

for filling the measuring tank. Ensure that the measuring tank has controls that track the quantity of water in the tank.

Use methods and equipment to add air-entraining agents or other admixtures to within a ± 3 percent tolerance of the mix design.

2. *Mixers.* Mount a manufacturer's plate on the mixer that indicates total drum capacity, concrete mixing capacity, and recommended mixing speed of the drum or attached blades. Keep mixers clean and operable. Repair or replace the drum pickup and throw-over blades when they show more than $\frac{3}{4}$ -in. (20-mm) wear from the original height. Provide, at the concrete plant, a copy of the manufacturer's drum blade design showing the original height and depth dimensions and blade arrangement. Mark blades or drill a $\frac{1}{4}$ -in. (6-mm) hole near each end and at the midpoint of each blade to show $\frac{3}{4}$ -in. (20-mm) wear from the new condition.
 - a. *Central Plant.* Furnish mixers that thoroughly combine the aggregates, cement, and water and discharge the mixture. Equip mixer with a timing device that automatically prevents discharge during mixing and allows discharge only when mixing is finished. Mix each batch at least 90 seconds. Provide a bell or other audible warning device to sound when the lock is released. Equip the mixer with a counter to record the number of batches mixed.

Start measuring mixing time when all materials, except water, are in the mixing drum. Mix and deliver ready-mixed concrete according to AASHTO M 157. Post the manufacturer's recommended number of revolutions at mixing speeds on the mixer's mounted serial plate. Reduce the number of revolutions if test data verify that the make and model of the mixer can produce uniform concrete.

Mix concrete for 90 seconds. Add 4 seconds if timing starts the instant the skip reaches its maximum raised position. End mixing time when the discharge chute opens. Include transfer time in mixing time for multiple drum mixers.

Reject concrete mixed less than the specified time. Limit drum speed and batch volume to that shown on the manufacturer's standard rating plate posted on the mixer.

Charge the drum so that some water enters the mixer before the cement and aggregates. Maintain an even flow so that all of the water is in the drum within the first 15 seconds of the mixing period. Keep the drum throat clean to ensure the free flow of materials into the drum.

After adding the water to the mix, deposit the concrete within 45 minutes if hauled in nonagitating trucks or within 90 minutes if hauled in truck mixers or truck agitators. Reduce the placement time if hot weather or other conditions might cause the concrete to set prematurely. Avoid adding water or other additives to retemper concrete.

- b. *Truck Mixers and Truck Agitators.* Furnish truck mixers for mixing and hauling concrete and truck agitators for hauling central-mixed concrete, both of which meet AASHTO M 157.

The Contractor may add water to concrete mixes delivered by transit mix trucks if the specified water to cementitious material ratio is met and the concrete is placed within 45 minutes of the water addition. Do not use concrete that does not meet specified slump and water–cement ratio limits.

- c. *Nonagitator Trucks.* Use nonagitating vehicles with smooth, mortar-tight, metal containers that can discharge concrete evenly from the bottom end or side of the container. Provide covers to protect the concrete from hot weather and rain.
3. *Finishing Equipment.* Use slip-form paving equipment or equipment with stationary side forms to construct pavement.

Provide vibrators to consolidate the concrete for the full width. Use either the surface pan type (limited to pavements 8 in. (200 mm) thick or less) or the internal type with either immersed tube or multiple spuds. Ensure that vibrators attached to the spreader or finishing machine, or mounted on a separate carriage, do not touch joints, load transfer devices, the subgrade, or side forms. Limit the minimum vibration frequency, in impulses per minute, of surface vibrators to 3500, tube vibrators to 5000, and spud vibrators to 7000.

Maintain a minimum vibration frequency of 3500 when using spud-type internal vibrators next to the forms.

