Chapter 7 - Concrete Pavements

2-701 New Pavement

Concrete pavement consists of a mixture of portland cement, fine and coarse aggregate, and water. Additives may be used to entrain air in the concrete or to retard set. Fly ash may be used to replace part of the portland cement. The pavement may be reinforced with steel fabric or bars.

There are two basic types of concrete plants. Central mix plants proportion and mix the concrete. Dry batch plants only proportion the ingredients of the concrete; the concrete is mixed in trucks. Either of the two types of plants may furnish concrete for a paving project.

The pavement is supported by the subgrade and subbase. Volume 2, Chapter 5, “Base Courses,” covers these two subjects. Because the quality of the subgrade and subbase are very important in concrete paving, selected parts of subgrade and subbase construction are covered in this chapter, as well.

There are two basic methods of placing and finishing concrete pavements: side-form paving and slip-form paving. Stationary forms are used in side-form paving. The forms are built to the line and grade of the finished pavement, and the paving equipment rides on the forms. Slip-form paving usually uses string lines for line and grade. The paving units are equipped with sensors that run along the string lines. Concrete is contained by short side-forms built into the paving equipment. Both of the two basic methods are included in the chapter.

Before the concrete is placed, the subgrade is prepared, and the subbase is constructed. Forms or string lines are set, depending on the type of paving operation. Steel dowels are put in position at joints. The concrete is mixed at a central plant or in a truck mixer. While the concrete is being placed, joints are formed, and steel reinforcement is placed, if it is required. After the concrete is placed and its surface is finished, it must be cured and protected from damage while it gains strength. Before the highway is opened to traffic, the joints must be sealed.

2-702 Specifications and Plans

2-702A Specifications

Article 4.01 of Standard Specifications contains information about the mixing of concrete for pavements and the methods of construction for placing and finishing concrete pavements, as well as the methods of measurement and bases of payment for the associated contract items. Article M.03 of the Standard Specifications contains information about the materials used for concrete mixes, and Article M.06.01 addresses steel reinforcement. The contract special provisions and the Standard Specifications are binding on both the State and contractor in the performance of the work.

2-702B Plans

Contract plans provide information related to roadway pavements:

- The typical cross sections show the location, depth, width, and class of pavement to be constructed.
- The plan sheets provide a visual representation of the roadway and the width of the roadway at specific stations.
- The cross sections show finished pavement line and grade by station.
2-703 Inspection Team

The Chief Inspector assembles a paving team consisting of Concrete Inspectors, Form Inspectors, Paving Inspectors, and Finishing Inspectors. The team should be organized as far in advance of the actual paving as practicable. The Chief Inspector should make all members of the paving team aware of their specific duties and make certain they are familiar with the contract specifications.

The Chief Inspector is responsible for the performance and quality of the work, the inspection service, and the inspection personnel assigned to the project. Because of the many operations being performed during the paving phase of the work and the time limitations imposed on them, complete cooperation between the members of the paving team and the Chief Inspector is required.

2-704 Mix Request

Annually, the Central Laboratory approves the operation of all concrete batch plants that will furnish concrete to DOT projects. Additionally, all materials to be incorporated in concrete mixes are tested for approval. The Laboratory designs the standard DOT concrete mixes for each concrete plant. If the concrete for the paving project is furnished from an approved plant, the Chief Inspector should obtain a copy of the approved mixes. An example mix design is shown in Figure 2-7.1.

The contractor may deviate from the approved mixes or use an unapproved plant, such as a batch plant at the construction site. All mix changes require Laboratory approval. Unapproved plants require Laboratory approval and mix designs.

The Chief Inspector should check the contract special provisions for special requirements on additives, aggregate size, cement, and air content. For a mix design, the volume of the batch should not exceed the manufacturer's rated capacity of the drum by more than 10 percent.

2-705 Materials Control

Material sampling requirements are in the publication “Schedule of Minimum Requirements for Sampling Material for Test,” published by the Division of Materials Testing. The “Schedule” shows who samples a material, the location from which samples are taken, and the frequencies of sampling. A Request for Test form (MAT-100) must accompany all samples, Certified Test Reports, Material Certificates, and items on the Approved Product List that are submitted to the Laboratory. The Request for Test form is discussed in Volume 1, Chapter 4, “Materials Testing,” where a form example can be found.

The Chief Inspector sees that samples of all materials to be incorporated in the work, except materials tested at their sources, are forwarded to the Materials Testing Division as soon as the materials arrive on the job. If a material is to be tested at its source, the Inspector sends a Request for Test form (MAT-100) to the District Laboratory. The Laboratory representative for the District takes the sample.

Materials cannot be used until a favorable test report is received from the Materials Testing Division or until the Engineer gives written permission. The State does not pay for work in which unapproved materials are used.
**Figure 2-7.1 Mix Design**

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**PORTLAND CEMENT CONCRETE MIX DESIGN**

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<th>April 2003</th>
<th>Producer:</th>
<th>Tilcon CT</th>
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<tbody>
<tr>
<td>Class:</td>
<td>PAVEMENT</td>
<td>Location:</td>
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**Coarse Aggregate**

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<th>Traprock</th>
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<tbody>
<tr>
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<td>Tilcon CT</td>
</tr>
<tr>
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**Fine Aggregate**

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<tr>
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</tr>
<tr>
<td>Location:</td>
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**Cement**

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</tr>
<tr>
<td>Location:</td>
<td>Catskill, NY</td>
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</table>

**BATCH INFORMATION**

- **Cement:** 615 lb, 365 kg
- **Water:** 285 lb, 169 kg
- **Coarse Aggregate:**
  - #4: 825 lb, 489 kg
  - #6: 625 lb, 371 kg
  - #8: 525 lb, 311 kg
- **Fine Aggregate:** 1120 lb, 669 kg

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**Approved Admixtures:** Darex II, WRDA w/hycot

1) All weights (masses) are in pounds for one cubic yard (kg for one cubic meter) of concrete.
2) One gallon of water weighs (has a mass of) 8.33 lbs (3.78kg).
3) Mix design is based on the weight (mass) of dry aggregate (i.e., the delivered aggregate weight (mass) will be adjusted due to moisture and the amount of water will be decreased).
4) “Butter batches” used for the coating of washed truck mixers shall be in accordance with section 6.01.03(b) of the Standard Specifications, and shall be reflected on the batch ticket.
5) Original mix design from the producer has been approved and is on file at the Division of Materials Testing, 261 West Street, Rocky Hill, Connecticut 06067.
2-706 Batching and Mixing Equipment

There are two basic types of concrete plants:

- Dry-batch plants proportion the ingredients of the concrete but do not mix the concrete. The concrete is mixed in trucks.

- Central-mix plants proportion and mix the concrete.

Most central-mix plants are automated. There are a few that are not automated, but they are used infrequently. Dry-batch plants are not common in Connecticut. They are used on occasion for limited concrete pavement operations. Generally, they serve as backup plants. Truck-mixed or transit-mixed concrete may be used only with the written permission of the Engineer for limited amounts of pavement and for exceptional cases.

The Chief Inspector is responsible for seeing that batching and mixing equipment is inspected and approved as meeting the requirements of the contract specifications. The Inspector performs much of the required inspection, although parts of the inspection must be performed by other agencies or divisions of the Department. For example, batch-plant scales are sealed by the Department of Consumer Protection, Weights and Measures. As mentioned, the Division of Materials Testing approves all batch plants.

2-707 Plant Personnel

The District is responsible for furnishing Batch Inspectors if they are needed. Automated central-mix plants that are approved by the Laboratory do not require Batch Inspectors. Approved nonautomated plants and dry-batch plants require oversight from Batch Inspectors during the start of operations, when changes are made in the mix, and when the Chief Inspector considers it necessary.

Batch-plant personnel and Inspectors must become familiar with and must enforce Article 4.01.03 of the Standard Specifications and the rules and procedures that have been set up by the Department governing the control of batching operations. Batch-plant personnel cannot waive any rules or requirements set up by the Department for the control of batching operations. They cannot change the mix, except for adjustments to compensate for variations in water content of the materials. The Chief Inspector should be consulted immediately on any question about the performance of the contractor or operations connected with the plant.

2-708 Truck Mixers

Truck mixers must be certified by the National Ready Mix Concrete Association or approved equal. Certification stickers, verifying approval, will be located on the drivers side door of all certified vehicles.

If the use of truck mixers and truck-mixed or transit-mixed concrete is allowed, the provisions of the Standard Specifications must be applied fully. The Chief Inspector or the Concrete Inspector must check to ensure that each truck mixer has been inspected and approved by the Division of Materials Testing and become familiar with Article 4.01.03–C of the Standard Specifications.

2-709 Preliminary Checks

The Inspector should conduct preliminary checks of labor for finishing the pavement, miscellaneous tools for placing
and finishing, and sampling and testing equipment. The checks should be performed well in advance of the paving operations to allow sufficient time to correct items that do not pass inspection. If cold weather is expected, the Inspector should check that the proper provisions are on hand.

### 2-710 Finishing Labor

The Inspector should check the staffing for the concreting operation with the contractor to see if sufficient finishers are assigned to satisfactorily complete the pavement as it is placed. For guidance, the Inspector can compare the actual staffing with the material submitted by the contractor regarding placement and finishing.

### 2-711 Placing and Finishing Tools

The following tools must be on hand, checked, and approved before paving work starts:

- fine-grade template (scratch board),
- form gauge
- transverse expansion and contraction joints,
- joint caps,
- large square for setting bulkheads and transverse joints,
- vibrators for consolidating concrete along the sides of the forms,
- two concrete spades or two immersion-type high-frequency vibrators,
- a hand-operated screed that can be used in case of breakdown of the finishing machine,
- a burlap drag for finishing,
- material for foot bridges,
- ¾ in. × 1½ in. (19 mm × 38 mm) spring-steel strips to serve as guides for finishing the expansion joints,
- a device for forming joints,
- at least three lutes of an approved type,
- a master straightedge,
- two 10 ft. (3 m) aluminum straightedges,
- edging tools,
- a hose line or watering carts for curing, and
- curing mats.

The Inspector should check the dimensions and trueness of the fine-grade template and form gauge. All lutes and straightedges should be checked with a string or wire before the operation starts and each morning afterward.
2-712 Testing Equipment

The Inspector should ensure that the following equipment is immediately available for use:

- a slump cone and 5/8 in. (16 mm) bullet-pointed rod, including suitable platform;
- an air meter or scales and a calibrated container for determining the air content of the concrete;
- at least six cylinder molds; and
- a set of dies and brass tags.

The Inspector should check these items frequently during the project to ensure that deficiencies are promptly corrected.

2-713 Cold Weather Provisions

If cold weather procedures are in effect, sufficient protection material must be on hand, together with approved means to heat water, aggregates, and the contents of the mixer drum, before paving work can proceed. If liquid membrane curing compound is used, a water bath apparatus must be provided, if necessary, to bring the material to the consistency required for application.

2-714 Subgrade

The subgrade acts as a support for the pavement structure. It must be properly shaped and compacted, and the elevation should agree with plan profile and cross-section sheets. The primary concern is to develop an embankment surface that provides firm, uniform support for the subbase and pavement.

All loose rock or boulders over 5 in. (125 mm) must be removed or broken off to a depth of not less than 12 in. (300 mm) below subgrade. The depressions made by removing the large rocks or boulders should be filled with suitable material and satisfactorily compacted.

Trouble areas should be corrected prior to placing subbase. All soft, yielding, unstable material should be removed. The work may involve excavation in fill areas, if there is an indication that the material near the surface is retaining moisture, or it may involve additional excavation in cut areas and the use of a greater subbase depth. It may indicate the need for an underdrain installation. If the surface of the embankment is low, be selective in the type of material used to bring it to grade.

The subgrade must be brought to the required elevation and thoroughly compacted with a power roller weighing not less than 10 tons (9,100 kg) or with an equivalent vibratory roller.

2-715 Subbase

Granular subbase material must conform to the requirements of Grade B, from Article M.02.06 of the Standard Specifications, and should be placed in layers not exceeding 6 in. (150 mm) after compaction. The subbase should be compacted with the correct type of compaction equipment. If hauling is done over the surface, it is important to have the traffic distributed evenly.
The Inspector should watch for hard spots in the travelway and soft spots along the edges. If water is applied, the equipment should begin working while conditions are optimum. Scarify or remove the top surface, if it develops an impervious skin because of traffic, concentration of fine soil, and/or puddling action of surface water. Tighten up soft areas with coarse material.

If slip-form paving is used, the contractor must, at no cost to the State, stabilize the subbase on which the pavement is placed and the travel path of the paver. The travel path must not vary more than 3/16 in. (5 mm) from the established grade.

In addition to increasing the structural support for the pavement, the subbase should improve the drainage of the pavement and intercept the upward flow of water caused by capillary action. The Inspector should check the plans for the location of subbase depth changes and eliminate any potential water traps by providing outlets.

