SHRP-C/FR-92-101

A Guide to Evaluating Thermal Effects in Concrete Pavements

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Strategic Highway Research Program
National Research Council
Washington, DC 1992

SHRP-C/FR-92-101
ISBN: 309-05266-1
Contract C-206

Program Manager: *Don M. Harriott*
Project Manager: *Inam Jawed*
Production Editor: *Marsha Barrett*
Program Area Secretary: *Ann Saccomano*

August 1992

key words:
activation energy
cement
compressive strength
concrete
curing
fly ash
freezing
heat of hydration
maturity
pavements
temperature
thermal cracking

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Acknowledgments

The research described herein was supported by the Strategic Highway Research Program (SHRP). SHRP is a unit of the National Research Council that was authorized by section 128 of the Surface Transportation and Uniform Relocation Assistance Act of 1987.

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Abstract

This report describes the use of tables developed to help determine problems that may result from early thermal effects in concrete. The thermal behavior of concrete can be estimated from a knowledge of concrete temperature, air temperature, type of cement, and content of cement in the mixture. The thermal effects tables can be used to predict whether too high a temperature will be reached in the pavement; whether early thermal cracking will result from large differences between the temperature of the concrete slab and the temperature of either the air or the base; or whether there is a risk of early cracking of the concrete. Examples of the use of the tables are given along with guidelines for avoiding undesirable thermal effects.

Executive Summary

The effects of temperature and moisture early in the life of concrete strongly influence early strength development and long-term durability. This guide is intended to aid highway personnel responsible for acceptance of concrete pavements. The guide will demonstrate how knowledge of concrete temperature, air temperature, and concrete mix characteristics allow the user to determine whether temperature-induced problems may be expected. Guidelines for avoiding such problems are also included.

Thermal conditions, if not addressed, can lead to significant problems, including the following:

- Cracking caused by large temperature differentials between the interior of the concrete and the external environment.
- Strength loss caused by the freezing of concrete before it has reached sufficient strength.
- Strength loss caused by high internal temperatures within the concrete mass.

To avoid such problems, the rate of heat development within the concrete as well as its dissipation to the external environment must be known. The hydration of cement is an **exothermic** process, in which heat is liberated during the reaction of cement with water. The amount of heat liberated is primarily a function of the composition of the cement, the fineness of the cement, and the temperature at which hydration takes place. Cements having a high tricalcium silicate (C_3S) content and a high fineness, such as Type III cements, generate more heat during their hydration. Cements having relatively low C_3S content and low fineness, such as certain Type II cements, can have relatively low heats of hydration. Pozzolonic admixtures, particularly Class F fly ashes, can be used to replace part of the cement and thereby lower the heat of hydration.

Development of heat in a concrete mass due to hydration of cement is a function of the *maturity* of the concrete. Maturity is a time/temperature function that requires a knowledge of the activation energy of the cement being used. Activation energies for a variety of cements were determined in this study and were used to develop relationships between heat development and maturity. Relationships between strength gain and maturity for these cements were also determined. Maturity is normally expressed relative to a reference condition. For instance, a maturity of 72 hours indicates that a particular concrete has reached a degree of hydration (and corresponding heat development) equivalent to 72 hours of curing at a reference temperature of 68° F (20° C).

As heat is generated within the concrete, an exchange with the external environment begins. Heat transport occurs both from the top of a pavement slab into the air, and from the bottom of the slab into the base. Heat is transported by thermal conduction, convection, and radiation. Thermal conduction is controlled primarily by the thermal conductivities of concrete and base course and by the existing temperature gradients. Convection is controlled by the top surface convection coefficient and the difference between the temperature of the concrete and the temperature of the air. Radiation is controlled by a radiation constant and the surface temperature.

The balance between heat generation and heat loss is controlled by a number of parameters, knowledge of which allows prediction of thermal effects under a wide range of conditions. The parameters used in this study include type of cement (and its rate of heat development), amount of cement used per cubic yard of concrete, presence of pozzolonic admixtures, concrete placement temperature, air temperature at placement, energies of activation of cement, wind velocity, pavement thickness, thermal properties of the base course, and the surface covering used on the pavement (if any) after finishing. To obtain a viable set of tables, the base properties, wind velocity, and thermal conductivity were assumed at constant levels. Surface protection was assumed to be initiated 3 hours after curing for temperatures below 40° F (5° C).

The tables were prepared from the output of a computer simulation of heat flow and strength development, using the parameters described above. The simulation was carried out during the first 72 hours after placement. The following parameters must be entered for the tables to be used:

- Type of cementitious material.
- Content of cementitious material.
- Concrete temperature.
- Air temperature.
- Thickness of the pavement.

The output of the tables consists of one of the following four symbols for any given combination of inputs.

- * = Satisfactory thermal conditions.
- TD = Risk of differentials of temperature within the concrete slab that are too large.
- EF = Risk of early freezing.
- HT = Risk of temperatures within the concrete slab that are too high.

Cracking from large temperature differentials can occur when the difference exceeds 36° F (20° C). Large differentials can be minimized by reducing the temperature of the concrete mix, reducing the amount or changing the type of cement in the mix, reducing the pavement thickness, or insulating the slab so that differential temperature is reduced. All of these cautions (except the use of insulation) may also be applied to reducing the actual temperature generated within the concrete. Risk of early freezing can be avoided by increasing the temperature of the concrete, increasing the amount of cementitious materials, increasing pavement thickness, and insulating the pavement slab.

1

Introduction

The interaction between temperature and moisture conditions in concrete structures within the first few days after the concrete is cast has an important influence on the quality and durability of the concrete during its total lifespan. This means that processes occurring in concrete at an early age can have a decisive influence on concrete quality and durability.

This guide deals solely with the effects of temperature on concrete pavements at early ages. The effects of moisture conditions on curing concrete are not addressed.

Unsatisfactory thermal conditions may seriously damage concrete:

- Large temperature differences may cause thermal cracking.
- The freezing of concrete before it has reached sufficient strength may cause permanent strength loss.
- Too high a concrete temperature may cause permanent strength loss.

To prevent such damage and to ensure satisfactory performance, it is necessary to accurately plan both the concrete placement and subsequent protection procedures and to maintain a satisfactory level of control with both procedures.

The planning of concrete placement and protection procedures should include an initial calculation and evaluation of the temperature and strength development in the concrete during the first few days after it is cast.

Control of the concreting procedure should include the measurement and control of those parameters that directly influence the hardening process, e.g., the concrete temperature at placement and the air temperature. Control of the process should include on-site measurements of such properties as strength and temperature.

This guide is intended as a tool for planning the placement of concrete pavements. Its overall purpose is to help highway personnel evaluate the potential risk of thermal problems. The guide does not address such topics as concrete mixture proportioning, paving techniques, or paving equipment.

Calculating and evaluating the temperature and strength development of hardening concrete is an important aspect of concrete construction. In geometrically simple concrete structures, temperature and strength development can be calculated and evaluated by using existing methods based on the application of the maturity concept (Freiesleben Hansen, 1978b). These methods can be implemented in a computer program capable of simulating temperature and strength development as well as temperature distribution throughout geometrically simple concrete structures.

The strength of a given concrete mixture is a function of its age and temperature history. The temperature history of concrete is rather complex and is influenced by many parameters, such as composition of the concrete mixture, temperature of the concrete at the time of placement, dimensions of the pavement, climatic conditions, and curing procedures.

This guide contains a number of tables that can be used for preliminary evaluation of the potential risk of thermal problems when casting concrete pavements under specific conditions. In the tables, the type and content of cementitious material, slab thickness, air temperature, and concrete temperature at the time of placement are varied within certain limits; whereas parameters such as wind velocity, type of base, type of surface protection, and time for initiation and removal of surface protection remain constant.

The guide adheres to the following general outline:

A short introduction to the theoretical background of the simulation of temperature and strength development in hardening concrete is given in Chapter 2. Input and output parameters for the computer simulation program as well as criteria used to evaluate thermal conditions are outlined in Chapter 3. Chapter 4 contains the values of the various input parameters used for computer simulations. Chapter 5 is intended as a users' guide to the thermal effects tables. Table setup and the use of the tables are described, and some practical hints concerning actions to be taken in case of undesirable thermal conditions are given.

The appendix contains the thermal effects tables, which are sorted by type and content of cementitious material. The tables can be used as described in Chapters 3, 4, and 5. These chapters also describe limitations on use of the tables. Persons interested in an introduction to the theoretical background of the tables are advised to read Chapter 2.

2

Theoretical Background

The properties of concrete during its hardening are developed through the hydration process (the chemical reaction between cement and water). The hydration of portland cement leads to development of heat. Depending on the conditions under which the concrete is placed and cured, the development of heat may either be beneficial or have detrimental effects.

Large temperature differences within a concrete element may cause thermal cracking, or strength loss may result from the freezing of concrete before it has reached sufficient strength. For concrete placed under hot weather conditions, heat generation may lead to permanent strength loss due to high concrete temperatures. To prevent such problems, knowledge of the development of concrete properties during hardening is required.

The development of concrete properties cannot be described unambiguously as a function of time as the rate of hydration increases with temperature. This is the background for the introduction of the maturity concept. The maturity concept makes it possible to compare development of concrete properties at different temperatures.

Maturity is defined as an equivalent age (time of hydration) at a reference temperature.

Fundamentals

The basic principles that are most important for calculation and evaluation of concrete thermal effects are described briefly in the following sections.

Heat of Hydration

The generation of heat during the hydration process is influenced by various parameters. Some of the most important of these parameters are the following (Freiesleben Hansen 1978a):

- Cement composition
- Cement fineness
- The temperature at which the hydration process takes place.

The heat of hydration is influenced by the content of the four clinker minerals C_3S, C_2S, C_3A, and C_4AF in the cement. The four clinker minerals have different characteristics with regard to the development of heat. At completion of hydration, the following values for the heat generation of the clinker minerals emerge (Table 2.1) according to Rasmussen and Andersen (1989).

Clinker mineral	C_3S	C_2S	C_3A	C_4AF
Heat of hydration Btu/lb	215	110	310	130

Table 2.1. Total heat of hydration for the four clinker minerals.*

*At a temperature of 73° F (23° C) for a water-to-cement (W/C) ratio of 0.45 and a Blaine fineness of 3,100 cm^2/g.

The fineness of the cement affects the generation of heat. The more finely ground a cement, the more rapid is the rate of hydration, and the greater is the proportion of the cement that reacts. A finely ground cement leads to a rapid development of heat.

The temperature at which the hydration process takes place influences the rate of hydration. The rate of hydration increases with temperature.

The development of heat for a specific concrete mixture can be determined on the basis of laboratory experiments such as adiabatic calorimetry.

During the hydration process, the degree of hydration α is defined as the ratio between the quantity of hydrated cementitious material and the original quantity of cementitious material. The degree of hydration is a function of time, the value varying between 0 and 1. The rate of hydration F can be expressed as the derivative of the degree of hydration with respect to time:

$$F = \frac{d\alpha}{dt}$$

As the rate of hydration increases with temperature, the development of concrete properties is not unambiguously determined as a function of time. To make it possible to compare the development of concrete properties as a function of time for different temperatures, the principle of maturity functions is introduced, relating time and temperature to an equivalent maturity age at a reference temperature.

Maturity Functions

The use of maturity functions is based on the assumption that the rate of hydration F for a given cementitious material at a given degree of hydration α can be approximated as the product of a function of the degree of hydration and a function of the actual temperature T:

$$F = \frac{d\alpha}{dt} = g(\alpha) \cdot f(T) \tag{2.1}$$

This assumption requires a sufficient amount of water to be available to allow the hydration process to proceed unhindered throughout the entire time.

Temperature T is a function of time t during the hardening of concrete. According to equation 2.1, this gives—

$$\frac{d\alpha}{dt} = g(\alpha) \cdot f(T(t))$$

Separation of the variables and integration leads to—

$$\int_0^{\alpha} \frac{1}{g(\alpha)} d\alpha = G(\alpha) = \int_0^{\tau} f(T(t))dt \tag{2.2}$$

The function f(T(t)) in equation 2.2 is often normalized with respect to the value of the function at a reference temperature T_0, and a new function $H_0(T)$ is introduced:

$$H_0(T) = \frac{f(T(t))}{f(T_0)}$$

The function H_0 is called the temperature function.

If a process occurring at temperature T is compared with a process occurring at the constant reference temperature T_0 at the same degree of hydration, the value of the function $G(\alpha)$ in equation 2.2 is the same for both processes. This gives—

$$\int_0^{\tau} f(T(t))dt = \int_0^{\tau_0} f(T_0)dt = f(T_0) \cdot \tau_0$$

The maturity M_0 at the time $t = \tau$ is now defined as the equivalent age τ_0 at reference temperature T_0:

$$M_0 = \tau_0 = \int_0^\tau \frac{f(T(t))}{f(T_0)} dt = \int_0^\tau H_0(T) dt$$

As an example, a maturity of 72 hours indicates that the cementitious material has reached a degree of hydration corresponding to 72 hours of curing at the reference temperature. Several investigations to determine temperature function have been made (Freiesleben Hansen 1978b; Rastrup 1955; Bergstrøm 1953). It has been shown (Freiesleben Hansen 1978b) through laboratory experiments that the Arrhenius equation can be used for thermally activated chemical reactions as an expression for f(T):

$$f(T) = \exp\left(-\frac{E}{R \cdot T_K}\right) \tag{2.3}$$

where

E = an empirical energy of activation.
R = the gas constant.
T_K = the absolute temperature.

The calculations performed in this report are based on the use of the Arrhenius model for temperature function.

For portland cement-based systems, an empirical energy of activation has been determined as a function of the temperature in degrees Celsius (Freiesleben Hansen and Pedersen 1977):

E(T) = 33.5 kJ/mole, for T ≥ 68° F (20° C)
E(T) = 33.5 + 1.47 (20−T) kJ/mole, for T < 68° F (20° C)

The energy of activation can be determined on the basis of laboratory experiments such as chemical shrinkage measurements.

By using the Arrhenius equation (2.3) and the reference temperature of 68° F (20°C), the temperature function $H_{20}(T)$ can be calculated as—

$$H_{20}(T) = \frac{f(T)}{f(20°C)} = \exp\left(\frac{E(T)}{R} \cdot \left(\frac{1}{293} - \frac{1}{T+273}\right)\right)$$

where T is the temperature in degrees Celsius.

The maturity M_{20} at the time $t = \tau$ is then—

$$M_{20} = \int_0^\tau H_{20}(T)dt = \int_0^\tau \exp\left(\frac{E(T)}{R}\cdot\left(\frac{1}{293}-\frac{1}{T+273}\right)\right)dt \tag{2.4}$$

In numerical calculations, equation 2.4 is replaced by—

$$M_{20} = \sum_{i=1}^{n} H_{20}(\underline{T}_i)\cdot \Delta t_i$$

where

n	=	the number of time intervals.
$\underline{T}_i$	=	the average temperature for time interval i.

The hydration period is divided into n time intervals. For each time interval, the average temperature $\underline{T}_i$ is determined and the corresponding temperature function $H_{20}(\underline{T}_i)$ is calculated. The maturity at any given time is equal to the summation of the contributions to the maturity during each of the preceding time intervals.

Heat Development in Concrete

With the introduction of the maturity concept, the development of heat in concrete can be described as a function of maturity. The relationship between the development of heat and the maturity form an s-curve when plotted in a single logarithmic scale (ACI Standard 308 1986). This curve can be described mathematically as—

$$Q(M) = Q_\infty \cdot \exp\left[-\left(\frac{\tau_e}{M}\right)^\alpha\right] \tag{2.5}$$

where

Q_∞	=	the total development of heat (for $M \rightarrow \infty$).
τ_e	=	the characteristic time constant.
α	=	the curvature parameter.
M	=	the maturity.

Equation 2.5 is an empirical equation. For a specific concrete mixture, the parameters Q_∞, τ_e, and α can be calculated from experimental data for the development of heat as a function of time Q(t) and the maturity as a function of time and temperature M(t,T). The development of heat as a function of time is often determined on the basis of adiabatic calorimetry.

Strength Development in Concrete

Strength development in concrete is influenced by temperature development and can be described with the maturity concept. Experiments have shown that the relationship between compressive strength and maturity form an s-curve when plotted on a single logarithmic scale (Idorn 1990). Analogous to heat development, development of compressive strength can, as a good approximation, be described as—

$$\sigma = \sigma_{\infty} \cdot \exp\left[-\left(\frac{\tau_e}{M}\right)^{\alpha}\right] \tag{2.6}$$

where

σ_{∞} = the potential final strength (for $M \rightarrow \infty$).
τ_e = the characteristic time constant.
α = the curvature parameter.
M = the maturity.

