# PLACEMENT OPERATIONS
# 5-694.600

## 5-694.601 GENERAL

Concrete placing, finishing, and curing operations are just as important in obtaining quality in the completed structure as the inspection of the materials and the mixing operations. It is essential that the Inspector observe these operations to assure that they comply with good construction procedures. This section provides guidance for both the Contractor and the Agency.

Form construction and inspection for bridge construction is addressed in the Mn/DOT Bridge Construction Manual and Inspectors should refer to that manual for further information. See the Bridge Manual 5-391 for additional items pertaining to structures.

## 5-694.602 PAVEMENT STATION NUMERALS

Imprint station numbers in the surface by using steel stencils after finishing and texturing (and tining if required) the concrete, but prior to the application of any curing material. Place the numerals along the right-hand edge of the pavement, in the direction of traffic, so that a driver can read while traveling on the shoulder. See Figures A and B 5-694.602 for examples of concrete pavement stationing. The beginning station is marked, to the nearest meter (foot), at the start of paving. Centerline stations are marked at all 200 m (500 ft.) station intervals thereafter. All equations of one meter (foot) or more are stenciled so that the equality sign is at the point of the equation. Finally, the stationing of all header joints are marked to the closest meter (foot) reading in the direction of paving.

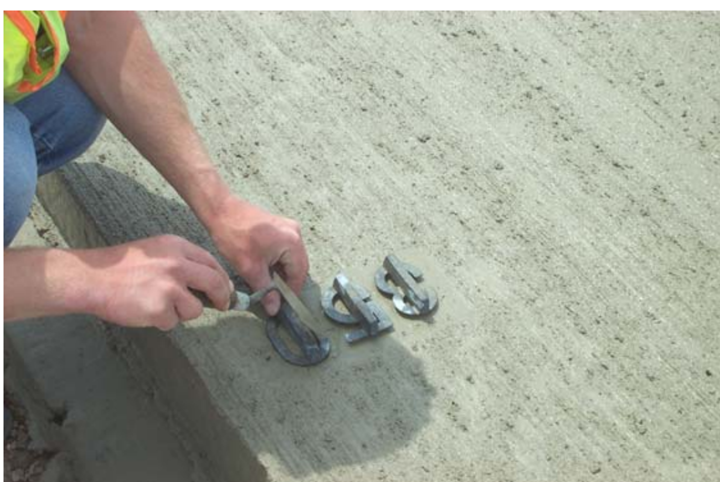

**Figure A 5-694.602**


**Figure B 5-694.602**

## 5-694.603 TEMPERATURE LIMITATIONS

DO NOT expose concrete to temperature extremes. Concrete shall have a temperature of 10 to 30°C (50 to 90°F) at the time of placement, except a temperature of not less than 5°C (45°F) is allowed with the use of an approved accelerator. If the materials used in the production of concrete will not produce concrete in this temperature range, heat or cool one or more of the materials as necessary. If the temperature of all the concrete materials is above 10EC (50EF), it is not necessary to heat any of the materials.

Water is the easiest of the materials to adjust for temperature control. When the average temperature of the cement and aggregate is between 2 and 10EC (35 and 50EF), control the concrete temperature by heating only the water. By using hot or cold mixing water (whichever is necessary), you can maintain the temperature within the above range. Mixing water must never exceed 80EC (180EF) since there is danger of flash set at these high temperatures. This method is not acceptable in cold weather when the aggregates contain frost. The aggregates then require heating as specified in 2461.4A3.

Overheated dry aggregates may result in cement dusting or dry coating of cement on the particles with a partial or complete loss in bond. Heat the material sufficiently to remove the frost lumps.

Figure A 5-694.603 indicates the temperature of freshly mixed concrete as affected by the temperature of its ingredients in hot weather concreting. The chart in Figure B 5-694.603 indicates the approximate temperature expected in the concrete for various temperatures of mixing water and solids. This chart is based on an average mix and is sufficiently close for estimating temperature of mixing water when knowing the average temperature of the solids.

DO NOT place concrete when there is danger of damage from frost in the first 24 hours after the pour. DO NOT place when the air temperature is below 2°C (36°F) except when the structure is enclosed and heated or when sufficient cover is provided to protect the concrete from freezing. See Specification 2461.4A2.

In the late spring, summer, and early fall the normal temperatures that prevail are not detrimental to the concrete, provided moisture control is maintained. When the temperature during the night approaches or falls below 0°C (32°F), protect the concrete from freezing. The extent of protection depends on the expected temperature. Protection may require several layers of curing paper or plastic blankets and, if needed, placing of straw hay between the blankets to improve the insulating value. In the fall of the year it is good practice to use a double layer of paper or plastic, or a combination thereof, to retain the heat of hydration and increase strength gain. Remove and replace concrete that is frozen within the first 24 hours since concrete frozen during early stages of hydration will never produce durable concrete. See 5-694.680 for additional information on concrete curing.

Additional heat can aid in production of early strength in concrete when it is accompanied by adequate moisture. Heat without applied moisture will dry out the concrete. When heat and steam are applied for accelerated cure, the operation should not begin until one or two hours after the initial set. Heat applied early is detrimental.

## TEMPERATURE OF FRESHLY MIXED CONCRETE AS AFFECTED BY TEMPERATURE OF ITS INGREDIENTS IN HOT WEATHER CONCRETING

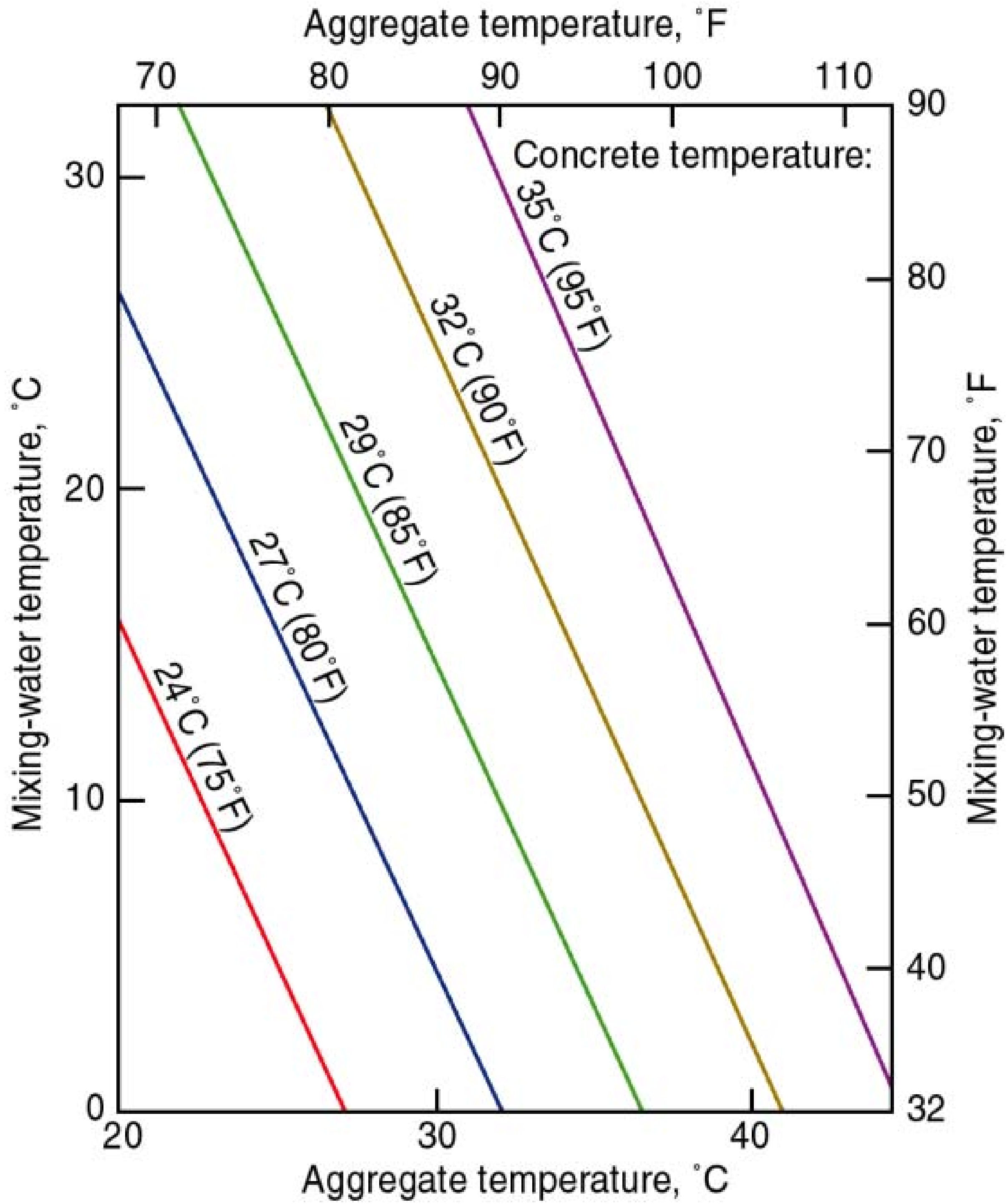


**Figure A 5-694.603**[1]

**TEMPERATURE OF MIXING WATER NEEDED TO PRODUCE HEATED CONCRETE OF REQUIRED TEMPERATURES IN COLD WEATHER CONCRETING**

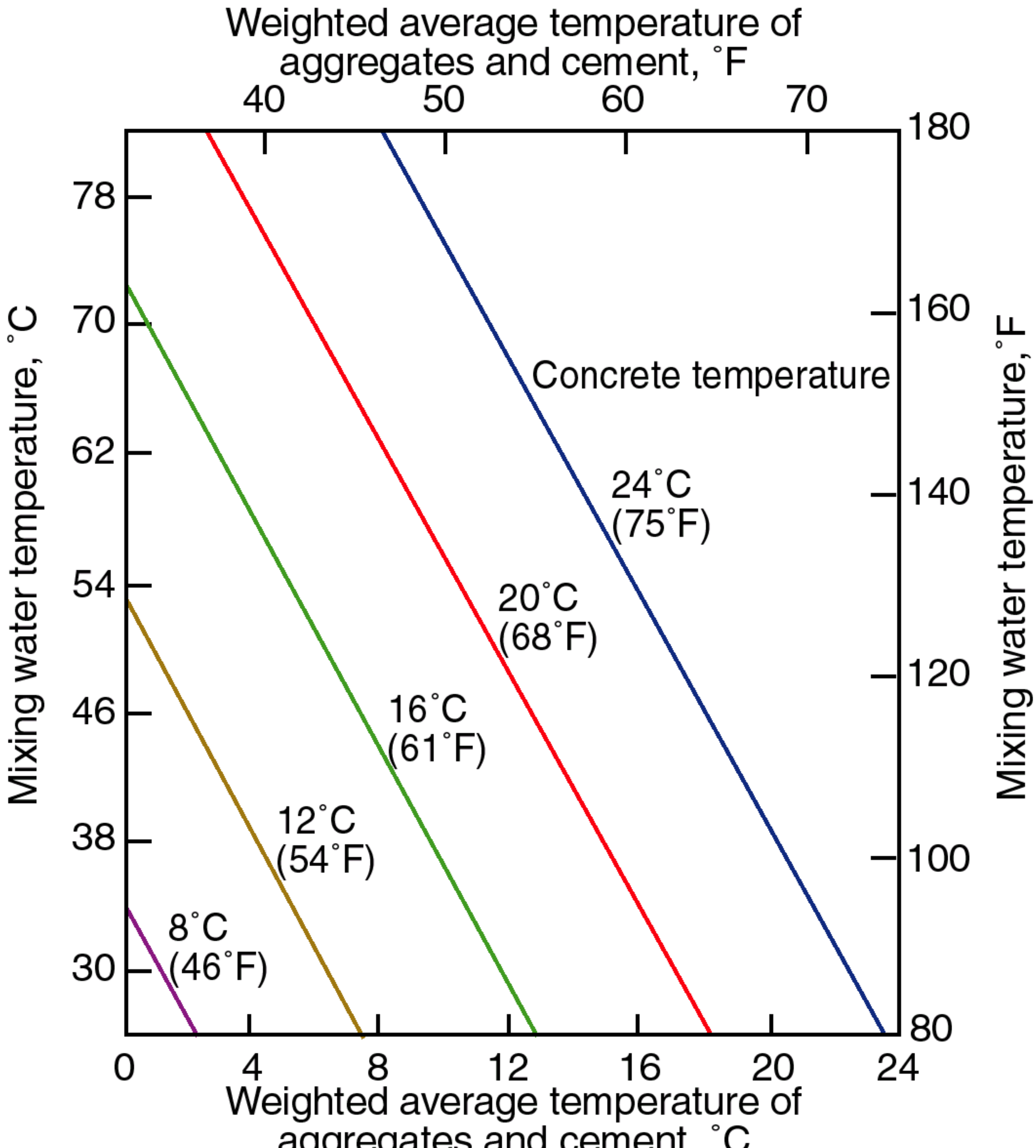


**Figure B 5-694.603[2]**

## 5-694.610 PLACING CONCRETE

Properly mixed concrete having good workability at the time of placement may lose some or all of its desirable characteristics due to mishandling at the job site. Concrete can segregate in the same way coarse aggregate could segregate during stockpiling operations. The “free fall” of concrete (outside the limits of a spout or chute) should not exceed 1.2 m (4 ft.). Always place concrete as near as possible to its final position in the completed structure.

## 5-694.611 BUCKETS

Check concrete buckets for accumulation of dry and hardened concrete and have the material removed prior to use. Control segregation by minimizing the fall of concrete when charging the concrete bucket. Move the bucket during discharge into the forms to prevent the formation of concrete piles. See Figure A 5-694.611 for an example of placing concrete with a bucket.

**Figure A 5-694.611**

## 5-694.612 CHUTES AND BELTS

Divert the fall of concrete discharged from the ends of chutes and belts by a baffle. Unrestricted fall permits the coarse portion of the batch to separate and carry to the front end of the discharge while the soft or mortar portion of the batch flows under and to the back of the discharge.

When concrete is discharged from a ready-mix concrete truck, move the chute back and forth to reduce segregation. Do not permit the concrete to build up in piles if the concrete is spouted onto the ground as in curb and gutter or pavement construction. Spread by moving the chute in as large an arc as possible within the form area. Once the concrete is slightly above the form elevation, move the truck to a new location and repeat the operation. Move concrete from high to low areas by shoveling; never move concrete with a vibrator. See Figure A 5-694.612 for an example of placing concrete from the end of a chute.

**Figure A 5-694.612**

## 5-694.613 BUGGIES

Concrete placement should start at the far end of the section whenever concrete buggies are used on flat slab construction. Always place concrete from buggies toward the top edge of the previously deposited concrete. Shovel out concrete that appears segregated and spread over the bottom of the pour. Fill any depressions left by the removal of the segregated material by placing fresh concrete in the cavity and not by vibrating the concrete from the edges of the cavity.

