National Concrete Pavement
Technology Center

Concrete Paving Training & Field Reference

for Preventing Common Problems

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Center for Transportation Research and Education

Iowa State University

1.1. Inventorying Concrete Materials

Overview

To ensure that high-quality materials are used in concrete mixing, all materials delivered to the site should be inspected to ensure that they meet specification requirements. All materials should be delivered with the proper certifications, invoices, or bill of lading. These records should indicate when the shipment arrived, the amount and identification of material delivered, and the laboratory report certification number, invoice number, and ticket number.

Common Problems

- Non-certified materials
- Materials with outdated shelf life
- Contaminated materials
- Frozen or damaged materials

Aggregates

Description

Aggregates (60%–70% of mix by volume) affect mix workability and concrete strength and durability. Aggregates may consist of crushed stone, gravel, or sand. Well-graded aggregate contains many sizes of aggregate. Gap-graded aggregate contains little or no material retained on certain sieve sizes. Gap-graded aggregates make concrete more difficult to place and require more paste. Ideal aggregate shape is smooth and round like gravels.

Recommended Procedures

- Incorporate certified aggregate into a project if certified truck tickets are provided with delivery.
- Use well-graded aggregate in the mixture when available.
- Use natural gravel or limestone aggregate when available.

Gradations of aggregate

Cementitious Materials

Description

Cementitious materials (9%–15% of mix by volume) control certain characteristics of the mixture and of the finished concrete. Portland cement forms the "glue" that hardens and holds aggregate particles together. Supplementary cementitious materials, including industrial byproducts such as fly ash and ground granulated blast furnace slag, are also used in concrete and can affect concrete properties.

Recommended Procedures

- Incorporate portland cement, fly ash, and slag on the basis of manufacturer certification and as called for in the mix design.

Water

Description

Water (15%–16% of mix by volume) hydrates cement and makes the mixture workable.

Recommended Procedures

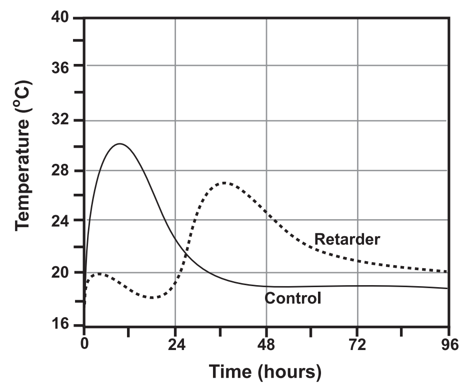
- Use water secured from streams, lakes, and other non-potable sources only after it is tested and approved.
- Water suitable for drinking is suitable for concrete.

Chemical Admixtures

Description

Chemical admixtures fall into the following categories:

- **Air entrainers** are used to stabilize air bubbles that improve freeze-thaw durability. Air entrainers also improve mix workability.
- **Water reducers** maximize the use of the existing water in the mix and decrease the amount of water added.
- **Retarders** slow the hydration process, providing more time for delivery of concrete mixtures that need to be transported long distances or placed during particularly hot weather to delay initial set until placement is completed. When retarders are added, non-agitating dump trucks generally have 60 minutes instead of 30 minutes to deliver the mixture.



Effects of retarders on concrete mixture temperature over time

Recommended Procedures

- Use only chemical admixtures that appear on the approved list.
- Do not use an admixture suspected of being frozen unless it has additional testing and approval.
- Do not use an admixture suspected of being older than 18 months unless it has additional testing and approval.
- Mix admixtures thoroughly once per day prior to proportioning to maintain the solids in suspension.

1.2. Storing Concrete Materials

Overview

Proper storage practices are critical to protect materials from intermingling, contamination, or degradation, and to maintain consistent aggregate gradation throughout a project.

Common Problems

- Segregation of aggregate (example: large aggregate rolls down the side of a tall cone pile)
- Degradation of aggregate (example: endloaders or trucks on pile crush the aggregate)
- Contamination of materials by deleterious substances (example: trucks track clay and mud onto aggregate)
- Inconsistent or undesirable moisture content (example: materials are not wetted or allowed to drain properly)
- Lumps in cementitious materials due to heat or moisture in material
- Frozen lumps of aggregates due to lack of precautions in cold weather

Mudball resulting from stockpile contamination

Recommended Procedures

Cementitious Materials

- Store cementitious materials in separate silos or storage units.
- Clearly identify the contents of storage units.

Chemical Admixtures

- Clearly label storage tanks for chemical admixtures.
- Protect admixtures from freezing.
- Agitate admixtures regularly to prevent settling.

Aggregates

- Store aggregates in separate bunkers when many gradations and types of aggregate are required in small quantities for relatively low-production operations.
- Otherwise, store aggregate in open stockpiles.

Well-built and well-maintained aggregate stockpile

Proper end-loader operation

Stockpiling Aggregate

Locating Stockpiles

- Locate stockpiles where they will not be driven on. Driving on stockpiled aggregate segregates and degrades the aggregate, affecting its performance.
- Separate stockpiles from each other. If there is not enough space between them to keep them separate, use a separating wall.