Expression 2.6 is an empirical expression. The parameters σ_{∞}, τ_e, and α can be calculated from experimental data for the development of compressive strength as a function of time ($\sigma(t)$) and the maturity as a function of time and temperature ($M(t,T)$). The development of compressive strength as a function of time $\sigma(t)$ can be determined by testing the compressive strength of concrete cylinders at different times.

Exchange of Thermal Energy with the Environment

Temperature development in a concrete structure is determined by the balance between heat generation in the concrete and heat exchange with the environment. This balance can be controlled by variation of such parameters as the following:

- Temperature of the concrete.
- Cement type and cement content.
- Type of formwork and surface protection.
- Time at which forms are removed and time at which surface protection is initiated and removed.

The most important mechanisms of heat exchange between concrete and environment are conduction, convection, and radiation.

Conduction

Thermal conduction is defined as heat transport in a material by transfer of heat between portions of the material that are in direct contact with each other. Thermal conduction can be assessed by using Fourier's law:

$$\frac{dQ}{dt} = -k \cdot A \cdot \frac{dT}{dx} \tag{2.7}$$

where

dQ/dT	=	rate of heat transfer.
k	=	thermal conductivity.
A	=	area.
dT/dx	=	temperature gradient.

Equation 2.7 is valid for two dimensions, but Fourier's law can be extended to three dimensions.

Convection

Thermal convection is the transfer of heat between the surface of a material and the environment. Convection can be assessed by using the following empirical equation:

$$\frac{dQ}{dt} = h \cdot A(T_s - T_a)$$

where

dQ/dt	=	rate of heat transfer.
h	=	surface convection coefficient.
A	=	area.
T_s	=	surface temperature.
T_a	=	air temperature.

Convection can be either forced or free. In the case of forced convection, there is a forced transport of heat by the surrounding media. In the case of free convection, the transport of heat is the result of temperature gradients. For concrete pavements, wind velocity across the concrete surface determines whether the convection is free or forced. The magnitude of the surface convection coefficient (h) is influenced by the wind velocity.

Radiation

The Stefan-Boltzmann law expresses the heat exchange by radiation between a plane object and the hemispherical sky:

$$\frac{dQ}{dt} = c \cdot A(T_K)^4 = c \cdot A(273+T_C)^4$$

where

dQ/dt	=	rate of heat emission from the surface.
c	=	radiation constant.
A	=	area.
T_K	=	temperature in degrees Kelvin.
T_C	=	temperature in degrees Celsius.

The small contribution of solar radiation to light-colored surfaces such as concrete pavements (especially where white curing compounds are used) has been ignored in the computer simulations of the development of strength and temperature.

3

Calculation and Evaluation of Thermal Effects

The background of the calculation and evaluation of thermal effects in concrete pavements is described in following sections.

Calculation of Temperature and Strength Development

Temperature and strength development in geometrically simple concrete elements can be calculated with a computer simulation program. The computer program is based on the application of the maturity concept described in Chapter 2.

The input parameters for the program include the following:

- Types of materials.
- Specific gravity of the materials.
- Composition of the cementitious materials.
- Proportions of constituent materials.
- Concrete properties–temperature at the time of placement, slump, air content (percent by volume), water-to-cement (W/C) ratio, thermal conductivity, energy of activation, specific heat, and unit weight.
- Parameters required to mathematically describe the development of heat and compressive strength as functions of maturity, i.e., for use in equations 2.5 and 2.6.
- Air temperature.
- Wind velocity (which affects the surface convection coefficient).

- Slab thickness.
- Properties of the base material–type, density, specific heat, thermal conductivity, and temperature.
- Type of surface protection (which affects the surface convection coefficient).
- Casting time, interval between castings, and number of castings.
- Time of placement and removal of the surface protection.
- Total time of simulation and time step in the calculations.

Values for a number of the input parameters are given in Chapter 4.

The output from the program consists of five graphs showing the following variables as functions of time:

- Temperature at the upper surface.
- Maximum temperature within the concrete slab.
- Temperature at the bottom of the concrete slab.
- Maximum temperature difference within the slab.
- Strength of the concrete at the upper surface.

To produce an easy-to-use guide for evaluating thermal effects in concrete pavements, the output from the computer program has been simplified and reduced to a number of thermal effects tables.

Evaluation of Thermal Effects

A complete prediction of potential thermal problems must include a comparison between the temperature and strength development of concrete to ensure that the strength of the concrete is at all times sufficient to resist thermal stresses. In preparing the thermal effects tables, however, it is considered sufficient to use the following criteria for an initial estimate:

- *Evaluation of the risk of thermal cracking due to large temperature differences–* A temperature difference of 36° F (20° C) is known from both practical experience and laboratory experiments to be sufficient to cause thermal cracking (Freiesleben Hansen and Pedersen 1982).
- *Evaluation of the risk of damage due to freezing of concrete of insufficient strength*–ACI Standard 308 (1986) states that freezing of concrete must be

prevented until the concrete has developed a compressive strength of at least 500 psi (approximately 5 MPa).

- *Evaluation of the risk of permanent strength loss due to high concrete temperatures*–Permanent strength loss can be experienced (Idorn 1990; Danish Ministry of Transport 1985) when concrete temperatures are higher than approximately 140° F (60° C).

In the thermal effects tables, thermal conditions are considered satisfactory if none of the above three criteria is fulfilled. The recommendations may be conservative, but this is acceptable because the cost of removing concrete that has suffered distress due to thermal effects is very high.

4

Input Parameters

To produce a handbook of a manageable size, it has been necessary to limit the range of values for the input parameters needed to calculate temperature and strength development. It has also been necessary to keep several of the less important parameters constant and to select appropriate limits and intervals for the remaining, more important, parameters. The input parameters, both constants and variables, are described in the following sections.

Materials

The thermal history of hardening concrete structures is affected by the various properties of the materials used in the concrete.

Cementitious Materials

The thermal effects tables have been prepared for three types of cement and one type of fly ash. The cement types are Type I, II, and III; and the fly ash is Class F. The densities for the materials are as follows:

- Type I cement, 3.18 gm/cm^3 (3,180 kg/m^3).
- Type II cement, 3.08 gm/cm^3 (3,080 kg/m^3).
- Type III cement, 3.18 gm/cm^3 (3,180 kg/m^3).
- Class F fly ash, 2.54 gm/cm^3 (2,540 kg/m^3).

Thermal effects tables have been produced for five compositions of these cementitious materials: Type I cement; Type II cement; Type III cement; Type I cement containing 20% by weight of class F fly ash based on the total weight of cementitious material; and Type II cement containing 20% by weight of class F fly ash based on the total weight of cementitious material.

Aggregates

Aggregates for the concrete mixtures are assumed to be of a quartzitic composition. The specific gravity for both coarse and fine aggregate is assumed to be 2.64. Aggregates have a maximum size of 3/8 to 2 inches (10 to 50 mm), depending on the content of cementitious material and pavement thickness.

Water

Water is assumed to be tap water, with a density of 1.00 gm/cm^3 (1,000 kg/m^3).

Concrete Mixtures

For each of the five cementitious systems, ten different concrete mixtures are included in the tables. Each mixture corresponds to a specific content of the cementitious material. The content of cementitious material varies between 525 and 750 lbs/yd^3 (311 and 445 kg/m^3) in steps of 25 lbs/yd^3 (15 kg/m^3). All concrete mixtures are assumed to be air entrained according to ACI Standard 211.1 (1986).

For the concrete mixtures, the following parameters were used:

- The estimated compressive strength was varied between 4,300 and 5,400 psi (30 and 37 MPa), depending on the composition of the concrete mixture (the strength is estimated by Feret's [1982] formula).
- An air content of 5–7.5% by volume (following ACI recommendations for severe environments).
- A slump of 2 or 3 inches (50 or 75 mm).
- A W/C ratio of 0.45.

The composition of the various concrete mixtures is shown in Tables 4.1–4.5.

ACI Guide 305 (1986) recommends that the concrete temperature be maintained below 100° F (38° C), and ACI Standard 308 (1986) recommends that the concrete temperature be maintained above 50° F (10° C). The upper and lower limits for the placement temperature of the concrete are therefore set at 50° and 100° F (10° and 38° C), and the temperature is increased in steps of 10° F (6° C).

The thermal conductivity of the concrete mixtures is assumed to be 1.3 Btu/ft·h·° F (8.1 kJ/m·h·° C).

The values of the energy of activation used for the computer simulations were determined experimentally. The energies of activation obtained were as follows:

- Type I cement, E = 46.2 Btu/mole (48.8 kJ/mole).
- Type II cement, E = 39.1 Btu/mole (41.3 kJ/mole).
- Type III cement, E = 40.3 Btu/mole (42.5 kJ/mole).
- Type I cement with fly ash, E = 36.2 Btu/mole (38.2 kJ/mole).
- Type II cement with fly ash, E = 34.9 Btu/mole (36.8 kJ/mole).

The parameters describing the development of heat according to equation 2.5 were also determined experimentally on the basis of adiabatic calorimetry. For the calculation of the parameters, the experimentally determined energies of activation were used. The parameters describing the development of heat are as follows:

- Type I cement, Q_∞ = 139.2 Btu/lb cement (323.4 kJ/kg cement)
  τ_e = 13.55 h
  α = 1.03
- Type II cement, Q_∞ = 134.9 Btu/lb cement (313.5 kJ/kg cement)
  τ_e = 15.20 h
  α = 0.95
- Type III cement, Q_∞ = 154.4 Btu/lb cement (358.8 kJ/kg cement)
  τ_e = 8.26 h
  α = 0.99
- Type I cement with fly ash, Q_∞ = 165.1 Btu/lb cement (383.6 kJ/kg cement)
  τ_e = 13.66 h
  α = 1.08
- Type II cement with fly ash, Q_∞ = 160.1 Btu/lb cement (372.0 kJ/kg cement)
  τ_e = 20.69 h
  α = 0.94

The parameters describing the development of strength according to equation 2.6 have not been determined experimentally, but have been approximated. For each concrete mixture, the value of σ_∞ was approximated by the estimated compressive strength given in Tables 4.1–4.5. The values of the parameters τ_e and α were approximated by the values of the parameters determined for the development of heat.

Cement (lbs/yd³*)	525	550	575	600	625	650	675	700	725	750
Water (lbs/yd³)	236	248	259	270	281	293	304	315	326	338
Aggregate (lbs/yd³)	3166	3093	3043	2970	2920	2825	2752	2768	2673	2601
Air (% of concrete)	5.0	5.5	5.5	6.0	6.0	7.0	7.5	6.0	7.0	7.5
Density (lbs/yd³)	3927	3891	3877	3840	3826	3767	3731	3783	3725	3688
Compressive strength (psi†)	5030	4944	5023	4944	5016	4809	4751	5209	5006	4944
Max. aggregate size (inches‡)	2	1 1/2	1 1/2	1	3/4	1/2	3/8	3/4	1/2	1/2
Slump (inches)	2	2	2	2	2	2	2	3	3	3

Table 4.1. Concrete mixtures—cement Type I.

*1kg/m³ = 1.685 lb/yd³
†1MPa = 145.0 psi
‡1mm = 0.0394 in

Cement (lbs/yd³*)	525	550	575	600	625	650	675	700	725	750
Water (lbs/yd³)	236	248	259	270	281	293	304	315	326	338
Aggregate (lbs/yd³)	3152	3078	3027	2954	2903	2807	2734	2749	2654	2580
Air (% of concrete)	5.0	5.5	5.5	6.0	6.0	7.0	7.5	6.0	7.0	7.5
Density (lbs/yd³)	3913	3876	3861	3824	3809	3750	3713	3764	3705	3668
Compressive strength (psi†)	5246	5157	5238	5157	5231	5018	4958	5430	5221	5156
Max. aggregate size (inches‡)	2	1 1/2	1 1/2	1	1/4	1/2	3/8	3/4	1/2	3/8
Slump (inches)	2	2	2	2	2	2	2	3	3	3

Table 4.2. Concrete mixtures—cement Type II.

*1kg/m³ = 1.685 lb/yd³
†1MPa = 145.0 psi
‡1mm = 0.0394 in

Cement (lbs/yd³*)	525	550	575	600	625	650	675	700	725	750
Water (lbs/yd³)	236	248	259	270	281	293	304	315	326	338
Aggregate (lbs/yd³)	3166	3093	3043	2970	2920	2825	2752	2768	2673	2601
Air (% of concrete)	5.0	5.5	5.5	6.0	6.0	7.0	7.5	6.0	7.0	7.5
Density (lbs/yd³)	3927	3891	3877	3840	3826	3767	3731	3783	3725	3688
Compressive strength (psi†)	5030	4944	5023	4944	5016	4809	4751	5209	5006	4944
Max. aggregate size (inches‡)	2	1½	1½	1	¾	½	⅜	¾	½	⅜
Slump (inches)	2	2	2	2	2	2	2	3	3	3

Table 4.3. Concrete mixtures—cement Type III.

*1kg/m³ = 1.685 lb/yd³
†1MPa = 145.0 psi
‡1mm = 0.0394 in

Cement + Fly Ash (lbs/yd³*)	525	550	575	600	625	650	675	700	725	750
Cement (lbs/yd³)	420	440	460	480	500	520	540	560	580	600
Fly Ash (lbs/yd³)	105	110	115	120	125	130	135	140	145	150
Water (lbs/yd³)	236	248	259	270	281	293	304	315	326	338
Aggregate (lbs/yd³)	3144	3070	3019	2945	2894	2798	2724	2739	2643	2569
Air (% of concrete)	5.0	5.5	5.5	6.0	6.0	7.0	7.5	6.0	7.0	7.5
Density (lbs/yd³)	3905	3868	3853	3815	3800	3740	3703	3754	3694	3657
Compressive strength (psi†)	4533	4454	4526	4454	4521	4329	4276	4699	4511	4454
Max. aggregate size (inches‡)	2	1½	1½	1	¾	½	⅜	¾	½	⅜
Slump (inches)	2	2	2	2	2	2	2	3	3	3

Table 4.4. Concrete mixtures—cement Type I plus fly ash Class F.

*1kg/m³ = 1.685 lb/yd³
†1MPa = 145.0 psi
‡1mm = 0.0394 in

Cement + Fly Ash (lbs/yd³*)	525	550	575	600	625	650	675	700	725	750
Cement (lbs/yd³)	420	440	460	480	500	520	540	560	580	600
Fly Ash (lbs/yd³)	105	110	115	120	125	130	135	140	145	150
Water (lbs/yd³)	236	248	259	270	281	293	304	315	326	338
Aggregate (lbs/yd³)	3133	3058	3006	2932	2880	2784	2709	2724	2627	2553
Air (% of concrete)	5.0	5.5	5.5	6.0	6.0	7.0	7.5	6.0	7.0	7.5
Density (lbs/yd³)	3894	3856	3840	3802	3786	3726	3688	3739	3679	3641
Compressive Strength (psi†)	4706	4624	4699	4624	4693	4496	4441	4876	4683	4624
Max. aggregate size (inches‡)	2	1½	1½	1	¾	½	⅜	¾	½	⅜
Slump (inches)	2	2	2	2	2	2	2	3	3	3

Table 4.5. Concrete mixtures—cement Type II plus fly ash Class F.

*1kg/m³ = 1.685 lb/yd³
†1MPa = 145.0 psi
‡1mm = 0.0394 in

Climatic Conditions

Climatic conditions such as air temperature and wind velocity influence temperature development in concrete pavements during hardening.

Air Temperature

Air temperature is varied within the interval from 0° to 100° F (−18° to 38° C) in steps of 20° F (11° C).

Wind Velocity

The velocity of the wind across a newly cast concrete surface influences the rate of heat transfer from the surface to the air. An increase in wind velocity increases the heat loss from the surface. The ASHRAE Handbook (1989) recommends wind velocities of 15 mph (7 m/s) in the winter and 7.5 mph (3 m/s) in the summer. In the computer simulations of the temperature and strength development in the hardening concrete, the average wind velocity was maintained at 11 mph (5 m/s).

Pavement Construction

Temperature development in a newly cast concrete pavement is, among other parameters, influenced by the structure of the pavement and the construction practices applied.

Temperature development is affected by factors such as the thickness of the pavement, the condition of the pavement base, and the methods used to protect the pavement surface.

Dimensions of the Pavement

The pavement is assumed to be a plate of infinite width and length. The only dimension affecting temperature development is the thickness of the pavement. The thermal effects tables include the following slab thicknesses: 8, 12, 16, and 20 inches (0.2, 0.3, 0.4, and 0.5 m).

Condition of the Base

For concrete pavements, the properties of the base underlying the concrete as well as the temperature of the base have a large influence on the temperature development in the hardening concrete. The thermal characteristics of the base affect the rate of dissipation of heat from and to the pavement and affect the magnitude of the thermal gradients. The thermal characteristics and the density of the three most commonly used base materials are given in Table 4.6, according to Freiesleben Hansen and Pedersen (1982).