## 5-694.614 PUMPING CONCRETE

The Contractor may elect to place concrete by pumping. See Figure A 5-694.614 for an example of concrete pumping on a bridge deck. Concrete has a tendency to become stiffer or lose more slump and entrained air from pumping than with other placement methods. This is partly due to additional heat caused by friction as the concrete is forced through the pipe. You may need to increase the slump and entrained air content of the concrete from the specified range for this reason to assure that it meets Specification 2461.4A4a and 2461.4A4b at the point-of-placement. Discharge of concrete from the end of the pump is controlled similar to that for chutes or buggies, since concrete discharged from the pump has the same tendency to segregate. Make sure both air and slump tests are measured at the discharge end of pump. Establish a correlation of slump and air between the ready-mix truck discharge and the pump outlet if it is not practical to take slump and air tests at the point-of-placement. Pumping concrete through aluminum pipes causes some of the pipe walls to wear away and become mixed with the concrete. The aluminum has a deleterious effect on the concrete; therefore, Contractors are not permitted to use aluminum pipes.

Ensure that a restrictor is provided near the outlet of the pipe in order to minimize uneven discharge (spitting).

**Figure A 5-694.614**

## 5-694.615 SPREADERS OR BELT PLACERS

Concrete spreaders are used on all large paving projects to aid in the distribution of concrete over the entire area. They are also used on bridge decks and some large slab work.

The purpose of the spreader is to move large quantities of concrete short distances with minimum segregation and deposit the concrete within the forms or on the grade as near as possible to its final position. The spreader will even out the irregularities by moving the concrete from high areas to low areas when sufficient concrete is placed.

The placer/spreader generally involves any combination of the following: unloading belts, augers, plow systems, or strike offs. Sensors may control steering, grade, or both. See Figures A and B 5-694.615 for examples of a belt placer and spreader.

**Figure A 5-694.615**

**Figure B 5-694.615**

## 5-694.620 CONSOLIDATION OF CONCRETE

All concrete, regardless of workability and consistency, needs some consolidation to remove air pockets and settle the concrete into place. The degree or extent of such consolidation depends on the consistency of the concrete, placement method, and the shape of the section into which the concrete is placed.

Specifications require filling cavities, evident when the forms are removed, with mortar. Proper consolidation techniques will reduce the number of patched areas.

## 5-694.621 HAND TAMPING AND SPADING

Tamp or spade the concrete by hand along forms and headers whenever other methods of consolidation are not used.

Work the area within the mass of concrete by tamping with either a sharp object such as a shovel, or with a blunt object such as a base tamper, or even a piece of wood. The purpose of this tamping is to cause slight movement of the concrete that forces the air and water to the surface and helps consolidate the concrete. Concrete will settle during the tamping to the extent that air and water are removed. The desirable entrained air is not removed by tamping, but tamping works out the objectionable entrapped air and consolidates the concrete mass.

Consolidate areas along forms and headers with a smooth flat blade. In most cases, the backside of a flat shovel or a long concrete finishing trowel will do a very good job of spading. The object of spading is to work the mortar around the coarse aggregate next to the forms and also to permit the escape of the entrapped air that builds up next to the forms.

Areas at the intersection of the forms and the divider plates, such as in concrete curb and gutter work, is a place where honeycombing often occurs.

Proper concrete placement, spading and tamping in these critical areas reduces honeycombing. The same is true near the bottom of the forms where they rest on the base. The Inspector should see that proper consolidation is practiced in these areas.

When constructing deeper structures (retaining walls, footings, etc.), place the concrete in multiple layers and consolidate each layer if there is trouble consolidating the full depth of concrete.

Tamping the outside of the forms with a solid object will decrease entrapped air and reduce the voids in the finished surface. When this procedure is used, tamp with care so that the forms retain their desired alignment and shape.

## 5-694.622 INTERNAL VIBRATION

Vibration of concrete makes it more workable and will make relatively dry concrete behave like concrete having a higher slump. Internal vibration is performed using a long, slender, vibrating cylinder that is projected into the concrete. The ratio of diameter to length of the head, the weight and speed of vibration for internal vibrations, will vary with the workability of the concrete and the type of section constructed. In the construction of large heavy sections, the concrete used may appear harsh and stiff. The vibrating head for this work is shorter with a larger diameter up to 75 mm (3 in.).

On thin sections, the concrete is more plastic (having both a lower coarse aggregate content and a smaller size aggregate), and a vibrator with a longer head and a smaller diameter of 19 to 32 mm (3/4 to 1 1/4 in.) is used. See Figure A 5-694.622 for an example of a hand vibrator.

**Figure A 5-694.622**

**Instructions for Proper Internal Vibration:**

1. Insert the vibrator head vertically into the concrete for the full depth of the lift and extend down into the previous lift 50 to 75 mm (2 to 3 in.) to blend the two lifts together.
2. Withdraw the device in a smooth vertical motion while the unit is vibrating.
3. Never over vibrate by leaving the vibrator head in one location too long.
4. Vibration shall continue by lowering and raising the vibrator in different areas until the concrete is completely consolidated.
5. The distance between points of vibration will vary with the concrete workability, consistency, quantity of steel, and the shape of the section, but distance between the insertions of the vibrator head along the form shall never exceed 0.5 m (2 ft.).

Pulling the vibrator head laterally along the concrete promotes segregation and is not allowed. Vibration is not allowed as a method of moving concrete from high areas to low areas or along forms.

# 5-694.630 PLACING OPERATIONS[3]

### A. Reinforcement

Install reinforcement and anchor in place to prevent movement during concrete placement operations.

Baskets are placed so dowels are parallel to the grade and the centerline. Anchor in place at the proper alignment and grade within a 3 mm (1/8 in.) tolerance, and mark location for sawing joint.

Headers require care in setting. Place permanent terminal headers or temporary terminal headers at the beginning and end of the job. Install construction headers during the day's operation for delivery interruptions or equipment breakdowns if necessary.

### B. Utilities and Drainage Structures

Urban projects involving storm sewer inlets, junction boxes, water valves, sanitary sewer manholes, natural gas facilities, electrical vaults, and cables of all kinds may require prior adjustments to proposed grade of various cast iron items or boxing-out.

Proper compaction over and around these facilities is necessary to provide uniformity in subgrade support. This includes controlling the moisture content of the material to near optimum.

All types of utility and drainage structures, depending on size and location, may require special jointing of the slab to avoid random cracking. The plans should indicate the joint layouts of street intersections, alleys, etc. Make this information available to the saw crew.

### C. Delivery of Concrete

- Designate a haul route for concrete delivery trucks and communicate to all drivers.
- Make sure trucks do not disturb the forms or grade near the forms.
- Ensure that the delivery of concrete is consistent and sufficient in quantity to keep forward progress of paving operations at a rate compatible with placement and finishing operations.
- Check the slump and air content of the concrete to assure that it is consistent and within the specified mix design requirements.
- Safety is to be enforced at all times. Consider backup alarms, dumping procedures, following dumper's directions, traffic patterns, etc.
- Remember, a controlled uniform delivery rate is one of the first steps to construction of a quality pavement. A uniform process in the quality of concrete, head of material, rate of delivery, placement, creating uniform forces in front of and under the machine produces a good pavement. Pavers are finishers, not bulldozers.
- The distance from batch plant to the grade operation is a governing factor in obtaining timely delivery of concrete to the paver. The travel time to and from the paving spreader is also governed by the haul road conditions. A paved surface and minimal traffic friction would allow usage of a more distant plant site, conversely a dirt surface for the entire round trip would increase the haul time and require an increase in the number of haul units.
- Numerous variables enter into supplying concrete to the paver in consistent volumes. Close coordination involving the plant foreman, truck foreman, and concrete foreman is a necessity. The Contractor must coordinate the number of trucks needed to keep the paver speed uniform.

When truck mixed concrete is used the Contractor and the Concrete Producer must establish a realistic rate of delivery. Calculate the rate of production and delivery on a desired cycle time for each truck mixer for loading, mixing, delivery, discharging, and return to the plant.

The placement rate is defined as the paver speed in meters (feet) per minute times the material needed per meter (foot) of length. The following is an example of concrete truck unloading times to assure the paver continues to move at a constant speed.

- Paver speed of 2 m (6.6 ft.) per minute,
- Grade yield loss of 5%,
- Pavement section 7.2 m (24 ft.) wide and 200 mm (8 in.) thick,

$$2\,m/\text{min.} \times 7.2m \times 0.20m \times 1.05 = 3.024\,m^3/\text{min.}$$

$$\left(6.6\ ft./\text{min.} \times 24\,ft. \times 8in. \times 1\,ft./12in. \times 1.05 = 4\,yd^3/\text{min.}\right)$$

Unloading time is a small part of the overall cycle time. However, anticipate that concrete mixes having varying slumps have different unloading characteristics.

An important factor in an urban area is the anticipated congestion that is encountered by the concrete delivery vehicles. Determine estimated delivery and return times based on speed limits, anticipated congestions, and distance to the project. The project itself will likely cause some lane closures and/or detours in the area.

**D. Paving Operations**

Regardless of the paving method used, it is essential that the concrete is discharged, consolidated, and finished in a uniform manner to eliminate segregation or non-uniform density. Non-uniform placement creates differences in density, allows variance in shrinkage and may result in a rough riding pavement.

**UNIFORMITY** is the key to placing, consolidating, and finishing concrete pavement with any paving equipment or method.

Maintain a consistent and uniform head of concrete in front of the strike-off screed. A head of concrete that does not run over forms or the screed works best. This applies to equipment of all types and sizes.

**E. Small Screeds and Hand Placement**

For small machines or hand placement, screeding is accomplished in numerous ways, including clary screeds, revolving triple tubes, single tube (drum) finishers, hand-operated and self-propelled vibratory screeds, and hand-operated bull floats. The roller screeds and vibratory screeds are commonplace for small machine and hand placement operations.

Perform small machine or hand placement with care. On handwork sections and some short mainline sections, the vibration is generally limited to hand-operated spud vibrators working in the concrete ahead of the screed and along the forms.

The following are the key elements in placement:

- Check that the concrete is placed and spread uniformly. Move concrete with shovels, not rakes or hand spud vibrators, which can segregate the mix.
- See that vibration is adequate over the total concrete area to obtain proper consolidation.
- Check that the workers keep the vibrating screed moving forward on the forms. If hand screeding and consolidation is required, assure that it is performed in a vigorous manner.
- Two people operating hand floats and straightedges usually float the surface. Again, assure that the work is done thoroughly so the pavement is finished to the proper grade and cross section.
- Successive passes of the screed, if required, should overlap the previous passes. Waste any natural laitance over the sides.
- Small irregular areas are often finished with straightedges and hand floats, following consolidation with a hand spud vibrator.

### F. Curb Placement

The finishing process in the gutter line is critical to maintain water flow, especially on flat grades, high or low points of vertical curves and near storm water intakes. Establish and finish the top edge and face of the curb, or the acceptability of the pavement is visually in question.

## 5-694.631 AGGREGATE BASE LAYERS

### A. Dense-Graded Aggregate Base[3]

Dense-graded aggregate bases are used as either a filter layer beneath an open-graded base or in the case of granular subgrade soils, the sole base layer. In either case, confirm that the base is well compacted and damp enough to prevent absorption of moisture from the concrete during placement. In the case of a dense-graded aggregate base filter layer assure that there are no areas of insufficient thickness that may cause subgrade soils to pump into the overlying OGAB thereby contaminating it.

### B. Open Graded Aggregate Base (OGAB)

Many paving projects use OGAB to facilitate drainage under the pavement. See Figure A 5-694.631 for an example of OGAB prepared for concrete paving. The base is constructed of coarse aggregate meeting the gradation in the Special Provisions of the contract. The OGAB is often treated with asphalt to stabilize the material, this is referred to as permeable asphalt stabilized base (PASB).

In any case, check the cross-section of the OGAB just like the dense graded base. Again, the Inspector should record base elevation checks at least every 0.8 kilometers (0.5 mile).

If PASB is used, treat the surface with a lime solution before paving. This lime solution helps keep the temperature of the base low so the concrete mixture does not “flash-set”. This is important for base stability and for proper curing of the concrete.

No construction traffic, including loaded or unloaded haul trucks, is allowed on either the OGAB or the PASB unless the Contractor can demonstrate that it will not contaminate, rut or tear the base. The major concern is to verify that the base is not contaminated and will still allow drainage.

**Figure A 5-694.631**

**C. Permeable Aggregate Stabilized Stress Relief Course (PASSRC)**

PASSRC is a stabilized, permeable aggregate base layer that serves both as an interlayer and drainage layer for an unbonded concrete overlay.

After placement and compaction, the inspector should check the PASSRC layer to ensure that there is no displacement or rutting occurring. A curing period may be needed to allow the PASSRC to "firm up" before the overlaying concrete is placed.

Although concrete hauling units are permitted on the PASSRC, it is the Contractor’s responsibility to maintain the surface. If contamination, rutting or other damage occurs to the PASSRC or underlying structure, the affected areas must be cleaned and/or repaired and leveled, or removed and replaced prior to placement of the concrete overlay/pavement to assure drainage capacity as designed.

If concrete hauling units turn around on the PASSRC, the Contractor shall protect the PASSRC from deformation by any method acceptable to the Engineer. See Figure B 5-694.631 for an example of using plywood as a turnaround point on the PASSRC.

Within two hours prior to constructing the concrete overlay, the PASSRC layer shall be coated with a whitewash of hydrated lime and water. The proportions used in the whitewash mixture and the rate of application shall be such that a uniform color, not darker than uncoated concrete after curing, will be produced on the surface of the PASSRC layer. The purpose of the whitewash is to reduce the heat generated from the black surface of the PASSRC, and thus give an even curing temperature within the pavement depth. If the whitewash should wear off due to construction operations, it shall be replaced or the surface cooled with water prior to paving. Damage to the PASSRC layer shall be repaired promptly by the Contractor, as directed by the Engineer, at no expense to the Agency.

**Figure B 5-694.631**

## 5-694.632 PAVEMENT STEEL AND PLACEMENT[3]

Dowel bars are designed to provide effective load transfer across joints. Reinforcing steel is not used in pavements as reinforcement in the traditional sense. Reinforcing steel in pavements is designed to hold random cracks together and facilitate aggregate interlock load transfer.

The Contractor can set imbedded steel items ahead of the placement of concrete, or insert them into the plastic concrete. When steel is set ahead of paving operations, the Contractor must secure the steel firmly in place so that it cannot move during the placement, vibration and finishing of concrete.

### A. Dowel Bars

Only dowel bar assemblies pre-approved by the Mn/DOT Concrete Engineering Unit are allowed. Remove and replace assemblies that become bent or damaged prior to or during concrete placement. Currently Mn/DOT allows epoxy coated, solid stainless steel, and stainless steel clad dowel bars based upon the specifications for each project. See Figure A 5-694.632 for an example of epoxy coated dowels and Figure B 5-694.632 for an example of solid stainless steel dowels.

