulated form a plywood washer (3/4 in. x 6 in. approx.) shall be placed on top of the insulation blanket and secured in a manner to provide adequate protection satisfactory to the engineer.
- G. The tops of all pours (horizontal and vertical) shall be covered with insulating blanket except for inaccessible areas around protruding reinforcement bars which may be insulated with salt hay or wrapped with approved insulation. Tarpaulins shall be used to cover the top of such pours as directed by the engineer.

### 4. GENERAL REQUIREMENTS

- A. Table I shall be used to select the amount of insulation necessary for good protection of the concrete sections shown for the temperatures listed.



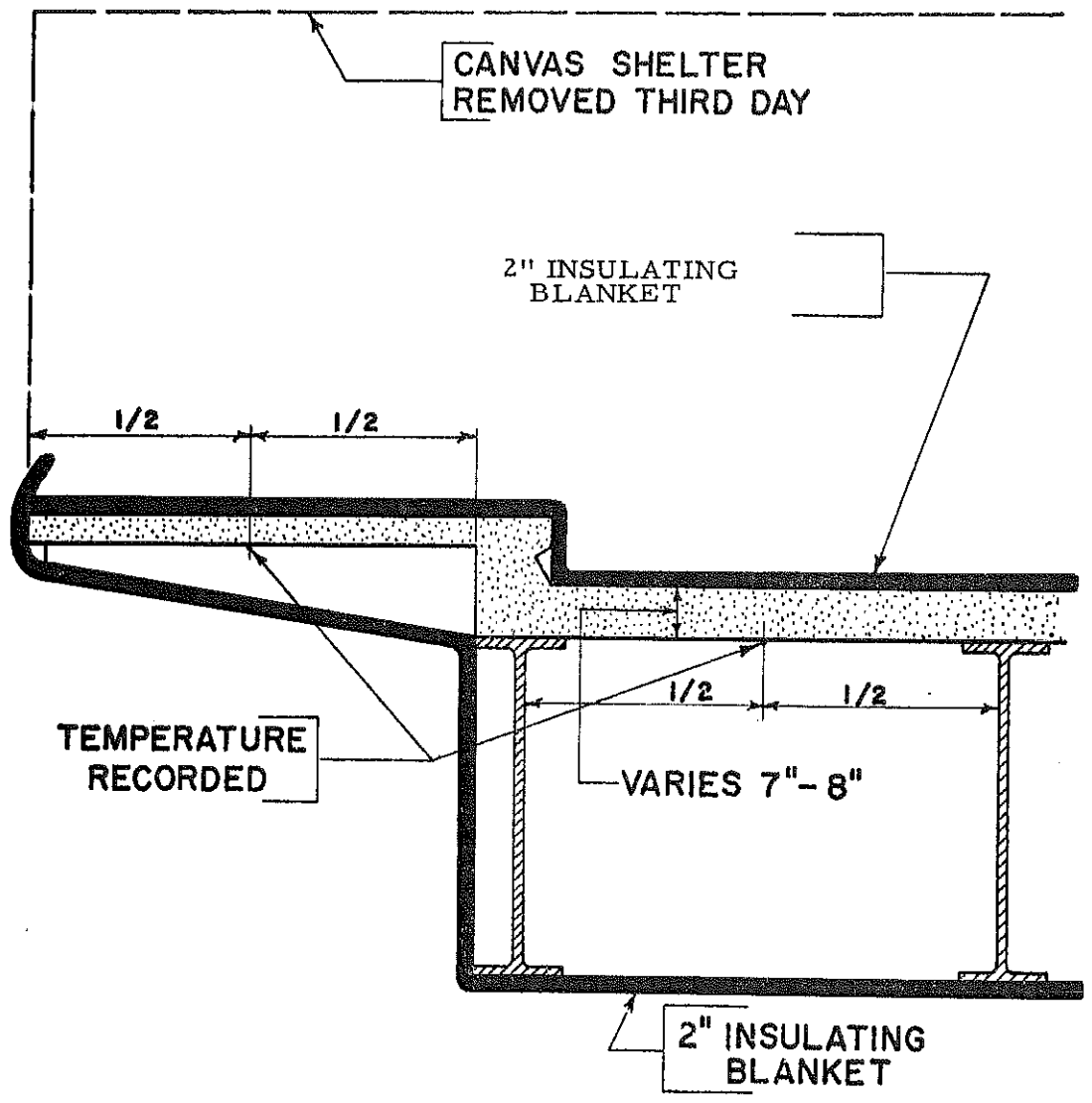


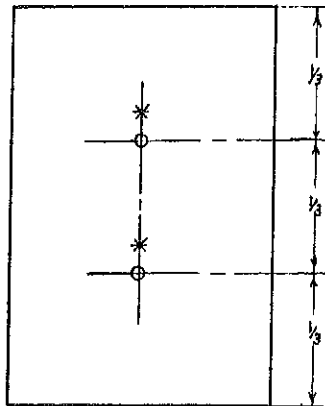
FIGURE II

Table 1: Insulation Requirements for Concrete Walls, Piers, Abutments and Floor Slabs Above Ground (Concrete Placed at 50°F)