- a. *Slip-Form Method.* Place concrete with a slip-form paver that can spread, consolidate, screed, and finish the freshly placed concrete in one complete pass. Ensure the paver provides a dense, homogeneous pavement, with a surface tolerance that requires minimum hand finishing. Use reference lines outside the finished concrete limits to regulate the paver's alignment and elevation during concrete placing and finishing operations.
 - b. *Stationary Side-Form Method.* Equip the finishing machine with at least two oscillating-type transverse screeds that can finish the surface to the specified tolerance.
4. *Concrete Saw.* Provide saws to cut joints and backup saws in case of equipment failure. Furnish adequate lighting for night sawing.
5. *Forms.* Furnish 10-ft (3-m) long straight-side forms of at least $\frac{7}{32}$ -in. (5-mm) thick metal. Ensure forms are as deep as the pavement edge is thick, without the horizontal joint. Use only solid forms. Ensure base width equals form depth. Use flexible or curved forms for curves up to 100-ft (30-m) radius. Keep the forms rigid during paving. Extend flange braces outward on the back of the forms to at least two-thirds the height of the form. Remove forms with battered top surfaces or forms that are bent or broken. Maintain the maximum variance of the top form of $\frac{1}{8}$ in. (3 mm) in 10 ft (3 m) from a true plane, and

maintain the maximum face variance of $\frac{1}{4}$ in. (6 mm) in 10 ft (3 m). Ensure that forms tightly lock together the ends of abutting form sections and are set securely on the grade.

- C. *Mixing Limitations.* Ensure adequate natural or artificial light when mixing, placing, or finishing concrete. Place mixed concrete only when its temperature is between 50°F and 85°F (10°C and 30°C).

Stop mixing and concreting operations if shaded ambient air temperature away from artificial heat is 40°F (5°C) or less. Resume operations only when the ambient air temperature is 40°F (5°C) and rising. Place concrete only on unfrozen subgrade. Ensure that no frozen aggregate is in the concrete mix.

Heat aggregates by steam or dry heat before placing in the mixer when unable to sustain the specified concrete temperature range. Use a method that will heat the aggregate mass evenly so as not to injure the materials. Heat water and aggregates to between 70°F and 150°F (20°C and 65°C).

- D. *Conditioning Subgrade or Base Course.* Construct subgrade or base course to the specified cross section. Trim high areas and fill and compact low areas to a condition similar to the surrounding grade. Maintain the finished subgrade in a smooth, compact condition and restore disturbed areas prior to placing the pavement.

Keep the subgrade and base course uniformly moist when placing concrete, unless a waterproof cover material is specified.

- E. *Preparing the Proper Grade.* Trim beyond the edges of the proposed concrete pavement to hold the forms or slip-form paving equipment. Fill and thoroughly compact all irregularities below the established grade with subgrade or base course material, in lifts of up to $\frac{3}{8}$ in. (10 mm), for a width of 16 in. (400 mm) on both sides of the base of the form. Tamp or trim above-grade defects or variations to plan elevation.

- F. *Setting Forms.* Compact the foundation under the forms to provide continuous contact with the forms.

Set and check forms before placing concrete to ensure correct form line and grade and to allow continuous concrete placement. Tamp thoroughly the inside and outside edges at the base of the forms. Use three pins for each 10-ft (3-m) section to stake forms in place. Place pins on each side of every joint. Lock form sections to prevent play or movement in any direction. Ensure forms remain true within $\frac{1}{4}$ in. (6 mm). Set forms to withstand the impact and vibration of consolidating equipment. Clean and coat forms with an approved form release agent or oil before placing concrete.

Check and correct alignment and grade elevations of the forms immediately before placing concrete. Correct and recheck disturbed forms or unstable subgrade.

- G. *Placing and Consolidating Concrete.* Deposit concrete with a minimum of handling. Use a spreading device and mechanically distribute concrete evenly. Place concrete continuously

between transverse joints without using intermediate bulkheads. Ensure workers wear clean footwear.

Except for concrete sawing equipment, restrict operation of mechanical equipment on the pavement until after the specified 14-day strength has been obtained. Pave adjacent lanes only after the concrete reaches a flexural strength of [50 psi (345 kPa)] when tested according to AASHTO T 97.

1. *Slip-Form Method.* Vibrate the concrete to consolidate it throughout the depth and width.