**Figure A 5-694.632**

**Figure B 5-694.632**

Dowels are installed at contraction joints to provide load transfer from slab to slab without faulting of the joint. They are generally installed in a heavy wire assembly staked to the base. **The staking must prevent movement of the dowel basket assembly during concrete coverage. Failure to satisfactorily anchor these baskets in the past has resulted in joint failures on many projects. This issue is especially critical on unbonded concrete overlays where it is difficult to anchor the baskets through the bituminous stress relief layer (PASSRC) and into the underlying in-place concrete.** Cutting the tie wires on the dowel bar assembly prior to paving is required.

No greater than 30 minutes prior to concrete placement, lubricate the entire dowel with a form release agent meeting Specification 3902 to allow movement as the slabs expand or contract. The key is to provide a thin film of lubricant to assist the movement of the concrete at the dowel. A thick film of grease can react with the concrete and allow voids, which can lead to socketing at the dowel and contribute to premature faulting of the joint.

When placing doweled transverse expansion joints a dowel cap is needed over the end of the dowel to permit movement into the cap as the expansion material is compressed.

Place dowels parallel to the centerline of the pavement that allow the concrete pavement to expand and contract. The lubricated dowel accommodates this movement. When dowels are misaligned the joint can lock and cause cracking near the contraction joint.

The Mn/DOT Concrete Engineer may approve the use of dowel bar inserters (DBI) as an alternative to dowel bar assemblies on a case-by-case basis. The approval is made on a performance basis. There are two common types of DBI's in use. One system is called the mid-mount inserter in which the inserter is an integral part of the paver. Another system utilizes a separate paver for inserting the bars and is followed by another paver for final finishing operations.

When using a DBI, the dowel basket assembly is not needed since the dowel bars are mechanically inserted into the fresh concrete. The elimination of the basket assemblies also provides an open paving lane for hauling and dumping concrete ahead of the paver. The bars are sprayed with a form release agent prior to placement. Vibrating forks are used to insert the oiled dowels into the concrete at the correct depth. See Figure C 5-694.632 for an example of a DBI. Correction of the concrete surface is necessary after the dowel bars are inserted. Contractor personnel should perform periodic probing for proper dowel alignment and depth and Agency personnel should perform spot checks. The Contractor must mark doweled joints carefully for joint sawing.

**Figure C 5-694.632**

**B. Tie Bars**

Tie bars are installed in most longitudinal joints. The purpose of tie bars at the centerline longitudinal joint is to prevent lane separation. In the case of centerline joints, the bars are installed at mid-slab depth in a "hinged joint". In slipform operations, these bars are pre-placed on bar chairs in front of the paver or placed in the plastic concrete with a wheel or stabbed into the slab with an automatic inserter. See Figure D 5-694.632 for an example of inserting tie bars using a wheel.

**Figure D 5-694.632**

The tie bars involved in longitudinal joints constructed for additional lanes are generally installed with either air, hydraulic, or manual side bar inserters. Bent tie bars are normally installed by placing them on a horizontal plate, attached to the side form, prior to installation. There is a slit in the traveling side form, also known as "keyway steel", to accommodate these bars. See Figure E 5-694.632 for an example of installed keyway steel. These bars require straightening prior to placing the added lane or shoulder. If the bars being installed are straight they are normally placed on a guide, attached to the side form, prior to installation.

**Figure E 5-694.632**

Epoxy-coated tie bars are required for concrete pavement construction. It is of the utmost importance that these bars are placed at least 450 mm (18 in.) from any contraction or expansion joint to avoid tying up the joint. Many of today's joint spalls were caused by tie bars crossing a joint and tying the joint together.

### C. Supplemental Steel

Inspect the reinforcing steel to assure it is sufficiently cross-tied to retain the steel in its planned position and that the steel is free of foreign matter and scaly rust. The Contractor must place the steel on chairs to ensure it is at the correct height. See Figure F 5-694.632 for an example of supplemental steel over a culvert.

There are four instances where supplemental steel may be required.

**1. Reinforced Panel over Culverts - Standard Plate 1070L**

- Use when height of fill ($H_f$) < 3 m (10 ft.). This is regardless of the pipe diameter.
- Use No.13 bars for pavement thickness < 305 mm (12 in.). Use No.16 bars for thicknesses ≥ 305 mm (12 in.). Placement depth shall be t/2 ± 25 mm (t/2 ± 1 in.).

- Assumed definition of a culvert – pipe open on one or both ends. If a pipe is closed on both ends, it is unlikely to have the outside cold air flow that could cause settlement/heaving problems and would reduce the need for reinforced panels as long as pipe $H_f$ is 1.2 m (4 ft.) or greater below grade.

**Figure F 5-694.632**

2. **Concrete Mainline Pavement - Standard Plan 5-297.217**
   - Place in panels where pavement width exceeds 4.6 m (15 ft.) without a longitudinal joint, and in the middle lanes where tied pavement width exceeds 4 lanes.
   - Use No.13 bars for pavement thickness 255 mm (10 in.) or less. Use No.16 bars for thickness over 255 mm (10 in.). Placement depth shall be t/2 ± 25 mm (t/2 ± 1 in).

3. **Concrete Ramp Pavement – Standard Plan 5-297.219 – See Note 1**
   - Place in panels where pavement widths exceed 4.6 m (15 ft.) without a longitudinal joint.
   - Use No.13 bars for pavement thickness 255 mm (10 in.) or less. Use No.16 bars for thickness over 255 mm (10 in.). Placement depth shall be t/2 ± 25 mm (t/2 ± 1 in.).

4. **Storm Sewers and Water Mains – No standard**
   - If height of fill ($H_f$) < 1.2 m (4 ft.), no matter what diameter, supplemental steel is needed.

## 5-694.633 PAVEMENT PRE-CONSTRUCTION MEETING[3]

There are numerous critical factors involved in the construction of a typical concrete pavement project. An important beginning step is the implementation of a communication network between the Paving Contractor, Concrete Producer/Supplier, Agency and Testing Personnel.

Everyone involved must have the information available in a timely manner to perform his or her functions, starting with the pre-construction meeting to final project acceptance. They need to discuss all project elements related to slipform paving with special emphasis on communication, safety, paving access, traffic control, scheduling and interpretation of project specifications.

## 5-694.640 SLIPFORM PAVING APPLICATIONS[3]

This section covers the construction of a typical concrete pavement using the slipform paving method of construction. The practices presented represent “good practice” and are not meant to limit innovation of any kind.

Slipform when applied to concrete pavement construction means to consolidate, form into geometric shape, and surface finish a concrete mass (vertical or horizontal) by “slipping” or pulling the forms continuously through and surrounding the plastic concrete mass. In slipform paving of a roadway the forms for shaping the mass, the tools for consolidation, and the tools for surface smoothing are firmly mounted into a self-propelled machine.

Slipform is used in almost every type of paving operation. This technique has broad application for highway and street construction. Contractors have identified the following common construction advantages:

- Uses lower slump concrete
- Permits high production paving
- Capable of producing a very smooth riding surface

High quality slipform concrete pavement is achieved with:

- Accurate line and grade control
- Uniform, well compacted grade
- Consistent concrete production and delivery
- Consistent, uninterrupted forward motion of paver
- Adequate internal vibration
- Timely texturing and curing

## 5-694.641 SLIPFORM PAVING OPERATIONS[3]

All slipform pavers in the world market are of the “extrusion-type process”. The extrusion process is simply defined as forcing, pressing or pushing a material through a die or mold to create the desired shape. The concrete is squeezed through the mold to form and shape the pavement in the slipform paver. See Figures A and B 5-694.641 for examples of concrete going through a slipform paver.

Concrete mixtures have many unique elements. More importantly, its behavior as a fluid is a critical factor during paving operations. Fluids are incompressible. Energy applied to a fluid results in equal and opposite transmittal throughout the confined area. A change in delivery or constituents of the mixture (mainly water) changes the hydraulic forces imparted by the concrete. These changes require a variation in the applied energy (pressure and vibration).

**Figure A 5-694.641**

**Figure B 5-694.641**

**Uniformity** is a critical issue; in design (mix and geometrics), in logistics (supply and delivery), and in energy levels (vibration, head pressure, and movement) are vital for machine performance and paving results. Any change in these variables can produce a rough-riding pavement.

The slipform paver contains the mold components. These components consist of the bottom of the "profile pan" or "forming plate" and the side forms. This system confines the concrete and provides the die or mold for the desired shape. The base is the bottom of the mold.

The pressure to the concrete comes from the mass weight of the machine upon the forming plate and the taper adjustment, if present, of the side forms confining the concrete. The pressure also comes from the power of the vibrators as they pressurize the area under the paving form and between the side forms.

Tools are utilized during the paving process to perform the functions of filling the forms and creating a uniform shape. These tools are an auger spreader, spreader plow, strike-off, tamper bar, or any combination of these items. There is also a secondary finishing process of some kind to remove slight irregularities from the surface finish.

The extrusion pressure comes from the continuous movement of the slipform mold through the confined mass of concrete. The energy is also applied by continuous vibration that changes particle distribution and lowers face-to-face and particle-to-steel friction by fluidizing the concrete.

The result desired is a uniform geometric shape and uniform exact surface in the horizontal and vertical dimension. This is best accomplished by a constant mixture and uniform movement of the paver.

Placing operations must include the following elements:
- Uniform particle content
- Uniform fluid (water) content
- Constant pressure and vibration
- Uniform machine movement

## 5-694.642 SUBGRADE[3]

The construction of a quality concrete pavement begins with a good subgrade. A uniform grade must sustain hauling units to place the base material and provide a platform that will support the compactive effort necessary to densify the base material. This requires a subgrade well compacted to profile with tolerances within the specified limits.

There are instances where the grade is in place for a lengthy period prior to commencing final grade preparations for paving. There are also cases where the grading is not finished to the required tolerances. When these conditions are encountered it becomes necessary to make some parallel grade adjustments rather than move large quantities of earth to match the original plan profile. This is accomplished by lowering or raising the existing profile to meet the existing grade. Always balance cut and fill whenever practical. Adequate transitions within acceptable geometric tolerances are provided to meet the adjusted profiles. Any profile adjustments must match the existing structures.

Accurate grade trimming is necessary to construct a smooth pavement of uniform thickness.

In most instances of subgrade trimming, windrows of cut material are deposited on the embankment edges. Cutting slots through the berms establish drainage for the trimmed grade at adequate intervals to prevent ponding of water. This is especially critical on the low side of super-elevated sections. Proper drainage planning will pay off during all subsequent construction activities including paving.

Full-width trimmers are commonly used on highway projects. The accuracy of these machines is very good when they are controlled from string lines.

## 5-694.643 LINE AND GRADE[3]

The Survey Crew and Paving Contractor must coordinate surveying to ensure complete understanding concerning the elevations and offset distances established for grade reference points. The elevations and offsets provide the basis for establishing the string line. The string line is used to provide an accurate reference for elevation and alignment control of the subgrade trimming, base placement and trimming, and paving operations.

### A. Setting Reference Hubs

Hubs are placed with the use of a total station, Electronic Distance Measuring (EDM) equipment or transit and have a tack or punch hole in the top to provide a line exactly referenced to centerline and normal (at a right angle). The tops of the hubs are shot for elevations that relate to plan profiles.

The Contractor determines the offsets of the hubs for the particular equipment and operations. These offset distances may differ on each side of the slab. At times the Contractor must adjust the location normally selected for hubs to accommodate specific project staging and phasing.

When setting the hub offset, the Contractor must consider all elements of the construction and grading operations including width of equipment, windrows of material, drainage trenches, and other site-specific variables.

### B. Establishing the String Line

Wire, cable, woven nylon, polyethylene rope, or other similar materials are all acceptable as string line sensor line. The stake must have sufficient length to maintain rigidity when driven into the grade. The stake must have an adequate length exposed above grade to allow adjustment of the string line to the desired height above the profile grade.

The string line stake is placed in a vertical position outside the hub line. The line is inserted into the holder arm slot and adjusted to a point directly over the hub tack point.

The string line supports are located at approximately 7 m (25 ft.) intervals unless horizontal or vertical curves are encountered. In those cases, place the string line supports at closer intervals. Occasionally, in very uniform conditions, string line supports with a 14 m (50 ft.) interval are used. See Figure A 5-694.643 for an example of string line staking.

Many Contractors prefer to run a string line on each side of the paver. A smoother ride is usually obtained with this dual string line system. The decision to run two string lines is made based on the Contractor's experience. Dual string lines are required on unbonded overlays in Minnesota.

**Figure A 5-694.643**

Prior to beginning paving, check the string line several times to ensure it is correct. Several factors that could affect the string line are as follows:

- Air temperature and relative humidity variations during the day affect the length of line. Check line tension and periodically tighten the winches.
- Equipment bumping the line and personnel stumbling into or tripping over the line will require immediate checking and corrective action. All personnel should exercise caution while working in the vicinity of the string line.
- In many instances the haul road is located parallel to the string line. This requires periodic eyeballing of the string line to determine if any heaving of the grade has occurred that could disturb the hubs and/or line stakes.
- Replace string lines that have broken rather than tying knots in the line. A break generally is an indication that weather and use have taken their toll.
- Check the string line stake arms and adjust bolt sets during installation to make sure that thread wear or mis-threading does not allow arm movement.

Projected grades are extensions of an imaginary line connecting the top of the proposed edges of the pavement slab. They are located in line with the offset reference hubs. To construct a super-elevated curve, rotation of this imaginary line about a point on the slab centerline results in one edge being lowered accompanied by a corresponding rise on the opposite edge. This is the fundamental concept in establishing grades and utilization of elevated string lines for grade control of automated trimming of grade, laying bases, and placing concrete pavement.

The paving equipment accommodates the paving crown, super-elevated transitions, and super-elevated sections. The various shapes are created by adjustments in the paving equipment.

The survey party will calculate the top of both edges of the slab from the plan profiles and cross-sections. The imaginary line, previously discussed, is connected through the edges of slab and extended to a point over the hubs. The determination of the elevation of this imaginary line at the hub location enables the calculation of the difference in elevation between the point on line and the top of the hub.

At this point, communication about proper interpretation of the information shown on the grade stakes is absolutely critical. Miscommunication about how the grades were established could result in constructing the improper super-elevation.

The grade information generally includes the following:

- Centerline stationing
- Curve information
- Offset distance from edge of slab
- Cut (C) or Fill (F) to within 3 mm (0.125 in.)

See Figure B 5-694.643 for an example of hub information.

**Figure B 5-694.643**

Generally, grade information is referenced to the top edge of slab. On tangent sections of alignment where both edges of slab are the same elevation, offset and projected grade information are identical.

Proper communication during the setting of these hubs and recording of the information on the grade stakes is absolutely essential. All parties must meet to reach agreement for this activity to avoid confusion between the paving crew, the trimming crew, and the survey crew.

The staking system normally includes hand winches placed at approximate intervals, not more than 300 m (1000 ft.), to tighten the line to the extent necessary to avoid any perceptible sag between stakes. Use caution when tensioning the string line. A sudden break in the string line could cause severe injuries. Increase the visibility of string lines by placing ribbons on them.

