MICHIGAN CONCRETE ASSOCIATION

GUIDE FOR

COLD WEATHER CONCRETING

For the purposes of this document and the MCA Special Provision for Cold Weather Concreting, cold weather is determined to occur when the air temperature has fallen to, or is expected to fall below 40°F, prior to the concrete reaching its opening to traffic strength. Opening to traffic strengths typically range from 1000 to 3000 psi compressive, or 300 to 550 psi flexural.

A cold weather management plan, developed by the contractor and/or concrete producer, should contain detailed information on the changes in production, transportation, placement, protection, curing, and temperature monitoring of concrete during cold weather. The plan should include procedures and actions to be taken for accommodating abrupt changes in weather conditions.

Any combination of the following methods can be used to help ensure the concrete maintains adequate temperatures for curing and gains the proper strength prior to opening.

Heating the Concrete Ingredients

At a minimum, the concrete mix temperature should be no less than 55°F when mixed and placed. After placement, the concrete temperature should be maintained above 50°F until it gains opening to traffic strength. Higher concrete mix temperatures (up to 90°F max.) will result in higher early strengths and earlier opening to traffic, provided that protective measures are incorporated to keep both the initial heat and heat of hydration in the slab.

An effective method for maintaining the minimum concrete mix temperature is using heated water. Hot water improves the set time of cold weather concrete and helps kick off the hydration process quicker. Ensure that the capacity of the boiler is adequate for the volume of concrete production needed. Heat the water to a temperature between 80 and 200°F.

Another method of ensuring adequate mix temperatures is to use heated aggregates. Fine and/or coarse aggregate can be heated by processing it through a heated drum such as in an asphalt plant, by a series of coils buried in the pad underneath the stockpile through which a hot liquid passes, by steam, or by other methods. Heating coils can also be used in the aggregate bins at the concrete plant itself. Aggregates can also be supplied to a plant site already heated by the producer. When both fine and coarse aggregates are heated, it is rarely necessary to heat them much above 80°F. If the sand only is heated, it may be necessary to heat it to as much as 150°F.

Insulating the Concrete after Placement

The following materials (also see Table 1) can be used to insulate and protect the concrete pavement after it has been placed and finished. If insulation material is applied within one hour of concrete placement and left in place until the opening-to-traffic strength is obtained, curing compound may not be necessary. If insulation material is applied before initial set, the materials might mar the surface and/or disturb the surface texture, so contractors, engineers, and owners should be aware of any possible aesthetic requirements prior to application of the material.

- Plastic sheeting – Often used in combination with other insulating measures, but will also provide a measure of protection alone during mildly cold weather, i.e. ambient temperatures in the range of 40 to 55°F. The plastic will trap a thin layer of air against the slab, which will afford some insulation value. It will also protect the concrete by reducing the amount of moisture and heat lost through wind blowing over the surface.
- Insulating blankets – Made of fiberglass, sponge rubber, open-cell or closed-cell polyurethane foam, vinyl foam, mineral wool, or cellulose fibers. The outer covers are made of canvas, woven polyethylene, or other tough fabrics that will take rough handling. Since R values are not always marked on the blankets, their effectiveness may need to be checked with a thermometer. If necessary, they can be used in two or three layers to attain the desired insulation.
- Loose straw or hay – Typically placed in a layer 6 inches to 2 feet thick, sandwiched between two layers of plastic sheeting.

Table 1. R-values of typical concrete pavement insulation measures.

Material	**R-value** °F·hr·ft^2/Btu	**Typical Thickness**
Plastic sheeting	~0.5	minimum 6 mils thick
Insulating blankets	~7.0 3.23 per inch	1.5 to 2.75 inches thick
Loose straw or hay	1.4 to 2.4 per inch	6 inches to 2 feet thick

Place the insulation material as soon as it will not significantly mar the surface of the pavement and so that it protects the full exposed pavement surface as long as required. Table 2 lists examples of common MDOT concrete mixtures that would fit the four portland cement content values contained in Tables 3 and 4. Table 3 lists the R-values needed to insulate concrete slabs of varying thicknesses in order to maintain 50°F in the concrete under three different ambient temperatures. Table 4 contains examples of insulation methods that can be used to achieve those R-values listed in Table 3.