Follow standard paving method requirements or use false forms placed next to the slip forms to place and finish pavement sections that abut other lanes with longitudinal joints. Construct false forms of metal gauge strong enough to maintain the shape and continuity of the form line. Discontinue use of false forms when there is measurable edge slump or misalignment. Limit the maximum length of unbraced false forms to 10 ft (3 m). Keep the false forms in place for at least 90 minutes or until they can be removed without damaging adjacent concrete.

Use mechanical equipment to place and position pavement reinforcing steel or fabric.

Spread, consolidate, screed, and float finish the concrete in one pass to lessen the need of hand floating. Operate the slip-form paving equipment in an even forward motion to avoid stop-and-go operation.

Complete the final finish as specified in Subsection 501.3(K)(7). Attach a burlap drag, if used, to the trailing forms.

Cure the surface and edges as specified in Subsection 501.3(M). Protect the unhardened concrete edges and surface from rain.

2. *Stationary Side-Form Method.* Use vibrators to consolidate concrete against and along the faces of all forms and the length and both sides of all joint assemblies. Limit vibrator operation to 5 seconds in any location.

Deposit concrete as near as possible to expansion and contraction joints without disturbing the joint assembly. Do not deposit concrete directly on a joint assembly.

- H. *Test Specimens.* Furnish concrete for casting test beams and cylinders and for testing air content and slump.

- I. *Striking Off Concrete and Placing Reinforcing Steel.* Strike off concrete in two layers to the cross section shown on the plans. Strike off and consolidate the bottom layer to the depth necessary to place the fabric or reinforcing steel mat directly on the concrete. If the top layer is not placed within 30 minutes of the first layer, remove and replace the lower layer with freshly mixed concrete.

Position reinforcing steel before placing the concrete when placing concrete in one layer, or use mechanical or vibratory methods after spreading the plastic concrete. Ensure reinforcing steel is free of oil, paint, grease, mill scale, loose or thick rust, or other foreign material.

J. *Joints*. Protect all joints against intrusion of foreign material until sealed.

1. *Longitudinal Joints*:

- a. *Dimensions*. Saw the first cut or insert the joint material to one third of the depth.
- b. *Tiebars*. Place [30-in. (750-mm)] long No. 5 tiebars of Grade 60 steel, spaced [30 in. (750 mm)] center-to-center to one half of the depth of the PCCP. Place tiebars using mechanical equipment or secure them with chains to prevent movement during concrete placement. Ensure that tiebars are placed perpendicular to the face of the joint, centered in the slab depth, and parallel to the finished surface.
- c. *Construction*. Form or saw longitudinal joints in the plastic concrete. Saw the joints within 4 to 24 after placing the concrete and immediately after completing the transverse joints. Allow only the saw on the pavement during sawing operations. Clean joints before curing them. Cure the joints by one of two methods:
 - i. *Method 1*. Center a 2¹/₂-in. (64-mm) wide polyethylene tape, with adhesive material at each edge over the joint, and press into place.
 - ii. *Method 2*. Install a rope or rod insert that is nonmetallic, inert, resilient, compressive, nonabsorbent, and nonshrinking along the top of the joint flush with the pavement surface. Spray curing compound over the joint to form a vapor barrier and to touch up areas of curing compound damaged during sawing operations. Use rope or rod that is approximately 25 percent larger than the joint width.
- d. *Sealing*. Seal joints after the curing period and before opening the pavement to traffic. Use sandblasting followed by an oil-free air jet to clean the faces and joint openings before sealing. Seal joints only when they are completely dry. Do not dry joints with a heat lance. Use an approved backer rod to seal the lower portion of the joint groove to a uniform depth to prevent sealant from entering beneath the specified depth. Ensure that backer rod is compatible with the sealant type specified and install according to the manufacturer's recommendations.

Place hot-poured sealants only when the pavement temperature is above 50°F (10°C).

Place silicone and cold-applied sealants at the pavement temperatures recommended by the sealant manufacturer. Follow the sealant manufacturer's recommended application rate and cure time when using silicone sealants that require priming of the joint.

Ensure that the top surface of the joint sealant is ¹/₈ in. to ⁵/₁₆ in. (3 mm to 8 mm) below the pavement surface.