If subbase is placed in cut sections, the Inspector must be sure that the underdrains provided for extra depth sections are functioning such that no water is trapped below the subbase. If suitable underdrains were not provided, they must be installed before any concrete is placed.

The grade of the subbase should be left slightly on the high side. The subbase should never be left low so that it is necessary to place material along or under the forms to raise them to the desired grade. The subbase should be brought up to just above fine-grade level prior to beginning form work. The slight excess of material is then removed during the fine grading and form setting operations and disposed of outside of the lane area.

The contractor is required to protect the subbase against the action of the elements or any damage resulting from construction activities. The contractor must provide for draining surface water from the subbase at all times. After the forms are placed, the contractor must take care to prevent water from collecting on the subbase and softening the subbase or forming muddy pockets.

2-716 Side Forms

2-716A Reference Line

The Inspector must use an offset longitudinal grade line as a reference line to check the location of the actual form line. Following the semifinal grading of the subbase material, the survey party establishes an offset longitudinal grade line parallel to the roadway base line, centerline, or lane lines.

2-716B Form Condition

When the forms are first spread out, the Chief Inspector assigns the Concrete Inspector to straightedge each individual form to ensure that each form is free of warps and bends. The top surface must not show a deviation from a straight line of more than 1/8 in. (3 mm) in 10 feet (3 m). The lateral deviation must not exceed 1/4 in. (6 mm) per 10-ft. (3-m) section of form. The form locks must be checked to ensure that the forms can be properly locked together when set.

If the forms are bent, twisted, or have irregularities of any kind, the Inspector must order them removed from the work until the defects are corrected. If necessary, the Inspector should mark the forms needing repair with paint. Forms must be clean of all dirt, concrete particles, and rust. Approval of the forms on another project is no reason to accept them.

2-716C Bracing Pins

At least three bracing pins are used to anchor a section of form. The size and length of the pins is important. The requirements vary with differing subsoil materials. However, the pins must be of sufficient size and length to hold the
forms firmly in the required position. If the forms show movement during the first placing of concrete, or through use of a fine grading machine, the size and length of the pins are one of the chief items of possible correction.

2-716D Wooden Forms

A wooden form usually is made of well-seasoned lumber of adequate thickness and of a width equal to the depth of the pavement to be placed against it. The form must be thoroughly pinned and braced so that deviations in the line or grade of the completed pavement do not exceed the allowance of the specifications.

2-716E Sharp Curves

If a curve is so sharp that the use of standard steel forms will result in a series of chords, wooden forms or acceptable metal forms must be used. Saw cuts are made at frequent intervals, when necessary, in wooden forms to obtain the true curvature. For a sharp curve, the Inspector must not approve the use of standard steel forms and then depend on the finisher to edge a true line at peaks of the curve. It cannot be done satisfactorily.

2-716F Line and Grade

Before placing the forms, the alignment and grade of the lane, as indicated by the concrete stakes, are transferred to steel pins placed on the actual form line. Offset measurements are made, and the pins are placed for line so that the outer face of a pin is on the edge of the lane. Grades are transferred, and the form grade is marked on the pins with a sharp keel or scratch mark. Masons line, free from knots, is attached at grade elevation and stretched from pin to pin. The line should be carefully checked by eye for any minor irregularities or kinks in either alignment or grade. The string line closely represents the top inside edge of the forms. A slight lateral allowance usually must be made for the longitudinal keyway.

At points of intersection, change of pavement widths or other special joints, a special form layout must be planned so that no featheredge is left. For this reason, it generally is necessary to build the beginning of the flare or taper with the nearest adjacent lane. This special construction should be planned to extend 12 in. (300 mm) or more outside the normal lane edge. An example layout is shown in Figure 2-7.2.

When placing forms adjacent to a completed lane, a grade line should be used. Elevation checks should be made using the completed lane as a grade line, applying the pavement crown or superelevation.

2-716G Form Placement

Forms are set only after the subbase is properly prepared, including the area under the forms. The Inspector must ensure that forms rest firmly on a prepared surface throughout their entire length and width.

The form area is excavated by hand to pavement depth below the string, and each section of form is placed in its approximate position. When a few hundred feet (hundred meters) of forms have been placed, final adjustment is made to the positions of the forms.

Before any concrete is placed, the forms must be in proper alignment and grade for at least 500 ft. (150 m) in advance of a single-lane-width paving operation. The Chief Inspector may allow some deviation from this rule. However, the Inspector may never permit concrete to be mixed and placed if less than 350 ft. (100 m) of forms are properly set in advance of the strike-off machine. If less than 350 ft. (100 m) are ready for pavement, the paving operation must be shut down until the form work is carried ahead at least the initial 500 ft. (150 m). The Chief Inspector must report deviations from the rule to the Project Engineer. The number of deviations should be kept to a minimum.
When approaching or leaving horizontal or vertical curves, the Inspector must ensure that sufficient forms are set ahead to make a satisfactory transition.

The surfaces of all forms that come in contact with the concrete must be thoroughly cleaned and lightly coated with oil. Leaning forms or forms sprung into line are removed and reset.

When paving operations are in progress, the Concrete Inspector must be assured that the forms immediately in advance of the strike-off machine have not been forced out of line by the trucking equipment operating between or adjacent to the forms. If forms are forced out of line, immediate adjustment must be made to bring the forms back and hold them in their original positions.

**2-716H Longitudinal Joint Key**

The longitudinal construction-joint key is placed in accordance with the standard paving details and must be securely held in position so that it will not move out of alignment if the concrete along the forms is spaded or vibrated. It must extend to within 6 in. (150 mm) of each transverse expansion joint, and particular care must be taken to see that the extremities of the key are supported in the proper alignment.
2-717  String Lines

2-717A  Slip-Form String Lines

Slip-form paving operations usually use equipment units that automatically sense line and grade from a string line. One string line usually is used for both fine grading and paving. It is set on one or both sides of the grade, depending on the design of the equipment. Regardless of the terrain over which the machine must track, it will maintain the grade indicated by the string line. It is important that the string line is as accurate as practicable.

2-717B  Normal String-Line Setting

The location of the metal stakes that support the string line is oriented to the grade stakes. Before the hubs are set, the terrain should be visually inspected by the survey party. The following factors must be considered before any hubs are set, to determine the most feasible location for the string line:

- other work that may be performed either between the string lines or along the shoulders,
- the amount of material to be wasted near the string lines and the disposition to be made of the material,
- obstructions along either side of the roadway,
- the limits of the machine sensor-arm supports,
- the height of the string line above grade required for the paving equipment, and
- the percent of fall (cross slope) from the centerline of the roadway to the hubs or edge of pavement.

Location of the string line may vary with each section of the roadway because of superelevations, crowns, and offsets. Each section should be evaluated separately to determine the proper location or position of the line.

Hubs are set after considering the factors above. Setting hubs is one of the more critical phases of the paving operation, as the line and grade for all following work depends on them. The Chief Inspector must ensure that a DOT survey party checks the completed hub run for accuracy of line and grade prior to installing the string line.

Metal stakes are driven into the ground, normally at 50 ft. (15 m) intervals, along one side of the roadway if using a machine equipped with a cross-slope system or along both sides of the roadway if using a machine with sensors installed on both sides. On ramps and superelevations, stakes may be set at 25 ft. (7.5 m) intervals for greater accuracy.

The stake should be located 12 in. (300 mm) to the rear of the hub. It should be vertical and driven deep enough for good stability. The slotted end of the string-line rod must be directly over the center of the tack in the top of the hub and slightly above the intended string-line elevation. The Inspector can use a rule to measure the height of the road above the tack and a plumb bob to assure the rod end is over the tack. Figure 2-7.3 shows a typical setup.

The string line itself is checked, after it is installed and tensioned, so that no sag between stakes is visible. Check the string line with a rule for the exact height above the tack. After the string line is adjusted to the exact height, check for a smooth alignment of the string line by sighting down the line.


2-717C String-Line Repairs

A break in the string line can be repaired by tying the string line together with a square knot. The knot does not affect the accuracy of the machine but must be tied securely enough to permit retensioning of the string line.

If the string line is repaired, moved, damaged, or partially dismantled for any reason, paving operations must be halted until the line can be reset and rechecked. During actual grading or paving operations, a constant watch over the string line must be maintained to prevent interference of any kind from causing a deflection in the line. Examples are personnel leaning against the line, lifting the line to crawl under, and hanging coats or tools on the line, and stakes being nudged by passing equipment.
2-718  Fine Grade

The fine-grade elevation may be determined from accurately set forms or completed lanes of pavement. The Chief Inspector assigns the work to the inspector ahead of the paving operation. It is that inspector's responsibility to see that the subbase is ready to receive the concrete pavement.

The grading is checked with an approved template or scratch board as grading progresses. The bottom contour of the scratch board must conform precisely to the desired contour of the subbase.

The template may be furnished by the contractor and designed to ride the forms; it should be moved along as the fine grading operation progresses. Areas where the points scratch the surface must be cut down and low areas filled in and compacted. There should be at least two templates available for use. When the templates are in use, they must be checked at least twice daily by the Inspector. The Inspector also can check the grade with the use of string lines tied between each form.

If the fine grading is done by a machine, it is adjusted to cut accurately to the required grade. The Inspector must check the fine grade as conscientiously as if the work was done by hand. Some fine grading machines produce a lateral thrust that causes the forms to rock and the form pins to become loose. If this occurs, the operation of the machine must be immediately corrected, or the forms must be more firmly fastened, so that there is no further rocking of the forms.

The current trend favors an adjustable blade unit that is mounted on a grader. The grader works between the forms. The blade unit rolls along the top of the forms, and the surplus material is carried along within the forms and usually removed with a front-end loader. The grade of the blade can be closely controlled, and only a minimum amount of hand labor is required to complete the shaping operation.

Immediately after grading to the required elevation, the fine grade is rolled with an approved roller. The subgrade template is drawn over the completed area for a final check, and irregularities are corrected. The Inspector must be sure that the entire depth of the forms, including bottom edges, is fully exposed.

When concrete is being placed, any irregularities in the subbase surface caused by trucking equipment working between forms must be reshaped and rolled, as needed. If the trucking equipment ruts the subbase, it is an indication that the subbase is not in proper condition for the work.

The Concrete Inspector must continually observe the condition of the fine grade surface immediately ahead of the paving train and keep a close check on its elevation and state of compaction. The check must be by template, as described above. The Inspector should see that the fine grade is thoroughly dampened well in advance of the paving train to prevent drawing excessive amounts of water from the fresh concrete. The procedure of dampening the fine grade must be regulated so that concrete is never placed within 100 ft. (30 m) of the sprinkled fine grade. Concrete must never be placed on a subbase that contains frost.

2-719  Joints

2-719A  Transverse

Transverse joint layout is the responsibility of the field forces. Approximate locations of the transverse expansion and contraction joints can be determined well in advance of the paving operation. It is customary to plot the various joints on a set of construction plans. The preferred spacing of the joints is as shown in Figure 2-7.4 and Standard Sheet 401-A.

At bridge structures, ramps or pavement widening it usually is necessary to adjust the length of one or two pavement slabs. The maximum desired length of a slab is 50 ft. (15 m); the minimum length is 20 ft. (6 m). If it is necessary to adjust a slab length, consideration should be given to the length of the fabric or mat reinforcement. The use of short
lengths is discouraged. Adequate provisions must be made for expansion. The maximum expansion-joint spacing should not exceed 1000 ft. (300 m).

If pressure relief joints are called for on the plans, the contractor must construct the joints in accordance with the plan details. A sketch of a pressure relief joint is shown in Figure 2-7.5.

2-719B Longitudinal

The longitudinal joint arrangement must conform to the details shown on the plan sheets or the orders of the Engineer. The current trend in design is to show the specific locations of the longitudinal joints on a plan sheet, providing for lane continuity and delineation that best serve traffic needs. The starting and ending stations of all pavement widening must be complied with unless it is apparent that a minor change satisfies other joint criteria better.

2-719C Locating Transverse Joints

The location of joints for the first lane is made by measurement along the forms with a tape. The transverse line of the

Figure 2-7.4 Transverse Joint Layout

\[ d = \text{DISTANCE BETWEEN TRANSVERSE CONTRACTION JOINTS} = 12.160 \text{ mm} \]

TRANSVERSE EXPANSION JOINTS ARE PLACED AT INTERVALS OF NOT LESS THAN 150 m AND NOT MORE THAN 300 m, 500 FT. AND NOT MORE THAN 1,000 FT.

BE LIBERAL IN THE ESTIMATE OF TRANSVERSE EXPANSION JOINTS TO ALLOW FOR THE JOINT NECESSITATED BY END OF EACH DAY'S POUR.
joint is obtained by pulling a string across the forms and, with the use of a good square, obtaining a point on the opposite form. Be sure the line is at right angles to the centerline or on a radial line if the joint is in a curve.