To ensure even tension in the string, pull it out of the rod holders before applying force to tighten the line. Use a small triangular file to remove all nicks or projections in the string slots to prevent tearing of the string.

The machine elevation-sensing wand rides beneath the string, and the alignment-sensing wand rides against the inside of the string. See Figure C 5-694.643 for an example of elevation and alignment sensing wands. Neither of these wands should deflect the line a measurable amount.

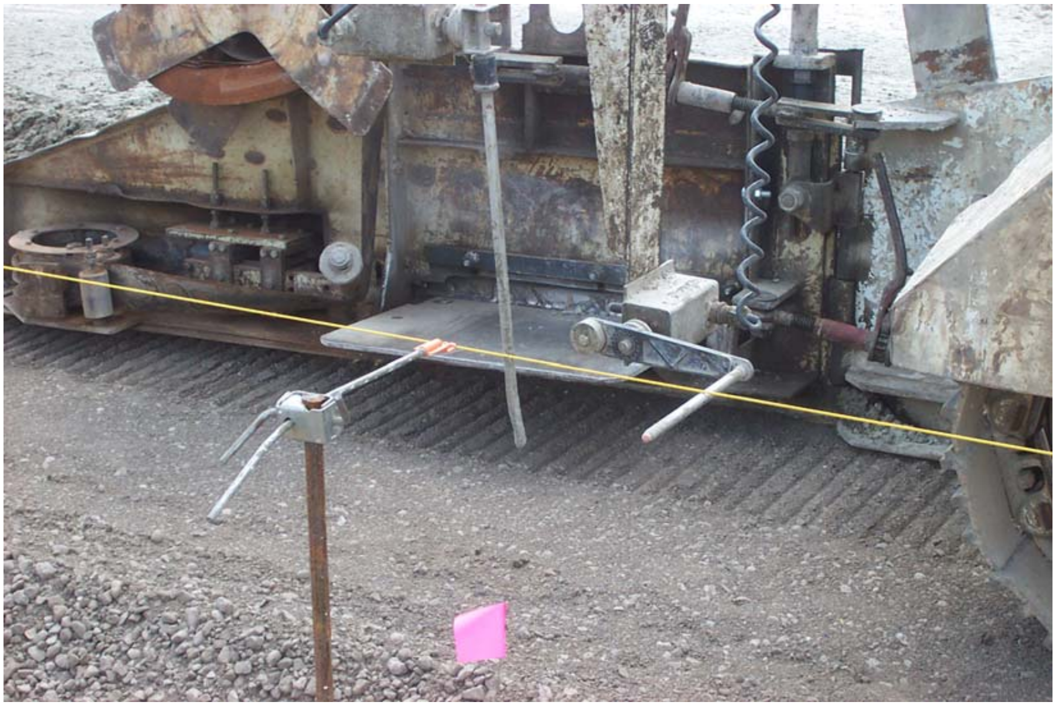

**Figure C 5-694.643**

Check the completed line installation by eye. This check will help detect mistakes in setting the line and any survey staking errors. Communicate with surveyors and ask them to re-survey any areas in question before making changes.

Correcting surveying mistakes by eyeballing is a poor substitute for accurate surveying. Resolve all questions, prior to pavement placement.

In some situations the stringline elevation is set as a low-line. This will enable unloading belts to extend it without disturbing the line.

To cross the string line with hauling units or other equipment, remove the string line for about 30 m (100 ft.) and place it securely on the ground. Check for any damage before re-tensioning and using for paving operations.

**C. Adjustments of the Sensor System**

Check the sensor system thoroughly following paver set up. Many types of sensing systems exist including electric, hydraulic, laser, or sonic. Installation and operation of these sensors according to the manufacturer's recommendations or the Contractor’s experience is imperative.

Set the sensor wands as near horizontal as possible and at the same distance from the unit to the string line. Adjust the pressure of the wand against the string line as needed during paving.

Set the sensor wands at the same distance, approximately 200 to 250 mm (8 to 10 in.) from the unit to the string line. Adjustment of the counterbalances will determine the pressure against the lines during operation and will probably require some experimentation. Adjust the dampening setscrew on each unit to lessen continual seeking movement and rapid changes.

When setting the sensors on the same side of the paver, take into account the location of the string line stakes. Set the sensors at different spacing than the string line stakes. When the sensor is set at a different distance, the wands are not at the sag point between the string line stakes at the same time. This minimizes the chance of building a uniformly occurring sag in the pavement.

## 5-694.644 PLACING BASE TO SPECIFICATION AND TOLERANCE[3]

In the language of pavement design, the word *base* represents the layer of a selected material placed immediately beneath the pavement surfacing. Any selected course of material placed beneath the base is referred to as a *subbase*. The earth grade at the bottom of the pavement structure, whether modified by special treatment or not, is referred to as the *subgrade*.

Good construction practices provide that all of these bases, regardless of placement methods, are built to acceptable tolerances and provide the working platform necessary to:

- Enhance the quality of performance of the finished product
- Minimize loss of concrete
- Eliminate short core penalties
- Contribute to incentives such as smoothness

Perform the trimming in a manner that accommodates the slipform paving operation. The trimming must coordinate with the paving operation.

Grades are trimmed using electronically controlled trimmers to a specified tolerance prior to any pavement construction.

Pad line, track line, or form line are terms often used to describe the area outside the edge of the proposed pavement which provides the foundation for all of the paving equipment operations.

Most Contractors believe that this line is one of the major keys to smooth pavement and should encompass the following characteristics.

- Extend the base itself to a point at least 1 m (3 ft.) beyond the outside edge of the pavement. Figure A 5-694.644 illustrates an extended track line.
- Construct the base or trim parallel to the projected cross slope of the base. The creation of parallel planes is essential in minimizing the yield loss. In addition, parallel planes ensure that the proper thickness of pavement is placed over the entire roadbed.
- Build a base durable enough to provide a relatively smooth passage for the entire paving train, including the texturing and curing equipment. Avoid placing edge drains beneath the track

lines (longitudinally) prior to paving. The weight of the paving equipment can crush the drainage pipes. Place these drains after placement of the pavement.
- Keep the pad line clean of dirt, debris, and surplus concrete during the pavement operations.

**Figure A 5-694.644**

## 5-694.645 BEGINNING PAVING OPERATIONS[3]

Prior to beginning paving there are some critical elements in the process that need extra attention and understanding. These include but are not limited to paver set up and vibration.

A review of safety measures and cautions for everyone concerned, including Agency personnel, is a necessary starting point.

Getting started properly includes the following elements:
- Check all of the equipment in the paving train to verify its operational readiness
- Verify that an acceptable distance of grade is approved for concrete placement
- Check that approved test reports are available for all materials presently in storage on the job site and the plant site
- Verify that back-up testing equipment is available
- Verify that all the necessary concrete placement tools are available, such as hand tools, straight edges, hand floats, edgers, and hand vibrators
- Determine that radio/telephone communication with the plant is operational
- Verify that equipment is available to water the grade
- Check the stringline again
- Verify that the day's work header is in place
- Check weather forecast
- Make sure polycure plastic is available in case of rain

The paving train consists of a number of pieces of equipment. Many paving operations utilize a placer/spreader as the first piece of equipment. Second in line is the paver that consolidates and places the materials to final line and grade. This is followed by texturing equipment. The pavement is then transversely tined if required for final friction needs. Many times the texturing machine and the curing machine are the same piece of equipment. After texturing (and tining if required), the pavement is sprayed with a curing compound. The track line must have adequate stability to support all of the above pieces of equipment.

**A. Paver Set-up**

Check the various components of the paver prior to commencing paving operations.

- The Contractor must provide a “square” paving kit. This is not a problem with two track pavers, but more likely a problem with four track machines. The paving frame must parallel the line control. If not, the machine is skewed in forward motion even though the tracks appear in line. A straightforward approach to adjust the paving kit to “square” is use of the “3-4-5” right triangle technique.
- Following paver set up, string line the pan or forming plate. Check both edges and centerline for trueness. Adjust the proposed crown in the pan and any following float.
- Set the pan parallel to the string line and in accordance with the Manufacturer's recommendations or the Contractor's experience. Many operators state that operating the pan as close to parallel with the string line will provide the best results. This is called adjusting the machine attitude, draft, or angle of attack.

**B. Start-up Operations**

The day’s paving operations should begin with the production of two batches. Check the two batches for slump and air at the plant. Acceptance or rejection is at that point. Upon determination that the batches produced are acceptable, delivery and dumping/spreading begins for paving operations. All additional paving operations can now begin. Delivery of additional batches to load up the machines in the paving train begins at this time. Loading and developing proper spacing normally takes about one-half hour. Paving operations are considered fully underway at this point.

Start-up operations also include construction of the day's header or matching the in-place pavement. The finishers are in charge of this operation.

After coming off the header, other general concerns are addressed as follows:

- Check for proper alignment and elevation of dowels
- Plan ahead for placement of tie steel and supplemental steel
- Mix workability
- Staying within allowable water/cementitious ratio
- Adjustments in delivery of concrete and paving train forward progress to concrete supply
- Check for proper internal vibration at paver
- Probe for depth
- Surface condition behind the paver
- Control slump between 25 and 50 mm (1 and 2 in.)
- Coordinate slump with plant and provide concrete with a consistent slump to the paver
- Begin grade yield checks

**C. Yield Checks**

Check yield often to verify proper machine adjustments and grade preparation. Yield is the actual amount of concrete placed at the field project site based on the production of a given volume. Slightly more material is needed to compensate for job variations. Calculation of the grade yield allows the Contractor and the Agency to determine the actual amount of material placed. The Contractor will probably check the yield every 1 or 2 hours and the Agency will check yield as needed.

To determine the yield, calculate the difference between the theoretical volume required and the actual volume placed.

Example:

Theoretical volume required for pavement (Length x Width x Depth):

$$\left(328\,ft.\times 24\,ft.\times 10in.\times 1\,ft./12in.\times 1yd^3/27\,ft^3\right) = 243yd^3$$

Actual volume placed was 246 $yd^3$:

$$YieldLoss = \left(1-(243/246)\right)\times 100\% = 1.2\%$$

The most critical factor in controlling yield loss is constructing the pavement to the proper depth. Contractor personnel will continually probe to assure correct slab depth and that there are no short cores. A simple way to measure thickness is to set a plate on an unstablized base and probe for thickness at that location. Log these results and compare them with yield loss during the day's paving. Also compare these results with core results.

## 5-694.646 PAVER INTERNAL VIBRATION

Internal vibration is the vibrator-applied energy (centrifugal force) within and internal to the mass of concrete (vertically or horizontally).

The purpose of vibration in the paving process is two-fold:

- To consolidate the concrete mass or remove undesirable voids
- To fluidize the mass to aid the "flow-through" of the concrete in the slipform process

Cores are taken after paving to verify if good vibration techniques were used. The cores should indicate good aggregate distribution and very little entrapped air voids.

**A. Metering**

Some slipform pavers have an area between the auger-strike off and the pan called the "meter box" or "grout box". This area contains the vibrators and tamper bars, if applicable. Other slipform pavers do not have this box, but have an area where there is a static head above the vibrators. This area is adjacent to the vibrator eccentrics or the zone of influence. The concrete becomes energized (particles in motion), water bubbles exploding, entrapped air rising to escape, and the volume of the mix is reduced.

**B. Static Head**

There is another important characteristic of the internal vibrator. An increase of height of the static head developed during the paving process causes an increase in vibrator efficiency.

The vibrators are mounted on equipment with what is known as an “isolation mounting”. Vibrators will work and have equal characteristics in the vertical or horizontal position. They are mounted ahead of the extrusion meter. The energy transmitted by the vibrator is directly proportional to the size of the weight, and the speed of rotation (RPM). The weight is fixed, as is the back and forth distance (amplitude) that the head of the vibrator moves.

Speed is the only variable that is controllable. This is done by varying or controlling the volume of hydraulic fluid to the hydraulic motor. This controls the speed of rotation, and is measured in vibrations per minute (VPM). The amount of the energy and the energy influence change as VPM varies. On electric vibrators, varying the speed of the generator or alternator controls VPM.

The energy level (vibration) required to consolidate and fluidize the concrete mass during paving operations is different for each mix design and depth of concrete. Specification 2301.3H1c requires vibrators to operate at a frequency of not less than 3600 nor more than 6000 impulses per minute in concrete. When checked in air, the appropriate VPM is 4150 minimum and 6900 maximum. A hand-held tachometer (Vibro-tach) can be used to check the VPM of vibrators. This process is an important step in vibrator maintenance. Regular checks can reduce the unwanted results of malfunctioning units. Vibrator manufacturers have developed monitoring systems that give the paver operator continuous readouts of vibrator activity. Electronic vibration monitors are required on all slip-form paving equipment.

The energy transmitted by the vibrator is transmitted in a circle and is cone-shaped. The transmitted energy is equal to 360E surrounding the rotating weight is known as the “zone of influence”. See Figure A 5-694.646 for an illustration of the zone of influence.

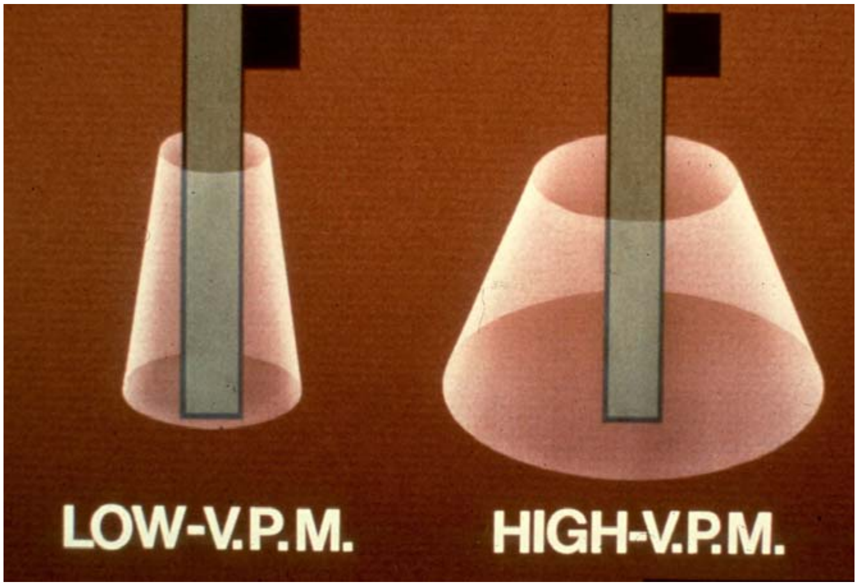


**Figure A 5-694.646**

The zone of influence will vary with:

- Paver speed
- The distance of the weight from the driving motor and shaft
- The care and cleanliness of the isolator mount

**C. Location**

The Contractor should adjust the position of the vibrators according to the Manufacturer's recommendations or experience with the specific mix. Depending on the appearance of the concrete reaction behind the paver, the energy level is adjusted to a uniform level of VPM to begin paving and readjusted to appropriate levels.

