Inspection of Concrete
Part 2

JOINTING IN SLABS, DRIVES, WALKS
HOT WEATHER
COLD WEATHER

Steve Waalkes, P.E.
Dir. of Engineering – W. Mich.
Jointing

- Why do we joint?
- Reinforcement
- Types of Joints
- Sawing & Saw timing
- Joint Layout Guidelines
- Jointing Plans
- Joint Sealing
- Jointing Practice
Why Put Joints in Concrete?

- Drying Shrinkage
- Thermal Contraction
- Curling/Warping
- Loading
Whose fault is it?
Whose fault is it?
Natural Crack Development

- Temperature Gradients
- Moisture Gradients
- Thermal Cycles
- Loading

Usually occurs sometime after 12 hours and may take months.

8-25 ft
Natural Crack Development

- Proper jointing provides a series of saw cuts (joints) spaced to control crack formation.
Steel Mesh

- **NOT** a structural element
- Holds cracks together *after the cracks form.*
- If used, must be discontinued at all joints
- **NOT RECOMMENDED** to be used in Michigan
Types of Joints

- Isolation/Expansion
  - Between different elements or at structures
- Contraction
  - Saw cuts or tooled joints
- Construction
  - Edge of pours or form lines

US-40, Marion County (Indianapolis), IN, 1938
Isolation/Expansion Joint
Isolation/Expansion Joint

What were they thinking?
Transverse Contraction Joints
Transverse Contraction Joints

- Conventional Sawing
  - Joint Depth:
    - T/4
    - T/3
- Early-entry Saws – Approx. 1” deep regardless of pavement thickness.
Saw Cut Timing

The “sawing window” is the brief period of time during which joints can be sawed successfully.

- Begin saw cuts after the concrete has hardened enough to permit sawing without raveling or moving aggregates.
- Finish saw cuts before random, uncontrolled cracking takes place.
- Conventional saws – There is generally an 8 – 12 hour window.
- Early entry saws – The window begins as soon as walking on the pavement is permitted, generally within approx. 3 hours.
- To finish sawing joints before the window ends, it may be necessary to continue regardless of weather or daylight conditions.

**IMPORTANT NOTE**: if cracks develop ahead of a saw, STOP sawing that joint. Later, use crack saws to form joint sealant reservoirs along the crack line.
Sawing Window

Too Early: Raveling

Sawing Window

Too Late: Cracking

Restraint Stress Equals Concrete Strength

Minimum Strength to Avert Excessive Saw Cut Raveling
Sawing Window

The Sawing Window varies with:

- Temperature
- Admixtures
- Humidity/Weather

We need to be aware of these effects on the concrete sawing window and be prepared to make adjustments as necessary for optimal placement.
Sawing
Sawing
Sawing
The Rules of Jointing

**Things to Do**
- Match existing joints or cracks
- Place joints to meet in-pavement structures
- Remember max. joint spacing
- Place isolation joints where needed
- Can make field adjustments to joint location!
- Be Practical

**Things to Avoid**
- Slabs < 1 ft (0.3 m) wide
- Slabs > 15 ft (5.0 m) wide
- Angles < 60° (~90° is best)
- Do this by dog-legging joints through curved radius points
- Creating interior corners (L-shaped slabs)
- Odd Shapes (keep slabs square or pie-shaped)
Recommended Joint Spacing for **Exterior** Slabs, Pavements

- Max. slab size = 2 x thickness  (inches⇒feet)
  
  = 24 x thickness  (inches⇒inches)

- 15 ft absolute max.

- Smaller is better
  - 4-inch:  6 ft x 6 ft squares
  - 5-inch:  8 ft x 8 ft squares
  - 6-inch:  10 ft x 10 ft squares
  - 7-inch:  12 ft x 12 ft squares
Recommended Joint Spacing for Interior Floors, Slabs

- Max. slab size = 2.5 x thickness (inches⇒feet)
  = 30 x thickness (inches⇒inches)
- 20 ft absolute max.
- Match column spacing; add joints in between
- Smaller is better
  - 4-inch: 8 ft x 8 ft squares
  - 5-inch: 10 ft x 10 ft squares
  - 6-inch: 12 ft x 12 ft squares
  - 7-inch: 15 ft x 15 ft squares
Doglegs

Definition: Construction Block-outs where the pavement changes width.

A Width change and dogleg in gutter near point of curvature

B Width change and dogleg in gutter near start of a taper

C Width change and dogleg in paving lane for hand-pours
Joint layout

Problem

Solution
How to Deal with Structures
Manholes, Inlets, Columns, etc.