Preparing Stockpile Base

- Make sure the stockpile base is firm and uniform because it supports the pile and prevents soil from being scooped in with the aggregate.
- Provide adequate base of a differing aggregate type to prevent pumping mud into the bottom of the aggregate pile.

Building Stockpiles

- Determine the equipment to be used and personnel responsible before delivering aggregate to the plant site.
- Do not pile aggregate in a high cone shape because it will segregate.
- Do not make the stockpile higher than the lift of the end-loader's bucket.
- Build the pile outward, not upward.

Maintaining Stockpiles

- Do not drive on stockpiles; this may break down the aggregate and segregate the particle sizes.
- Keep the area clean and discard contaminated materials.
- When removing aggregate from a pile with a front-end loader, attempt to get a portion of each layer in each load.
- Work the aggregate stockpile to maintain uniform moisture and gradation.
- Do not allow stockpile to get so low that the loader digs into soil base.
- Avoid careless dumping of material into the wrong stockpile.

Managing Stockpile Moisture

- Keep the aggregate moisture content at or above the saturated surface dry condition, especially for absorptive aggregates used during hot weather. Drain fine aggregate at least 24 hours before use.
- Note differences in aggregate moisture throughout the stockpile since the moisture condition of aggregate affects the workability of concrete. The moisture content of successive batches should not vary by more than 0.5%.
- If aggregate moisture varies through the day, measure moisture content more frequently.
- Regularly mix aggregate from different areas of the pile for each batch so that the overall aggregate moisture level is consistent from batch to batch.

1.3. Water-Cement Ratio

Overview

The amount of water in the concrete mixture has a direct effect on the quality of the plastic concrete paste that glues the aggregate particles together and, subsequently, on the strength, permeability, and durability of the hardened concrete. The water-cement ratio is the weight of water divided by the weight of cementitious materials in a concrete mix.

Common Problems

- Water-cement ratio too low, resulting in a mix that is difficult to place and finish
- Water-cement ratio too high, resulting in weak, porous paste that has low strength and is less durable

Recommended Procedures

- Use only enough water to make the mix workable and achieve the desired strength.
- Account for the moisture content of the aggregate in determining the amount of free water added to the mix.
- Do not add extra water during mixing, placing, and especially on the surface during finishing.

1.4. Concrete Batching

Overview

Batching is the process of measuring concrete mix ingredients and introducing them into the mixer to produce concrete of a uniform quality. Concrete batch plants need to be well maintained and properly operated to produce a uniform concrete mix from batch to batch.

Common Problems

- Aggregate segregation
- Varying moisture content
- Addition of too much water, resulting in reduced concrete strength and increased shrinkage
- Overdose of admixture, resulting in poor workability and retardation

Recommended Procedures

- Use separate aggregate bins for each size of coarse aggregate. Bins should be capable of shutting off material with precision.
- Use controls to monitor aggregate quantities during hopper charging.
- Use standard test weights for checking scale accuracy.
- Maintain mixer blades. Watch for wear and coating.
- Do not load mixer above rated capacity.
- Operate mixer at manufacturer-recommended speed.
- Mix all concrete thoroughly until it is uniform in appearance, with all ingredients evenly distributed.
- Take samples from different portions of a batch to ensure that the whole batch has the same air content, slump, unit weight, and aggregate proportions.

1.5. Stationary Mixing and Delivery

Overview

Stationary mixed concrete is often used where large volumes of concrete need to be placed in a short period of time.

Common Problems

- Short mixing times resulting in non-uniform mixtures, poor distribution of air voids, poor strength gain, and early stiffening problems
- Insufficient monitoring of aggregate moistures
- Lumps or segregation resulting in non-uniform mixture

Mixing

Description

Stationary mixing is the mixing of concrete at a nearby or on-site concrete batch plant.

Recommended Procedures

- Set and lock the mixer timing device to the recommended mixing time if possible.
- Measure the mixing period from the time all cement and aggregates are in the mixer drum.
- Add supplementary cementitious materials after the cement.
- Add all of the water before one-fourth of the mixing time has elapsed.
- When two or more admixtures are used in the same batch of concrete, introduce them separately to avoid any interaction that might compromise the effectiveness of the admixtures.
- Introduce admixtures in the same sequence in the charging cycle.
- Complete the addition of admixtures not later than one minute after adding water to the cement or prior to the start of the last three-fourths of the mixing cycle, whichever occurs first.

Delivery

Description

Standard dump trucks or agitor trucks are used to transport the already-mixed concrete the relatively short distance from the stationary batch plant to the mix placement site. Agitor trucks have an agitator paddle inside the truck box. If the paddle is not rotating, the vehicle is no different from a dump truck.

Recommended Procedures

- Transport mix in well-maintained vehicles.
- Deliver and place concrete mixture at the job site within the specified time period. Retarding admixtures may be used to extend the time limit. The time limit may also be longer with continuous agitation than without continuous agitation.
- Check that delivery vehicles are free from concrete build-up. Check boxes between loads.

Dump truck

Agitor truck

1.6. Ready Mixing and Delivery

Overview

Ready mixed concrete is often used for lower volume paving projects such as urban paving. Ready mixed concrete is proportioned and mixed off the project site and is transported to the construction site in a freshly mixed state in ready mix trucks.