After locating the first joint, the Inspector should scribe a line at right angles to the pavement surface on the inside of the forms at the locations of the other joints. If the joint is accurately located for the first lane constructed, the placing and aligning of joints in subsequent lanes is simplified. Any slight deviation in the line of the first joint probably will be amplified in the line of the adjacent joint. On dual-lane projects, care should be taken to see that the line of the joints in each lane is continuous.

There may be changes in length of an original slab because of intersections, drainage structures, inside or outside lanes on horizontal curves, or dual lanes divided by a median area. The Chief Inspector should determine the correct joint location before the concrete pavement is placed. Thus, any adjustment in slab length can be distributed among the slabs to ensure a satisfactory appearance.

**2-719D Transverse Joint Construction**

The transverse joints normally are expansion, contraction or construction joints. The expansion joint units consist of a horizontally mounted, capped, sliding dowel assembly that is attached to a compressible, yet rigid, piece of joint filler. The height of the joint filler varies with the depth of pavement. However, the top surface is always located ¾ in. (19 mm) below finish grade. Figure 2-7.6 is a drawing of an expansion joint.

A contraction-joint unit consists of a horizontal sliding dowel assembly that is installed on the subgrade and extends approximately to mid-depth of the pavement. Figure 2-7.7 is a drawing of a contraction joint. A shallow vertical joint has to be formed in the pavement surface to develop a plane of weakness over the center of the dowel assembly. The vertical joint may be formed in either of two ways:
A steel strip is installed in a holding device prior to placing the concrete. The strip should be removed following the finishing operation.
A contraction-joint groove is saw cut into the finished concrete to a depth indicated in the specifications or on the plans.

Transverse joints must be installed perpendicular to the pavement surface. If the concrete surfaces adjacent to the joint assembly are inclined, the pavement can slide upward as the slabs expand during long periods of hot weather. Transverse joints must be installed perpendicular to the centerline on tangents or radially on curves.

2-719E Load-Transfer Assemblies

Omission or improper installation of load-transfer units may result in joint faulting, transverse or corner cracking of the ends of slabs, leakage, and pumping. The joint assembly must be installed so that the longitudinal axes of the load-transfer units are not only parallel to the surface of the concrete but also parallel to the longitudinal axis of the pavement. A relatively small deviation from the correct alignment may cause a very high localized stress in the concrete surrounding a load-transfer unit, particularly during extreme temperatures that cause relatively large movements of the concrete at the joints.

Joint assemblies must not be installed until after the final check on the subbase is completed. Place the expansion assembly in the proper location. Make sure that the ends of the joint butt against the forms and coincide with the vertical line drawn on forms. The bottom of the joint, as well as the joint supports, must rest on the subbase for the entire length. Preventing mortar from flowing around the ends or under the joint helps ensure a cleaner joint, less hampered movement under temperature changes, and freedom from localized stresses.

Check all caps on load transfer units with expansion slip dowels for adequate expansion space.

The joint should be anchored in the manner indicated by the Standard Specifications or the standards attached to the plans. Recheck the line of the transverse joint with a square, and check the line of one or two load transfer units for right angles with the joint. After placing the metal protection cap on the joint, pull a string across the forms and check the depth of the joint below finished grade. Pull a string slightly ahead of the joint and check the distance down to several of the load transfer units. Repeat the operation in back of the joint. After a joint is set and checked, do not allow the workers to walk on it or to disturb it in other ways.

Tie down the transverse joint units with suitable pins or 60d nails. Be sure that the assemblies are not cocked or tipped and that the dowel component is parallel to the base and surface. Lubricate the caps on the ends of all expansion joint dowels.

2-719F Dummy Joints

Dummy transverse joints, or weakened plane joints, are constructed at the locations and according to the dimensions shown on the plans. The horizontal controls that apply to transverse expansion joints are applied to the locations and line of dummy joints.

After the transverse screeding operation is complete, but prior to longitudinal screeding or luting, a groove is made in the soft concrete by a suitable device. It should extend vertically downward from the surface to the depth shown on the plans and be true to line. Insist on a uniform depth throughout the length of the dummy joint, as well as a consistent depth for each joint. Do not allow the workers to enlarge the groove when edging. The larger the opening, the greater are the chances of obtaining a rough-riding pavement.

2-719G Bulkheads

Bulkheads are constructed if the end of a day's run or shutdown for lunch occurs at a transverse expansion joint. Install a 2 in. (50 mm) wooden bulkhead, cut to proper depth and contour, and slotted to slip over the load-transfer units in
back of the transverse joint. Securely stake the bulkhead to prevent misalignment of the joint. About 5 ft. (1.5 m)
beyond the joint, place a section of regular road form transversely across the road with its top at finished grade, for use
as a second rail. Operation of the lute at the end of the slab is to be done from the concrete and the top of this cross
form to prevent a short wave in the end of the slab.

2-719H Construction Joints

Transverse construction joints are formed only in case of breakdown causing a delay of more than 30 minutes in the
concreting operations. The length of pavement laid up to the time of breakdown cannot be less than 10 feet (3 meters)
from the nearest joint. Shorter sections must be removed. Transverse construction joints are constructed in the same
manner as transverse expansion joints, except that a bulkhead of wood or steel is used, and no expansion material or
load-transfer units are required. Tie bars conforming to the requirements of longitudinal tie bars are placed at intervals
of 2½ ft. (0.75 m) or less across all transverse construction joints.

2-719I Longitudinal Joint Construction

Longitudinal joints serve to delineate traffic lanes for the motorist. If improperly laid out, the joints can have an
adverse effect on the planned flow of traffic. Thus, it is vitally important that the pavement layout and longitudinal joint
details do not deviate from the requirements of the construction plans.

For single-lane construction, the longitudinal joint between slabs must be of the tongue-and-groove type, equipped with
tie devices. Figure 2-7.8 shows this kind of joint. The keyway form should be checked for size, shape, and proper
attachment to the pavement form. It should be continuous on the inside lane form and properly installed on the outside
lane form for abutting ramps and pavement widening. The joint keyway form should extend to within 6 in. (150 mm)
of each transverse joint. If the joint keyway form is steel, it is necessary to cut the end of the transverse expansion joint
filler material to fit. However, before placing the abutting lane, a precut piece of suitable filler material should be
placed in the form cutout. The longitudinal joint support units should be properly installed, firmly attached to the form,
and properly oriented.

The normal spacing of the tie devices is 5 ft. (1.5 m) center to center. Ten foot (three meter) forms generally have holes
spaced 2½ ft. (0.75 m) on centers. If the Inspector establishes the location of the first transverse joint closest to the
point where the forms are being set, the proper location for the tie device can be easily established. succeeding
longitudinal joint assemblies then can be installed at the prescribed spacing. If lane length differences result from
horizontal curvature or other reasons and the prescribed joint spacing and clearance cannot be satisfied, additional holes
might have to be made in the forms. The holes are usually needed at transverse joint units.

Figure 2-7.8 Longitudinal Joint

![Figure 2-7.8 Longitudinal Joint](image)
If new lanes are constructed adjacent to existing roadways, special types of longitudinal joint assemblies are specified. Grouted-in-place dowels and expansion shield bolts are frequently used.

For multilane pavement construction, the longitudinal joint support units may be installed prior to the placement of the lower course when the transverse baskets are set, or they may be placed by hand or by a mechanical placer after the lower course has been brought to grade. The joint supports consist of steel tie bars and are 5 ft. (1.5 m) on center.

Longitudinal joints for single-lane construction are usually finished by hand. For multilane construction, the joints may be formed by means of an approved nonmetallic joint forming insert or by saw cutting.

2-720 Paving Trains

Different types of equipment are needed to spread, consolidate and strike off the concrete, place reinforcement if required, and finish the pavement. The equipment units follow each other in a line during paving operations and, taken together, are called a “paving train.” The types of equipment vary considerably. Some machines perform a specific operation; others perform several.

2-720A Side-Form Paving

One type of paving train can be called the “open screed” type. Distribution of the concrete between the forms is achieved initially by spreading out the material as it is being discharged from trucks or hoppers, such that the transverse screeds on the finishing equipment can complete the placement. The train normally is made up of the following sequence of equipment units:

- a lower course strike-off machine,
- a top course strike-off machine,
- a transverse screeding machine,
- a longitudinal finishing machine, and
- a tining machine.

The transverse screeding machine can serve as the top course strike-off machine; however, this usually means it must make two passes over the pavement surface.

Another type of paving train can be called the “hopper” type. The concrete is discharged from trucks or a mixer into hopper units on the finishing machines. The hoppers travel across the lane, discharging the concrete through a hopper gate. Fixed plates and transverse screeds strike off and consolidate the concrete. This type of train usually has the following:

- a lower course strike-off machine,
- a top course strike-off machine,
- a longitudinal finishing machine, and
- a tining machine.

All of the machines probably would have transverse screeds, except for the tining machine.
Either of these paving trains is acceptable. It is permissible to place the slab full depth at one time and vibrate the reinforcement into position. Substituting a comparable piece of equipment used in one train for that used in another is permissible, providing the paving train is complete and the necessary operations are performed satisfactorily.

The paving train machinery should be placed on graded forms before the following components or operations are checked. The inspection should be performed a few days before pavement operations are scheduled to start, so that adjustments can be made without delaying work.

2-720A.1 Initial Strike-Off Spreader

The Inspector should check for the conditions listed below.

- The strike-off plate is straight and clean.
- The strike-off plate is properly set for the lower course depth.
- The distributing or spreader arm on a Blaw-Knox unit travels the full width of the lane.
- The distributing hopper on an M-xon unit travels the full width of the lane.
- The hopper gates open and close properly.
- The distributing movement is smooth and does not rack the forms.
- The strike-off plate can be readily raised and reset for expansion joints.
- The wheels have scrapers.

2-720A.2 Transverse Finishing Machine

The Inspector should check for the conditions below.

- The screeds are clean and straight.
- The leading edge of the front screed is set 1/8 to 3/16 in. (3 to 5 mm) above the rear edge.
- The rear screed has a front tilt of 0 to 1/8 in. (0 to 3 mm).
- The screed frequency can be changed.

2-720B Slip-Form Paving

A slip-form paving train is made up of self-propelled equipment units designed with side forms. The side forms must support the concrete long enough to avoid appreciable edge slumping and to allow necessary finishing while the concrete still is within the forms. The units usually are:

- a slip-form spreader machine,
- a slip-form paver machine, and
- a finishing machine
2-720B.1 Spread
er
The spreader receives the concrete from the hauling units and places it in rough form in its proper location on the roadbed to the depth of the mat reinforcement. Reinforcement mats are placed immediately behind the spreader.

2-720B.2 Paver
The paver normally performs the following functions: depresses the mesh; consolidates the concrete; strikes off, screeds, and floats the surface; forms the slab edge, including keyways; and inserts the longitudinal joint support units. Before starting, the Inspector should check for the following conditions.

- Mesh depressor is set to the correct depth.
- Screeds are set to grade and the pavement template.
- Float pan is clean and properly adjusted.
- There is a sufficient supply of longitudinal joint support unit inserts on board.
- All attachments (depressor, vibrators, etc.) are properly functioning.

2-720C Finishing Machines
Finishing machines are used both in side-form and slip-form paving. They may be of the transverse screed type, longitudinal screed type or longitudinal float type. Check for the following conditions.

- The screeds are straight and clean.
- The screed end pans are not worn excessively.
- The connection and fit of the end pans on the screed are satisfactory.
- The screed is set according to the manufacturer's recommendation.
- The screed distributing arms are operable.
- The float unit is clean and straight.
- The float unit is adjustable and can be raised and lowered easily.
- The float unit is not subject to distortion in its raised position, as when moving.

2-720C.1 Longitudinal Float
The longitudinal float should be checked by using the guidelines below.

- The screed blade must be straight. It can be checked with a taut wire held along each edge and along the center of the blade. Adjustments can be made by bolts provided for the purpose. If the screed blade is dented or bent so that proper adjustment cannot be made by the bolt adjustment, a new blade must be provided.
- The blade must be flat and smooth at the bottom, with relatively sharp corners. Check by placing a straightedge transverse to the screed at several points. If the bottom is worn round inside the original bevel, the blade must be discarded. Failure to provide a blade that is a plane on the bottom may cause longitudinal rippling or tearing.
The bottom of the screed must be the plane of the top of the concrete. Check for longitudinal compliance with wires stretched across the forms, or by running the screed over the forms and checking for any variation along the length of the blade. Check for lateral compliance by running the screed toward the center of the lane, stopping the screed at intervals and checking with a wire stretched from form to form. If the wire is not parallel to the bottom of the blade at both ends, adjust the screed and its supports on the carriage.