2. *Contraction Joints*.

- a. *Location and Dimensions*. Form or saw joints as narrowly as possible, to at least one third of the pavement depth; saw a reservoir to provide the correct shape factor.

- b. *Load Transfer.* Install load transfer dowel bars of specified grade and size, spaced at [10-ft (3-m)] centers, and secured with a wire basket or implanted mechanically. Place dowel bars one half of the depth parallel to the surface and pavement edge to an alignment tolerance of $[\pm 1/4 \text{ in. } (\pm 5 \text{ mm})]$. Vibrate concrete around all dowel bars without misaligning them. Place dowel bars securely to remain in the proper location after the paving train makes its final pass over the joint. Mark the center of the dowel bar assembly on both sides of the pavement slab as a reference to form and saw the contraction joint.

Coat the length of each dowel bar thoroughly with an approved lubricant to prevent concrete cement from sticking to it.

- c. *Construction.* Place formed joints while the concrete is plastic. Begin relief-cut joint sawing immediately after the concrete hardens to the stage that it can be sawed without raveling. Saw all joints between 4 and 24 after placing concrete but before uncontrolled shrinkage cracking develops. Avoid uncontrolled cracking before or during joint sawing by moving the operation ahead, and, if necessary, provide additional sawing units to eliminate shrinkage cracking. When early sawing fails to prevent uncontrolled cracking, change the paving operations by forming a contraction joint groove before the initial set of concrete. Allow only concrete saws on the pavement during the sawing operation. Repair uncontrolled cracks at no cost to the Agency by removing and replacing the pavement, including load transfer devices, across the full width of all affected lanes or shoulders and to the nearest transverse joint in each direction.

Wait at least 72 before beginning final or second-step sawing to create the proper sealant reservoir.

- d. *Sealing.* Create the required reservoir for the specified sealant by sawing. Place sealant as specified in Subsection 501.3(J)(1)(d).

When using preformed elastomeric seals, apply lubricant-adhesive to the joint faces and sides of the seals to facilitate installation and to secure the seal in the joint. Apply the lubricant-adhesive to the full area of the seal that touches the joint faces. Remove any excess material on top of the joint immediately.

Install preformed seals in a compressed condition with the vertical axis of the seal parallel to the joint faces. Install seals using machines or tools that do not twist, curl, nick, notch, or damage the seal, and that insert the seal so that the seal elongation is no more than 5 percent.

Construct without splicing throughout the limit of the joint.

3. *Expansion Joints.* Construct $3/4$ -in. (20-mm) wide expansion joints and fill with a continuous preformed material. Depress the material $3/8$ in. (10 mm) below the surface.

Use a metal channel to hold the expansion joint material in a vertical position that deviates no more than $1/4$ in. (5 mm) from the centerline of the joint. Remove the metal channel after the initial set of the concrete.

Secure dowel bars and preformed material for the load transfer units in place with a metal basket that remains in the pavement. Use a metal dowel cap or sleeve on each dowel bar to adjust to expansion. Equip the cap with a stop to prevent closing during the pavement service. Maintain a 1-in. (25-mm) clearance between the closed end of the cap and the end of the dowel bar to allow future movement of the concrete slab.

4. *Transverse Construction Joints.* Install transverse construction joints at the end of each day's placement. Form bulkheads when stopping the placement in an emergency or at the end of each day's pour.

In addition to the joints installed at the end of each day's pour, construct transverse construction joints whenever concrete placement stops for more than 30 minutes. If, at the time of interruption, there is not enough concrete to form a 10-ft (3-m) slab, remove concrete to the preceding transverse joint.

K. *Final Strike-Off, Consolidating, and Finishing.*

1. *Sequence.* Order the operation sequentially as follows:
 - a. strike-off,
 - b. consolidate,
 - c. float,
 - d. remove laitance,
 - e. straightedge, and
 - f. final surface finish.

Provide work bridges or other devices to reach the pavement surface to finish, straight-edge, and make corrections.

Finish the concrete surface without adding additional water.