Common Problems

- Mixing at high speeds for long periods of time, resulting in reduced air content and decreased workability
- Excess water added to ready mixed concrete, resulting in decreased long-term pavement durability
- Lumps or segregation, resulting in nonuniform mixture

Recommended Procedures

- Once all materials have been added, apply at least 70 to 100 revolutions of the ready mix drum at the manufacturer-recommended mixing speed (6 to 18 rpm).
- Make sure the ready mix drum is constantly revolving during delivery.
- Deliver and place concrete mixture at the job site within 90 minutes of initial mixing.
- Check each mix truck for worn blades or concrete build-up. Keep blades clean and replace them when they become worn.

1.7. Hot Weather Batching

Overview

Hot weather (air temperatures over 90°F) during concrete batching can reduce mix workability. Many states specify a maximum concrete temperature limit of 90°F.

Common Problems

- Drying of aggregate stockpiles
- Accelerated rate of cement hydration
- High concrete temperatures, resulting in premature setting
- Thermal cracking
- Plastic shrinkage cracking

Recommended Procedures

- Avoid use of fresh or hot cement or fly ash.
- Use slag and/or fly ash as a substitute for some portion of portland cement to lower the peak concrete temperature.
- Do not exceed the maximum allowed water-cement ratio.
- Add chilled water to the concrete mix when necessary.
- Do not exceed the manufacturer's maximum recommended dosage of admixtures.
- If necessary, increase the dosage of air entraining admixture to maintain air content.
- Use retarding admixtures based on trial batch performance.
- Take precautions when concrete temperatures exceed 90°F.

1.8. Cold Weather Batching

Overview

Cold weather (air temperatures under 50°F) during concrete batching can cause plastic shrinkage cracking, especially if the concrete temperature is much warmer than the air or if the wind is blowing. Keeping the concrete mixture at a temperature of at least 50°F helps to maintain mix workability.

Common Problems

- Plastic shrinkage cracking
- Slow strength gain

Recommended Procedures

- Do not use aggregates with frozen lumps.
- Use heated materials.
- Reduce or eliminate slag and fly ash because they slow hydration.
- If necessary, decrease the dosage of air entraining admixture to maintain air content.
- Increase cement content of the mixture to generate more heat.

2.1. Preparing the Subgrade and Subbase

Overview

Concrete pavement failures are often not caused by failure of the concrete slab, but by problems with the materials beneath the slab. Adequate preparation of the roadbed, including subgrade and subbase, is essential for a strong, durable concrete pavement system.

Common Problems

- Unstable or non-uniform materials
- Poor compaction of utility trenches or the subgrade itself
- A rough or rutted subgrade, resulting in pavement of varying thickness and poor overall smoothness
- Separation of fine aggregates during the subbase trimming process, resulting in reduced subgrade permeability
- Dry subbase that draws water from the concrete mixture
- Poor drainage leading to standing water

Subgrade

Description

The subgrade is earth graded to the desired elevation.

Recommended Procedures

- Extend the subgrade at least 3' beyond the outside edge of the planned pavement. This provides a foundation for a solid pad line for paving equipment tracks.
- Cut high points and fill low areas to achieve the desired roadway profile elevation. For embankment fill, use cut material, except for peat, organic silt, or soil with high organic content.
- Remove localized pockets of undesirable material and replaced with soil similar to the surrounding subgrade or with select backfill, or treat with stabilizing additives such as lime, portland cement, or fly ash.
- Compact the subgrade with proper moisture control to the required density.
- Proof-roll the subgrade to detect soft areas that require additional stabilization.
- Trim the subgrade surface to achieve the desired profile grade.
- When conditions warrant and it is practical, avoid operating equipment on the subgrade.

Subbase

Description

The subbase is a course of material placed on the subgrade to provide drainage and stability. Different kinds of subbases are used based on the need to balance drainability and stability. A granular subbase (mixture of uniformly shaped and minimally compacted granular material) is the most drainable subbase, but it does not provide significant structural support. A subbase containing a greater percentage of crushed particles and a denser gradation than a granular subbase is moderately drainable and provides more stability than a granular subbase. Special backfill (such as a uniform mixture of crushed concrete or crushed limestone, or a mixture of gravel, sand, and soil with or without crushed stone) may provide more stability and support but is the least drainable.

Recommended Procedures

- Place the subbase course on the subgrade.
- Keep the subbase surface moist prior to paving. Spray water on the grade as needed, but do not leave standing water.

2.2. Setting String Line

Overview

The string line controls the alignment and elevation of the fine grader, paver, and sometimes belt placer and tining machine. String lines should be carefully protected and maintained because even small disturbances in a string line can reduce pavement smoothness. A damaged or loose string line can cause a dip or hump in the pavement profile.

Description

The string line can be wire, cable, woven nylon, or polyethylene rope. The string line is usually set up on both sides of the proposed pavement edge and is supported by stakes outside the edge of the pad line.

Common Problems

- Surveyor error in staking string line
- Misalignment of string-line pins, causing the distance between string lines on each side of the road to vary, resulting in variation from desired alignment
- Sag in string line
- People, equipment, or wild animals bumping string line

Recommended Procedures

- Install string line as low as possible.
- Make sure string line is tight, with no sags between stakes, and is free of obstructions including weeds.
- Eyeball the string line immediately before and during paving as a final check for horizontal or vertical alignment.
- Notify supervisor if you notice a disturbance or possible error in the string line.