Vibrators in a paver are mounted to take advantage of the zone of influence. Each vibrator is adjustable for position and energy level. Position is a mechanical adjustment performed prior to the paving operation.

The horizontal spacing is set to have a slight overlap of the zone of influence. This overlap normally ranges between 50 to 75 mm (2 to 3 in.). This is done to eliminate segregation, as is the case if the zones were apart. Many Contractors prefer a closer spacing because the zone of influence overlap is increased. This closer spacing allows the operator to better control the slab texture.

At a constant forward speed of the paver, the zones of influence change as the VPM change. Increased VPM widen the zones; decreased VPM narrow the zones. The energy level required for a particular mix design, at a given paver speed and depth of placement may require more or less vibrators operating at higher or lower energy levels.

Vibrators, while necessary for the paving process, are NOT a cure-all for other problems. The vibrator may identify and exacerbate a concrete mix (design) problem, but not cause the problem. The vibrator will not overcome poor paver adjustment, improper paving technique, or mix design. Proper vibration will produce a well-consolidated concrete mass and leave a uniform surface behind the paver. Control vibration to prevent vibrator trails. Too much vibration can segregate the concrete and drive out entrained air. Too little vibration results in a high volume of entrapped air reducing the strength.

Significant improvement in mix uniformity is noted at a lower paver speed with the vibrators located at the finished surface of the pavement. There is a small amount of entrapped air.

Tuning the vibration to the concrete mix is very important. Particular attention paid to this phase of the operation pays off in a sound durable pavement.

**D. Operations**

Most vibrators used in slipform paving are hydraulic; therefore check them for any evidence of oil leakage. Have a supply of replacements readily available during paving operations. Do not mix sizes of vibrators on a paver. Check the performance of vibrators again near the end of the day's paving. Any deficiency is evident when the oil is the hottest.

During paving operations, observing the vibrator gangs is necessary at frequent intervals. Any failure of an individual vibrator is readily apparent. The appearance of the concrete within the grout box area changes if there is a problem with a vibrator. Notice how the top of the static head changes from a uniform to non-uniform appearance.

## 5-694.647 TAMPER BAR[3]

The tamper bar is located just in front of the pan of a slipform paver. It oscillates in a vertical direction to "tamp" the concrete as it moves under the paving pan. The tamper bar is a feature found on some slipform pavers. Operate in accordance with the manufacturer's instructions. The tamper bar performs several functions. It helps "tamp" the large aggregate below the surface of the paving pan so none of the large aggregate are dragged as the concrete moves through the paver. It also helps keep material moving at the meter point so as not to accumulate on the meter. See Figure A 5-694.647 for an illustration of the extrusion process and Figure B 5-694.647 for an example of the auger screw and vibrators.

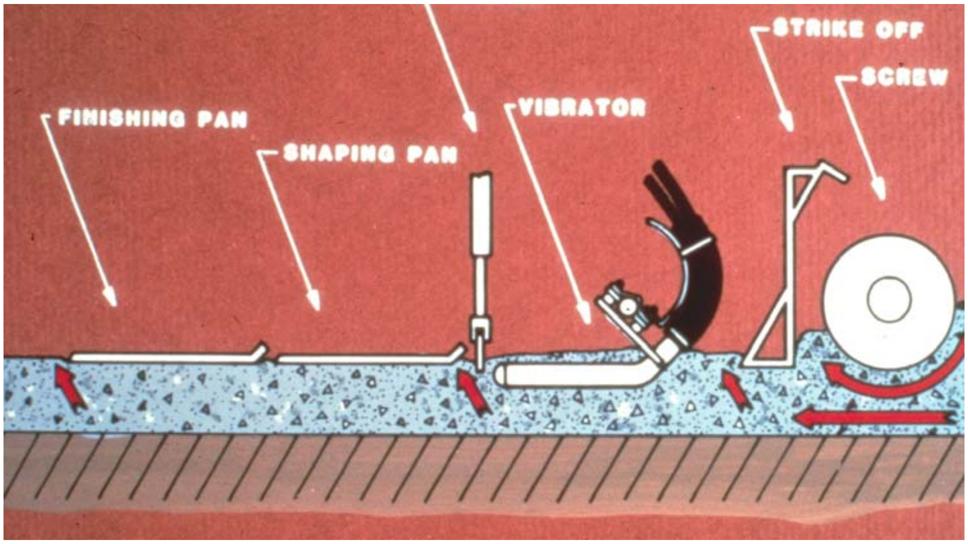


**Figure A 5-694.647**

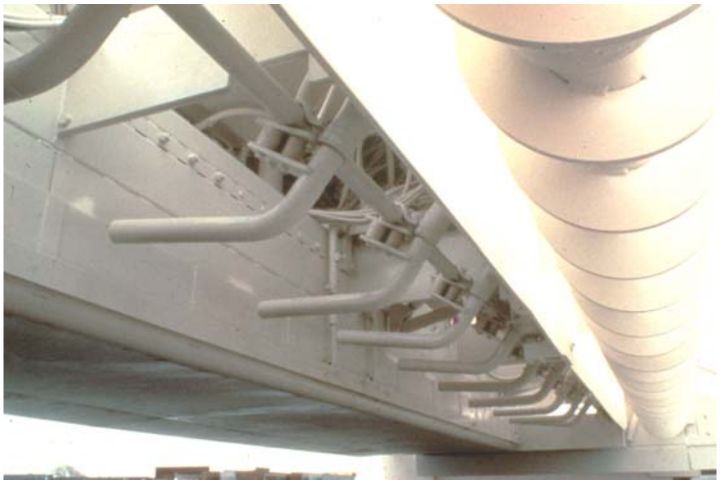

**Figure B 5-694.647**

# 5-694.648 PAVER OPERATION[3]

## A. Paving Speed

Normal paving speeds are in the range of 0.5 to 3 m (2 to 10 ft.) per minute. The volume of concrete delivered to the paver should ensure a continuous paving speed. When delivery does not permit a constant speed, vary the speed to match a decrease in delivery and vice-versa. Speeds of 3 m (10 ft.) per minute or greater may require a change in the number and spacing of the vibrators.

## B. Concrete Head

Concrete head is a constant concern of the paver operator, spreader operator, and truck dump operator. Coordinating their efforts can result in a nominal depth of concrete being pushed ahead by the machine and at the same time avoid having to fill holes at the edges. The goal is to keep the depth of static head about the same thickness as the concrete pavement placed. Operators use a variety of techniques to keep just enough excess material for dispersal if a shortage develops.

## C. Finishing

When everything (mix, equipment, timing, delivery, etc.) is substantially correct, no finishing other than texturing (and tining if required) is necessary. However, many things can happen to this outdoor assembly line process requiring correction in the final phase. Do not undertake finishing while any bleed water is present. Bleed water is significant under some weather conditions or with some mix peculiarities.

The Contractor may utilize several pieces of equipment to correct minor variations and help seal any small imperfections in the finished slab surface. Floats will not remove any significant bumps. The Contractor may use any combination of these machines on the same slab for finishing:

- A tube float is a round tube or tubes that operate in a diagonal direction in relation to the slab centerline. The tube does not rotate but rests on its own mass on the slab surface. The tube float is normally a self-propelled machine and is not attached to the paver.
- A longitudinal float, attached to the paver or self-propelled, is a float that is up to 0.3 m (1 ft.) wide and 4.5 m (14 to 15 ft.) long. See Figure A 5-694.648 for an example of a longitudinal float. This float is placed parallel or close to parallel with the centerline of the slab. The float is carried from one side of the slab to the other while oscillating front to rear. This is commonly termed the final finisher.

Checking the surface behind the paver with a 3 m (10 ft.) straight edge is a normal procedure. For any surface imperfections, correct with a hand-operated float. See Figure B 5-694.648 for an example of a hand-operated float. Periodically check the trueness of the straightedge with a string line.

**Figure A 5-694.648**

**Figure B 5-694.648**

**Excess water, if worked into the surface, can cause plastic shrinkage, excessive water cementitious ratio at the surface, and eventual spalling of the surface. If there isn't any daylight under the bull float and there are no major holes or tears, move on. It is also important to remember that it is not necessary to seal every small dimple or hole in the pavement surface. Over-finishing can lead to problems such as scaling and premature deterioration of the surface.**

**D. Texturing**

Plastic concrete is textured to increase skid resistance of its natural finished surface. Texture is defined in terms of “macro” and “micro”. Engineers feel both micro texture and macro texture are necessary to ensure the maintenance of acceptable friction numbers throughout the surface life of the pavement. Macro texture on concrete paving is generally achieved by astroturf or broom drag. See Figures C and D 5-694.648 for examples of astroturf and broom drag. Typically broom texturing is performed on bridge decks.

**Figure C 5-694.648**

**Figure D 5-694.648**

### E. Tining

In addition to and immediately following the texturing, provide the pavement surface with a transverse metal-tine surface if required. This operation requires a mechanized device providing a randomized spacing of 16 to 26 mm (approximately 5/8 to 1 in.). See Figure E 5-694.648 for a mechanized tining device. The required tine width is 2 to 3 mm (approximately 1/12 to 1/8 in.) and the required tine depth is 3 to 8 mm (approximately 1/8 to 5/16 in.). Take care not to dislodge coarse aggregate particles. Manual methods are used for ramps, etc., but are subject to the approval of the Engineer.

Make sure the tining machine is parallel to the pavement surface. If the tining bar is not parallel to the pavement surface an uneven pressure is exerted on the pavement surface, resulting in a non-uniform texture.

At each transverse joint location, a 100 to 150 mm (4 to 6 in.) wide strip of the pavement surface is protected from the tining operation to provide a transverse tineless surface centered over the joint saw cut. The Engineer may eliminate this requirement for right-angle joints.

**Figure E 5-694.648**

## 5-694.649 TROUBLESHOOTING CHECKLISTS[3]

During paving, certain situations occur that require particular attention. The following are possible circumstances that might arise and a list of some of the factors to consider when trouble shooting the problem.

### A. Tearing of the Mix

- Speed of the paver
- “Square” of paving kit to string line
- Vibration frequency

- Draft of the pan
- Mix proportions
- Air content
- W/C ratio

**B. Bleed Water**
- Wait until bleed water evaporates before tining (if required) and curing
- Air content

**C. Too Much Grout on Surface**
- Too much water applied to surface
- Over vibration (vibration speed too high)
- Machine moving too slow for vibration
- Rain

**D. Crawdaddy Holes**
- Check air content
- Check W/C ratio and adjust if necessary
- Check vibrators that align with the holes
- Check for proper paver travel speed

**E. Trackline and Stringline**
- Clean trackline
- Protect the stringline from displacement
- Avoid knots in the stringline

**F. Equipment Maintenance**
- Repair hydraulic leaks
- Use proper replacement parts
- Clean up after each use – don’t create soft spots in base

**G. Vibrator Streaking (Vibrator Trails Visible Behind the Paver)**
- Head above vibrators
- Materials and mixtures
- Frequency
- Paver speed
- Vibrator positions and spacing
- Blown vibrator

**H. Edge Slump**
- Consistency of concrete
- Air content
- Gradation
- Position of edge vibrators

- Vibrator frequency
- W/C ratio
- Mix design (some are more prone to caving edges)

**I. Wide Variances in Texturing**

- Inconsistent concrete (review mixing operation, placing, and finishing process)
- Placing and finishing process
- Adjustment of the final finisher
- Observe operation of texturing equipment
- Condition and cleanliness of texturing equipment (astroturf or brooms)
- Vibrator positioning
- Speed of paver

## 5-694.650 FIXED FORM PAVING OPERATIONS[3]

Fixed form paving has many uses, ranging from placing mainline pavements to constructing city streets. Setting forms for irregularly shaped areas is a generally accepted technique. However, Contractors are continually devising methods to reduce the areas that require forms.

Form paving is used for streets, local roads, airports, and complicated, short length and variable-width pavements. Ramp tapers and similar variable-width areas are generally constructed using fixed form equipment.

A conventional form riding train of equipment includes a spreader that has a gang of interval vibrators embedded in the struck-off concrete prior to the finishing machines.

The finishing machine has twin-oscillating screeds, which assist the consolidation process and strike off the concrete to the proper shape. Some trains include two finishing machines. Some finishing machines have a cantilevered pan float mounted on the rear of the machine that adds a compressive force as the final machine shaping.

On some smaller projects, only the finishing machine is used, and internal vibrators are mounted near the form on each side.

Automatic machines, utilizing a heavy duty paving carriage to vibrate, strike off, and longitudinally smooth, seal, and texture the concrete are also used. These machines ride on the forms or on pipe laid outside the forms, with or without string line leveling.

## 5-694.651 TRIM GRADE AND COMPACTION[3]

Establishing the correct grade is the first critical step in constructing a smooth, high quality pavement. Grades that are trimmed following form placement are either trimmed with a fine grade machine that cuts to the proper depth or by motor patrols and a tail planer that ride on the forms. A flat steel roller is used following final shaping. Check the form alignment and profiles following these operations on grade.

When granular bases are used, the Contractor may do the final trimming after the forms are in place. The cut material is normally hauled ahead and incorporated into the base being laid. Moisture is usually added, the base is re-compacted (if necessary), and final steel rolling is then accomplished prior to any steel being set.

## 5-694.652 SETTING THE STRING LINE[3]

If form-line grading is done by machine, set the string line twice. First, set the string line at an offset height to meet the requirements of the mechanical grader, and then set the string line for form setting.

For form setting, the string line is set at the face and top elevation of the form (pavement). The string line is installed on form pins located with the outside edge of the pins on the proposed edge of slab alignment as measured from the reference hub. Set a string line pin opposite each reference hub. A carpenter's level is generally used to transfer the grade from the hub to the string line pin. Hubs are normally set on 10 m (25 ft.) intervals for tangent sections and closer for curves. The string line is then put up, fastened securely on each pin, and drawn as taut as is necessary to prevent string line sags between pins.

Generally, the opposite reference hubs are not tacked for exact alignment control and are used for elevation reference only. Therefore, the alignment for the opposite side of slab string line is obtained by measuring across the proposed width of slab.

After the string lines are set, the subbase elevation check at the form line is made. Deviations must be addressed before forms can be set. Make certain the line did not slide up or down during the tightening process.

## 5-694.653 FORMS[3]

The key ingredient in a fixed form paving operation is the form. The form is the mold that determines the pavement depth, width, and ride.

A typical paving form is made of interlocking steel sections. The face of the form is the same height as the proposed pavement thickness. The form has a wide, flat base to give the form stability and an upper rail to carry the paving equipment. Provisions are also made for fastening the form to the base and grade with form "pins" (stakes).