Table 2. Example MDOT mix types corresponding to the four levels of portland cement content contained in Tables 3 and 4.

Portland Cement Content	**MDOT Mix Type**	**Total Cementitious**	**SCM Content**
300 lb/yd^3	P1M w/ slag	500 lb/yd^3	200 lb/yd^3
400 lb/yd^3	P1M w/ fly ash	500 lb/yd ^{3}	100 lb/yd^3
500 lb/yd^3	P1WR, P1FA	526 to 595 lb/yd^3	0 to 78 lb/yd^3
600 lb/yd^3	P1 / HE	564 to 658 lb/yd^3	0 lb/yd^3

Do not remove the insulation material until the temperature of the concrete slab is within 50°F of the ambient temperature. Gradually remove the insulation material. Do not shock the slab with extreme temperature differentials, as this may cause uncontrolled cracking.

Table 3. R-values needed to maintain 50°F in the concrete slab for various thicknesses and ambient temperatures; fresh concrete temperature = 50°F.

(adapted from ACI 306R-88)

Slab thickness, in.	Minimum R-value of insulation, °F·hr·ft^2/Btu, needed at listed average ambient air temperature		
	T = 20°F	T = 30°F	T = 40°F
portland cement content = 300 lb/cu. yd.			
4	N/A *	N/A *	N/A *
6	N/A *	10.8	8.0
8	11.2	9.5	5.9
10	10.6	8.0	4.5
12	9.3	6.6	3.6
portland cement content = 400 lb/cu. yd.			
4	N/A *	N/A *	9.4
6	12.4	10.2	6.1
8	10.8	7.9	4.3
10	8.8	6.2	3.4
12	7.4	5.1	2.8
portland cement content = 500 lb/cu. yd.			
4	N/A *	N/A *	8.4
6	11.8	9.0	5.2
8	9.4	6.6	3.7
10	7.3	5.1	2.9
12	6.0	4.2	2.4
portland cement content = 600 lb/cu. yd.			
4	15.7	12.3	7.2
6	10.5	7.7	4.3
8	7.9	5.6	3.1
10	6.9	4.4	2.4
12	5.2	3.6	2.0

* Do not place concrete under these conditions; it is nearly impossible to prevent concrete from freezing or experiencing severe distress given these conditions.

Table 4. Insulation types needed to maintain 50°F in the concrete slab for various thicknesses and ambient temperatures; fresh concrete temperature = 50°F.

Slab thickness, in.	Insulation type needed at listed average ambient air temperature		
	T = 20°F	T = 30°F	T = 40°F
portland cement content = 300 lb/cu. yd.			
4	N/A *	N/A *	N/A *
6	N/A *	6” of straw	blankets
8	6” of straw	5”of straw	blankets
10	6” of straw	blankets	blankets
12	5”of straw	blankets	plastic
portland cement content = 400 lb/cu. yd.			
4	N/A *	N/A *	5” of straw
6	7” of straw	6” of straw	blankets
8	6” of straw	blankets	blankets
10	5”of straw	blankets	blankets
12	blankets	blankets	plastic
portland cement content = 500 lb/cu. yd.			
4	N/A *	N/A *	5” of straw
6	6” of straw	5” of straw	blankets
8	5”of straw	blankets	blankets
10	blankets	blankets	plastic
12	blankets	blankets	plastic
portland cement content = 600 lb/cu. yd.			
4	8” of straw	7” of straw	blankets
6	6” of straw	blankets	blankets
8	blankets	blankets	blankets
10	blankets	blankets	plastic
12	blankets	blankets	plastic

* Do not place concrete under these conditions; it is nearly impossible to prevent concrete from freezing or experiencing severe distress given these conditions.