2.3. Placing, Spreading, Striking Off, and Consolidating Concrete

Overview

After the grade and subbase have been prepared, the mix is placed. The slip-form paving machine has three main parts—augers or plows, profile pan, and vibrators—to spread, strike off, and consolidate the concrete as it travels forward.

Placing Concrete

Description

Concrete mixes are best deposited from off the grade or the side of the grade by belt placers. Alternatively, to prevent trucks from driving on the grade after it's been trimmed, special conveyors are sometimes used to move the mix from delivery trucks over the fine grade trimmer to the grade just in front of the paver.

Common Problems

- Uneven depositing of concrete mix
- Inconsistent workability and/or durability due to different rates of mix production and delivery
- Surface smoothness problems due to inconsistent paver speed or excessive stopping

Recommended Procedures

- Deposit concrete as uniformly as possible in front of the paver.
- Do not overload either side of paver. Adjust the height of placement for the size of the paver so that the head of the concrete does not cause the paver pan to rise.
- Operate the paver at a slow, consistent speed and avoid unnecessary stops to ensure a smooth pavement. The paver speed should match production rate of the batch plant and the rate of concrete delivery to the paver.

Spreading Concrete

Description

Augers, large horizontal screws across the front of the paver, or plows spread the concrete sideways across the width of the pavement to create a uniform depth ahead of the profile pan.

Common Problems

- Too much concrete in front of the paver, causing the profile pan to rise, resulting in a bump in the finished pavement
- Too little concrete in front of the paver, resulting in voids in the finished pavement

Recommended Procedures

- Maintain a uniform head of concrete—not too big and not too small.

Striking Off Concrete

Description

The profile pan, located behind the augers or plow, strikes off excess concrete to the desired pavement elevation and smooths the surface.

Recommended Procedures

- Adjust the profile pan to construct the specified crown or super-elevations.

Consolidating Concrete

Description

Vibrators on the paver consolidate the concrete mix. Consolidation should be carefully monitored because the vibrators have the potential to produce concrete mix segregation and adversely affect the air void system. Proper vibration should be controlled to not adversely affect the strength or long-term durability of the concrete.

Common Problems

- Too little vibration, resulting in low concrete strength and large pockets of entrapped air. Possible causes:
  - Concrete mix design that produces poor workability
  - Vibrators not functioning properly
  - Too fast a paver speed
- Too much vibration, resulting in aggregate segregation, vibrator trails, and freeze-thaw durability problems. Possible causes:
  - Concrete mix design that produces poor workability
  - Improperly installed vibrators or excessive frequency
  - Reducing paver speed without compensating vibrator frequency

Recommended Procedures

- Install vibrators according to the manufacturer recommendations or specifier's requirements.
- Synchronize and monitor vibrators within the specified range.
- Check vibrator frequencies and amplitudes under load at the beginning of the process.
- For large pours, equip pavers with continuous monitoring.
- Adjust the vibrator frequency for varying paver speeds.
- Turn off vibrators when the paver stops.

2.4. Finishing

Overview

Finishing determines the final appearance, smoothness, and other surface properties of concrete that affect the long-term durability of a pavement surface.

Description

Longitudinal, Oscillating Floats

Longitudinal, oscillating floats (Auto-Floats) may be either attached to the paver or self propelled. The floats are attached parallel or near parallel with the center line of the slab and move from one side of the slab to the other while oscillating front to rear. The floats are used to shape and smooth the surface.

Mechanical Truss Floats

Mechanical truss floats (V-Floats) consist of a truss with narrow floats attached. They are normally attached to the paver near the centerline and fan out toward the edge of the pavement. The floats rest on the slab and are typically pulled by the paver.

Hand Floats

When hand floats are used for finishing, the surface is first checked behind the paver with straight edge and surface imperfections are then corrected with a hand float.

Hand Trowels

Hand trowels can be used to create a hard, smooth finish; shape or finish pavement curbings or edges; finish around structures in the pavement (box-outs, manholes, utility appurtenances, etc.); and round the edges of formed joints.

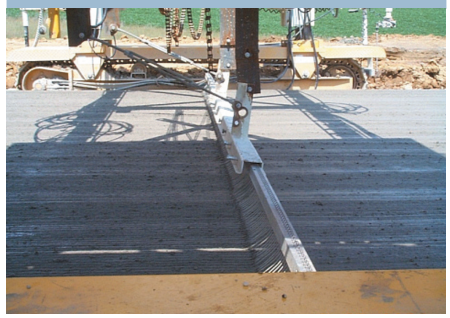
Common Problems

- Too much water on the concrete surface
- Aggregate dragged along or out of the surface
- Excessive finishing of the concrete

Recommended Procedures

- Do not add water to the concrete surface while finishing
- Do as little surface finishing as possible

2.5. Texturing



Overview

Pavement surfaces are textured to roughen the surface.

Microtexturing

Description

Microtexturing is accomplished by dragging wet burlap, artificial turf, or coarse carpet longitudinally along the concrete surface.