2. *Finishing at Joints.*
 - a. Consolidate concrete next to joints without voids or segregation against the joint material, load transfer devices, joint assembly units, and other devices extending into the pavement. Vibrate the concrete mechanically next to joints.
 - b. After placing and vibrating the concrete next to the joints, bring the finishing machine forward without damaging or misaligning the joints.

If the finishing operation causes concrete segregation, or damage to or misalignment of the joints, stop the finishing machine when the front screed is approximately 8 in. (200 mm) from the joint. Remove the segregated concrete from in front of and off the joint. Lift the front screed and set it directly atop the joint before continuing forward motion. When the second screed is close enough to force excess mortar over the joint,

lift the screed and carry it over the joint. For subsequent finishing, the machine may be run over the joint without lifting the screeds if segregation is prevented.

3. *Machine Finishing.*

- a. *Nonvibratory Method.* Use the finishing machine to strike off, screed, and texture the concrete immediately after it is distributed or spread. Avoid damage to, or misalignment of, joint assemblies, reinforcing steel, dowel bars, and other embedded items during finishing. Avoid excessive finishing. Keep top of form free of debris.

During the first pass of the finishing machine, maintain a uniform ridge of concrete along the entire paving width and ahead of the screed.

- b. *Vibratory Method.* Vibrate as specified in Subsection 501.3(B)(3).

4. *Hand Finishing.* Use hand-finishing methods only under the following conditions:

- a. When mechanical equipment breaks down, stop concrete placement and hand-finish concrete already in place on the grade.
- b. Hand finish narrow widths or irregularly shaped areas that cannot be finished by mechanical equipment. Use a portable screed to strike off and screed the concrete. Provide a second portable screed to strike off the bottom layer of concrete when placing reinforcing steel during two-layer concrete placement methods.

Use a rigid screed that is made of metal or reinforced with metal and at least 18 in. (0.5 m) longer than the widest part of the slab pour.

Consolidate the concrete with a hand-operated vibrator.

Move the screed along the forms in a forward direction that combines a longitudinal and transverse sheering motion without raising either end from the side forms. Repeat this strike-off process until the surface texture is uniform, true to grade and cross section, and free of porous areas.

5. *Floating.* Use a float to achieve the specified grade and surface smoothness after striking off and consolidating the concrete. Use one of the following methods:

- a. *Hand Method.* Use a hand-operated longitudinal float at least 12 ft (4 m) long, 6 in. (150 mm) wide, and stiffened to prevent flexibility and warping. Operate the longitudinal float from foot bridges. Work the float in a sawing motion while holding it in a position parallel to the road centerline and passing it gradually from one side of the pavement to the other. Move ahead, along the centerline of the pavement, advancing no more than one half of the length of the float length. Waste excess water or laitance over the side forms on each pass.
- b. *Mechanical Method.* Furnish a mechanical float that can accurately adjust to the required crown and coordinate with adjustments of the transverse finishing machine.

c. *Alternate Mechanical Method.* Use a machine with a cutting and smoothing float or floats suspended from and guided by a rigid frame mounted on four or more wheels. Maintain constant contact of all four wheels with the forms. Use hand method to fill open-textured areas in the pavement after mechanical floating.

6. *Surface Correction.* Correct surface irregularities while the concrete is plastic, after completing floating and removing excess water and laitance. Fill, strike off, consolidate, and refinish depressions. Cut down and refinish high areas. Smooth the surface across joints to meet specified tolerance.

7. *Final Finish.* Texture the surface without tearing it after the surface sheen disappears.

Texture the final surface to form an even grooved pattern perpendicular to the centerline. Provide a surface with individual grooves $\frac{1}{16}$ in. to $\frac{1}{8}$ in. (1.5 mm to 3 mm) wide and $\frac{1}{8}$ in. to $\frac{3}{16}$ in. (3 mm to 5 mm) deep, spaced on $\frac{3}{8}$ -in. to $\frac{3}{4}$ -in. (10-mm to 20-mm) centers. Use metal tines or finned ball float. Ramps, tapers, and miscellaneous areas may be textured manually.

