Special Report 76

A SURVEY OF
WINTER CONSTRUCTION PRACTICES
EARTHWORK, CONCRETE AND ASPHALT

by
Delmar Yoakem

JULY 1966

Conducted for
CORPS OF ENGINEERS, U.S. ARMY

by
U.S. ARMY MATERIEL COMMAND
COLD REGIONS RESEARCH & ENGINEERING LABORATORY
HANOVER, NEW HAMPSHIRE

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Haley and Aldrich, Inc.
Contract DA-27-021-AMC-7(X)
PREFACE

Authority for the investigation reported herein is contained in FY1963, "Instructions and Outline, Military Construction Investigations, Engineering Criteria and Investigation and Studies, Investigation of Arctic Construction, Sub-Project, 50, Wintertime Construction Techniques."

The study was made by Haley and Aldrich, Inc., Consulting Soil Engineers, Cambridge, Massachusetts, under contract DA-27-021-AMC-7 (X) with the U. S. Army Cold Regions Research and Engineering Laboratory (USA CRREL), as part of the program conducted for the Civil Engineering Branch, Engineering Division, Military Construction, Office, Chief of Engineers. Mr. Delmar Yoakem performed the investigation and prepared the report under the general supervision of Mr. James F. Haley. The overall program is under the general direction of Mr. K. A. Linell, Chief, Experimental Engineering Division, USA CRREL and the immediate direction of Mr. E. F. Lobacz, Chief, Construction Engineering Branch, USA CRREL with Mr. C. W. Fulwider as project engineer.

Grateful acknowledgement is given to the engineering personnel of the various government and private agencies who completed the questionnaires sent to them and provided pertinent information and reference material.

Colonel Philip G. Krueger was Commanding Officer of the Cold Regions Research and Engineering Laboratory during the preparation of this report and Mr. W. K. Boyd was Technical Director.

USA CRREL is an Army Materiel Command laboratory.
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  III. Summary of questionnaire replies, highway departments facing p. 10
Purpose

The object of this investigation was to review and summarize current cold weather construction specification requirements and practices in relation to soil, concrete, and asphalt utilized in foundations, structures, and pavements of the U. S. Army, Corps of Engineers, state and province highway departments, and other Federal and private agencies engaged in winter construction. The investigation covered only areas of seasonal frost and not areas of permafrost. The data obtained were evaluated and comments are made relative to specification requirements that appear best suited for adoption should changes in the Guide Specifications for Military Construction of the Corps of Engineers appear warranted.

Scope

The investigation consisted of the following six items:

a. Review the requirements of the Corps of Engineers Guide Specifications for Military Construction pertaining to winter construction with soil, concrete, and asphalt utilized in foundations or pavements.

b. Prepare and send to public agencies and private organizations in the United States and Canada who are involved in winter construction with soil, concrete and asphalt a questionnaire inquiring as to their cold weather construction practices. Prepare and send a similar but more comprehensive questionnaire to Corps of Engineers District and Division Offices.

c. Review existing specification requirements of the state and province highway departments and of several Federal agencies.

d. Consider problems associated with excavation, placement and compaction control of soil for embankments and for building foundations under winter conditions.

e. Consider problems involved in mixing, transporting, placing and protecting portland cement concrete and bituminous materials during winter periods.

f. Conduct a literature search for any additional information on cold weather construction practices.

This report presents a summary of the results of the investigation along with an evaluation of the results where pertinent, and comments on possible improvements in current Corps of Engineers Guide Specification requirements.

SPECIFICATION REQUIREMENTS OF CORPS OF ENGINEERS

All of the specifications made available to Haley and Aldrich, Inc. by the Cold Regions Research and Engineering Laboratory were examined and the following paragraphs are a summary of the standard requirements. The pertinent portions of the specifications relating to construction with soils, concrete and asphalt materials were abstracted, usually verbatim, and are presented in Appendix A. Requirements are summarized in Table I.
Earthwork construction

Earthwork specification requirements of the Corps of Engineers for various types of constructing are quite similar. It is specified that no frozen material will be used in constructing embankments or backfilling nor shall either embankment fill or backfill material be placed on frozen ground.

Subbase and base courses shall not be constructed when ambient temperatures are below 35°F, except for waterbound-macadam base courses, lime-stabilized and portland-cement-stabilized base and subbase courses, and subgrades, which shall not be constructed when the ambient temperatures are below 40°F.

Concrete construction

Pavements. Concrete shall be placed in forms and on a subgrade free from frost, and concrete shall not be placed when the temperature of the air, aggregate, or water is below 40°F, or when the concrete is likely to be subjected to freezing temperatures before expiration of the specified curing period, except with written approval of the Contracting Officer. The concrete must be placed at a temperature between 50 and 85°F. Water and aggregate may be heated if necessary to maintain a minimum temperature of the concrete of 50°F. When the air temperature is below 50°F, suitable covering shall be provided to maintain the temperature of the concrete at 50°F for not less than 3 days, and above freezing for the remainder of the curing period.

Structures. Concrete shall not be placed when the ambient temperature is below 35°F or when, without special protection, the concrete is likely to be subjected to freezing temperatures before expiration of the specified curing period, unless approved by the Contracting Officer. When it is necessary to place concrete at temperatures below 35°F, and approval has been obtained from the Contracting Officer, the mixing water and, if needed, the aggregate shall be heated so that the temperature of the concrete when placed shall be between 50 and 70°F, and the concrete shall be covered by suitable means to maintain the temperature of the concrete at 50°F or greater for the first 3 days and above freezing for the remainder of the curing period. Concrete shall be placed upon undisturbed, clean surfaces, free from frost, ice, mud and water.

For both pavements and structures salt, chemicals or other foreign materials shall not be mixed with the concrete to prevent freezing except that calcium chloride may be used as an accelerating agent upon approval by the Contracting Officer to permit finishing and protection of the concrete without undue delay.

Emergency building construction. The concrete shall be mixed and placed only when the temperature is above 45°F, or 40°F and rising, unless otherwise approved by the Contracting Officer. When approval has been obtained to place concrete at temperatures below 40°F, the materials shall be heated so that the temperature of the concrete at time of placement is above 50°F, and insulation or enclosures must be provided to maintain the temperature of the concrete at 50°F for 3 days or, when high-early-strength cement is used, 1 day.

For placing concrete at temperatures between 25 and 40°F, calcium chloride may be used as an accelerating agent in quantities not to exceed 2 lb per bag of cement. Salt, chemicals or other materials shall not be mixed in the concrete to prevent freezing.

Concrete shall be placed upon undisturbed, clean surfaces free of frost, ice, mud or water.

Asphalt pavement construction

The specifications for asphalt placement are all nearly the same with the exception of minimum allowable atmospheric temperatures. Almost all of the
<table>
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**NOTES**
- *Special notes for information obtained.*
- **A.** All materials to be ordered in multiples corresponding to the weight of 50 lb.
- **B.** All materials to be ordered in multiples corresponding to the weight of 50 lb.
- **C.** All materials to be ordered in multiples corresponding to the weight of 50 lb.
- **D.** All materials to be ordered in multiples corresponding to the weight of 50 lb.
- **E.** All materials to be ordered in multiples corresponding to the weight of 50 lb.
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**TABLE I (Cont.)**

- The table continues with additional states and details on the construction and design of the bridges.
- The table includes columns for Team, Type, Overall, Strength, Design, Length, Width, Depth, and Comments.
specifications state that the atmospheric temperature requirement may be waived by the Contracting Officer.

With the exception of specifications for bituminous stabilized base course, sub-base or subgrade for roads and streets, the specification requirements for placing asphalt do not list any restrictions on the ground temperatures. The ground temperature is very important. A thin film of applied bitumen will quickly lose heat and tend to congeal on the surface rather than penetrate if the ground temperature is below 40 to 45F just below the surface of the base.


The following paragraphs list the pertinent specification requirements for placing asphalt in cold weather. Emergency requirements are noted.

Bituminous prime coat and tack coat (standard and emergency). The respective coat shall be applied only when the atmospheric temperature in the shade is 50F (45F, prime coat, emergency) or above and when the atmospheric temperature has not been below 35F for 12 hours immediately prior to application. Emergency specifications also state that it shall be applied only when the base or pavement to which the coat is to be applied is dry.

Bituminous seal coat (standard and emergency). Asphalt will be placed only when the atmospheric temperature is above 60F (50F, emergency) and the pavement surface is above 50F (40F, emergency) unless otherwise directed.

Bituminous binder and surface courses (central-plant hot-mix) for all purposes. The binder and surface courses shall not be constructed unless base course or existing pavement is dry and the atmospheric temperature is above 40F except for tar courses for which the minimum placement temperature is 50F. The requirements may be waived by the Contracting Engineer.

Bituminous binder and surface courses (central-plant cold-mix) and fluxed-natural-rock-asphalt wearing course (standard and emergency). Such courses shall be constructed only on dry base or binder courses and when the atmospheric temperature is above 60F (50F, emergency) unless otherwise directed.

Bituminous macadam (penetration method) and blended-natural-rock-asphalt surface courses (standard and emergency). Such courses shall be constructed only on dry base or binder courses and when the atmospheric temperature is above 60F (45F, emergency) unless otherwise directed.

Keystone binder and plant-mix surface course (standard and emergency). Bituminous materials and aggregate for the keystone construction shall be applied only on a dry surface and when the atmospheric temperature is above 50F (45F emergency). The surface course shall be applied in accordance with requirements for the type used.

Single and double bituminous surface treatments and bituminous road-mix surface course (all standard and emergency). Bituminous materials shall be applied only when the existing surface or base course is dry or contains moisture not in excess of that which will permit uniform distribution and desired penetration, and when the atmospheric temperature in the shade is above 50F (45F, emergency). The requirements may be waived by the Contracting Officer.

Bituminous stabilized base course, subbase and subgrade (standard and emergency). Bituminous material shall not be placed when the air temperature is less than 45F in the shade, or when in the opinion of the Contracting Officer the condition of the base upon which bituminous material is to be applied or the weather is unsuitable. Bituminous materials shall not be applied to soils that contain frost, and asphalt already in place shall be protected by approved methods if the air temperature falls below 35F.
CORPS OF ENGINEERS REPLIES TO QUESTIONNAIRE

Thirty-five questionnaires were sent to the various Corps of Engineers District and Division Offices in the United States. Two questionnaires were also sent to the Corps of Engineers Ballistic Missile Construction Offices at Minot, North Dakota, and Grand Forks, North Dakota. A copy of the questionnaire may be found in Appendix D. Twenty-two replies were received; only sixteen contained completed questionnaires. A list of the offices to which the questionnaire was sent and a condensation of the answers received is presented in Table II.

Nine of the replying offices indicated that they thought differentiation should be made in specification requirements for cold weather construction of dams and airfields. The common comment was that requirements should be different for massive sections such as those found in dams and thin sections such as those found in pavements.

To the second general question, ten offices replied that no change in specification requirements was needed. Others replied that concreting requirements should be changed. One suggestion was to require adequate insulation to protect against large thermal and moisture gradients in the concrete. It was felt that cracking would thus be reduced. Other suggestions were to extend the curing period when temperatures are low or permit the use of type III cement or accelerators in standard cement. Both ideas are designed to increase the strength of the concrete before removing forms.

The effect of wind chill on any type of construction was considered by six of the district offices. The Rock Island, Walla Walla, Pittsburgh and Sacramento District Offices all take wind chill into consideration in protecting curing concrete. The Seattle and Walla Walla District Offices both consider wind effects when placing asphaltic materials.

Four of the replying offices indicated that their District or Division Offices have permitted construction of embankments or backfill with soil materials when temperatures were below freezing. The Memphis District and the Seattle District Offices have participated in construction with both cohesive and cohesionless soil materials during freezing weather, while the North Atlantic Division and the New England Division Offices have participated in construction with dry cohesionless materials only. Only the Seattle District reported unsatisfactory performance. Backfill material in the Seattle District consisted of frozen chunks of shale and clay shale. The Memphis district has constructed levees of cohesive and cohesionless materials when the air temperature was below 32°F for a few days. Frozen surficial material that developed was excavated and wasted in borrow pits or on berms.

Both the North Atlantic Division and the New England Division Offices have constructed embankments with relatively dry, clean granular material when temperatures were below freezing. In their projects the material froze after compaction and was recompacted before adding additional lifts.

The North Atlantic Office reported that they had allowed a foundation or pavement to be placed on frozen soil. The material consisted of gravel frozen to a thickness of about 6 in. Again the project was considered to have performed satisfactorily.

The lowest temperatures at which satisfactory placement of concrete was reported was 20°F, in gravity type dams reported by the North Pacific Division and the Sacramento District Offices. The North Pacific Division Office reported that the concrete was insulated with ¼-in. foam rubber bats. The Sacramento District Office reported that the concrete temperature when placed was 40°F and that the concrete was not protected other than by the forms.

*Fourteen of the 35 were districts which perform only Civil Works construction and six of these returned completed questionnaires. Because of the similarities between Civil Works and Military Construction Guide Specifications, the answers from these districts are included without differentiation in the following paragraphs. Districts doing Civil Works construction only are so designated in Table II.
A SURVEY OF WINTER CONSTRUCTION PRACTICES

The lowest temperature at which pavements were noted to have been placed satisfactorily was 28F. This was reported by the Rock Island District Office.

Several offices reported that they had witnessed concrete being placed in structures when atmospheric temperatures were at 35F.

Four offices reported that they allowed calcium chloride to be added to concrete as an antifreeze; however, in view of the answers given by the four offices, it is believed that they meant that calcium chloride is allowed as an accelerator, not as an antifreeze.

The replies to the "CONCRETE" and "ASPHALT" sections indicated that the offices, for the most part, follow the guide specification requirements.

SPECIFICATION REQUIREMENTS OF STATE AND PROVINCE HIGHWAY DEPARTMENTS

The standard specifications for 44 of the U. S. state highway departments and four Canadian province highway departments were examined and specifications related to cold weather construction were abstracted, usually verbatim. The abstracts are presented in Appendix B. Requirements are summarized in Table I.

Five states from which no standard specifications were obtained reported that the cold season in their state was so short that operations were suspended when weather conditions were such that the construction project would be detrimentally affected. Usually the decision to stop operations is left to the discretion of the "Engineer." The Yukon Highway Department reported that specifications had not been prepared because construction operations are suspended during winter.

Earthwork construction

Most states require that frozen material containing frost shall not be used in construction of embankments or in backfilling around structures and that embankments shall not be constructed on frozen ground. Maine, Pennsylvania and Wisconsin actually state in their specifications that material which may be frozen may be placed in the embankments. Maine's specification requirements are that embankments may be formed when the depth of the fill plus the depth of the frozen ground does not exceed 5 ft. Maine's specifications also state that base courses may be formed on frozen subgrade when the subgrade had been properly constructed of unfrozen material and properly compacted prior to freezing.

Pennsylvania allows forming of embankments on ground which is frozen to a thickness no greater than 3 in.

Wisconsin prohibits the formation of embankments in fall or early winter except when the material is primarily granular.

Five of the state highway departments do not state specifically that frozen material shall not be used in embankments but they do specify that embankments shall be constructed of material acceptable to the Engineer and of soil which contains no unsuitable, perishable or deleterious material.

The highway departments of New Hampshire, New York, and Wyoming do not prohibit placement of frozen soils in embankments; however, it is believed that their density requirements would restrict placement to free-draining low moisture content cohesionless soils.

Concrete construction

The requirements of most of the highway departments for placing concrete in cold weather are similar to those set forth by the Portland Cement Association.
Approximately 10% of the highway specification requirements listed seasonal restrictions on placement of concrete from about the first of November to the first of April. The period varies with the geographic location of the state (a longer restricted season in the northern states).

Pavements. Nineteen of the state and province highway departments specify that concreting operations shall be discontinued when the atmospheric temperature in the shade and away from artificial heat is 40°F and falling and shall not be resumed until the atmospheric temperature in the shade and away from artificial heat is 35°F and rising. Others specify minimum placement temperatures of 40, 45 and 50°F and New Jersey specifies that concrete shall not be placed when the air temperature is less than 36°F. The highway departments of Kansas, Michigan, and Vermont have absolute minimum placement temperatures of 20°F for pavements. Alberta, Ohio, and Washington, D. C., do not specify minimum temperatures for placement of concrete. Ohio does, however, have a seasonal limitation and all three states require heating of water and/or aggregates when the air temperatures are below 40, 35 and 50°F for each state, respectively.

Twenty-one of the forty-nine highway department specification requirements reviewed state that the Engineer may waive the temperature and the seasonal requirements.

For placing concrete in cold weather, 29 of the highway departments require heating the water and/or aggregates before mixing all of the constituents of concrete together. In most cases the constituents shall be heated until the temperature of the final mix is not less than the minimum allowable air temperature and usually 50°F. The Portland Cement Association recommends that the temperature of the concrete should be 50-70°F upon placing.

Enclosing and heating the area or covering the concrete after it is in place is required by 38 of the highway departments during "cold weather." The requirements are, for most departments, to maintain the temperature of the concrete above a minimum of 40 or 50°F.

Most of the highway departments allow the use of calcium chloride in quantities of 1 to 2% by weight of cement as an accelerator. None of the departments allow the use of any chemicals as antifreeze, because many antifreeze additives reduce the quality of the concrete. Curing periods and temperatures vary considerably throughout the United States and Canada. Curing periods for protecting pavements range from 3 days above freezing to 7 days above 50°F or 5 days above 70°F.

Most of the highway departments hold to curing periods of 5 days at 32 to 50°F. The Portland Cement Association recommends protecting freshly placed concrete at temperatures of not less than 70°F for 3 days or 50°F for 5 days and the American Concrete Institute recommends that, as an absolute minimum, concrete should be kept above freezing for the first 3 days after placement. However, for optimum quality A. C. I. recommends that concrete be maintained at its minimum allowable placement temperature for 3 days and kept from freezing for 3 additional days. Thus, all states and provinces require at least the minimum protection specified by A. C. I. All except Nevada require the same protection or less than that recommended by the Portland Cement Association. Nevada requires 5 days at 70°F or 7 days at 50°F.

Only four highway department specifications indicated any changes in requirements when using high-early-strength cement in cold weather concreting operations. The placement temperature restrictions and the length of the curing period are reduced when high-early-strength cement is used. In general the allowable placement temperatures are reduced by 5°F and the required protection periods for curing are shortened by 1 or 2 days.
Almost all highway departments require that all forms, reinforcing steel, and foundations be above freezing, and some require that the forms, reinforcing steel, and foundations be at or above the minimum allowable air temperature before concrete may be placed.

**Structures.** Approximately one third of the specifications reviewed have different protection requirements for pavements and structures. The distinction is due primarily to ease of protecting the concrete once it is placed, and is, consequently, concerned primarily with protective curing restrictions rather than placing restrictions.

Three state and three province highway departments have minimum air temperature requirements for placing concrete in structures which are different from the requirements for pavements. Alaska, Missouri, Alberta, British Columbia, and Ontario all require that concrete shall not be poured when the air temperature is below 35 to 40°F. Michigan requires that concrete shall not be placed when the atmospheric temperature is below 30°F for superstructures and below 15°F for substructures.

In all cases the curing protection required for structures is greater than that required for pavements. Most states require 7 days at 50 or 60°F for concrete placed in structures. The Ontario Highway Department specifications state 7 days at 70°F and the Vermont specifications state 7 days at 70°F plus 9 days at 40°F.

**Asphalt construction-pavements**

Bituminous sections of highway department specifications are the least standardized of any of the sections containing cold weather restrictions. Very few departments use the same names for the various courses of asphalt paving; thus, the asphalt application course given under a certain name for one highway department may not be the same as a course under the same name for another highway department. The names are given unaltered in Appendix B. For this section of the report and for Table II, the names as used in Corps of Engineers Guide Specifications are followed as closely as possible.

Limiting temperatures for bituminous application should vary with the grade of asphalt used as well as the method of application. The highway departments are not consistent in the grade of asphalts used in the different asphalt application courses; thus, the minimum temperatures specified by the various highway departments are not consistent.

The only cold weather limitations on asphalt placement are minimum atmospheric temperatures, seasonal restrictions, and restriction from use of frozen subgrades. In most cases the seasonal restrictions are merely an indication of the time of the year that the mean daily air temperature approaches the minimum allowable placement temperature for the particular state. Most of the highway departments in the United States and southern Canada do not allow asphalt pavement construction from generally 1 October to 1 May with seasons as short as 1 December to 1 March in southern states and as long as 1 September to 1 June in northern states. Approximately 50% of the highway departments allow the seasonal restrictions to be waived by the Engineer.

Many of the states require that asphalt shall not be placed on frozen subgrade. Seven also specify a minimum ground temperature which is somewhat above freezing. The minimum ground temperatures specified are for sprayer type bituminous application and are in general sufficiently above the temperature at which the bituminous materials become too viscous to adequately penetrate and coat the base aggregate.

The following paragraphs list the general temperature requirements of the highway departments for placing the various courses.
Prime coat. Minimum air temperatures 50 to 60°F, with two states specifying 70°F and one state specifying 40°F.

Tack coat. Minimum air temperatures 40 to 60°F with two states requiring minimum air temperatures of 70°F.

Seal coat. Minimum allowable air temperatures 50 to 70°F.

Traveling plant mix. Minimum atmospheric temperatures of 40 to 60°F with one state requiring 70°F and two states requiring 35°F.

Central-plant hot mix. Minimum atmospheric temperature 40 to 50°F, 70°F for Arizona and 35°F for Massachusetts and South Dakota.

Central-plant cold-mix. Only eight highway department specifications had any requirements for central-plant cold-mix, requiring minimum atmospheric temperatures of 40 to 50°F.

Macadam base course (penetration method). Bituminous material shall not be applied when atmospheric temperatures are below 40 to 70°F, with the province of Ontario requiring 35°F.

Macadam base course (asphalt emulsion). Asphalt emulsion shall not be applied when atmospheric temperatures are below 50 to 70°F. Only eight highway departments had specifications on asphalt emulsion macadam base course.

Macadam wearing course (penetration method). Bituminous materials shall not be applied when the atmospheric temperatures are below 40 to 70°F with one state requiring a minimum temperature of 35°F.

Road-mix surface course. The minimum atmospheric temperatures are 40 to 60°F with one state requiring a minimum temperature of 70°F.

HIGHWAY DEPARTMENT REPLIES TO QUESTIONNAIRE

One hundred and ten questionnaires were sent to chief engineers and other engineering personnel of state and province highway departments in the United States and Canada. Forty-nine replies were received from 39 states and five province highway departments. A copy of the questionnaire as sent to the highway departments may be found in Appendix D.

The answers given to the first two general questions indicate that all of the specifications reviewed are currently in use by the highway departments with only minor revisions having been made since the specifications were printed. Six states reported that new specifications are being prepared and will be in use by the department by mid-1964. Four replies did, however, indicate that minimum temperature requirements for placing various asphalt pavement courses should be made more strict. The only other expression that changes should be made was made in a questionnaire returned from Maine, suggesting that density requirements for construction of embankments and subbase be increased to meet AASHO Test Designation T-180 requirements and that the maximum height of embankment formed during the winter be less than 5 ft.

The effect of wind chill on any type of construction was considered by only six of the highway departments. Idaho, Oregon and Texas take wind chill into account when placing asphalt. Maine and Alberta highway departments both stated that for structures the effect of wind is taken into account in insulating concrete.

The questionnaire sent to the highway departments did not contain questions relevant to cold weather construction with concrete and asphalt, as it was felt that returns would be better if the questionnaire was not too long. It was also felt that construction practices with asphalt and concrete were probably reasonably standardized and followed the individual state specification requirements.
A SURVEY OF WINTER CONSTRUCTION PRACTICES

Twenty-five of the forty-four highway departments which replied to the questionnaire stated that they do not construct embankments using frozen soil during freezing weather and they do not allow footings or pavements to be placed on frozen soil. The remaining 19 highway departments stated that they have allowed frozen soil to be incorporated in embankments.

Table III presents, in a condensed form, answers to the soils questions given by 24 highway departments which completed the questionnaire. Of the 19 highway departments that have allowed formation of embankments in freezing weather, nine have allowed cohesionless material only. Maine State Highway Department reported minor failures in embankments formed of partly frozen cohesionless material placed over rock fill. All others reported that their projects formed of cohesionless materials have performed satisfactorily.

Four of the states that had placed frozen cohesive material in embankments reported that the projects had performed satisfactorily. All four departments have end result density requirements in their embankment construction specifications; that is, the fill material must be compacted to at least 95% of standard AASHO Designation T99-57 Method C compaction effort or greater.

According to the comments made by the various departments, it is doubtful that any of the embankments contained much material which was frozen and yet compacted to specified density. Several commented that it is nearly impossible to compact frozen material to required density.

New York State Highway Department reports that they have had considerable experience placing cohesionless granular soil in embankments during winter months. Because of difficulty in obtaining adequate compaction on a particular project one winter, they initiated an investigation on relatively clean granular material both in the field and in their soil mechanics laboratory. Their results indicated that "even when using relatively clean cohesionless granular materials, as the temperature dropped below 30°F, the compactive effort necessary to achieve specified densities increased tremendously, and when a soil temperature approximating 20°F was reached, it was almost impossible to achieve specified densities, regardless of the compactive effort or the type of equipment."* Research during subsequent winters verified their previous findings that, when soil temperature reached 20 to 25°F, it was extremely uneconomical and impractical, if not impossible, to achieve specified densities.

New York reported that a few serious embankments stability problems have been attributed to thawing of frozen layers. Pavement settlement problems have also been attributed to inadequate densities obtained during construction of embankments composed of cohesionless granular materials during the winter months.

The New York Highway Department has also tried mixing calcium chloride in the soil to prevent freezing, but abandoned the practice because of the cost of the chemical and the effort required to properly mix the chemical into the soil.

In conclusion, the New York Highway Department felt that it is extremely uneconomical to construct embankments using soils, even relatively clean, cohesionless, granular soils, during winter months.

Not one department reported that they had ever allowed a footing or pavement to be placed on a frozen subgrade.

COLD WEATHER CONSTRUCTION PRACTICES OF OTHER AGENCIES

Other agencies contacted for this investigation include U. S. Soil Conservation Service, U. S. Bureau of Public Roads, U. S. Bureau of Reclamation, U. S. Federal Aviation Agency, U. S. Navy Bureau of Yards and Docks, Hydro Quebec, Hydro Electric Power Commission of Ontario, Prairie Farm Rehabilitation Administration, Saskatchewan. The foregoing agencies were contacted by the same questionnaire sent to the highway departments. Also contacted by letter of inquiry or telephone were agencies such as Portland Cement Association, American Concrete Institute, Atlas Chemical Industries (explosives), The Asphalt Institute, National Bituminous Concrete Association, American Road Builders Association, Canadian Industries, Ltd., National Research Council of Canada, American Association of State Highway Officials, Canadian Good Roads Association, E. I. DuPont DeNemours and Company (explosives), International Harvester Company, Le Tourneau - Westinghouse Company, Caterpillar Tractor Company, Allis-Chalmers Manufacturing Company, Raymond Concrete Pile Company, Hedge and Metheis Construction Equipment, C. L. Guild Construction Company (pile driving contractor), New England Foundation Company and the Massachusetts Turnpike Authority.

The standard specifications were reviewed and requirements pertinent to cold weather construction were abstracted from the following organizations: U. S. Federal Aviation Agency, U. S. Bureau of Public Roads, U. S. Bureau of Reclamation, U. S. Soil Conservation Service and American Association of State Highway Officials. Abstracts of standard specifications of the above referenced organizations are presented in Appendix C. The Bureau of Yards and Docks, Department of the Navy, Guide Specifications were also reviewed; however, their specifications contained no provisions for cold weather construction. Abstracts of the specification requirements are shown in Appendix C and a summary of the requirements are shown in Table I.

The requirements set forth by the above organizations as well as cold weather construction practices and recommendations of many other organizations are presented in the following paragraphs.

Soil

Embankment construction. The standard specification requirements of most organizations do not allow the use of frozen soil in embankments nor do they allow embankments to be constructed on a frozen base.

Four organizations report satisfactory construction of soil embankments during sub-freezing weather. The Hydro-Electric Power Commission of Ontario has constructed granular fills during freezing temperatures on their own roads with no discernible detrimental results. They have found that frost penetration in the surface of uncompleted embankments has not produced any detrimental results provided the specified compaction densities were obtained before freezing occurred. Even in granular fills, however, the Commission attempts to form the embankments as free from any frozen material as possible.

The Michigan Highway Department has satisfactorily compacted both cohesive and granular soil at about optimum moisture content at temperatures as low as 20°F. The soil was always placed unfrozen, but froze somewhat after adequate compaction was obtained. The Department also felt that granular materials could be satisfactorily placed at temperatures as low as 15°F provided the material was compacted to proper density immediately after placing. The Department stresses that material already frozen is not acceptable and that it is very difficult to properly place soils at temperatures as low as 20°F.
TABLE II - SUMMARY OF QUESTIONNAIRE REPLIES - HIGHWAY DEPARTMENT

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Note: The table above is a placeholder for the actual data that would be present in the document.
In a letter reply, the Canadian Good Roads Association stated, "Normally contractors are not allowed to place frozen materials in highway fills. Exceptions to this are when large fills are to be constructed of clean granular material of low moisture content, and when the fills will be left to consolidate for a year or more."

Mr. Raymond McGinnis of the Massachusetts Turnpike Authority, in a telephone interview, stated that during the winter of 1955 a high embankment was constructed on the Massachusetts Turnpike near Broomfield, Massachusetts. The fill consisted of alternating layers of 8 in. of glacial till (30 to 35% finer than the No. 200 sieve) and 8 in. of clean sand compacted to 90% of Standard Proctor. Overnight temperatures were as low as zero. During the day the soils did not freeze; however, overnight the surface of the fill froze to a thickness of about 3 in. The thin crusts were not removed before placing additional material in the morning. Since construction no noticeable settlement of the embankment has been observed.