Recommended Procedures

- Do not allow turf drags to disrupt or pull aggregate to the surface.
- If a bridge is used, pull it with the paver so that it provides a straight, uniform texture. Do not hand pull or push the bridge because that can result in a cracked or wavy surface texture.

Macrotexturing/Tining

Description

Macrotexturing is generally required on pavements with speed limits greater than 35 mph. Macrotexturing is created by a mechanical device (tining machine) that makes grooves typically longitudinally or sometimes transversely in the pavement surface.

Common Problems

- Bent tines
- Tine length not uniform, causing non-uniform depth
- Tines too deep
- Tining machine wandering off of parallel to centerline

Recommended Procedures

- Follow specifier’s recommendations for tine groove spacing, width, and depth.

2.6. Curing

Overview

Curing is a process of protecting the new pavement to regulate moisture loss from the concrete surface. Curing also ensures that concrete gains strength uniformly. Applying curing compounds is the most commonly used curing technique.

Description

Curing compounds reduce the rate of water evaporation from the concrete surface. White pigments in the compounds reduce solar heat gain on sunny days and are a way to visually judge the application rate.

Common Problems

- Dirty or poorly maintained equipment, resulting in clogged nozzles and nonuniform application
- Too little curing compound applied
- Non-uniform application of compound, especially by hand spraying
- Vertical edge of slab not cured

Recommended Procedures

- Clean spray nozzles frequently to prevent clogging.
- Thoroughly mix and agitate compound using diaphragm pumps or mechanical agitators. Do not use gear pumps and high shear devices.
- Mix compound daily before application and at least once every 4 days when not in use.
- Check that the temperature is above 40°F before applying.
- Mount spray equipment on a self-propelled frame that spans the entire width of the slab.
- Provide wind protection to avoid spray drift.
- Set application rate and calibrate equipment to ensure specified coverage. Application rate may have to be increased during extremely hot weather.
- Apply curing compounds evenly immediately after finishing and texturing, especially during extremely hot, dry, or windy weather.
- Spray the entire concrete surface and all exposed vertical edges, including the back of the curb.
- Perform yield checks to ensure proper rate of application.
- Store well-mixed material in clean bulk containers with clearly marked batch numbers on the bulk tanks.

2.7. Hot, Dry Weather Paving

Overview

Hot, dry weather can impair the quality of freshly mixed or hardened concrete by accelerating the rate of moisture loss and the rate of cement hydration. Hot weather precautions are important because once heat-related problems develop in concrete, it may be too late to correct them. Hot, dry weather precautions typically apply when the air temperature is above 90°F and there is low relative humidity, high wind speed, and sun exposure.

Common Problems

- Drying out of aggregate stockpiles and subbase, resulting in aggregate absorbing water from the concrete mix, impairing workability
- Rapid water evaporation from the pavement surface, resulting in shrinkage cracking
- Difficulty controlling air entrainment
- Rapid hardening of the concrete, resulting in accelerated slump loss
- Delayed joint sawing, possibly leading to cracking

Recommended Procedures

- Keep aggregate stockpiles, grade, subbase, forms, and equipment moist.
- Use fly ash and slag in the mixture to slow hydration.
- Use retarders to aid in placement.
- Pave in the morning, evening, or night when it is cooler.
- Apply curing compound immediately after final finish treatment. Increased dosage of curing compound may be needed.

2.8. Cold Weather Paving

Overview

Special precautions must be taken when paving in cold weather. Cold weather precautions apply when the air temperature is 50°F or colder for more than one-half of any 24-hour period, or when the average daily air temperature is less than 40°F for three consecutive days.

Common Problems

- Aggregate with frozen lumps
- Concrete cooling faster at the surface than inside the slab, resulting in stress & cracking
- Frozen concrete, resulting in lack of strength gain and deterioration

Recommended Procedures

- Do not pave on frozen subgrade.
- Do not use aggregates with frozen lumps.
- Heat materials.
- Minimize use of fly ash and slag.
- Do not pave if the concrete cannot reach adequate strength before it freezes.
- For the first two to three days, protect new concrete pavement from cold weather with adequate layers of burlap or other insulating material.

2.9. Preventing Rain Damage

Overview

Layers of burlap or plastic film are used to protect fresh concrete in case of rain.

Common Problems

- Surface damage of concrete that has not achieved final set
- Thermal restraint stresses in pavement that has achieved final set leading to uncontrolled cracking, even if saw cutting is underway.
- Surface texturing damage
- Strong wind blows the covering off the slab

Recommended Procedures

Rain Damage Prevention

- Subscribe to and monitor weather forecasting services.
- Have protective materials such as burlap or plastic film available on site at all times.
- Stop batching and transporting of mix in a timely manner.
- Use early-entry saws to quickly cut the joints.

When It Starts Raining

- Cover fresh concrete as soon as possible.
- Do not finish the concrete surface after unprotected pavement is exposed to rain.
- Do not try to remove extra surface water prior to covering the concrete.
- Do not add dry cement to the surface.

After the Rain

- Apply curing compound as soon as the concrete surface is dry.
- Saw joint as quickly as possible to reduce potential early-age cracking by rapid surface cooling.
- Diamond grind the surface to remove blemishes and add texture.
- Remove the concrete if it was exposed to significant rain while it was loose or unconsolidated since it likely absorbed enough water to affect the water/cement ratio and strength of the surface.