- Place structure **exactly** in middle of slab
- Place joints to intersect at the structure, through the middle of the casting
Huh?
Jointing – Keys to Success

- Proper joint spacing
- Proper placement of isolation joints
- Remember rules of jointing
- Be practical and flexible!
- If tooling, make sure they are deep enough!
- If sawing, saw them on time!!
Hot Weather Defined

Any combination of the following conditions that tends to impair the quality of freshly mixed or hardened concrete by accelerating the rate of moisture loss and cement hydration:

- high ambient temperature
- high concrete temperature
- low relative humidity
- high wind speed
- solar radiation

Reference: ACI 305R
Hot Weather

Hot weather conditions can create difficulties in fresh concrete such as:

1. increased water demand
2. increased concrete temperature (material temperatures)
3. accelerated slump loss (water added to offset)
4. increased rate of setting (finishing difficulties)
5. difficulties in controlling entrained air
6. increased tendency for plastic shrinkage cracking
7. increased potential for thermal cracking
Plastic Shrinkage Cracking

Cracks that sometimes appear in horizontal surfaces soon after placement.
- the result of rapid evaporation through air temperature, concrete temperature, relative humidity and wind speed
  - normally associated with hot weather conditions
  - can be substantially eliminated with preventive measures
- elevated decks particularly susceptible
When the evaporation rate exceeds 0.2 lbs/ft²/hr precautionary measures are required to prevent plastic shrinkage cracks from forming.

- apps are available to calculate evaporation rate
Batching ‘Cool’ Concrete Material Effects

During hot weather conditions, keep aggregates and water as cool as possible.

To lower the temperature of concrete by 1°F it takes:

1. a 1.5 - 2°F change in coarse aggregate temperature
2. a 3.5 - 4°F change in water temperature or
3. a 9°F change in cement temperature

Note: Temperature effects are dependent on the mass (weight) of the materials in the mix design.
Stockpile Conditioning
Cooling Concrete

- crushed ice is more effective than chilled water in lowering the concrete temperature
- mixing time must be long enough to melt the ice
- volume of ice should not replace more than 75% of the total batch water
- maximum temperature reduction is 20°F
Fog Spraying

Fogging cools the air and increases the relative humidity above the surface of the concrete thereby reducing the rate of evaporation.

- fog nozzles atomize water using pressurized air
Hot weather conditions affect both the fresh and hardened properties of the concrete. The ready mix concrete supplier and contractor play critical roles in constructing the best possible product.

**CONCRETE MUST BE CURED!**
Cold-Weather Concreting
Cold weather conditions occur when the air temperature has fallen to, or is expected to fall below, 40°F during the protection period.

For concreting in Michigan, cold weather practices typically begin in early November and continue until late April.

Reference: ACI 306
Cold Weather Placement

Provided the necessary precautions have been taken, concrete can be placed year round. Such precautions may include the following:

- windbreaks
- heated enclosures
- insulated forms
- insulating blankets
Temperature Effects

Temperature affects the rate at which hydration occurs - low temperatures slow the rate of strength gain.

Significant strength reductions (up to 50%) can occur if concrete freezes within a few hours of placement or before reaching a compressive strength of 500 psi.

Note: At normal temperatures, 500 psi occurs within the first 24 hours of placement.
Concrete that has froze just once at an early age can be restored to nearly normal strengths by providing a proper curing environment. Such concrete, however, will not be as resistant to weathering nor as impermeable as concrete that had not froze.
Cold Weather Damage
Cold Weather Damage
Aggregates usually contain frozen lumps and ice that must be thawed before using.

When compared to the same mass of cement and aggregates, water is the easiest and most practical to heat.
# Concrete Temperature

## Table 5.1—Recommended concrete temperatures

<table>
<thead>
<tr>
<th>Line</th>
<th>Air temperature</th>
<th>Section size, minimum dimension</th>
<th>Minimum concrete temperature as placed and maintained</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>&lt; 12 in. (300 mm)</td>
<td>12 to 36 in. (300 to 900 mm)</td>
</tr>
<tr>
<td>1</td>
<td>—</td>
<td>55°F (13°C)</td>
<td>50°F (10°C)</td>
</tr>
<tr>
<td>2</td>
<td>Above 30°F (-1°C)</td>
<td>60°F (16°C)</td>
<td>55°F (13°C)</td>
</tr>
<tr>
<td>3</td>
<td>0 to 30°F (-18 to -1°C)</td>
<td>65°F (18°C)</td>
<td>60°F (16°C)</td>
</tr>
<tr>
<td>4</td>
<td>Below 0°F (-18°C)</td>
<td>70°F (21°C)</td>
<td>65°F (18°C)</td>
</tr>
<tr>
<td>5</td>
<td>—</td>
<td>Maximum allowable gradual temperature drop in first 24 hours after end of protection</td>
<td>50°F (28°C)</td>
</tr>
</tbody>
</table>

*For colder weather, a greater margin in temperature is provided between concrete as mixed and required minimum temperature of fresh concrete in place.*
Higher early strengths and accelerated set are necessary during cold weather construction to reduce the length of time that protection is required. A cold weather mix can be designed using one, or a combination, of the following:

1. high early strength cement - Type III
2. add additional Type I - approximately 1 bag
3. add accelerating admixtures
   - either chloride or non-chloride ($$)

Note:
1. Accelerators must not be used as a substitute for proper curing and protection.
2. Consider reducing or eliminating supplementary materials.
Accelerators...Calcium Chloride

Calcium chloride is used to accelerate the set and early age strength development of concrete in cold weather. Calcium chloride accelerators may contribute to the following:

1. corrosion of reinforcing steel
2. discoloration of concrete
3. an increase in shrinkage cracking

Never add flaked calcium chloride directly into the mixer.