Base Material	Density (lbs/yd³*)	Thermal conductivity (Btu/ft · h · ° F†)	Specific heat (Btu/lb · ° F‡)
Gravel, dry	2,870	0.3	0.20
Gravel, moist	3,200	1.4	0.25
Asphalt	3,880	0.8	0.25
Econocrete	3,200	1.4	0.25

Table 4.6. The properties of various base materials.

*1 kg/m³ = 1.685 lb/yd³
†1 kJ/m·h·° C = 0.161 Btu/ft·h·° F
‡1 J/kg·° C = 2.388 x 10^{-4} Btu/lb·° F

Because the use of asphalt as a base material for concrete pavements is limited, and the base material is normally wet before concreting begins, the tables are based on the thermal characteristics and the density for moist gravel/econocrete: a density of 3,200 lbs/yd³ (1,900 kg/m³), a thermal conductivity of 1.4 Btu/ft·h·° F (9 kJ/m·h·° C), and a specific heat of 0.25 Btu/lb·° F (1 kJ/kg·° C).

The temperature of the base before placement of concrete is influenced by air temperature. It is assumed that the temperature of the base in general is 8° F (5° C) lower than the air temperature, except when air temperatures fall below 40° F (5° C). In this case, the base temperature is considered constant at 32° F (0° C), because concrete according to ACI Guide 306 (1986) must not be placed on frozen ground.

Surface Protection

To minimize evaporation from the surface of a newly placed concrete pavement, the surface is usually covered with a curing compound or plastic sheeting after the pavement is finished. During winter construction, a surface protection with sufficient insulating properties is used to prevent damage due to early freezing of concrete of insufficient strength.

The insulating properties of the surface cover affect the rate of heat transfer from the newly cast concrete to the air. The coefficient of transmission expresses the transmission of energy per unit area per hour per degree. The coefficient of transmission thus depends on the insulating properties of the surface cover and the surface convective coefficient of transmission α_k, which is a function of the wind velocity across the surface of the pavement. (See section above entitled "Wind Velocity" for the wind velocity used for computer simulations.)

In the calculations, it is assumed that the concrete pavement is covered with wet burlap, white curing compound, wet cotton, or polyethylene film, except in air temperatures below 40° F (5° C). If the air temperature is below 40° F (5° C), the pavement is assumed to be covered with 2 inches (50 mm) of straw or another insulating material. The coefficients of transmission for the chosen wind velocity and surface coverings (Freiesleben Hansen and Pedersen 1982) follow in Table 4.7.

Type of surface cover	Wind velocity (mph*)	Coefficient of transmission ($Btu/ft^2 \cdot h \cdot {}^\circ F$†)
No cover	11	Approx. 90
Wet burlap, polyethylene film, white curing compound, or wet cotton	11	Approx. 60
Straw (2 inches) or other insulating material	11	Approx. 5

Table 4.7. Coefficients of transmission.

*1 m/s = 2.24 mph
†1 $kJ/m^2 \cdot h \cdot {}^\circ C = 4.896 \times 10^{-2}\ Btu/ft^2 \cdot h \cdot {}^\circ F$

The protection of the pavement surface is assumed to be initiated 3 hours after casting. If the air temperature is below 40° F (5° C) and an insulating material is used, the insulation is assumed to be removed 24 hours after casting. For the remaining curing period, the pavement is assumed to be covered with wet burlap, polyethylene film, white curing compound, or wet cotton.

The Concreting Procedure

The following assumptions have been made for the concreting procedure:

- Casting time is 2 hours.
- Concrete is placed in one layer.

The Simulation Process

Temperature and strength development are calculated over an elapsed time of 72 hours. The time step in the calculations is 1 hour.

Summary of the Input Parameters

A summary of all the input parameters for the computer simulations follows.

Materials

The materials are as follows:

- Cement Types I, II, and III.
- Class F fly ash.
- Aggregate of a quartzitic composition.
- Water.

The specific gravities for the materials are as follows:

- Type I cement, 3.18 gm/cm^3 (3,180 kg/m^3).
- Type II cement, 3.08 gm/cm^3 (3,080 kg/m^3).
- Type III cement, 3.18 gm/cm^3 (3,180 kg/m^3).
- Class F fly ash, 2.54 gm/cm^3 (2,540 kg/m^3).
- Aggregate, 2.64 gm/cm^3 (2,640 kg/m^3).
- Water, 1.00 gm/cm^3 (1,000 kg/m^3).

In percentage by weight of the total weight of cementitious material, the five compositions of the cementitious material are as follows:

- Type I cement, 100%.
- Type II cement, 100%.
- Type III cement, 100%.
- Type I cement, 80% plus Class F fly ash, 20%.
- Type II cement, 80% plus Class F fly ash, 20%.

Concrete Mixtures

The composition of the various mixtures are shown in Tables 4.1–4.5.

The concrete pouring temperatures are 50°, 60°, 70°, 80°, 90°, or 100° F (10°, 16°, 21°, 27°, 32°, or 38° C) in the tables.

The slump is 2 or 3 inches (50 or 75 mm), the air content ranges from 5 to 7.5%, and the W/C ratio is 0.45.

The thermal conductivity is 1.3 Btu/ft·h·° F (8.1 kJ/m·h·° C) for all concrete mixtures.

The specific heat and unit weight for all concrete mixtures are calculated by the program.

The energies of activation are as follows:

- Type I cement, E = 46.2 Btu/mole (48.8 kJ/mole).
- Type II cement, E = 39.1 Btu/mole (41.3 kJ/mole).
- Type III cement, E = 40.3 Btu/mole (42.5 kJ/mole).
- Type I cement with fly ash, E = 36.2 Btu/mole (38.2 kJ/mole).
- Type II cement with fly ash, E = 34.9 Btu/mole (36.8 kJ/mole).

The parameters describing the development of heat according to equation 2.5 are as follows:

- Type I cement, Q_∞ = 139.2 Btu/lb cement (323.4 kJ/kg cement)
  τ_e = 13.55 h
  α = 1.03

- Type II cement, Q_∞ = 134.9 Btu/lb cement (313.5 kJ/kg cement)
  τ_e = 15.20 h
  α = 0.95

- Type III cement, Q_∞ = 154.4 Btu/lb cement (358.8 kJ/kg cement)
  τ_e = 8.26 h
  α = 0.99

- Type I cement with fly ash, Q_∞ = 165.1 Btu/lb cement (383.6 kJ/kg cement)
  τ_e = 13.66 h
  α = 1.08

- Type II cement with fly ash, Q_∞ = 160.1 Btu/lb cement (372.0 kJ/kg cement)
  τ_e = 20.69 h
  α = 0.94

Strength development is described with the same values used for τ_e and α as were used for heat development. For each concrete mixture, σ_∞ is approximated by the estimated value for the compressive strength given in Tables 4.1–4.5.

Climatic Conditions

The thermal effects tables include the following air temperatures: 20°, 40°, 60°, 80°, or 100° F (–18°, –7°, 4°, 16°, 27°, or 38° C).

The wind velocity is assumed to be 11 mph (5 m/s) in all cases.

Pavement Construction

The tables include the following slab thicknesses: 8, 12, 16, or 20 inches (0.2, 0.3, 0.4, or 0.5 m).

The base is assumed to be of a quartzitic composition, and the density of the base material is 3,200 lbs/yd^3 (1,900 kg/m^3).

The specific heat of the base is 0.25 Btu/lb·° F (1 kJ/kg·° C) and the thermal conductivity is 1.4 Btu/ft·h·° F (9 kJ/m·h·° C).

The three different types of surface covers leading to the following coefficients of transmission for the chosen wind velocity were given in Table 4.7, i.e., 90 Btu/ft^2·h·° F (1,838 kJ/m^2·h·° C) for no cover; 60 Btu/ft^2·h·° F (1,225 kJ/m^2·h·° C) for wet burlap, polyethylene film, white curing compound, or wet cotton; and 5 Btu/ft^2·h·° F (102 kJ/m^2·h·° C) for 2 inches (50 mm) of straw or other insulating material.

Concreting Procedure

The casting time is 2 hours, and the concrete is placed in one layer.

The surface protection is assumed to be initiated 3 hours after concrete is cast.

If the temperature falls below 40° F (5° C) and an insulating surface protection is used, it is assumed that the insulating protection is removed 24 hours after casting and is replaced with wet burlap, polyethylene film, white curing compound, or wet cotton.

The Simulation Process

The total simulation time is 72 hours, and the time step in the calculations is 1 hour.

5

Users' Guide

This chapter gives instructions for the use of the thermal effects tables. Persons interested in information regarding the theoretical background for the tables are advised to read Chapter 2. A short description of the calculation and evaluation of the curing processes is given in Chapter 3, and the input parameters for the computer simulations are outlined in Chapter 4.

Description of the Table Setup

Tables are prepared by using the output from a computer simulation of temperature and strength development in the concrete pavement in the first 72 hours after it is placed.

For each composition of the cementitious material and for each of the ten different concrete mixtures (characterized by the content of cementitious material), 144 simulations of temperature and strength development have been performed varying air temperature, concrete temperature, and slab thickness. The simulated temperature and strength developments have been (1) evaluated according to the three criteria described in the section of Chapter 3 entitled "Evaluation of Thermal Effects" and (2) organized into the thermal effects tables.

The following data are entered into the tables:

- Type of cementitious material—Cement Type I, Type II, Type III, Type I containing 20% by weight Class F fly ash based on the total weight of cementitious material, or Type II containing 20% by weight Class F fly ash based on the total weight of cementitious material.

- Total content of cementitious material—For each of ten concrete mixtures, the total content of cementitious materials are 525, 550, 575, 600, 625, 650, 675, 700, 725, or 750 lbs/yd^3 (311, 326, 341, 356, 371, 386, 400, 415, 430, or 445 kg/m^3).

- Concrete temperature—50°, 60°, 70°, 80°, 90°, or 100° F (10°, 16°, 21°, 27°, 32°, or 38° C).

- Air temperature—0°, 20°, 40°, 60°, 80°, or 100° F (−18°, −7°, 4°, 16°, 27°, or 38° C).

- Pavement thickness—8, 12, 16, or 20 inches (0.2, 0.3, 0.4, or 0.5 m).

Output from the tables consists of one of the following four symbols:

*	=	Satisfactory thermal conditions.
TD	=	Risk of differentials of temperature within the concrete slab that are too large.
EF	=	Risk of early freezing.
HT	=	Risk of temperatures within the concrete slab that are too high.

In the thermal effects tables, satisfactory conditions are defined as conditions that do not cause any of these three to be encountered. An example of a table is shown in Figure 5.1.

For each table, a major heading states the type and content of cementitious material used. The type and content of cementitious material refers directly to one of the compositions of concrete mixtures shown in Tables 4.1–4.5.

A horizontal axis at the top of each table shows the concrete temperature (in degrees Fahrenheit) at the time of placement.

The expected average air temperature (in degrees Fahrenheit) during the first 72 hours after placement is shown in a vertical row of numbers to the left in the tables; the slab thickness (in inches) is given in a vertical row of numbers to the right.

For a given average air temperature, a horizontal table consisting of six columns and four rows is shown. Each of the columns represents a specific concrete temperature at the time of placement, and each row represents a specific slab thickness. The content of the tables is one of four symbols. These symbols are the output from the tables. An explanation of the symbols is given in table footnotes.

How To Use and Interpret the Tables

It is important to realize that these tables represent computer simulations of temperature and strength development in hardening concrete and are only a guide for the planning of concreting and curing procedures. The tables in this guide are intended to help in preliminary evaluations of the thermal conditions for hardening concrete pavements.

CEMENT TYPE I, CONTENT 525 LBS/CU.YD.

AIR TEMP. [Degree F]	CONCRETE TEMPERATURE [Degree F] 50	60	70	80	90	100	SLAB THICKNESS [Inches]
0	EF	EF	EF/TD	TD	TD	TD	20
	EF	EF	EF	TD	TD	TD	16
	EF	EF	EF	EF	TD	TD	12
	EF	EF	EF	EF	EF	•	8
20	EF	•	•	TD	TD	TD	20
	EF	•	•	•	TD	TD	16
	EF	•	•	•	•	TD	12
	EF	EF	EF	•	•	•	8
40	•	•	•	TD	TD	TD	20
	•	•	•	•	TD	TD	16
	•	•	•	•	•	TD	12
	•	•	•	•	•	•	8
60	•	•	•	•	•	TD	20
	•	•	•	•	•	TD	16
	•	•	•	•	•	•	12
	•	•	•	•	•	•	8
80	•	•	•	•	•	HT/TD	20
	•	•	•	•	•	•	16
	•	•	•	•	•	•	12
	•	•	•	•	•	•	8
100	•	•	•	•	HT	HT/TD	20
	•	•	•	•	•	HT	16
	•	•	•	•	•	HT	12
	•	•	•	•	•	•	8

NOTES:

- • satisfactory thermal conditions
- TD risk of too large Temperature Differences within the concrete slab
- EF risk of Early Freezing
- HT risk of too High Temperatures within the concrete slab

Figure 5.1. Example of a thermal effects table.

In general, the climatic conditions and structural dimensions of the pavement are given; these parameters are therefore normally outside the influence of the contractor.

The following parameters that affect the temperature and strength development in concrete may be modified within the specifications: cement type, cement content, and composition of the concrete mixture. Varying these parameters must not change the specified concrete properties.

A contractor must often vary the following parameters to achieve the optimum properties of concrete for a given job:

- Extent of insulation (surface protection).
- Concrete temperature at the time of placement.
- Time for removal of the surface protection.

The thermal effects tables provide information on the type of cementitious materials, the content of cementitious materials, the air temperature, and the slab thickness. In this case, the contractor need only determine a safe concrete temperature at the time of placement.

Use of the tables is illustrated by the following three examples.

First it is planned to cast a concrete pavement with a thickness of 16 inches (0.4 m) in a hot period of the summer. The concrete contains 650 lbs/yd^3 (386 kg/m^3) Type I cement. The expected average air temperature during the first 72 hours after casting is 100° F (38° C). What would a suitable concrete placement temperature be?

From the thermal effects table for Type I cement and a cement content of 650 lbs/yd^3 (386 kg/m^3), it is found that an average air temperature of 100° F (38° C) and a pavement thickness of 16 inches (0.4 m) will be satisfactory for a concrete pouring temperature of 50° or 60° F (10° or 16° C). For concrete temperatures higher than 60° F (16° C), there is a risk of concrete temperatures being too high or thermal differences being too large.

Next, it is planned to cast a concrete pavement with a slab thickness of 8 inches (0.2 m) during the winter. The concrete contains 575 lbs/yd^3 (341 kg/m^3) Type III cement. The concrete temperature at the time of placement is to be 50° F (10° C), and the expected average air temperature for a period of 72 hours is 40° F (4° C). It is planned to cover the concrete surface with 2 inches (50 mm) of insulating material in the period from 3 to 24 hours after casting. Shortly before casting, the weather conditions change—the expected average air temperature is now 20° F (–7° C). What effect will this have on the thermal conditions for the pavement?

From the table for Type III cement and a cement content of 575 lbs/yd^3 (341 kg/m^3), it is found that an average air temperature of 40° F (4° C), a slab thickness of 8 inches (0.2 m), and a concrete placement temperature of 50° F (10° C) are satisfactory. With a change of the average air temperature to 20° F (–7° C), there is a risk of early freezing of the concrete. The concrete placement temperature must therefore be raised to 60° F (16° C) by using heated mixing water or aggregates.

Finally, four experimental sections of a concrete pavement have been planned. The four sections have four different slab thicknesses: 20, 16, 12, and 8 inches (0.5, 0.4, 0.3, and 0.2 m). The concrete for the four sections contains 600 lbs/yd^3 (356 kg/m^3) Type I cement and 150 lbs/yd^3 (89 kg/m^3) Class F fly ash. The concrete temperature at the time of placement is

90° F (32° C), and the expected average air temperature for the first 72 hours after casting is 60° F (16° C). Will satisfactory thermal conditions exist for all four pavement sections?

From the table for Type I cement with fly ash, a cement content of 600 lbs/yd³ (356 kg/m³), and a content of Class F fly ash of 150 lbs/yd³ (89 kg/m³), it is found that an average air temperature of 60° F (16° C) and a concrete placement temperature of 90° F (32° C) will provide satisfactory thermal conditions only for slab thicknesses of 16, 12, and 8 inches (0.4, 0.3, and 0.2 m). For a slab thickness of 20 inches (0.5 m), there is a risk of temperature differences being too large. The concrete pouring temperature should be reduced to 80° F (27° C) or below to avoid potential problems.

If the thermal effects tables indicate a risk of damage to the concrete (TG, HT, EF), it may be necessary to take precautions to avoid problems.

Actions To Be Taken in Case of Undesirable Thermal Conditions

If predictions made during the planning of the concreting procedure show that the thermal conditions are undesirable, then actions must be taken to achieve satisfactory results. In this section, some practical hints are given as examples of such actions to be taken. It should be pointed out that all actions must be taken under consideration of fulfillment of the specifications for a given job; it is outside the purpose of this guide to estimate the economical consequences of the suggested actions.