Foundations. All specification requirements reviewed stated that in no case should foundations be placed on frozen soil and not one instance was found in literature where a foundation had been placed on frozen soil.

Haley and Aldrich has had some experience in placing foundations on frozen soil with no detrimental results. One such project was a 120,000-ft² single story department store constructed on a fill 6 to 15 ft high in Revere, Massachusetts. The fill was formed during the months of November 1962 through February 1963 when temperatures were as low as zero. During the month of January, the fill was subjected to intermittent rain alternating with freezing temperatures. The fill material was a clean sandy gravel with less than 5% passing the No. 200 sieve, placed in 6 to 12-in. lifts and compacted to 95% of AASHO Test Designation T-180-57, Method D. In most cases the material was compacted to proper density before freezing. Each morning, before adding a new lift of fill, ice formed by freezing of rain in ruts was removed. Also on several occasions it was necessary to remove snow from the building site.

Examination of the fill material during May and early June 1963, when excavations for spread footings were in progress, revealed that the pore water in the gravel fill was frozen in a zone 4 to 6 ft in thickness starting at a depth of 3 to 4 ft below the fill surface. The exterior wall footings were placed 4 ft below the fill surface except for the rear wall, which was placed at an 8-ft depth to accommodate the truck loading area, at which the final exterior grade was to be 4 ft below finished floor grade. All interior footings were placed 2 ft below the surface of fill.

A detailed visual examination of the frozen material generally revealed an ice coating up to about 1/16 in. thick at the underside of stones and boulders in the fill. At a few locations segregated ice in the form of thin horizontal lenses up to about 1/16 in. thick were noted. The soil in which this segregated ice occurred was a silty sand. For the most part, however, the ice appeared to be within the natural soil voids.

At one isolated location at the rear corner of the building an ice mass 12 in. thick and 2 by 3 ft in plan area was exposed at a depth of 6 ft in the side of the footing excavation. The field inspector and earthwork contractor believed this was part of the ice or snow removed from the building site. Ice had been wasted at this corner of the site and apparently had been placed within, rather than a minimum of 10 ft outside of, building lines, as required by the specifications. It was quite evident that the ice had been incorporated in the fill rather than formed during the freezing process. This large chunk of ice was removed and exploratory excavation extended into the building area at this location, to insure that no other large ice masses were present.

There was no evidence whatsoever of settlement or cracking of the building during careful examination in the fall of 1963. The walls of the building are of 8-in. concrete block with brick veneer, except the rear wall which is 12-in. concrete block. The foundation wall is poured concrete 16 in. in width. The interior columns support a bar joist roof and the floor of the building is a slab-on-grade.
Excavations. The practice of excavating frozen soil is becoming more common as more construction is being carried on throughout the year. Most excavation of frozen soil is performed on a small scale through the ingenuity of the contractors; however, excavation of frozen soil on a large scale is usually preplanned using the most practical and economical methods available.

Large scale excavation of soil frozen deeper than about 2 ft is normally carried on by blasting with explosives or by breaking up the frozen ground with tractor-mounted rippers.\(^1,2\) Other methods such as continuously spraying the surface with water, flooding the area with water, and steam jetting have also been used to a lesser degree and over smaller areas.\(^1,3\)

In the past, explosives have been the most commonly used agent for breaking up thick layers of frozen soil. The use of explosives has the disadvantage that holes must be drilled in the frozen soil before the charges may be set.

Recently, such equipment manufacturing companies as Caterpillar Tractor Company, ATECO Earthmoving Equipment associated with International Harvester Company, and LeTourneau-Westinghouse Company have produced tractor-mounted rippers which have proven to be more economical and more efficient in loosening frozen soil than blasting. A system of cross ripping has been found to be most satisfactory. Several passes are sometimes required, but all frozen soils and subsoils can be loosened.\(^5\) The spacing of the passes by the tractor-ripper should vary with the condition of the frozen soil and the desired breakage size.\(^4\)

The process of spraying or flooding an area with water is slow, and a considerable amount of water becomes mixed with the soil. Unless the soil is sluiced away, thawing by either of the water application methods will penetrate only about 2\(\frac{1}{2}\) ft.\(^1\) This method has been successfully used for excavating material to be used in constructing hydraulic fill dams in Alaska.\(^3\)

Steam jets are used quite extensively for thawing frozen soil in localized areas such as structure foundation excavations or where piling is to be driven.\(^1,3\)

Soil which is frozen to depths less than 2 ft is excavated by any of the above-mentioned methods. In addition, for local areas, practice has been to cover the ground with hot sand or a mixture of salt and hay covered by tarpaulins 3 or 4 days before excavation. Fires are also built over the areas to be thawed. These methods are slow but may thaw up to 2\(\frac{1}{2}\) ft of frozen ground.

At a recent project in Hartford, Connecticut, Gow caissons were being excavated by machine auger. The sandy silt surface soils were frozen for a depth of 1\(\frac{1}{2}\) to 2 ft. The auger could not penetrate the frozen crust. Hot sand heated in an asphalt plant was placed over the caisson location and covered with a few layers of tarpaulin. As a rule of thumb, a thickness of sand equal to the frozen soil layer would thaw the soil overnight. The cost of this thawing was approximately $4.00 per caisson location.

Equipment such as the Pow-R-Frost trench cutter manufactured by Vermeer Manufacturing Company of Pella, Iowa, as well as drop and pneumatic hammers are used for breaking up frozen soil in small areas.

A snow cover or a layer of straw over an area to be excavated limits the depth of frost penetration, especially if the ground is covered early enough in the season. Black polyethylene sheeting placed over limited areas has been found effective in limiting freezing or promoting thawing by high absorption of solar radiation.

Piling. Steel H piles are commonly driven with a conventional type hammer through about 3 to 4 ft of frozen soil. In the New England area it is common practice to proceed with normal pile driving operations, for steel piles only until the ground is frozen to a depth of 2 to 3 ft, the depth depending on the type of soil. In the New England area frozen saturated granular soils are more resistant to driving or

*Numbers refer to references at end of this report.
breaking up than cohesive soils. When the frost has reached a depth greater than 3 ft, the contractor will, many times, prebore, a hole through the frozen portion of the ground by chopping with an open-end pipe, dropping a dead-weight hammer or drill or by driving a mandrel. Other methods used by New England pile driving contractors are to cover the area with hot sand, salt, straw, or water, a few days before piles are to be driven. The latter method is not too desirable because water generally creates a sloppy working area when the ground thaws.

The Bodine sonic pile hammer is capable of driving steel piles through ground frozen to depths greater than 3 ft; the maximum thickness is not known at this time. However, tests are presently in progress to determine its capabilities in frozen soil.

All of the pile driving contractors in the New England area recommend that wood or precast concrete piles not be driven through frozen soil more than about 2 in. thick.

Concrete

Concreting practices vary considerably throughout the United States and Canada. Most United States organizations are reluctant to place concrete at freezing temperatures and even prefer atmospheric temperatures above 40 to 50°F. Canadian organizations such as the Hydro-Electric Power Commission of Ontario and the Foundation Company of Canada, spurred on by the National Research Council of Canada, pour concrete at temperatures of -40°F. They do this by housing the concreting area with temporary heated enclosures.

The curing protection requirements are all nearly the same throughout the United States and Canada and are patterned after the recommendations set forth by the American Concrete Institute. However, the general practices in the two countries differ primarily in that the Canadians are prone to construct and heat enclosures around their concreting areas in the winter. This practice is presently becoming more common in the United States with the use of plastic enclosures.

Pavements. Specification requirements for most organizations are similar. The requirements are that concrete shall be placed when the temperature is below 40°F only with permission of the Engineer. In a letter reply, Mr. Gordon Campbell of the Canadian Good Roads Association stated that no cement concrete pavements are placed in Canada when the temperature is below 40°F and that an attempt is made to place all concrete pavements during the warmest part of the summer, 15 June to 15 September. When the temperature is below 40°F the water or aggregate, or both if necessary, are heated so that the average temperature of the concrete as it is deposited in the forms is between 50 and 70°F. The American Concrete Institute and and the National Research Council of Canada recommend heating the water to not more than 140°F and the aggregates to not more than 60°F. Both organizations recommend mixing the aggregate and water together before adding the cement.

The American Concrete Institute recommends the least curing protection of any of the organizations reviewed. They recommend that the temperature of the concrete be kept above the minimum recommended placement temperature for 3 days (2 days for high-early-strength cement) and above freezing for an additional 3 days. The minimum recommended placement temperature varies with maximum aggregate size and the types of section, i.e. thin or massive, ranging from 40°F for massive sections with 6-in. maximum size aggregate to 55°F for thin sections with 6-in. aggregate.6

The Portland Cement Association recommends more conservative curing requirements which are followed by many other organizations. The PCA recommends that the temperature of the concrete be maintained above 50°F for 5 days or 70°F for 3 days for normal concrete and above 50°F for 3 days or 70°F for 2 days for high-early-strength concrete.
All of the organizations prohibit the use of salts or chemicals to lower the freezing point of the mixing water.

Accelerators in concrete are permitted by all of the organizations reviewed. Most of the organizations require permission of the Engineer and specify percentages which will not have an injurious effect on the quality of the concrete. Calcium chloride, some of the soluble carbonates, silicates and fluorosilicates, and some organic compounds such as triethanolamine are accelerators used in concrete. Calcium chloride, one of the most commonly used accelerators, should not be used in amounts in excess of 2% by weight of the cement. Accelerators are considered safety factors to produce higher than normal strengths at early periods before subjecting the concrete to freezing temperatures. None of the organizations permit the curing time to be reduced when accelerators are used.

The preferred method of protecting pavement from cold weather is to cover it with straw which is held in place by tarpaulins. Other suggestions are to cover the pavement, as soon as the concrete sets, with dry soil to a thickness of several inches, or to cover the pavement with some sort of windproof framework heated by lanterns or small heaters.

Resistance to frost can also be improved by adding air-entraining agents to the concrete. Air-entrainment improves workability and protects against freezing, but reduces the strength slightly. Hence, addition of an air-entraining agent and an accelerator such as calcium chloride to concrete will form a concrete which will be able to withstand, in a shorter period after placement, lower atmospheric temperatures than normal concrete.

Structures. Concreting practices on structures are nearly the same as those for pavements. For massive structures such as bridge piers, retaining walls, and dams, the Portland Cement Association recommends that concrete may be placed at temperatures as low as 40°F. The curing protection required for massive structures usually amounts to covering the surface of the mass with enough insulation to prevent freezing on the surfaces.

Canadian organizations place a considerable amount of emphasis on enclosing and heating concreting areas. The Portland Cement Association and the American Concrete Institute also recommend building enclosures around thin section structures such as buildings to improve protection of the concrete.

The Bureau of Reclamation has satisfactorily used insulated forms to protect fresh concrete in dam construction with average air temperatures at 0°F. They now feel that insulated forms offer many advantages over the use of tarpaulins and heat. Types of form insulation used successfully by the Bureau consist of 2-in. Rockwool bats on 3 in. of wood sheathing, 1 in. of glass fiber on a 2-in. sheathing of plywood, and 6 in. of planer shavings on horizontal surfaces.

Asphalt

The requirements for placing asphalt in cold weather are similar for all organizations, including highway departments which were discussed previously. As a general rule, asphalt pavement is not constructed on a frozen base or subbase, and, except when directed by the Engineer, asphaltic mixture is not placed when the atmospheric temperature is below 40°F (Bureau of Public Roads specification states 40°F and rising, or 50°F and falling). Placement of some courses such as prime coat and seal coat is not allowed below atmospheric temperatures of 60 and 70°F, respectively.

Although all of the organizations require atmospheric temperatures of not less than 40°F, asphalt has been placed at temperatures below freezing. The asphalt surfacing of Calumet Skyway Bridge in Chicago was constructed through the winter of 1957 when temperatures were below freezing with no apparent loss of strength or durability of the asphalt pavement. The asphaltic mixture was transported to the paving machines in covered and insulated trucks and rolled immediately after placing
before the mixture cooled appreciably. The approach embankment was formed and properly compacted during nonfreezing weather. The only restriction in placing the asphalt was that no asphalt would be laid on a surface which contained free surface ice or snow. The pavement was rolled first by a 10-ton three-wheel roller, then by a 12-ton pneumatic roller, and was finished with a 12-ton tandem roller.15

Mr. W. R. MacAtee, formerly managing director of the Asphalt Institute, feels that hot-laid asphalt mixtures are not injured by freezing weather and may be placed at temperatures as low as zero provided that the mixture is compacted to proper density immediately after placing.16

**QUESTIONNAIRE REPLIES FROM OTHER AGENCIES**

Twelve questionnaires were sent out to agencies in the United States and Canada such as U. S. Bureau of Reclamation, U. S. Bureau of Public Roads, Bureau of Yards and Docks of the U. S. Department of the Navy, Hydro-Electric Power Commission of Ontario, U. S. Federal Aviation Agency, and Canadian National Railways. A sample of the questionnaire is presented in Appendix D.

Seven organizations replied to the questionnaire. Four of the organizations replied that they did not do any winter construction other than emergency construction. The remaining three organizations, the U. S. Bureau of Reclamation, the Federal Aviation Agency, and the U. S. Bureau of Public Roads, replied that the specifications reviewed for this project were in current use by their department with no revisions.

All three organizations replied that they did not consider the effect of wind in any of their construction practices.

The Federal Aviation Agency did not complete the "Soils" part of the questionnaire, stating that they did not have any detailed information relative to the questions under "Soils." The Bureau of Reclamation answered the first question under the "Soils" section with a "no" and did not complete the rest of the questionnaire.

The Bureau of Public Roads has placed cohesionless soil in embankments when temperatures were below freezing with minor settlement and instability resulting. The Bureau of Public Roads also reported that they have placed many foundation footings and pavements on ground underlain by permanently frozen soils.

**DISCUSSION**

**General**

This section of the report discusses cold weather construction practices based on our review of the Corps of Engineers Guide Specification, the information gathered, and our experiences. A limited number of changes in the guide specification requirements are indicated when certain phases of construction are to be performed during the winter months. Possibly the text of the guide specifications could be revised or suggested modifications could be appended to the guide specifications, under Instructions to the Contracting Officer.

It is generally necessary for specifications to be definite as to minimum air temperatures during placement of soil, asphalt and concrete. However, in some instances satisfactory construction may be accomplished at temperatures below the minimum specified. There seems to be a need for the publication of information dealing with procedures for field inspection and control of winter construction. Methods for testing and observing materials during a construction period should be formulated in order to determine if the condition of the materials is proper for satisfactory construction.

**Earthwork construction**

**Excavation.** A considerable amount of excavation work, clearing, and grubbing can be carried on relatively unhampered by winter weather conditions. Difficulties
arise, however, in the proper placement of most of the excavated materials in embankments for dams, paved areas or future building sites.

Removal and wasting of unsuitable foundation material such as peat or organic silt beneath highway and airfield locations can be accomplished in the winter. The normal procedure for such work would be to replace the peat with an underwater backfill, which generally contains less than about 10 to 15% by weight finer than the No. 200 mesh sieve. The relatively small amount of moisture in such fill materials allows satisfactory placement. It has been observed that, even if there are occasional chunks of frozen fill present, these chunks quickly thaw when placed in the water. The end result should be the same as that for underwater backfill placed in the summer.

It has been noted that stockpiles of peat which have frozen and subsequently been covered by additional excavated peat have remained frozen for several months into the summer. This can create some difficulty in later excavation and disposal of the peat. For this reason it may be preferable to waste the peat at the final disposal location during the excavation process.

In areas where there is a thick vegetative cover to limit the depth of freezing, the difficulty of beginning excavation work is minimized. Where any substantial thickness of frozen soil has accumulated prior to the start of excavation work, considerable difficulty and expense may be involved in removing the frozen layer. If the frozen layer is not too thick for heavy duty rooters to be used effectively, then a sufficiently large area can be opened up for the use of scrapers. Excavation by scrapers during the winter period should be planned so that no surface is exposed to freezing for more than a day or two prior to reexcavation. This may require confining the area of the work.

Excavation at the face of a pit with a dipper shovel is less affected by winter weather than excavation by scrapers. Once an area is opened up and the floor of the pit established, excavation can be readily accomplished, if it is continuous from day to day. However, as in the case of all excavation in the winter period, the coarser, more free-draining, and lower water content materials are more readily excavated than other types of materials when a frozen crust develops on the surface.

Drilling and blasting, and rock excavation is another item of work well suited for winter construction. The stockpiling of the material from the rock excavation in a manner that will permit drainage is desirable if the rock is to be used for filling during the winter. This will prevent the accumulation of ice in the voids of the rock, which would be very difficult to separate during the filling operations.

The operation of borrow areas during the winter period requires special techniques and procedures. A borrow pit for use during the winter should generally be a clean, free-draining coarse sand or sandy gravel. Such materials are suitable for placement during the winter under controlled conditions. It is necessary to carefully remove all snow at the surface of the borrow pit and to strip organic materials and roots. In addition, in most cases a silty subsoil or horizon B material exists beneath the top soil layer. This layer generally contains enough silt and moisture to be very hard when frozen and very difficult to break up during the fill placement operations. For summer construction this material frequently is left in place and in the operation of the high face is blended in with the sand or gravel without detrimental results. For winter operations, however, this layer should be completely stripped down to a material that is sufficiently clean and free draining so that when frozen it is sufficiently friable to be broken up during the fill placement.

Filling. Construction of fills using quarry run rock, crushed rock, or slag can be accomplished during the winter construction period with no loss in quality of the end result. It is of course necessary to prevent the accumulation of large chunks
of ice or snow in these fills. Any such materials should be allowed only within the interstices of the rock fill so that future melting of the ice will not result in subsidence of the fill.

As previously mentioned, underwater backfill for peat replacement can be accomplished effectively in winter. For placement of fills above the water table difficulties are minimized by use of coarser and more free-draining materials. It is, of course, necessary to exercise careful control of construction, particularly if the fill is to support building foundations or a slab-on-grade. In our experience we have found it completely feasible to place compacted fills using clean sandy gravels, with less than 5% by weight finer than the no. 200 sieve, during the entire winter period. Such fills have satisfactorily supported one and two-story masonry structures. Great care must be exercised to remove any accumulated snow or ice from the surface of each lift prior to placing an additional lift. Frequently, during the course of the work, melting snow and rain penetrates the surface of the gravel so that the surface materials are virtually saturated at time of freezing. Careful examination of this frozen surface layer is essential to insure that the ice is not segregated outside the natural voids of the soil. If there is evidence of ice segregation it may be necessary to remove the frozen layer or allow the frozen layer to thaw and then recompact.

On an airfield project in northern New York State Warren Brothers Roads Co. reports that a gravelly sand base material was preheated in the asphalt plant to approximately 325F. The material was then placed and compacted as rapidly as possible in air temperatures of 10 to 15F. This preheated material would have to be well graded and stable to permit compaction in the completely dry state. Because of the expense involved, preheating could be feasible only for very special situations where it is essential for the work to be completed at an early date.

Protection of the surface of fills and excavations. In order to prevent or minimize freezing overnight or over a week-end the surfaces of fills are sometimes protected by spreading calcium chloride, or placing a layer of salt hay. The use of calcium chloride has been found to be reasonably effective when the air temperature during the night does not go below approximately 25F. The expense of placing and removal of the salt hay layer makes this method practical only when the surface area is relatively small or protection is required for several days.

Salt hay is frequently used to protect a bearing surface between the time of excavation and the time of pouring the concrete footing. Another effective means of protecting a bearing surface is calcium chloride and a polyethylene sheet. A small air space should be created between the bearing surface and the polyethylene sheeting by the use of several small boards. The air should be prevented from circulating beneath the polyethylene by placing boards along the edge of the sheeting. This method has protected a frost-susceptible silt bearing surface over a week-end period when the nighttime temperatures were on the order of 15F.

Foundation details for winter construction

Design criteria and construction methods are well established for preventing damage to building foundations after the structure has been completed. The protection of foundations during the construction period however may be difficult and expensive for the contractor, if the foundation work has to be accomplished during the winter period.

Consideration should be given in the design to the possible construction problems created by freezing temperatures. Shallow interior footings or shallow strip footings for support of interior partitions may be subject to heaving if not properly protected. In school construction particularly, work may commence in the late summer or fall with the completion date the middle of the following summer and much of the foundation work accomplished during the winter. Interior partitions
supported on shallow strip footings have been damaged due to frost heaving during the construction period.

It is possible for the contractor to protect against this heaving by placing a thick layer of salt hay over and on each side of the footing, after constructing and backfilling around the footing. This protection must be placed immediately to prevent heaving of the footing prior to construction of the partition. Where there are a large number of partitions and protection measures would be particularly difficult, it may be desirable to place the footings at greater depths below the surface to provide adequate protection and minimize construction difficulties.

Bituminous and portland cement concrete construction

The storage and processing of aggregates for bituminous and portland cement concrete is hampered during the winter period. Here again the cleaner and more free-draining materials present fewer problems. When unprocessed materials are stockpiled and a frozen crust forms on the surface or unprocessed materials are delivered to the plant with frozen chunks, processing the materials is difficult. The frozen chunks of material are either stopped by the grizzly and are processed with the coarse aggregates or the frozen material is retained on a coarser sieve than would be the case if the material was unfrozen.

At portland cement concrete mixing plants frozen chunks of aggregates, particularly the fine aggregates, tend to plug the gates and have to be broken up by hand or removed. The cold temperature of the aggregates also creates a problem. Most specifications require that the ready mixed concrete be delivered to the job at a temperature of not less than 60°F. Some specifications require a minimum of 70°F. Using mixing water with a temperature of approximately 180°F, which will not flash when it comes in contact with the aggregate, will heat the concrete mix to between 60 and 65°F. The process of mixing while in transit together with the heat of hydration maintains the temperature so that a minimum temperature of 60°F at time of delivery is possible without undue difficulty. A specification requiring delivery of the ready mixed concrete at a temperature of 70°F or higher usually will require preheating of the aggregates. This is usually done by the use of steam and most of the larger ready mixed plants have provisions for heating the aggregates by steam. The use of steam, however, increases the difficulty of controlling the water content and the slump of the mix, as the moisture content of the aggregates will fluctuate erratically.

In asphalt plant operation the problems of processing the aggregates are similar to those for portland cement concrete. The problem of manufacturing the asphalt mix is alleviated considerably as the aggregates are preheated. However, because of the high temperature at which the asphalt must be placed and rolled to attain adequate density, the loss of heat during transport is a serious problem during the winter period. The mix must be kept covered with one or more layers of tarpaulin to minimize heat loss. The normal covering used as well as the truck body provides little insulation and thus the outer surfaces of the load tend to cool quite rapidly. The transported material retains its temperature primarily as a result of the mass of the load. When the material is dumped and spread, and during the period of rolling, the surface of cooling is much greater, and a rapid drop in temperature occurs. The rate of temperature drop would be significantly influenced by the wind velocity as well as the temperature. We have not found any specific criteria that relate both temperature and wind to control placement of asphaltic concrete.

The detrimental effects of cold joints between paving lanes are difficult to prevent. One method is to employ the so-called wedge type joint, in which the screed is allowed to overlap by 3 or 4 in., and place a \( \frac{1}{2} \) to \( \frac{3}{4} \)-in. thickness of the hot mix over the edge of the previously placed lane. The immediate rolling of this joint tends to provide greater density at the joint with the objective of minimizing the future development of a longitudinal opening at the joint.
Preheating of the joint is sometimes employed. However, the problem of overheating and damaging the asphalt mix must be considered. Recent development of infrared heating units permits heating at the joint to prevent damage. The State of New York Highway Department uses infrared heating of joints when pavements are placed in cold weather. At a highway project in upper New York State tests indicated that the density of the pavement after rolling was below the specification requirements relative to the maximum Marshall density. The pavement was reheated using an infrared heating unit and rolled to meet the specification requirements. The use of infrared heaters for heating the exposed joint of previously placed lanes should be standard practice for cold weather construction.

LITERATURE CITED

6. American Concrete Institute (1956) Recommended practices for winter construction (ACI 604-56), Detroit, Michigan.
APPENDIX A

Appendix A is composed of abstracted construction requirements pertaining to cold weather construction from Corps of Engineers. Some statements are taken verbatim from the specifications, others present only the pertinent ideas.
Source: CE-203, 30 April 1964, EXCAVATION, FILLING AND BACKFILLING FOR BUILDINGS.

FILLING AND SUBGRADE PREPARATION-MATERIALS: Satisfactory material shall be free from roots and other organic matter, trash, debris, frozen materials and stones larger than 3 inches in any dimension.

FILLING AND SUBGRADE PREPARATION-PLACING: No material shall be placed on surfaces that are muddy, frozen, or contain frost.

BACKFILLING: Backfill shall not be placed in wet or frozen areas.

Source: CE-801, 15 April 1963, Revis. 28 April 1965, GRADING.

FILL: No frozen material will be permitted in the fill.

Source: CE-802, 14 June 1963, Revis. 1 January 1965, EXCAVATION, EMBANKMENT AND PREPARATION OF SUBGRADE FOR ROADWAYS, RAILROADS, AND AIRFIELDS.

EMBANKMENTS: Earth embankments shall be constructed from satisfactory materials free of organic or frozen material and rocks with maximum dimensions greater than 3 inches.

SUBGRADE AND EMBANKMENT PROTECTION: In no case shall subbase, base, surfacing, pavement, or ballast be placed on muddy, spongy, or frozen subgrade.

Source: CE-807.01, 30 December 1958, Revis. 1 June 1961, SELECT-MATERIAL SUBBASE COURSE.

WEATHER LIMITATIONS: Select-material subbase courses shall not be constructed when the atmospheric temperature is below 35°F. When the temperature falls below 35°F, all areas of completed select-material subbase course shall be protected by approved methods against any detrimental effects of freezing. Any area of completed select-material subbase course that is damaged by freezing, rainfall or other weather conditions shall be brought to a satisfactory condition by the Contractor in conformance with the requirements of this section of the specifications and without additional cost to the Government.

Source: CE-807.02, 15 February 1959, Revis. 1 June 1961, SUBBASE COURSE.

WEATHER LIMITATIONS: Subbase courses shall not be constructed when the atmospheric temperature is below 35°F. When the temperature falls below 35°F, all areas of completed subbase course shall be protected by approved methods against any detrimental effects of freezing. Any areas of completed subbase course that are damaged by freezing, rainfall, or other weather conditions shall be brought to a satisfactory condition by the Contractor in conformance with the requirements of this section of the specifications.

Source: CE-807.03, 15 January 1959, Revis. 1 February 1961, STABILIZED-AGGREGATE BASE COURSE.

WEATHER LIMITATIONS: Stabilized-aggregate courses shall not be constructed when the atmospheric temperature is below 35°F. When the temperature falls below 35°F, it shall be the responsibility of the Contractor to protect, by approved method or methods, all areas of the completed stabilized-aggregate base course against any detrimental effects of freezing.

Source: CE-807.04, 30 May 1959, Revis. 16 May 1960, LIMEROCK BASE COURSE.

WEATHER LIMITATIONS: Limerock base courses shall be constructed only when weather conditions do not detrimentally affect the quality of the finished course. Any portions or areas of the base course damaged by effects of freezing temperatures or other adverse weather conditions during any phase of
the construction shall be removed and replaced in kind with approved material, reshaped and recompacted by the Contractor in conformance with this section of the specifications.

Source: CE-807.05, 15 September 1959, Revis. 15 June 1961, DRYBOUND-MACADAM BASE COURSE.

WEATHER LIMITATIONS: Drybound-macadam base courses shall be constructed only when weather conditions will not detrimentally affect the quality of the finished course. Any areas of the base course that are damaged by freezing temperatures, rainfall, or other weather conditions during any phase of the construction shall be removed and replaced with approved material, reshaped and recompacted by the Contractor in conformance with this specification without additional cost to the Government.

Source: CE-807.06, 15 March 1960, Revis. 1 June 1961, WATERBOUND-MACADAM BASE COURSE.

WEATHER LIMITATIONS: Work on the base course shall not be performed during freezing temperatures. When the temperature is below 40°F, the completed base course shall be protected against freezing by a sufficient covering of straw, or by other approved methods, until the course has dried out. Any areas of completed base course that are damaged by freezing, rainfall or other weather conditions shall be brought to a satisfactory condition in conformance with this specification without additional cost to the Government.

Source: CE-807.07, 20 June 1961, GRADED, CRUSHED AGGREGATE BASE COURSE.

WEATHER LIMITATIONS: Base courses shall not be constructed when the atmospheric temperature is below 35°F. When the temperature falls below 35°F, it shall be the responsibility of the Contractor to protect by approved methods all areas of completed base course against any detrimental effects caused by freezing. Any areas of completed base course that are damaged by freezing, rainfall, or other weather conditions shall be brought to a satisfactory condition in conformance with the requirements of this specification without additional cost to the Government.

Source: CE-807.32, 15 December 1961, Revis. 1 June 1965, LIME-STABILIZED BASE COURSE, SUBBASE, OR SUBGRADE FOR ROADS AND STREETS.

WEATHER LIMITATIONS: No lime shall be applied except when the air temperature is at least 40°F in the shade and is rising. No lime shall be applied to soils that are frozen or contain frost. If the air temperature falls below 35°F in the shade, completed lime-treated areas shall be protected by approved methods against any detrimental effect of freezing. Any portion of the completed soil-lime treated areas damaged by freezing shall be completely removed and replaced with the new soil-lime material in accordance with this specification with no additional cost to the Government.

Source: CE-807.33, 30 November 1961, Revis. 15 July 1965, PORTLAND-CEMENT STABILIZED BASE COURSE, SUBBASE OR SUBGRADE FOR ROADS AND STREETS.