Scraper attachments for keeping the top of form and wheels clean must be adjusted to remove all concrete. Failure to maintain clean contact surfaces introduces slight irregularities in the surface.

2-720C.2 Flexplane Float

The Flexplane float has transverse screeds to smooth and shape the surface and a rear-mounted, pan-shaped float for longitudinal finishing.

2-720C.3 Chevron Float

The chevron float is a V-shaped drag float that provides for transverse screeding as well as longitudinal finishing.

Attention should be given to the adjustment of the float. This channel section is flexible. When the machine is picked up and moved, it flops around and is easily sprung. The truss members are easily bent. Turnbuckles are built into the truss work, and they should be used to make adjustments. Never use a sledge hammer. All edges of the channel sections must be straight and smooth, and the screed should be adjusted so that the forward edge is slightly above the surface, while the rear edge appears to be slightly indented. On superelevated sections, the transverse setting of the float must be adjusted to compensate for the pavement slump.

2-720C.4 Tube Float

The tube float is a pipe tube about 20 ft. (6 m) long that is suspended diagonally across the paved lane on a carriage assembly, similar to the other finishing machines. This type of float is usually used with a slip-form paver.

2-720D Tining Machine

The tining machine applies a textured finish transverse to the centerline of the surface. The Specifications call for the tines to be 0.03 in. (0.75 mm) thick, 0.08 in. (2 mm) wide, and 4 to 6 in. (100 to 150 mm) long, spaced ½ in. (12 mm) apart.

2-721 Final Preparations for Placement of Concrete

The mat reinforcement is placed along the forms, the forms are oiled, and all scuff marks are removed from the fine grade. The fine grade is moistened. The inspection team and testing equipment are assembled at the paving site.

When the concrete delivery starts, the batch tickets are signed by the supplier, and the discharge times are noted on each ticket.

The following sections describe the duties of the inspectors. Depending on the type of operation, the duties may be varied to ensure a smooth running, well-organized team.
2-722 Inspection Team

2-722A Concrete Inspector

The Concrete Inspector is responsible for the placing and finishing of the concrete. To satisfactorily cover each detail of the work, the Inspector will be very busy at times. However, if conditions warrant, the Concrete Inspector will be required to spend the major portion of the time with the paving operations. In addition, the Concrete Inspector may delegate the immediate responsibility for the inspection and control of certain operations.

If air-entraining admixtures are used, the Inspector must ascertain that the approved measuring device is in satisfactory working order and that a suitable supply of the admixture is on hand or is readily available. The Concrete Inspector must arrange for the inspector ahead of the paving equipment to check the fine grade with a subgrade template and to true up the form alignment, if necessary.

Cement having a temperature higher than 160 °F (71 °C) must not be used in the concrete. The temperature of cement at the plant must be measured and recorded at least four times daily. Concrete delivered in place must be at least 60 °F (15 °C) and must not exceed 90 °F (32 °C).

2-722B Paving Inspector

The Paving Inspector must check the following conditions.

- Forms, if used, are set at the correct line and grade.
- The transverse and dummy joint locations are properly laid out for a suitable distance ahead.
- The reinforcement, when placed, is not bent and is lapped the required distance.
- The batch or delivery tickets are properly received.
- The lower course and mat reinforcement is properly placed.
- The top course of concrete is placed within the allowable 45-minute interval.

The Inspector also is responsible for field testing the concrete for air content and slump and for casting test cylinders. Daily paving reports must be completed. The reports should show the roadway stations for the beginning and end of the placement, the quantity of the items involved, and the results of the field control tests.

2-722C Finishing Inspector

The Finishing Inspector must check all lutes and straightedges for trueness and all edging tools for size and wear. The Inspector should learn to use a straightedge in a manner that does not disturb the pavement surface. The Inspector straightedges the pavement along three points for the full length of each slab and has irregularities corrected. The Inspector should critically review the finishing of all joints and insist that the surface texturing operation be performed at the proper time, so that the desired surface finish and texture are attained. The Inspector must determine when the concrete cure operation should begin.

To identify each starting point, the Finishing Inspector must make up a brass tag showing the station and date of the beginning of the day's work. This tag is placed on the outside edge of the lane within the edged area of the first joint.
Immediately after the forms are removed from the previous day's run, the Inspector checks that all honeycomb is suitably patched and that the ends of the expansion joints are open to their full depth. When this work is complete, the Inspector checks that sides of the pavement are properly covered with the cure cover material.

The finishing work is the final control, and its results will be reflected in the appearance, durability, and riding qualities of the pavement. The finishing operation should keep pace with the placing operation. A satisfactory surface can be attained only if competent workers are able to perform their duties before initial set takes place.

2-723 Concrete Mix

As previously stated, if sources of the cement and aggregates are known, tested, and approved, the Division of Materials Testing will design a mix for the job.

2-723A Mix Adjustments

Any mix adjustments must be approved by the Laboratory.

2-723B Consistency

The consistency of the mix is important. Excess water greatly reduces the strength of the concrete and results in concrete outside the required slump range. If proper consistency is maintained, the finishing process can be carried out in a consistent manner.

For a central-plant-mix operation, concrete that is not placed within 45 minutes of the time of mixing, concrete that has developed initial set, or concrete that has a slump not in accordance with the limits established by the Engineer is rejected and disposed of outside the work.

2-723C Slump Test

Slump tests are made to help control the consistency of the mix during paving operations. The Inspector must make each slump test exactly alike so that the results are uniform.

Measurements of slumps are recorded to the nearest \( \frac{1}{4} \) in. (6 mm) and are included in the CON-134 Inspector's Daily Report.

The first slump test should be made on the first or second truckload. Subsequent tests should be made at pavement intervals of not over 500 ft. (150 m). In addition, the Inspector should make tests anytime the batches appear to change consistency. If the concrete is too dry or too wet, the Batch Plant Inspector must be immediately instructed to make another moisture test.

To perform a test, a clean standard slump cone is placed on a dampened test board set on a level surface. The slump cone must be kept clean, smooth inside, and free of dents or other distortions. It must be moistened with enough water to wet the surface but not leave any free water. The cone then is filled with the concrete in three layers, each layer approximately one-third of the volume of the cone.

Each layer must be rodded with 25 strokes of a 5/8 in. (16 mm) rod, 24 in. (600 mm) in length, bullet-pointed at the lower end. The strokes must be distributed in a uniform manner over the cross section of the mold and must penetrate into the underlaying layer. The bottom layer must be rodded throughout its depth. After the top layer has been rodded, the surface of the concrete is struck off such that the mold is exactly filled. The mold is immediately removed from the concrete by raising it carefully in a vertical direction. The slump is measured immediately by determining the
difference between the height of the cone and the height of the slumped concrete measured at the vertical axis of the specimen.

The allowable slump for paving mixtures should be kept as low as possible, consistent with workability of the concrete. The slump must be between 1½ in. (38 mm) and 3 in. (76 mm) for side-form paving and between 1 in. (25 mm) and 1½ in. (38 mm) for slip-form paving.

The Inspector must never accept ease of distribution as a reason for using mixes that are too wet to finish properly. Mixes that contain sufficient water to bleed and prevent proper finishing must be avoided, regardless of the measured slump.

2-723D Test Cylinders

Test cylinders are cast by placing fresh concrete in the mold in three layers, each approximately one-third the volume of the mold. The concrete is rodded with twenty-five strokes of the tamping rod. The strokes should be distributed in a uniform manner over the cross section of the mold and should penetrate into the underlying layer by 1 in. (25 mm). The bottom layer should be rodded throughout its depth. After the top layer is rodded, the surface of the concrete is finished to a true plane. Care should be taken in moving the cylinders to the curing box after their initial set. After standing for twenty-four hours, specimens are removed from the molds and cured.

2-724 Concrete Placement—Side-Form Paving

This section covers concrete placement using side-form paving methods and general paving information, such as placing concrete adjacent to transverse joints, paving adjacent lanes, and cold weather paving. The section, “Concrete Placement—Slip-Form Paving,” Section 2-725 covers concrete placement using slip-form paving methods. The section, “Finishing Pavement,” Section 2-726 covers finishing operations for both side-form and slip-form paving.

2-724A Side-Form Placement of Lower Course

Prior to the placing of any pavement concrete, the subbase and form alignment must be checked as previously noted, and the fine grade must be suitably sprinkled. The sprinkling of the fine grade should be carefully observed. Workers often do not realize the importance of this operation, and they are apt to become careless and fail to properly take care of the work. Immediately after the fine grade has been sprinkled, a worker should clean the subbase adjacent to the forms to ensure that the bottom is exposed at all points. This is an important step in attaining the required depth at the pavement edges. All scuff marks should be removed from the fine grade.

The operation of depositing and spreading must be continuous between transverse joints. In case of an unavoidable interruption, a joint should be formed at the point at which the work stops, provided that the section on which the work has been suspended is at least long enough to permit one mat of reinforcement to be placed. Shorter sections should be removed.

Covers for all underground structures should be set accurately to grade. Care must be exercised to place the covers such that they will conform as nearly as possible to the finished contour of the pavement. To accomplish this, the cover grade should be set by a string line drawn taut between the forms or between the finished lane and the form. The center of each end of the cover should be held to a point 1/8 in. (3 mm) below the line.
2-724B Spreading

The concrete should be deposited on the subbase as rapidly as possible, and every effort should be made to avoid breaking the continuity of the successive batches placed. The concrete must be reasonably distributed as it is dumped onto the subbase. If successive batches are dumped in piles, unequal settlement of the materials occurs in the vicinity of the piles, which is reflected in the finished surface.

The Inspector should note the condition of the concrete.

- It should be in a plastic condition and have the appearance of a homogeneous mass.
- There should be no indication of segregation.
- There should be no free water along the edges of the pile.

The concrete should be deposited on the subbase in a manner that requires as little rehandling as practicable. The bottom layer should be struck off to the required grade to receive the mesh or bar mat reinforcement, again with a minimum amount of handling. The operation should be performed with an approved mechanical spreader or with shovels. The use of rakes or any other type of equipment that causes segregation should not be permitted. If the concrete is placed along the forms with shovels, the workers should be instructed to turn the shovels over as they place the concrete, so that the backs of the shovels are toward the forms as the concrete leaves them. This procedure helps minimize honeycomb along the edges of the lanes, particularly where the horizontal key prevents easy spading.

2-724C Consolidation

An immersion vibrator should be used for consolidating the concrete. It should have a frequency of not less than 3500 impulses per minute. Avoid contact with the forms and load transfer assemblies when vibrating. Do not allow the vibrator to be held in one spot for more than 10 seconds. Pay particular attention to the transverse expansion-joint units. Watch for displacement of the dowels from the longitudinal joint-support units.

Because of the obstruction caused by the horizontal key, the concrete placed adjacent to the form supporting it must be consolidated by use of spades or an immersion high-frequency vibrator. This operation should be carefully observed because lack of or improper vibration results in objectionable honeycomb adjacent to the key. The Inspector must see that the operator does not over-vibrate and does not leave the vibrator unattended while it is in operation. When the forms are removed the following day, the edges of the pavement are observed for honeycomb. All honeycomb should be immediately patched with mortar.

2-724D Placing Concrete Adjacent to Transverse Joints

Placing concrete adjacent to transverse joints must be done with care to avoid moving, tipping or damaging the joint assembly. Technological changes in the design and operation of concrete placing and finishing equipment have helped to eliminate many of the problems associated with the placement and consolidation of concrete at transverse joints. However, the following precautions and restrictions should be followed.

- If discharging directly onto the subgrade from trucks, do not allow the concrete to drop on or against expansion joints or contraction joints with attached joint forming strips as it invariably knocks the assemblies out of line. The concrete should be deposited on the subbase as near to the respective joint as practicable.
- Consolidation of the concrete at all transverse joints is essential to the proper functioning and finishing of the concrete. Careful spading or vibrating around the joint and load-transfer units helps to ensure a good joint.
Spreading equipment that employs a traveling distributing arm or rotary screws to strike off the concrete placed within the forms should not be allowed to work close to expansion- or contraction-joint units. The Inspector should observe the forward movement of the concrete to determine just when the machine should stop.

At all expansion-joint units and at some strip-type contraction-joint units, the spreading machine should be stopped while the height of the distributing device is reset. When going from one slab to the next, some operators attempt to judge the location of the joint and begin lowering the spreading device without stopping the forward motion of the machine. The procedure often moves or damages the joint.

2-724E Reinforcement

The reinforcement for concrete pavement consists of either fabric reinforcement or bar-mat reinforcement. Samples must be submitted to the Laboratory and approved before use. The details of the design and method of spacing and lapping, together with the location of the reinforcement, are indicated on the standards. The Inspector should thoroughly examine the standards, to obtain a full understanding of the requirements, as well as knowledge about the manner in which the reinforcement should be placed.