The risk of temperature differences being too large within the concrete slab may be reduced by—

- Reducing the concrete placement temperature.
- Insulating the concrete slab immediately after casting and finishing.
- Reducing the content of the cementitious materials.
- Choosing a cement type with a lower heat of hydration.
- Raising the temperature of the surroundings (e.g., using heat-vented tents).

It should be pointed out that the effects of the second action described above cannot be investigated through use of this guide. As stated earlier, the time before insulating the concrete surface remains constant in all the tables. If the concrete slab is to be insulated immediately after casting and finishing, it will be necessary to perform a temperature and strength calculation based on actual conditions.

The risk of damage due to early freezing may be reduced by—

- Increasing the concrete placement temperature.
- Insulating the concrete slab immediately after casting and finishing.
- Lengthening the period of insulation of the concrete surface.
- Increasing the content of cementitious materials.
- Choosing a cement type with a higher heat of hydration.
- Raising the temperature of the surroundings (e.g., using heat-vented tents).

It should be pointed out that the effects of the second and third actions listed above cannot be investigated through use of this guide. The time for initiation and removal of the insulation of the concrete surface remains constant in all the tables. If the concrete slab is to be insulated for a longer period of time, it will be necessary to perform a temperature and strength calculation based on actual conditions.

The risk of temperatures becoming too high within a concrete slab may be reduced by—

- Reducing the concrete placement temperature.
- Reducing the content of cementitious materials.
- Choosing a cement type with a lower heat of hydration.
- Reducing the temperature of the surroundings (e.g., shading).

The effects of some of the actions mentioned above are illustrated by the following examples.

First, a concrete pavement with a thickness of 20 inches (0.5 m) is planned to be cast during winter. The expected average air temperature is 40° F (4° C). The concrete contains 600 lbs/yd^3 (356 kg/m^3) Type II cement, and the concrete temperature at the time of placement is 80° F (27° C). The concrete surface is covered with 2 inches (50 mm) of insulating material in the period from 3 to 24 hours after casting. The tables indicate that, under these conditions, a risk of too large temperature differences within the concrete slab exists. The following actions can be taken to provide satisfactory thermal conditions.

- Concrete placement temperature can be decreased to 70° F (21° C).
- Cement content can be reduced to 575 lbs/yd^3 (341 kg/m^3).
- Temperature of the surroundings can be raised to 60° F (16° C).

Second, it has been planned to cast a concrete pavement with a thickness of 12 inches (0.3 m) during the winter. The expected average air temperature for the period is 20° F (–7° C). The concrete contains 580 lbs/yd^3 (344 kg/m^3) Type II cement and 145 lbs/yd^3 (86 kg/m^3) Class F fly ash. The concrete temperature is 60° F (16° C) at the time of placement. The concrete surface is covered with 2 inches (50 mm) of insulating material in the period from 3 to 24 hours after casting. Under these conditions, early freezing of the concrete may take place. The following actions can be taken to provide satisfactory thermal conditions.

- Concrete placement temperature can be increased to 70° F (21° C).
- Cement content can be increased to 600 lbs/yd^3 (356 kg/m^3), and fly ash content can be increased to 150 lbs/yd^3 (89 kg/m^3).
- The cement can be changed to Type I.
- The temperature of the surroundings can be increased to 40° F (4° C).

Finally, it is planned to cast a concrete pavement with a thickness of 20 inches (0.5 m) during a summer period with an average air temperature of 100° F (38° C). The concrete contains 600 lbs/yd^3 (356 kg/m^3) Type III cement, and the concrete pouring temperature is 60° F (16° C). Under these conditions, a risk of too high temperatures within the concrete slab exists. The following actions can be taken to provide satisfactory thermal conditions.

- Concrete placement temperature can be reduced to 50° F (10° C).
- Cement content can be reduced to 575 lbs/yd^3 (341 kg/m^3).
- The cement can be changed to Type I or Type II.
- The temperature of the surroundings can be changed to 80° F (27° C).

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Appendix

Thermal Effects Tables

This appendix contains the thermal effects tables for the report titled "A Guide to Evaluating Thermal Effects in Concrete Pavements." The guide was prepared for the Strategic Highway Research Program C206 by G.M. Idorn Consult A/S.

A users' guide to the thermal effects tables is included in Chapter 5 of the main report. The guide describes the limitations of the tables, table setup, how to use the tables, and what actions should be taken if undesirable thermal conditions are encountered. The main report also contains an introduction to the theoretical background for the tables (Chapter 2).

The thermal effects tables are divided into five groups that correspond to the cementitious systems used. The tables are arranged according to content of cementitious material.

Type I Cement

CEMENT TYPE I, CONTENT 525 LBS/CU.YD.

AIR TEMP. [Degree F]	CONCRETE TEMPERATURE [Degree F] 50	60	70	80	90	100	SLAB THICKNESS [Inches]
0	EF	EF	EF/TD	TD	TD	TD	20
	EF	EF	EF	TD	TD	TD	16
	EF	EF	EF	EF	TD	TD	12
	EF	EF	EF	EF	EF	*	8
20	EF	*	*	TD	TD	TD	20
	EF	*	*	*	TD	TD	16
	EF	*	*	*	*	TD	12
	EF	EF	EF	*	*	*	8
40	*	*	*	TD	TD	TD	20
	*	*	*	*	TD	TD	16
	*	*	*	*	*	TD	12
	*	*	*	*	*	*	8
60	*	*	*	*	*	TD	20
	*	*	*	*	*	TD	16
	*	*	*	*	*	*	12
	*	*	*	*	*	*	8
80	*	*	*	*	*	HT/TD	20
	*	*	*	*	*	*	16
	*	*	*	*	*	*	12
	*	*	*	*	*	*	8
100	*	*	*	*	HT	HT/TD	20
	*	*	*	*	*	HT	16
	*	*	*	*	*	HT	12
	*	*	*	*	*	*	8

NOTES:

*	satisfactory thermal conditions
TD	risk of too large Temperature Differences within the concrete slab
EF	risk of Early Freezing
HT	risk of too High Temperatures within the concrete slab

CEMENT TYPE I, CONTENT 550 LBS/CU.YD.

AIR TEMP. [Degree F]	CONCRETE TEMPERATURE [Degree F] 50	60	70	80	90	100	SLAB THICKNESS [Inches]
0	EF	EF/TD	EF/TD	TD	TD	TD	20
	EF	EF	EF	TD	TD	TD	16
	EF	EF	EF	EF	TD	TD	12
	EF	EF	EF	EF	EF	*	8
20	EF	*	*	TD	TD	TD	20
	EF	*	*	*	TD	TD	16
	EF	*	*	*	*	TD	12
	EF	EF	EF	*	*	*	8
40	*	*	*	TD	TD	HT/TD	20
	*	*	*	*	TD	TD	16
	*	*	*	*	*	TD	12
	*	*	*	*	*	*	8
60	*	*	*	*	TD	TD	20
	*	*	*	*	*	TD	16
	*	*	*	*	*	*	12
	*	*	*	*	*	*	8
80	*	*	*	*	*	HT/TD	20
	*	*	*	*	*	TD	16
	*	*	*	*	*	*	12
	*	*	*	*	*	*	8
100	*	*	*	HT	HT	HT/TD	20
	*	*	*	*	HT	HT	16
	*	*	*	*	*	HT	12
	*	*	*	*	*	*	8

NOTES:

*	satisfactory thermal conditions
TD	risk of too large Temperature Differences within the concrete slab
EF	risk of Early Freezing
HT	nsk of too High Temperatures within the concrete slab

CEMENT TYPE I, CONTENT 575 LBS/CU.YD.

AIR TEMP. [Degree F]	CONCRETE TEMPERATURE [Degree F] 50	60	70	80	90	100	SLAB THICKNESS [Inches]
0	EF	EF/TD	EF/TD	TD	TD	TD	20
	EF	EF	EF	TD	TD	TD	16
	EF	EF	EF	EF	TD	TD	12
	EF	EF	EF	EF	EF	*	8
20	EF	*	*	TD	TD	TD	20
	EF	*	*	*	TD	TD	16
	EF	*	*	*	*	TD	12
	EF	EF	EF	*	*	*	8
40	*	*	*	TD	TD	HT/TD	20
	*	*	*	*	TD	TD	16
	*	*	*	*	*	TD	12
	*	*	*	*	*	*	8
60	*	*	*	*	TD	TD	20
	*	*	*	*	*	TD	16
	*	*	*	*	*	*	12
	*	*	*	*	*	*	8
80	*	*	*	*	TD	HT/TD	20
	*	*	*	*	*	HT/TD	16
	*	*	*	*	*	*	12
	*	*	*	*	*	*	8
100	*	*	*	HT	HT	HT/TD	20
	*	*	*	*	HT	HT/TD	16
	*	*	*	*	*	HT	12
	*	*	*	*	*	*	8

NOTES:

- * satisfactory thermal conditions
- TD risk of too large Temperature Differences within the concrete slab
- EF risk of Early Freezing
- HT risk of too High Temperatures within the concrete slab

CEMENT TYPE I, CONTENT 600 LBS/CU.YD.

AIR TEMP. [Degree F]	CONCRETE TEMPERATURE [Degree F] 50	60	70	80	90	100	SLAB THICKNESS [Inches]
0	EF	EF/TD	EF/TD	TD	TD	TD	20
	EF	EF	EF	TD	TD	TD	16
	EF	EF	EF	EF	TD	TD	12
	EF	EF	EF	EF	EF	*	8
20	EF	*	*	TD	TD	HT/TD	20
	EF	*	*	*	TD	TD	16
	EF	*	*	*	*	TD	12
	EF	EF	EF	*	*	*	8
40	*	*	TD	TD	TD	HT/TD	20
	*	*	*	TD	TD	TD	16
	*	*	*	*	*	TD	12
	*	*	*	*	*	*	8
60	*	*	*	*	TD	HT/TD	20
	*	*	*	*	*	TD	16
	*	*	*	*	*	*	12
	*	*	*	*	*	*	8
80	*	*	*	*	HT/TD	HT/TD	20
	*	*	*	*	*	HT/TD	16
	*	*	*	*	*	*	12
	*	*	*	*	*	*	8
100	*	*	*	HT	HT/TD	HT/TD	20
	*	*	*	HT	HT	HT/TD	16
	*	*	*	*	HT	HT	12
	*	*	*	*	*	*	8

NOTES:

*	satisfactory thermal conditions
TD	risk of too large Temperature Differences within the concrete slab
EF	risk of Early Freezing
HT	risk of too High Temperatures within the concrete slab

CEMENT TYPE I, CONTENT 625 LBS/CU.YD.

AIR TEMP. [Degree F]	CONCRETE TEMPERATURE [Degree F]						SLAB THICKNESS [Inches]
	50	60	70	80	90	100	
0	EF	EF/TD	EF/TD	TD	TD	HT/TD	20
	EF	EF	EF	TD	TD	TD	16
	EF	EF	EF	EF	TD	TD	12
	EF	EF	EF	EF	EF	*	8
20	EF	*	TD	TD	TD	HT/TD	20
	EF	*	*	*	TD	TD	16
	EF	*	*	*	*	TD	12
	EF	EF	EF	*	*	*	8
40	*	*	TD	TD	TD	HT/TD	20
	*	*	*	TD	TD	TD	16
	*	*	*	*	*	TD	12
	*	*	*	*	*	*	8
60	*	*	*	*	TD	HT/TD	20
	*	*	*	*	*	TD	16
	*	*	*	*	*	*	12
	*	*	*	*	*	*	8
80	*	*	*	*	HT/TD	HT/TD	20
	*	*	*	*	*	HT/TD	16
	*	*	*	*	*	*	12
	*	*	*	*	*	*	8
100	*	*	HT	HT	HT/TD	HT/TD	20
	*	*	*	HT	HT	HT/TD	16
	*	*	*	*	HT	HT	12
	*	*	*	*	*	*	8

NOTES:

*	satisfactory thermal conditions
TD	risk of too large Temperature Differences within the concrete slab
EF	risk of Early Freezing
HT	risk of too High Temperatures within the concrete slab

CEMENT TYPE I, CONTENT 650 LBS/CU.YD.

AIR TEMP. [Degree F]	CONCRETE TEMPERATURE [Degree F] 50	60	70	80	90	100	SLAB THICKNESS [Inches]
	EF	EF/TD	EF/TD	TD	TD	HT/TD	20
	EF	EF	EF/TD	TD	TD	TD	16
0	EF	EF	EF	EF	TD	TD	12
	EF	EF	EF	EF	EF	*	8
	EF	*	TD	TD	TD	HT/TD	20
	EF	*	*	*	TD	TD	16
20	EF	*	*	*	*	TD	12
	EF	EF	EF	*	*	*	8
	*	*	TD	TD	HT/TD	HT/TD	20
	*	*	*	TD	TD	HT/TD	16
40	*	*	*	*	*	TD	12
	*	*	*	*	*	*	8
	*	*	*	TD	TD	HT/TD	20
	*	*	*	*	*	TD	16
60	*	*	*	*	*	*	12
	*	*	*	*	*	*	8
	*	*	*	TD	HT/TD	HT/TD	20
	*	*	*	*	TD	HT/TD	16
80	*	*	*	*	*	*	12
	*	*	*	*	*	*	8
	*	*	HT	HT/TD	HT/TD	HT/TD	20
	*	*	HT	HT	HT/TD	HT/TD	16
100	*	*	*	HT	HT	HT/TD	12
	*	*	*	*	*	HT	8

NOTES:

- * satisfactory thermal conditions
- TD risk of too large Temperature Differences within the concrete slab
- EF risk of Early Freezing
- HT risk of too High Temperatures within the concrete slab

CEMENT TYPE I, CONTENT 675 LBS/CU.YD.

AIR TEMP. [Degree F]	CONCRETE TEMPERATURE [Degree F] 50	60	70	80	90	100	SLAB THICKNESS [Inches]
0	EF	EF/TD	EF/TD	TD	TD	HT/TD	20
	EF	EF	EF/TD	TD	TD	TD	16
	EF	EF	EF	EF	TD	TD	12
	EF	EF	EF	EF	EF	*	8
20	EF	*	TD	TD	HT/TD	HT/TD	20
	EF	*	*	*	TD	HT/TD	16
	EF	*	*	*	*	TD	12
	EF	EF	EF	*	*	*	8
40	*	*	TD	TD	HT/TD	HT/TD	20
	*	*	*	TD	TD	HT/TD	16
	*	*	*	*	*	TD	12
	*	*	*	*	*	*	8
60	*	*	*	TD	TD	HT/TD	20
	*	*	*	*	*	TD	16
	*	*	*	*	*	*	12
	*	*	*	*	*	*	8
80	*	*	*	HT/TD	HT/TD	HT/TD	20
	*	*	*	*	HT/TD	HT/TD	16
	*	*	*	*	*	*	12
	*	*	*	*	*	*	8
100	*	HT	HT/TD	HT/TD	HT/TD	HT/TD	20
	*	*	HT	HT/TD	HT/TD	HT/TD	16
	*	*	*	HT	HT	HT/TD	12
	*	*	*	*	*	HT	8

NOTES:

*	satisfactory thermal conditions
TD	risk of too large Temperature Differences within the concrete slab
EF	risk of Early Freezing
HT	risk of too High Temperatures within the concrete slab

CEMENT TYPE I, CONTENT 700 LBS/CU.YD.

AIR TEMP. [Degree F]	CONCRETE TEMPERATURE [Degree F] - 50	60	70	80	90	100	SLAB THICKNESS [Inches]
	EF	EF/TD	EF/TD	TD	TD	HT/TD	20
	EF	EF	EF/TD	TD	TD	TD	16
0	EF	EF	EF	EF	TD	TD	12
	EF	EF	EF	EF	*	*	8
	EF	*	TD	TD	HT/TD	HT/TD	20
	EF	*	*	TD	TD	HT/TD	16
20	EF	*	*	*	*	TD	12
	EF	EF	EF	*	*	*	8
	*	TD	TD	TD	HT/TD	HT/TD	20
	*	*	*	TD	TD	HT/TD	16
40	*	*	*	*	*	TD	12
	*	*	*	*	*	*	8
	*	*	*	TD	TD	HT/TD	20
	*	*	*	*	TD	TD	16
60	*	*	*	*	*	*	12
	*	*	*	*	*	*	8
	*	*	*	HT/TD	HT/TD	HT/TD	20
	*	*	*	*	HT/TD	HT/TD	16
80	*	*	*	*	*	HT/TD	12
	*	*	*	*	*	*	8
	TD	HT/TD	HT/TD	HT/TD	HT/TD	HT/TD	20
	*	HT	HT	HT/TD	HT/TD	HT/TD	16
100	*	*	*	HT	HT	HT/TD	12
	*	*	*	*	*	HT	8

NOTES:

*	satisfactory thermal conditions
TD	risk of too large Temperature Differences within the concrete slab
EF	risk of Early Freezing
HT	risk of too High Temperatures within the concrete slab

CEMENT TYPE I, CONTENT 725 LBS/CU.YD.