WEATHER LIMITATIONS: No cement shall be applied except when the air temperature is at least 40°F in the shade and is rising. No cement shall be applied to soils that are frozen or contain frost. If the air temperature falls below 35°F in the shade, completed cement treated areas shall be protected by approved methods against any detrimental effects of freezing. Any portion of the completed cement treated areas that is damaged by freezing shall be completely removed and replaced.
GUIDE SPECIFICATIONS FOR EMERGENCY CONSTRUCTION

Source: CE-E-62-2, 15 November 1963, EXCAVATION, EMBANKMENT AND PREPARATION OF SUBGRADE FOR ROADWAYS, RAILROADS AND AIRFIELDS.

EMBANKMENTS: Construct earth embankments from satisfactory materials free of organic or frozen materials and rocks with maximum dimensions greater than 3 inches.

SUBGRADE AND EMBANKMENT PROTECTION: Do not place subbase, base course, ballast or pavement until the subgrade has been checked and approved, and in no case place the subbase, base, surfacing, pavement, or ballast on a muddy, spongy, or frozen subgrade.

Source: CE-E-67-1, 31 December 1962, SELECT-MATERIAL SUBBASE COURSE.

WEATHER LIMITATIONS: Unless otherwise directed, do not construct select-material subbase courses when the atmospheric temperature is below 35°F. When the temperature falls below 35°F, protect all areas of completed select-material subbase course by approved methods against any detrimental effects of freezing. Repair any areas of completed select-material subbase course that are damaged by freezing, rainfall, or other weather conditions in conformance with the requirements of this section of the specifications and without additional cost to the Government.

Source: CE-E-67-2, 31 December 1962, SUBBASE COURSE.

WEATHER LIMITATIONS: Unless otherwise directed, do not construct subbase courses when the atmospheric temperature is below 35°F. When the temperature falls below 35°F, protect all areas of completed subbase course by approved methods against any detrimental effects of freezing. Repair areas of completed subbase course damaged by freezing, rainfall, or other weather conditions in conformance with the requirements of this specification and without additional cost to the Government.

Source: CE-E-67-3, 29 November 1963, STABILIZED-AGGREGATE BASE COURSE.

WEATHER LIMITATIONS: Unless otherwise directed, do not construct stabilized-aggregate courses when the atmospheric temperature is below 35°F. When the temperature falls below 35°F, protect, by approved methods, areas of the completed stabilized-aggregate base course against detrimental effects of freezing. Repair areas of completed stabilized-aggregate base course that are damaged by freezing, rainfall or other weather conditions in conformance with this specification without additional cost to the Government.

Source: CE-E-67-4, 29 November 1963, LIMEROCK BASE COURSE.

WEATHER LIMITATIONS: Construct lime rock base courses only when weather conditions do not detrimentally affect the quality of the finished course. Remove and replace with approved material any portion or area of the base course damaged by effects of freezing temperatures or other adverse weather conditions during any phase of the construction, and reshape and recompact in conformance with this section of the specification, without additional cost to the Government.

Source: CE-E-67-5, 20 November 1963, DRYBOUND-MACADAM BASE COURSE.

WEATHER LIMITATIONS: Construct drybound-macadam base courses only when weather conditions will not detrimentally affect the quality of the finished course. Remove and replace with approved material areas of the base course that are damaged by freezing temperatures, rainfall or other weather conditions during any phase of the construction. Reshape and compact these areas in conformance with this specification, without additional cost to the Government.
WEATHER LIMITATIONS: Do not perform work on the base course during freezing temperatures. When the temperature is below 40°F, protect the completed base course against freezing by a sufficient covering of straw, or by other approved methods, until the course has dried out. If during any phase of the construction any areas of the base course are damaged by freezing, rainfall or other weather conditions, repair these areas in conformance with this specification by removing the damaged area, replacing with approved material, and reshaping and recompressing, without additional cost to the Government.

WEATHER LIMITATIONS: Do not construct base courses when the atmospheric temperature is below 35°F. When the temperature falls below 35°F, protect by approved methods all areas of completed base course against freezing. Restore any areas of completed base course that are damaged by freezing, rainfall or other weather conditions to a satisfactory condition in conformance with the requirements of this specification without additional cost to the Government.

WEATHER LIMITATIONS: Do not apply lime except when the air temperature is at least 40°F in the shade and is rising. Do not apply lime to soils that are frozen or contain frost. If the air temperature falls below 35°F in the shade, protect completed lime-treated areas by approved methods against detrimental effects of freezing. Completely remove and replace any portion of the completed soil-lime-treated areas damaged by freezing with new soil-lime material in accordance with this specification at no additional cost to the Government.

WEATHER LIMITATIONS: Do not apply cement except when the air temperature is at least 40°F in the shade and is rising. Do not apply cement to soils that are frozen or contain frost. If the air temperature falls below 35°F in the shade, protect completed cement-treated areas by approved methods against detrimental effects of freezing. Completely remove and replace any portion of the completed cement-treated areas that is damaged by freezing in accordance with this specification at no additional cost to the Government.

CONCRETE

COLD WEATHER REQUIREMENTS: Concrete shall not be placed when the ambient temperature is below 35°F nor when, without special protection, the concrete is likely to be subjected to freezing temperature before the expiration of the specified curing period. If necessary to place concrete under conditions of low temperature, placement shall be approved by the Commanding Officer. The temperature of the concrete when placed shall be not less than 50°F nor more than 70°F. Heating of the mixing water and/or aggregates will be required as necessary to maintain the minimum temperature of 50°F, and all methods and equipment for heating shall be subject to the approval of the Contracting Officer. Materials shall be free from ice, snow and frozen lumps. Suitable covering and other means as approved by the Contracting Officer shall be provided for maintaining the concrete at a temperature of at least 50°F for not less than 72 hours after placing and at a temperature above freezing for the
remainder of the curing period. Salt, chemicals or other foreign materials shall not be mixed with the concrete to prevent freezing, except that calcium chloride may be used as an accelerating agent only after specific approval. Any concrete damaged by freezing shall be removed and replaced at the expense of the Contractor.

EARTH-FOUNDATION PLACEMENT: Concrete footings shall be placed upon undisturbed, clean surfaces, free from frost, ice, mud and water.

Source: CE-204.01, 16 January 1961, Revis. 15 November 1962, CONCRETE (FOR SPECIAL PURPOSES).

PLACING TEMPERATURES: Concrete shall not be placed when the ambient temperature is below 35°F nor when, without special protection, the concrete is likely to be subjected to freezing temperature before the expiration of the specified curing period. If necessary to place concrete under conditions of low temperature, placement shall be approved by the Contracting Officer. The temperature of the concrete when placed shall not be less than 50°F nor more than 85°F. Heating of the mixing water and/or aggregates will be required as necessary to maintain the minimum temperature of 50°F, and all methods and equipment for heating shall be as approved. Materials shall be free from ice and snow before entering the mixer. Salt, chemicals, or other foreign materials shall not be mixed with the concrete to prevent freezing. Any concrete damaged by freezing shall be removed and replaced at the expense of the Contractor.

EARTH-FOUNDATION PLACEMENT: Concrete footings shall be placed upon undisturbed, clean surfaces, free from frost, ice, mud and water.

CURING AND PROTECTION-COLD WEATHER: Air, water and forms in contact with concrete shall be maintained at temperatures above 50°F for at least the first 7 days, or not less than 70°F for the first 3 days and 40°F for the next 4 days, and at a temperature above freezing for the remainder of the specified curing period. The temperature protection equipment, the curing water and the removal of forms shall be handled in such manner that the surface concrete will not be subjected to a temperature differential of more than 40°F in 24 hours. Concrete permitted to be cured with curing compounds shall be provided the same protection against freezing and low temperatures as provided herein for moist-cured concrete.

Source: CE-204.02, 30 April 1959, Revis. 1 June 1965, CONCRETE (FOR BUILDING CONSTRUCTION-MINOR REQUIREMENTS).

PLACING CONCRETE: Unless otherwise approved, concrete shall be mixed and placed only when the temperature is at least 35°F and rising. Concrete footings shall be placed only upon surfaces that are free from frost, ice, mud, loose or unsound rock, and other detrimental substances.

Source: CE-806.01, 15 May 1964, CONCRETE PAVEMENT FOR ROADS AND AIRFIELDS.

SUBGRADE BASE AND FORMS-SUBGRADE BETWEEN FORMS: In cold weather, the subgrade, base course, or filter course shall be so prepared and protected as to be in a satisfactory condition and entirely free from frost when the concrete is placed. The use of chemicals to eliminate frost in the subgrade, base course or filter course will not be permitted.

PLACING-GENERAL: Concrete shall be placed within 45 minutes from the time all ingredients are charged into the mixing drum and before the concrete has obtained its initial set. The temperature of the concrete as deposited in the forms shall be not less than 50°F nor more than 85°F.
PLACING DURING COLD WEATHER: If it is necessary to place concrete when the temperature of the air, aggregates, or water is below 40°F, or when the unprotected concrete is likely to be subjected to freezing temperatures before the expiration of the specified curing period, placement shall be approved in writing. Such approval shall be contingent upon full compliance with the following provisions: The subgrade shall be prepared and protected so that it is entirely free of frost when the concrete is deposited. Mixing water and/or aggregates shall be heated as necessary to result in an in-place-concrete temperature of between 50°F and 85°F. Methods and equipment for heating shall be approved. The aggregates shall be free from ice, snow and frozen lumps before entering the mixer. Covering and other means shall be provided for maintaining the concrete at a temperature of at least 50°F for not less than 72 hours after placing, and at a temperature above freezing for the remainder of the curing period. Salt, chemicals, or other foreign material shall not be mixed with the concrete to prevent freezing. Concrete damaged by freezing shall be removed and replaced without additional cost to the Government.

GUIDE SPECIFICATIONS FOR EMERGENCY CONSTRUCTION


COLD WEATHER PLACEMENT: Unless otherwise approved, by the Contracting Officer, mix and place concrete only when the temperature is at least 40°F; if the temperature is less than 45°F it must be rising. For placing at lower temperature, when permission to pour is obtained from the Contracting Officer, heat all material and otherwise prepare so that batching and mixing can proceed as specified. Provide means for maintaining the concrete at a temperature of at least 50°F for 72 hours after placing, except that where high-early-strength cement is used, this period may be reduced to 24 hours. Methods proposed for heating materials and protecting concrete to be as approved by Contracting Officer. Do not mix salt, chemicals or other materials with concrete to prevent freezing or use accelerating agents except when necessary to pour concrete in existing or probable ambient temperature of between 25 and 40°F, when calcium chloride or other substance approved by Contracting Officer may be used in a proportion not exceeding 2 pounds per bag of cement.

EARTH-Foundation PLACEMENT: Place concrete footings upon undisturbed clean surfaces, free from frost, ice, mud and water.

Note: The following excerpts from Technical Manuals are included to show modifications which may be made in the Guide Specifications for construction during cold weather.


APPENDIX I, INFORMATION AND INSTRUCTIONS FOR USE OF GUIDE SPECIFICATION CE-204.01:

MATERIALS; ADMIXTURES-CALCIUM CHLORIDE: In some instances it may be desirable to require the use of calcium chloride in concrete placed during cold weather to accelerate the set and thus permit the finishing and protection of the concrete without undue delay. When this circumstance can be foreseen during the planning stage, the following subparagraph will be inserted after subparagraph: Water content:

Accelerator: Calcium chloride shall be used in all concrete placed when cold-weather protection is required, in accordance with subparagraph:
Cold weather. The amount of calcium chloride to be added shall be as required by the Contracting Officer but shall not exceed 2 percent of the weight of the cement. Calcium chloride shall be measured accurately and shall be added to the batch in solution in a portion of the mixing water. The use of calcium chloride in the concrete will in no way relieve the contractor of the responsibility for compliance with the specifications governing protection and curing of the concrete.

PLACING DURING COLD WEATHER: The placement and protection of the concrete during moderately cold weather is specified. American Concrete Institute Standard ACI 604-56, Recommended Practice for Winter Concreting, contains additional information on winter concreting. It is essential that the necessary covers and other means of protecting the concrete during cold weather be available on the job before concrete placement is started.

(1) Use of calcium chloride. When calcium chloride is required for use as an admixture to accelerate the setting time of concrete, subparagraph: Placing temperature will be modified by deleting the sentence,

Salt, chemicals, or other foreign material shall not be mixed with the concrete to prevent freezing.

No change will be permitted in the requirements for temperature of the concrete when placing, nor in the requirements for protection of the concrete against freezing when calcium chloride is used.

Source: TM5-822-7 (formerly Engineering Manual EM 1110-345-307) 15 May 1964, STANDARD PRACTICE FOR CONCRETE PAVEMENTS,

USE OF GUIDE SPECIFICATIONS: Guide Specification CE-806.01 will be used as the basis for the preparation of contract specifications for concrete pavements.

MATERIALS, ADMIXTURES-CALCIUM CHLORIDE: This paragraph is essentially the same as in TM5-805-1.

PLACING DURING COLD WEATHER: This paragraph is basically the same as in TM5-805-1 except for the addition of this sentence: It is seldom desirable to place pavement concrete when the air temperature is below 20°F and special provisions for placement and protection of the concrete will be necessary for such construction.

ASPHALT

Source: CE-807.09, 30 November 1958, Revis. 29 June 1962, BITUMINOUS PRIME COAT.

WEATHER LIMITATIONS: The prime coat shall be applied only when the atmospheric temperature in the shade is 50°F or above and when the temperature has not been below 35°F for 12 hours immediately prior to application, unless otherwise directed.

Source: CE-807.10, 15 January 1959, Revis. 29 June 1962, BITUMINOUS TACK COAT.

WEATHER LIMITATIONS: The tack coat shall be applied only when the atmospheric temperature in the shade is 50°F or above and when the temperature has not been below 35°F for 12 hours immediately prior to application, unless otherwise directed.

Source: CE-807.11, 30 January 1959, Revis. 29 June 1962, BITUMINOUS SEAL COAT.

WEATHER LIMITATIONS: The seal coat shall not be applied when the atmospheric temperature is below 60°F in the shade or when the pavement surface temperature is below 50°F unless otherwise directed.
WEATHER LIMITATIONS: Unless otherwise directed, asphalt courses shall not be constructed when the atmospheric temperature is below 40°F and tar courses shall not be constructed when the atmospheric temperature is below 50°F.

WEATHER LIMITATIONS: Such courses shall not be constructed when the atmospheric temperature is below 60°F in the shade, unless otherwise directed.

WEATHER LIMITATIONS: Blended natural rock asphalt wearing course shall be constructed only on dry base or binder courses when the atmospheric temperature in the shade is above 60°F and when the weather is not foggy or rainy. The temperature requirement may be waived only when so directed.

WEATHER LIMITATIONS: Fluxed natural rock asphalt wearing courses shall be constructed only on dry base or binder courses when the atmospheric temperature in the shade is above 60°F and when the weather is not foggy or rainy. The temperature requirement may be waived only when so directed.

WEATHER LIMITATIONS: Bituminous materials and aggregate for the keystone construction shall be applied and spread only when the surface is dry, when the atmospheric temperature in the shade is above 50°F, and when the weather is not foggy or rainy. The atmospheric temperatures limiting the application of the bituminous wearing course shall be in accordance with the requirements of SECTION: (BITUMINOUS BINDER AND SURFACE COURSES (CENTRAL-PLANT, HOT-MIX)), (BITUMINOUS BINDER AND SURFACE COURSES (CENTRAL-PLANT, COLD-MIX)), unless otherwise directed.

WEATHER LIMITATIONS: The double bituminous surface treatment shall be applied only when the existing surface or base course is dry or contains...
moisture not in excess of that which will permit uniform distribution and desired penetration. It shall not be applied when the atmospheric temperature in the shade is below 50°F unless otherwise directed.


WEATHER LIMITATIONS: Bituminous courses shall be constructed only when the base course or the existing pavement is dry, and when the weather is not rainy. Unless otherwise directed, asphaltic courses shall not be constructed when the atmospheric temperature is below 40°F and tar courses shall not be constructed when the atmospheric temperature is below 50°F.

Source: CE-807.31, 15 December 1961, Revis. 15 July 1964, BITUMINOUS STABILIZED BASE COURSE, SUBBASE OR SUBGRADE FOR ROADS AND STREETS.

WEATHER LIMITATIONS: No bituminous material shall be applied when the air temperature is less than 45°F in the shade or when, in the opinion of the Contracting Officer, the weather or the condition of the material to which the bituminous material is to be applied is unsuitable. No bituminous materials shall be applied to soils that are frozen or contain frost. If the air temperature falls below 35°F in the shade, completed bitumen-treated areas shall be protected by approved methods against any detrimental effects of freezing.

GUIDE SPECIFICATIONS FOR EMERGENCY CONSTRUCTION

Source: CE-E-67-9, 28 February 1963, BITUMINOUS PRIME COAT.

WEATHER LIMITATIONS: Apply prime coat only when the subgrade, subbase, or base course is dry or contains moisture not in excess of the amount that will permit uniform distribution and the desired penetration. Apply prime coat only when the atmospheric temperature in the shade is 45°F or above and when the temperature has not been below 35°F for the 12 hours immediately prior to application, unless otherwise directed.

Source: CE-E-67-10, 1 August 1962, BITUMINOUS TACK COAT.

WEATHER LIMITATIONS: Apply tack coat only when the binder course, base course, or existing pavement is dry, and only when the atmospheric temperature in the shade is 50°F or above, and when the temperature has not been below 35°F for 12 hours immediately prior to application unless otherwise directed by the Contracting Officer.

Source: CE-E-67-11, 28 February 1963, BITUMINOUS SEAL COAT.

WEATHER LIMITATIONS: Apply seal coat only when the surface to be sealed is dry, and when weather is not foggy or rainy. Do not apply when atmospheric temperature is below 50°F in the shade or when the pavement surface temperature is below 40°F unless otherwise directed.


WEATHER LIMITATIONS: Unless otherwise directed, do not construct asphalt courses when the atmospheric temperature is below 45°F and do not construct tar courses when the atmospheric temperature is below 50°F.

WEATHER LIMITATIONS: Construct bituminous courses on dry base or binder course when the temperature in the shade is above 50° F and when the weather is not foggy or rainy.

Source: CE-E-67-14, 14 June 1963, BLENDED NATURAL ROCK ASPHALT SURFACE COURSE.

WEATHER LIMITATIONS: Construct blended natural rock asphalt surface course on dry base or binder course when the atmospheric temperature in the shade is above 45° F. The temperature requirement may be waived when so directed.


WEATHER LIMITATIONS: Construct fluxed natural rock asphalt surface course on dry base or binder course when the atmospheric temperature in the shade is above 50° F. The temperature requirement may be waived when so directed.

Source: CE-E-67-16, 15 June 1964, BITUMINOUS MACADAM SURFACE COURSE (PENETRATION METHOD).

WEATHER LIMITATIONS: Construct bituminous macadam surface course on a dry base course. Apply bituminous material only when the aggregate is dry, when the atmospheric temperature is above 45° F in the shade, and when the weather is not foggy or rainy.

Source: CE-E-67-17, 2 January 1964, KEYSTONE BINDER AND PLANT-MIX SURFACE COURSE.

WEATHER LIMITATIONS: Apply and spread bituminous materials and aggregate for the keystone construction only when the surface is dry, when the atmospheric temperature in the shade is above 45° F, and when the weather is not foggy or rainy. Apply the bituminous surface course at a temperature within the limits specified in SECTION: (BITUMINOUS BINDER AND SURFACE COURSES (CENTRAL-PLANT, HOT-MIX)) (BITUMINOUS BINDER AND SURFACE COURSES (CENTRAL-PLANT COLD-MIX)), unless otherwise directed.

Source: CE-E-67-18, 31 August 1964, BITUMINOUS ROAD-MIX SURFACE COURSE.

WEATHER LIMITATIONS: Construct bituminous courses only when the surface is dry and the weather is not foggy or rainy. Do not construct the bituminous course when the atmospheric temperature is below 45° F in the shade, unless otherwise directed.

Source: CE-E-67-19, 15 July 1963, SINGLE BITUMINOUS SURFACE TREATMENT.

WEATHER LIMITATIONS: Unless otherwise directed, do not apply the surface treatment when the atmospheric temperature is below 45° F in the shade.

Source: CE-E-67-20, 14 June 1963, DOUBLE BITUMINOUS SURFACE TREATMENT.

WEATHER LIMITATIONS: Unless otherwise directed, do not apply surface treatment when the atmospheric temperature is below 45° F in the shade.


WEATHER LIMITATIONS: Unless otherwise directed, do not construct asphaltic courses when the atmospheric temperature is below 40° F nor tar courses when the atmospheric temperature is below 50° F.
Source: CE-E-67-31, 15 January 1964, BITUMINOUS-STABILIZED BASE COURSE, SUBBASE, OR SUBGRADE,

WEATHER LIMITATIONS: Do not apply bituminous material when the air temperature is less than 45°F in the shade or when, in the opinion of the Contracting Officer, the weather or the condition of the material to which the bituminous material is to be applied is unsuitable. Do not apply bituminous materials to soils that are frozen or contain frost. If the air temperature falls below 35°F in the shade, protect completed bitumen-treated areas by approved methods against detrimental effects of freezing. Completely remove and replace any portion of the completed bituminous-treated areas damaged by freezing with new soil-bitumen material in accordance with this specification at no additional cost to the Government.
APPENDIX B

Appendix B is composed of abstracted cold weather construction requirements from state and province highway department standard specifications for road and bridge construction. Some statements are taken verbatim from the specifications, others present only the pertinent ideas.
STATE OF ALASKA DEPARTMENT OF HIGHWAYS presently uses BUREAU OF PUBLIC ROADS STANDARD SPECIFICATIONS FOR CONSTRUCTION OF ROADS AND BRIDGES ON FEDERAL HIGHWAY PROJECTS, FP-57 with a number of SPECIAL PROVISIONS.

EMBANKMENT from FP-57: Material for embankments shall consist of suitable material approved by the Engineer. Embankments and backfills shall contain no muck, frozen material, roots, sod, or other deleterious matter.

PORTLAND CEMENT CONCRETE PAVEMENT from FP-57: Unless the Engineer specifically so authorizes in writing, mixing and concreting operations shall not be continued when a descending air temperature in the shade and away from artificial heat reaches 45°F, nor resumed until an ascending air temperature in the shade and away from artificial heat reaches 40°F.

When concreting is authorized during cold weather, the aggregates shall be heated by use of steam or dry heat before being placed in the mixer. The aggregates shall be heated uniformly, but not hotter than 150°F. Water may be heated, but shall not be hotter than 175°F. Unless otherwise authorized, the temperature of the mixed concrete shall be not less than 60°F nor more than 80°F when it is placed.

Concrete shall not be placed on a frozen roadbed.

During the first 24 hours, the concrete shall be maintained at a temperature of not less than 50°F, using approved enclosures and/or devices if required.

During the first 5 days, the concrete shall be protected against freezing at any time when the Engineer considers that freezing temperatures are to be expected, using blanketing course of straw, hay, or other suitable material satisfactory to the Engineer.

CONCRETE STRUCTURES from SPECIAL PROVISIONS: Concreting operations shall not be carried out when the descending air temperature in the shade, away from artificial heat, falls below 40°F nor resumed before the ascending air temperature reaches 35°F, without specific written authorization from the Engineer. When the above temperature conditions exist, or are, in the opinion of the Engineer, likely to be encountered within a 24-hour period after placing concrete, the Contractor shall have ready on the job, materials and equipment required to heat mixing water and aggregate to protect freshly placed concrete from freezing.

Concrete placed at temperatures below those noted above shall have a temperature not less than 60°F nor greater than 80°F when placed in the forms. Material containing frost or lumps of frozen material shall not be used.

The use of chemicals or other foreign materials to lower the freezing point of the concrete is prohibited. Calcium chloride may be added to the
mixing water to accelerate hardening of the concrete when approved by the Engineer.

When placing concrete in cold weather, heat shall be applied to forms and reinforcing before placing concrete as required to remove all frost, ice, and snow from all surfaces which will be in contact with fresh concrete.

Freshly placed concrete shall be maintained at a temperature of not less than 70°F for 3 days or 50°F for 5 days when Type I or Type II Portland Cement is used, and not less than 70°F for 2 days or 50°F for 3 days if Type III Portland Cement is used.

When temperatures below 20°F are not expected during the curing period and, in the opinion of the Engineer, no other adverse conditions, such as high winds, are expected, concrete temperatures may be maintained in thick concrete sections by retention of heat of hydration by means of adequately insulated forms.

When in the opinion of the Engineer, greater protection is required to maintain the specified temperature, the fresh concrete shall be completely enclosed and an adequate heat source provided. Such enclosure and heat source shall be so designed that evaporation of moisture from the concrete during curing is prevented. Precautions shall be taken to protect the structure from dangers of overheating and fire.

At the end of the required curing period, protection may be removed, but in such a manner that the drop in temperature of any portion of the concrete will be gradual and not exceed 30°F in 24 hours.

BITUMINOUS PRIME COAT from FP-57: Prime coat shall be applied only when the surface to be treated is dry or slightly damp when the atmospheric temperature in the shade is above 55°F and rising or above 60°F if falling and when the weather is not foggy or rainy.

BITUMINOUS PRESERVATIVE TREATMENT from FP-57: Bituminous materials shall be applied only when the surface to be treated is dry or slightly damp; when the atmospheric temperature in the shade is above 55°F and rising, or above 60°F, if falling, and when the weather is not foggy or rainy.

BITUMINOUS SEAL COAT from FP-57: Seal coat shall be applied only when the surface to be treated is dry or slightly damp, when the temperature of the road surface is 70°F or more, and when the weather is not foggy or rainy.

BITUMINOUS SURFACE TREATMENTS from FP-57: Surface treatments shall be applied only when the existing surface is dry or slightly damp, when the atmospheric temperature in the shade is above 55°F and rising or above 60°F if falling and when the weather is not foggy or rainy.

BITUMINOUS PLANT-MIX SURFACING from FP-57: Plant-mix surface course shall be constructed only when the surface is dry and when the atmospheric temperature in the shade is above 40°F and rising or above 50°F if falling and when the weather is not foggy or rainy.
BITUMINOUS ROAD-MIX SURFACING from FP-57: Bituminous material shall be applied only when the existing surface is dry or slightly damp, when the atmospheric temperature in the shade is above 55°F and rising or above 60°F and falling and when the weather is not foggy or rainy.
PORTLAND CEMENT CONCRETE: Except by specific written authorization by the Engineer, concreting operations shall not be continued when a descending air temperature in the shade and away from artificial heat reaches 35°F. Concrete shall not be placed on frozen ground.

When concreting is authorized during cold weather, the aggregates may be heated by the use of steam coils or dry heat before being placed in the mixer. The aggregate shall be heated uniformly, but not hotter than 150°F. Water may be heated, but shall not be hotter than 150°F. Unless otherwise authorized, the temperature of the mixed concrete shall not be less than 60°F and more than 90°F when it is placed. After placement concrete blanketing material shall be provided and shall be spread over the pavement to a sufficient depth to prevent freezing of the concrete.

PORTLAND CEMENT CONCRETE FOR STRUCTURES: Except by specific written authorization by the Engineer, concreting operations shall not be continued when a descending air temperature in the shade and away from artificial heat reaches 35°F. When concrete is being placed during cold weather and the air temperature may be expected to drop below 35°F, the air temperature surrounding the concrete shall be maintained at a temperature of from 60°F to 90°F for at least 72 hours and a temperature of not less than 40°F for a period of not less than seven days. If specifically approved by change order, the Contractor may use calcium chloride as an accelerator.

When concreting is authorized during cold weather, the aggregates may be heated by the use of steam coils or dry heat before being placed in the mixer. The aggregate shall be heated uniformly, but not hotter than 150°F. Water may be heated, but shall not be hotter than 150°F. Unless otherwise authorized, the temperature of the mixed concrete shall not be less than 60°F and not more than 90°F when it is placed.

APPLICATION OF BITUMINOUS MATERIALS: No bituminous material shall be applied to or road-mixed with mineral aggregates when the air temperature in the shade is 70°F or below.
EARTH WORK: Frozen excavation or a blanket of snow will be considered cause for shutting down grading operations.

PORTLAND CEMENT CONCRETE PAVEMENT: Concrete shall not be placed on frozen ground nor shall be mixed or placed when the atmospheric temperature is below 35°F or when conditions indicate that the temperature may fall to 35°F within 24 hours, except with the written permission of the Engineer and only after such precautionary measures for the protection of the pavement have been taken, as he may direct.

ROAD MIXED SURFACING: Prime coat shall not be applied when the temperature of the subgrade material is below 60°F.

ASPHALT CONCRETE PAVEMENT: No material shall be spread when the atmospheric temperature is below 50°F or during unsuitable weather.

SEAL COAT: Bituminous binders shall not be spread when weather conditions are unsuitable or when either the atmospheric or pavement temperature is below 65°F.

BINDER COAT: Bituminous binders shall be spread only when the atmospheric temperature is 65°F or above. In no case shall bituminous binders be spread between October 1 and May 1 except on written consent of the Engineer.
EMBANKMENTS: Frozen material shall not be used in construction of embankments.

PORTLAND CEMENT CONCRETE: Except by specific written authorization, concreting operations shall not be continued when a descending air temperature in the shade and away from artificial heat falls below 40°F, nor resume until an ascending air temperature in the shade and away from artificial heat reaches 35°F. In such cases, the aggregates may be heated either by steam or dry heat prior to being placed in the mixer. The temperature of the mixed concrete shall not be less than 50°F nor more than 80°F at the time of placing in the forms. If the temperature during the ten hours previous to the placing of the concrete has been 32°F or less, the aggregates and water shall be heated. Material containing frost or lumps of hardened material shall not be used.

BITUMINOUS MATERIAL: Seal or fog coats shall not be placed during rain or snow or high winds or other unfavorable weather conditions. It shall be placed only when the temperature of the roadway surface is 70°F or higher. All seal or fog coating shall be suspended in the fall season when temperature may be expected which will not result in good workmanship.