Typical Specifications may place the following requirements on paving forms:

- Each form section is usually made of metal at least 5.6 mm (1/4 in.) thick and 3 m (10 ft.) long
- Form depths should equal the edge thickness of the pavement
- Buildup permitted on form bottom, bolted on to provide proper depth, with 50 mm (2 in.) maximum thickness
- Sometimes wood boards are bolted on to the bottom of the forms to provide proper depth, with 50 mm (2 in.) maximum thickness
- The base width of the forms should provide stability
- Flange braces should extend outward on the base not less than 2/3 the depth of the form

Specifications will differ, but generally the top of the forms must not vary from a true plane (perfectly flat surface) by more than 3 mm (1/8 in.) in 3 m (10 ft.). The face of the forms should not vary from a true plane by more than 6 mm (1/4 in.) in 3 m (10 ft.). Detect any variances with a straightedge or string line.

Before the forms are set, individually inspect them to determine if they meet the specified requirements. Check that the pin keys are straight and free moving in the pockets and capable of holding forms tight against the pins. Check that joint locks are not bent or worn and are capable of holding the ends of the form in true alignment. This criterion is an absolute must if the forms are to serve as rails for paving equipment.

Drive pins of sufficient length to securely hold the forms in place during placing and finishing the concrete in all pinholes, and drive all keys and form locks tight. As the key or form locks are driven in, they stabilize the form against the pin, preventing it from moving. Check these pins regularly to prevent any form movements caused by equipment moving over the forms.

The top of the inside edge of the form shall match the previously set string line. Make minor alignment corrections utilizing the twin point keys located on the inside and outside of each pin pocket.

If any form sits above the string line, remove the form and tamp or trim the base to the proper grade. If the form sits below the string line, remove the form and scarify the base. This will prevent separation or peeling of the additional material that the Contractor must add to bring the form to the proper grade line. A firm bed of fine crushed aggregate works well to fill in the low spots.

## 5-694.654 SETTING FORMS[3]

The proof of a good form-setting job is the absence of form rocking during equipment passage.

### A. Forming Curves

Provide flexible forms (steel or wood) used on street returns and other curves of specified radii equal in depth to the pavement thickness and staked or braced to prevent movement during concrete placement.

Metal forms are most efficient for straight-line work. When curves are needed, you can use metal forms if the radius of the curve is greater than 30 m (100 ft.). On a curve, set 3 m (10 ft.) straight metal forms as arc tangents. Paving equipment can “track” a curve set as described. The final decision regarding form use is based on equipment and the appearance of the finished pavement.

If a curve has a radius less than 30 m (100 ft.), use flexible form sections to shape the curve. Curved metal forms are used, but it is not always practical to order these metal forms to fit only one radius. However, if the radius is too small, metal forms may not achieve a smooth curve. In these situations the Contractor could attach wood to metal forms. However, this creates a new problem: form-paving equipment cannot ride on these wood forms. Hence, the Contractor must use approved equipment for hand placement, consolidation and strike off. You may need extra form-pins to hold the wooden forms. Making a smooth curve may require form-pins both inside and outside the forms. Pull any extra form pins placed inside the forms before the concrete is consolidated and before final finishing.

After a curve is formed, notify the Survey Crew to check it. Compare the findings with the curve data shown in the plans.

**B. Curbs**

Make sure the correct curb type is used. If integral curbs are constructed following the placement of the pavement, by either hand forming or use of a curb mule, clamp or pin a curb depth form to the top of the slab form. The curb mules (right and left hand required) are winch propelled. Some machines include integral curb placement as part of one process.

Form setting is a critical construction step. You must assure that the forms are accurately set to line and grade and are supported uniformly by a firm foundation.

The finished smoothness of the pavement depends on the care with which the forms are set and maintained, since the finishing equipment generally rides on the forms. Proper alignment and elevation of the forms will contribute to a smooth pavement.

Because the majority of subgrades and bases are now trimmed full width with string line controlled equipment, the form lines are compacted and are at plan grade. Some Contractors still use form-line graders that operate with a string line to trim the form grade lines. A firm and level foundation under all forms is required. The forms must not rest on pedestals of dirt or rock; a uniform base is required for support.

Set the forms to proper grade and line. Once the forms have been set, check them for overall alignment and tolerance before any paving occurs. The quickest and simplest way of checking is to use the “eyeball” method. Sight along each form line to see that the forms are straight (alignment) and the tops are smooth (tolerance). Most deviations are obvious. However, you can use a level, a 3 m (10 ft.) straightedge, or string line to check minor errors. Check horizontal alignment against the offset hubs. Check the width of the roadway between the forms to assure it conforms to the plans. Immediately reset any form section that is out of line.

Check that the joints between forms are tight and smooth.

When keyway strips are specified, attach them to the faces of the forms after the forms are in place. Keyways are grooves formed in the vertical edge of one lane of concrete to facilitate tie steel installation, which later become filled with concrete of the adjacent lane. This provides for load transfer between adjacent lanes.

Run forms beyond headers for proper grades and to allow placing and finishing equipment a platform on grade line to work beyond the pavement’s end.

**C. Preparing Forms for Paving**

Start with clean forms, oil them inside and out prior to keyway, tie bar, and concrete placement, and handle them with care. Oiling the outside of the form prior to use makes removal of concrete spilled over the forms during finishing much easier. Oil forms before installation of tie bars to avoid oiling tie bars.

Check the ends of the form sections to see that they are flush and securely attached to one another. If the adjoining ends are not flush, the paving equipment is forced up and down, resulting in a bumpy, uneven surface.

All forms should allow for tightly locking the ends of adjacent form sections. When in position, the forms must match-up in a flush condition.

For a secure setting, stake forms with a minimum of three iron pins for every 3 m (10 ft.). When in place, the forms should not spring or settle due to the mass and vibration of equipment. Any up-and-down movement of the forms will result in rough pavement.

Sometimes the adjacent pavement lanes or curb and gutter section act as the side form. Make certain there are no irregularities at the edge or the top of pavement.

## 5-694.655 FORM REMOVAL[3]

In most instances, remove the forms within 6 to 8 hours if extreme care is taken during the pin pulling and unlocking of the forms. Pull pins first with pin extractor (mechanical or hydraulic), and then remove forms without prying between the edge of the forms and the concrete. A light tap followed by hand removal is preferred.

After removing the forms, check to see that there was adequate vibration to produce dense concrete along the form line. Honeycombing indicates insufficient vibration. If necessary, adjust the vibration process when paving resumes.

Cure the edges of the pavement as soon as possible after form removal.

## 5-694.656 FORM MANAGEMENT[3]

If possible, clean forms immediately after removal otherwise they are difficult to clean. Dirty forms are difficult to check with straightedges, and make concrete placement difficult. Treat the forms with care so they are ready for the next day or job. Properly handled, the forms will last for years.

## 5-694.657 FACTORS OF FIXED FORM CONCRETE PAVING AFFECTING PAVEMENT SMOOTHNESS[3]

Producing a good ride with forms is dependent upon numerous factors, including the following, exclusive of design considerations:

- Uniform grade - properly compacted and moistened ahead of concrete placement
- Good form line compaction, properly graded
- Forms that meet the Specifications
- Proper string line erection and form placement, including oiling
- Proper construction and grading of boxouts and fixture adjustments
- Proper placement of dowel baskets and pre-placed reinforcement, including keyway
- Consistent mix, slump, and timely delivery
- Proper timing and placement of the mix on the grade. Cover grade, avoid excessive piles.
- Adequate vibration and consolidation. If hand puddling, do not use rakes, move surplus concrete with shovels. Use extra care in placing concrete over the basket assemblies and in vibrating that area.
- Proper machine adjustments and operation. Steady machine progress enhances smoothness. Avoid excessive finishing. No water buckets or paste brushes. Straightedge check of slab. Use float to fill any surface voids that show up behind finishing machine.
- Use edger on slab edges, top of curb if placed, and around boxouts and expansion joints if included. Use minimum radius edger compatible with mix being used, especially where future placement of slab will abut.
- Wait for sheen to disappear before texturing
- Adequate and timely application of cure
- Cure sides of slab after form removal

## 5-694.660 JOINTS

Since concrete is a material of low tensile strength and since concrete construction may require staging in operations, the construction of joints is necessary to alleviate problems due to random cracking. See Standard Plan 5-297.221 for joint details.

## 5-694.661 CONSTRUCTION JOINTS

A construction joint is needed wherever the concrete placement operation is terminated prior to completion of the structure and concrete placement is resumed later. The locations of these joints are generally known in advance and are indicated on the plans for reinforced structures. These joints are substituted for either a contraction or expansion joint since there is no problem of stress on curb and sidewalk work.

A construction joint, normally called a “header joint” or “header”, is placed at the beginning and completion of each day of paving operations. The header joint is formed by using a “board” shaped to the desired cross-section of the pavement. See Figure A 5-694.661 for an example of a completed header joint.

Headers are considered a perpetual problem to concrete foremen, finishers, and are a continuing challenge. Headers are placed at mid-panel. Install side forms, approximately 3 m (10 ft.) in length, to provide proper edge alignment and confine the area for consolidation. Set the side forms to match the width of the pavement.

**Figure A 5-694.661**

Tie bars, 1.5 m (5 ft.) long, are inserted 0.75 m (2.5 ft.) into the fresh concrete. Concrete around the header joint is thoroughly consolidated by vibration to give strong, dense concrete. A point of weakness may develop at the joint if poor construction practices are followed. The "cream" carried along in the paver is not allowed in the header. Take care not to damage the in-place pavement when paving resumes.

Provide fresh concrete for the final few meters. Do not use the slurry that may have collected in the spreader rolls. Provide thorough but not excessive patterned hand consolidation.

Use a straightedge of sufficient length that laps back onto the existing concrete that has the proper shape. String lining is also recommended.

Near the end of large placements, carefully measure the remaining volume to adjust the amount in the last two or three trucks to provide the required concrete. Aim high, this can prevent waiting for a short load after the plant has closed or the concrete truck is scheduled for other jobs. Do not use concrete spilled or disposed of on the ground to make up any deficiency in material. The material placed at the end of the day's placement should have the same quality consistent with the other material used.

Edge tool the side form edges and the header itself. Use an edging tool with only a minimal radius. Texture and apply cure in a timely manner. Many times this operation at the header is performed by hand. When starting operations the next day, repeat the process of straight edging and string lining across the joint.

## 5-694.662 EXPANSION JOINTS

Concrete is subject to expansion and contraction due to temperature and moisture changes. In some instances, it is necessary to construct expansion joints in the structure to provide for relief of the stresses that occur. Expansion joints are always used at bridges.

In curb, gutter, and sidewalk work, expansion joints are required as explained in Specification 2531.3C. The joint used is a plain butt joint with non-extruding preformed joint filler. The Contractor must place the joint filler absolutely vertical; otherwise (since it is a plain butt joint), one section will tend to slide up on the other when the concrete expansion becomes large enough. Follow good consolidation methods at these joints.

Expansion joints are rarely used in concrete pavements. If used, the size and spacing of dowel bars are indicated in the plans. Place non-extruding pre-molded joint filler vertically and straight across the pavement. Check to make sure the dowel bars are parallel. Obtain good consolidation around the dowels, joint filler, and protection angles to obtain a strong joint. The use of preformed expansion baskets tends to cause problems when they are used in pavements. The preformed expansion material acts as a dam, catching the progressing concrete during normal operation, and can either tip the basket or prevent consolidation. Either situation can cause early deterioration of the joint.

If the joint filler is tipped during the construction, remove the concrete around the joint, straighten or replace the filler, and then replace the concrete. If a tipped joint is discovered after the concrete has hardened, a standard full-depth concrete repair is necessary. In this case, remove approximately 1.5 m (5 ft.) of concrete on each side of the joint (excluding bridges) to properly repair the defect. Use the newest concrete pavement rehabilitation standards available to replace the joint.

## 5-694.663 CONTRACTION JOINTS

There are several types of contraction joints used in concrete construction. The purpose of a contraction joint is to induce a crack to occur at a predetermined location rather than allow the inevitable random cracks.

In some types of construction, divider plates are used to help hold the forms during concrete placement. This is a practice used in curb, gutter, and sidewalk construction. When the divider plate is removed, there is a small opening, which then acts as a contraction joint. It will open up slightly when the concrete contracts, but provides little if any space for expansion. Obtain good consolidation around the divider plates. More commonly, hand tooling forms the joints.

The contraction joints for concrete paving are divided into two main classes; doweled and undoweled joints. Standard practice in Minnesota, in almost every case, is using doweled joints since undoweled joints will fault over time. Dowel bars provide for load of the vehicles to transfer across the joint from one pavement slab to the next. The minimum dowel bar size is 32 mm (1 1/4 in.) in diameter by 380 mm (15 in.) long. Joints without dowel bars provide for only partial load transfer through aggregate interlock.

The joints are normally constructed by sawing a groove in the concrete after it has hardened. Contraction joints in pavement usually have a depth of t/4 (thickness of the pavement divided by 4). The exception is on unbonded concrete overlays that have a joint depth of t/3.

Only pre-approved dowel bar assemblies are permitted. Saw the joint directly over the center of the dowel bars. It is very probable that a secondary crack will occur near the joint if the plane of weakness is 50 mm (2 in.) or more off center. The section of concrete between the crack and groove will soon spall out. The crack may occur outside the limits of the dowel bars resulting in no load transfer if the joint is 100 to 125 mm (4 to 5 in.) off center of the dowel assembly.

Flush all debris left on the pavement surface and in the joints after the saw cut is completed. Check to assure saw cut depth meets Specifications.

Joints that are over 13 mm (1/2 in.) in an uncracked condition will require oversized sealers. Contact the Mn/DOT Concrete Engineering Unit for specific recommendations.

The Contractor must assure that the construction sequence is performed in a timely manner so that no random cracks occur. Usually sawing is done about 8 to 12 hours after placement, but each situation is unique due to mix design, temperature, thickness, etc.

## 5-694.664 LONGITUDINAL JOINTS

Three types of longitudinal joints are predominately used.

- L1T or L1 joint - This is a sawed joint down the center of a roadway or section, either tied or untied.
- L3 joint - This is a construction joint between two concreting operations, which are not tied to one another, essentially a butt joint.
- L2KT joint - This is similar to the L3 joint except the two operations are tied together. This joint calls for placing the first pavement with an indented keyway and bent tie steel installed and tucked into the keyway. The tie steel is straightened before the second operation is begun allowing the tying of the two together.

The sawed longitudinal joint is often used as a traffic marker for two lanes of traffic and is used on double lane pavement construction. Most of these joints contain steel tie bars placed approximately at the mid-depth of the pavement. The size, length, and spacing will vary and this data is obtained from the plans. This steel is inserted into the concrete while it is plastic. A mechanical placing device is used. This is usually located on the front of the paver and automatically spaces and places the steel.

All other longitudinal joints are considered a type of construction joint. These joints may or may not contain tie steel. Check the plans for this feature. Make sure good consolidation is obtained around and under any keyways. Remove the concrete that is spilled on the previously constructed portion the same day the work is performed.