AIR TEMP. [Degree F]	CONCRETE TEMPERATURE [Degree F] - 50	60	70	80	90	100	SLAB THICKNESS [Inches]
	EF	EF/TD	EF/TD	TD	HT/TD	HT/TD	20
	EF	EF	EF/TD	TD	TD	HT/TD	16
0	EF	EF	EF	EF	TD	TD	12
	EF	EF	EF	EF	*	*	8
	EF	TD	TD	TD	HT/TD	HT/TD	20
	EF	*	*	TD	TD	HT/TD	16
20	EF	*	*	*	*	TD	12
	EF	EF	EF	*	*	*	8
	*	TD	TD	TD	HT/TD	HT/TD	20
	*	*	TD	TD	TD	HT/TD	16
40	*	*	*	*	TD	TD	12
	*	*	*	*	*	*	8
	*	*	*	TD	HT/TD	HT/TD	20
	*	*	*	*	TD	HT/TD	16
60	*	*	*	*	*	*	12
	*	*	*	*	*	*	8
	*	*	TD	HT/TD	HT/TD	HT/TD	20
	*	*	*	TD	HT/TD	HT/TD	16
80	*	*	*	*	*	HT/TD	12
	*	*	*	*	*	*	8
	HT/TD	HT/TD	HT/TD	HT/TD	HT/TD	HT/TD	20
	*	HT	HT/TD	HT/TD	HT/TD	HT/TD	16
100	*	*	HT	HT	HT/TD	HT/TD	12
	*	*	*	*	HT	HT	8

NOTES:

*	satisfactory thermal conditions
TD	risk of too large Temperature Differences within the concrete slab
EF	risk of Early Freezing
HT	risk of too High Temperatures within the concrete slab

CEMENT TYPE I, CONTENT 750 LBS/CU.YD.

AIR TEMP. [Degree F]	CONCRETE TEMPERATURE [Degree F] 50	60	70	80	90	100	SLAB THICKNESS [Inches]
0	EF	EF/TD	EF/TD	TD	HT/TD	HT/TD	20
	EF	EF	EF/TD	TD	TD	HT/TD	16
	EF	EF	EF	EF	TD	TD	12
	EF	EF	EF	EF	*	*	8
20	EF	TD	TD	TD	HT/TD	HT/TD	20
	EF	*	*	TD	TD	HT/TD	16
	EF	*	*	*	*	TD	12
	EF	EF	EF	*	*	*	8
40	*	TD	TD	HT/TD	HT/TD	HT/TD	20
	*	*	TD	TD	HT/TD	HT/TD	16
	*	*	*	*	TD	TD	12
	*	*	*	*	*	*	8
60	*	*	*	TD	HT/TD	HT/TD	20
	*	*	*	*	TD	HT/TD	16
	*	*	*	*	*	TD	12
	*	*	*	*	*	*	8
80	*	TD	HT/TD	HT/TD	HT/TD	HT/TD	20
	*	*	*	HT/TD	HT/TD	HT/TD	16
	*	*	*	*	*	HT/TD	12
	*	*	*	*	*	*	8
100	HT/TD	HT/TD	HT/TD	HT/TD	HT/TD	HT/TD	20
	HT/TD	HT/TD	HT/TD	HT/TD	HT/TD	HT/TD	16
	*	HT	HT	HT	HT/TD	HT/TD	12
	*	*	*	HT	HT	HT	8

NOTES:

*	satisfactory thermal conditions
TD	nsk of too large Temperature Differences within the concrete slab
EF	risk of Early Freezing
HT	nsk of too High Temperatures within the concrete slab

Type II Cement

CEMENT TYPE II, CONTENT 525 LBS/CU.YD.

AIR TEMP. [Degree F]	CONCRETE TEMPERATURE [Degree F] 50	60	70	80	90	100	SLAB THICKNESS [Inches]
0	EF	EF	EF/TD	TD	TD	TD	20
	EF	EF	EF	TD	TD	TD	16
	EF	EF	EF	EF	TD	TD	12
	EF	EF	EF	EF	EF	*	8
20	EF	*	*	*	TD	TD	20
	EF	*	*	*	*	TD	16
	EF	*	*	*	*	TD	12
	EF	EF	EF	*	*	*	8
40	*	*	*	*	TD	TD	20
	*	*	*	*	*	TD	16
	*	*	*	*	*	TD	12
	*	*	*	*	*	*	8
60	*	*	*	*	*	TD	20
	*	*	*	*	*	*	16
	*	*	*	*	*	*	12
	*	*	*	*	*	*	8
80	*	*	*	*	*	*	20
	*	*	*	*	*	*	16
	*	*	*	*	*	*	12
	*	*	*	*	*	*	8
100	*	*	*	*	*	HT	20
	*	*	*	*	*	*	16
	*	*	*	*	*	*	12
	*	*	*	*	*	*	8

NOTES:

*	satisfactory thermal conditions
TD	risk of too large Temperature Differences within the concrete slab
EF	risk of Early Freezing
HT	risk of too High Temperatures within the concrete slab

CEMENT TYPE II, CONTENT 550 LBS/CU.YD.

AIR TEMP. [Degree F]	CONCRETE TEMPERATURE [Degree F] 50	60	70	80	90	100	SLAB THICKNESS [Inches]
0	EF	EF	EF/TD	TD	TD	TD	20
	EF	EF	EF	TD	TD	TD	16
	EF	EF	EF	EF	TD	TD	12
	EF	EF	EF	EF	EF	*	8
20	EF	*	*	*	TD	TD	20
	EF	*	*	*	*	TD	16
	EF	*	*	*	*	TD	12
	EF	EF	EF	*	*	*	8
40	*	*	*	*	TD	TD	20
	*	*	*	*	*	TD	16
	*	*	*	*	*	TD	12
	*	*	*	*	*	*	8
60	*	*	*	*	*	TD	20
	*	*	*	*	*	*	16
	*	*	*	*	*	*	12
	*	*	*	*	*	*	8
80	*	*	*	*	*	*	20
	*	*	*	*	*	*	16
	*	*	*	*	*	*	12
	*	*	*	*	*	*	8
100	*	*	*	*	*	HT	20
	*	*	*	*	*	HT	16
	*	*	*	*	*	*	12
	*	*	*	*	*	*	8

NOTES:

*	satisfactory thermal conditions
TD	risk of too large Temperature Differences within the concrete slab
EF	risk of Early Freezing
HT	risk of too High Temperatures within the concrete slab

CEMENT TYPE II, CONTENT 575 LBS/CU.YD.

AIR TEMP. [Degree F]	CONCRETE TEMPERATURE [Degree F] 50	60	70	80	90	100	SLAB THICKNESS [Inches]
0	EF	EF	EF/TD	TD	TD	TD	20
	EF	EF	EF	TD	TD	TD	16
	EF	EF	EF	EF	TD	TD	12
	EF	EF	EF	EF	EF	*	8
20	EF	*	*	*	TD	TD	20
	EF	*	*	*	*	TD	16
	EF	*	*	*	*	TD	12
	EF	EF	EF	*	*	*	8
40	*	*	*	*	TD	TD	20
	*	*	*	*	*	TD	16
	*	*	*	*	*	TD	12
	*	*	*	*	*	*	8
60	*	*	*	*	*	TD	20
	*	*	*	*	*	*	16
	*	*	*	*	*	*	12
	*	*	*	*	*	*	8
80	*	*	*	*	*	*	20
	*	*	*	*	*	*	16
	*	*	*	*	*	*	12
	*	*	*	*	*	*	8
100	*	*	*	*	*	HT	20
	*	*	*	*	*	HT	16
	*	*	*	*	*	*	12
	*	*	*	*	*	*	8

NOTES:

*	satisfactory thermal conditions
TD	risk of too large Temperature Differences within the concrete slab
EF	risk of Early Freezing
HT	risk of too High Temperatures within the concrete slab

CEMENT TYPE II, CONTENT 600 LBS/CU.YD.

AIR TEMP. [Degree F]	CONCRETE TEMPERATURE [Degree F] 50	60	70	80	90	100	SLAB THICKNESS [Inches]
0	EF	EF/TD	EF/TD	TD	TD	TD	20
	EF	EF	EF	TD	TD	TD	16
	EF	EF	EF	EF	TD	TD	12
	EF	EF	EF	EF	EF	*	8
20	EF	*	*	TD	TD	TD	20
	EF	*	*	*	*	TD	16
	EF	*	*	*	*	TD	12
	EF	EF	*	*	*	*	8
40	*	*	*	TD	TD	TD	20
	*	*	*	*	*	TD	16
	*	*	*	*	*	TD	12
	*	*	*	*	*	*	8
60	*	*	*	*	*	TD	20
	*	*	*	*	*	*	16
	*	*	*	*	*	*	12
	*	*	*	*	*	*	8
80	*	*	*	*	*	TD	20
	*	*	*	*	*	*	16
	*	*	*	*	*	*	12
	*	*	*	*	*	*	8
100	*	*	*	*	HT	HT	20
	*	*	*	*	*	HT	16
	*	*	*	*	*	*	12
	*	*	*	*	*	*	8

NOTES:

- * satisfactory thermal conditions
- D risk of too large Temperature Differences within the concrete slab
- F risk of Early Freezing
- HT risk of too High Temperatures within the concrete slab

CEMENT TYPE II, CONTENT 625 LBS/CU.YD.

AIR TEMP. [Degree F]	CONCRETE TEMPERATURE [Degree F] 50	60	70	80	90	100	SLAB THICKNESS [Inches]
0	EF	EF/TD	EF/TD	TD	TD	TD	20
	EF	EF	EF	TD	TD	TD	16
	EF	EF	EF	EF	TD	TD	12
	EF	EF	EF	EF	EF	*	8
20	EF	*	*	TD	TD	TD	20
	EF	*	*	*	TD	TD	16
	EF	*	*	*	*	TD	12
	EF	EF	*	*	*	*	8
40	*	*	*	TD	TD	TD	20
	*	*	*	*	*	TD	16
	*	*	*	*	*	TD	12
	*	*	*	*	*	*	8
60	*	*	*	*	*	TD	20
	*	*	*	*	*	*	16
	*	*	*	*	*	*	12
	*	*	*	*	*	*	8
80	*	*	*	*	*	HT/TD	20
	*	*	*	*	*	*	16
	*	*	*	*	*	*	12
	*	*	*	*	*	*	8
100	*	*	*	*	HT	HT	20
	*	*	*	*	*	HT	16
	*	*	*	*	*	*	12
	*	*	*	*	*	*	8

NOTES:

- * satisfactory thermal conditions
- TD risk of too large Temperature Differences within the concrete slab
- EF risk of Early Freezing
- HT risk of too High Temperatures within the concrete slab

CEMENT TYPE II, CONTENT 650 LBS/CU.YD.

AIR TEMP. [Degree F]	CONCRETE TEMPERATURE [Degree F] 50	60	70	80	90	100	SLAB THICKNESS [Inches]
0	EF	EF/TD	EF/TD	TD	TD	TD	20
	EF	EF	EF	TD	TD	TD	16
	EF	EF	EF	EF	TD	TD	12
	EF	EF	EF	EF	EF	*	8
20	EF	*	*	TD	TD	TD	20
	EF	*	*	*	TD	TD	16
	EF	*	*	*	*	TD	12
	EF	EF	*	*	*	*	8
40	*	*	*	TD	TD	HT/TD	20
	*	*	*	*	TD	TD	16
	*	*	*	*	*	TD	12
	*	*	*	*	*	*	8
60	*	*	*	*	*	TD	20
	*	*	*	*	*	*	16
	*	*	*	*	*	*	12
	*	*	*	*	*	*	8
80	*	*	*	*	*	HT/TD	20
	*	*	*	*	*	*	16
	*	*	*	*	*	*	12
	*	*	*	*	*	*	8
100	*	*	*	HT	HT	HT/TD	20
	*	*	*	*	HT	HT	16
	*	*	*	*	*	HT	12
	*	*	*	*	*	*	8

NOTES:

*	satisfactory thermal conditions
TD	risk of too large Temperature Differences within the concrete slab
EF	risk of Early Freezing
HT	risk of too High Temperatures within the concrete slab

CEMENT TYPE II, CONTENT 675 LBS/CU.YD.

AIR TEMP. [Degree F]	CONCRETE TEMPERATURE [Degree F] 50	60	70	80	90	100	SLAB THICKNESS [Inches]
0	EF	EF/TD	EF/TD	TD	TD	TD	20
	EF	EF	EF	TD	TD	TD	16
	EF	EF	EF	EF	TD	TD	12
	EF	EF	EF	EF	EF	*	8
20	EF	*	*	TD	TD	TD	20
	EF	*	*	*	TD	TD	16
	EF	*	*	*	*	TD	12
	EF	EF	*	*	*	*	8
40	*	*	*	TD	TD	HT/TD	20
	*	*	*	*	TD	TD	16
	*	*	*	*	*	TD	12
	*	*	*	*	*	*	8
60	*	*	*	*	*	TD	20
	*	*	*	*	*	*	16
	*	*	*	*	*	*	12
	*	*	*	*	*	*	8
80	*	*	*	*	*	HT/TD	20
	*	*	*	*	*	*	16
	*	*	*	*	*	*	12
	*	*	*	*	*	*	8
100	*	*	*	HT	HT	HT/TD	20
	*	*	*	*	HT	HT	16
	*	*	*	*	*	HT	12
	*	*	*	*	*	*	8

NOTES:

*	satisfactory thermal conditions
TD	risk of too large Temperature Differences within the concrete slab
EF	risk of Early Freezing
HT	risk of too High Temperatures within the concrete slab

CEMENT TYPE II, CONTENT 700 LBS/CU.YD.

AIR TEMP. [Degree F]	CONCRETE TEMPERATURE [Degree F] 50	60	70	80	90	100	SLAB THICKNESS [Inches]
0	EF	EF/TD	EF/TD	TD	TD	TD	20
	EF	EF	EF	TD	TD	TD	16
	EF	EF	EF	EF	TD	TD	12
	EF	EF	EF	EF	*	*	8
20	EF	*	TD	TD	TD	HT/TD	20
	EF	*	*	*	TD	TD	16
	EF	*	*	*	*	TD	12
	EF	EF	*	*	*	*	8
40	*	*	TD	TD	TD	HT/TD	20
	*	*	*	*	TD	TD	16
	*	*	*	*	*	TD	12
	*	*	*	*	*	*	8
60	*	*	*	*	TD	TD	20
	*	*	*	*	*	TD	16
	*	*	*	*	*	*	12
	*	*	*	*	*	*	8
80	*	*	*	*	*	HT/TD	20
	*	*	*	*		*	16
	*	*	*	*	*	*	12
	*	*	*	*	*	*	8
100	*	*	*	HT	HT	HT/TD	20
	*	*	*	*	HT	HT	16
	*	*	*	*	*	HT	12
	*	*	*	*	*	*	8

NOTES:

*	satisfactory thermal conditions
TD	risk of too large Temperature Differences within the concrete slab
EF	risk of Early Freezing
HT	risk of too High Temperatures within the concrete slab

CEMENT TYPE II, CONTENT 725 LBS/CU.YD.

AIR TEMP. [Degree F]	CONCRETE TEMPERATURE [Degree F] 50	60	70	80	90	100	SLAB THICKNESS [Inches]
0	EF	EF/TD	EF/TD	TD	TD	TD	20
	EF	EF	EF/TD	TD	TD	TD	16
	EF	EF	EF	EF	TD	TD	12
	EF	EF	EF	EF	*	*	8
20	EF	*	TD	TD	TD	HT/TD	20
	EF	*	*	*	TD	TD	16
	EF	*	*	*	*	TD	12
	EF	EF	*	*	*	*	8
40	*	*	TD	TD	TD	HT/TD	20
	*	*	*	*	TD	TD	16
	*	*	*	*	*	TD	12
	*	*	*	*	*	*	8
60	*	*	*	*	TD	HT/TD	20
	*	*	*	*	*	TD	16
	*	*	*	*	*	*	12
	*	*	*	*	*	*	8
80	*	*	*	*	HT/TD	HT/TD	20
	*	*	*	*	*	HT/TD	16
	*	*	*	*	*	*	12
	*	*	*	*	*	*	8
100	*	*	HT	HT	HT/TD	HT/TD	20
	*	*	*	HT	HT	HT/TD	16
	*	*	*	*	HT	HT	12
	*	*	*	*	*	*	8

NOTES:

*	satisfactory thermal conditions
TD	risk of too large Temperature Differences within the concrete slab
EF	risk of Early Freezing
HT	risk of too High Temperatures within the concrete slab

CEMENT TYPE II, CONTENT 750 LBS/CU.YD.