After the first layer of concrete is screeded to the desired level, the mats are set in the concrete at the elevation shown on the plans, placed in the center of the lane, and lapped the required 14 in. (360 mm) with the preceding mat. If any of the members are bent, they should be straightened out before placing the mat. If the screeding has been properly performed, it is not necessary to stamp the mat into its proper position.

The Inspector should carefully observe the placement of reinforcing steel to ensure the mats are properly lapped and placed at the required elevation and that they are not disturbed by the forward motion of the spreading machine or screed. It must be particularly observed that no bars are bent upward at lap points. The mat reinforcement should extend to within 2 in. (50 mm) of all transverse and longitudinal joints.

To prevent the mats from being carried ahead by the forward motion of the screed or spreading machine, they should be placed such that the mat to the rear laps over the forward mat. The position of the mats should be checked occasionally by digging down with a trowel after the final screed has passed to see that the mats have not moved. If the mats have moved, they could be located directly above the load transfer device, thus destroying the intended weak plane. If using bar-mat reinforcement, C-clips should be used to tie the mats together between contraction joints.

Any portion of the bottom layer of concrete that has developed initial set or has been in place longer than 45 minutes without being covered by the top layer must be removed and replaced with new concrete. Otherwise, there is a risk of creating a plane of separation between the bottom and top layers of concrete at the elevation of the reinforcing; the plane reduces the strength of the pavement. The initial set and time limit for the bottom layer can be used to govern the distance between pavers in a two-paver operation.

An alternative method of placing reinforcing is to vibrate the mat into the full depth of concrete by an approved machine. The equipment manufacturer's procedure is used.

2-724F Side-Form Placement of Top Course

The concrete being discharged from the trucks or equipment hoppers should be spread evenly over the lower course, not placed in piles. The forward screed of the strike-off machine should carry a small surplus of concrete. Avoid overloading the screed.

The concrete carried by the rear screed should not be excessive. If carrying surplus material, this screed has a tendency to float, so that the surface is not even with the forms. If a surplus accumulates, have the machine move ahead on the
forms and lose it. Then back it up and make another pass. More than two passes of the strike-off machine should not be required. If, after the second pass, the surface is still high or rough-looking, review the concrete placing operation.

2-724G Paving Adjacent Lanes

2-724G1 Equipment Operation

Paving operations that require operating equipment on the older lane are not allowed until the required structural strength is attained. The strength is determined by the compressive strength obtained for test cylinders for the section of pavement in question. The operation of all equipment on the older pavement must be so that no marking or chipping of joints and longitudinal edges occurs.

Flat, rubber-tired wheels must be used in place of flanged wheels if finishing and spreading equipment travels on the concrete. If heavy equipment is operated or moved on concrete pavement, secure the maximum protection to the longitudinal and transverse edges. Center the equipment in the pavement width. Do not permit equipment to travel up to a transverse joint and stop. Instead, the equipment should be stopped at a point such that its load is somewhat equally distributed on both sides of the joint. To protect the surface of the pavement from abrasion, the paver must be operated on wooden mats having thicknesses of not less than 2 in. (50 mm) or on suitable fiber belting at least 1 in. (25 mm) thick and 2 in. (50 mm) wider than the width of the treads.

Caution the contractor that breaking or spalling of the concrete edges due to operation of equipment on or adjacent to the new concrete is not acceptable and must be repaired at the contractor's expense, as required in the Standard Specifications.

2-724G2 Longitudinal Joint

If the expansion joint filler was notched on the completed lane to fit around the longitudinal keyway, remove all concrete from the recess and carefully install a properly shaped piece of expansion material. Locate the edge of the inserts. Be sure the ends butt and the joints are straight. Be certain all of the longitudinal joint support units are installed. Insist that the top surface of both lanes along the longitudinal joint be at the same level. Caution the finishers during the edging operation to keep the longitudinal joint as narrow and tight as possible.

2-724H Construction Joints

In case of a breakdown or long delay where a regular joint cannot be formed, install a construction joint. The minimum length of pavement allowed is one mat length. Longitudinal-joint tie bars, rather than transverse contraction or expansion joint units, should be placed at intervals of 2½ feet (0.75 m) or less across all transverse construction joints. In normal operations, a reinforced expansion-joint unit is customarily used at the terminating point of a day's pour as the bulkhead.

2-724I Cleanup

When paving operations are completed adjacent to a paved lane, but before the curing mats are placed, the edge of the adjacent lane should be cleaned of all excess material that would cause unsightly appearance or an irregular surface. The cleaning may be accomplished with shovels and brooms.

If the adjacent lane is still under cure, have the covers carefully replaced. If membrane cure is being used, the disturbed work area should be given another application of the cure compound.
2-724J  Cold Weather

Cold weather procedures are used from October 15 to April 15, unless the Engineer directs otherwise. The procedures are in Article 6.01.03–12 of the Standard Specifications, covering structural concrete.

The temperature of the concrete must be no less than 60 °F (16 °C) when placed in the forms. The temperature surrounding the pavement must be kept above 60 °F (16 °C) for five days after placement, above 40 °F (5 °C) for an additional nine days, and then gradually lowered to the ambient air temperature. Mixing water must be heated, but its temperature cannot exceed 150 °F (65 °C). If aggregate is heated, its temperature must be between 50 °F and 100 °F (10 °C and 37 °C). The Engineer may vary the temperatures for the mix, water, or aggregate in extreme weather.

Every precaution must be taken to protect the concrete from freezing. If it is expected that the temperature will drop below 35 °F (2 °C) during the curing period, the concrete is cured using one of the approved methods. Then a layer of hay or straw 6 in. (150 mm) to 8 in. (200 mm) thick is placed on the concrete, and a layer of mats or cover sheets is spread over the hay or straw. The edges of the mats are firmly fastened in place. The covering remains in place until no further protection is needed.

The Standard Specifications state that any concrete placed during cold weather is done at the contractor's risk, and damaged sections must be removed and replaced at the contractor's expense. However, if in doubt as to whether paving operations should be started or resumed, consult the Assistant District Engineer.

2-725  Concrete Placement—Slip-Form Paving

2-725A  Slip-Form Spreader Operation

The spreader places the concrete to the depth of the mat reinforcement, 2½ in. (65 mm) below finish grade if the concrete is placed in two layers. The placement width is approximately 6 to 12 in. (150 to 300 mm) less than the lane width. The remaining part of the slab is filled in by the paver when the top course is placed. Some important points are below.

- The subbase must be thoroughly moistened directly ahead of the spreader to prevent rapid loss of water from the concrete, to a depth of at least 1 in. (25 mm).
- Care must be taken to see that the correct quantity of concrete is placed; too much will overload the following paver, and too little will result in having to halt the paving while additional material is added.
- The interval between the spreader and paver is important; the distance should be kept as short as possible because the concrete will set in about 20 minutes.

The reinforcing mats are placed immediately behind the spreader. They are placed from a mesh cart or from previously distributed piles along the roadway. The mats must be overlapped 14 in. (360 mm) in the direction of travel, and the sheets should be locked together to prevent dragging by the paver or depressor. Locking is by bending two or three wire ends around a transverse wire in the preceding mat. If bar mat reinforcement is used, C-clips should be used to lock the mats together. The mats should be placed so that the transverse wires are up, to prevent depressor bars from breaking the wire welds.

If placing the concrete in two layers, the second course is placed in a windrow on the center of the reinforcement. The concrete should be placed so as not to shift the reinforcement laterally. The windrow helps to hold the mats in place when clipped together and lessens the possibility of being dragged by the paver.
2-725B  Slip-Form Paver Operations

The paver is the most important piece of equipment in a slip-form paving train. It is directly responsible for the riding quality, thickness, and cross section of the finished pavement. Errors made by the paver are practically impossible to correct; therefore, constant inspection of the machine is an absolute necessity.

2-725C  General Inspection

During operation, the Inspector should check for the following:

- steel depth is correct,
- pavement thickness is correct,
- vibrators are working,
- screed board is allowing sufficient material to pass to carry proper surcharge ahead of screeds,
- longitudinal joint-support units are inserted at proper intervals,
- float pan is leaving the desired surface,
- pavement edges are vertical, square, no honeycombing, and
- pavement width and template are correct.

2-725D  Paver Speed

The paver should travel at the slowest possible forward speed that the screeding action allows. The concrete must be consistent in slump (1 to 1½ in. [25 to 38 mm]). The slow forward speed allows the edges to stay in the slip form longer for support, allows the longitudinal joint assemblies to be inserted squarely, and prevents the mat reinforcement from dragging.

2-725E  Paver Movement

A smoother pavement results if the paving can be done without interruption than if the paver must stop due to lack of concrete, difficulty in steel placement, or other delays in the paving cycle. Each paving project should be examined for proper balance between mix production, delivery, and lay down, so that the operation can proceed smoothly and orderly.

Moving forward at a very slow rate is preferable to stopping. The operator should anticipate foreseeable delays caused by lack of concrete and slow the machine to reduce the number of times it must be stopped.

2-725F  Base Irregularities

If running with one string line or running locked to grade, it is very important that the paver tracks move on a smooth surface. Bumps will be reflected in the finished pavement. It may be necessary to assign a laborer to clear spilled concrete from the track path.

The possibility of base irregularities showing up in the surface depends on the paving machine's length of skid and the closeness of the irregularities. In many instances, the skid is able to bridge across irregularities, and they do not show
up on the surface. Subbase irregularities that produce variable concrete thickness do not necessarily result in decreased yield. The irregularities can balance themselves out such that the overall yield is not affected.

Slip-form pavers use their own weight (up to 20 tons [18 metric tons]) to mold the plastic concrete into the correct shape. As a result of this extreme load on the subgrade and base materials, consolidation of the base materials may cause undulations to appear on the pavement surface. If the embankment is compacted uniformly, each area of the grade is compressed an equal amount. However, around drainage structures having minimum cover and bridge approaches, adjacent sections of the subbase are unequal in compressibility. The sensing units detect the settlement of the paver, but due to a time lag in actual response of the screeds, the adjustment always is too late to balance the settlement with increased slab thickness. This causes undulations that may not be detected by a 10 ft. (3 m) straightedge. Even though not detected by the straightedge, they affect pavement roughness as measured by the profilograph.

Shoulder areas require additional care in their construction. Concrete batch trucks ride the shoulders and quickly cause soft areas to distort. The areas affect the smooth flow of truck deliveries and may cause the paths for the paver to be unstable.

**2-725G Mix Consistency and Quality**

The mix should be uniform from batch to batch. Edge slumping occurs if the concrete's slump is in excess of 1½ in. (38 mm). (The standard mix probably will be changed to accommodate the paver being used.) If the mix does not have enough water, depressions occur around the transverse joint ties. The mix does not flow readily around the steel cage, causing a depression extending approximately 4 ft. (1 m) long in back of the joint. The depression is easily found by straightedging.

A sandy mix is quickly identified. The roll in front of the spreader or paver has areas with large amounts of mortar that appear to remain stationary. Another sign is tearing of the pavement surface behind the finishing machine. Concrete that is on the sandy side of the design mix helps the edges stand without sloughing.

**2-725H Edge Slumping**

Edge slumping usually is caused by excessive water in the concrete mix. However, it may be caused by improper vibration frequency of the finishing screeds or by operating the vibrators when the paver is stopped. The roll in front of the paver may become too high or too low from time to time. The height of the roll should be corrected by changing the speed of the paver. Controlling the roll height by varying the height of the strike-off screed manually is unsatisfactory, as it causes pavement roughness.

**2-725I Consolidation**

Proper consolidation of the concrete is obtained by the action of several vibratory elements. Improper frequency is rarely a problem because the frequency of the vibrators is set at the factory and most machines do not have the ability to vary it. However, the amplitude of the vibrators is variable and can be controlled by the operator. The proper amplitude vibrates the concrete at least 12 in. (300 mm) from the vibrating element.

**2-726 Finishing Pavement**

**2-726A Hand Finishing**

The number and ability of the finishers must be adequate. These workers must be experienced and capable. Correction must be made, if there is an insufficient number of finishers or if they are not capable of satisfactorily completing the
work as required. Finishing operations must keep pace with the placing of the concrete, and all other pavement operations must be geared accordingly.

2-726B Finishing Machine

As soon as the full depth of the concrete is spread to approximate uniform elevation, it is struck off by the finishing machine. A slight excess of concrete must be maintained ahead of the transverse screed to ensure cutting action at all times. Material must not pile up in front of the forward screed so that there is a heavy flow under it. Too much material tends to lift the screed above the forms, while too little leaves low spots on the surface. Depressions or torn areas that develop in the surface must be filled at once with fresh concrete. Mortar or material picked up outside the forms must not be used for filling depressions.