PLANT-MIXED ASPHALTIC SURFACING: No surfacing shall be placed unless the atmospheric temperature in the shade is at least 40°F and rising or 50°F and falling, and other weather conditions are suitable. In no case shall the pavements be laid on foundations on which frost is present.

ASPHALTIC SURFACE TREATMENT: No surface treatment shall be carried on unless the atmospheric temperature is at least 60°F and rising, nor when the weather is foggy or rainy or when the surface is not dry or when frost is present.
EMBANKMENTS: Frozen material, otherwise suitable for formation of embankments, shall be placed on embankment slopes or disposed of as directed by the Engineer. The Engineer may direct the removal of any portion of an accepted layer which has become frozen after placement and compaction. This frozen material shall be placed on embankment slopes or disposed of as directed by the Engineer. The removal and placement of frozen material shall be at the sole expense of the Contractor.

No embankment layer shall be deposited on surfaces of snow or ice, nor shall it be placed on frozen or unstable surfaces. If the Contractor elects, and is permitted to continue work, he shall remove, at no cost to the State, any frozen embankment material unless otherwise directed.

CONCRETE MIXING CONDITIONS: In general, concrete shall be placed only during the period from April 1 to November 1. With written permission of the Engineer, concrete may be laid during the period from November 1 to April 1 subject to the following provisions. When in the opinion of the Engineer, the condition of the weather is such that any pavement which has not been properly cured is liable to be frozen, such pavement shall be protected by covering it, as soon as the concrete has hardened sufficiently, with the curing material of the quality specified, upon which shall be placed a layer of hay or straw 6 to 8 inches in thickness over which another layer of mats or cover sheets be spread. Any concrete laid during cold weather is done at the Contractor's risk as all damaged sections shall be removed and replaced at his own expense.

During cold weather, concrete may be mixed when the air temperature inside the forms and in the shade and away from artificial heat is 40°F or above and rising. It shall not be mixed when the air temperature inside the forms and in the shade and away from artificial heat is below 40°F and falling unless specifically authorized by the Engineer.

When directed by the Engineer, the Contractor shall enclose structures in such a way that the air within the enclosure can be kept above 60°F for a period of 5 days.

BITUMINOUS CONCRETE BINDER COURSE: Unless the restriction is waived by written consent of the Engineer, the mixture shall be laid only during the period from April 15 to October 15 and, further, these operations shall be carried on only when the surface is dry, the atmospheric temperature in the shade is at least 50°F and the weather is not foggy or rainy.

HOT ASPHALT CONCRETE PAVEMENT: Unless the restriction is waived
by written consent of the Engineer, the mixture shall be laid only during the period from April 15 to October 15 and, further, these operations shall be carried on only when the surface is dry, the atmospheric temperature in the shade is at least 50°F and the weather is not foggy or rainy.

DENSE GRADED BITUMINOUS CONCRETE PAVEMENT: Unless the restriction is waived by written consent of the Engineer, the mixture shall be laid only during the period from April 15 to October 15 and, further, these operations shall be carried on only when the surface is dry, the atmospheric temperature in the shade is at least 50°F and the weather is not foggy or rainy.

BITUMINOUS MACADAM PAVEMENT (PENETRATION METHOD): Bituminous material shall not be applied on a wet surface, or when the temperature is below 60°F in the shade and falling, or below 55°F in the shade and rising, or when the weather conditions are otherwise unfavorable. No bituminous surfacing work shall be performed between October 15 and April 15, except with the written consent of the Engineer.
EMBANKMENT: No spongy or frozen material will be permitted in the embankment nor will the embankment be allowed to be placed on any wet, unstable or frozen materials.

PENETRATION MACADAM BASE COURSE: Surface treatment shall only be applied between May 1 and October 15 and when the condition of the base is satisfactory to the Engineer. When the atmospheric temperature is above 60°F and when the weather is neither foggy nor rainy, the temperature and seasonal requirements may be waived by written order of the Engineer.

SOIL-CEMENT BASE COURSE: No cement shall be applied when the soil or base is frozen. The air temperature shall be at least 40°F in the shade and rising.

PORTLAND CEMENT CONCRETE: The following requirements shall govern the mixing of concrete during cold weather. Materials containing frost or hardened lumps shall not be used. Concrete may be placed when the air temperature in the shade and away from artificial heat is 35°F and rising. Concrete shall not be placed when the air temperature in the shade and away from artificial heat is 40°F and falling. Chemical admixtures for lowering the freezing point shall not be added without permission of the Engineer. When concrete is being placed during cold weather, and the air temperature may be expected to drop below 35°F, a sufficient supply of straw, hay, grass or other suitable blanketing material shall be provided along with the line of work, to be used at any time when the temperature may be expected to reach the freezing point during the day or night. The insulating material should be adequately secure to hold it in place on the pavement. The period of time over which such protection shall be maintained will be not less than five days. In no case should pavement be placed on a frozen subgrade, frost crystals or mud caused by freezing and thawing shall be removed and replaced with suitable material before placing any pavement on the subgrade.

HOT-MIXED HOT-LAID ASPHALTIC CONCRETE PAVEMENT: No mixture shall be placed when the air temperature in the shade and away from artificial heat is 40°F or less. The Engineer however, may permit work to continue when overtaken by rain.

BITUMINOUS SURFACE TREATMENT: Surface treatment shall be applied only between May 1 and October 15 and when the condition of the base is
satisfactory to the Engineer. When the atmospheric temperature is above 60°F and when the weather is neither foggy nor rainy, the temperature and seasonal requirements may be waived by written order of the Engineer.
SOIL CEMENT STABILIZED BASE COURSE: Mixing shall not be begun unless the air temperature is above 40°F in the shade and rising.

PORTLAND CEMENT CONCRETE PAVEMENT: Concrete shall not be mixed when the air temperature in the shade and away from artificial heat is as low as 40°F and falling but may be placed when the temperature measured under the same conditions is not lower than 35°F and rising. No chemicals or heating of aggregates shall be used to keep the concrete from freezing nor shall lumps of materials held together by frost be used. If the air temperature is below freezing during the curing period specified, the pavement shall be covered with at least 2 inches of straw held in place by burlap or canvas.

CONCRETE FOR STRUCTURES: No concrete shall be placed when the temperature of the air is below 35°F nor when it is below 40°F and falling.

SOIL-BITUMINOUS STABILIZED BASE COURSE: The bituminous materials shall not be applied when the air temperature is less than 60°F in the shade nor when the temperature during the preceding 24 hours has been below 50°F.

BITUMINOUS PRIME: Bituminous prime shall not be placed on any day when the temperature of the air at 7:00 a.m. is below 40°F, nor when the temperature of the air is below 60°F in the shade except that if cut-backs for an emulsion is specified, it shall not be applied when the temperature of the air is less than 50°F in the shade.

BITUMINOUS TACK COAT: Tack coat shall not be placed during rainy weather or when the subgrade or base course is frozen or shows any evidence of excess moisture, nor when the moisture on the surface to be paved would prevent proper bond nor when the air temperature is less than 45°F in the shade and away from artificial heat.

BITUMINOUS SEAL: The days between which various bituminous materials shall not be applied for surface treatments vary between October 1 and April 30. No exceptions will be permitted unless they are authorized by the State Highway Engineer. Asphalt cement and cutback asphalt shall not be applied on any day when the temperature at 7:00 a.m. is below 50°F nor when the air temperature at the time of application is below 60°F in the shade. Cutback asphalt emulsion and emulsified asphalt shall not be applied
on any day when the temperature at 7:00 a.m. is below 40°F nor when the air temperature at the time of application is below 50°F in the shade.

BITUMINOUS PLANT MIX FACES AND SURFACE COURSES: Bituminous mixtures shall not be produced or placed during rainy weather or when the subgrade or base course is frozen or shows any evidence of excess moisture, nor when the moisture on the surface to be paved would prevent proper bond nor when the air temperature is less than 45°F in the shade away from artificial heat.

PENETRATION MACADAM: The days between which various bituminous materials shall not be applied for surface treatments vary between October 1 and April 30. No exceptions will be permitted unless they are authorized by the State Highway Engineer. Asphalt cement and cutback asphalt shall not be applied on any day when the air temperature at 7:00 a.m. is below 50°F nor when the air temperature at the time of application is below 60°F in the shade. Cutback asphalt emulsion and emulsified asphalt shall not be applied on any day when the temperature at 7:00 a.m. is below 40°F nor when the air temperature at the time of application is below 50°F in the shade.

SINGLE BITUMINOUS SURFACE COURSES: The days between which various bituminous materials shall not be applied for surface treatments vary between October 1 and April 30. No exceptions will be permitted unless they are authorized by the State Highway Engineer. Asphalt cement and cutback asphalt shall not be applied on any day when the air temperature at 7:00 a.m. is below 50°F nor when the air temperature at the time of application is below 60°F in the shade. Cutback asphalt emulsion and emulsified asphalt shall not be applied on any day when the temperature at 7:00 a.m. is below 40°F nor when the air temperature at the time of application is below 50°F in the shade.
EMBANKMENTS: Snow shall be removed from the embankment foundation prior to construction of the embankment. No embankment shall be constructed on frozen foundation unless permitted in writing. All materials used in embankments shall be entirely free of frozen soil. Unless permitted in writing, no material shall be placed in the embankment when the material or the embankment on which it would be placed is frozen.

SUBGRADE: Unless ordered in writing, no material shall be placed on a frozen or muddy subgrade.

CEMENT TREATED BASE COURSE: No cement treated base construction shall be carried on during seasons of probable freezing weather. No base material shall be deposited on a frozen subgrade or base course. No cement shall be applied when the temperature of the aggregate is less than 50°F or the atmospheric temperature is 40°F and falling. The Contractor may maintain operations during unfavorable weather at his own risk.

PORTLAND CEMENT CONCRETE PAVEMENT: Except by written authorization concreting operations shall not be continued when a descending air temperature in the shade and away from artificial heat falls below 40°F nor be resumed until an ascending air temperature in the shade and away from artificial heat reaches 35°F. Material containing frost or frozen aggregates shall not be used. When the average daily temperature is below 50°F curing shall consist of covering the newly laid pavement with not less than 12 inches of loose, dry hay or straw which shall be retained in place for ten days. Neither salt nor other chemical admixtures shall be added to the concrete to prevent freezing. When concrete is being placed during cold weather and the air temperature may be expected to drop below 35°F a sufficient supply of straw, hay, grass or other suitable blanketing material shall be provided along the line of the work. At any time when the air temperature may be expected to reach the freezing point, during the day or night, the material so provided shall be spread over the pavement to a sufficient depth to prevent freezing of the concrete.

ASPHALTIC MATERIALS: Asphaltic materials shall not be applied when the atmospheric temperature is 50°F and falling or to aggregates containing more than 2% moisture by dry weight of the aggregates. Moisture limitation does not apply when emulsified asphalt is used. Application of asphaltic material will not be permitted prior to May 15 or after September 15 except when authorized in writing.
BACKFILLING FOR STRUCTURES: No sod, frozen material or any material which, by decay or otherwise, might cause settlement, shall be placed or allowed to remain in the backfill.

EMBANKMENTS-PREPARATION OF SUBGRADE: If embankments are being constructed during the winter, snow and ice shall be removed from the area to be covered by the embankment.

CONCRETE: Concrete may be placed when the air temperature in the shade and away from artificial heat is above 45°F or is between 40°F and 45°F and rising. Concrete shall not be placed when the air temperature is below 40°F or between 40 and 45°F and falling. If the aggregates contain frost, a lump of frozen material or if the temperature at anytime during the ten hours previous to placing has been 32°F or less, the aggregates and water shall be heated to a temperature of not less than 70°F nor more than 150°F before placing in the mixer.

When the average daily temperature is below 50°F, the newly laid pavement shall be protected with not less than 12 inches of loose, dry straw which shall remain in place for ten days.

SEAL COAT FOR BITUMINOUS SURFACES: Seal coat work shall be done only between May 1 and September 15. Bituminous material shall be applied only when the temperature of the air in the shade is above 60°F.

BITUMINOUS SURFACE TREATMENT FOR GRAVEL AND CRUSHED STONE BASES: This work shall be done only between May 1 and September 15. Bituminous material shall be applied only when the temperature of the air in the shade is above 60°F.

BITUMINOUS CONCRETE DENSE-GRADED AGGREGATE TYPE: The cover coat shall be constructed only between May 1 and October 15. Bituminous mixtures shall be placed only when the temperature of the air in the shade is above 40°F.

BITUMINOUS MACADAM SURFACE COURSE: This work shall be done only between May 1 and September 15. Bituminous materials for the prime and cover coat shall be applied only when the temperature of the air in the shade is above 60°F. Bituminous material for the seal coat shall be applied only when the temperature of the air in the shade is above 80°F.

BITUMINOUS CONCRETE BINDER AND SURFACE COURSES, FINE DENSE-GRADED AGGREGATE TYPE: No mixture shall be laid when the
temperature of the air in the shade is below $40^\circ F$ unless permitted by the Engineer.

SHEET ASPHALT BINDER AND SURFACE COURSE-HOT PLANT MIX: The leveling binder, binder course and surface course mixtures shall not be laid when the temperature of the air in the shade is below $40^\circ F$ unless permitted by the Engineer.

BITUMINOUS CONCRETE BINDER AND SURFACE COURSE: The leveling binder, binder course and surface course mixtures shall be laid only on a base which is dry and only when weather conditions are suitable. No mixtures shall be laid when the temperature of the air in the shade is below $40^\circ F$ unless permitted by the Engineer.
EMBANKMENTS: No frozen materials, stumps, roots or all or parts of trees or other perishable material except as herein provided for shall be placed in embankments. The original ground surface or the surface of any lift in place shall not be frozen and shall be free from objectionable quantities of snow, ice or mud when the subsequent lift is placed thereon.

SUBGRADE: Paving materials shall not be placed before the subgrade is checked and approved and at no time when the subgrade is frozen.

SPECIAL FILL AND BACKFILL: Material used for special filling shall be of acceptable quality, free from large or frozen lumps or other extraneous matter.

REINFORCED CONCRETE PAVEMENT: If the temperature in the shade and away from artificial heat is not lower than 35°F and rising, concrete may be placed, but if 40°F and below and falling, it shall not be placed. All concrete placed when the temperature within the preceding twenty-four hours has reached 35°F or lower, shall, if damaged by frost, be replaced by the Contractor at his expense.

BITUMINOUS PENETRATION BASE: No bituminous material shall be applied when the air temperature is below 45°F nor when the air temperature within the preceding 8 hours has been below 35°F. No bituminous material shall be applied between September 15 and May 15 without written permission of the Engineer.

BITUMINOUS PLANT MIX BASE: No mixture shall be placed when the air temperature in the site of the work is at or below 35°F.

HOT ASPHALTIC SURFACE: No mixture shall be mixed or shall be spread between November 1 and April 1 without written permission of the Engineer, nor when the temperature is at or below 40°F, nor when the base or binder is wet, nor when other conditions are obviously unsuitable.

BLENDED AGGREGATE SURFACE: No mixture shall be mixed or shall be spread between November 1 and April 1 without written permission of the Engineer, nor when the temperature is at or below 40°F, nor when the base or binder is wet, nor when other conditions are obviously unsuitable.

BITUMINOUS COATED SURFACE: No course in any designated area shall be constructed between September 15 and May 15 without written permission
of the Engineer. No bituminous materials shall be applied or mixtures laid when the air temperature is below $50^\circ F$, nor when the air temperature within the preceding ten hours has been $35^\circ F$ or lower.

ROAD-MIX BITUMINOUS SURFACE: No surface shall be constructed between September 15 and May 15 without written permission of the Engineer. No bituminous materials shall be applied when the air temperature is below $50^\circ F$ nor when the air temperature within the preceding ten hours has been below $35^\circ F$. 
STRUCTURAL BACKFILL: Material used for backfilling shall be free from spongy or vegetable substances, free from frozen material, free from boulders or broken concrete over 6 inches in the greatest dimension.

PORTLAND CEMENT CONCRETE: Concrete shall not be placed when inclement weather will prevent good workmanship. No aggregates containing frozen lumps may be used, and concrete shall not be placed on a frozen subgrade. If weather conditions are favorable, concreting operations may be started when the temperature of the concrete, as delivered to the subgrade, is $40^\circ F$ or higher and may be continued as long as this temperature requirement is met and the temperature remains above $38^\circ F$. Concrete placed when the air temperature is below $45^\circ F$ shall be covered with burlap and at least six inches of straw before completion of the day's operations. No concrete shall be placed without the specific permission of the Engineer when the air temperature is at or below $40^\circ F$. In no case shall any frozen material be used in concrete. Concrete shall not be deposited against frozen forms, earth or rock or against other concrete having a temperature below $40^\circ F$. Before concrete is placed at atmospheric temperatures below $40^\circ F$, the Contractor shall have provided protection and heating facilities adequate to maintain the temperatures as follows: Concrete and the area surrounding it shall be maintained at a temperature of between $50^\circ F$ and $100^\circ F$ for the first 72 hours after the concrete has been placed, and at a temperature between $40^\circ F$ and $100^\circ F$ for the next 48 hour period.

ASPHALTIC CONCRETE: Asphaltic concrete shall not be placed on a wet or damp surface and shall not be placed when the temperature of a shaded portion of the road surface is less than $40^\circ F$. Asphaltic concrete shall not be placed after November 15, except with the approval of the Construction Engineer.
The seasonal limitations may be waived but only when so directed by the Engineer.

EMBANKMENTS: Frozen soil or other undesirable material shall not be placed in embankments. When frozen soil exists in either the surface of the original ground or the surface of a partially constructed embankment, work shall not proceed until such time as the frozen soil has completely thawed or been removed.

SOIL CEMENT BASE COURSE: During periods when there is a possibility of freezing temperatures, no cement shall be applied unless the temperature is at least 40°F in the shade and rising.

CONCRETE: Except by specific written authorization, concreting operations shall not be continued when a descending air temperature in the shade and away from artificial heat falls below 40°F, nor shall operations be resumed until an ascending air temperature in the shade and away from artificial heat reaches 35°F. When specific written authorization is given to permit concreting operations at temperatures below those specified above, the Contractor shall furnish equipment to heat the aggregates and water and may use calcium chloride as an accelerator. Materials containing frost or hardened materials shall not be used. Under no circumstances shall concreting operations continue when the air temperature is at less than 20°F. When concrete pavement is being placed during cold weather, and the air temperature may be expected to drop below 35°F, a sufficient supply of burlap, straw or hay or other suitable blanketing material shall be provided at the work site. At any time when the air temperature may be expected to reach the freezing point during the day or night, sufficient protection shall be given to the concrete to maintain a temperature of not less than 60°F surrounding the concrete for a period of at least 24 hours after the concrete has been placed in and/or between the forms.

BITUMINOUS BASE - ROAD MIX: Bituminous base shall be constructed only between May 1 and October 1 and operations shall be carried on only when the surface is dry, when the atmospheric temperature is about 60°F and when the weather is not foggy.

BITUMINOUS BASE: Hot asphaltic mixtures shall be placed only when the air temperature is 40°F or above and when the weather is not foggy or rainy and when existing surface is free from moisture.
BITUMINOUS PRIME COAT: This work shall be constructed only between May 1 and October 15 and operations shall be carried on only when the surface is dry, when the atmospheric temperature is above 60°F and when the weather is not foggy or rainy. The seasonal requirements may be waived, but only when so directed by the Engineer.

SINGLE AND DOUBLE ASPHALTIC SURFACE TREATMENT: This work shall be constructed only between May 1 and October 15 and operations shall be carried on only when the surface is dry, when the atmospheric temperature is above 60°F, and when the weather is not foggy or rainy. The seasonal requirements may be waived, but only when so directed by the Engineer.
EMBANKMENT: No frozen material or other perishable material shall be placed on any embankment. Embankments shall not be constructed upon frozen areas. All snow and ice shall be removed from the area to be covered prior to placement of embankment material.

BASE STABILIZATION WITH PORTLAND CEMENT: During seasons of probable freezing temperatures, no cement shall be applied unless the temperature is at least 40°F in the shade and rising.

CEMENT CONCRETE TEMPERATURE LIMITATION: Concrete may be placed when the air temperature in the shade and away from artificial heat is more than 35°F and rising. Concrete shall not be placed when the air temperature in the shade and away from artificial heat is less than 40°F and falling.

ROCK ASPHALT SURFACE COURSE: No rock asphalt shall be placed between August 31 and May 1 except by written permission of the Engineer, nor when the base or previous course is wet, nor when other weather conditions are unsuitable. Only with special permission shall rock asphalt be laid when the atmospheric temperature is below 50°F and when so permitted the rock asphalt shall be dry heated as herein before specified.

BITUMINOUS PRIME AND TACK COATS: The seasonal and temperature limitations for applying prime and tack coats shall be there specified with the type of construction with which such work is included.

BITUMINOUS CONCRETE SURFACE: No bituminous concrete shall be laid between November 15 and April 1 nor when the temperature is below 40°F except by written permission of the Engineer, nor when the underlying course is wet nor when other weather conditions are unsuitable.

BITUMINOUS MACADAM SURFACE: No bituminous penetration macadam shall be constructed between October 31 and May 1, nor when the atmospheric temperature is below 50°F, nor when the atmospheric temperature at any time during the preceding 24 hours has been below 35°F, nor when the pavement is damp or in other unsatisfactory conditions.

BITUMINOUS SURFACE: No bituminous surface shall be constructed between October 31 and May 1, nor shall mixing on the roadway be done when the atmospheric temperature is below 50°F nor when the atmospheric temperature within the preceding 24 hours has been 40°F or lower, except by written permission from the Engineer.
CONCRETE: Except by written authorization of the Engineer, concreting operations of mixing and placing shall not be continued when a descending atmospheric temperature in the shade and away from artificial heat falls below 40°F nor resumed until an ascending atmospheric temperature in the shade and away from artificial heat reaches 35°F. If such authorization is granted, the aggregate shall be heated by either steam or dry heat to a temperature of not less than 70°F nor more than 150°F. The water shall be heated to a temperature of between 130°F and 150°F. The temperature of the mixed concrete shall not be less than 60°F nor more than 100°F at the time of placing it in the form. Neither salt nor chemical admixture shall be added to the concrete to prevent freezing. When directed by the Engineer, the Contractor shall furnish sufficient canvas and frame work, or type of housing, to enclose and protect the structure in such a way that the air surrounding the fresh concrete can be kept at a temperature above 50°F for a period of five days after the concrete has been placed.

BITUMINOUS MATERIALS: Bituminous materials shall not be applied during the calendar months of December, January and February. During the remainder of the year bituminous materials shall not be applied on a wet base nor when the temperature of the air is less than 60°F in the shade.
EMBANKMENT CONSTRUCTION - GENERAL: Frozen material shall not be placed in the embankment. The embankment shall not be placed upon frozen material, except that the construction of embankments may be allowed when the depth of fill plus the depth of frozen ground beneath does not exceed 5 feet.

The construction of embankments may continue during cold weather, if all frozen soil in the top of the embankment is moved to the outside of the slopes before placing additional material. All material must be free from frost.

SAND BASE COURSE - GRAVEL BASE COURSE: May be placed upon frozen subgrade only when such subgrade has been properly constructed and compacted of unfrozen soil and/or on unfrozen embankment.

CONCRETE: Concreting shall be discontinued when the atmospheric temperature is below $40^\circ F$ in the shade and is descending, and shall not be resumed until the atmospheric temperature is as high as $35^\circ F$ in the shade and ascending.
CONSTRUCTION METHODS-EMBANKMENTS: No frozen materials shall be placed in embankments and any material which freezes after being placed in the embankment shall not be covered over until it has thawed out. Any frozen material removed from embankments shall be stockpiled outside of construction limits, and reserved for future use at a time when its condition is satisfactory to the Engineer and at no expense to the Commission. Any such material which is wasted shall be replaced by the Contractor with other acceptable material at no expense to the Commission.

SUBGRADE: No subsequent cover or surfacing material shall be deposited upon a subgrade when it is frozen, nor until it has been checked and approved by the Engineer.

DENSE GRADED STABILIZED AGGREGATE BASE COURSE: This course shall not be placed between November 15 and March 1, nor at any time when the air temperature in the shade and away from artificial heat is lower than 32°F at the location where the base material is being placed.

SAND AGGREGATE BASE COURSE: This course shall not be placed between November 15 and March 1 or at any time when the air temperature in the shade and away from artificial heat is lower than 32°F. No frozen materials shall be placed and no material shall be spread on unstable or frozen subgrade.

SOIL CEMENT BASE COURSE: No cement or soil cement mixture shall be spread when the soil or subgrade is frozen or when the air temperature is less than 40°F in the shade and falling.

PLAIN AND REINFORCED PORTLAND CEMENT CONCRETE PAVEMENT: Except by specific written authorization, concrete pavement shall not be constructed between November 16 and March 15 inclusive, nor shall concreting operations be continued when a descending temperature in the shade and away from artificial heat falls below 45°F nor may they be started until an ascending air temperature in the shade and away from artificial heat rises to 40°F or above. No cement or aggregates containing frost, frozen lumps or crusts of hard materials shall be used. No concrete shall be placed in a subgrade that is frozen or that has frost in it. During cold weather when the air temperature may be expected to drop below 40°F, a sufficient supply of hay, straw or other materials suitable for covering shall be provided along the line of work. At anytime when the air temperature
may be expected to reach the freezing point during the day or night, ma-
terial specified herein shall be spread to a sufficient depth to prevent freez-
ing, and shall remain for not less than 5 days or until the concrete has har-
dened thoroughly.

BITUMINOUS STABILIZED BASE COURSE: Bituminous materials shall be applied only between the date of May 15 and October 1 unless otherwise specified, and in no case when the air temperature is lower than 55°F.

GENERAL REQUIREMENTS FOR BITUMINOUS PENETRATIONS, BITUMINOUS ROAD MIXES, BITUMINOUS BOUND SURFACE COURSES, PRIME AND SEAL COATS OR BITUMINOUS SURFACE TREATMENTS: No bituminous material shall be applied between the dates of November 15 and March 31. Application shall be made only when weather conditions are suitable and the air temperature in the shade and away from artificial heat or road surface temperature is not less than 50°F at the location where the application is made.

SAND BITUMINOUS ROAD MIX: No bituminous material shall be applied when the air temperature is less than 60°F in the shade or when in the opinion of the Engineer, the weather conditions or the condition of the road materials are unsuitable, nor shall any bituminous material be applied except between the days of May 15 and September 30.

BITUMINOUS BOUND SURFACE COURSE: Operations on bituminous bound construction shall be discontinued in foggy or rainy weather, or when in the opinion of the Engineer, the condition of the existing surface or of the aggregate is unsatisfactory. Bituminous bound mixtures shall not be placed when the air temperature is 60°F or less and falling, but such mixtures may be placed when the air temperature is 50°F or above and rising.

PENETRATION MACADAM SURFACE COURSE: No bituminous materials may be applied unless the entire depth of the stone surface course is thoroughly dry and the air temperature is 65°F or above for Maryland A or RT-12 or 40°F or above for RC-5 and has been above 32°F for at least 8 hours.
EMBANKMENTS: Stumps, rubbish, sod or any other unsuitable materials shall not be incorporated in the embankment.

CEMENT CONCRETE PAVEMENT: Concrete shall not be placed on a frozen foundation.

Newly laid pavements shall be protected from damage by sun, rain, or cold weather, by covering it with a canvas cover supported above the surface of the pavement by wooden frames in such a manner that neither the canvas nor the frames will rest upon the surface of the concrete. Sufficient canvas to protect at least 200 lineal feet of pavement shall be provided and available for use at all times.

During cold weather, the aforesaid canvas cover shall remain in place until the concrete has dried out and hardened sufficiently to proceed with the final stage of cold weather curing. This shall consist of covering the surface of the pavement to the depth of not less than 6 inches with dry, loose straw or other approved material, which shall remain in place for not less than three days.

CEMENT CONCRETE FOR MASONRY AND BRIDGES: Concrete shall not be mixed or placed when the temperature is at or lower than $35^\circ F$ except with approval and according to directions of the Engineer. During cold weather the concrete shall be placed and maintained at a minimum temperature of $50^\circ F$. In case of extreme weather, the Engineer may, at his discretion, raise the lower limiting temperatures for water, aggregate, and mixed concrete. In cold weather, concrete for pavements shall be mixed and placed in accordance with the following special requirements: Except by written permission of the Engineer, concreting operations shall not be continued when a descending air temperature in the shade and away from artificial heat falls below $40^\circ F$ nor resumed until an ascending air temperature in the shade and away from artificial heat reaches $35^\circ F$.

When concrete operations are permitted during cold weather, the mixing water and/or aggregates may be heated by approved methods so that the temperature of the concrete shall not be less than $60^\circ F$, nor more than $100^\circ F$, at the time of placing it in the forms. The heating shall be done in a manner to preclude the occurrence of overheated areas which might result in damage to the materials. Any material containing frost or lumps of hardened materials shall not be used. If the air temperature in the shade and away from artificial heat has been at $32^\circ F$ or less during the 10 hours previous to the placing of concrete, aggregates and water shall be heated to not less than $70^\circ F$ or more than $150^\circ F$. 

Source: STANDARD SPECIFICATIONS FOR HIGHWAYS AND BRIDGES, COMMONWEALTH OF MASSACHUSETTS DEPARTMENT OF PUBLIC WORKS, 1953.
If the air temperature in the shade and away from artificial heat may be expected to reach 50°F or lower at any time during the day or night of the 24 hours following the placing of the concrete, calcium chloride shall be incorporated in the concrete mixture when directed by the Engineer.

The unit shall be entirely covered and fully cured under double thickness of saturated burlap or by an equivalent approved method for a period of seven days at a temperature of not less than 60°F. The burlap shall be kept thoroughly saturated for the entire curing period.