- always dissolve in water first
Cold Weather

Contractor responsibilities:

- check the weather forecast
- never place concrete on a frozen subgrade
  - minimum recommended temperature is 40°F
- incorporate a cold weather mix design
- after placement, cure and protect concrete
- protect cylinders from the elements
Subgrade Conditioning

Hydronic heaters
- transfer heat by circulating a glycol/water solution in a closed system of pipes or hoses
- used to either pre-heat or thaw subgrades
Protecting Concrete

Heat and moisture are retained by covering concrete with:

1. plastic sheeting,
2. insulating blankets, or
3. straw/hay that is typically covered by polyethylene.

- corners and edges are most vulnerable to freezing
- the material selected for providing cold weather protection must be moisture-proof and able to withstand exposure to the weather

Note: To avoid thermal shock that might induce contraction cracking, allow the slab to cool before removing the protective covering.
Protection...Insulating Blankets
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)

<table>
<thead>
<tr>
<th>Slab thickness, in.</th>
<th>Minimum R-value of insulation, °F·hr·ft²/Btu, needed at listed average ambient air temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>T = 20°F</td>
</tr>
<tr>
<td></td>
<td>T = 30°F</td>
</tr>
<tr>
<td></td>
<td>T = 40°F</td>
</tr>
<tr>
<td>4</td>
<td>N/A *</td>
</tr>
<tr>
<td>6</td>
<td>N/A *</td>
</tr>
<tr>
<td>8</td>
<td>11.2</td>
</tr>
<tr>
<td>10</td>
<td>10.6</td>
</tr>
<tr>
<td>12</td>
<td>9.3</td>
</tr>
<tr>
<td>portland cement content = 300 lb/cu. yd.</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>N/A *</td>
</tr>
<tr>
<td>6</td>
<td>12.4</td>
</tr>
<tr>
<td>8</td>
<td>10.8</td>
</tr>
<tr>
<td>10</td>
<td>8.8</td>
</tr>
<tr>
<td>12</td>
<td>7.4</td>
</tr>
<tr>
<td>portland cement content = 400 lb/cu. yd.</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>N/A *</td>
</tr>
<tr>
<td>6</td>
<td>11.8</td>
</tr>
<tr>
<td>8</td>
<td>9.4</td>
</tr>
<tr>
<td>10</td>
<td>7.3</td>
</tr>
<tr>
<td>12</td>
<td>6.0</td>
</tr>
<tr>
<td>portland cement content = 500 lb/cu. yd.</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>N/A *</td>
</tr>
<tr>
<td>6</td>
<td>10.5</td>
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<tr>
<td>8</td>
<td>7.9</td>
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<tr>
<td>10</td>
<td>6.9</td>
</tr>
<tr>
<td>12</td>
<td>5.2</td>
</tr>
<tr>
<td>portland cement content = 600 lb/cu. yd.</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>15.7</td>
</tr>
<tr>
<td>6</td>
<td>10.6</td>
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<tr>
<td>8</td>
<td>7.9</td>
</tr>
<tr>
<td>10</td>
<td>6.9</td>
</tr>
<tr>
<td>12</td>
<td>5.2</td>
</tr>
</tbody>
</table>

* Do not place concrete under these conditions; it is nearly impossible to prevent concrete from freezing or experiencing severe distress given these conditions.
**Table 7.1—Length of protection period for concrete placed during cold weather**

<table>
<thead>
<tr>
<th>Line</th>
<th>Service condition</th>
<th>Normal-set concrete</th>
<th>Accelerated-set concrete</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>No load, not exposed</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>No load, exposed</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>Partial load, exposed</td>
<td>6</td>
<td>4</td>
</tr>
<tr>
<td>4</td>
<td>Full load</td>
<td>Refer to Chapter 8</td>
<td></td>
</tr>
</tbody>
</table>

*Protection period at minimum temperature indicated in Line 1 of Table 5.1, days*

*A day is a 24-hour period.*
Heated enclosures are expensive to construct and operate but allows for construction to continue during cold weather conditions.
Construction Heaters

The two types of heaters used during cold-weather concrete construction include:

1. Direct-fired (unvented)
2. Indirect-fired (vented)

Carbon dioxide (CO$_2$) in the exhaust of heaters must be vented to the outside and not allowed to react with a fresh concrete surface or carbonation will occur.

- carbon monoxide (CO), another by-product of combustion, is usually not a problem for concrete but poses a potentially serious health risk to workers.
Carbonation – Mild/Severe
Avoid the use of direct fired (unvented) heaters.

If direct fired heaters are used:

- avoid using older, less efficient heaters
- provide good air exchange and circulation
- minimize the period of exposure
- if carbonation occurs, clean/grind surface and apply a chemical hardener (densifier)
Cold Weather Cylinder Protection

For specified compressive strengths less than 6000 psi, initial curing requires cylinders be stored at a temperature between 60-80°F for a period not exceeding 48 hrs.

- Construct your own insulated curing box or purchase a commercially sold unit
THANK YOU!

Questions / Comments?