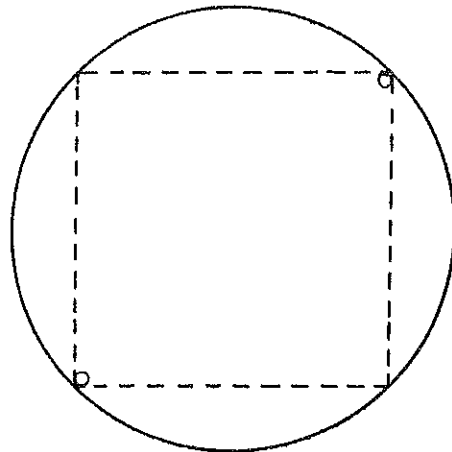
Cement Content lbs/cu. yd.	Wall Thickness ft.	Minimum Air Temperature Allowable	
		For 1 in. Insul. Blanket °F	For 2 in. Insul. Blanket °F
400 (4.26 bags/yd.)	0.5	38	21
	1.0	22	-11
	1.5	8	-39
	2.0	2	-53
	3.0	-6	
	4.0	-8	
	5.0	-10	
500 (5.32 bags/yd.)	0.5	35	14
	1.0	15	-26
	1.5	-3	-65
	2.0	-10	
	3.0	-20	
	4.0	-23	
	5.0	-25	
600 (6.38 bags/yd.)	0.5	32	6
	1.0	8	-41
	1.5	-14	-89
	2.0	-22	
	3.0	-34	
	4.0	-38	
	5.0	-40	

Note: This table is calculated for the stated thickness of blanket type insulation with a thermal conductivity of 0.25 Btu per hr. per sq. ft. for a thermal gradient of 1 degree F per in. Thermal resistance of the forms is not included. The values given are for still air conditions and will not be realized where air infiltration due to wind occurs.

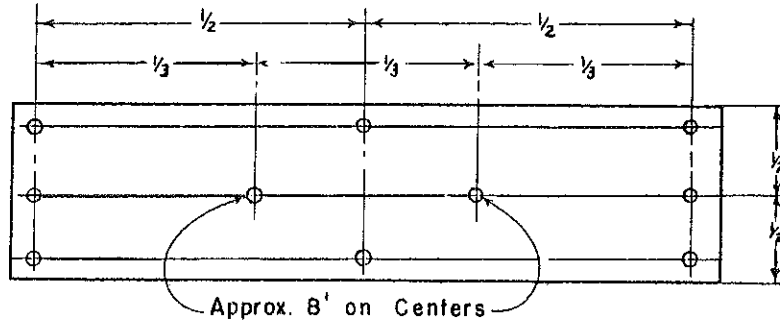
- B. Care shall be exercised to insure that the cover on all insulation remains intact so that the insulating mat will remain dry at all times. Any insulation which becomes waterlogged shall not be acceptable for use.
- C. Forms shall be insulated with a 1 in. insulation blanket as directed by the engineer on all sections more than 24 in. in thickness when concrete mixture is made with 5-1/2 bags or more of cement per cubic yard. All sections 24 in. or less in thickness shall have forms insulated with an approved 2-in. insulation blanket.
- D. Insulation used to protect the top of slabs shall be approved types of blankets, 1 in. or 2 in., as directed by the engineer.
- E. When insulated forms are used, the temperature of the concrete mixture (5-1/2 bags of cement or more per cu. yd.) shall, unless otherwise directed, have a temperature of not less than 50°F or more than 60°F. When concrete is to be placed in contact with previously placed (cold) concrete or in contact with an excessive amount of cold reinforcing bars or other steel members, the temperature inside the insulated form shall be raised, as directed by the engineer, to bring the temperature of the previously placed members to approximately 50°F.
- F. Constant temperature checks of the concrete and surrounding air shall be maintained and recorded. The concrete temperature shall be determined by inserting a stem thermometer in a well in the concrete or between the form and the blanket. Thermometers and forms for recording the temperatures of the concrete and air shall be provided by the contractor. Figure III indicates the method and locations for recording temperatures and attached is a typical temperature record form.
- G. Unless otherwise directed by the engineer, the forms shall not be removed when the outside air temperature is 0°F or below, or when the weather forecast for the next 24 hrs. is for a temperature of 0°F or below. They may be removed when outside temperature is below 32°F providing the temperature difference between the air and the concrete surface is no more than 30°F. If possible, forms shall be removed about the middle of the day to take advantage of the generally higher afternoon temperatures and radiant heat from the sun. However, in no case shall the forms be removed before the end of six (6) full days after the final placement of concrete in an individual unit.
- H. Stand-by heat shall be provided if ordered by the Engineer. The application of exterior heat will only be necessary when thin slabs formed on one side only and in contact with structural steel are protected as indicated in Figure II,