BITUMINOUS TREATED GRAVEL: No bituminous work shall be done during rainy weather or when weather conditions as to temperature or otherwise, in the opinion of the Engineer, are unfavorable for obtaining satisfactory results.

BITUMINOUS ROAD-MIX SURFACING: No bituminous work shall be done during rainy weather or when weather conditions as to temperature or otherwise are, in the opinion of the Engineer, unfavorable for obtaining satisfactory results.

BITUMINOUS MACADAM SURFACING: No bituminous materials shall be applied until the entire depth of surface course stone is thoroughly dry or when weather conditions as to temperature or otherwise are unsatisfactory for obtaining good results.

BITUMINOUS CONCRETE PAVEMENT: Mixture shall be placed only upon an approved, dry course and only when weather conditions are suitable. No mixture shall be placed when the temperature in the shade and away from artificial heat is 35°F or less, except by written permission from the Engineer.
BASE COURSES: Aggregate base course shall not be placed during the period from November 1 to April 15 without authorization. In addition to the above limitations, aggregate shall not be placed when there are indications that the mixture may become frozen before the maximum unit weight is obtained and, in no case, shall the aggregate be placed on a frozen subgrade.

CONCRETE PAVEMENT: Concrete shall not be deposited on a frozen subgrade, nor shall frozen materials be charged into the mixer at any time.

No pavement may be placed between November 1 and May 1 in the lower peninsula, or between November 1 and May 20 in the upper peninsula, unless it is provided for in the proposal or authorized by the Engineer. When paving is permitted during this period, the following requirements shall apply:

When the temperature of the air in the shade and away from artificial heat falls below 50°F, the mixing water or the aggregates, or both, shall be heated as required by the Engineer. The water and the aggregates shall be heated to a temperature of not less than 70°F, nor more than 150°F. The heating of aggregates shall be done by the use of steam pipes under the aggregate piles or by free steam discharged into the aggregate piles, or by steam heat in the batching bins. The temperature of the concrete at the time of placing on the subgrade shall be not less than 60°F nor more than 85°F.

Between September 15 and October 15 in the lower peninsula, when the temperature falls below 40°F at any time within 4 days after placing the pavement, the pavement shall be protected by not less than 12 inches of loose, dry straw or hay or with waterproof paper blankets, and such protective covering shall remain in place until the concrete has developed a modulus of rupture of not less than 550 lbs. per square inch as determined by testing specimens placed adjacent to the pavement and cured by the same method and materials as used for curing the pavement or until the pavement has obtained at least 70 percent of its design strength, as determined by assumed daily percentage increases in strength of concrete at various temperatures.

No concrete shall be placed when the temperature of the air in the shade and away from artificial heat is less than 20°F.

CONCRETE BRIDGE CONSTRUCTION: When ordinary protection or low temperature protection is necessary, temperature of concrete, as it is placed in the forms, shall be not less than 50°F nor more than 85°F and shall be as near 70°F as possible. At times when the prevailing temperature will produce concrete of less than 50°F, mixing water shall be heated
in order to produce concrete within the specified temperature range. If the water is heated in excess of $165^\circ F$ it shall be mixed with aggregates before the cement is added. When in the opinion of the Engineer, the air temperature may drop temporarily to not less than $35^\circ F$ during the curing period, and when it may remain less than $50^\circ F$ during such periods, the concrete shall be protected by means of tarpaulins, straw covering or other approved means.

During and after the period of pouring concrete, the heating plant shall be operated so as to maintain the temperature of the air within the enclosure as near $70^\circ F$ as possible, and it shall be maintained at all times between $50^\circ F$ and $85^\circ F$. Such temperatures shall be maintained within the enclosure until the concrete has obtained at least 50 percent of its designed strength.

Unless otherwise provided in the plans or specified, protection of concrete in low temperatures may be accomplished by the use of insulated forms as an alternate to the method of heating and housing.

Forms shall be free of ice, snow and frost at the time of pouring. No substructure concrete shall be poured when the atmospheric temperature is below $35^\circ F$ unless the interior of forms, metal surfaces and the surface of the concrete adjacent to the new pour are preheated to that temperature or higher. No substructure concrete shall be cast using insulated forms when the atmospheric temperature is below $15^\circ F$. No superstructure concrete shall be poured when the atmospheric temperature is below $40^\circ F$, unless the interior of the forms, metal surfaces and surface of the concrete adjacent to the new pour are preheated to that temperature or higher. No superstructure concrete shall be poured when the atmospheric temperature is below $30^\circ F$.

**Nonskid Surface Treatment (Distributor Application):** No bituminous materials shall be applied during rainy or threatening weather, or when the moisture on the surface to be treated would prevent satisfactory bond, or when the air temperature in the shade is less than $60^\circ F$, except by the approval of the Engineer.

**Bituminous Aggregate Surface Course - Road Mix:** Bituminous materials shall not be applied to the grade or mineral aggregate when the weather is threatening or when the temperature in the shade is less than $60^\circ F$.

The bituminous surfacing shall be performed in the lower peninsula during the period of June 1 to September 15, and in the upper peninsula during the period of June 15 to September 1, unless otherwise authorized by the Engineer.

**Bituminous Aggregate Surface Course - Plant Mix:** Bituminous mixture shall not be produced or placed during rainy or threatening weather
or when the moisture on the surface to be treated would prevent satisfactory bond or when the air temperature is less than 40°F, except by the approval of the Engineer.

The bituminous surfacing shall be performed in the lower peninsula during the period May 15 to November 1 and in the upper peninsula during the period June 1 to October 1, unless otherwise authorized by the Engineer.

BITUMINOUS AGGREGATE SURFACE COURSE - HOT PLANT MIX: Bituminous mixture shall not be produced or placed during rainy or threatening weather or when the moisture in the surface to be treated would prevent satisfactory bond or when the air temperature is less than 40°F, except by the approval of the Engineer. The bituminous surfacing shall be performed in the lower peninsula during the period May 15 to November 1 and in the upper peninsula during the period June 1 to October 1, unless otherwise authorized by the Engineer.

BITUMINOUS CONCRETE PAVEMENT: Prime coat or bond coat shall not be applied when the rain is threatening. Prime coat shall not be applied when the air temperature in the shade is less than 50°F, and the bond coat shall not be applied when the temperature is less than 40°F unless otherwise approved by the Engineer. Bituminous mixture shall not be produced or placed during the rainy or threatening weather or when the moisture on the surface to be treated would prevent satisfactory bond or when the air temperature is less than 40°F, except by the approval of the Engineer. The bituminous surfacing shall be performed in the lower peninsula during the period May 15 to November 1 and in the upper peninsula during the period June 1 to October 1 unless otherwise authorized by the Engineer.

SHEET ASPHALT: Bituminous mixture shall not be produced or placed during the rainy or threatening weather or when the moisture on the surface to be treated would prevent satisfactory bond or when the air temperature is less than 40°F, except by the approval of the Engineer. The bituminous surfacing shall be performed in the lower peninsula during the period May 15 to November 1 and in the upper peninsula during the period June to October unless otherwise authorized by the Engineer.
EMBANKMENT CONSTRUCTION: No embankment shall be constructed during periods when the embankment material freezes while being placed and compacted. No embankment shall be placed on ground frozen to a depth greater than 3 inches. Frozen lumps exceeding 6 inches in greatest dimension will not be permitted in embankments. Sod and frozen lumps less than 6 inches in greatest dimension may be placed only in that portion of the embankment which is outside of a 1 to 1 slope outward from the shoulder line but not over or adjacent to structures.

EMBANKMENTS ADJACENT TO STRUCTURES: Embankments adjacent to existing structures shall be made of suitable selected soils free of all frozen lumps.

CONCRETE PAVEMENTS: Concrete shall not be placed on any foundation whose temperature is $32^\circ F$ or less. Concrete may be placed during a period of rising temperature after the air temperature in the shade and away from artificial heat has reached $35^\circ F$. During a period of falling temperature, the placement of concrete shall be suspended when the air temperature in the shade and away from artificial heat reaches $40^\circ F$. In addition to the required curing covering, the Contractor shall place such additional covering as shall be necessary to protect the newly placed concrete from damage by freezing during the curing period.

STRUCTURAL CONCRETE: During the season of the year when atmospheric temperature of $40^\circ F$ or less may normally be expected, the work shall be protected by a substantial and wind proof housing except when the Engineer permits the use of insulated forms. Concrete shall not be placed on frozen ground nor shall it be placed on or against concrete with steel when the temperature of such concrete with steel is less than $35^\circ F$. During freezing weather, all keyways, anchor bolt holes or other depressions in horizontal concrete surfaces exposed to the weather shall be sealed against the admission of water.

CONSTRUCTION REQUIREMENTS FOR BASE COURSE, LEVELING COURSE, BINDER COURSE AND WEARING COURSE AND ANY COMBINATION THEREOF, AND ASPHALTIC CONCRETE SURFACING AND PLANT-MIXED BITUMINOUS SURFACE: Bituminous mixtures shall be placed only during the hours of daylight and when the road surfaces are dry. Mixtures may be placed when the air temperature is more than $40^\circ F$ or when the air temperature is $33^\circ F$ or more and rising, but shall not be placed when the air temperature is $40^\circ F$ or less and falling. Mixtures shall not be placed when in
the opinion of the Engineer, the weather or road bed conditions are not favorable.

LIGHT BITUMINOUS SEAL COAT: Seal coat operations shall be conducted only during hours of daylight when the air temperature is 60°F or higher, the relative humidity is less than 75% and the road surface is dry. Seal coat operations shall not be conducted before June 1 or after September 1 in that part of the state north of the east and west line through St. Cloud nor before May 15 or after September 15 in the part of the state south of that line.

SPECIAL WEARING COURSE FOR BRIDGES: Asphalt plant wearing course. Unless the air temperature is either above 50°F or between 45 and 50°F and rising, the asphalt shall be heated before being laid.

BITUMINOUS STABILIZED BASE: Bituminous material shall be applied and the mixing done only during daylight hours and when the air temperature is 50°F or higher if the blade mix method is employed. Mixing in a traveling plant may be done when the temperature is 40°F or higher.
SOIL CEMENT BASE: During seasons of probable freezing temperatures, no cement shall be applied unless the temperature is at least $40^\circ F$ in the shade and rising.

CONCRETE - GENERAL: No concrete shall be placed when the temperature is below $40^\circ F$ or when $50^\circ F$ and falling, with indications of freezing weather within 12 hours unless written permission is given by the Engineer. The use of salt or other chemical admixtures in lieu of heating aggregates and water to counteract cold weather conditions will not be permitted. When concrete is being placed during cold weather and the air temperature drops below $35^\circ F$ the Contractor shall provide suitable means for protection of the freshly poured concrete. In the case of concrete pavement, the curing water shall be omitted and the pavement covered with suitable blanketing materials such as hay, straw, or grass, to a sufficient depth to prevent freezing of the concrete before it is adequately hardened.

BITUMINOUS SURFACE TREATMENTS: Emulsified Asphalt, Cut-Back Asphalt and Light Tars shall be applied only when the air temperature is above $60^\circ F$. Heavy Tars and Asphalt Cement shall be applied only when the air temperature is above $75^\circ F$ in the shade.

Bituminous materials shall not be placed during the period between November 1 and March 1, nor when the weather is rainy or foggy.

BITUMINOUS PLANT MIXTURES: Bituminous plant mixtures shall be placed only when the air temperature is above $40^\circ F$ and rising. Bituminous material shall not be placed on frozen subgrade or when the soil contains frost.

SAND BITUMINOUS ROAD-MIX: Bituminous material shall not be applied when the temperature of the air is less than $60^\circ F$ in the shade or when, in the opinion of the Engineer, the weather conditions or that of the road bed are unsuitable.
EMBANKMENTS: Stumps, trees, rubbish, unstable soil, frozen lumps or any other deleterious materials or substances shall not be placed in embankments. Additional lifts shall not be placed if the previous lift contains an excessive amount of frost.

EXCAVATION FOR STRUCTURES: Backfill material shall be of an acceptable quality and shall be free from large or frozen lumps, wood or other extraneous material.

SOIL-CEMENT BASE: Cement shall not be applied when the material to be processed or the subgrade is frozen and unless the ambient temperature is at 40°F and rising. At any time within 7 days after placement, when the ambient temperature is expected to be 32°F, or below, the soil-cement base shall be protected against freezing.

PORTLAND CEMENT CONCRETE - PAVEMENT: Concrete shall not be mixed while the ambient temperature is at or lower than 40°F unless permission has been secured from the Engineer. Cement of fine aggregate containing lumps or crusts of hardened material or frost shall not be used. All concrete shall be effectively protected from the action of frost for a period of at least 5 days after it has been placed or until a minimum flexural strength of 500 pounds per square inch as determined by beam tests has been attained. Concrete shall not be placed upon a frozen subgrade except with the written permission of the Engineer. If the Engineer grants permission for the Contractor to place the concrete while the ambient temperature is at or lower than 40°F, the Contractor shall take precautionary measures to prevent damage by freezing, such as heating mixing water, applying a blowtorch flame directly upon the contents of the mixer, or adding a calcium chloride to the mix. Regardless of the precautions taken, the Contractor will be considered as having elected to assume all risks, and all frozen concrete shall be replaced at his expense, (Missouri allows the use of calcium chloride and air-entraining agents).

PORTLAND CEMENT CONCRETE - STRUCTURES: Cold weather concreting shall proceed on all structures, except bridge superstructures, whether or not heating is required, unless it can be definitely established that the over-all progress of the project will not be affected. Concrete placed in cold weather shall be protected from frost action during the curing period by the use of a heated weather-proof enclosure. Concrete shall not be
placed on frozen ground, or against steel or concrete surfaces with temperatures lower than 35°F, and concrete in bridge superstructures shall not be placed when the ambient temperature is below 45°F.

Curing of superstructure concrete and substructure units above ground surface, when the ambient temperature is below 40°F shall be within a weatherproof enclosure which shall be kept uniformly heated to a temperature between 50°F and 70°F for a period of at least 7 days or until the concrete has attained its specified flexural strength. When dry heat is used, at least 40 percent relative humidity shall be provided. The exposed surfaces of the concrete shall be kept moist either by the application of steam or by wet burlap mats. Calcium chloride in solution form may be added to the mix to obtain an early specified flexural strength. When curing is complete, the temperature within the enclosure shall be lowered gradually at a rate not to exceed 3°F per hour, until outside temperatures are reached. Substructure concrete below ground surface may be protected by submersion provided the temperature of the water is maintained between 45°F and 90°F for a period of 7 days.

PREPARATION OF BASE AND APPLICATION OF PRIMER: Primer shall be applied only when the ambient temperature is above 50°F, and when the ground and other conditions are favorable.

PLANT-MIX BITUMINOUS SURFACE: Bituminous mixture shall not be mixed or placed when the ambient temperature is below 40°F, or when there is frost in the subgrade or any other time when weather conditions are unsuitable for the type of material being placed. In general, bituminous materials shall not be placed between October 1 and May 1 unless the ambient temperature is not less than 40°F and rising and weather conditions within the dates set are such as to approximate those normally occurring beyond the date set in which case the placing of such materials may be permitted provided it is advantageous to the commission to do so.

WATERBOUND MACADAM BASE: CONSTRUCTION PROCEDURE: (Subgrade) Screenings shall not be spread on a wet or frozen subgrade nor for more than an average day's work ahead of the base course.

Coarse stone shall not be placed while the subgrade is soft, muddy or frozen.

ASPHALTIC CONCRETE PAVEMENT-CENTRAL PLANT-CONSTRUCTION PROCEDURE: Bituminous material shall not be mixed or placed when the ambient temperature is below 40°F or when there is frost in the subgrade or any other time when weather conditions are unsuitable for the type of material being placed. In general, asphaltic materials shall not be placed between October 1 and May 1 unless the ambient temperature is not less than 40°F and rising.
PENETRATION MACADAM SURFACE - CONSTRUCTION PROCEDURE:
No bituminous material shall be applied before May 1 nor after October 1 unless otherwise permitted by the Engineer. It shall be applied when the aggregate is dry and when the ambient temperature is above 50°F.
EMBANKMENT: Frozen materials shall never be placed in embankments. Whenever the surface of a cut or the site of an embankment is covered with snow or ice sufficient to impair the stability of the work, snow and ice must be removed and deposited beyond the slope stakes at the Contractor's own expense. Frozen excavation or that lying under a blanket of snow of such extent as to preclude its placement in the embankment will be considered cause for shutting down grading operations. Embankments constructed to grade and cross-section during the winter shall be refinished to grade and cross-section after the frost is out of the ground and the embankment is in suitable condition for this work.

SOIL CEMENT: No soil cement stabilization work shall be carried on during the seasons of probably freezing temperatures. No cement shall be applied unless the temperature is at least $40^\circ$ and rising.

PORTLAND CEMENT CONCRETE PAVEMENT: Except by specific written authorization, concreting operations shall not be continued when a descending air temperature in the shade and away from artificial heat falls below $40^\circ$ F, nor resumed until an ascending temperature in the shade and away from artificial heat reaches $35^\circ$ F. Material containing frost or lumps of hardened material shall not be used. Neither salt nor chemical admixtures shall be added to the concrete to prevent freezing. When concrete is being placed in cold weather and the air temperature may be expected to drop below $35^\circ$ F, a sufficient supply of straw, hay, grass or other suitable blanket material shall be provided along a line of the work and at any time when the air temperature may be expected to reach the freezing point during the day or night the material so provided shall be spread over the pavement to a sufficient depth to prevent freezing of the concrete before it is thoroughly hardened. The period of time over which such protection shall be maintained shall not be less than ten days.

BITUMINOUS PRIME OR TACK COAT: Prime coat may be applied only during the daylight when the atmospheric temperature is not less than $50^\circ$ F and rising. Tack coat may be applied only during daylight when the atmospheric temperature is not less than $40^\circ$ F and rising.

SEAL COAT: Seal coat operations shall not be performed prior to May 15 nor shall they be continued later than September 15. No bituminous material shall be applied when the roadway surface is damp or wet or when the atmospheric temperature or the temperature of the oil mat to which the material is being applied is less than $55^\circ$ F and rising or weather conditions are such
that the bitumen will become chilled before the cover material can be spread and rolled.

BITUMINOUS SURFACING PLANT-MIX: Plant mix bituminous surfacing shall be placed only during daylight when the air temperature is $40^\circ F$ and rising and the road surface is dry.

BITUMINOUS SURFACING ROAD MIX: The operations of bitumen application, machine or blade mixing, aeration, spreading or compacting shall not be done prior to May 15 nor shall they be continued later than September 15. Such operations shall not be done when temperature, weather and road conditions are such that the specified result cannot be obtained.
CONCRETE PAVEMENT: Concrete shall not be placed when stormy or inclement weather prevents good workmanship. The air temperature shall be at least 40°F and rising and no concrete shall be placed when the air temperature is below 40°F, except by permission of the Engineer in writing. In no case shall concrete be placed upon a frozen subgrade or granular foundation course. The pavement shall be protected against freezing for at least 7 days by covering with an adequate layer of straw or similar material. Any concrete showing injury by freezing shall be removed and replaced at the expense of the Contractor.

When it is expected that, during the progress of the work, and before all concrete has attained final set, the temperatures may fall below 40°F a sufficient supply of straw, hay, grass, or other material suitable in the judgment of the Engineer, must be maintained on hand along the roadway being concreted, to cover the concrete and to sufficiently protect the surface and edges against freezing until it is at least 10 days old. Whenever the temperature falls below 40°F, freshly finished concrete shall be protected by frames enclosed by canvas or other suitable type of housing and the temperature of the air surrounding the concrete shall be maintained at not less than 45°F. Sufficient heating apparatus, such as lanterns, suitable stoves or steam equipment, shall be furnished and maintained by the Contractor. When temperature and weather conditions are sufficiently favorable, and after the finished concrete has attained final set, the straw or other cover material may be applied to the depth and quantity ordered, in lieu of the housing and heating.

STRUCTURES - CONCRETE CONSTRUCTION: Concrete shall not be placed unless the atmospheric temperature is at least 40°F and rising without the written permission of the Engineer. When such permission is given, the Contractor shall furnish sufficient canvas and framework, or other type of housing, to enclose and protect the structure in such a way that the concrete and air surrounding it shall be maintained at a temperature between 50 and 100°F for the first 72 hours after the concrete has been placed, and at a temperature between 40 and 100°F for the next 48 hour period. The temperature of the air surrounding the concrete shall be gradually reduced to the outside air temperature at a rate not faster than 5°F in any one hour.

BITUMINOUS SAND BASE COURSE: The asphaltic materials shall not be applied when the atmospheric temperature is below 60°F, except with written approval of the Engineer. The application of asphaltic mat materials will not be permitted after September 15, except when, in the judgement of the
Engineer, temperature and other weather conditions are conducive to thorough and uniform dispersion of the asphaltic materials throughout the natural sand, and to the satisfactory drying and compaction of the bituminous sand base course.

**BITUMINOUS BASE COURSE AND BITUMINOUS MAT SURFACE COURSE:** Cut-back asphalts shall not be applied to the mineral aggregates when the atmospheric temperature is below 60°F when the blade mix method is used or below 50°F when the traveling plant method is used. The application of asphaltic materials will not be permitted after the 15th day of September without the written approval of the Engineer.

**PRIME COAT:** The application of asphaltic materials for prime coat will be permitted only when the moisture content of the surface to be covered is such as to permit satisfactory penetration, and when the atmospheric temperature is above 60°F.

**ARMOR COAT:** Application of asphaltic materials for armor coat will be permitted only when the surface to be covered is dry and the atmospheric temperature is above 60°F.

** ASPHALTIC CONCRETE SURFACE COURSE:** The asphaltic concrete mixture shall be laid only upon pavement, base course or previously laid asphaltic concrete which is dry and free from frost. The minimum atmospheric temperature at which the placement of asphaltic concrete will be permitted shall be 40°F provided that proper spreading, finishing, compacting and bonding is obtained.

**MIXED IN PLACE-BITUMINOUS SURFACE COURSE:** Asphaltic cement shall not be applied when the atmospheric temperature is below 60°F, except with the special written permission of the Engineer. The application and mixing of asphalt cement will not be permitted after September 15, except when in the judgement of the Engineer, temperature and other weather conditions are conducive to thorough and uniform dispersion of the asphalt cement throughout the natural sand, and to satisfactory drying and compaction of the bituminous surface course.

**TACK COAT:** The application of asphaltic materials for tack coat will be permitted only when the moisture content of the surface to be covered is such as to permit satisfactory penetration and when the atmospheric temperature is above 60°F.
EMBANKMENTS: Ice and snow shall be removed from the surface of the ground prior to the placing of embankment thereon. However, if subsurface materials are frozen, operations shall be suspended. No material shall be placed in the embankment when either the material foundation or the embankment on which it shall be placed is frozen.

BACKFILL: Structural backfill material shall be free from stones or lumps of material exceeding 3 inches in its greatest dimension. It shall be free from frozen earth materials and organic materials.

PORTLAND CEMENT CONCRETE: No concrete shall be mixed or placed when the atmospheric temperature is below 40°F without written permission of the Engineer, and then only when adequate means are employed to heat aggregate and water, to protect the concrete from freezing after being placed. Before concrete is placed in any form or around any reinforcement or on any surface, all ice, snow and frost shall be completely removed and the temperature of all surfaces in contact with the concrete raised above the freezing point. No concrete shall be poured on a frozen subgrade or on one that contains frozen materials. When air temperatures do not fall below 30°F, artificial heat will not be required if the concrete surface is covered with forms or with canvas arranged so that air spaces are maintained between the canvas and the concrete. Newly placed concrete shall be kept at a temperature of not less than 50°F for 7 days or not less than 70°F for 3 days and maintain a temperature of at least 40°F for the next 4 days.

BITUMINOUS BINDERS: Application of bituminous binders will not be permitted when the surface to be treated is damp or wet, or when weather conditions are unsuitable or when the atmospheric temperature or aggregate temperature is below 50°F.

BITUMINOUS ROAD MIX SURFACING: Bituminous material shall not be spread when weather conditions are unsuitable or when the atmospheric temperature or the temperature of the mineral aggregate is below 50°F.

BITUMINOUS PLANT MIX SURFACING: The bituminous mixture shall be placed only on bases that are dry, when weather conditions are suitable and the atmospheric temperature is above 50°F. The open graded plant mix surface shall be placed only when the atmospheric temperature is above 60°F.
EMBANKMENTS: Frozen material shall not be used in the construction of embankments. Embankments shall not be placed upon frozen ground. Embankments may be constructed during cold weather if all the frozen material in the top of the embankment is removed before placing additional material. The frozen lumps of earth removed shall be placed outside the limits of an assumed one and one-half to one slope, spreading outward from the break in the shoulder. The material placed in embankments shall be compacted to the required density before it has an opportunity to freeze. If this cannot be accomplished, earthwork operations shall be suspended.

BASE AND SURFACING MATERIALS AND PAVEMENTS: Only one layer of special subbase, sand or gravel shall be placed on top of any material which is frozen up to a depth of two feet. No permission will be granted to place any special subbase, sand or gravel on material containing more than 2 feet of frost.

CEMENT CONCRETE PAVEMENT: Specifications recommend that when this item is included in a proposal, all specifications will closely conform to those recommended by the AASHO and Portland Cement Association for construction methods.

STRUCTURAL CONCRETE: After the first frost, and until the mean daily temperature at the job site falls below 40°F for more than one day, concrete shall be protected from freezing not less than 48 hours after it is placed. All snow and ice shall be removed from the forms and sufficient heat shall be introduced inside of the forms to obtain and maintain a temperature above 32°F while the concrete is being placed. When insulated forms are not used and the mean daily temperature falls below 40°F for more than one day, concrete shall thereafter be placed in the forms at a temperature not less than 50°F nor more than 80°F, the warmer concrete being used on the colder days.

CLASS A BITUMINOUS SURFACE TREATMENT: Bituminous material shall be applied only when weather conditions in the opinion of the Engineer are suitable.

BITUMINOUS MACADAM: Bituminous macadam shall not be constructed from October 15 to May 15 except by written permission of the Engineer. Bituminous material shall be applied only when the air temperature is above 50°F and when the lowest air temperature in the preceding 8 hours has been
above 32°F, the weather is not foggy nor rainy, and the aggregate is dry.

HOT ASPHALT CONCRETE: The mixture shall be placed only when the underlying surface is dry, when the atmospheric temperature is above 40°F and rising and when the weather is not rainy. No material shall be laid upon a frozen base course or when conditions are such that rapid cooling will prevent unsatisfactory compaction. In special instances, when the Engineer determines that it is in the best interest of the state, he may waive the temperature requirement.
EMBANKMENT: Embankment shall not be constructed between December 1 and March 1 unless the soil moisture conditions are such that compaction can be performed as specified herein. Embankments shall not proceed during freezing weather except upon approval of, and under the regulations prescribed by, the Engineer. Embankments shall not be constructed on ice, frozen ground, or on frozen layers of embankment. Frozen embankment material shall not be used under any conditions.

CONCRETE SURFACE PAVEMENT: Concrete shall not be mixed and placed when the atmospheric temperature is at or below 36°F except with the written approval of the Engineer. If such approval be given, the Engineer may prescribe the manner in which the work is to be done, which may include the heating of the aggregate and water and the use of the accelerators or non-freezing compounds. The water shall not be heated above 165°F.

In cold weather the temperature of the concrete mixture when discharged from the mixer shall not be less than 50°F, and the concrete when placed shall be protected from freezing by covering it with a layer of hay or straw not less than 8 inches thick, over which canvas shall be spread. The canvas shall be not less than 4 feet longer than the width of the pavement and shall be laid across it with edges overlapping and ends firmly fastened. In severe weather another layer of hay or straw shall be placed above the canvas. Concrete which is frozen before it is 5 days old shall be replaced at the Contractor's expense. In advance of concreting operations, the subgrade shall not be muddy or frozen.

CONCRETE STRUCTURES: Concrete shall not be placed when the atmospheric temperature is below 36°F, except by the Engineer's approval.

In cold weather, the concrete aggregates and water shall be heated so that the concrete mass, when placed in forms, shall have a temperature not lower than 60°F, and higher if the Engineer so directs. The aggregates and the water may be heated by dry heat, steam, or if approved by the Engineer, by torch, so as to produce a uniform temperature throughout the mass without local overheating. The water shall not be heated to a temperature of more than 165°F. The concrete shall be kept at a temperature not lower than 60°F for a period of seven days after placing the concrete, and at a temperature not lower than 40°F for a period of four days thereafter; then the temperature may be gradually changed to that of the atmosphere. The concrete shall be protected by means of an enclosure or by insulation.

PENETRATION AGGREGATE SURFACE COURSE: Bituminous binder shall be applied only when the atmospheric temperature is about 50°F and has remained above 40°F for the preceding 8 hours, and the aggregate surfaces are
dry for the full depth of the course and the conditions are favorable for proper penetration and adhesion, and when the weather conditions otherwise are favorable in the opinion of the Engineer.

PENETRATION MACADAM SURFACE COURSES (HOT APPLICATION AND COLD APPLICATION): Bituminous binder shall be applied only when the atmospheric temperature is above $50^\circ F$ and has remained above $40^\circ F$ for the preceding 8 hours, when the aggregate surfaces are dry for the full depth of the course and the conditions are favorable for proper penetration and adhesion, and when the weather conditions otherwise are favorable in the opinion of the Engineer.

HOT - MIXED BITUMINOUS CONCRETE AND SHEET ASPHALT: Bituminous concrete mixture shall not be placed when the atmospheric temperature is below $40^\circ F$ except when approved by the Engineer, or when the weather is foggy, rainy, or otherwise unfavorable in the opinion of the Engineer.