3.1. Providing Load Transfer Mechanisms

Overview

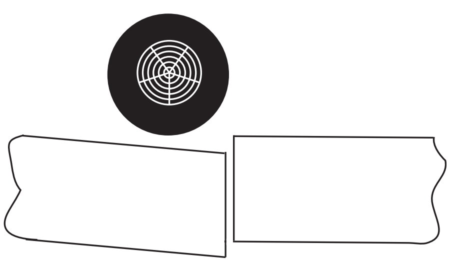
As heavy traffic crosses a pavement joint, the slab on either side may move up and down. This can lead to subgrade pumping and ultimately pavement damage. Joints need load transfer to minimize up and down movement. Load transfer mechanisms include aggregate interlock, doweled joints, and keyed joints.

Common Problems

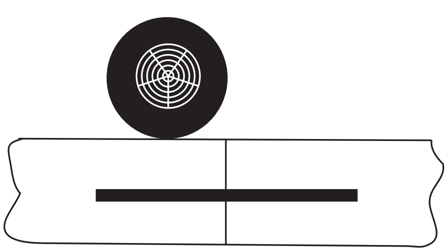
- Pavement damage due to slab movement
- Faulting of the pavement joint caused by insufficient load transfer
- Loss of base support caused by pumping of subgrade material

Aggregate Interlock

Aggregate particles on each side of a joint interlock, reducing pavement movement. Pavement slabs less than 8” thick generally depend on aggregate interlock in the crack below the saw cut to keep the slabs in place. Aggregate interlock can provide load transfer at contraction joints on low-volume roads where contraction joints are closely spaced and truck loading is minimal.



Pavement slabs moving due to lack of load transfer mechanism



Dowels providing load transfer between pavement slabs

Doweled Joints

For 8” or thicker pavements, smooth dowel bars are placed across joints to transfer heavy loads without restricting horizontal joint movement. Properly sized and placed dowel bars can provide the needed load transfer and are recommended at transverse contraction joints when the pavement will experience high traffic volumes and/or large truck traffic. The dowels are typically installed in prefabricated baskets or inserted into the pavement using a dowel bar inserter during construction.

Recommended Procedures

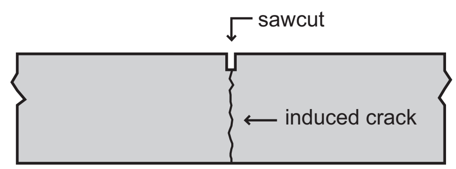
- After the subgrade has been prepared for paving, dowel assemblies can be placed. Set out pins or paint marks on either side of the roadway to mark locations.
- Align dowels exactly centered over the joint line.
- Anchor dowel baskets securely into the subgrade. For 12' or 14' lane widths, typically a minimum of 4 stakes are installed on the leave side of both basket legs.
- Do not place bent dowel baskets. Do not leave bent dowel baskets in place.
- As a final check, make sure
  - All dowels are parallel to the center line of the roadway
  - All dowels are parallel to the base
  - All baskets are properly pinned
  - The center of each basket (i.e., the joint location) is clearly marked

Staking dowel baskets (paver traveling ↓)

3.2. Joint Sawing

Overview

Without planned joints, new pavement will experience random cracking within the first 72 hours of life. This random cracking is aesthetically undesirable and can be detrimental to the long-term durability of the pavement. Joints are cut to control random cracking, accommodate slab movements, ensure joint locations match load transfer device placements, and divide the pavement into practical construction elements. Cuts sawed into the surface of hardening concrete form a line of weakness, causing the concrete to crack below the sawcut instead of cracking randomly.

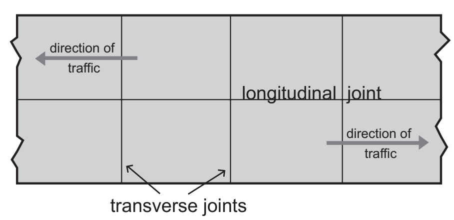


Cross section of contraction joint

Description

Joint Orientation

Joint orientation can be either longitudinal (parallel to the centerline) or transverse (perpendicular to the centerline).



Plan view of transverse and longitudinal joint orientations

Sawing Window

The timing of saw cutting is critical to preventing random cracking. New pavement must develop enough strength to allow saw equipment to get on the slab and to resist raveling of the joints. The sawing window is the brief period of time during which joints can be sawed before stresses in the concrete cause random cracks to develop.

Conventional Sawing vs. Early Sawing

Early-age (or green) saws can be used to create transverse joints earlier than conventional, heavy sawing equipment. Early-age saws are light weight and use a special skid plate to allow sawing of tender concrete.