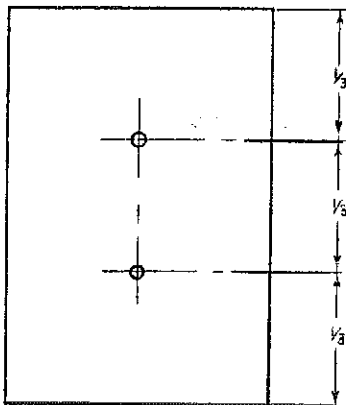
Elev. of Pier Column  
Windward side only



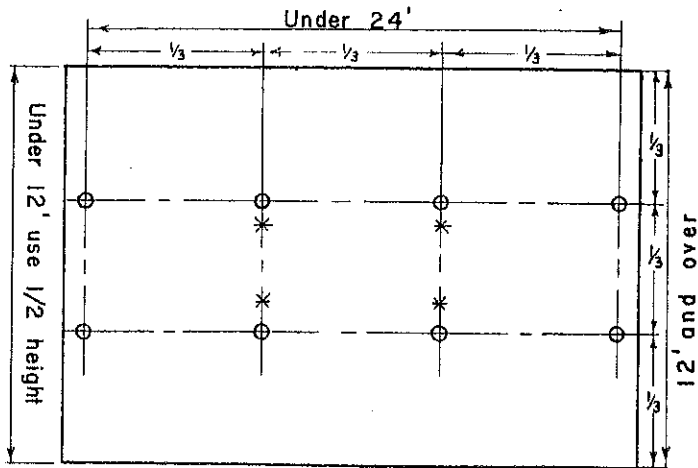
o-Location of Thermometers on top  
of Pier Columns under Insulation



Top of Wall or Beam under Insulation



End View



Side of Wall (both sides)  
Under Insulation

Approx. 8' on Centers, over 24'  
Longitudinally.

o-Thermometer Locations  
\*Thermocouple Locations  
at C. of G. of section

FIGURE III

# TEMPERATURE REPORT

CONTRACT NO. \_\_\_\_\_

COUNTY \_\_\_\_\_

\*

<p>SKETCH</p>	LOCATION _____ DATE OF POUR _____ DATE TEMP TAKEN _____ OUTSIDE TEMP. AM _____ OUTSIDE TEMP. PM _____ TIME TEMP TAKEN AM _____ PM _____ WEATHER _____ WIND N S E W _____ * - THERMOCOUPLE _____ O - THERMOMETER _____ TEMP AGGREGATE _____ TEMP WATER _____ TEMP CONCRETE at POUR MIX _____
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TOP			( ) SIDE			( ) SIDE			ENDS		
LOCATION	AM	PM	LOCATION	AM	PM	LOCATION	AM	PM	LOCATION	AM	PM
1			1			1			1		
2			2			2			2		
3			3			3					
4			4			4					
5			5			5					
6			6			6					
THERMOCOUPLE											
LOCATION	AM	PM	DESCRIPTION OF TYPE AND KIND. OF PROTECTION								
			TOP			SIDES			ENDS		

REMARKS

\_\_\_\_\_  
ENGINEER IN CHARGE

\* - NAME AND LOCATION OF PROJECT & STRUCTURE



or where the Engineer may direct in heavily reinforced sections, in lieu of altering the temperature of the concrete mix. When slabs are constructed and protected in conformance with Figure II, external heat shall be introduced through the ducts formed by the enclosure between the structural steel members prior to pouring the concrete, in order to pre-heat those members as directed by the Engineer. A uniform temperature of 50°F - 70°F shall be maintained during the curing period. The external heat shall be transferred to the enclosure above the slab before the placement of the concrete, as directed by the Engineer. The canvass enclosure shall provide protection for the slab and personnel during the placing and finishing operation and shall be removed to the direction of the Engineer. Insulating blankets shall be placed on the surface of the slab as soon as the concrete has set so the surface will not be marred. The blankets shall be tightly butted together with the top of the joints covered and the edges held down with planks to prevent the wind from penetrating under them.

- I. During mild weather, if the temperature readings indicate that the concrete is getting too warm, the forms shall be loosened slightly to control the temperature rise. The maximum permissible temperature shall be 80°F and the temperature rise or fall resulting from loosening forms shall not be more than 20°F in a 24-hr. period. Forms shall not be loosened for temperature control without the approval of the Engineer.
- J. No concrete shall be poured when existing temperatures are lower than 20°F higher than the minimum air temperatures allowable for the section and insulation involved as given in Table I, unless otherwise directed by the Engineer.
- K. The earliest permissible time for removal of supporting falsework and centering shall be determined from the strength of specimens exposed to approximately the same but not more favorable temperature and curing conditions as concrete in the structure. The Engineer shall indicate the minimum strengths required and no falsework shall be removed without his consent. Such consent of the Engineer shall not relieve the contractor of full responsibility for the safety of the work.
- L. Permission to use this method does not relieve the contractor of any of his responsibility under the contract nor does it change or modify any of the requirements of the specifications regarding concreting in cold weather except as stated herein.