COLD - MIXED BITUMINOUS CONCRETE: Bituminous concrete mixture shall not be placed when the atmospheric temperature is below $40^\circ F$ except when approved by the Engineer, or when the weather is foggy, rainy, or otherwise unfavorable in the opinion of the Engineer.
EMBANKMENT: Embankment materials shall contain no leaves, grass, sod or roots and shall be entirely free of all frozen or other deleterious materials. Embankment construction shall be suspended when embankment materials become frozen and construction operations shall not be resumed until the materials are thoroughly thawed and sufficiently dried for satisfactory compaction.

SUBGRADE: In no case shall any base or surface course be laid on a frozen or muddy subgrade.

FLEXIBLE BASE: Flexible base shall not be placed on frozen subgrade nor on subgrade which has been sufficiently softened by rain to rut under construction traffic.

PORTLAND CEMENT CONCRETE: No concrete shall be placed when the atmospheric temperature, taken in the shade and away from artificial heat, is below 40°F without the written permission of the Engineer. When such permission is given and when the official weather forecasts indicate the temperature may be expected to fall below 35°F within the next 72 hours, the following requirements shall be complied with:

For temperatures above 30°F the mixing water shall be heated to a minimum temperature of 70°F and not over 120°F. For temperatures below 30°F the mixing water shall be heated to a minimum temperature of 70°F and not over 120°F, the fine and coarse aggregate shall be heated sufficiently to prevent any frost or frozen lumps from entering the mixture, but not over 120°F.

The temperature of the mixed concrete shall not be less than 60°F at the time it is placed in the work.

The temperature of the air surrounding the exposed surface of the concrete and the temperature of the air surrounding the forms within which the concrete is placed, shall be maintained in a minimum temperature of 50°F and not to exceed a maximum temperature of 70°F for 3 consecutive days. Following this three day period the exposed surface of the concrete and the form in which the concrete is placed shall be protected from air temperatures below 35°F for 4 additional consecutive days. When high early strength concrete is used the above time limit shall be reduced as directed by the Engineer.

BITUMINOUS PRIME COAT: Bituminous prime coat shall not be applied when the temperature below the surface is below 70°F nor when in the opinion of the Engineer, general weather conditions are not suitable.
ROAD-MIXED SURFACE COURSE: Road-mixed surface course shall be placed only when a prepared base is dry, free from frost and when the surface temperature of the base is $70^\circ F$ or above.

SEAL COAT: Road-mixed surface course shall be placed only when a prepared base is dry, free from frost and when the surface temperature of the base is $70^\circ F$ or above.

ONE, TWO AND THREE COURSE SURFACE TREATMENT: One, two and three course surface treatment shall be placed only when a prepared base is dry, free from frost and when the surface temperature of the base is $70^\circ F$ or above.

PLANT-MIXED SURFACE COURSE: Plant-mixed surface course shall be placed only when the prepared base is dry, free from frost and when the weather is not foggy nor rainy. The minimum air temperature in the shade at which the pavement may be laid shall be $35^\circ F$ if rising or $40^\circ F$ if falling. No pavement shall be placed when in the opinion of the Engineer weather conditions are not suitable.

HOT-MIXED COLD-LAID SURFACE COURSE: Hot-mixed cold-laid surface course shall be placed only when the prepared base is dry, free from frost and when the weather is not foggy nor rainy. The minimum air temperature in the shade at which the pavement may be laid shall be $35^\circ F$ if rising or $40^\circ F$ if falling. No pavement shall be placed when in the opinion of the Engineer, weather conditions are not suitable.
EMBANKMENTS: Embankments shall be formed of suitable materials. Sods, roots, stumps, trees, brush, and frozen soil shall not be used. Grading operations shall not be performed from November 1 to April 1 except with written permission of the District Engineer.

SUBGRADE: When unsuitable material has been removed within the subgrade area, the material used for replacement shall not contain stones larger than 6 inches, sod, roots, frozen soil, or other objectionable material.

PROVISIONS FOR CONCRETING IN COLD WEATHER: No concrete shall be placed when the atmospheric temperature is below 40°F unless permission to do so is granted in writing by the Engineer. When directed by the Engineer the Contractor shall furnish sufficient canvas and framework, or other type of housing to enclose and protect the structure in such a way that the air, surrounding the fresh concrete, can be kept at a temperature above 50°F but not over 80°F for a period of 5 days after the concrete is placed. At the end of this five day period, the heat shall be gradually reduced no faster than one degree per hour until it equals the surrounding outdoor temperature.

Within the enclosure, such means of artificial heat shall be provided as will maintain the temperatures specified continuously and with a reasonable degree of uniformity in all parts of the enclosure. All exposed concrete surfaces within the heated area shall be kept wet during the heating period unless artificial heat is supplied in the form of live steam.

All water used for mixing concrete shall be heated to a temperature of at least 70°F but not over 150°F. Aggregates shall be heated either by steam or by dry heat to a temperature of at least 70°F but not over 150°F. The heating apparatus shall be such as to heat the mass uniformly and preclude the possibility of the occurrence of hot spots which will overheat the material. The temperature of the mixed concrete shall be not less than 60°F at the time of placing in the forms.

In cases of extreme weather conditions the Engineer may, at his discretion, raise the lower limiting temperatures for water, aggregate and mixed concrete.

CURING CONCRETE: All exposed surfaces of structural concrete and all concrete pavement on bridges shall be cured by means of quilted covers which shall be kept wet and left in place for a period of not less than 5 days. This curing period is the minimum which will be allowed not counting the
days in which the temperature is below $40^\circ F$. Quilted covers shall be placed on all exposed surfaces, which do not require forms, immediately after the concrete has been finished. This work shall be performed in a manner satisfactory to the Engineer.

Immediately prior to the placing of the pavement concrete the top of the structural slab shall be thoroughly wetted down as directed by the Engineer, if the air temperature is above $50^\circ F$, to reduce the heat in the slab.

BITUMINOUS PAVING MATERIAL: Bituminous paving material may be placed between May 15 and October 15 when the air temperature is $50^\circ F$ and rising, and the surface temperature is $45^\circ F$ or higher. Paving shall be discontinued when falling temperatures reach $50^\circ F$ in the shade.
Source: STANDARD SPECIFICATIONS FOR ROADS AND STRUCTURES, NORTH CAROLINA STATE HIGHWAY COMMISSION, APRIL 1, 1959.

SUBGRADE: In no case shall any base course, surface course, or pavement be placed on frozen or muddy subgrade. Frost crystals or mud caused by freezing and thawing shall be removed and replaced for suitable material before placing any base course or pavement on the subgrade.

COARSE AGGREGATE BASE COURSE: Subgrade reinforcement or base course materials should not be placed in a subgrade that is frozen.

STABILIZED AGGREGATE BASE COURSE: Subgrade reinforcement or base material shall not be placed on a subgrade that is frozen or soft enough to rut beneath the wheels of the hauling equipment.

PORTLAND CEMENT STABILIZED BASE COURSE: During seasons of probable freezing temperatures, no cement shall be applied unless the temperature is at least 40°F in the shade and rising.

CONCRETE PAVEMENT: Concreting operations shall not be undertaken or continued when any of the following conditions exist: (1) When atmospheric temperature during the preceding 24 hours has not risen above 40°F, (2) when atmospheric temperature has not reached 40°F by 10:00 A.M., (3) when the subgrade is frozen, (4) when aggregate either coarse or fine contains frozen particles, (5) when atmospheric temperatures falling reach 40°F, (6) when local weather reports or conditions indicate the possibility of temperatures at 32°F or lower within the ensuing 24 hours. Concrete less than 24 hours old that may be subjected to temperatures of less than 32°F shall be protected by the customary curing method and in addition, a layer of not less than 12 inches of loose dry hay or straw or other acceptable thermal insulation shall be placed on the concrete and retained in place until the required curing period is completed.

BITUMINOUS SURFACE TREATMENT CLASS A: No bituminous material shall be applied between September 30 and April 1. No prime shall be applied between September 15 and April 1, and the mat and seal application shall be applied only when the weather and temperature conditions will permit in accordance with the requirements as set forth herein. Bituminous material shall be applied only when the surface to be treated is dry and when the atmospheric temperature is above 60°F in the shade away from artificial heat.

BITUMINOUS PLANT MIX BASES AND SURFACE COURSES: No hot bituminous mixtures shall be produced or placed between December 1 and March 15 unless otherwise approved by the Engineer. Prime coat or tack coat shall not be applied when the weather is foggy or rainy or when rain
is threatening. Prime coat shall not be applied when the air temperature in the shade is less than $50^\circ F$ while tack coat shall not be applied when the temperature is less than $40^\circ F$ unless otherwise approved by the Engineer. Bituminous mixtures shall not be produced or placed during rainy weather, when the subgrade or base course is frozen or shows any evidence of excess moisture, or when the air temperature is less than $40^\circ F$ in the shade away from artificial heat.

SAND BITUMINOUS SURFACE COURSE - ROAD MIX: Bituminous material shall be applied only between the period of April 1 and October 31 when the atmospheric temperature is above $60^\circ F$ in the shade and away from artificial heat, and when the weather is not foggy or rainy.
EMBANKMENT-CONSTRUCTION METHODS: Frozen material shall not be used in construction of embankments. Frozen excavation or a blanket of snow will be considered cause for shutting down grading operations.

SOIL-CEMENT: During seasons of probable freezing temperature no cement shall be applied unless the temperature is at least 40°F and rising.

PORTLAND CEMENT CONCRETE PAVEMENT: Concrete shall not be placed upon frozen subgrade. Subgrade shall be considered as frozen if particles of frost are found in the subgrade material. After the first frost and until the mean daily air temperature at the work site falls below 40°F for more than one day the pavement shall be protected from freezing for not less than the first 48 hours after it is placed. When the mean daily air temperature falls below 40°F for more than one day the pavement shall be protected from freezing for 6 days after placement.

Admixtures to prevent freezing shall not be allowed. Protection from freezing shall consist of a cover of at least 12 inches of loose, dry hay or straw. The hay or straw cover shall completely enclose the pavement slab and shall be prevented from being blown off by wind.

STRUCTURAL CONCRETE: No concrete shall be placed when the air temperature is 35°F or lower or when such temperature can be expected within a 24 hour period immediately following the placing of the concrete unless the precautionary and protective measures specified are complied with.

BITUMINOUS TREATED BASE OR SUB-BASE: Mixing operations shall not be continued when descending free air temperature falls below 40°F and shall not be resumed until ascending free air temperature reaches 35°F. When asphalt cement is used in the mixture, mixing or laying operations will not be permitted at a free air temperature below 30°F. No material will be mixed or laid when the roadway is frozen or when any frost is evident in the material.

BITUMINOUS TREATED SOIL BASE: Mixing operations shall not be continued when a descending free air temperature falls below 40°F and shall not be resumed until an ascending free air temperature reaches 35°F. Mixing and laying operations will not be performed when the roadbed or the materials are frozen or when frost particles are present in either the roadbed or materials.
BITUMINOUS BASE COURSE: Mixing operations shall not be continued when a descending free air temperature falls below 40°F and shall not be resumed until an ascending free air temperature reaches 35°F. Mixing and laying operations will not be performed when the roadbed or the materials are frozen or when frost particles are present in either the roadbed or materials.

BITUMINOUS ROAD OR PLANT MIX WITH LIQUID ASPHALT MATERIALS: Bituminous material or mixtures shall not be mixed, laid or applied when the roadway or the material for the mixtures are frozen. The presence of frost particles in the roadbed or the materials will be sufficient evidence of being frozen. For either blade mix or traveling plant mix, no bituminous material shall be applied to the mineral aggregate when the atmospheric temperature is below 55°F. For stationary plant mix no bituminous material shall be mixed with the mineral aggregate when the atmospheric temperature is below 45°F.

HOT MIX ASPHALTIC CONCRETE WEARING COURSE: The mixture may be placed when the air temperature is more than 40°F or when the air temperature is 35°F and rising provided the temperature of the base is 35°F or higher.

BITUMINOUS SEAL COAT: Seal coat shall not be started after September 1 of any calendar year except on written permission of the Engineer. Seal work shall not be permitted when the pavement temperature is below 60°F. Coating aid shall be used when the asphalt pavement temperature is between 60 and 70°F.
EMBANKMENT: Frozen material shall not be placed in the embankment nor shall embankment be placed on frozen material.

CONCRETE: For concrete placed after November 15 and before April 1, and for that placed before or after this period when the temperature of the air, aggregates or water is $40^\circ F$ or below, the water or aggregates or both shall be heated, so that the concrete immediately after placing in the forms, shall have a temperature of between $65^\circ F$ and $85^\circ F$. Flake calcium chloride (two pounds per bag of cement) shall be incorporated into the concrete during the mixing as an accelerator.

The subgrade or subbase upon which concrete is to be placed shall be properly shaped and compacted and entirely free from frost, when the concrete is deposited.

Whenever the air temperature is less than $35^\circ F$, the concrete shall be covered and kept covered with at least 12 inches of straw.

BITUMINOUS PRIME COAT AND TACK COAT: Tack coats after September 1 and before June 1 shall not be applied when the atmospheric temperature is under $40^\circ F$. Prime coats for road mix or surface treatment work shall not be applied when the atmospheric temperature is below $50^\circ F$ nor when the air temperature within the preceding 24 hours has been $40^\circ F$ or lower. Prime coats on new macadam stabilized and granular base courses may be applied when the atmospheric temperature is $40^\circ F$ or higher.

ASPHALTIC CONCRETE SURFACE COURSE: When any mixtures are being transported at prevailing air temperatures below $50^\circ F$ or when the length of haul exceeds 20 miles, all truck pits shall be insulated to maintain workable temperatures of the mixture. All coverage shall be so fastened as to exclude all wind. No asphaltic concrete shall be placed between October 31 and May 15 of the succeeding year except by special permission by the director, nor shall asphaltic concrete be placed when weather conditions are such that proper spreading, finishing, compaction and bonding may not be obtained.

BITUMINOUS PREMIXED SURFACE COURSE: No mixtures shall be spread and finished when the air temperature is less than $40^\circ F$.

PENETRATION CHoke: The bituminous material used for penetration choke shall have the same characteristics as that used in coating the aggregate. No penetration shall be applied when the course is wet or when the
air temperature is less than $60^\circ F$ or when the air temperature during the preceding 8 hours has been less than $50^\circ F$.

**ASPHALT EMULSION:** No asphalt shall be applied when the air temperature at the job site is below $50^\circ F$ nor when the air temperature within the preceding 8 hours at the job site has been $40^\circ F$ or lower.

**PENETRATION MICARTA SURFACE COURSE:** Bituminous binders shall be applied only when the atmospheric temperature is about $50^\circ F$ and has remained above $40^\circ F$ for the preceding 8 hours. When the aggregate surfaces are dry for the full depth of the course and the conditions are favorable for proper penetration and adhesion and when the weather conditions otherwise are favorable in the opinion of the Engineer.

**BITUMINOUS CONCRETE SURFACE COURSE - HOT MIX AND CHEAP ASPHALT SURFACE COURSE:** Bituminous concrete mixtures shall not be placed when the atmospheric temperature is below $40^\circ F$ except when approved by the Engineer or when the weather is foggy, rainy or otherwise unfavorable in the opinion of the Engineer.

**BITUMINOUS MACADAM BASE COURSE:** No bituminous material shall be applied when the temperature of the atmosphere on the site is below $40^\circ F$, or when the temperature of the atmosphere within the preceding 8 hours has been $25^\circ F$, or lower nor when the aggregate in the course is damp or wet.
PORTLAND CEMENT CONCRETE PAVEMENT: Concrete shall not be placed when air temperature in the shade and away from artificial heat is below 35°F. At no time shall concrete be deposited upon a frozen subgrade nor shall chemicals be added to lower the freezing point. Materials containing frost or lumps or crust hardened materials shall not be used. If concrete has been placed in accordance with the above provisions and the temperature falls from a higher temperature to 35°F, the concrete shall be covered with dry burlap and sufficient depth of straw to prevent damage to the concrete. Concrete shall not be placed on a frozen subgrade or foundation course.

STRUCTURAL CONCRETE: No concrete shall be placed without the specific permission of the Engineer when the air temperature is at or below 35°F. If concreting in freezing weather is permitted by the Engineer, care shall be taken to prevent the use of any frozen material. In addition to adequate provision for protecting the concrete against chilling or freezing, the Contractor shall be required to heat the water and aggregate so that when deposited in the forms, the concrete will have a temperature of not less than 50°F nor more than 100°F. The concrete shall be adequately protected so as to maintain this temperature for a minimum of 72 hours after it has been placed and above 32°F for a period of 2 days additional. In the case of floor slabs, when freezing temperatures prevail, after the concrete has been placed, before danger of injury to the floor has passed, the surface shall be covered with straw mats or a layer of dry straw at least 8 inches thick or protected with sufficient lanterns or salamanders placed under canvas. This protection shall remain on the slab until danger from frost action has passed.

SOIL-ASPHALT BASE: Bituminous materials shall not be incorporated in a soil mixture when temperature in the shade is less than 50°F.

ASPHALTIC CONCRETE PAVEMENT: The minimum air temperature in the shade at which the asphaltic concrete may be laid shall be 35°F if rising, or 40°F if falling. No asphaltic concrete shall be laid when there is frost in the foundation course.

ASPHALTIC SURFACE COURSE - COLD LAID: No asphalt material shall be applied or mixed material laid down and consolidated on a damp surface or during rainy weather or when the temperature in the shade is below 50°F. No asphalt shall be applied during the calendar period of
November 1 to March 31 without written permission of the Engineer.

BLEND ROCK ASPHALT SURFACE COURSE: No rock asphalt shall be spread on a damp surface or rolled when the air temperature in the shade and away from artificial heat is below 50°F. No construction of blended rock asphalt surface course will be permitted during the calendar period from November 1 to March 31.

SAND ASPHALT BASE COURSE - HOT MIX - HOT LAID: The minimum air temperature in the shade in which asphalt may be laid shall be 35°F if rising or 40°F if falling. No sand asphalt base shall be laid when there is frost in the foundation course.

ASPHALTIC SURFACE COURSE - HOT MIX - COLD LAID: No asphaltic material shall be applied or mixed material laid down and consolidated on a damp surface or during rainy weather or when the temperature in the shade is below 50°F. No asphalt shall be applied during the calendar period of November 1 to March 1, without written permission of the Engineer.

DOUBLE BITUMINOUS SURFACE TREATMENT: No asphaltic material shall be applied or mixed material laid down and consolidated on a damp surface or during rainy weather, or when the temperature in the shade is below 50°F. No asphalt shall be applied during the calendar period of November 1 to March 21 without written permission of the Engineer.

SINGLE BITUMINOUS SURFACE TREATMENT: No asphaltic material shall be applied or mixed material laid down and consolidated on a damp surface or during rainy weather, or when the temperature in the shade is below 50°F. No asphalt shall be applied during the calendar period of November 1 to March 1 without written permission of the Engineer.
COLD WEATHER CONCRETING: Except by specific written authorization, concreting operations shall not be continued when a descending air temperature in the shade and away from artificial heat falls below 40°F, nor resume until an ascending temperature in the shade and away from artificial heat reaches 35°F. When concreting is permitted during cold weather, the aggregates may be heated by either steam or dry heat prior to being placed in a mixer. Material containing frost or lumps of hardened materials shall not be used. When the average daily temperature is below 50°F, curing will consist of covering the newly laid pavement with not less than 12 inches of loose, dry hay or straw or equivalent protective curing authorized by the Engineer, which shall be retained in place for 10 days. Admixtures for curing or temperature control may be used only when authorized by the Engineer.

CONCRETE FOR STRUCTURES: No concrete shall be placed when the atmospheric temperature is below 35°F without written permission of the Engineer. When directed by the Engineer, the Contractor shall enclose the structure in such a way that the concrete and air within the enclosure can be kept above 60°F for a period of 7 days after placing the concrete.

OIL MAT AND BITUMINOUS MACADAM WEARING SURFACES, PENETRATION TYPE: All work must be done during dry weather with dry materials and while the rock base and all other parts of the work that are being worked upon are dry and in an otherwise satisfactory condition. In general, it is a policy of the state not to permit the application of bituminous cement when the atmospheric temperature is below 70°F. Bituminous cement may be applied in lower temperatures only in cases of expediency when authorized by the Engineer. Unless otherwise specified, the special provisions of placing of asphalt or oil will be permitted only between the portion of the year which is between May 1 and October 1.
EMBANKMENT: Frozen material shall not be placed in embankments nor shall embankment be placed on material frozen to a depth of over 3 inches. If during the construction of an embankment the top layer becomes frozen to a depth of over 3 inches, the frozen material shall be removed before a succeeding layer is placed on the embankment. This work shall be performed at no additional expense to the Department. Frozen excavated material which will be suitable when dry shall be allowed to thaw, and dry and then be placed in the embankment.

SUBBASE: Subbase shall not be placed on soft, muddy or frozen subgrade nor until all irregularities in the prepared subgrade have been satisfactorily corrected.

SOIL-CEMENT BASE COURSE: Cement shall not be applied on frozen soil or base course area, nor mixed with material having a temperature less than 35°F. The surrounding air temperature must be at least 35°F and rising. The operations shall be discontinued when a descending air temperature falls below 40°F.

REINFORCED OR PLAIN CEMENT CONCRETE PAVEMENT: Any concrete placed during cold weather is at the Contractor's risk and any damaged concrete shall be removed and replaced at no expense to the Department. Except by written approval of the Engineer concrete operations shall not be continued when a descending air temperature in the shade and away from artificial heat falls below 40°F, nor resumed until an ascending air temperature in the shade and away from artificial heat reaches 35°F. When the air temperature may be expected to reach 50°F or lower at any time during the day or night, calcium chloride solutions shall be used as specified. When the air temperature may be expected to fall below 40°F at any time during the day or night of the 24 hours following placement of the concrete, the surface of the pavement shall be covered with a double thickness of saturated burlap or jute mats, and an additional layer of straw or hay which shall be placed at the rate of 300 pounds for each 35 sq. yd. of finished concrete. In lieu of this straw or hay protection the Contractor may use additional mats three or four layers in thickness as directed. Cement concrete shall be maintained at a temperature of not less than 50°F for the first 96 hours after it is placed.

BITUMINOUS MATERIAL: No bituminous material shall be applied unless the entire surface has been in condition to permit a satisfactory penetration
and adhesion and both the air temperature and surface course aggregate on which it is placed are at 50°F or above.

ASPHALTIC CONCRETE: Placing of asphaltic concrete shall be terminated between October 15 and October 31 and shall not be resumed prior to April 1 to April 15 as determined by the chief Engineer depending on weather conditions and the location of the project. Asphaltic concrete shall not be placed when the air temperature is 40°F or lower nor when the temperature of the pavement base or binder on which it is to be placed is 40°F or lower.
EMBANKMENT: Frozen soil, ice, snow, trees, stumps, rubbish or other perishable materials shall not be placed in embankments.

BACKFILL FOR STRUCTURES: All material used for backfill shall be of a quality acceptable to the Engineer and shall be free from large or frozen lumps and other unsatisfactory material.

SOIL-CEMENT BASE COURSE: At any time when the air temperature may be expected to reach the freezing point during the day or night, sufficient protection shall be given to soil-cement base course to prevent its freezing for 7 days after placement and until the soil-cement base course has hardened.

PORTLAND CEMENT CONCRETE PAVEMENT: Except by a specific written authorization, concrete operations shall not be continued when a descending air temp in the shade away from artificial heat falls below 40°F, nor resumed until an ascending air temperature in the shade and away from artificial heat reaches 35°F. When concreting is permitted during cold weather, the aggregates may be heated by either steam or dry heat prior to being placed in an exit. If the temperature is 32°F or less at the time of placing concrete, the Engineer may require either or both of water and aggregates to be heated to not less than 70°F and not more than 150°F. Material containing frost or lumps of hard material shall not be used. When the average daily temperature is below 50°F, curing shall consist of covering the newly laid pavement with not less than 12 inches of loose, dry hay or straw or equivalent protective curing authorized by the Engineer, which shall be retained in place for 10 days. When concrete is being placed during cold weather and the air temperature may be expected to drop below 35°F, a sufficient supply of straw, hay, grass, or other suitable blanketing material shall be provided along the work, and any time when air temperature may be expected to reach the freezing point during the night, the materials so provided shall be spread over the pavement to a sufficient depth to prevent freezing of the concrete.

BITUMINOUS PRIMER COAT: The primer application shall be put on only during daylight hours in favorable weather, namely dry, warm, and reasonably clear. The air temperature shall be at least 60°F in order to be considered suitable for primer application. The temperature requirement may be waived if deemed advisable by the Engineer. No primer application will be permitted later than November 1 nor earlier than May 1.
SEAL COURSE-FLUSH SEAL: Flush seal shall consist of a light uniform application of the plan shown grade of asphalt immediately covered with blotting sand at the plan shown rates for each. Air temperature and weather requirements for the project shall be warm, dry, clear and at least $50^\circ F$ air and road surface temperature. No flush seal shall be applied when the wind velocity is greater than 20 MPH or later than November 15.

SAND SEAL: The application requirements for the asphalt that is considerably prepared by bituminous mat surface shall be the same as described in the foregoing except that a minimum air temperature on the project of $60^\circ F$ is required instead of $50^\circ F$. Also, the work shall be limited to that time of the year between May 1 and October 1 inclusive.

CHIP SEAL: It shall be warm, at least $70^\circ F$ on the project, dry, and be between June 1 and October 1 inclusive.

BITUMINOUS TREATED GRADED AGGREGATE: The traveling plant shall be operated to mix mineral aggregate and bitumen only during favorable weather, namely dry and warm. The air temperature on the project shall be at least $50^\circ F$ and rising. The mat shall be laid immediately, during a daylight hour, following the tack coat application during favorable weather, namely $60^\circ F$ or more and dry.

STATIONARY PLANT MIX: The mat course shall be constructed only between May 1 and November 15 inclusive, and operations shall be carried on only when the base and surface is dry, when the atmospheric temperature on the project is at least $35^\circ F$ and rising, and when the weather is dry and favorable.
EMBANKMENTS: Only suitable materials shall be used in construction of embankments. Unsuitable or perishable materials such as rubbish, sod, brush, hedge, roots, stumps, bodies, limbs, and branches of trees, logs, poles, or pole stubs, heavy vegetation, etc. shall not be incorporated, imbedded or buried in an embankment.

WATERBOUND MACADAM BASE: Waterbound macadam base unless otherwise stipulated, shall not be constructed when the temperature of the air, in the shade and away from artificial heat, is $35^\circ F$ and falling but may be constructed when said air temperature is $35^\circ F$ and rising; shall not be constructed when freezing temperatures are anticipated, by weather reports or otherwise, before the construction has had time to dry sufficiently to prevent freezing; and shall not be constructed on a subgrade or subbase which is frozen or contains frost.

GRAVEL OR CHERT BASE: Gravel or chert, unless otherwise stipulated, shall not be constructed when the temperature of the air, in the shade and away from artificial heat, is $35^\circ F$ and falling but may be constructed when said air temperature is $35^\circ F$ and rising; shall not be constructed when freezing air temperatures are anticipated, by weather reports or otherwise, before the construction has had time to dry sufficiently to prevent freezing; and shall not be constructed on a subgrade or subbase which is frozen or contains frost.

SOIL CEMENT BASE COURSE: During seasons of probable freezing temperatures, no cement shall be applied unless the temperature is at least $40^\circ F$ in the shade and rising.

CEMENT CONCRETE BASE: Concrete shall not be mixed, except as hereinafter provided, when the air temperature in the shade and away from artificial heat is as low as $40^\circ F$ and falling. Concrete may be mixed and placed when the air temperature in the shade and away from artificial heat is $35^\circ F$ and rising. The temperature of the concrete when placed shall not be less than $45^\circ F$.

When the temperature of the air in the shade and away from artificial heat is below $50^\circ F$ but not below $35^\circ F$ wetting shall be admitted. When concrete is being placed during cold weather, and the air temperature in the shade, away from artificial heat, is or may be expected to drop below $35^\circ F$, a sufficient supply of straw, hay, grass, or other suitable blanket material shall be provided along the line of the construction and at any
any time when the air temperature may be expected to reach the freezing point during the day or night, materials so provided, shall be spread over the surface and sides of the slab to sufficient depth to prevent freezing of the concrete before it has thoroughly hardened, but care must be taken during application not to mar the surface of the concrete. If required by the Engineer, concrete laid less than 24 hours when the air temperature in the shade and away from artificial heat drops or may be expected to drop below 35°F, shall be enclosed by canvas or other approved material stretched on frames or similar heating enclosures, or devices, capable of maintaining the temperature within the enclosure at not less than 50°F.

CEMENT CONCRETE PAVEMENT: Concrete shall not be mixed, except as hereinafter provided, when the air temperature in the shade and away from artificial heat is as low as 40°F and falling. Concrete may be mixed and placed when the air temperature in the shade and away from artificial heat is 35°F, and rising. Concrete shall not be deposited when its temperature is lower than 45°F. Concrete may be mixed during the prohibited temperature periods provided the aggregates and water are heated to between 70°F and 150°F.

Approved chemical admixtures will be permitted to be used in lieu of heating the material when approved by the Engineer.

Concrete shall not be placed on a subgrade which is frozen or which contains frost.

When the temperature of the air in the shade away from artificial heat is below 50°F and not below 35°F wetting shall be omitted.

When concrete is being placed during cold weather and the air temperature in the shade and away from artificial heat, is or may be expected to drop below 35°F sufficient supply of straw, hay, grass or other suitable blanket material, shall be provided along the line of the construction and, at any time when the air temperature may be expected to reach freezing point during the day or night, the material so provided shall be spread over the surface and side of the slab to sufficient depth to prevent freezing of the concrete before it has thoroughly hardened, but care must be taken during application not to mark the surface of the concrete. The concrete shall be protected until it has obtained an age of at least 5 days or longer if it is the opinion of the Engineer that the concrete has not developed the strength that would protect it from freezing. If required by the Engineer, concrete laid less than 24 hours when air temperature in the shade and away from artificial heat drops below 35° F shall be enclosed by canvas or other approved material stretched on frames or similar heating enclosures. Devices shall be operated capable of maintaining the temperatures in the enclosures at not less than 50°F.

