



A summary of chapter 8 (pages 203–240) of the *IMCP Manual* (reference information on page 4)

crack will initiate and then propagate to the bottom of the slab.

For unreinforced pavements, joint spacing (slab length) depends on slab thickness, concrete aggregate, subbase, and climate. Typical spacing is as follows:

- Transverse joints—maximum 4.5 m (15 ft) apart.
- Longitudinal joints—typically 3.0 to 4.2 m (10 to 13 ft) apart, depending on lane width.

### Saw Timing

The optimum time to saw contraction joints in new concrete is known as the sawing window. The window is a short period of time when the concrete pavement can be cut to successfully control crack formation (figure 2).

For conventional saws, it is defined by the following characteristics:

- Begins when concrete strength is sufficient for sawing without excessive raveling.
- Ends when random cracking starts to occur.

The window for early-entry saws begins earlier (about the time of final set) and ends sooner than for conventional saws.

### Sawing Techniques

Smaller and lighter than conventional saws, first-generation early-entry saws make shallow cuts that work well for transverse joints.

Longitudinal joints are often cut later than transverse joints. Consequently, the concrete has developed more strength and a deeper cut is required. Newer early-entry saws make deeper cuts, so they or conventional saws may be used.

Joints should be at least 6 mm ( $\frac{1}{4}$  in.) wide to allow room for joint sealant, if it is specified. As longitudinal joints are normally tied and are not working joints, they may not always require sealant. If unsealed, they may be narrower than transverse joints (generally 3 mm [ $\frac{1}{8}$  in.]).

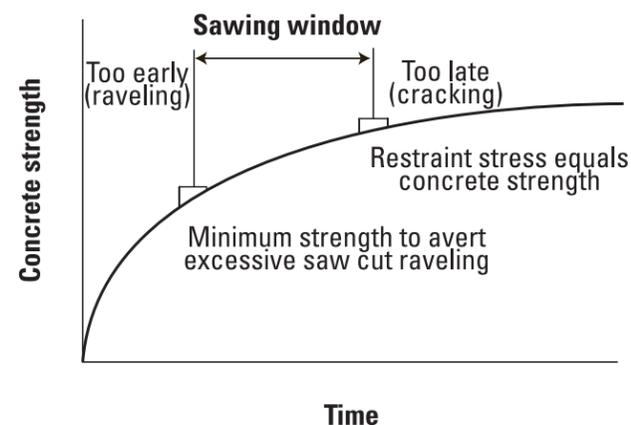


Figure 2. Sawing window

## Concrete Pavement Construction

This document is one of a set of technical summaries of chapters 1 through 10 of the *Integrated Materials and Construction Practices for Concrete Pavements: A State-of-the-Practice Manual* (IMCP manual). The summaries provide an overview of the manual and introduce its important concepts. To be useful for training, the summaries should be used in conjunction with the manual.

This document summarizes the construction variables and methods which contribute to concrete pavement performance. The variables and methods described include typical field adjustments, critical elements of slipform paving operations, effective concrete curing practices, the importance of timely joint sawing and proper sawing techniques, and issues related to hot- and cold-weather concrete placement.

### Why is Construction Important for Concrete Pavement Durability?

To produce concrete of consistent quality and uniformity, the variability of the production processes must be minimized while recognizing and accounting for material variations.

### Minimizing Variability

Use the following guidelines to minimize variability of production processes:

- Ensure quality and uniformity of materials. Follow any established quality control plan or specifications which outline the material verification process.
- Set up the concrete plant with consideration of the need for consistent, timely delivery of materials to the construction site.
- Monitor aggregate moisture in the stockpiles and adjust the amount of batch water accordingly.
- Prevent aggregate stockpile contamination and segregation.

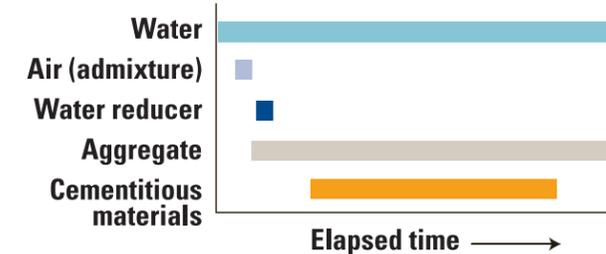
- Batch dry ingredients by weight; batch water and chemical admixtures by volume.
- Add materials to the mixer in a consistent order (figures 1a and 1b).
- Allow consistent, adequate mixing time to ensure a homogenous mixture and proper air entrainment.