Restore pavement texture damaged by rain by grooving while the concrete is in a plastic state. If the concrete has reached its initial set, restore the texture by sawing grooves in damaged areas to specified depth, width, and spacing.

8. *Edging at Forms and Joints.* Tool pavement edges after the final finish along both sides of each slab and on both sides of transverse expansion joints, formed joints, transverse construction joints, and emergency construction joints to the specified radius. Produce a smooth, dense, mortar finish.

Eliminate tool marks on the slab next to the joints. Avoid disturbing the rounding of the slab corners and remove concrete from the joint filler top. Test the joints with a straight-edge before the concrete sets and correct any unevenness between the joints and the adjacent slabs.

L. *Surface Tolerances.* The Engineer will test pavement surfaces as specified in Subsection 401.3(L). If pavement fails to meet the specified surface tolerances, perform corrective work as directed.

M. *Curing.* Cure the concrete for at least 3 days immediately after the finishing operation. Avoid exposing concrete for more than 30 minutes during curing. Use an atomized fog spray to apply water to the surface as an interim cure but only until the final cure is in place.

Fog spray the surface prior to treatment. Treat surfaces exposed during the curing period. Overlap curing blankets at least 8 in. (200 mm), and secure them to rest on the pavement surface. Prevent curing blanket joints from opening or separating. Extend curing blankets 8 in. (200 mm) beyond the pavement edges to cover the sides.

Protect the concrete for at least 10 days or until the concrete achieves a compressive strength of [2,200 psi (15 MPa)] when tested according to AASHTO T 97. Protect the concrete from freezing with blankets, or other materials, when the temperature drops below 35°F (2°C).

Remove and replace all concrete damaged by freezing. Cover and cure the entire surface and edges using any of the following methods:

1. *Impervious Membrane Method.* Apply curing compound only during dry weather.

Use a fully atomized mechanical sprayer equipped with a tank agitator and wind guard to apply the curing compound at a rate of 1 gal/15 yd² (1 L/3.5 m²).

Continuously agitate the compound during application, and keep it thoroughly mixed so that the pigment disperses evenly. Hand spray irregular widths, shapes, and surfaces exposed by removing forms.

2. *White Opaque Polyethylene Film.* Meet the requirements of ASTM C171. Extend film beyond the edges of the slab by at least twice the thickness of the pavement edge. Overlap film sheeting by at least 18 in. (450 mm).
 3. *Cloth.* Extend cloth such as burlap or cotton beyond the edges of the slab by at least twice the thickness of the pavement edge. Use two layers of cloth. Saturate with water before placing and keep saturated during the curing period.
 4. *Waterproof Paper.* Use waterproof paper having a mass of at least 0.4 lb/ft² (200 g/m²).
- N. *Removing Forms.* Keep forms in place for at least 12 and remove carefully to avoid damaging the pavement. Use fresh mortar to repair damaged pavement and honeycombed areas on the edges.
- O. *Repairing Defective Pavement Slabs.* Replace all pavement slabs that have uncontrolled cracks as specified in Subsection 501.3(J)(2)(c). If directed by the Engineer, rather than pavement removal and replacement, rout and seal cracks that penetrate the full depth of the pavement.
- P. *Protecting the Pavement.* Meet the approved traffic control plan.
- Q. *Opening to Traffic.* Allow traffic on the pavement after 14 days or when test specimens, molded and cured according to AASHTO T 23, attain the flexural or compressive strengths specified in Table 713.1-1.
- R. *Tolerance in Pavement Thickness.* Determine pavement thickness according to AASHTO T 148.

Take one core for each lot of 1,000 ft (300 m) per traffic lane. Consider intersections, entrances, crossovers, and ramps as separate lots and determine the thickness of each separately. Consider small irregular unit areas as parts of other lots. Take two additional cores at intervals of at least 300 ft (90 m) to determine the average thickness for that lot when the measure varies between 0.21 in. and 1 in. (5 mm and 25 mm) from the specified thickness.

Remove the entire unit when any core thickness measurement is deficient by more than 1 in. (25 mm) from the specified thickness.