BITUMINOUS MAGADAM BASE (PENETRATION METHOD): Bituminous materials shall be applied only when the crushed stone is dry; only between
April 1 and November 1; and, unless otherwise directed, only when the temperature of the air in the shade and away from artificial heat, is above 50°F and when said air temperature, during the eight hours immediately preceding, has not been below 35°F. It shall not be applied when it chills too rapidly to permit the proper sequence of construction operations; nor when the crushed stone is so cold that proper bond between the constituents fails to develop during the construction operations.

BITUMINOUS STABILIZED BASE COURSE (TAR): No tar shall be applied unless the air temperature is above 50°F in the shade, nor between October 31 and March 15, except with the written consent of the Engineer.

SAND ASPHALT BASE COURSE: Bituminous materials shall be applied only on a dry unfrozen subgrade; only when the temperature of the air is higher than 40°F, in the shade; only between March 1 and December 1, except with the written permission of the Engineer.

BITUMINOUS PRIME COAT: Bituminous material shall be applied only on a surface which may be slightly damp but is not wet; only when the air temperature in the shade and away from artificial heat is more than 60°F; and only between April 1 and November 1.

HOT BITUMINOUS SEAL COAT: Bituminous material shall be applied only on the surface designated which shall be intact, firm, properly cured, and thoroughly dry; only between April 1 and November 1; and, unless otherwise directed, only when the temperature of the air, in the shade and away from artificial heat, is above 60°F and when said air temperature, during the 4 hours immediately preceding, has not been below 45°F. Bituminous material shall not be applied when it chills too rapidly to permit the proper sequence of construction operation; and when the mineral aggregate is too cold for the proper bond between the constituents to develop during construction operations.

COLD BITUMINOUS SEAL COAT (DRAG SEAL): Bituminous material shall be applied only on the designated surface which shall be firm, intact, properly cured, and thoroughly dry; only when the temperature of the air in the shade and away from artificial heat is above 60°F and when said air temperature, during the 4 hours immediately preceding, has not been below 45°F.

SINGLE BITUMINOUS SURFACE TREATMENT: Bituminous material shall be applied only on the surface designated which shall be intact, firm, properly cured, and thoroughly dry; only between April 1 and November 1; and,
unless otherwise directed, only when the temperature of the air, in the shade and away from artificial heat, is above 60°F and when said air temperature during the 4 hours immediately preceding, has not been below 45°F.

Bituminous materials shall not be applied when it chills too rapidly to permit the proper sequence of construction operations; nor when the mineral aggregate is so cold that the proper bond between the constituents fails to develop during construction operations.

BITUMINOUS ROAD MIX SURFACE COURSE: Bituminous material shall be applied only when the surface and mineral aggregate are dry, only between April 1 and November 1; and, unless otherwise directed, only when the temperature of the air in the shade and away from artificial heat is above 60°F and when said air temperature during the 4 hours immediately preceding has not been below 45°F.

BITUMINOUS MACADAM SURFACE COURSE (PENETRATION METHOD): Bituminous material shall be applied only when the crushed stone is dry; only between April 1 and November 1; and, unless otherwise directed, only when the temperature of the air in the shade and away from artificial heat, is above 50°F and when said air temperature during the eight hours immediately preceding has not been below 35°F. It shall not be applied when it chills too rapidly to permit the proper sequence of the construction operations; nor when the crushed stone is so cold that proper bond between the constituents fails to develop during the construction operation.

 ASPHALTIC CONCRETE BINDER COURSE: The mixture shall be spread only on the surface designated, only when the said surface has been previously prepared, is intact, firm, properly cured, dry, and the tack coat is in satisfactory condition; only between March 1 and December 1; and unless otherwise directed, only when the air temperature in the shade and away from artificial heat is above 40°F.

 ASPHALTIC CONCRETE SURFACE COURSE: The mixture shall be spread only on the surface designated; only when the said surface has been previously prepared, is intact, firm, properly cured, dry, and the tack coat is in satisfactory condition; only between March 1 and December 1; and unless otherwise directed, only when the air temperature in the shade is above 40°F.

SHEET ASPHALT SURFACE COURSE: The mixture shall be spread only between March 1 and December 1 and, unless otherwise directed, only when the air temperature, in the shade and away from artificial heat is above 40°F.

STRUCTURAL BACKFILL: Backfill material shall be free from large or frozen lumps, wood or other extraneous material.

PLACING CONCRETE: Concrete shall not be placed when the temperature is below 40°F and falling; but may be placed when the temperature is above 35°F and rising, the temperature being taken in the shade away from artificial heat. When such permission is granted, the Contractor shall furnish an approved enclosure, such as canvas-covered framework, to enclose and protect all pavements so placed and shall maintain the temperature of the air surrounding the concrete at not less than 50°F, for not less than 5 days. When concrete is being placed in cold weather, other than under the conditions stated above, Contractor shall have available a sufficient supply of an approved covering material to immediately protect the concrete when the air temperature falls to 32°F before concrete has been placed 4 hours. Neither salt nor other chemical admixtures shall be added to the concrete to prevent freezing. Concrete shall not be placed before the time of sunrise and shall not be placed later than will permit the finishing of the concrete during sufficient natural light.

ASPHALT UNDERSEAL FOR CONCRETE PAVEMENT: The asphalt shall not be applied when the air temperature is below 60°F and is falling, but it may be applied when the air temperature is above 50°F and is rising, the temperature being taken in the shade and away from artificial heat, with the further provision that the asphalt shall be placed only when general weather conditions, in the opinion of the Engineer, are suitable.

PRIME COAT, TACK COAT, AND ASPHALTIC MIXTURE: The prime coat, tack coat or the asphaltic mixture when placed for the spreading and finishing machine shall not be placed when the air temperature is below 50°F, and is falling, but it may be placed when the air temperature is above 40°F and is rising. The asphaltic mixture when placed with a motor grader shall not be placed when the air temperature is below 60°F, and is falling but may be placed when the air temperature is above 50°F and is rising. The air temperature shall be taken in the shade away from artificial heat.

ONE, TWO, AND THREE COURSE SURFACE TREATMENTS: Surface treatments shall not be applied when the air temperature is below 60°F and falling, but it may be applied when the air temperature is above 50°F and is rising, the air temperature being taken in the shade and away from artificial heat. Asphaltic material shall not be placed when general weather conditions, in the opinion of the Engineer, are not suitable.
SEAL COAT: Seal coat shall not be applied when the air temperature is below 60°F and falling, but it may be applied when the air temperature is above 50°F and is rising, the air temperature being taken in the shade and away from artificial heat. Asphaltic material shall not be placed when general weather conditions, in the opinion of the Engineer, are not suitable.
EMBANKMENT: If the top layer of embankment becomes frozen or if frozen material is delivered to the fill, operations shall be suspended until conditions are favorable for proper compaction.

PORTLAND CEMENT CONCRETE PAVEMENT—PREPARATION OF BASE: The subgrade shall be in a moist but not muddy or frozen condition at the time of placing concrete. Concrete shall not be placed on a frozen subgrade.

PORTLAND CEMENT CONCRETE PAVEMENT: Except by specific written authorization, concreting operations shall not be continued when a descending air temperature in the shade and away from artificial heat falls below 45°F, nor resumed until an ascending air temperature in the shade and away from artificial heat reaches 40°F. A membrane curing agent shall be applied and newly laid pavement shall be protected with not less than 12 inches of loose, dry hay or straw, which shall be retained in place for 7 days. Neither salt nor chemical admixtures shall be added to the concrete to prevent freezing.

CONCRETE STRUCTURES: Except by specific written authorization from the Engineer, concreting operations shall not be continued when a descending air temperature in the shade and away from artificial heat falls below 40°F, nor shall operations be resumed until ascending air temperature in the shade and away from artificial heat reaches 35°F. The use of chemical additives to prevent freezing will not be permitted. When concrete is being placed during cold weather and the air temperature may be expected to drop below 35°F the air temperature surrounding the concrete shall be maintained at a temperature of 60°F for at least 72 hours, and not less than 40°F for a period of not less than 7 days. Under no circumstances shall concreting operations continue when the air temperature is less than 20°F.

BITUMINOUS PRIME AND TACK COAT: Prime coat shall be applied only between May 1 and October 1 and applications shall be made only when the surface to be treated is dry and the atmospheric temperature is above 50°F and when the weather is not foggy or stormy. The temperature and seasonal requirements may be waived, but only by written authorization of the Engineer.

SEAL COAT: Seal coat shall be applied only between May 1 and October 1 and application shall be made only when the surface to be treated is dry and the atmospheric temperature is above 50°F and when the weather is not
foggy nor rainy. The temperature and seasonal requirements may be waived but only if so directed by written authorization of the Engineer.

BITUMINOUS CONCRETE SURFACE COURSE: The bituminous concrete shall not be placed if the air temperature is below 50°F or when, in the opinion of the Engineer, weather conditions are unsuitable.

ROAD MIXED BITUMINOUS SURFACE: Bituminous materials shall not be spread when the air temperature is less than 60°F without written permission from the Engineer.
EMBANKMENTS: Frozen material shall not be used in the construction of embankments, nor shall the embankments be placed upon frozen material.

CEMENT CONCRETE PAVEMENT: Except by specific written authorization, concreting operations shall not be continued when a descending air temperature in the shade and away from artificial heat falls below 40°F, nor resumed until an ascending air temperature in the shade and away from artificial heat reaches 35°F. When concreting is permitted in cold weather, the aggregates may be heated either by steam or dry heat prior to being placed in the mixer, or they may be heated after being placed in the mixer by heaters which project a flame into it. Both fine and coarse aggregates shall be heated to a temperature of at least 70°F and not more than 150°F. If necessary, the water shall be previously heated so as to maintain proper temperature in the mix. The temperature of the mixed concrete shall not be less than 60°F nor more than 100°F at the time of placing it in the forms.

When concrete is placed under the conditions stated above and it is expected that the temperature will fall below 32°F, a sufficient supply of straw, hay or other suitable material must be on hand along the roadway being concreted to cover the pavement and to sufficiently protect its surface and sides against freezing. The concrete shall be kept at a minimum temperature of 50°F for a period of at least 5 days. Lanterns hung within frames enclosed by canvas or other approved material, or fires built in containers or on the ground and maintained at close intervals along the roadside, may be used. The period of time over which such protection shall be maintained need not, in general, exceed 72 hours prior to the placing of the hay cover.

The Contractor shall be responsible for the quality and strength of the concrete laid during cold weather and any concrete injured by frost action shall be removed and replaced at his expense.

CONCRETE STRUCTURES: When placing concrete at or below a temperature of 40°F, or whenever, in the opinion of the Engineer, atmospheric temperatures will probably fall below this limit within the next 24 hours period after placing concrete, the mixing water and aggregates shall be heated and the freshly placed concrete protected by adequate housing or covering and heating. No concrete shall be poured when the temperature of the atmosphere is lower than 10°F except by special permission of the Engineer.
The water used for mixing concrete shall be heated to a temperature of at least 70°F, and to the boiling point if necessary, so that, when mixed with the heated aggregates, the temperature of the concrete at the time of placing in the forms shall be not less than 60°F nor more than 100°F. No aggregate containing frozen lumps, ice or snow, shall be allowed to enter the mixer.

The use of salts, chemicals or other foreign materials in the mix to lower the freezing point of the concrete is prohibited.

Before placing the concrete in any form, or on any surface or around reinforcement, heat shall be applied in such a manner that ice, snow, and frost will be completely removed.

No concrete shall be placed on a subgrade that is frozen or on one that contains frozen materials. Frozen subgrade shall be thawed the day previous to the placing of the concrete and shall be kept continuously thawed until the concrete is poured.

The Contractor shall furnish sufficient canvas and framework or other suitable type of housing, to enclose and protect the structure in such a way that the air surrounding the fresh concrete can be kept continuously at a temperature of 70°F, or greater, for the period specified below. All housing shall be built in such a manner that, if the river rises, it will not interfere with heating of the enclosure.

Structural concrete shall be heated in such a manner that the air within the enclosure and the concrete can be kept at 70°F or above for a period of 5 days (7 days for floor slabs) and for whatever additional time may be required to develop a modulus of rupture of 380 pounds as shown by test beams. It shall then be kept above 40°F for an additional period of 9 days. The temperature may then be gradually lowered to that of the surrounding atmosphere, taking at least 48 hours for the transition. These periods may be reduced if, in the opinion of the Engineer, the beam tests indicate that the concrete has attained a sufficient strength and degree of curing in a shorter time.

STABILIZED GRAVEL SURFACE COURSES-BITUMINOUS MATERIALS:
No mixing shall be done when the atmospheric temperature is 50°F or below. No bituminous material shall be applied when, in the judgement of the Engineer, the road surface or the aggregate is not dry, or when weather conditions or other conditions are unfavorable to the performance of satisfactory work. No bituminous material shall be applied for mixing or seal coat after October 1 unless permitted in writing by the Engineer.

TACK COAT: No bituminous material shall be applied when the atmospheric temperature is 50°F or below. No bituminous material shall be applied after October 1 unless permitted in writing by the Engineer.
PREMIXED BITUMINOUS GRAVEL: No bituminous material shall be applied when the atmospheric temperature is 50°F or below. No bituminous material shall be used in mixing and placing of Premixed Bituminous Gravel Shoulder Course after November 1 unless permitted in writing by the Engineer.

CRUSHED GRAVEL MIXED IN PLACE: No bituminous material shall be applied when the atmospheric temperature is 50°F or below. No bituminous material shall be applied for mixing or seal coat after October 1 unless permitted in writing by the Engineer.

HOT-MIXED MACADAM: No bituminous materials shall be applied when the atmospheric temperature is 50°F or below. Bituminous material shall not be applied, when in the judgement of the Engineer, circumstances, including but not limited to the road surface conditions and the weather conditions, are unfavorable to the performance of satisfactory work. No bituminous material shall be used for mixing or for seal coat after October 1, unless permitted in writing by the Engineer.

BITUMINOUS MACADAM: No asphalt cement shall be applied unless the No. 1 Stone is thoroughly dry for its entire depth and the air temperature is at or above 50°F. No asphalt cement shall be applied after October 1 unless permitted by the Engineer.

BITUMINOUS CONCRETE: No mixture shall be placed when the air temperature in the shade and away from artificial heat is 40°F or less, except by written permission of the Engineer. No bituminous material for top course shall be applied after October 15 unless permitted in writing by the Engineer. No bituminous material for bottom course shall be applied after November 15 unless permitted in writing by the Engineer.
SOIL CEMENT BASE COURSE: Soil cement shall not be applied on frozen soil or when the subgrade beneath it is frozen. The air temperature shall be $40^\circ F$ and rising before processing operations are begun each day.

BITUMINOUS STABILIZED BASE COURSE: No bituminous stabilized base construction shall be performed between November 1 and April 1 without written authority. The bituminous material shall not be applied when the earth temperature is less than $40^\circ F$ or when the weather conditions are otherwise unfavorable.

COMBINATION WATERBOUND AND PENETRATION MACADAM BASE: No bituminous material shall be applied when the air temperature is less than $40^\circ F$, when the No. 3 aggregate is damp or when the bottom course contains water.

PLAIN CEMENT CONCRETE PAVEMENT: At the time of placing the concrete the subgrade shall not be soft or frozen.

No concrete shall be mixed while the air temperature is below $35^\circ F$ without the approval of the Engineer, and only when adequate means are employed to heat the water and aggregate, to raise the temperature of the concrete to not less than $75^\circ F$ or more than $100^\circ F$ when placed in the forms.

For all concrete placed at any time when the air temperature is $50^\circ F$ or below, adequate means shall be employed to heat the water and the aggregates so that the concrete after placing in forms shall be between $75^\circ F$ and $100^\circ F$. The pavement shall be covered in a suitable manner to maintain the temperature of the deposited concrete for a minimum of 72 hours at not less than $60^\circ F$. When approved, other methods of curing and protecting the new concrete may be used.

Between November 1 and April 1 the Contractor shall use waterproof paper or other approved materials for curing and shall take such condition- al measures as may be necessary to prevent damage to the concrete from freezing and frost action. The protective covering shall be left in place not less than 72 hours or as much longer as may be required according to the weather conditions.

BITUMINOUS SURFACE TREATMENTS: No bituminous material shall be applied between November 1 and April 1 except by written authorization. Treatment shall be applied only when the atmospheric temperature is above $50^\circ F$, and when the weather is not foggy and damp, or as directed.
BITUMINOUS CONCRETE PAVEMENTS: Bituminous concrete pavement shall not be applied between November 1 and April 1. It shall not be applied on wet surfaces; when the air temperature is below 45°F in the shade and falling or below 40°F in the shade and rising during clear weather, or when the weather conditions otherwise prevent the proper handling or finishing of the bituminous paving mixtures. Any changes in these limitations shall be specifically authorized.
SUBGRADE: When in the opinion of the Engineer, the weather is such that satisfactory results cannot be secured, the Contractor shall suspend operations until the weather is favorable. No surfacing materials shall be placed in the snow, or on a soft, muddy, or frozen subgrade.

CEMENT CONCRETE PAVEMENT: Cement concrete pavement shall not be placed when the atmospheric temperature is below 40°F nor during heavy rainfall nor when the surface upon which it is to be placed is frozen. If during the contract the temperature will, in the opinion of the Engineer, drop to 30°F within 24 hours, all concrete that has been cured less than 50% of the specified time for wet curing and which has not already been protected by the earth covering method shall be immediately covered with at least 2 inches of earth upon which no water shall be applied until the Engineer shall determine there will be no further danger from freezing. If at any time during the progress of the work the temperature will, in the opinion of the Engineer, drop to 24°F, all concrete pavement that has not been cured for 50% of the time specified for the wet curing shall immediately be covered with 12 inches of loose, dry straw. Straw or earth covering as above provided shall remain in place for at least the length of time for which the mix is designed and for such additional length of time as the Engineer may direct.

CONCRETE STRUCTURES: Concrete for structures shall not be placed on frozen ground nor shall it be mixed or placed while the atmospheric temperature is below 35°F unless adequate means are employed to heat the aggregates and water and satisfactory provision has been made for protecting the water. Concrete shall be effectively protected from cold temperatures for a period of 5 days after placing. Forms shall not be released from under concrete which has been placed at a temperature under 50°F without first determining if the concrete has gained adequate strength without regard to the time element.

BITUMINOUS SURFACE TREATMENT: Asphalt shall not be applied to wet material. It is the policy of the state to prohibit the application of any asphalt when the ground temperature is less than 50°F. The Engineer may require the Contractor to delay the application of asphalt until the atmospheric and roadway conditions are satisfactory. Construction of bituminous surface treatments on any travel way shall not be carried out between the dates September 15 and June 15 of any year except upon written order from the District Engineer.
BITUMINOUS ROAD MIX: It is the policy of the state to prohibit the application of any asphalt cement when the ground temperature is below 50°F. The Engineer may require the Contractor to delay the application of asphalt and cover stone until the roadway and atmospheric conditions are satisfactory. Asphalt for prime coat shall not be applied when the ground temperature is lower than 50°F without written permission of the Engineer. Asphalt concrete shall not be placed when the atmospheric temperature is lower than 40°F nor during heavy rain fall nor when the surface upon which it is to be placed is frozen.

EMBANKMENT CONSTRUCTION: Sod, stumps, spongy or frozen soil and other material which is unsuitable or which cannot be satisfactorily compacted shall not be used for backfilling, embankments, subgrade, or shoulders, but shall be disposed of by the Contractor in a manner approved by the Engineer.

PLACING OF EMBANKMENT: Material to be used in embankment shall be reasonably free of organic materials, spongy or frozen soil or other objectionable material or substances which will prevent satisfactory compaction.

TRAFFIC BOUND BASE COURSE: No aggregates shall be laid upon a wet, muddy, frozen or unstable subgrade.

CRUSHED SUBBASE COURSE: No aggregates shall be laid upon a wet, muddy, frozen or unstable subgrade.

SOIL-CEMENT BASE COURSE: No cement shall be applied when the soil in subgrade is frozen. The air temperatures shall be at least $40^\circ F$ in the shade and rising.

PORTLAND CEMENT CONCRETE PAVEMENT: Except by specific written authorization, concreting operations shall not be undertaken or continued when a falling air temperature in the shade and away from artificial heat falls below $40^\circ F$, nor resumed until the rising air temperature in the shade and away from artificial heat reaches $35^\circ F$. After November 15 and before April 1, and before and after this period when the temperature of the air, aggregate or water is $40^\circ F$ or below, flake calcium chloride, at the rate of 1 pound per bag of cement, shall be incorporated into the concrete as an accelerator. The use of other admixtures except those permitted as air entraining agents will not be allowed. If during the 10 hours previous to the placing of the concrete, the temperature has been $32^\circ F$ or less, the aggregates and water shall be heated to not less than 70 nor more than $150^\circ F$. Materials containing frost or lumps of hard materials shall not be used. Neither salt nor chemical admixtures shall be added to the concrete to prevent freezing. When concrete is being placed during the cold weather and the air temperature may be expected to drop below $35^\circ F$ a sufficient supply of straw, hay, grass or other suitable blanketing material shall be provided along the line of work and when in the opinion of the Engineer the air temperature may be expected to reach the freezing point this material shall be spread over the pavement as above specified to prevent freezing of the concrete. This protection shall be maintained for not less than 10 days.
BITUMINOUS PRIME COAT: Bituminous prime coat or tack coat shall be applied only between May 1 and October 1 and when the conditions of the base or existing surfaces is satisfactory to the Engineer, the atmospheric temperature is above 50°F and when the weather is not foggy or rainy. The temperature and seasonal requirements may be waived but only if so directed by the Engineer in writing. Also for road mix surfaces and bituminous surface treatment placed by travel plant and penetration macadam.

HOT LAID ASPHALTIC CONCRETE BASE, BOTTOM WEARING AND PATCHING, AND LEVELING COURSE: Asphalt concrete pavement shall be constructed only between April 15 and November 1 and application of bituminous materials shall then be made only when the condition of the aggregate in base is satisfactory to the Engineer, the atmospheric temperature is about 45°F, and the weather is not foggy, or rainy. Temperature and seasonal requirements may be waived but only when directed by the Engineer in writing.

LIGHT SEAL, SINGLE AND DOUBLE SURFACE TREATMENTS: Light seal treatments and single and double surface treatments shall be applied only between May 1 and October 1 and when the conditions of the base or existing surfaces are satisfactory to the Engineer, the atmospheric temperature is above 50°F, and when the weather is not foggy, or rainy. The temperature and seasonal requirements may be waived but only if so directed by the Engineer in writing.

ROAD-MIX SURFACES: Road-mix surfaces shall be applied only between May 1 and October 1 and when the conditions of the base or existing surfaces are satisfactory to the Engineer, the atmospheric temperature is above 50°F, and when the weather is not foggy or rainy. The temperature and seasonal requirements may be waived but only if so directed by the Engineer in writing.

TRAVEL PLANT BITUMINOUS SURFACE TREATMENT: Bituminous material shall be applied only between May 1 and October 1 and when the conditions of the base or existing surfaces are satisfactory to the Engineer, the atmospheric temperature is above 50°F, and when the weather is not foggy or rainy. The temperature and seasonal requirements may be waived but only if so directed by the Engineer in writing.

PENETRATION MACADAM: Penetration macadam shall be applied only between May 1 and October 1 and when the conditions of the base or existing surfaces are satisfactory to the Engineer, the atmospheric temperature is above 50°F, and when the weather is not foggy or rainy. The temperature and seasonal requirements may be waived but only if so directed by the Engineer in writing.
EMBANKMENTS: Frozen lumps of soil shall not be permitted to be placed in embankments inside the slope limits of 1:1. Ice and snow shall be removed from the surface of the ground prior to placing embankment thereon. Unless otherwise provided in the contract, the construction of embankments shall be discontinued in the fall or early winter when weather conditions prevail which will cause substantial freezing of the material as they are placed in the embankment except when the materials used are from rock excavation and contain only minor quantities of silt, clay, loam, or similar materials.

SUBGRADE: No subgrade material shall be placed on a subgrade covered by ice or snow nor on a wet or soft subgrade unless specifically directed.

SOIL-CEMENT BASE COURSE: Bituminous membrane shall be applied as soon as practicable after the completion of a section of base course and may be applied when the air temperature is not less than 35°F. Base course constructed when freezing weather may be expected during a curing period shall be protected from freezing by covering with hay, straw or other insulating material.

CONCRETE: Concreting shall not be continued when a descending air temperature in the shade falls below 40°F, nor resumed until ascending air temperature in the shade reaches 35°F. Concrete placed after October 1 must have a temperature of not less than 50°F nor greater than 80°F.

BITUMINOUS MATERIAL - PRIME COAT: Bituminous material shall be applied only during daylight hours and when the air temperature is 40°F or more and when the surface of the previously prepared roadbed base or existing surface is dry and reasonably free of loose dirt, dust or other foreign matter.

BITUMINOUS SURFACE TREATMENT: Bituminous material shall be applied only when the air temperature is 50°F or above and when the roadbed is dry. It shall not be applied when the weather is foggy or rainy or prior to impending rains. The work may be commenced at such time after May 1 when in the opinion of the Engineer the materials in the roadbed underlying the proposed work have sufficiently recovered from frost lift and have become sufficiently dry and stable. Work shall be discontinued in the fall of the year when the air or roadbed temperatures or both are subject to chill in the applied bituminous material to the degree that satisfactory adhesion of the aggregates is not obtained.
BITUMINOUS ROAD MIX SURFACE: Bituminous material shall be applied only when the air temperature is 50°F or more and the roadbed is dry. Mixing and placing operations may be continued in the fall until September 30 at times when the atmospheric temperatures are 50°F or over and field conditions are otherwise favorable.

PLANT MIXED BITUMINOUS BASES AND PAVEMENTS: Bituminous paving mixtures shall not be placed over frozen subgrade or base or where the roadbed underlying the foundation or base is temporarily unstable from the effects of frost heaving. Bituminous paving mixtures shall not be placed when it is raining or snowing and any mixture exposed to rain or snow before final loading which has in the judgement of the Engineer been adversely affected thereby shall be removed and replaced at the Contractor's expense. Bituminous paving mixtures shall not be placed where the air temperature about 3 feet above ground at the site of the work in the shade and away from the effects of artificial heat is less than 40°F. Bituminous paving mixture shall not be placed during the calendar period between October 15 and the date of May 1 next succeeding, except with specific written approval or order of the Engineer. In the event of such approval or order the conditions and restrictions as to placement set forth in the preceding paragraph shall apply. When placing a bituminous paving mixture continued after October 15 with the Engineer's approval the bituminous paving work so performed will be construed to have been done at the Contractor's risk and final inspection thereof will be deferred until May of the succeeding year.

SEAL COAT: Bituminous material shall be applied only when the air temperature is 50°F and more and when the surface to be sealed is dry and in proper condition to receive the seal.
EMBANKMENT CONSTRUCTION: Materials used in the construction of embankments shall be approved by the Engineer for the particular part of the embankment under construction and in general shall be free from frozen material or other deleterious matter. If prevailing temperatures have induced frost into the top three lifts in amounts where it is considered by the Engineer to be contributing to unsatisfactory density, the placing of embankment shall be suspended. The inability of the Engineer to make density determinations as required in the top three lifts of embankment being placed shall be evidence of frost penetration that is prohibitive of the watering, mixing, and compacting of the materials.

STRUCTURE BACKFILL: All use of the backfill of structures shall be of a superior quality and free from large size rocks or frozen lumps or other extraneous materials.

CEMENT TREATED BASE: Cement treated base shall not be applied when the base material or the subgrade is frozen. The air temperature shall be at least 40°F in the shade and rising. Any mixture of base materials, cement and water on the subgrade that has not been compacted and finished shall not remain undisturbed for more than 30 minutes.

PORTLAND CEMENT CONCRETE - WINTER CONSTRUCTION: Before placing the concrete in any form on any surface, or around reinforcement, heat shall be applied in such a manner that ice or snow will be completely removed. The concrete shall not be placed on a subgrade that is frozen or on one that contains frozen materials. Whenever the temperature of the surrounding air is at or below 40°F, or whenever low temperatures are expected after the concrete has been placed, or whenever the Engineer so directs, all concrete placed in the form shall have a temperature of not less than 50°F. The use of salts, chemicals or other foreign materials in the mix to prevent freezing of the concrete is prohibited. No materials containing frozen lumps, ice or snow shall be allowed to enter the mixture.

When mixing and placing concrete at/or below a temperature of 40°F or whenever low temperatures are expected after concrete has been placed or whenever the Engineer so directs the mixing water or aggregates or both shall be heated and the freshly poured concrete protected by adequate housing or covering and if necessary, heating.

SURFACE TREATMENT-INVERTED PENETRATION TYPE: Asphalitic surface treatments shall be applied only when the air temperature in the shade is 60°F and rising and when the weather is not foggy, rainy, or stormy.

ASPHALTIC TREATED SURFACING - ROAD MIX: Oiling or processing shall
be carried on only when the atmospheric temperature in the shade is above 50°F and rising and the weather is not foggy, rainy, or stormy.

PLANT MIXED SURFACING: Plant mixed surface shall be constructed only when the surface is dry and when the atmospheric temperature is 40°F and rising, or 50°F if falling and when the weather is not foggy, rainy, or stormy and when the foundation is free of all frost.

SEAL COAT AND COVER AGGREGATES: Asphaltic material of the type and grade specified shall be applied in a number of applications and at the rate shown and only when the air temperature is 60°F and rising and when the weather is not foggy, rainy, or stormy, except that a plain seal may be applied when the weather is not foggy, rainy, or stormy, and the air temperature is 40°F and rising.
EMBANKMENT: Frozen material shall not be used nor shall material be placed on frozen embankment foundation, embankment subbase, base or stabilized surface course. Frozen material shall not be used and the moisture content of the trench backfill materials shall be within the rates specified.