## 5-694.665 JOINT SEALING

The Contractor shall fill the joints with an approved sealing compound prior to allowing any traffic on the roadway. The sealant type is specified in plans. All approved joint sealants are available on the Office of Materials website at www.mrr.dot.state.mn.us/pavements/concrete/products.asp.

Assure that the joints are cleaned of all debris and dust and **completely dry** just prior to the sealing operation otherwise it is possible the joints could have adhesion failure. The other type of failure that may occur is cohesion failure that is generally contributed to the wrong type of sealant, a poor shape factor, or the joint spacing frequency. See Figure A 5-694.665 for an example of these types of failures.

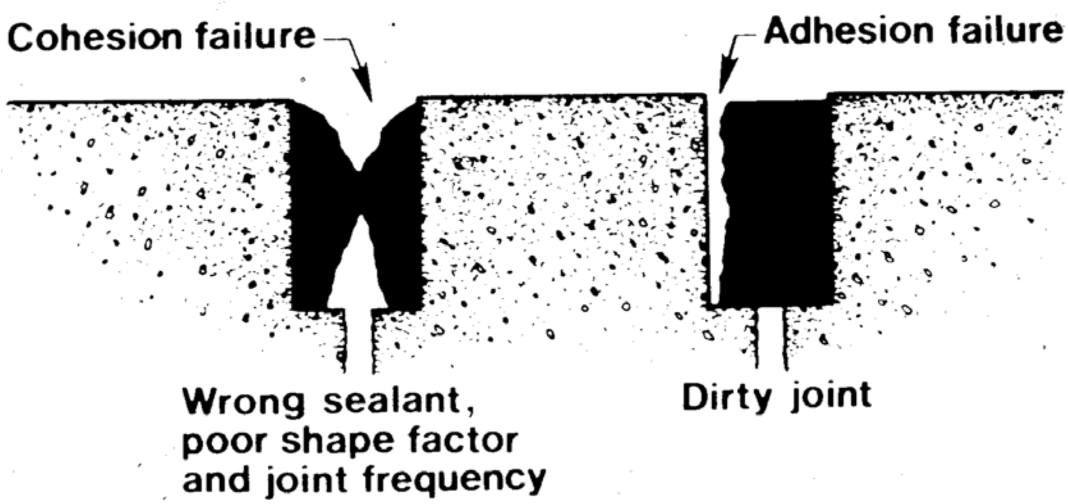


**Figure A 5-694.665**

### A. Hot Pour Sealants

The Contractor shall handle the joint material as prescribed by the Manufacturer and also as required by the Specifications. All material is pre-approved by the Mn/DOT Office of Materials. Call 651-779-5617 if a material needs verification. Fill longitudinal joints to a slightly under-filled to flush level. An operating tolerance from level to 3 mm (1/8 in.) under the pavement surface is allowed. If any areas of the sealant have settled more than 3 mm (1/8 in.) below the surface of the pavement during the first 24 to 48 hours, the Contractor shall refill to the previously mentioned tolerance.

Rubber asphalt is a material that requires good temperature control during the heating cycle. A slight increase in temperature above the normal operating temperature can change the characteristics of the material and render it unfit for use. For this reason, the Inspector must make sure that the material is heated at the temperature recommended by the Manufacturer. See Specification 3719, 3723, or 3725.

**B. Silicone Sealants**

Confirm that the joint is completely clean and dry and also free of all incompressibles prior to sealing. An oversized backer rod is placed before silicone is added to the joint. See Figure B 5-694.665 for an example of backer rod installation. Some of the sealants are tooled into the joint with an approved device to ensure the correct shape factor and performance; other silicones are self-leveling. All of the sealants are installed according to Manufacturer's recommendations unless modified by the Mn/DOT Concrete Engineering Unit. The Contractor shall clean excess sealant from the upper face of the joint and salvage and reuse if in an acceptable condition. See Specification 3722 in the Special Provisions for silicone joint sealant requirements. See Figure C 5-694.665 for an example of sealing contraction joints with silicone.

**Figure B 5-694.665**

**Figure C 5-694.665**

**C. Preformed Joint Sealant**

Preformed sealants are commonly used in Minnesota. They are used in areas where there are problems with other sealants bonding to the sawed faces of the pavement joint and in areas where high performance concrete is specified. If these sealants are specified, they are installed according to the Manufacturer's recommendations unless modified by the Mn/DOT Concrete Engineering Unit. See Specification 3721. See Figure D 5-694.665 for installation of preformed compression joint sealants.

**Figure D 5-694.665**

## 5-694.670 FINISHING

A final finish is applied to all surfaces exposed during concrete consolidation. The extent of such finishing depends on the type of work. The Inspector should refer to the Specifications for the specific requirements on the type and degree of finishing required.

## 5-694.671 FINISHING CONCRETE PAVEMENTS

The Contractor should not add water to the surface of the concrete to aid in finishing without the approval of the Engineer. The Engineer will only give this approval to replace evaporated surface water directly behind the paver caused by a halt in forward progress from a short-term breakdown in equipment or supply of concrete. The Contractor should supply sufficient trucks to assure a steady forward progress of the paver. **Pavement sections where water is added without the approval of the Engineer are not eligible for incentive payment for w/c or ride and are subject to the provisions of Mn/DOT 1503 and 1512.**

## 5-694.672 FINISHING CONCRETE BRIDGE DECKS

The Contractor shall perform the operations to finish the bridge deck to meet the criteria for acceptable placement rate, concrete density, and surface finish. This process consists of the use of mechanical-leveling plates attached to the finisher and/or the use of manual levels and floats or other approved hand finishing tools as well as the finishing broom from the work bridge. See Figure A 5-694.674 for an example of this process. Rails have to be set to the proper grade and elevation for an approved power operated finishing machine to travel on. Contractor should ensure that work bridges are stiff enough to minimize sagging unto the finished surface.

**Figure A 5-694.674**

Certain high strength concrete and low slump overlays are characterized by low bleed water. After finishing, the Contractor should continuously fog-spray in order to reduce evaporation. In micro silica decks, soaker-hoses produce the same effect. The Contractor should not use this process as a finishing tool but should use it along with similar evaporation control measures such as windbreaks.

## 5-694.673 FINISHING SMALL AREAS

Hand methods are usually used for spreading and screeding concrete in small areas. Repeat the screeding action, which in some instances is performed with a timber set on edge, until there are no open textured areas in the surface. If necessary, supplement the screeding operation with a long handle wood or magnesium float. The float will help iron out isolated high spots and will do a better job of filling in the open textured areas. Floating and screeding should stop when a smooth, closed surface is obtained.

Do all edging as soon as possible after the screeding. Work large aggregate particles that are near the edge into the concrete. Repeat the edging when the concrete is starting to obtain its initial set. **Concrete reworked will produce defective surfaces**.

Surfaces of sections such as culvert walls and columns require very little finishing. Float the surface and remove any laitance accumulating at the surface. Properly finish the surface to provide for the next section placed on it.

## 5-694.674 CHECKING THE FINISHED WORK

After each operation or section of work is completed, inspect it and have the Contractor correct the defects to the satisfaction of the Engineer. The Contractor shall correct the defects that reflect poor workmanship by improved operations.

## 5-694.680 CURING CONCRETE

One of the most important steps in concrete paving is the method used to prevent loss of mix water. Moisture is maintained in the concrete for the following reasons:

- Facilitate hydration
- Prevent surface (map) cracking
- Allow the concrete to reach its design strength

The cure is applied when the finishing of an area is complete. If the texturing went well, it is time to cure. Begin cure application when the original sheen has nearly disappeared. When weather conditions exist that make the decision when to spray difficult, it is better to spray too early rather than too late.

A minimum curing period of at least 3 days at about 15 to 20°C (60 to 70°F) is necessary to give the concrete an ability to attain its potential strength. For adequate curing, the concrete must remain moist and have favorable temperature conditions. Standard practice includes several methods of moisture and temperature control. Check the Specification 2301.3M to determine the specific requirements.

There are several methods of curing:

- Water
  - Wet Burlap
  - Fogging (See Figure A 5-694.680)
  - Ponding
  - Others
- Polyethylene sheeting (Plastic)
- Liquid Membrane

**Figure A 5-694.680**

## 5-694.681 WET BURLAP

Burlap is often used for curing culverts and bridges. It is required to pre-wet burlap and maintain in a moist condition; otherwise, it will tend to remove moisture from the concrete. Evaporation of water from the burlap has a cooling effect, which is desirable in hot weather but is objectionable when air temperatures are below 10°C (50°F). Confirm that the burlap is securely tied or weighted down so the concrete will remain covered at all times.

## 5-694.682 POLYETHYLENE SHEETS (PLASTIC)

These materials are generally used as an alternate to curing membranes or to protect the surface from rain or frost. No tears and holes are allowed in the material at the time of use. The Contractor must place the material at the correct time and place continuously with the phase of concrete placement. If the material is placed too soon, it will mar the surface. When it is placed after final set has occurred, too much moisture is lost from the concrete. Make sure the sheets are securely placed. See Figure A 5-694.682 for an example of curing with plastic on a bridge deck.

**Figure A 5-694.682**

## 5-694.683 CURING MEMBRANES

This is the most widely used form of cure. Curing membranes are pre-approved by the Mn/DOT Office of Materials Laboratory. Verify the membrane-curing compound is approved for use by contacting the Mn/DOT Cement and Soils Lab at 651-779-5556. Review the Specifications and Special Provisions to determine which curing compound is required for the particular construction and the time of year. Specification changes preclude the use of water-based curing compounds.

The surface is sprayed with curing compounds to prevent evaporation of mix water. Standard curing materials used include both white-pigmented cure and plastic sheets (in case of rain). Curing compounds are visible when applied and provide an opportunity to determine uniformity of placement.

Thoroughly mix and continually agitate curing compounds. Larger projects utilize bulk delivery and storage. The bulk storage is normally air agitated, and the spray machine tank is stirred with electrically driven paddles. Smaller deliveries are usually in barrels.

Preparing and maintaining the cure-spraying machine includes flushing the nozzles before operating. Most texturing machines have shields or hoods that shelter the nozzle application operation to prevent spray drift, especially in windy conditions. See Figure A 5-694.683 for an example of a curing cart on a concrete paving project.

**Figure A 5-694.683**

Specifications require that the concrete is covered with at least the minimum quantity of membrane, normally specified as $m^2/L$ ($ft.^2/gal.$) of compound. Inspectors should verify the rate of application and record the test data. It is desirable to spray in both directions so the membrane will get into all depressions and around all particles. Be sure to apply the cure to the vertical slab edges. Re-spray any damaged areas and check that no areas are left uncoated. Cure the edges of the pavement as soon as possible after form removal.

## 5-694.684 SURFACE TREATMENTS

Certain items of work require that the concrete is given a coating of material to further protect it. Normally this material is a concrete treating oil, but other materials are also specified. Use only the material listed in the Specifications or Special Provisions. The treatment is used to provide additional protection to the surface from scaling. Concrete scaling is caused by freezing and thawing, by the application of salts, or by a combination of both.

Only apply the concrete treating oil when the concrete is dry so it will penetrate as far as possible into the concrete. It is preferable to apply it on a clear, warm day. Apply in two separate applications, the second application is delayed until the first completely absorbs into the concrete.

## 5-694.690 CONCRETE PAVEMENT SMOOTHNESS

After completion of the initial curing period and prior to the opening of the roadway to traffic, the Contractor shall test the pavement surface for surface smoothness and ride quality. The profile index is used for measurement of pavement smoothness and for acceptance and payment on most concrete paving projects. Profile Index is calculated according to California Test Method 526.

### A. Surface Smoothness

Surface Smoothness shall be measured with a 7.62 m (25 foot) California type profilograph, or a Lightweight Inertial Profiler (IP), which produces a profilogram (profile trace of the surface tested). See Figure A 5-694.690 for an example of a California Profilograph and Figure B 5-694.690 for an example of a Lightweight Inertial Profiler. The Contractor shall furnish a properly calibrated, documented and certified 7.62 m (25 foot) wheel base, California type, computerized profilograph or Lightweight Inertial Profiler (IP) and competent operator to measure pavement surface deviations in the longitudinal direction. The computer shall generate a profile index, using a 5.08 mm (0.2 inch) blanking band and the required bump threshold based upon the speed limit of the segment, to identify "must grind" locations.

In the longitudinal direction, determine deviations according to California Test Method 526. In the transverse direction, determine deviations using a 0.9144 m (3 foot) straightedge. See Figure C 5-694.690 for an example of a 3 foot straightedge.

**Figure A 5-694.690**


**Figure B 5-694.690**

**Figure C 5-694.690**

## B. Ride Quality

The Engineer will determine the final ride quality based on the results of the California profilograph or Lightweight Inertial Profiler data.

Only bridge surfaces, bridge approach panels, and pavements within 75 m (250 feet) of a terminal header, not adjacent to a paved surface, are exempt from ride quality requirements.

## C. Smoothness Measuring Device Certifications

Certified smoothness-measuring devices are required by Contract, for evaluating final mainline smoothness on Agency concrete paving projects. The procedure for certification of smoothness measuring devices is on file in the Mn/DOT Concrete Engineering Unit. Regardless of when a smoothness device is certified, the certification is only valid for the remainder of the same calendar year. A decal is issued to each smoothness device and is displayed on the device in an obvious location at all times the device is present on an Agency construction project.

Certification does not eliminate the need for daily calibration of the smoothness device on the project site.

## 5-694.691 ROUTINE CORE DRILLING

It is standard practice to drill and test cores from finished concrete pavements. Concrete base, curb and gutter work, sidewalks, and bridge construction may also require coring. These cores are taken to determine the thickness of the pavement and the concrete strength. They are sent to the Mn/DOT Office of Materials to determine their height. This verifies the thickness of the pavement for compliance with Specification 2301.3P2.

Cores are tested for compressive strengths at an age of 60 days. In specialized cases, cores are tested for durability by measuring their resistance to freezing and thawing. The Project Engineer is responsible for determining coring locations for paving. The Project Engineer arranges to have the core locations marked on the pavement for the guidance of the Contractor's core driller. The locations are determined using a random number table. See Figure A 5-694.691 for a random number table. Mainline pavement is divided into 1500 m (5000 ft.) sections as specified in 2301.3P2. Each section requires 1 core every 300 m (1000 ft.) per lane. Therefore, a standard 8.2 m (27 ft.) wide roadway requires 10 cores per 1500 m (5000 ft.), 5 in each lane. Turn lanes, bypass lanes, tied shoulders and third lanes are separated into their own sections.

The steps for core layout are:

See Figure B 5-694.691 (English)

1. Divide project into 1500 m (5000 ft.) sections.
2. Divide sections into 300 m (1000 ft.) subsections.
3. Calculate the number of cores required in each subsection.
4. Use a random number system to choose the station and location of each core. Stay 0.5 m (2 ft.) away from edges and centerline.
5. List the core locations on the *Field Core Report* (Form 24327). See Figure A 5-694.742.

It frequently happens that the list location of a core coincides with that of a joint or manhole. In these cases, the Engineer is to shift the core location so that it is not drilled closer than 1.5 m (5 ft.) from the joint or manhole. The Engineer then records the revised location on the list.