### Verifying Mixtures

Mixture design properties must be verified both before and during construction to confirm that the concrete mix is suitable for the intended use. Field testing of mixtures should meet the following conditions:

- Uses production equipment anticipated for the job.
- Includes construction of a test strip, if possible.

#### a) Mix plant



#### a) Truck mixer

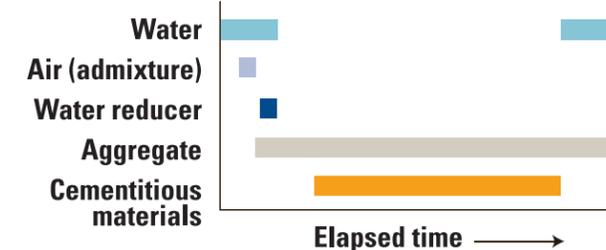


Figure 1. Typical sequence of adding material

## National Concrete Pavement Technology Center



### August 2007

This technical summary is based on chapter 8 of the *IMCP Manual* (Taylor, P.C., et al. 2006. *Integrated Materials and Construction Practices for Concrete Pavement: A State-of-the-Practice Manual*, Ames, Iowa, Iowa State University [FHWA HIF-07-004] [www.cptechcenter.org/publications/imcp/]) and was sponsored by the Federal Highway Administration. (References for any citations in this summary are at the end of the chapter.)

Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the view of Federal Highway Administration or Iowa State University.

### CP Tech Center Mission

The mission of the National Concrete Pavement Technology Center is to unite key transportation stakeholders around the central goal of advancing concrete pavement technology through research, tech transfer, and technology implementation.

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## Making Field Adjustments

The materials used to make concrete are inherently variable, as are the conditions in which they are mixed and placed. To account for this variability, the properties of fresh concrete must be closely monitored and proportions adjusted (within the constraints of the specifications) to maintain uniformity of the final product from batch to batch.

### Adjusting for Ambient Temperatures

Temperature variations impact the slab's rate of stiffening and strength gain. Excessively hot or cold temperatures or rapidly falling temperatures therefore require field adjustments to achieve concrete with the appropriate fresh and hardened properties, like sprinkling aggregate stockpiles, chilling the mix, and using ice. See sidebars.

### Adjusting for Materials Variability

Raw and manufactured materials in a concrete mixture are inherently variable. As a result, the properties of concrete mixtures will always have some variability. To promote consistency and minimize materials variability, monitor and adjust the following attributes as necessary within state specifications:

- Moisture of stockpiled aggregates—Sample and test daily or more frequently. Compensate for differences in aggregate moisture by adjusting mixing water.
- Aggregate gradation—Monitor at least daily. Reject or rebuild severely segregated stockpiles.
- Variability in cementitious materials—Adjust based on feedback from the paver regarding workability. Changes in fineness of materials may affect the amount of water and air-entraining admixture

necessary to maintain proper workability and air content.

### Adjusting for Materials Supply Changes

When a material's source is changed or the required material content changes by more than five percent (excluding admixtures used within recommended dosages), trial batches are needed. If substitutions have not been laboratory-tested, compare workability, setting time, air entrainment properties, and early-age strength to the initial mix design. Increase testing frequency during initial days with new materials.

### Slipform Paving

Contractors use either slipform or fixed-form paving methods, depending on the nature of the placement. In slipform paving operations, the paver extrudes concrete pre-formed into the slab shape.

For most applications, slipform paving is more efficient than fixed-form paving, which requires the setting up of forms to hold the concrete in place while it sets. Because fixed-form paving is generally reserved for specialty applications, it is not covered in this technical summary.

### Placement

For slipform paving, follow these placement guidelines:

- Use a mixture that will not slough at the edges after extrusion from the paver.
- Distribute concrete uniformly in front of paver.
- Adjust the paver's speed and frequency of internal vibrators as required without sacrificing surface quality or consolidation. (Frequently stopping to make adjustments or pushing a large pile of concrete ahead will impair surface smoothness.)