AIR TEMP. [Degree F]	CONCRETE TEMPERATURE [Degree F] 50	60	70	80	90	100	SLAB THICKNESS [Inches]
0	EF	EF/TD	EF/TD	TD	TD	HT/TD	20
	EF	EF	EF/TD	TD	TD	TD	16
	EF	EF	EF	EF	TD	TD	12
	EF	EF	EF	EF	*	*	8
20	EF	*	TD	TD	TD	HT/TD	20
	EF	*	*	*	TD	TD	16
	EF	*	*	*	*	TD	12
	EF	EF	*	*	*	*	8
40	*	*	TD	TD	TD	HT/TD	20
	*	*	*	TD	TD	TD	16
	*	*	*	*	*	TD	12
	*	*	*	*	*	*	8
60	*	*	*	*	TD	HT/TD	20
	*	*	*	*	*	TD	16
	*	*	*	*	*	*	12
	*	*	*	*	*	*	8
80	*	*	*	*	HT/TD	HT/TD	20
	*	*	*	*	*	HT/TD	16
	*	*	*	*	*	*	12
	*	*	*	*	*	*	8
100	*	*	HT	HT	HT/TD	HT/TD	20
	*	*	*	HT	HT	HT/TD	16
	*	*	*	*	HT	HT	12
	*	*	*	*	*	*	8

NOTES:

*	satisfactory thermal conditions
TD	risk of too large Temperature Differences within the concrete slab
EF	risk of Early Freezing
HT	risk of too High Temperatures within the concrete slab

Type III Cement

CEMENT TYPE III, CONTENT 525 LBS/CU.YD.

AIR TEMP. [Degree F]	CONCRETE TEMPERATURE [Degree F] 50	60	70	80	90	100	SLAB THICKNESS [Inches]
0	EF/TD	EF/TD	EF/TD	TD	TD	TD	20
	EF	EF	EF/TD	TD	TD	TD	16
	EF	EF	EF	TD	TD	TD	12
	EF	EF	EF	EF	*	TD	8
20	EF	*	TD	TD	TD	HT/TD	20
	EF	*	*	TD	TD	TD	16
	EF	*	*	*	*	TD	12
	EF	*	*	*	*	*	8
40	*	TD	TD	TD	TD	HT/TD	20
	*	*	*	TD	TD	TD	16
	*	*	*	*	*	TD	12
	*	*	*	*	*	*	8
60	*	*	*	TD	TD	HT/TD	20
	*	*	*	*	TD	TD	16
	*	*	*	*	*	TD	12
	*	*	*	*	*	*	8
80	*	*	*	TD	HT/TD	HT/TD	20
	*	*	*	*	TD	HT/TD	16
	*	*	*	*	*	*	12
	*	*	*	*	*	*	8
100	*	*	*	HT	HT/TD	HT/TD	20
	*	*	*	HT	HT	HT/TD	16
	*	*	*	*	HT	HT	12
	*	*	*	*	*	*	8

NOTES:

*	satisfactory thermal conditions
TD	risk of too large Temperature Differences within the concrete slab
EF	risk of Early Freezing
HT	risk of too High Temperatures within the concrete slab

CEMENT TYPE III, CONTENT 550 LBS/CU.YD.

AIR TEMP. [Degree F]	CONCRETE TEMPERATURE [Degree F] 50	60	70	80	90	100	SLAB THICKNESS [Inches]
0	EF/TD	EF/TD	EF/TD	TD	TD	HT/TD	20
	EF	EF/TD	EF/TD	TD	TD	TD	16
	EF	EF	EF	TD	TD	TD	12
	EF	EF	EF	EF	*	TD	8
20	EF	*	TD	TD	TD	HT/TD	20
	EF	*	*	TD	TD	TD	16
	EF	*	*	*	*	TD	12
	EF	*	*	*	*	*	8
40	*	TD	TD	TD	HT/TD	HT/TD	20
	*	*	TD	TD	TD	HT/TD	16
	*	*	*	*	TD	TD	12
	*	*	*	*	*	*	8
60	*	*	*	TD	TD	HT/TD	20
	*	*	*	*	TD	TD	16
	*	*	*	*	*	TD	12
	*	*	*	*	*	*	8
80	*	*	*	TD	HT/TD	HT/TD	20
	*	*	*	*	TD	HT/TD	16
	*	*	*	*	*	TD	12
	*	*	*	*	*	*	8
100	*	*	HT	HT	HT/TD	HT/TD	20
	*	*	*	HT	HT/TD	HT/TD	16
	*	*	*	*	HT	HT/TD	12
	*	*	*	*	*	HT	8

NOTES:

- `*` satisfactory thermal conditions
- TD risk of too large Temperature Differences within the concrete slab
- EF risk of Early Freezing
- HT risk of too High Temperatures within the concrete slab

CEMENT TYPE III, CONTENT 575 LBS/CU.YD.

AIR TEMP. [Degree F]	CONCRETE TEMPERATURE [Degree F] 50	60	70	80	90	100	SLAB THICKNESS [Inches]
0	EF/TD	EF/TD	EF/TD	TD	TD	HT/TD	20
	EF	EF/TD	EF/TD	TD	TD	TD	16
	EF	EF	EF	TD	TD	TD	12
	EF	EF	EF	EF	*	TD	8
20	EF	TD	TD	TD	TD	HT/TD	20
	EF	*	*	TD	TD	HT/TD	16
	EF	*	*	*	TD	TD	12
	EF	*	*	*	*	*	8
40	*	TD	TD	TD	HT/TD	HT/TD	20
	*	*	TD	TD	TD	HT/TD	16
	*	*	*	*	TD	TD	12
	*	*	*	*	*	*	8
60	*	*	*	TD	HT/TD	HT/TD	20
	*	*	*	*	TD	HT/TD	16
	*	*	*	*	*	TD	12
	*	*	*	*	*	*	8
80	*	*	*	HT/TD	HT/TD	HT/TD	20
	*	*	*	*	HT/TD	HT/TD	16
	*	*	*	*	*	HT/TD	12
	*	*	*	*	*	*	8
100	*	*	HT	HT/TD	HT/TD	HT/TD	20
	*	*	HT	HT	HT/TD	HT/TD	16
	*	*	*	HT	HT	HT/TD	12
	*	*	*	*	*	HT	8

NOTES:

*	satisfactory thermal conditions
TD	risk of too large Temperature Differences within the concrete slab
EF	risk of Early Freezing
HT	risk of too High Temperatures within the concrete slab

CEMENT TYPE III, CONTENT 600 LBS/CU.YD.

AIR TEMP. [Degree F]	CONCRETE TEMPERATURE [Degree F] 50	60	70	80	90	100	SLAB THICKNESS [Inches]
0	EF/TD	EF/TD	EF/TD	TD	TD	HT/TD	20
	EF	EF/TD	EF/TD	TD	TD	TD	16
	EF	EF	EF	TD	TD	TD	12
	EF	EF	EF	EF	*	TD	8
20	EF	TD	TD	TD	HT/TD	HT/TD	20
	EF	*	TD	TD	TD	HT/TD	16
	EF	*	*	*	TD	TD	12
	EF	*	*	*	*	*	8
40	*	TD	TD	TD	HT/TD	HT/TD	20
	*	*	TD	TD	TD	HT/TD	16
	*	*	*	TD	TD	TD	12
	*	*	*	*	*	*	8
60	*	*	TD	TD	HT/TD	HT/TD	20
	*	*	*	TD	TD	HT/TD	16
	*	*	*	*	*	TD	12
	*	*	*	*	*	*	8
80	*	*	TD	HT/TD	HT/TD	HT/TD	20
	*	*	*	TD	HT/TD	HT/TD	16
	*	*	*	*	*	HT/TD	12
	*	*	*	*	*	*	8
100	*	HT	HT/TD	HT/TD	HT/TD	HT/TD	20
	*	*	HT	HT/TD	HT/TD	HT/TD	16
	*	*	*	HT	HT	HT/TD	12
	*	*	*	*	HT	HT	8

NOTES:

*	satisfactory thermal conditions
TD	risk of too large Temperature Differences within the concrete slab
EF	risk of Early Freezing
HT	risk of too High Temperatures within the concrete slab

CEMENT TYPE III, CONTENT 625 LBS/CU.YD.

AIR TEMP. [Degree F]	CONCRETE TEMPERATURE [Degree F] 50	60	70	80	90	100	SLAB THICKNESS [Inches]
0	EF/TD	EF/TD	EF/TD	TD	HT/TD	HT/TD	20
	EF	EF/TD	EF/TD	TD	TD	HT/TD	16
	EF	EF	EF	TD	TD	TD	12
	EF	EF	EF	EF	*	TD	8
20	EF	TD	TD	TD	HT/TD	HT/TD	20
	EF	*	TD	TD	TD	HT/TD	16
	EF	*	*	*	TD	TD	12
	EF	*	*	*	*	*	8
40	TD	TD	TD	HT/TD	HT/TD	HT/TD	20
	*	TD	TD	TD	HT/TD	HT/TD	16
	*	*	*	TD	TD	TD	12
	*	*	*	*	*	*	8
60	*	*	TD	TD	HT/TD	HT/TD	20
	*	*	*	TD	TD	HT/TD	16
	*	*	*	*	*	TD	12
	*	*	*	*	*	*	8
80	*	TD	TD	HT/TD	HT/TD	HT/TD	20
	*	*	*	HT/TD	HT/TD	HT/TD	16
	*	*	*	*	TD	HT/TD	12
	*	*	*	*	*	*	8
100	TD	HT/TD	HT/TD	HT/TD	HT/TD	HT/TD	20
	*	HT	HT/TD	HT/TD	HT/TD	HT/TD	16
	*	*	HT	HT	HT/TD	HT/TD	12
	*	*	*	*	HT	HT	8

NOTES:

- * satisfactory thermal conditions
- TD risk of too large Temperature Differences within the concrete slab
- EF risk of Early Freezing
- HT risk of too High Temperatures within the concrete slab

CEMENT TYPE III, CONTENT 650 LBS/CU.YD.

AIR TEMP. [Degree F]	CONCRETE TEMPERATURE [Degree F] 50	60	70	80	90	100	SLAB THICKNESS [Inches]
0	EF/TD	EF/TD	EF/TD	TD	HT/TD	HT/TD	20
	EF	EF/TD	EF/TD	TD	TD	HT/TD	16
	EF	EF	EF	TD	TD	TD	12
	EF	EF	EF	EF	*	TD	8
20	EF/TD	TD	TD	HT/TD	HT/TD	HT/TD	20
	EF	*	TD	TD	HT/TD	HT/TD	16
	EF	*	*	*	TD	TD	12
	EF	*	*	*	*	*	8
40	TD	TD	TD	HT/TD	HT/TD	HT/TD	20
	*	TD	TD	TD	HT/TD	HT/TD	16
	*	*	*	TD	TD	TD	12
	*	*	*	*	*	*	8
60	*	TD	TD	TD	HT/TD	HT/TD	20
	*	*	*	TD	TD	HT/TD	16
	*	*	*	*	TD	TD	12
	*	*	*	*	*	*	8
80	TD	TD	HT/TD	HT/TD	HT/TD	HT/TD	20
	*	*	TD	HT/TD	HT/TD	HT/[illegible]	16
	*	*	*	*	HT/TD	HT/[illegible]	12
	*	*	*	*	*	*	8
100	HT/TD	HT/TD	HT/TD	HT/TD	HT/TD	HT/TD	20
	*	HT/TD	HT/TD	HT/TD	HT/TD	HT/TD	16
	*	HT	HT	HT/TD	HT/TD	HT/TD	12
	*	*	*	HT	HT	HT	8

NOTES:

- * satisfactory thermal conditions
- TD risk of too large Temperature Differences within the concrete slab
- EF risk of Early Freezing
- HT risk of too High Temperatures within the concrete slab

CEMENT TYPE III, CONTENT 675 LBS/CU.YD.

AIR TEMP. [Degree F]	CONCRETE TEMPERATURE [Degree F] 50	60	70	80	90	100	SLAB THICKNESS [Inches]
	EF/TD	EF/TD	EF/TD	HT/TD	HT/TD	HT/TD	20
	EF	EF/TD	EF/TD	TD	TD	HT/TD	16
0	EF	EF	EF	TD	TD	TD	12
	EF	EF	EF	EF	*	TD	8
	EF/TD	TD	TD	HT/TD	HT/TD	HT/TD	20
	EF	TD	TD	TD	HT/TD	HT/TD	16
20	EF	*	*	TD	TD	TD	12
	EF	*	*	*	*	*	8
	TD	TD	TD	HT/TD	HT/TD	HT/TD	20
	*	TD	TD	TD	HT/TD	HT/TD	16
40	*	*	*	TD	TD	HT/TD	12
	*	*	*	*	*	*	8
	*	TD	TD	HT/TD	HT/TD	HT/TD	20
	*	*	*	TD	HT/TD	HT/TD	16
60	*	*	*	*	TD	TD	12
	*	*	*	*	*	*	8
	TD	TD	HT/TD	HT/TD	HT/TD	HT/TD	20
	*	TD	TD	HT/TD	HT/TD	HT/TD	16
80	*	*	*	*	HT/TD	HT/TD	12
	*	*	*	*	*	*	8
	HT/TD	HT/TD	HT/TD	HT/TD	HT/TD	HT/TD	20
	HT/TD	HT/TD	HT/TD	HT/TD	HT/TD	HT/TD	16
100	*	HT	HT/TD	HT/TD	HT/TD	HT/TD	12
	*	*	*	HT	HT	HT/TD	8

NOTES:

*	satisfactory thermal conditions
TD	risk of too large Temperature Differences within the concrete slab
EF	risk of Early Freezing
HT	risk of too High Temperatures within the concrete slab

CEMENT TYPE III, CONTENT 700 LBS/CU.YD.

AIR TEMP. [Degree F]	CONCRETE TEMPERATURE [Degree F] 50	60	70	80	90	100	SLAB THICKNESS [Inches]
	EF/TD	EF/TD	EF/TD	HT/TD	HT/TD	HT/TD	20
	EF/TD	EF/TD	EF/TD	TD	HT/TD	HT/TD	16
0	EF	EF	EF	TD	TD	TD	12
	EF	EF	EF	EF	*	TD	8
	EF/TD	TD	TD	HT/TD	HT/TD	HT/TD	20
	EF	TD	TD	TD	HT/TD	HT/TD	16
20	EF	*	*	TD	TD	TD	[illegible]
	EF	*	*	*	*	*	8
	TD	TD	HT/TD	HT/TD	HT/TD	HT/TD	20
	*	TD	TD	HT/TD	HT/TD	HT/TD	16
40	*	*	TD	TD	TD	HT/TD	12
	*	*	*	*	*	*	8
	*	TD	TD	HT/TD	HT/TD	HT/TD	20
	*	*	TD	TD	HT/TD	HT/TD	16
60	*	*	*	*	TD	HT/TD	12
	*	*	*	*	*	*	8
	TD	HT/TD	HT/TD	HT/TD	HT/TD	HT/TD	20
	*	TD	HT/TD	HT/TD	HT/TD	HT/TD	16
80	*	*	*	TD	HT/TD	HT/TD	12
	*	*	*	*	*	*	8
	HT/TD	HT/TD	HT/TD	HT/TD	HT/TD	HT/TD	20
	HT/TD	HT/TD	HT/TD	HT/TD	HT/TD	HT/TD	16
100	HT	HT	HT/TD	HT/TD	HT/TD	HT/TD	12
	*	*	HT	HT	HT	HT/TD	8

NOTES:

*	sa[illegible]ctory thermal conditions
TD	nsk of too large Temperature Differences within the concrete slab
EF	risk of Early Freezing
HT	nsk of too High Temperatures within the concrete slab

CEMENT TYPE III, CONTENT 725 LBS/CU.YD.