There often is a tendency on the part of the operator of the transverse finishing machine to make too many passes over the surface, with the result that excess mortar accumulates on the surface. This weak, segregated material must be floated over the forms. The Inspector must never allow the material to be carried ahead to the transverse joint. Do not allow any wet mortar to be deposited along the slab edges. Special care must be taken to see that good quality concrete is always used along the edges and joints, because they are subject to the greatest stresses. If added mortar is used in the finishing of the edges and joints, the pavement will be defective.

In general, the transverse finishing machine should not make more than two passes. The Inspector should never allow an excess of concrete (8 in. [200 mm] or more) to pile up in front of the forward screed. The equipment should be operated so that it moves forward slowly at a uniform speed and should not stop in the section being screeded. The rear screed should carry a roll of concrete not more than 2 to 3 in. (50 to 75 mm) deep. If it is deeper than that, excess material is flowing under the forward screed.

If air-entrained concrete is being used, there is little sedimentation or bleeding and, thus, very little free water for surface lubrication during finishing operations. Sometimes as a result, the concrete adheres to the finishing-machine screeds, causing a torn surface. The tearing usually can be overcome by increasing the rate of screed oscillation. If the air temperature is high and there is a drying wind, it is very important that the hand-finishing operations follow closely behind the finishing machine. If this is not done and a flash set occurs before the final finishing and edging are completed, a poor surface will result.

Operation of the transverse screed must be carefully observed up to and over the transverse joint. Do not allow the screed operator to bring up an accumulated roll of mortar on the rear screed and deposit it into depressions around the transverse joint. Do not allow the screed operator to pass over the joint with a large amount of concrete carried on the front screed.

Instruct the supervisor to have the large accumulation of mortar and concrete removed before screeding is carried over the joint. Depressions at the joint must be filled in with good unsegregated concrete. Never allow the use of mortar in filling depressions, whether it is at a joint or elsewhere in the pavement.

The tops of the forms and the wheels of the finishing machine must be kept free of concrete. Inspection of the shoes or wear plates should be made at least once daily to ensure that they are not worn sufficiently to affect the cross section of the pavement.

2-726C Longitudinal Floats

The Standard Specifications provide for longitudinal floating as soon as possible after the concrete has been consolidated by the transverse screed. The Specifications require that the longitudinal float be mechanically operated. Where mechanical longitudinal floating cannot be done, a hand float must be provided and used. There are four basic types of equipment currently in use: the longitudinal or bull float, the Flexplane type of drag float, Lewis type of chevron float, and the tube float.
2-726C.1 The Longitudinal Float

The longitudinal float, or sometimes referred to as the bull float, should operate within 100 ft. (30 m) of the transverse screed. The distance may vary, however, because of weather that causes excessive drying, excessively humid weather, or variations of the mix. In general, it is desirable to delay the operation until the surface has started to dry out slightly, so that some settlement has begun to take place. It is not desirable to delay the operation too long because the concrete will be too dry for the final finish work.

When properly operated, the screed should carry a small roll of concrete along all but about the rear 24 in. (600 mm) of its length. The roll is largest at the forward part of the screed and tapers off toward the rear half of the screed.

If the concrete is of the desired consistency, it rolls rather than flows. If the roll is small, say less than 1½ in. (40 mm) in diameter, the screed may be lifted as it reaches the form, and the roll of mortar picked up for the return pass. If the roll grows larger than this, or if the material flows in front of the screed, it is to be wasted over the forms. The forward speed of the longitudinal float should be regulated so that, if necessary, two complete passes can be made over each area. The operator must continuously observe the amount of mortar being carried by the screed. The material must be distributed along the length of the screed and must not roll off the rear to form a ridge. The operator should force down any large aggregate that might tear the surface.

2-726C.2 The Flexplane Float

The Flexplane float has transverse screeds to smooth and shape the surface, and a rear-mounted, pan-shaped float unit to provide for the longitudinal finish.

The float should have a slight front-to-back tilt, exert a slight amount of pressure on the surface, have about a 1/8 in. (3 mm) crown at the center, and be free of nicks and dents. The finished surface should be smooth and free of all finishing marks.

2-726C.3 The Chevron Float

The chevron float is a V-shaped drag float that provides for transverse screeding as well as longitudinal finishing. The float component is suspended from the rear of the machine. It consists of two sections of a trussed 12 in. (300 mm) wide channel section, each about 12 ft. (3.5 m) long, jointed at the front to form a “V.” The flat surface of the channel is placed in contact with the screeded surface, and the forward travel of the machine drags it over the surface, smoothing out all remaining marks.

The amount of concrete carried by the two transverse screeds should be held to a maximum 5 in. (125 mm) diameter roll for the forward screed and a 2 in. (50 mm) roll for the rear screed. If you note a buildup of concrete on the screeds, the material should be wasted, the machine backed up to where it appears the surface is to grade (a string line pulled across the forms will help confirm this), and another pass made.

A check should be made to determine if a localized high spot was the reason for the screed buildup, or if the forward transverse screeding machines are leaving too much concrete. If the concrete has a tendency to roll down at the forms, again check the surface with a string. The operator might have raised the screeds to cover up a high spot. This shows up as a dip along the longitudinal joint. Watch the action of the end pans. They are hinged and float easily.

2-726C.4 The Tube Float

This type of finisher requires extremely good grade control and surface finishing by the screeds on the top course strike-off machine on the slip-form paver.
As the finishing machine moves longitudinally, the tube smooths the wet concrete surface. Excess concrete is pushed ahead of the tube and, because of its diagonal orientation, eventually rolls to the edge of the lane. Two passes of the float usually are required for a satisfactory surface finish. If more passes are required, check the adjustment of the top course strike-off machine. As in normal concrete paving, overworking the surface should be avoided. The spray bar should be used sparingly to keep the float from dragging.

The most important consideration with this machine is that the float or burlap drag should only be raised or lowered when the machine is in motion. Stopping the finisher prior to raising the float or drag results in a ridge of material that is extremely difficult to remove.

2-726D Luting

All small irregularities and the longitudinal screed trail must be removed immediately after the surface is consolidated. The Standard Specifications provide for the use of a manually operated smoothing lute or striking straightedge of approved type and dimensions to follow the longitudinal floating operation. The lutes must be equipped with either an aluminum or steel blade, 10 ft. (3 m) long. The use of paddle-type lutes to finish pavement should not be permitted.

At the beginning of the day's work, the lutes must be lapped back at least 5 ft. (1.5 m) on the preceding day's pavement and then moved slowly over the surface of the concrete from one side to the other. Movements longitudinally must be made by raising the lute completely above the surface and lifting it ahead not more than half its length or by sliding it along the form the same distance.

Luting should eliminate all finishing machine marks and remove all small irregularities. The lute should barely scratch the surface, except where high spots occur. For low areas, fresh concrete should be carried back, spread in the low area, hand floated to the correct grade, and smoothed with the lute. The luting operation should be carried across all joints as if they were not present. At the end of the day's run, considerable care should be exercised in luting the area over and adjacent to the final joint.

If the finishing machine operations are carried out correctly, the surface should be smooth enough so that very little luting is required. Often a finisher has the tendency to do too much floating, and the Inspector should insist that only enough of it is performed to ensure a smooth texture of surface that will straightedge properly.

As mentioned previously, the use of paddle-type lutes to finish the pavement surface should not be permitted. However, a float suitable for cutting excessive high spots or floating fresh concrete placed in low spots should be available.

2-726E Joints

2-726E.1 Expansion Joints

Immediately after the surface has been luted, a pointed trowel should be run along each side and to the full depth of the protection cap. (Figure 2-7.6 shows an expansion joint.) The cap is removed and a spring-steel strip equal to the width of the joint is carefully placed on the filler. It is important that the joint is finished with the material originally deposited adjacent to the joint. Never allow the finisher to remove the coarse aggregate and substitute mortar or segregated material to facilitate finishing.

When the spring-steel strip has been placed, the concrete adjacent to it is thoroughly consolidated, floated and given a preliminary edging. On completion of the preliminary edging, the joint is checked with a straightedge designed to check joints. The blade of this straightedge may be of wood at least 4 ft. (1.2 m) in length, 4 to 5 in. (100 to 125 mm) high, and 2 in. (50 mm) wide. It must have a 14 ft. (4.3 m) handle attached and a notch in the center of the cutting
edge, so that it can ride over the spring-steel strip and so that the pavement on either side of the joint can be properly checked.

The steel strip is removed carefully so that the concrete adjacent to the joint is not disturbed. The removal of the steel strip should leave the top of the joint filler fully exposed. The finisher should run a pointed trowel, held vertically, along both sides of the filler. This ensures that the joint opening is directly over the filler and that the vertical sides do not overhang any part of the filler.

The importance of the proper installation and finishing of each transverse expansion joint cannot be overemphasized, as poor workmanship will result in pavement spalling and rough riding conditions. The Inspector must be present at the installation, finishing and straightedging of every joint installation made throughout the day. Extra efforts must be taken with the preliminary straightedging, as any correction found necessary at or adjacent to the joint after the final edging has taken place will generally result in an unsatisfactory joint.

When the forms are stripped, the joints should be inspected to see that there is no grout around the ends or on top of the expansion material. Remove any immediately after the removal of the forms.

Do not permit the use of caps or spring-steel strips that are bent or deformed in any way. See that the caps are clean of hardened concrete that may prevent the cap from resting on the joint for its entire length. Do not permit the joint finish to be overworked.

2-726E.2 Contraction Joints

Forming of the transverse contraction joint groove over the previously placed load transfer assemblies follows the longitudinal finishing equipment. The grooves may be formed either by using steel strips or by saw cutting. (Figure 2-7.7 shows a contraction joint.)

For 9 in. (230 mm) concrete, a $\frac{1}{4} \times 2$ in. ($6 \times 50$ mm) strip of steel may be manually inserted into the steel guides attached to the load transfer assembly. The strip should be as wide as the lane, clean of all foreign material, free of kinks, and straight. The strips are very limber and flexible and are easily distorted. They should be installed so that the tops of the strips are $\frac{3}{4}$ in. (19 mm) below the finished surface.

The strips can be installed after the lower course has been placed. Bridges must be placed across the forms at each joint and a trowel used to remove enough concrete so that the strips can be installed. Do not allow the workers to walk in the fresh concrete or use sledge hammers to straighten kinked strips. The concrete that was removed should be replaced, and the new material consolidated and smoothed off with a float.

In the second method, the contraction joint groove is cut with an approved concrete saw. Adequate water and lighting equipment must be provided before sawing operations begin. At all times during the sawing operations, there must be available on the project at least one standby saw in good working order and an ample supply of saw blades.

Positive methods, subject to the approval of the Engineer, are employed to assure that the sawed groove is centered directly over the transfer unit from edge to edge of pavement. Reference stakes or nails should be used. Contraction joint grooves must be sawed normal to the pavement surface, true in alignment, at the intervals and to the minimum depth and width specified or approved.

It is the contractor's responsibility to perform all joint sawing operations at such times and in such sequence as to preclude unsatisfactory results due to uncontrolled cracking or excessive raveling. The time of sawing depends on existing and anticipated weather conditions and must be such as to prevent uncontrolled cracking. Time of sawing is particularly critical at contraction joints in lanes adjacent to previously constructed lanes. Normally, all transverse joints are sawed as soon as possible and in consecutive sequence. If climate or other conditions warrant, the contractor may deviate from normal.
If a crack has developed, sawing should be omitted at the joint location. Otherwise, sawing should commence as soon as the concrete has hardened sufficiently to permit sawing without excessive raveling. Once started, the sawing operations must not be stopped, except for raveling or uncontrolled cracking.

Immediately upon completion of sawing a joint, it is thoroughly cleaned with air (when dry cutting blades are used) or with water (when wet cutting blades are used) until all dust or slurry has been removed. If found necessary, the sawed joint must be cleaned again immediately before being sealed.

2-726E.3 Transverse Joints

A 10 ft. (3 m) metal straightedge placed at right angles to the joint should show no variation over 1/8 in. (3 mm) in the surfaces of adjacent slabs. Edging of joints should be carefully inspected, particularly for maintaining a true grade across the joint. Particular attention should be paid to the finishing and edging of the joint that occurs at the beginning of each day's run so that the grade of slabs matches just before final texturing. This edging should be done at a stage when the surface is dry enough to prevent any settlement under the weight of the tool, but not before initial set.

2-726F Straightedging

After the luting has been completed, the surface must be systematically checked for smoothness with a 10 foot (3 m) straightedge. Straightedging is performed over the entire length of the slab and along three points in width while the concrete is still plastic.

The more common type of straightedge in use today consists of an aluminum blade, different in shape from the lute, 10 foot (3 m) long, mounted on a long handle. The straightedge should be checked frequently and, when not in use, it should be placed where it cannot be injured. The straightedge should never be used for luting or floating.