Common Problems

- Early cracking due to subgrade restraint, concrete drying shrinkage, temperature/moisture differentials, traffic loading, and/or the combined effects of daytime/nighttime slab curling and warping
- Random crack forming due to late sawing
- Joint raveling due to saw cutting performed too early or improper joint sawing, resulting in spalled joints
- Pavement surface scarring due to sawing equipment operating on pavement too early
- Saw cuts too shallow, thereby insufficient to initiate a crack and prevent random cracking
- Saw cuts too deep, requiring an unnecessary amount of time and work and resulting in reduced aggregate interlock

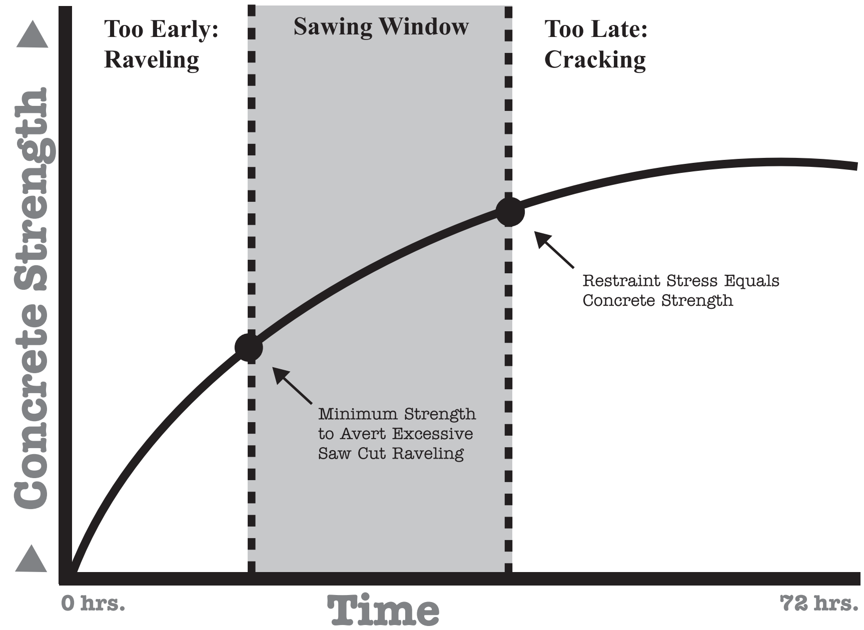
Recommended Procedures

Before Sawing

- Follow the layout on project plans. The engineer must approve any change. If joint layout plans are not available, work with the engineer.
- Clearly and carefully mark the centerline of dowels on forms or the subgrade so joints can be cut in the correct location after concrete is placed.

Conventional Sawing

- Begin saw cutting immediately after the concrete has hardened enough to permit sawing without raveling.



Window of time for sawing

- Start sawing at the beginning of the sawing window, usually 8–12 hours after placement for conventional saws.
- Saw at the minimum design depth, usually about 1/3 of the pavement thickness for conventional saws.
- Continue sawing regardless of weather or daylight conditions in order to complete sawing before random cracking occurs.

Early Sawing

- Perform scratch test, using a nail or knife blade, to see how deeply the surface scratches. As surface hardness increases, scratch depth decreases. Do not saw if scratching removes surface texture.
- Begin sawing as soon as the slab supports the weight of the saw and operator without disturbing the finish, often within about 3 hours of placement, depending on mix and weather conditions.
- Saw at least 1-1/4" deep.
- Monitor the concrete surface temperature. Complete the sawing before the surface temperature begins to fall. On a large pour or thin overlay, several saws may be needed to complete sawing within the sawing window.
- Stop saw cuts 1/2" short of the pavement edge to prevent "blow out" spalls at the slab edge. Once the crack forms at the joint, it will proceed through the uncut portion of the slab to the edge.

Sawing Troubleshooting

- Monitor blade wear and buildup of curing compound on the wheels of the sawing equipment to ensure the minimum depth of saw cuts.
- Saw joints in succession, but if random cracking starts to be encountered, skip three or four joints at a time and move down the slab as rapidly as possible and/or add additional saws. Skipped joints should be sawed with a conventional saw once the cracking potential has been controlled.
- If crack forms before sawing begins, don't saw the design joint but use a crack saw along the line of the crack.
- If crack develops ahead of the saw, stop sawing immediately. Form the joint sealant reservoir later with a crack saw along the line of the crack.
- If joint begins to ravel, stop sawing and wait for more strength to develop.

Stop early-age saw cut just short of pavement edge

3.3. Constructing Headers (Construction Joints)

Overview

Headers are constructed at the end of a section of pavement, when paving is delayed by 30 minutes or more, or at the end of a day's pour. Common interruptions include bridges or structures, intersections, and emergency shutdowns.

Headers are oriented perpendicularly to the centerline, even if the regular transverse joints are designed to be skewed. The two most common methods of header construction are (1) installing header boards for fresh concrete construction and (2) sawing header joints for hardened concrete construction.