AIR TEMP. [Degree F]	CONCRETE TEMPERATURE [Degree F] 50	60	70	80	90	100	SLAB THICKNESS [Inches]
0	EF/TD	EF/TD	EF/TD	HT/TD	HT/TD	HT/TD	20
	EF/TD	EF/TD	EF/TD	TD	HT/TD	HT/TD	16
	EF	EF	EF	TD	TD	TD	12
	EF	EF	EF	EF	*	TD	8
20	EF/TD	TD	HT/TD	HT/TD	HT/TD	HT/TD	20
	EF	TD	TD	HT/TD	HT/TD	HT/TD	16
	EF	*	*	TD	TD	HT/TD	12
	EF	*	*	*	*	*	8
40	TD	TD	HT/TD	HT/TD	HT/TD	HT/TD	20
	TD	TD	TD	HT/TD	HT/TD	HT/TD	16
	*	*	TD	TD	TD	HT/TD	12
	*	*	*	*	*	TD	8
60	TD	TD	TD	HT/TD	HT/TD	HT/TD	20
	*	*	TD	TD	HT/TD	HT/TD	16
	*	*	*	*	TD	HT/TD	12
	*	*	*	*	*	*	8
80	TD	HT/TD	HT/TD	HT/TD	HT/TD	HT/TD	20
	TD	HT/TD	HT/TD	HT/TD	HT/TD	HT/TD	16
	*	*	*	HT/TD	HT/TD	HT/TD	12
	*	*	*	*	*	TD	8
100	HT/TD	HT/TD	HT/TD	HT/TD	HT/TD	HT/TD	20
	HT/TD	HT/TD	HT/TD	HT/TD	HT/TD	HT/TD	16
	HT/TD	HT/TD	HT/TD	HT/TD	HT/TD	HT/TD	12
	*	HT	HT	HT	HT/TD	HT/TD	8

NOTES:

*	satisfactory thermal conditions
TD	risk of too large Temperature Differences within the concrete slab
EF	risk of Early Freezing
HT	risk of too High Temperatures within the concrete slab

CEMENT TYPE III, CONTENT 750 LBS/CU.YD.

AIR TEMP. [Degree F]	CONCRETE TEMPERATURE [Degree F] 50	60	70	80	90	100	SLAB THICKNESS [inches]
0	EF/TD	EF/TD	EF/TD	HT/TD	HT/TD	HT/TD	20
	EF/TD	EF/TD	EF/TD	TD	HT/TD	HT/TD	16
	EF	EF	EF	TD	TD	HT/TD	12
	EF	EF	EF	EF	*	TD	8
20	EF/TD	TD	HT/TD	HT/TD	HT/TD	HT/TD	20
	EF	TD	TD	HT/TD	HT/TD	HT/TD	16
	EF	*	TD	TD	TD	HT/TD	12
	EF	*	*	*	*	*	8
40	TD	TD	HT/TD	HT/TD	HT/TD	HT/TD	20
	TD	TD	TD	HT/TD	HT/TD	HT/TD	16
	*	*	TD	TD	HT/TD	HT/TD	12
	*	*	*	*	*	TD	8
60	TD	TD	HT/TD	HT/TD	HT/TD	HT/TD	20
	*	TD	TD	HT/TD	HT/TD	HT/TD	16
	*	*	*	TD	TD	HT/TD	12
	*	*	*	*	*	*	8
80	HT/TD	HT/TD	HT/TD	HT/TD	HT/TD	HT/TD	20
	TD	HT/TD	HT/TD	HT/TD	HT/TD	HT/TD	16
	*	*	TD	HT/TD	HT/TD	HT/TD	12
	*	*	*	*	*	HT/TD	8
100	HT/TD	HT/TD	HT/TD	HT/TD	HT/TD	HT/TD	20
	HT/TD	HT/TD	HT/TD	HT/TD	HT/TD	HT/TD	16
	HT/TD	HT/TD	HT/TD	HT/TD	HT/TD	HT/TD	12
	*	HT	HT	HT/TD	HT/TD	HT/TD	8

NOTES:

*	satisfactory thermal conditions
TD	risk of too large Temperature Differences within the concrete slab
EF	risk of Early Freezing
HT	risk of too High Temperatures within the concrete slab

Type I Cement With Class F Fly Ash

CEMENT TYPE I, CONTENT 420 LBS/CU.YD.
FLY ASH CLASS F, CONTENT 105 LBS/CU.YD.

AIR TEMP. [Degree F]	CONCRETE TEMPERATURE [Degree F] 50	60	70	80	90	100	SLAB THICKNESS [Inches]
0	EF	EF	EF/TD	TD	TD	TD	20
	EF	EF	EF	TD	TD	TD	16
	EF	EF	EF	EF	TD	TD	12
	EF	EF	EF	EF	EF	*	8
20	EF	*	*	*	TD	TD	20
	EF	*	*	*	*	TD	16
	EF	*	*	*	*	TD	12
	EF	EF	*	*	*	*	8
40	*	*	*	*	TD	TD	20
	*	*	*	*	*	TD	16
	*	*	*	*	*	TD	12
	*	*	*	*	*	*	8
60	*	*	*	*	*	TD	20
	*	*	*	*	*	*	16
	*	*	*	*	*	*	12
	*	*	*	*	*	*	8
80	*	*	*	*	*	*	20
	*	*	*	*	*	*	16
	*	*	*	*	*	*	12
	*	*	*	*	*	*	8
100	*	*	*	*	*	HT	20
	*	*	*	*	*	*	16
	*	*	*	*	*	*	12
	*	*	*	*	*	*	8

NOTES:

*	satisfactory thermal conditions
TD	risk of too large Temperature Differences within the concrete slab
EF	risk of Early Freezing
HT	risk of too High Temperatures within the concrete slab

CEMENT TYPE I, CONTENT 440 LBS/CU.YD.
FLY ASH CLASS F, CONTENT 110 LBS/CU.YD.

AIR TEMP. [Degree F]	CONCRETE TEMPERATURE [Degree F] 50	60	70	80	90	100	SLAB THICKNESS [Inches]
0	EF	EF/TD	EF/TD	TD	TD	TD	20
	EF	EF	EF	TD	TD	TD	16
	EF	EF	EF	EF	TD	TD	12
	EF	EF	EF	EF	EF	*	8
20	EF	*	*	*	TD	TD	20
	EF	*	*	*	*	TD	16
	EF	*	*	*	*	TD	12
	EF	EF	*	*	*	*	8
40	*	*	*	TD	TD	TD	20
	*	*	*	*	*	TD	16
	*	*	*	*	*	TD	12
	*	*	*	*	*	*	8
60	*	*	*	*	*	TD	20
	*	*	*	*	*	*	16
	*	*	*	*	*	*	12
	*	*	*	*	*	*	8
80	*	*	*	*	*	*	20
	*	*	*	*	*	*	16
	*	*	*	*	*	*	12
	*	*	*	*	*	*	8
100	*	*	*	*	*	HT	20
	*	*	*	*	*	HT	16
	*	*	*	*	*	*	12
	*	*	*	*	*	*	8

NOTES:

- * satisfactory thermal conditions
- TD nsk of too large Temperature Differences within the concrete slab
- EF nsk of Early Freezing
- HT nsk of too High Temperatures within the concrete slab

CEMENT TYPE I, CONTENT 460 LBS/CU.YD.
FLY ASH CLASS F, CONTENT 115 LBS/CU.YD.

AIR TEMP. [Degree F]	CONCRETE TEMPERATURE [Degree F] 50	60	70	80	90	100	SLAB THICKNESS [Inches]
0	EF	EF/TD	EF/TD	TD	TD	TD	20
	EF	EF	EF	TD	TD	TD	16
	EF	EF	EF	EF	TD	TD	12
	EF	EF	EF	EF	EF	*	8
20	EF	*	*	TD	TD	TD	20
	EF	*	*	*	*	TD	16
	EF	*	*	*	*	TD	12
	EF	EF	*	*	*	*	8
40	*	*	*	TD	TD	TD	20
	*	*	*	*	*	TD	16
	*	*	*	*	*	TD	12
	*	*	*	*	*	*	8
60	*	*	*	*	*	TD	20
	*	*	*	*	*	*	16
	*	*	*	*	*	*	12
	*	*	*	*	*	*	8
80	*	*	*	*	*	TD	20
	*	*	*	*	*	*	16
	*	*	*	*	*	*	12
	*	*	*	*	*	*	8
100	*	*	*	*	HT	HT	20
	*	*	*	*	*	HT	16
	*	*	*	*	*	*	12
	*	*	*	*	*	*	8

NOTES:

*	satisfactory thermal conditions
TD	risk of too large Temperature Differences within the concrete slab
EF	risk of Early Freezing
HT	risk of too High Temperatures within the concrete slab

CEMENT TYPE I, CONTENT 480 LBS/CU.YD.
FLY ASH CLASS F, CONTENT 120 LBS/CU.YD.

AIR TEMP. [Degree F]	CONCRETE TEMPERATURE [Degree F] 50	60	70	80	90	100	SLAB THICKNESS [Inches]
0	EF	EF/TD	EF/TD	TD	TD	TD	20
	EF	EF	EF	TD	TD	TD	16
	EF	EF	EF	EF	TD	TD	12
	EF	EF	EF	EF	EF	*	8
20	EF	*	*	TD	TD	TD	20
	EF	*	*	*	*	TD	16
	EF	*	*	*	*	TD	12
	EF	EF	*	*	*	*	8
40	*	*	*	TD	TD	TD	20
	*	*	*	*	TD	TD	16
	*	*	*	*	*	TD	12
	*	*	*	*	*	*	8
60	*	*	*	*	*	TD	20
	*	*	*	*	*	*	16
	*	*	*	*	*	*	12
	*	*	*	*	*	*	8
80	*	*	*	*	*	HT/TD	20
	*	*	*	*	*	*	16
	*	*	*	*	*	*	12
	*	*	*	*	*	*	8
100	*	*	*	*	HT	HT	20
	*	*	*	*	*	HT	16
	*	*	*	*	*	*	12
	*	*	*	*	*	*	8

NOTES:

*	satisfactory thermal conditions
TD	risk of too large Temperature Differences within the concrete slab
EF	risk of Early Freezing
HT	risk of too High Temperatures within the concrete slab

CEMENT TYPE I, CONTENT 500 LBS/CU.YD.
FLY ASH CLASS F, CONTENT 125 LBS/CU.YD.

AIR TEMP. [Degree F]	CONCRETE TEMPERATURE [Degree F] 50	60	70	80	90	100	SLAB THICKNESS [Inches]
0	EF	EF/TD	EF/TD	TD	TD	TD	20
	EF	EF	EF	TD	TD	TD	16
	EF	EF	EF	EF	TD	TD	12
	EF	EF	EF	EF	EF	*	8
20	EF	*	*	TD	TD	TD	20
	EF	*	*	*	*	TD	16
	EF	*	*	*	*	TD	12
	EF	EF	*	*	*	*	8
40	*	*	*	TD	TD	TD	20
	*	*	*	*	TD	TD	16
	*	*	*	*	*	TD	12
	*	*	*	*	*	*	8
60	*	*	*	*	*	TD	20
	*	*	*	*	*	*	16
	*	*	*	*	*	*	12
	*	*	*	*	*	*	8
80	*	*	*	*	*	HT/TD	20
	*	*	*	*	*	*	16
	*	*	*	*	*	*	12
	*	*	*	*	*	*	8
100	*	*	*	HT	HT	HT/TD	20
	*	*	*	*	HT	HT	16
	*	*	*	*	*	HT	12
	*	*	*	*	*	*	8

NOTES:

*	satisfactory thermal conditions
TD	risk of too large Temperature Differences within the concrete slab
EF	risk of Early Freezing
HT	risk of too High Temperatures within the concrete slab

CEMENT TYPE I, CONTENT 520 LBS/CU.YD.
FLY ASH CLASS F, CONTENT 130 LBS/CU.YD.

AIR TEMP. [Degree F]	CONCRETE TEMPERATURE [Degree F] 50	60	70	80	90	100	SLAB THICKNESS [Inches]
0	EF	EF/TD	EF/TD	TD	TD	TD	20
	EF	EF	EF	TD	TD	TD	16
	EF	EF	EF	EF	TD	TD	12
	EF	EF	EF	EF	EF	*	8
20	EF	*	*	TD	TD	TD	20
	EF	*	*	*	*	TD	16
	EF	*	*	*	*	TD	12
	EF	EF	*	*	*	*	8
40	*	*	*	TD	TD	HT/TD	20
	*	*	*	*	TD	TD	16
	*	*	*	*	*	TD	12
	*	*	*	*	*	*	8
60	*	*	*	*	*	TD	20
	*	*	*	*	*	*	16
	*	*	*	*	*	*	12
	*	*	*	*	*	*	8
80	*	*	*	*	*	HT/TD	20
	*	*	*	*	*	*	16
	*	*	*	*	*	*	12
	*	*	*	*	*	*	8
100	*	*	*	HT	HT	HT/TD	20
	*	*	*	*	HT	HT	16
	*	*	*	*	*	HT	12
	*	*	*	*	*	*	8

NOTES:

*	satisfactory thermal conditions
TD	risk of too large Temperature Differences within the concrete slab
EF	risk of Early Freezing
HT	risk of too High Temperatures within the concrete slab

CEMENT TYPE I, CONTENT 540 LBS/CU.YD.
FLY ASH CLASS F, CONTENT 135 LBS/CU.YD.

AIR TEMP. [Degree F]	CONCRETE TEMPERATURE [Degree F] 50	60	70	80	90	100	SLAB THICKNESS [Inches]
	EF	EF/TD	EF/TD	TD	TD	TD	20
	EF	EF	EF/TD	TD	TD	TD	16
0	EF	EF	EF	EF	TD	TD	12
	EF	EF	EF	EF	EF	*	8
	EF	*	TD	TD	TD	HT/TD	20
	EF	*	*	*	*	TD	16
20	EF	*	*	*	*	TD	12
	EF	EF	*	*	*	*	8
	*	*	TD	TD	TD	HT/TD	20
	*	*	*	*	TD	TD	16
40	*	*	*	*	*	TD	12
	*	*	*	*	*	*	8
	*	*	*	*	TD	TD	20
	*	*	*	*	*	TD	16
60	*	*	*	*	*	*	12
	*	*	*	*	*	*	8
	*	*	*	*	TD	HT/TD	20
	*	*	*	*	*	*	16
80	*	*	*	*	*	*	12
	*	*	*	*	*	*	8
	*	*	*	HT	HT	HT/TD	20
	*	*	*	HT	HT	HT	16
100	*	*	*	*	*	HT	12
	*	*	*	*	*	*	8

NOTES:

*	satisfactory thermal conditions
TD	risk of too large Temperature Differences within the concrete slab
EF	risk of Early Freezing
HT	risk of too High Temperatures within the concrete slab

CEMENT TYPE I, CONTENT 560 LBS/CU.YD.

FLY ASH CLASS F, CONTENT 140 LBS/CU.YD.

AIR TEMP. [Degree F]	CONCRETE TEMPERATURE [Degree F] 50	60	70	80	90	100	SLAB THICKNESS [Inches]
0	EF	EF/TD	EF/TD	TD	TD	TD	20
	EF	EF	EF/TD	TD	TD	TD	16
	EF	EF	EF	EF	TD	TD	12
	EF	EF	EF	EF	EF	*	8
20	EF	*	TD	TD	TD	HT/TD	20
	EF	*	*	*	TD	TD	16
	EF	*	*	*	*	TD	12
	EF	EF	*	*	*	*	8
40	*	*	TD	TD	TD	HT/TD	20
	*	*	*	TD	TD	TD	16
	*	*	*	*	*	TD	12
	*	*	*	*	*	*	8
60	*	*	*	*	TD	TD	20
	*	*	*	*	*	TD	16
	*	*	*	*	*	*	12
	*	*	*	*	*	*	8
80	*	*	*	*	HT/TD	HT/TD	20
	*	*	*	*	*	HT	16
	*	*	*	*	*	*	12
	*	*	*	*	*	*	8
100	*	*	HT	HT	HT/TD	HT/TD	20
	*	*	*	HT	HT	HT	16
	*	*	*	*	HT	HT	12
	*	*	*	*	*	*	8

NOTES:

*	satisfactory thermal conditions
TD	risk of too large Temperature Differences within the concrete slab
EF	risk of Early Freezing
HT	risk of too High Temperatures within the concrete slab

CEMENT TYPE I, CONTENT 580 LBS/CU.YD.
FLY ASH CLASS F, CONTENT 145 LBS/CU.YD.

AIR TEMP. [Degree F]	CONCRETE TEMPERATURE [Degree F] 50	60	70	80	90	100	SLAB THICKNESS [Inches]
0	EF	EF/TD	EF/TD	TD	TD	HT/TD	20
	EF	EF	EF/TD	TD	TD	TD	16
	EF	EF	EF	EF	TD	TD	12
	EF	EF	EF	EF	EF	*	8
20	EF	*	TD	TD	TD	HT/TD	20
	EF	*	*	*	TD	TD	16
	EF	*	*	*	*	TD	12
	EF	EF	*	*	*	*	8
40	*	*	TD	TD	TD	HT/TD	20
	*	*	*	TD	TD	TD	16
	*	*	*	*	*	TD	12
	*	*	*	*	*	*	8
60	*	*	*	*	TD	HT/TD	20
	*	*	*	*	*	TD	16
	*	*	*	*	*	*	12
	*	*	*	*	*	*	8
80	*	*	*	*	HT/TD	HT/TD	20
	*	*	*	*	*	HT/TD	16
	*	*	*	*	*	*	12
	*	*	*	*	*	*	8
100	*	*	HT	HT	HT/TD	HT/TD	20
	*	*	*	HT	HT	HT/TD	16
	*	*	*	*	HT	HT	12
	*	*	*	*	*	*	8

NOTES:

*	satisfactory thermal conditions
TD	risk of too large Temperature Differences within the concrete slab
EF	risk of Early Freezing
HT	risk of too High Temperatures within the concrete slab

CEMENT TYPE I, CONTENT 600 LBS/CU.YD.
FLY ASH CLASS F, CONTENT 150 LBS/CU.YD.