CONCRETE: In lieu of whatever method of curing is being used, calcium chloride shall be incorporated in the concrete mix, as directed by the Engineer, whenever the temperature may be expected to reach $50^\circ F$ or lower during the 24 hour-period following the placing of the concrete. Temperature of the concrete at the time of placing shall be between $60^\circ$ and $90^\circ F$. Placing of concrete may be started as early in the morning as the Contractor desires but shall be discontinued at 2:00 P.M., so as to permit the setting of the concrete before the temperature begins to drop.

SHEET ASPHALT PAVEMENT: Asphalitic mixtures shall not be placed at temperatures below $50^\circ F$ without approval of the Engineer.

BITUMINOUS SURFACE TREATMENT: Bituminous material for surface treatment shall be applied only between 9:15 A.M. and 3:30 P.M. and when the condition of the surface is satisfactory to the Engineer. The atmospheric temperature shall be $50^\circ F$ or above and the weather not foggy or rainy. Temperature and seasonal requirements may be waived but only when so directed by the Engineer in writing.
REMOVAL OF SNOW: No snow or ice shall be placed in embankments or allowed to be covered up in them and the Contractor shall, at his own expense, remove snow and ice from any portion of the work, in any of its stages whenever deemed necessary by the Engineer.

EMBANKMENT: Embankment shall be formed of suitable material only; stumps, trees, rubbish, sods, topsoil or other unsuitable material shall not be placed in the embankment.

SPECIFICATIONS FOR BRIDGES, PROVINCE OF ALBERTA, DEPARTMENT OF HIGHWAYS.

CONCRETING IN COLD WEATHER: When the mean average temperature is below 40°F or when directed by the Engineer, the Contractor shall enclose the structure in such a way that the concrete and air within the enclosure can be kept above 60°F for a period of 7 days after placing the concrete. The use of salamanders, coke stoves, oil or gas burners and similar spot heaters which have an open flame and intense local heat is prohibited without special specific approval of the Engineer.

Steam heat or hot air blowers may be used, but means of maintaining atmospheric moisture of not less than 95% shall be provided. Where hot air blowers and the like are permitted they must be kept well clear of the formwork and housing. Adequate ventilation is required to provide air for combustion, and to prevent the accumulation of carbon dioxide which can be harmful to the concrete. All aggregate and mixing water shall be heated to a temperature of at least 70°F but not more than 150°F. The aggregates may be heated by either steam or dry heat. The temperature of the concrete shall not be less than 60°F nor more than 80°F at the time of placing in the forms.

Fully insulated formwork is an alternative to housing and heating. The formwork shall be designed and insulated with approved materials so that the initial heat of the mix, and the heat generated during the hydration of the cement is retained to provide the specified curing conditions.

Protection and heating, where used shall be withdrawn in such a manner as not to introduce thermal shock stresses in the concrete. The temperature of the concrete shall be gradually reduced at a rate not exceeding 30°F per day, to that of the surrounding air. To achieve this in a heated housing, the heat shall be slowly reduced and then shut off and the whole housing allowed to cool to air temperature before the housing itself or formwork is removed. With fully insulated formwork the forms themselves shall not be removed until the temperature of the concrete has fallen to that of the air.
ROADWAY AND DRAINAGE EXCAVATION - EMBANKMENT MATERIALS:
The placing of frozen material in embankments will not be permitted. Froze­
en excavated material which will be suitable when dry, shall be stored and
allowed to thaw and dry, and then placed in the embankment as directed by
the Engineer. No compensation will be allowed for the storing and rehand­
ing of this material.

Snow overlying the surface of a cut or the site of an embankment shall
be removed and deposited beyond the slope stakes at the Contractor's own
expense.

CONCRETE MASONRY - CONCRETING IN COLD WEATHER: No concrete
shall be placed when the atmospheric temperature is below 35°F without
written permission of the Engineer. When directed by the Engineer, the
Contractor shall enclose the structure in such a way that the concrete and air
within the enclosure can be kept above 60°F for a period of 7 days after
placing the concrete.

If high early strength cement is used these periods may be reduced as
directed by the Engineer.

The Contractor shall supply such heating apparatus as stoves, sala­
manders or steam equipment and the necessary fuel. When dry heat is used,
means of maintaining atmosphere moisture shall be provided. All aggregates
and mixing water shall be heated to a temperature of at least 70°F but not
more than 150°F; the aggregates may be heated by either steam or dry heat.
If permitted by the Engineer, the torch method of heating mixed concrete
may be used, provided the heating apparatus shall be such as to heat the
mass uniformly and avoid hot spots which will burn the materials. The
temperature of the concrete shall not be less than 60°F at the time of placing
in the forms. In case of extremely low temperatures, the Engineer may,
at his discretion, raise the minimum limiting temperature for water, aggre­
gates and mixed concrete. Admixtures shall not be used to prevent freezing.
EARTH EMBANKMENT CONSTRUCTION: Only materials approved by the Engineer shall be placed in embankments and such materials shall not contain frozen lumps, weeds, sod, roots, logs, stumps or any other objectionable matter.

SPECIFICATIONS FOR CONCRETE STRUCTURES, DEPARTMENT OF HIGHWAYS, ONTARIO

COLD WEATHER CONCRETING: Cold weather, for the purpose of this specification, is when the air temperature is at or below 40°F or is when, in the opinion of the Engineer, the air temperature is likely to fall below this limit within 24 hours. In these circumstances, concrete shall be heated for placing and then protected from the adverse effects of wind, weather, and low temperatures.

When the air temperature is at or below 40°F, the mix water shall be heated to that temperature not greater than 150°F which is required to produce concrete of the specified placing temperature. When the fine or coarse aggregate contains snow or ice or when heating the water alone is not enough to produce concrete of the specified placing temperature, then the aggregates too shall be heated. The aggregates shall be heated to a temperature between 50°F and 150°F. At no time shall the temperature of the concrete exceed 100°F.

Any frozen lumps of aggregates shall be discarded prior to batching.

Prior to the commencement, and where necessary during the placing operations, the formwork into which the concrete is to be placed, any existing concrete at a construction joint, and the reinforcing steel shall be freed of ice and snow and preheated to a temperature of not less than 40°F and so maintained to the satisfaction of the Engineer. Live steam or moist air shall be used.

Concrete shall not be placed on a frozen subgrade or against frozen ground. The Contractor shall protect excavations prepared for footings, etc., with straw or covers prior to opening for placing concrete.

Where the air temperature is 40°F or below when the concrete is placed or during all or any part of the curing period designated below, all concrete shall be protected and where necessary heated. The curing shall be moist. That is either the relative humidity of the atmosphere surrounding the concrete and formwork shall not be less than 95%; or any exposed surface of the concrete and the containing formwork within a housing shall be kept moist by one of the normal curing methods specified in this section; or the concrete shall sufficiently retain its original moisture while within insulated
formwork or under protective curing.

All concrete shall be kept from freezing for at least 3 days after the day on which the concrete is placed. Where strength development is required in order that the concrete may carry dead and live loads, the concrete shall be maintained as closely as possible to an optimum temperature of $70^\circ F$ for a period of 7 days after the day of placing. In no case shall the temperature of any part of the concrete fall below $50^\circ F$ nor exceed $160^\circ F$ during this curing period.

Protective curing or inundating with water which is kept at $50^\circ F$ or above, may be used. Protective curing may also be used for slabs or footings placed on the ground or within excavations or in general structural work on open surfaces where the air temperature is between $30^\circ F$ and $40^\circ F$.

**PLACING ASPHALT MIXTURE:** No surface course shall be laid in Northern Ontario after October 1st, and no surface course shall be laid in Southern Ontario after October 15th. In all cases, no surface course shall be started unless the air temperature at the surface of the pavement is $45^\circ F$ and rising and furthermore, not until any frost or moisture from previous inclement weather has evaporated to leave a dry surface.

Binder courses shall not be started unless the air temperature at the surface of the pavement is $35^\circ F$ and rising, and the grade is in such condition that it is conducive to good results.

During both binder and surface course construction, when the air temperature drops below the minimum specified above, the paving operations shall be suspended.
EMBANKMENTS: The materials shall consist of acceptable earth material and rock material free from objectionable quantities of organic matter, frozen soil, stumps, trees, moss, and other unsuitable materials.

SELECT SUBGRADE SURFACE COURSE: The material shall be free from objectionable quantities of organic matter, frozen soil, stumps, trees, or other unsuitable materials.

CONCRETE: For the purpose of this specification, cold weather requirements will apply when the atmospheric temperature is less than 45°F or when a minimum temperature of less than 40°F is predicted within 48 hours.

During cold weather, the following requirements will apply: 1. Ice and snow will be removed from formwork, existing concrete and reinforcing steel against which concrete is to be placed. When the atmospheric temperature is 30°F or less, the Contractor shall preheat the area in which the concrete is to be placed to a temperature of not less than 60°F for a period of not less than 8 hours.

Concrete shall not be placed on or against frozen subgrade or ground. The Contractor shall protect any of these areas with straw or covers to ensure that frost does not penetrate into the ground. 2. During the mixing operations, the temperature of the concrete mix shall not exceed 90°F. The temperature of the concrete mix, when placed, shall be not less than 60°F.

The water shall be heated to a temperature not greater than 150°F. Water heated over 90°F shall not be brought in direct contact with the cement but shall be added into the mixer and mixed with the aggregate before the cement is added.

If the atmospheric temperature is, or was at any time during the previous 24 hours, at 30°F or lower, or if the aggregate stockpiles contain frozen material, the aggregate shall be heated to a temperature not less than 70 and not greater than 150°F.

3. If the atmospheric temperature falls below 40°F during the 7 days after the concrete has been placed, the Contractor shall provide suitable protection, and heat if necessary, to ensure that the concrete cures at a temperature of not less than 55°F for the 7 days from the time that the concrete is placed.

Heating shall be provided by live wet steam or hot air blowers having a fine water spray in the stream of hot air.

Insulated formwork, as an alternative to housing and heating, may be approved by the Engineer. The formwork shall be designed and insulated so that the initial heat of the mix and the heat generated during the hydration of the cement is retained to provide the specified curing conditions.
The temperature of the concrete shall be gradually reduced, at a rate not exceeding 30°F per day, to the temperature of the surrounding air so as not to introduce thermal shock stresses in the concrete.

ASPHALT STABILIZED SAND BASE COURSE: Bituminous binder shall not be applied when the atmospheric temperature is less than 50°F.

BITUMINOUS PRIME, TACK, AND FLUSH COAT: Bituminous material for prime coat and tack coat shall be applied only when the surface to be treated is dry, when the weather is not foggy or rainy, and when the surface temperature is above 35°F.

Bituminous material for flush coat shall be applied only when the weather is not foggy or rainy, when the surface to be treated is dry, and when the surface temperature is above 50°F.

HOT-MIX BITUMINOUS SURFACE COURSE: Bituminous mix shall not be spread if the atmospheric temperature is less than 35°F.

SEAL COAT: Emulsified asphalt shall not be applied to the road when the atmospheric temperature is less than 60°F, the weather is misty or rainy, or an atmospheric temperature less than 45°F is predicted within 24 hours.

Cut-back asphalt shall not be applied when the air temperature is less than 70°F, the surface to be treated is wet or damp, the weather is misty or rainy, or an atmospheric temperature less than 45°F is predicted within 48 hours.
APPENDIX C

Appendix C is composed of abstracted cold weather construction requirements from the standard construction specifications of several U. S. Organizations and one Canadian organization. Some statements are taken verbatim, others present only the relevant ideas.
CONCRETE-CONCRETING IN COLD WEATHER: Concrete shall not be mixed nor placed when the daily minimum atmospheric temperature is less than 40°F unless facilities are provided to insure the adequate protection of the concrete.

The temperature of the concrete at the time of placing shall be not less than 50°F nor more than 90°F. The temperature of all aggregates and mixing water shall be not more than 150°F when introduced into the mixer.

When the daily minimum temperature is less than 40°F, the structures must be insulated or housed and heated for the duration of the placement and curing period and the temperature of the concrete and air within the enclosure shall be maintained at not less than 50°F nor more than 90°F.
EMBANKMENT: Material for embankments shall consist of suitable material approved by the Engineer. Embankments and backfills shall contain no muck, frozen soil, roots, sod, etc.

PORTLAND CEMENT CONCRETE: Unless the Engineer specifically so authorizes in writing, mixing and concreting operations shall not be continued when a descending air temperature in the shade and away from artificial heat reaches 40°F, nor resumed until an ascending air temperature in the shade and away from artificial heat reaches 35°F.

When concrete is being placed during cold weather and the air temperature may be expected to drop below 35°F, the air temperature surrounding the concrete shall be maintained at a temperature of 60°F for at least 72 hours and at not less than 40°F for a period of not less than 7 days. Under no circumstances shall concreting operations continue when the air temperature is less than 20°F.

GENERAL REQUIREMENTS FOR BITUMINOUS CONCRETE BASES AND PAVEMENTS: Mixtures shall be placed only when the surface is dry, when the atmospheric temperature in the shade is above 40°F and rising or above 50°F if falling when the weather is not foggy or rainy, and when the prepared roadbed is in satisfactory condition: provided, however, that the Engineer may permit, in case of sudden rain, the placing of mixture then in transit from the plant, if laid at proper temperature and if the roadbed is free from pools of water. Such permission shall in no way relax the requirements for quality and smoothness of surface.

BITUMINOUS PRIME COAT: Prime coat shall be applied only when the surface to be treated is dry or slightly damp when the atmospheric temperature in the shade is above 55°F and rising or above 60°F if falling and when the weather is not foggy or rainy.

BITUMINOUS PRESERVATIVE TREATMENT: Bituminous materials shall only be applied when the surface to be treated is dry or slightly damp; when the atmospheric temperature in the shade is above 55°F and rising, or above 60°F, if falling, and when the weather is not foggy or rainy.

BITUMINOUS SEAL COAT: Seal coat shall be applied only when the surface to be treated is dry or slightly damp, when the temperature of the road surface is 70°F or more, and when the weather is not foggy or rainy.
BITUMINOUS SURFACE TREATMENTS: Surface treatments shall be applied only when the existing surface is dry or slightly damp, when the atmospheric temperature in the shade is above 55°F and rising or above 60°F if falling and when the weather is not foggy or rainy.

BITUMINOUS PLANT MIX SURFACING: Plant mix surface course shall be constructed only when the surface is dry and when the atmospheric temperature in the shade is above 40°F and rising or above 50°F if falling and when the weather is not foggy or rainy.

BITUMINOUS MAT SURFACING: Bituminous mat surfacing shall be applied only when the existing surface is dry or slightly damp, when the atmospheric temperature in the shade is above 55°F and rising or above 60°F and falling and when the weather is not foggy or rainy.

BITUMINOUS ROAD MIX SURFACING: Bituminous material surfacing shall be applied only when the existing surface is dry or slightly damp, when the atmospheric temperature in the shade is above 55°F and rising or above 60°F and falling and when the weather is not foggy or rainy.
EMBANKMENTS: No embankment material shall be placed in the embankment when either the material or the foundation or embankment on which it would be placed is frozen.

If the contractor elects to work during freezing weather, it is his responsibility to conduct his operations to meet the requirements of the specifications.
EARTHWORK: The operations on earthwork shall be suspended at any time when satisfactory results cannot be obtained on account of rain, freezing weather, or other unsatisfactory conditions of the field.

Frozen material shall not be placed in the embankment nor shall embankment be placed upon frozen material.

CONCRETE: Concrete shall not be placed when the temperature of the air, aggregates, or water is 40°F, or below, except when directed by the Engineer. If placed under these conditions, the water or aggregates or both shall be heated, the aggregates preferably by steam, so that the concrete, immediately after placing in the forms, shall have a temperature of between 65°F and 85°F. In no case shall concrete be deposited upon a frozen course.

Adequate precautions shall be taken for such protection of all concrete after it is placed in position as well as prevent the temperature of the deposited concrete falling below 50°F, until the required curing period has elapsed.

BITUMINOUS BASE COURSE: Bituminous base course shall be constructed only when the surface upon which it is placed is dry, when the atmospheric temperature is above 40°F, and when the weather is not foggy or rainy. The temperature requirement may be waived but only when so directed by the Engineer.

MIXED IN PLACE BASE COURSE: Mixed in place base course shall not be constructed when the atmospheric temperature is below 50°F. The temperature requirement may be waived when directed by the Engineer.

BITUMINOUS SURFACE COURSE: Bituminous material shall not be applied when the atmospheric temperature is less than 40°F, except when directed by the Engineer.

BITUMINOUS SEAL COAT: Seal coating shall not be attempted except under favorable weather conditions and when the atmospheric temperature is above 60°F.
EXCAVATION AND FILL: All material used for Backfill shall be of a quality acceptable to the engineer and shall be free from large or frozen lumps, wood, or other extraneous material.

CONCRETING IN COLD WEATHER: No concrete shall be placed when the atmospheric temperature is below 35° F. without permission of the engineer. When directed by the engineer, the contractor shall enclose the structure in such a way that the concrete and air within the enclosure can be kept above 60° F. for a period of seven days after placing the concrete.

If high-early-strength cement is used these periods may be reduced, as directed by the engineer.

The contractor shall supply such heating apparatus as stoves, salamanders or steam equipment and the necessary fuel. When dry heat is used, means of maintaining atmospheric moisture shall be provided. All aggregates and mixing water shall be heated to a temperature of at least 70° but not more than 150° F; the aggregates may be heated by either steam or dry heat. If permitted by the engineer the torch method of heating mixed concrete may be used, provided the heating apparatus shall be such as to heat the mass uniformly and avoid hot spots which will burn the materials. The temperature of the concrete shall be not less than 60° at the time of the placing in the forms. In case of extremely low temperatures, the engineer may, at his discretion, raise the minimum limiting temperatures for water, aggregates and mixed concrete.

CURING CONCRETE: Concrete surfaces exposed to conditions causing premature drying shall be protected by covering as soon as possible with canvas, straw, burlap, sand or other satisfactory material and kept moist; or if the surfaces are not covered, they shall be kept moist by flushing or sprinkling. Curing shall continue for a period of not less than seven days after placing the concrete. If high-early-strength cement is used this period may be reduced, as directed by the engineer. Other precautions to insure the development of strength shall be taken as the engineer may direct.
FOUNDATIONS: A foundation shall not be placed in, on, or above any soil that is frozen or may subsequently thaw. Where a foundation is placed on frost susceptible soil during freezing weather, the soil shall be kept from freezing.

PLAIN, REINFORCED AND PRESTRESSED CONCRETE: When the air temperature is at, or below 40° F but when there is a probability of its falling to that limit during the placing period, the temperature of the concrete, when deposited shall be not less than 60° F nor more than 80° F; to accomplish this, the mixing water, and if necessary the aggregates, shall be heated. When the exposure is severe, either due to low air temperature, location of the work, or thin sections of concrete, the temperature of the concrete should approach the higher limit of 80° F. Aggregates shall not be heated above 180° F. To avoid the possibility of flash set when either water or aggregate is heated to a temperature in excess of 100° F, water and aggregate should come together first in the mixture in such a way that temperature of the combination is reduced to below 100° F before cement is added.

All frozen lumps of aggregate shall be excluded from the mix, For a mass concrete, the minimum temperature stated above may be reduced. Before depositing concrete on any surface, all snow and ice shall be removed, using heat where necessary. Concrete shall not be placed on, or against, any surface that is at a temperature less than 40° F.

Effective means shall be provided for maintaining the temperature of the concrete at all surfaces at not less than 70° F for three days, or at not less than 50° F for five days after placing. Concrete shall be kept above freezing temperature for a period of 7 days and shall be kept from alternate freezing and thawing for at least 14 days after placement. When high-early-strength cement is used or when an additional 20 percent cement is added to the mix, the protection period may be reduced to two-thirds of the time stated above. No salt or other chemicals shall be used to lower freezing point of the concrete as a substitute for the specified curing and protection. At the end of the specified protection period, the temperature of the concrete shall be reduced gradually at a rate not exceeding 20° F per day until the outside air temperature has been reached.

Protection requirements specified above may be maintained by the use of adequate supplementary insulation, by enclosing the concrete surfaces with raised tarps, or by building a complete housing around the concrete with provision for the introduction of heat into the enclosure or housing when required. Note that proper protection will depend upon the outside temperature, the wind velocity and the massiveness of the concrete.
When the outside temperature during the placing or during the protection period established may fall below 10°F complete housing of the concrete work together with supplementary heat should be provided, particularly in typical framed buildings.

When the outside temperature during placing or during the protection period established may fall below 25°F, but not below 10°F, then adequate enclosure of all concrete surfaces with tarps or insulation, together with supplementary heat should be provided.

When the outside temperature during placing or during the protection period established may fall to 25°F, then adequate enclosure of all surfaces with tarpaulins for insulation should be provided and supplementary heat shall be in readiness.

Means shall be provided to humidify the air within the enclosed space and to keep the concrete and framework continuously moist if dry heat is used. Combustion type heaters may be used, but they shall be so constructed and so placed that their combustion gases will not come in contact with the surfaces of the concrete.
Appendix D consists of two sample questionnaires. The first is a sample of the questionnaire sent to Corps of Engineers District and Division Offices throughout the United States. The second is a sample of the questionnaire sent to highway departments and other federal and private organizations in the United States and Canada.
STUDY OF CONSTRUCTION PRACTICES IN COLD WEATHER

GENERAL

1. In regards to cold weather construction restrictions in standard specifications, do you feel that any differentiation should be made for constructing dams and for constructing airfields?

2. Assuming that your current specifications were subject to revision at this time, would you have any recommendation relevant to changes in the present cold-weather construction methods? If so, please comment.

3. Do you consider the added effect of wind in any of your construction practices at low temperatures, other than its effect on personnel? If so, please comment.

SOILS

1. Has the Department sponsored or participated in any past construction projects where roadway embankments, base materials or foundation backfilling was placed during sub-freezing atmospheric temperatures? If so,
   a. Were the embankment fill materials predominantly cohesive or cohesionless in nature? (Please give classification.)

   b. Were atmospheric temperatures consistently below 32°F throughout forming of the embankment?

   c. Between periods of work, when experiencing sub-freezing temperatures, do you recommend stripping the frozen crust from the borrow area prior to beginning the day's haul activities?
d. Do you recommend that the frozen surficial material, formed between periods of work, be removed prior to placement of a new lift of fill? Under what circumstances would you allow it to remain, i.e., type of soil, depth of frozen soil, lack of segregated ice in soil?

e. How do you determine acceptability of the surficial material during periods of sub-freezing temperatures?

f. If the frozen surficial material is scraped off the roadway section, do you recommend depositing this material outside of any particular slope limit?

g. As a result of placing the frozen material outside of the roadway section, have there been any detrimental effects to the stability of the embankment slopes?

h. Have you ever used or recommended the use of such chemicals as granular calcium chloride to protect the surface layer prior to completing the day's work? If so, how was the chemical applied, and what rate of application used?

i. Was full-time inspection given to the soil placement operations?

j. To what maximum lift thickness (before compaction) was the fill placed?

k. To what degree was the material compacted, i.e., 95% modified AASHO, Test Designation T99-57.

l. How often were field control tests taken on the compacted material?

2. If the embankment fill materials were cohesive,
   a. How was excavation of the backfill materials accomplished, i.e. blasting, mechanical excavation, pre-thawing etc.
b. What type(s) of machinery was (were) used during placement, i.e. spreading?

c. What type(s) of equipment was (were) used for compaction?

d. Was the frozen surficial material, formed between periods of work, removed prior to placement of a new lift of fill?

e. To what maximum deviation from optimum moisture content could the material be satisfactorily placed?

3. If the fill materials were cohesionless,
   a. How was excavation at the borrow site accomplished?

   b. What type(s) of machinery was (were) used during placement?

   c. To what lift thickness, (before compaction) was the material placed?

   d. What type(s) of equipment was (were) used for compaction?

   e. If frozen fill material is used, what techniques are employed to break up the frozen soil?

4. Has the character of cohesionless material ever been noticed to change at temperatures below freezing? i.e. apparent cohesion?

5. Have the aforementioned projects performed satisfactorily, i.e. no excessive settlement or instability upon thawing?

6. Have you ever allowed a foundation footing or a pavement to be placed on a frozen soil:
   a. If so, what was the type of soil?
b. What was the thickness of frozen soil?

c. Any other pertinent comments you would like to make?

7. Have the aforementioned projects performed satisfactorily, i.e. no excess settlement or instability upon thawing?

8. Have blasting techniques been employed by the Department or at the direction of the Department for loosening frozen soils?

9. Have you any current or proposed research programs pertaining to cold-weather construction problems? If so, please comment.

10. Please make any additional comments that you feel would be pertinent to our study.

CONCRETE

1. What is the lowest ambient temperature at which you have witnessed or have knowledge of concrete being placed satisfactorily without the use of artificial heat, and what type of structure was the concrete placed in? i.e. building, bridge, pavement.

2. To your knowledge, what is the lowest ambient temperature that concrete has been subjected to without special protection before expiration of the specified curing period and has performed satisfactorily.

3. What is the minimum allowable temperature at which the Department will permit concrete to be placed in pavements? in structures?

4. What length of curing period at this minimum allowable temperature must the concrete be protected after placement?

5. What method of protection do you recommend in order to maintain these minimum temperatures during the curing period?

6. Does the department allow the use of admixtures to prevent freezing? If so, please list those in common use.
7. Does the department allow the use of admixtures to decrease the curing time of concrete?

**ASPHALT**

1. What is the minimum atmospheric temperature at which the department will allow construction of each of the following and how long must these temperatures be maintained in each case?

   a. Bituminous prime coat
   b. Bituminous tack coat
   c. Bituminous seal coat
   d. Bituminous macadam base course (penetration method)
   e. Bituminous macadam base course (asphalt emulsion)
   f. Bituminous macadam wearing course (penetration method)
   g. Bituminous road-mix surface course
   h. Bituminous surface treatment
   i. Bituminous (central-plant hot-mix)
   j. Bituminous (central-plant cold-mix)

2. Can these minimum temperatures be reduced under any circumstances? If so, please list them.

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Organization Completing Questionnaire

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Organizational Branch or Title of Person Completing Questionnaire

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STUDY OF CONSTRUCTION PRACTICES IN COLD WEATHER

Reference: "Standard Specifications, Volume I, Construction of Roads and Bridges," State Highway Department of Georgia, dated May 1, 1956

GENERAL

1. Is the above referenced publication the latest revision and is it in current use by the department?

2. Assuming that your current specifications were subject to revision at this time, would you have any recommendation relevant to changes in the present cold-weather construction methods? If so, please comment.

3. Do you consider the added effect of wind in any of your construction practices at low temperatures, other than its effect on personnel? If so, please comment.

SOILS

1. Has the Department sponsored or participated in any past construction projects where roadway embankments, base materials or foundation backfilling was placed during sub-freezing atmospheric temperatures? If so,
   a. Were the embankment fill materials predominantly cohesive or cohesionless in nature? (Please give classification.)

   b. Were atmospheric temperatures consistently below 32°F throughout forming of the embankment?

   c. Between periods of work, when experiencing sub-freezing temperatures, do you recommend stripping the frozen crust from the borrow area prior to beginning the day's haul activities?
d. Do you recommend that the frozen surficial material, formed between periods of work, be removed prior to placement of a new lift of fill? Under what circumstances would you allow it to remain, i.e., type of soil, depth of frozen soil, lack of segregated ice in soil?

e. How do you determine acceptability of the surficial material during periods of sub-freezing temperatures?

f. If the frozen surficial material is scraped off the roadway section, do you recommend depositing this material outside of any particular slope limit?

g. As a result of placing the frozen material outside of the roadway section, have there been any detrimental effects to the stability of the embankment slopes?

h. Have you ever used or recommended the use of such chemicals as granular calcium chloride to protect the surface layer prior to completing the day's work? If so, how was the chemical applied, and what rate of application used?

i. Was full-time inspection given to the soil placement operations?

j. To what maximum lift thickness (before compaction) was the fill placed?

k. To what degree was the material compacted, i.e., 95% modified AASHO, Test Designation T99-57.

l. How often were field control tests taken on the compacted material?

2. If the embankment fill materials were cohesive,
   a. How was excavation of the backfill materials accomplished, i.e. blasting, mechanical excavation, pre-thawing etc.
b. What type(s) of machinery was (were) used during placement, i.e. spreading?

c. What type(s) of equipment was (were) used for compaction?

d. Was the frozen surficial material, formed between periods of work, removed prior to placement of a new lift of fill?

e. To what maximum deviation from optimum moisture content could the material be satisfactorily placed?

3. If the fill materials were cohesionless,
   a. How was excavation at the borrow site accomplished?

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   c. To what lift thickness, (before compaction) was the material placed?

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   e. If frozen fill material is used, what techniques are employed to break up the frozen soil?

4. Has the character of cohesionless material ever been noticed to change at temperatures below freezing? i.e. apparent cohesion?

5. Have the aforementioned projects performed satisfactorily, i.e. no excessive settlement or instability upon thawing?

6. Have you ever allowed a foundation footing or a pavement to be placed on a frozen soil:
   a. If so, what was the type of soil?
b. What was the thickness of frozen soil?

c. Any other pertinent comments you would like to make?

7. Have the aforementioned projects performed satisfactorily, i.e. no excess settlement or instability upon thawing?

8. Have blasting techniques been employed by the Department or at the direction of the Department for loosening frozen soils?

9. Have you any current or proposed research programs pertaining to cold-weather construction problems? If so, please comment.

10. Please make any additional comments that you feel would be pertinent to our study.

Organization Completing Questionnaire

Organizational Branch or Title of Person Completing Questionnaire
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