Care must be taken to see that the straightedging is done at a stage when the surface is dry enough to prevent any settlement under the weight of the tool. If the concrete is too soft, the blade of the straightedge will sink into the surface, thus reducing the possibility of detecting minor variations of 1/8 in. (3 mm) or slightly over. If straightedging is delayed too long and the initial set takes place, the resulting delay in the final finishing operations often causes a bad section of surface finish and joint work. The Inspector must be alert to this condition, particularly on a hot, dry day. The Inspector should not permit water to be sprinkled on the surface of the concrete to facilitate finishing, because it causes scaling.

The contractor should perform the work by lowering the straightedge very carefully onto the concrete, so as not to mark the surface. All variations in the contour of the pavement surface of more than 1/8 in. (3 mm), as shown by the straightedge, require adjustment. Where adjustments are required, the Inspector must ensure that all irregularities are removed and the surface is properly floated.

High spots usually can be removed by the lute. Low spots should be brought to grade by placing fresh concrete in the depression and having the lute man strike off and smooth the surface. Straightedged all corrected areas. Pay particular attention to the transverse joints. Straightedged diagonally as well as conventionally to detect any unevenness. When starting a new pavement section, lap the tool back on the completed work at least one-half the blade length.

Shortly after curing mats or paper are removed from the pavement, the Chief Inspector should make immediate arrangements to have the cured surface straightedged. This inspection should be made without delay. When irregularities exist that reveal inferior workmanship, immediate corrective measures can be taken.

2-726G Tining

The surface texture is done by steel tines as soon as the concrete allows transverse grooves, 1/8 to 3/16 in. (3 to 6 mm) deep and ½ in. (12 mm) apart without tearing the surface or filling in the grooves. The grooves are placed across the
entire width of the pavement, perpendicular to the centerline.

2-726H  Edging

After luting is complete and before edging the sides of the pavement, a trowel should be run along the edges of the slab to free the concrete adjacent to the forms and expansion joints and to facilitate use of the edger. Then the edging tools should be worked along the edge of the lane, preparatory to the final tooling.

If the concrete is too soft when the edging work is done, the rounded corners become refilled, causing an unsightly edge. If edging work is delayed until the concrete has hardened, the bond is disturbed and it is difficult to secure a good finish.

Good edging tools must be used to help ensure edging uniformity throughout the job. Often the concrete finishers are loath to part with a worn edging tool, as such a tool offers little resistance and is easier to operate. The Inspector, therefore, should make frequent checks of the tools to see that the required radius is not distorted or entirely worn out, and should ensure that the contractor has a sufficient supply of edging tools on hand so that immediate replacement of worn tools can be made when necessary.

The Inspector must insist on uniform edging work. The radii must be true and the troweled surface uniform and in a plane with the slab surface. Tipping the edging tool causes an objectionable burr or depression and must be avoided. Likewise, stone encountered in the edge area must not be traveled over with the flange of the edger. If a piece of stone in the concrete is encountered, it should not be removed and replaced with mortar scraped from the surface or form; rather, it should be tamped below the required grade and the resulting depression filled in with fresh concrete and smoothed.

If it is necessary to hand-float the edges, some correction of the preceding operation is needed. Check the machines and method used in the prior work. It is particularly important to secure a true edge on the lane that will act as a form for an adjacent lane, so that the finishing machines will have a true surface to ride on.

Many of the current contracts do not require that the longitudinal-joint recess be filled with joint seal when the pavement is constructed on a single-lane basis. Smooth-riding longitudinal joints can be realized only if the joint recess is in accordance with the plan dimensions and shape and the edges of the abutting lanes are correct.

2-727  Curing and Protection

Curing is required to protect the concrete from rapid drying by preventing the loss of moisture through evaporation. Moisture is needed so that the water and cement can complete their chemical reaction and to protect concrete from shrinkage. Curing is done after the final finish. There are three acceptable curing methods: moist curing, membrane curing and polyethylene cover-sheet curing.

The wheels of paving equipment usually have flanges. When paving adjacent lanes, check to ensure that the flanges do not strike and spall the concrete along the longitudinal joint. During the curing period, do not allow the forms or form pins to be placed on the surface. Walking on the surface should be discouraged.
2-727A  Moist Curing

Quilted covers, if kept saturated, provide the required protection by permitting evaporation of water from their top surfaces. The dimensions of the mats must conform to the requirements of the Standard Specifications. They must extend over the sides to cover the edges of the pavement. As soon as the forms are removed, the mats are placed so as to fully cover the top and sides of the concrete and, if necessary, are held there by weights to prevent the wind from disturbing them. Each mat must be lapped at least 12 in. (300 mm) on adjacent mats. Mats that are torn or frayed or in which the lining is lumpy must not be used.

Curing must begin as soon as the finishing operations are completed and the concrete surface is set up enough to withstand marring by curing mats. During hot, drying weather, finishing must be completed and the curing material must be placed before the surface dries out to the extent that hairline cracks appear because of early shrinkage. The concrete surface is particularly susceptible to hairline cracking on a hot day that is accompanied by a stiff breeze. Under these conditions, a very close watch should be kept on the concrete and, at the very first signs of hairline cracking, the curing mats should be placed over the surface, even if the surface has not set up enough to resist marring.

Curing mats must be wet enough so that the side adjacent to the concrete remains damp. Dry mats absorb and tend to draw water out of the concrete, preventing proper curing. Do not place dry mats over the concrete, even though promises are made that they will be wet immediately afterward. This does not work out, as usually the amount of water sprayed on the mats is not sufficient to soak through to the bottom of the mat. Insist on the mats being damp before placing over concrete.

Wet blankets are heavy, and caution must be used to avoid dragging them over the surface when placing them. A blanket must be placed by unrolling it from a 2 × 4 (50 × 100) or by four workers carrying the blanket by the corners and lowering it carefully onto the concrete surface.

After mats have been placed, they must be immediately saturated and kept saturated with water throughout the required period, as prescribed by the special provisions of the contract or in the Standard Specifications. The Inspector should check occasionally during periods of exceptionally hot, drying weather by turning blankets up to see if the lower side is wet. Even with an apparently wet surface, from regular sprinkling, the bottom may be dry.

2-727B  Curing Compound

The curing compound must be white, pigmented 100-percent resin-based material or a water-soluble, linseed-oil-based compound. Both types of curing compounds must be sprayed uniformly over the surface by a self-propelled mechanical sprayer. The resin-based material must be applied as soon as the free water has disappeared, while the linseed-oil-based compound should be applied immediately after the finishing operation.

The Inspector should assure that the minimum coverage requirements are obtained by checking the gallons (liters) used against the square yards (meters) covered. The joints must be protected so that the curing material does not adhere to the edges of the joints, causing possible failure of the joint sealing compound. The surface should be checked during the curing period to ensure that no abrasion has occurred that would decrease the moisture-retaining qualities of the material.

The usual application rate is 1 gal./150 sq. ft. (0.3 L/m²). Cover sheets should be available on the project to protect the pavement from rain or for use if equipment breaks down. The equipment used for applying the material should be equipped with a device that provides for adequate agitation of the compound to prevent settlement of the coloring pigment.

When the side forms are removed, all honeycombed areas should be patched before the edges are spray cured.
2-727C Polyethylene Cover Sheet Curing

Polyethylene cover sheets must be placed in such a manner that the surface of the concrete is not marred. The adjoining covers must overlap at least 12 in. (300 mm), and the lap must be securely weighted down to form a closed joint. Before reusing polyethylene covers, they must be checked for rips or tears, and repairs must be made if required.

In the event that checking develops before the cover sheets can be placed, the normal procedure is modified at the direction of the Engineer. Moist curing mats must be used for the initial 24 hours of the curing period, and the cover sheets must be placed for the remainder of the curing period.

On removing forms, the edges must be covered down to the bottom of the pavement. The cover sheets must remain in place for seven days.

2-728 Temporary Crossovers

Prior to normal opening of the concrete pavement, it may be necessary to construct temporary crossovers at driveways or intersections. These crossovers must be constructed as shown on the standards that are a part of the pavement plans. A crossover bridge must be of sufficient height above the concrete so that it will not deflect against the concrete surface under maximum load. The crossing must bridge the lane completely from supports outside the concrete. Earth ramps are constructed so as to provide a smooth approach to and from the bridge.

2-729 Removing Forms

Forms must not be removed from freshly placed concrete until it has set for at least 12 hours. The workers who are assigned to remove the forms should be instructed in the proper manner to avoid spalling the edges of the concrete. Metal wedges, lever fulcrums, or stake-pulling devices are not permitted to have a bearing on the concrete when pulling forms or lifting pins. The Inspector must not allow the removed forms to be placed on the new concrete or the pins to be thrown carelessly about.

After the side forms are removed, the Inspector examines the ends of all joints to see that they are not bridged with grout. If they are bridged, they must be cleaned immediately. All honeycombed areas must be pointed up. Under no condition is the placement of shoulder material to be allowed until there is positive assurance that the joints are open. The workers must be instructed to replace the curing cover at the edges exposed by the removal of the forms.

2-730 Sawing Longitudinal Joints

Longitudinal joints must be constructed as shown in the plans and in conformance with the specifications, or as ordered by the Engineer. (Figure 2-7.8 shows a longitudinal joint.) The joints may be constructed by the following methods.

- If pavement is constructed a single lane at a time, the longitudinal joints between slabs must be of the tongue-and-groove type and constructed by means of the devices shown on the plans. The joints must be equipped with tie devices as shown on the plans.

- If multilane construction is used, the longitudinal joints may be formed by an approved nonmetallic joint forming insert introduced into the plastic concrete by mechanical equipment. The insert must be sufficiently rigid to remain in good alignment, and the size and shape must provide a joint of the specified configuration.

- If multilane construction is used, the longitudinal joint may be constructed with an approved concrete saw. It is the contractor's responsibility to perform the saw cutting operations at a time when excessive raveling or uncontrolled cracking does not occur. As sawing operations progress, the completed sawed joint must be thoroughly cleaned with air if dry cutting blades are used or with water if wet cutting blades are used until all dust or slurry is removed. Sawing must be performed within 4 to 24 hours of the placement of the concrete pavement.

In all cases, the longitudinal-joint groove must be constructed perpendicular to the pavement surface, true in alignment, and to the minimum depth and width specified or approved.
## 2-731 Sealing Joints

Before the pavement is opened to any traffic, public or contractor, all joints must be sealed as required. This is the last operation prior to opening the roadway to traffic. The sealing of the transverse and longitudinal joints prevents surface water from seeping through the joints and accumulating in the subgrade where frost action and other disintegrating effects may result.

The special provisions and plan notes should be reviewed to determine if the longitudinal joint is to be sealed. The current practice is not to seal the joint for single-lane construction.

Prior to pouring any filler, the joints must be swept clean, and any adhesions of dried grout particles must be chipped and removed or swept. The transverse joints must be cleaned for the full width of the expansion material, and the top of the expansion material must show over its entire area. The presence of any concrete in a transverse joint prevents free compression of the joint material and may cause spalling along the joint in hot weather. These joints and all others should be thoroughly cleaned of foreign material, including mortar, by scraping and blowing them out with compressed air. Watch for small stones that become lodged. They promote spalling of edges.

The joint seal material should be of the type specified. It should be mixed and heated in a suitable kettle, and a careful check should be made of the temperature as it is being heated. Particular care must be used in heating the material to avoid burning. The material usually is a rubber compound that is in a liquid or fluid state before heating. Heating activates the setting agents, and the material changes state when it cools to become a resilient solid. Heating too long or at too high a temperature may damage the material. The material is usually applied under pressure with a mechanical applicator. The joint should be completely and neatly filled. Avoid placing excess material. The limits are flush to 1/8 in. (3 mm) below the surface. The Inspector must ensure that the workers engaged in this operation do not allow the joint seal to spatter or drip onto the adjacent pavement.

Prior to the final acceptance of the pavement or before the suspension of work for the winter months, the joints must be inspected and defective joints must be resealed.

## 2-732 Daily Reports and Tests

Paving Inspectors usually make out the standard Inspector's Daily Report, CON-134. Designated Paving Inspectors are required to make out a supplemental inspection report, CON-135, Concrete Pavement Daily Inspection Report, to record quantities, personnel, work limits, work hours, concrete mix information, and test results for materials. Figure 2-7.9 is an example of CON-135M. CON-134 is covered in Volume 1, Chapter 3, “Project Documentation.”

During the course of each day’s paving operations, quality-control determinations are necessary to ensure that such things as air content, slump, and structural strength are satisfactory. The duties are performed by the Inspectors assigned to the paving operation.

- The air content and slump should be checked periodically during the day, especially in the morning when the operation begins, and when the concrete changes.

- Eight cylinders should be cast for each concrete placement, four in the morning and four in the afternoon. Should the operations suspend early, every effort should be made to cast the necessary cylinders. They should be properly marked and placed out of the way of things so they will not be damaged.