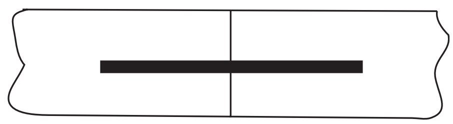
Common Problems

- Headers installed incorrectly, resulting in cracking or other joint problems
- Header slabs not strong enough when paving resumes the following day
- Dowel bars not level, resulting in future joint deterioration
- Misalignment of dowel bars on header using smooth dowels, resulting in a non-working joint that was intended to allow movement

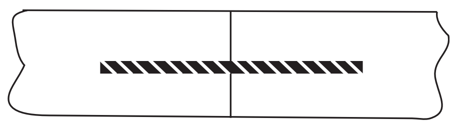
Recommended Procedures

Installing Header Boards

- Install header board.
- To construct a header at the normal location of a transverse contraction joint, properly install spaced smooth dowel bars.
- To construct a header at a location other than at the normal location of a transverse contraction joint, install the header within the middle third of a planned panel with properly sized and spaced deformed tie-bars. Deformed tie-bars should be the same size as transverse joint dowel bars.
- Place dowels or tie bars through the header board in predrilled locations.
- Ensure proper encasement of the dowel bars through additional consolidation with a hand held vibrator.
- Take special care to make sure that the tie or dowel bars are perfectly level and straight.
- Remove the header board before resuming paving.



Header at transverse joint; smooth dowel bar coated to prevent bond



Header at location other than transverse joint; deformed tie bar used

Sawing Header Joints

- Use this preferred method to reduce chance or severity of bump at joint.
- Saw header joint at the location specified.
- Mix the last two concrete batches approaching a sawed header for high early strength gain so that construction can resume the next day.
- Saw excess material full depth and remove it from the planned location.
- Drill holes and grout the dowel bars into the header face.
- Set epoxy grout before resuming paving.

3.4. Joint Cleaning

Overview

Before joints are sealed, joints must be cleaned to remove incompressible materials such as saw-cut swarf, soil, sand, or gravel. Cleaning can be accomplished by water or air blasting.

Common Problems

- Incompressible materials in joints, preventing proper sealant adhesion, resulting in joints that do not function properly.
- Debris in the joints, resulting in spalling, cracking, and other joint distresses

Recommended Procedures

Air Blasting

- After dry-sawing, remove residue by air blasting.
- Air blast immediately prior to sealing.
- Hold the nozzle no more than 2" from the paving surface to blow debris out of the joint.
- Repeat at those joints remaining open overnight or for extended period of time.
- Make sure that the air stream is free of oil. Many modern compressors automatically insert oil into air lines for lubrication. When air blasting joints, disconnect the oil line and install an effective oil and moisture trap.

Water Blasting (after wet sawing)

- Within three hours of wet-sawing, flush the residue away using a minimum water pressure of 1000 psi (7000 kPa).

3.5. Joint Sealing

Overview

Joint sealing prevents incompressible materials from getting lodged in the joint space, which can cause spalls. Joint sealing needs to be done properly to prevent water from entering the subgrade. Sealant materials must be able to withstand repeated expansion and compression as the pavement slabs expand and contract with temperature and moisture changes.

There are three different categories of sealants: hot-poured liquid sealants, cold-poured silicone sealants, and preformed compression sealers.

Hot-Poured Liquid Sealants

Common Problems

- Poured joint sealant does not adhere to the pavement because the joint face is not clean, the shape is not correct, or the face is too moist when the sealant is placed
- Hot-poured liquid sealant does not adhere because of overheating or underheating
- Backer rod traps moisture

Recommended Procedures

- Make sure sealant materials meet the design specification for the application, including compatibility between the sealant and concrete aggregates.
- Clean and dry the saw cut reservoir before sealing the joint. Seal joints only when the joint surfaces appear dry.
- Place joint sealer when the pavement and surrounding air temperature are about 40°F or higher because joint sealer is sensitive to temperature.
- Where specified, backer rods can be installed to provide proper shape factor.
- Use an indirect heating kettle with an agitator to prevent localized overheating. Discard overheated material.
- Use insulated hoses. Fit the application wand with a recirculation line to prevent the temperature of the sealant in the hose from dropping below application temperature.
- Make sure that the top of the sealant is 1/8"–1/4" below the pavement surface.
- Clean any spilled or overfilled joint sealant from the concrete surface.

Cold-Poured Silicone Sealants

Common Problems

- Poured joint sealant does not adhere to the pavement because the joint face is not clean, the shape is not correct, or the face is too moist when the sealant is placed
- Backer rod traps moisture

Recommended Procedures

- Make sure sealant materials meet the design specification for the application, including compatibility between the sealant and concrete aggregates.
- Clean and dry the saw cut reservoir before sealing the joint. Seal joints only when the joint surfaces appear dry.
- Place joint sealer when the pavement and surrounding air temperature are about 40°F or higher because joint sealer is sensitive to temperature.
- Where specified, backer rods can be installed to provide proper shape factor.
- Use joint primer provided by the manufacturer to ensure a good bond between the sealant and the joint reservoir face.
- Tool non-self-leveling sealants before the material cures.
- Clean any spilled or overfilled joint sealant from the concrete surface.

Preformed Compression Sealers

Common Problems

- Preformed compression sealer is loose in the reservoir because the sealant is not sized properly, the joint width is too large, or the sealant is overstretched

Recommended Procedures

- Make sure sealant materials meet the design specification for the application.
- Check joint width for compatibility.
- Make sure the joint width doesn't vary, especially at points where the saw reenters the joint.
- Clean and dry the saw cut reservoir before sealing the joint. Seal joints only when the joint surfaces appear dry.
- Follow the manufacturer's recommendation for sealant sizing and installation.
- Make sure the sealant is lubricated, straight, vertical, and undamaged before installation.
- Make sure that the installation device does not stretch the sealant.