Mark core locations by painting a 150 mm (6 in.) circle. The station location is painted alongside the circle. After the core is drilled, the drill operator will mark the core number on the top and the station number on the side.

The Agency shall field measure the core thickness and compare to the required thickness. If any core thickness is short by more than the tolerances allowed in Specification 2301.3P2, the Contractor shall take additional cores to find the extent of the thin pavement. It is best to measure the core thickness soon after it is taken so any additional cores, if required, are taken while the equipment is still at the project.

The Agency should check the cores against the list and see that all cores are properly marked before the driller leaves the project. Results of the tests obtained from the cores are furnished to the Project Engineer.

## RANDOM NUMBERS TABLE

| | | | | |
|---|---|---|---|---|
| .53 .74 .23 .99 .67 | .61 .32 .28 .69 .84 | .94 .62 .67 .86 .24 | .98 .33 .74 .19 .95 | .47 .53 .53 .38 .09 |
| .63 .38 .06 .86 .54 | .99 .00 .65 .26 .94 | .02 .72 .90 .23 .07 | .79 .62 .67 .80 .60 | .75 .91 .12 .81 .19 |
| .35 .30 .58 .21 .46 | .06 .72 .17 .10 .94 | .25 .21 .31 .75 .96 | .49 .28 .24 .00 .49 | .55 .65 .79 .78 .07 |
| .63 .43 .36 .82 .69 | .65 .51 .18 .37 .88 | .61 .38 .44 .12 .45 | .32 .92 .85 .88 .65 | .54 .34 .81 .85 .35 |
| .98 .25 .37 .55 .26 | .01 .91 .82 .81 .46 | .74 .71 .12 .94 .97 | .24 .02 .71 .37 .07 | .03 .92 .18 .66 .75 |
| .02 .63 .21 .17 .69 | .71 .50 .80 .89 .56 | .38 .15 .70 .11 .48 | .43 .40 .45 .86 .98 | .00 .83 .26 .91 .03 |
| .64 .55 .22 .21 .82 | .48 .22 .28 .06 .00 | .61 .54 .13 .43 .91 | .82 .78 .12 .23 .29 | .06 .66 .24 .12 .27 |
| .85 .07 .26 .13 .89 | .01 .10 .07 .82 .04 | .59 .63 .69 .36 .03 | .69 .11 .15 .83 .80 | .13 .29 .54 .19 .28 |
| .58 .54 .16 .24 .15 | .51 .54 .44 .82 .00 | .62 .61 .65 .04 .69 | .38 .18 .65 .18 .97 | .85 .72 .13 .49 .21 |
| .34 .85 .27 .84 .87 | .61 .48 .64 .56 .26 | .90 .18 .48 .13 .26 | .37 .70 .15 .42 .57 | .65 .65 .80 .39 .07 |
| .03 .92 .18 .27 .46 | .57 .99 .16 .96 .56 | .30 .33 .72 .85 .22 | .84 .64 .38 .56 .98 | .99 .01 .30 .98 .64 |
| .62 .95 .30 .27 .59 | .37 .75 .41 .66 .48 | .86 .97 .80 .61 .45 | .23 .53 .04 .01 .63 | .45 .76 .08 .64 .27 |
| .08 .45 .93 .15 .22 | .60 .21 .75 .46 .91 | .98 .77 .27 .85 .42 | .28 .88 .61 .08 .84 | .69 .62 .03 .42 .73 |
| .07 .08 .55 .18 .40 | .45 .44 .75 .13 .90 | .24 .94 .96 .61 .02 | .57 .55 .66 .83 .15 | .73 .42 .37 .11 .16 |
| .01 .85 .89 .95 .66 | .51 .10 .19 .34 .88 | .15 .84 .97 .19 .75 | .12 .76 .39 .43 .78 | .64 .63 .91 .08 .25 |
| .72 .84 .71 .14 .35 | .19 .11 .58 .49 .26 | .50 .11 .17 .17 .76 | .86 .31 .57 .20 .18 | .95 .60 .78 .46 .75 |
| .88 .78 .28 .16 .84 | .13 .52 .53 .94 .53 | .75 .45 .69 .30 .96 | .73 .89 .65 .70 .31 | .99 .17 .43 .48 .76 |
| .45 .17 .75 .65 .57 | .28 .40 .19 .72 .12 | .25 .12 .74 .75 .67 | .60 .40 .60 .81 .19 | .24 .62 .01 .61 .16 |
| .96 .76 .28 .12 .54 | .22 .01 .11 .94 .25 | .71 .96 .16 .16 .88 | .68 .64 .36 .74 .45 | .19 .59 .50 .88 .92 |
| .43 .31 .67 .72 .30 | .24 .02 .94 .08 .63 | .38 .32 .36 .66 .02 | .69 .36 .38 .25 .39 | .48 .03 .45 .15 .22 |
| .50 .44 .66 .44 .21 | .66 .06 .58 .05 .62 | .68 .15 .54 .35 .02 | .42 .35 .48 .96 .32 | .14 .52 .41 .52 .48 |
| .22 .55 .22 .15 .86 | .26 .63 .75 .41 .99 | .58 .42 .36 .72 .24 | .58 .37 .62 .18 .51 | .03 .37 .18 .39 .11 |
| .96 .24 .40 .14 .51 | .23 .22 .30 .88 .57 | .95 .67 .47 .29 .83 | .94 .69 .40 .06 .07 | .18 .16 .36 .78 .86 |
| .31 .73 .91 .61 .19 | .60 .20 .72 .93 .48 | .98 .57 .07 .23 .69 | .65 .95 .39 .69 .58 | .56 .80 .30 .19 .44 |
| .78 .60 .73 .99 .34 | .43 .89 .94 .36 .45 | .56 .69 .47 .07 .41 | .90 .22 .91 .07 .12 | .78 .35 .34 .08 .72 |
| .84 .37 .90 .61 .56 | .70 .10 .23 .98 .05 | .85 .11 .34 .76 .60 | .76 .48 .45 .34 .60 | .01 .64 .18 .39 .96 |
| .36 .67 .10 .08 .23 | .98 .93 .35 .08 .86 | .99 .29 .76 .29 .81 | .33 .34 .91 .58 .93 | .63 .14 .52 .32 .52 |
| .07 .28 .59 .07 .48 | .89 .64 .58 .89 .75 | .83 .85 .62 .27 .89 | .30 .14 .78 .56 .27 | .86 .63 .59 .80 .02 |
| .10 .15 .83 .87 .60 | .79 .24 .31 .66 .56 | .21 .48 .24 .06 .93 | .91 .98 .94 .05 .49 | .01 .47 .59 .38 .00 |
| .55 .19 .68 .97 .65 | .03 .73 .52 .16 .56 | .00 .53 .55 .90 .27 | .33 .52 .29 .38 .87 | .22 .13 .88 .83 .34 |
| .53 .81 .29 .13 .29 | .35 .01 .20 .71 .34 | ★.62 .33 .74 .82 .14 | .53 .73 .19 .09 .03 | .56 .54 .29 .56 .93 |
| .51 .86 .32 .68 .92 | .33 .98 .74 .66 .99 | .40 .14 .71 .94 .58 | .45 .94 .19 .38 .81 | .14 .44 .99 .81 .07 |
| .35 .91 .70 .29 .13 | .80 .03 .54 .07 .27 | .96 .94 .78 .32 .66 | .50 .95 .52 .74 .33 | .13 .80 .55 .62 .54 |
| .37 .71 .67 .95 .13 | .20 .02 .44 .95 .94 | .64 .85 .04 .05 .72 | .01 .32 .90 .76 .14 | .53 .89 .74 .60 .41 |
| .93 .66 .13 .83 .27 | .92 .79 .64 .64 .72 | .28 .54 .96 .53 .84 | .48 .14 .52 .98 .94 | .56 .07 .93 .89 .30 |
| .02 .96 .08 .45 .65 | .13 .05 .00 .41 .84 | .93 .07 .54 .72 .59 | .21 .45 .57 .09 .77 | .19 .48 .56 .27 .44 |
| .49 .83 .43 .48 .35 | .82 .88 .33 .69 .96 | .72 .36 .04 .19 .76 | .47 .45 .15 .18 .60 | .82 .11 .08 .95 .97 |
| .84 .60 .71 .62 .46 | .40 .80 .81 .30 .37 | .34 .39 .23 .05 .38 | .25 .15 .35 .71 .30 | .88 .12 .57 .21 .77 |
| .18 .17 .30 .88 .71 | .44 .91 .14 .88 .47 | .89 .23 .30 .63 .15 | .56 .34 .20 .47 .89 | .99 .82 .93 .24 .98 |
| .79 .69 .10 .61 .78 | .71 .32 .76 .95 .62 | .87 .00 .22 .58 .40 | .92 .54 .01 .75 .25 | .43 .11 .71 .99 .31 |
| .75 .93 .36 .57. 83 | .56 .20 .14 .82 .11 | .74 .21 .97 .90 .65 | .96 .42 .68 .63 .86 | .74 .54 .13 .26 .94 |
| .38 .30 .92 .29 .03 | .06 .28 .81 .39 .38 | .62 .25 .06 .84 .63 | .61 .29 .08 .93 .67 | .04 .32 .92 .08 .09 |
| .51 .28 .50 .10 .34 | .31 .57 .75 .95 .80 | .51 .97 .02 .74 .77 | .76 .15 .48 .49 .44 | .18 .55 .63 .77 .09 |
| .21 .31 .38 .86 .24 | .37 .79 .81 .53 .74 | .73 .24 .16 .10 .33 | .52 .83 .90 .94 .76 | .70 .47 .14 .54 .36 |
| .29 .01 .23 .87 .88 | .58 .02 .39 .37 .67 | .42 .10 .14 .20 .92 | .16 .55 .23 .42 .45 | .54 .96 .09 .11 .06 |
| .95 .33 .96 .22 .00 | .18 .74 .72 .00 .18 | .38 .79 .58 .69 .32 | .81 .76 .80 .26 .92 | .82 .80 .84 .25 .39 |
| .90 .84 .60 .79 .80 | .24 .36 .59 .87 .38 | .82 .07 .53 .89 .35 | .96 .35 .23 .79 .18 | .05 .98 .90 .07 .35 |
| .46 .40 .62 .98 .82 | .54 .97 .20 .56 .95 | .15 .74 .80 .08 .32 | .16 .46 .70 .50 .80 | .67 .72 .16 .42 .79 |
| .20 .31 .89 .03 .43 | .38 .46 .82 .68 .72 | .32 .14 .82 .99 .70 | .80 .60 .47 .18 .97 | .63 .49 .30 .21 .30 |
| .71 .59 .73 .05 .50 | .08 .22 .23 .71 .77 | .91 .01 .93 .20 .49 | .82 .96 .59 .26 .94 | .66 .39 .67 .98 .60 |

**Figure A 5-694.691**

**THIS IS AN EXAMPLE OF A TYPICAL CORE LAYOUT. (English)**

Step 1- Divide project into 1500 m (5000 ft.) sections.
Step 2- Divide project into 300 m (1000 ft.) sections.
Step 3- Calculate the number of cores required in each subsection.

| BEGIN | | 1000 ft. | | 1000 ft. | | 1000 ft. | | 1000 ft. | | END |
|---|---|---|---|---|---|---|---|---|---|---|
| 3958+00 | 2 | 3968+00 | 2 | 3978+00 | 2 | 3988+00 | 2 | 3998+00 | 2 | 4008+00 |
| 4008+00 | 2 | 4018+00 | 2 | 4028+00 | 2 | 4038+00 | 2 | 4048+00 | 2 | 4058+00 |
| 4058+00 | 2 | 4068+00 | 2 | 4078+00 | 2 | 4088+00 | 2 | 4098+00 | 2 | 4108+00 |
| 4108+00 | 2 | 4118+00 | 2 | 4128+00 | 2 | 4138+00 | 2 | 4148+00 | 2 | 4158+00 |
| 4158+00 | 2 | 4168+00 | 2 | 4178+00 | 2 | 4188+00 | 2 | 4198+00 | 2 | 4208+00 |
| 4208+00 | 2 | 4218+00 | 2 | 4228+00 | 2 | 4238+00 | 2 | 4248+00 | 2 | 4258+00 |
| 4258+00 | 2 | 4268+00 | 2 | 4278+00 | 2 | 4288+00 | 2 | 4298+00 | 2 | 4308+00 |
| 4308+00 | 2 | 4318+00 | 2 | 4325+86 | | | | | | |

Where 2 = Number of Cores Required in this case.

Total cores required is 74 - 7 full sections with 10 per section and 4 for the remaining section.

Step 4- Use a random number system to choose the station and location of each core. Alternate Left and Right.

Started with 0.62 and 0.33 on random number chart. Use numbers as decimal (i.e. 6.2 and 3.3). The first number is added for stations and the second is position from centerline.

3958+00 plus 6.2 6 Stations = 3964+20
3.3 rounds to 3 feet

Stay 0.5 m (2 feet) away from edges and centerline.

| | | | | | |
|---|---|---|---|---|---|
| Sec. 1 | 3964+20 | 3R | Sec. 3 | 4087+20 | 9R |
| | 3968+20 | 2L | | 4096+20 | 2L |
| | 3977+80 | 9R | | 4099+30 | 8R |
| | 3984+20 | 8L | | 4103+70 | 2L |
| | 3987+00 | 5R | | 4104+90 | 9R |
| | 3996+30 | 2L | | 4111+90 | 2L |
| | 4003+50 | 4R | | 4113+20 | 4R |
| | 4006+90 | 4L | | 4120+10 | 4L |
| | 4015+80 | 2R | | 4126+60 | 2R |
| | 4024+50 | 2L | | 4131+40 | 2L |
| Sec. 2 | 4031+90 | 2R | Sec. 4 | 4138+60 | 8R |
| | 4038+10 | 2L | | 4146+60 | 6L |
| | 4043+20 | 10R | | 4149+30 | 8R |
| | 4050+50 | 2L | | 4158+90 | 6L |
| | 4054+70 | 2R | | 4168+60 | 2R |
| | 4058+50 | 8L | | 4170+30 | 2L |
| | 4066+70 | 2R | | 4177+20 | 3R |
| | 4068+20 | 7L | | 4184+60 | 8L |
| | 4071+40 | 2R | | 4186+20 | 2R |
| | 4080+50 | 2L | | 4189+80 | 7L |

Continue on with the remaining sections.

**Figure B 5-694.691**

## REFERENCES


1. Figure A 5-694.603, Design and Control of Concrete Mixtures, 14th Edition, Portland Cement Association, 2002.
2. Figure B 5-694.603, Design and Control of Concrete Mixtures, 14th Edition, Portland Cement Association, 2002.
3. Section 5-694.630 through 5-694.657, FHWA HI-02-018, NHI Course 13133 - Construction of Portland Cement Concrete Pavements, American Concrete Pavement Association, 2000.