AIR TEMP. [Degree F]	CONCRETE TEMPERATURE [Degree F] 50	60	70	80	90	100	SLAB THICKNESS [Inches]
0	EF	EF/TD	EF/TD	TD	TD	HT/TD	20
	EF	EF	EF/TD	TD	TD	TD	16
	EF	EF	EF	EF	TD	TD	12
	EF	EF	EF	EF	EF	*	8
20	EF	*	TD	TD	TD	HT/TD	20
	EF	*	*	*	TD	TD	16
	EF	*	*	*	*	TD	12
	EF	EF	*	*	*	*	8
40	*	TD	TD	TD	HT/TD	HT/TD	20
	*	*	*	TD	TD	HT/TD	16
	*	*	*	*	*	TD	12
	*	*	*	*	*	*	8
60	*	*	*	*	TD	HT/TD	20
	*	*	*	*	*	TD	16
	*	*	*	*	*	*	12
	*	*	*	*	*	*	8
80	*	*	*	TD	HT/TD	HT/TD	20
	*	*	*	*	*	HT/TD	16
	*	*	*		*	*	12
	*	*	*	*	*	*	8
100	*	HT	HT	HT/TD	HT/TD	HT/TD	20
	*	*	HT	HT	HT	HT/TD	16
	*	*	*	*	HT	HT	12
	*	*	*	*	*	*	8

NOTES:

- * satisfactory thermal conditions
- TD risk of too large Temperature Differences within the concrete slab
- EF risk of Early Freezing
- HT risk of too High Temperatures within the concrete slab

Type II Cement With Class F Fly Ash

CEMENT TYPE II, CONTENT 420 LBS/CU.YD.
FLY ASH CLASS F, CONTENT 105 LBS/CU.YD.

AIR TEMP. [Degree F]	CONCRETE TEMPERATURE [Degree F] 50	60	70	80	90	100	SLAB THICKNESS [inches]
	EF	EF	EF/TD	TD	TD	TD	20
	EF	EF	EF	TD	TD	TD	16
0	EF	EF	EF	EF	TD	TD	12
	EF	EF	EF	EF	EF	EF	8
	EF	*	*	*	TD	TD	20
	EF	*	*	*	*	TD	16
20	EF	EF	*	*	*	TD	12
	EF	EF	EF	EF	*	*	8
	*	*	*	*	TD	TD	20
	*	*	*	*	*	TD	16
40	*	*	*	*	*	TD	12
	*	*	*	*	*	*	8
	*	*	*	*	*	*	20
	*	*	*	*	*	*	16
60	*	*	*	*	*	*	12
	*	*	*	*	*	*	8
	*	*	*	*	*	*	20
	*	*	*	*	*	*	16
80	*	*	*	*	*	*	12
	*	*	*	*	*	*	8
	*	*	*	*	*	*	20
	*	*	*	*	*	*	16
100	*	*	*	*	*	*	12
	*	*	*	*	*	*	8

NOTES:

*	satisfactory thermal conditions
TD	risk of too large Temperature Differences within the concrete slab
EF	risk of Early Freezing
HT	risk of too High Temperatures within the concrete slab

CEMENT TYPE II, CONTENT 440 LBS/CU.YD.

FLY ASH CLASS F, CONTENT 110 LBS/CU.YD.

AIR TEMP. [Degree F]	CONCRETE TEMPERATURE [Degree F] 50	60	70	80	90	100	SLAB THICKNESS [Inches]
0	EF	EF	EF/TD	TD	TD	TD	20
	EF	EF	EF	TD	TD	TD	16
	EF	EF	EF	EF	TD	TD	12
	EF	EF	EF	EF	EF	*	8
20	EF	*	*	*	TD	TD	20
	EF	*	*	*	*	TD	16
	EF	EF	*	*	*	TD	12
	EF	EF	EF	*	*	*	8
40	*	*	*	*	TD	TD	20
	*	*	*	*	*	TD	16
	*	*	*	*	*	TD	12
	*	*	*	*	*	*	8
60	*	*	*	*	*	*	20
	*	*	*	*	*	*	16
	*	*	*	*	*	*	12
	*	*	*	*	*	*	8
80	*	*	*	*	*	*	20
	*	*	*	*	*	*	16
	*	*	*	*	*	*	12
	*	*	*	*	*	*	8
100	*	*	*	*	*	*	20
	*	*	*	*	*	*	16
	*	*	*	*	*	*	12
	*	*	*	*	*	*	8

NOTES:

*	satisfactory thermal conditions
TD	risk of too large Temperature Differences within the concrete slab
EF	risk of Early Freezing
HT	risk of too High Temperatures within the concrete slab

CEMENT TYPE II, CONTENT 460 LBS/CU.YD.
FLY ASH CLASS F, CONTENT 115 LBS/CU.YD.

AIR TEMP. [Degree F]	CONCRETE TEMPERATURE [Degree F] 50	60	70	80	90	100	SLAB THICKNESS [Inches]
	EF	EF	EF/TD	TD	TD	TD	20
	EF	EF	EF	TD	TD	TD	16
0	EF	EF	EF	EF	TD	TD	12
	EF	EF	EF	EF	EF	*	8
	EF	*	*	*	TD	TD	20
	EF	*	*	*	*	TD	16
20	EF	EF	*	*	*	TD	12
	EF	EF	EF	EF	*	*	8
	*	*	*	*	TD	TD	20
	*	*	*	*	*	TD	16
40	*	*	*	*	*	TD	12
	*	*	*	*	*	*	8
	*	*	*	*	*	*	20
	*	*	*	*	*	*	16
60	*	*	*	*	*	*	12
	*	*	*	*	*	*	8
	*	*	*	*	*	*	20
	*	*	*	*	*	*	16
80	*	*	*	*	*	*	12
	*	*	*	*	*	*	8
	*	*	*	*	*	*	20
	*	*	*	*	*	*	16
100	*	*	*	*	*	*	12
	*	*	*	*	*	*	8

NOTES:

- * satisfactory thermal conditions
- TD risk of too large Temperature Differences within the concrete slab
- EF risk of Early Freezing
- HT risk of too High Temperatures within the concrete slab

CEMENT TYPE II, CONTENT 480 LBS/CU.YD.

FLY ASH CLASS F, CONTENT 120 LBS/CU.YD.

AIR TEMP. [Degree F]	CONCRETE TEMPERATURE [Degree F] 50	60	70	80	90	100	SLAB THICKNESS [Inches]
0	EF	EF	EF/TD	TD	TD	TD	20
	EF	EF	EF	TD	TD	TD	16
	EF	EF	EF	EF	TD	TD	12
	EF	EF	EF	EF	EF	*	8
20	EF	*	*	*	TD	TD	20
	EF	*	*	*	*	TD	16
	EF	EF	*	*	*	TD	12
	EF	EF	EF	*	*	*	8
40	*	*	*	*	TD	TD	20
	*	*	*	*	*	TD	16
	*	*	*	*	*	TD	12
	*	*	*	*	*	*	8
60	*	*	*	*	*	*	20
	*	*	*	*	*	*	16
	*	*	*	*	*	*	12
	*	*	*	*	*	*	8
80	*		*	*	*	*	20
	*		*	*	*	*	16
	*	*	*	*	*	*	12
	*	*	*	*	*	*	8
100	*	*	*	*	*	*	20
	*	*	*	*	*	*	16
	*	*	*	*	*	*	12
	*	*	*	*	*	*	8

NOTES:

*	satisfactory thermal conditions
TD	risk of too large Temperature Differences within the concrete slab
EF	risk of Early Freezing
HT	risk of too High Temperatures within the concrete slab

CEMENT TYPE II, CONTENT 500 LBS/CU.YD.
FLY ASH CLASS F, CONTENT 125 LBS/CU.YD.

AIR TEMP. [Degree F]	CONCRETE TEMPERATURE [Degree F] 50	60	70	80	90	100	SLAB THICKNESS [Inches]
0	EF	EF	EF/TD	TD	TD	TD	20
	EF	EF	EF	TD	TD	TD	16
	EF	EF	EF	EF	TD	TD	12
	EF	EF	EF	EF	EF	*	8
20	EF	*	*	*	TD	TD	20
	EF	*	*	*	*	TD	16
	EF	EF	*	*	*	TD	12
	EF	EF	EF	EF	*	*	8
40	*	*	*	*	TD	TD	20
	*	*	*	*	*	TD	16
	*	*	*	*	*	TD	12
	*	*	*	*	*	*	8
60	*	*	*	*	*	*	20
	*	*	*	*	*	*	16
	*	*	*	*	*	*	12
	*	*	*	*	*	*	8
80	*	*	*	*	*	*	20
	*	*	*	*	*	*	16
	*	*	*	*	*	*	12
	*	*	*	*	*	*	8
100	*	*	*	*	*	HT	20
	*	*	*	*	*	*	16
	*	*	*	*	*	*	12
	*	*	*	*	*	*	8

NOTES:

*	satisfactory thermal conditions
TD	risk of too large Temperature Differences within the concrete slab
EF	risk of Early Freezing
HT	risk of too High Temperatures within the concrete slab

CEMENT TYPE II, CONTENT 520 LBS/CU.YD.
FLY ASH CLASS F, CONTENT 130 LBS/CU.YD.

AIR TEMP. [Degree F]	CONCRETE TEMPERATURE [Degree F] 50	60	70	80	90	100	SLAB THICKNESS [Inches]
0	EF	EF	EF/TD	TD	TD	TD	20
	EF	EF	EF	TD	TD	TD	16
	EF	EF	EF	EF	TD	TD	12
	EF	EF	EF	EF	EF	*	8
20	EF	*	*	*	TD	TD	20
	EF	*	*	*	*	TD	16
	EF	EF	*	*	*	TD	12
	EF	EF	EF	*	*	*	8
40	*	*	*	*	TD	TD	20
	*	*	*	*	*	TD	16
	*	*	*	*	*	TD	12
	*	*	*	*	*	*	8
60	*	*	*	*	*	*	20
	*	*	*	*	*	*	16
	*	*	*	*	*	*	12
	*	*	*	*	*	*	8
80	*	*	*	*	*	*	20
	*	*	*	*	*	*	16
	*	*	*	*	*	*	12
	*	*	*	*	*	*	8
100	*	*	*	*	*	HT	20
	*	*	*	*	*	*	16
	*	*	*	*	*	*	12
	*	*		*	*	*	8

NOTES:

*	satisfactory thermal conditions
TD	risk of too large Temperature Differences within the concrete slab
EF	risk of Early Freezing
HT	risk of too High Temperatures within the concrete slab

CEMENT TYPE II, CONTENT 540 LBS/CU.YD.
FLY ASH CLASS F, CONTENT 135 LBS/CU.YD.

AIR TEMP. [Degree F]	CONCRETE TEMPERATURE [Degree F] 50	60	70	80	90	100	SLAB THICKNESS [Inches]
0	EF	EF	EF/TD	TD	TD	TD	20
	EF	EF	EF	TD	TD	TD	16
	EF	EF	EF	EF	TD	TD	12
	EF	EF	EF	EF	EF	*	8
20	EF	*	*	*	TD	TD	20
	EF	*	*	*	*	TD	16
	EF	EF	*	*	*	TD	12
	EF	EF	EF	*	*	*	8
40	*	*	*	*	TD	TD	20
	*	*	*	*	*	TD	16
	*	*	*	*	*	TD	12
	*	*	*	*	*	*	8
60	*	*	*	*	*	*	20
	*	*	*	*	*	*	16
	*	*	*	*	*	*	12
	*	*	*	*	*	*	8
80	*	*	*	*	*	*	20
	*	*	*	*	*	*	16
	*	*	*	*	*	*	12
	*	*	*	*	*	*	8
100	*	*	*	*	*	HT	20
	*	*	*	*	*	*	16
	*	*	*	*	*	*	12
	*	*	*	*	*	*	8

NOTES:

*	satisfactory thermal conditions
TD	risk of too large Temperature Differences within the concrete slab
EF	risk of Early Freezing
HT	risk of too High Temperatures within the concrete slab

CEMENT TYPE II, CONTENT 560 LBS/CU.YD.
FLY ASH CLASS F, CONTENT 140 LBS/CU.YD.

AIR TEMP. [Degree F]	CONCRETE TEMPERATURE [Degree F] 50	60	70	80	90	100	SLAB THICKNESS [Inches]
0	EF	EF	EF/TD	TD	TD	TD	20
	EF	EF	EF	TD	TD	TD	16
	EF	EF	EF	EF	TD	TD	12
	EF	EF	EF	EF	EF	*	8
20	EF	*	*	*	TD	TD	20
	EF	*	*	*	*	TD	16
	EF	EF	*	*	*	TD	12
	EF	EF	EF	*	*	*	8
40	*	*	*	*	TD	TD	20
	*	*	*	*	*	TD	16
	*	*	*	*	*	TD	12
	*	*	*	*	*	*	8
60	*	*	*	*	*	*	20
	*	*	*	*	*	*	16
	*	*	*	*	*	*	12
	*	*	*	*	*	*	8
80	*	*	*	*	*	*	20
	*	*	*	*	*	*	16
	*	*	*	*	*	*	12
	*	*	*	*	*	*	8
100	*	*	*	*	*	HT	20
	*	*	*	*	*	HT	16
	*	*	*	*	*	*	12
	*	*	*	*	*	*	8

NOTES:

*	satisfactory thermal conditions
TD	risk of too large Temperature Differences within the concrete slab
EF	risk of Early Freezing
HT	risk of too High Temperatures within the concrete slab

CEMENT TYPE II, CONTENT 580 LBS/CU.YD.
FLY ASH CLASS F, CONTENT 145 LBS/CU.YD.

AIR TEMP. [Degree F]	SLAB THICKNESS [Inches]	CONCRETE TEMPERATURE [Degree F] 50	60	70	80	90	100
0	20	EF	EF	EF/TD	TD	TD	TD
	16	EF	EF	EF	TD	TD	TD
	12	EF	EF	EF	EF	TD	TD
	8	EF	EF	EF	EF	EF	*
20	20	EF	*	*	TD	TD	TD
	16	EF	*	*	*	*	TD
	12	EF	EF	*	*	*	TD
	8	EF	EF	EF	*	*	*
40	20	*	*	*	*	TD	TD
	16	*	*	*	*	*	TD
	12	*	*	*	*	*	TD
	8	*	*	*	*	*	*
60	20	*	*	*	*	*	*
	16	*	*	*	*	*	*
	12	*	*	*	*	*	*
	8	*	*	*	*	*	*
80	20	*	*	*	*	*	*
	16	*	*	*	*	*	*
	12	*	*	*	*	*	*
	8	*	*	*	*	*	*
100	20	*	*	*	*	HT	HT
	16	*	*	*	*	*	HT
	12	*	*	*	*	*	*
	8	*	*	*	*	*	*

NOTES:

*	satisfactory thermal conditions
TD	risk of too large Temperature Differences within the concrete slab
EF	risk of Early Freezing
HT	risk of too High Temperatures within the concrete slab

CEMENT TYPE II, CONTENT 600 LBS/CU.YD.
FLY ASH CLASS F, CONTENT 150 LBS/CU.YD.

AIR TEMP. [Degree F]	CONCRETE TEMPERATURE [Degree F] 50	60	70	80	90	100	SLAB THICKNESS [Inches]
0	EF	EF	EF/TD	TD	TD	TD	20
	EF	EF	EF	TD	TD	TD	16
	EF	EF	EF	EF	TD	TD	12
	EF	EF	EF	EF	EF	*	8
20	EF	*	*	TD	TD	TD	20
	EF	*	*	*	*	TD	16
	EF	*	*	*	*	TD	12
	EF	EF	EF	*	*	*	8
40	*	*	*	*	TD	TD	20
	*	*	*	*	*	TD	16
	*	*	*	*	*	TD	12
	*	*	*	*	*	*	8
60	*	*	*	*	*	*	20
	*	*	*	*	*	*	16
	*	*	*	*	*	*	12
	*	*	*	*	*	*	8
80	*	*	*	*	*	*	20
	*	*	*	*	*	*	16
	*	*	*	*	*	*	12
	*	*	*	*	*	*	8
100	*	*	*	*	HT	HT	20
	*	*	*	*	*	HT	16
	*	*	*	*	*	*	12
	*	*	*	*	*	*	8

NOTES:

*	satisfactory thermal conditions
TD	risk of too large Temperature Differences within the concrete slab
EF	risk of Early Freezing
HT	risk of too High Temperatures within the concrete slab