### Consolidation

To achieve adequate consolidation without sacrificing air entrainment or causing segregation, follow these guidelines for slipform paving operations:

- Do not run the vibrator at a higher frequency to overcome poor equipment setup, alignment, or workability.
- For most mixtures, do not exceed 5,000 to 8,000 vibrations per minute.
- Maintain a paver speed above 0.9 m (3 ft) per minute for most mixes. When slower paver speeds are necessary, reduce vibration frequency to match the delivery of concrete.
- Reduce vibration frequency when using gap-graded mixtures.

## Following Good Curing Practices

Curing helps maintain moisture and reduce temperature variability in a freshly placed slab, allowing hydration and pozzolanic reactions to proceed. If the curing regimen is inadequate or applied too late, concrete will be vulnerable to plastic shrinkage cracking, excessive curling, and scaling.

### Curing Compound

Application of a curing compound is the most common curing method. Curing compounds are organic materials that form a skin over the surface of the concrete and reduce the rate of moisture loss from the concrete. A liquid membrane-forming compound that meets ASTM C 309 / AASHTO M 148 material requirements is adequate for most situations.

Follow these practices to ensure adequate curing:

- Apply as soon as possible after the water sheen has left the surface and texturing is complete.
- Apply to damp surface.
- Use power-driven spray equipment for uniform application of curing compound on large paving projects. Use hand-operated spray equipment only for small areas.
- Attain complete coverage of the surface. White-colored curing compound enhances visibility and supports easy inspection of coverage.
- Coat all exposed surfaces of the concrete slab, including the sides.
- If a second coat is necessary, apply as soon as the first coat becomes tacky.
- Measure the volume of compound applied to a given area and compare it to the specified or recommended application rate.

### Other Curing Methods

Other curing methods can be used to supplement the effects of curing compounds in the following ways:

- Plastic sheeting—Facilitates cold-weather placement, protects slabs from rain, and offers some protection to sustain heat of hydration and increase strength gain.
- Curing blankets—Have similar effects as plastic sheeting and moderate thermal gradients throughout the slab. Removing curing blankets too soon may induce thermal shock and result in cracking.

## Constructing Joints

Jointed concrete pavement designs rely on a jointing system that controls the amount and locations of expected cracking. Each transverse and longitudinal saw cut induces a point of weakness, controlling where a

### Hot-Weather Placement

When hot-weather paving is anticipated, verify performance of the mix and take the following precautions to keep the temperature of plastic concrete as low as practical (many states use 90°F as maximum):

- Dampen the subgrade or base before placing concrete.
- Moisten dry, absorptive aggregates.
- Chill the mix water or use ice in the mix.
- Consider adding or increasing dosages of retarding and air-entraining admixtures.
- Substitute GGBF slag or Class F fly ash for part of the portland cement.
- When mixture has a lower slump than specified, add water to remix concrete within w/cm ratio (according to ASTM C 94 / AASHTO M 157).
- Place and finish concrete quickly to expedite application of curing compound.
- Erect temporary sunshades to reduce concrete surface temperatures.
- Erect temporary windbreaks to reduce wind velocity over the concrete surface.
- If possible, pave at night, when it is cooler.

With any of these adjustments, do not exceed the maximum water-to-cementitious materials ratio or admixture dosage. If temperature, humidity, and wind are severe, consider placing concrete during the evening when temperatures are cooler or halting paving operations until weather conditions improve.

### Cold-Weather Placement

Key cold-weather paving concerns are keeping the concrete temperature above freezing so that hydration continues and controlling crack development through joint placement. The following are recommended options for cold-weather paving:

- Reduce or eliminate pozzolans from the mixture unless required for durability.
- Lower the air-entraining admixture dosage.
- Ensure that aggregates are free of ice, snow, and frozen lumps.
- Consider heating the mix water to raise the mix temperature (if practical).
- Avoid calcium chloride and admixtures containing added chlorides.
- Maintain concrete temperature at or above 10°C (50°F) for the first 72 hours after placement. Keep concrete temperature above freezing throughout curing.
- After applying curing compound, cover the slab with insulating blankets. Keep them in place until the slab is cool.
- Consider using a greater amount of portland cement in mix.
- Do not place concrete on frozen subgrade.

Because strength gain will be slowed, verify in-place strength and delay joint sawing and opening to traffic if necessary.