Using Chemical Accelerators

Chemical admixtures can accelerate the time of set and strength gain of the concrete mixture. Accelerating admixtures conforming to ASTM C 494 Types C (accelerating) and E (water-reducing and accelerating) are commonly used in cold weather. Calcium chloride is a common and cost effective accelerator, but should not exceed a maximum dosage of 2% by weight of cement. Calcium chloride may cause corrosion of embedded metals in the presence of oxygen and moisture. Non-chloride, non-corrosive accelerators should be used where there is concern about corrosion of uncoated steel reinforcement or other metal in contact with the concrete.

Accelerators do not prevent concrete from freezing; the concrete must still be cured and kept warm enough to allow hydration and strength gain to continue. Adding more accelerating admixture at the end of a pour will help speed up the setting of the latter mixes and have all the concrete in the pour reach set at about the same time in order to facilitate the finishing, curing, and jointing operations.

Changing the Mix Proportions

The concrete mixture must be resistant to alkali-silica reactiivity (ASR) even when paving during cold weather conditions. If a change in mix proportions or mix design is desired to gain high early strength, the mixture should either be a proven mixture that does not have a history of ASR, or the proper tests should be conducted to verify that the mixture will not exhibit deleterious ASR expansion.

Increasing the amount of portland cement in the mixture, and/or using Type III (high-early) cement are two methods of gaining high early strength. Alternatively, lowering the amount of supplementary cementitious materials (SCMs, such as slag cement or fly ash) will also assist with high early strength. However, these methods require assurance that the concrete mixture will be ASR-resistant, and the tests on the mixture must be run weeks, if not months or years, in advance.

Increasing the cement content of the concrete mixture without running the proper durability tests is not recommended. A switch to Type III cement, with the same proportions of the ingredients in the concrete mixture, may be sufficient to gain adequate strength in the required time. This usually allows the same amount of SCM usage as the normal weather mixture. SCMs can be used after October 15, if a cold weather plan is in place to address the potential for slow set times and strength gain with the use of these materials.

If there are no other cost-effective options and the portland cement content must be increased, a switch to low-alkali cement might be needed. Keep the alkali content of the mixture below 3.0 lbs/cu. yd. to limit the potential for ASR, unless testing shows that a higher alkali content can be used.

Minimizing the amount of water in the mixture will also help shorten the set time of the concrete. Concrete that is low-slump, with a low water-cementitious materials (w/cm) ratio will gain strength quicker, but may require more effort to place, consolidate, and finish. The use of mid-range and high-range (superplasticizing) water reducers are typically required to achieve workable concrete at low water-cementitious ratios.

NOTE: Changing the mix proportions or switching to a different mixture requires obtaining or re-analyzing additional maturity data (see next section) to determine opening to traffic strengths using the maturity method.

Strength and Maturity

Monitor the temperature of the in-place concrete, or of the specimens being cured in field conditions. Installing maturity sensors in the concrete will allow monitoring of both the temperature and strength of the in-place concrete, provided that the testing has been performed ahead of time to develop the correlation between time-temperature factor (TTF) and strength of the concrete using ASTM C 1074 or other established method. The information can be used in numerous ways, including:

- Checking to see that the temperature of the concrete has not fallen below 50°F.
- Monitoring the strength gain of the concrete.
- Ensuring that the concrete has not frozen prior to gaining at least 500 psi compressive.
- Evaluating whether or not the concrete has attained its open to traffic strength.

During the mix design process, develop the maturity relationship by casting 18 specimens (cylinders or beams) for each mixture used in the project. Place maturity sensors, devices, or probes in three of the specimens; do not break these specimens. Break three specimens at each age of 1, 3, 7, 14, and 28 days. Record the average of the maturity value from the three maturity specimens, as well as the average strength from the three specimens that were broken. Plot the data on a chart and/or determine the relationship between strength and time-temperature factor. This relationship is valid for that particular mixture, at almost any temperature range.

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