Remember, these cylinders are used to determine the strength of the pavement, and a satisfactory compressive strength must be obtained before the pavement can be opened to traffic. Should they fail, the quality of the pavement will be questioned, and more tests will be required.
### Figure 2-7.9 Concrete Base & Pavement Inspection Report (Form CON-135M)

<table>
<thead>
<tr>
<th>Plant Location</th>
<th>CON-135M REV. 3/97 (Metric)</th>
<th>Project No.</th>
</tr>
</thead>
<tbody>
<tr>
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**Paving Contractor**

<table>
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<tr>
<th>Location Sta. to Sta.</th>
<th>Slab</th>
<th>Lane</th>
<th>Width m</th>
<th>Length m</th>
<th>Depth m</th>
<th>Theoretical m³</th>
<th>Actual m³</th>
<th>Theoretical Actual</th>
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<table>
<thead>
<tr>
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<th>Item Description</th>
<th>Quantity</th>
<th>Sect.</th>
<th>Sub/Contr No.</th>
<th>Location/Station/Reference</th>
</tr>
</thead>
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**Paving Work Force and Equipment**

<table>
<thead>
<tr>
<th>List of Inspection Personnel Assisting in Operation</th>
<th>No. of Tickets by Class</th>
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</thead>
<tbody>
<tr>
<td></td>
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</tr>
</tbody>
</table>

- Information on Reverse
- Additional Sheets Attached
- IR Entered on CMR
- IR Accepted
- Reviewed by:
- Inspector’s Signature:
- Lane Closures
- Contractor’s Hours of Work:
  - Start
  - End
- Day of Week
- Date
- I.R.#

**Chief Inspector**

**Project Engineer**
Figure 2-7.9  Concrete Base & Pavement Inspection Report (Form CON-135M) (continued)

<table>
<thead>
<tr>
<th>m³ Rejected</th>
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#### Actual Batch Mass Used

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<tr>
<th>Cement - kg</th>
<th>Sand &amp; Moist. - kg</th>
<th>Stone - kg</th>
<th>Stone - kg</th>
<th>Mixing Water - kg</th>
<th>Total Mass</th>
</tr>
</thead>
<tbody>
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<td></td>
</tr>
</tbody>
</table>

#### Entrained Air

<table>
<thead>
<tr>
<th>Time Taken</th>
<th>Air-Entrained Agent</th>
<th>Amount Used - mL</th>
<th>% Air</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

#### Slump Tests

<table>
<thead>
<tr>
<th>Time Taken</th>
<th>Total Water per Batch - L</th>
<th>Amount of Slump - mm</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### Sketches / Computations:

Checked by __________________
2-733 Air Content

The air content of freshly made concrete is determined with a pressure air meter. A Chace air indicator is used to check air content to determine if additional pressure air meter tests should be run. The pressure air meter is more sensitive and accurate than the Chace air indicator and therefore must be used for acceptance tests. Simultaneous tests with the pressure meter and air indicator should be made in the morning at the start of the day's operation and again at midday to correlate the instrument readings. Additional tests with the pressure meter are performed if cylinders are cast of which the air content as determined by the Chace indicator approaches the allowable air content limits of the mix.

Periodically during the course of the day's operation, check tests should be made with the Chace indicator. To fully document the information, the Inspector must record the percent of entrained air and the instrument used to determine it.

The Inspector responsible for the quality-control testing of concrete must read and thoroughly understand the manufacturer's operating instructions for the equipment used. The general operating procedure for each of the instruments is below

2-733A Pressure Air Meter

The generalized procedure is as follows:

- Select a proper sample of concrete.
- Fill the measuring bowl in three equal layers.
- Rod each layer 25 times with an approved tamping rod.
- Tap the outside of the measuring bowl with an approved nonmetallic mallet after rodding each layer.
- Strike off the concrete flush with the top surface of the measuring bowl.
- Wipe the flange area of the measuring bowl.
- Place and secure the cover assembly.
- Open the fill valves and add water to the prescribed level.
- Set the meter's air gauge now at the zero calibration. The zero calibration for each meter is usually marked on the instrument. Depending on the type of instrument, the fill valves should be left open or shut while air is pumped into the meter to standardize the gauge. Tap the gauge lightly with the fingers and wait about 30 seconds. Add or bleed air, as required, to maintain the zero calibration reading.
- Depress the release valve.
- The gauge reading gives the air content.

2-733B Chace Air Indicator

The general procedure is:

- Fill the brass cup with cement mortar paste. Exclude particles larger than #10 sieve (2 mm). Rod the material in the cup with a knife or wire to compact the mortar and strike off the excess even with the top of the cup.
- Place a finger over the stem opening of the glass vial and fill the vial with alcohol.
• Insert the stopper in the vial, invert the vial, remove your finger, and adjust the alcohol level in the vial stem by manipulating the stopper. The level of the alcohol in the stem should coincide with the top stem marking.

• Place a finger over the stem opening. Roll the indicator from vertical to horizontal several times until all the mortar has been dissolved out of the cup. Keep the sand from entering the vial stem.

• Bring the indicator back to a vertical position. Remove your finger from the stem opening. Count the number of spaces from the top mark to the new liquid level.

• The number of spaces represents the air content in percent.

The Chace indicator reads direct for concrete mixes containing 15 cu. ft. (0.425 m$^3$) of mortar. Readings obtained for mixes containing other than 15 cu. ft. (0.425 m$^3$) of mortar are to be multiplied by a conversion constant to determine the actual air content.

The mortar content of the mix can be determined as follows.

• Get the specific gravity of the stone from the Laboratory.

• Multiply this specific gravity by 62.4 lbs./gal. (1,000 kg/m$^3$).

• Divide the product into the total weight (mass) of stone in the mix. This gives the stone content in cubic feet (meters).

• Subtract this from 27 cu. ft. (1 m$^3$) (if you are using a 27 cu. ft. [1 m$^3$] mix), and the answer will be the cubic feet (meters) of mortar.

• Refer to the design-mix letter from Central Laboratory.

• For the mortar content per cu. yd. (m$^3$), multiply the stem readings by the conversion factor below.

**Figure 2-7.10 Mortar Content Conversion Factors**

<table>
<thead>
<tr>
<th>Mortar Content ($m^3$)</th>
<th>Conversion Factor</th>
<th>Mortar Content ($m^3$)</th>
<th>Conversion Factor</th>
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</table>
2-734 Pavement Cores

Prior to opening the pavement to traffic, the Chief Inspector makes arrangements to have cores taken to determine pavement thickness for payment purposes.

2-735 Opening the Pavement to Traffic

Under no condition can the roadway be opened to traffic until the compressive strength of the concrete has reached a minimum value of 3,500 psi (25 MPa). Eight cylinders must be cast daily by the Inspector to represent each day's run of concrete, and arrangements must be made with the Laboratory to have the cylinders broken at the intervals required.

Before opening a section of pavement as a temporary detour to the general public, shoulder material should be placed along the outer edge of the lane up to the pavement level for at least 18 in. (500 mm) in width to eliminate abrupt drop-offs at the pavement edge. If the ends or sides of the slabs at intersections must be protected from abrasion of traffic, suitable approaches must be provided to form a smooth, easy approach to the pavement and that, at the same time, adequately protect the edges of the concrete from undue stresses that might cause cracking or spalling.

Concrete lanes adjacent to the opened section must be protected by barricades to prevent vehicles from driving onto the closed lane. Do not permit the contractor to use one opened strip of concrete for two-way travel by batch trucks, unless the shoulder is built up to the grade of the concrete pavement and is of sufficient width to permit passage of trucks side by side. Otherwise, there will be travel over the unopened section or severe damage to the edge of the concrete. Before opening a section of roadway, except as a temporary detour, all construction and safety appurtenances must be completed. Work outside the shoulders or safety appurtenances may continue to completion after opening the roadway to traffic.

2-736 Full-Depth Concrete Pavement Replacement

2-736A Concrete Removal

Before any existing concrete is removed, the Engineer inspects the concrete slabs where shown on the plans and designates any additional areas that require concrete removal. Full-depth repairs may be necessary because of the size of spalls, depth of deteriorated concrete or joint failure. Concrete removal is limited to the amount of concrete pavement that can be replaced during the working period.

2-736B Sawing

The existing pavement is sawed full depth along the boundaries designated by the Engineer. The sawing equipment must be capable of sawing neat vertical faces along the patch boundaries. Saw blades with toothed wheels are not permitted for sawing the patch boundaries. Saw cuts with a toothed-wheel saw blade are permitted inside the patch boundaries to facilitate concrete removal. If a toothed-wheel saw blade is used, a minimum 3 in. (75 mm) clearance must be maintained between the internal cuts and the boundaries of the patch.

It usually is necessary to saw into the adjacent slabs or shoulders to ensure that cuts are full depth in the corners. This “over-sawing” should be minimized. All over-sawed areas must be cleaned and filled with approved crack sealant.

Sawing may be performed in advance of the concrete removal operation. However, it is limited to a distance not to exceed the amount of patching that can be completed during the next five working periods. The distance is determined by the Engineer, based on past performance of the contractor.
2-736C Removal

The concrete can be lifted out with chains, lift-pins, or other approved devices. Breaking concrete in place is not permitted. During the removal operations, the contractor must be careful to minimize disturbance and damage to the subbase, adjacent pavement, or bituminous shoulder. Any areas damaged during either the concrete sawing or removal operation must be repaired to the satisfaction of the Engineer by extending the patch boundary at the sole expense of the contractor.

2-736D Existing Bituminous Patches

If existing bituminous concrete patches must be replaced with concrete, the pavement is cut full depth and removed. The adjacent concrete must be free of all bituminous material prior to placing the concrete. The edges of the existing concrete are inspected to ensure that neat vertical faces exist. The adjacent concrete edge must be repaired or recut if ordered by the Engineer.

2-736E Subbase

Disturbed or loose subbase is removed. The contractor is responsible for protecting the subbase and subgrade. The subbase is dampened prior to concrete placement, if ordered by the Engineer.

If the subbase or subgrade is too wet for concrete placement, the contractor is required to excavate and fill. Subbase replacement material must meet the requirements for graded aggregate subbase in accordance with Article M.02 of the Standard Specifications. Construction methods for the material must be in accordance with Article 2.12.03. The Engineer may require the contractor to install transverse subgrade drains in accordance with Article 7.51 of the Standard Specifications.

2-736F Load Transfer

Holes for load transfer devices must be drilled along the transverse joint at mid-slab depth, 12 in. (300 mm) center to center, as shown on the plans. Drills are mounted on a rigid frame to ensure proper horizontal and vertical alignment, and the holes are drilled to within a tolerance of ±1/8 in./ft. (±10 mm/m). The drilling equipment and procedure must have the prior approval of the Engineer.

No. 10 (No. 30M) deformed steel bars are used in all fixed transverse joints. Load transfer bars 1¼ in. (32 mm) in diameter are used in all working transverse joints, as shown on the plans. All bars are 18 in. (460 mm) long and embedded 9 in. (230 mm) into the existing, adjacent slab.

Holes for deformed tie bars are drilled along the longitudinal joint between adjacent lanes at mid-slab depth as shown on the plans. Tie-bar spacing is 24 in. (600 mm) center to center or as shown on the plans. Tie bars are No. 5 (No. 16M) deformed steel bars for 9in. or 10 in. (230 mm or 250 mm) concrete pavements and No. 4 (No. 10M) deformed steel bars for 8 in. (200 mm) concrete pavements. All tie bars are 30 in. (760 mm) long and embedded 15 in. (380 mm) into the slab of the adjacent lane. Tie bars must be installed as shown on the plans. If tie bars are not permitted, ¼ in. (6 mm) fiber board is used to break the bond between adjacent lanes.

The Engineer must inspect epoxy-coated bars to ensure that no damage has been sustained by the coating during shipment and handling.

Chemical anchor material is used to secure the load-transfer bars or tie bars in place. Chemical anchor material is placed using a flexible long-nose tube that injects the material in the back of the hole, in accordance with the manufacturer's recommendations. The injected chemical anchor material must be listed on the Approved Product List of the Department and approved by the Engineer for the specified use.
The bar is inserted in the hole with a slight twisting motion so that the material in the back of the hole is forced around the bar. A retention disk, made of polymeric material, is slipped tightly over the bar and against the slab face. The protruding ends of smooth load-transfer bars are lightly greased immediately in advance of concrete placement.

2-736G Forms

Forms are required on the bituminous shoulder side of the patch. To accommodate the side forms, the contractor must saw cut full depth and excavate 6 in. (150 mm) wide into the adjacent shoulder. Forms must extend along the existing shoulder pavement a minimum of 12 in. (300 mm) on either side of the patch and must be secured to prevent movement during concrete placement. After the removal of the form, the excavated portion of the shoulder is replaced with Bituminous Concrete Class 1 in accordance with Article M.04 of the Standard Specifications and must be true to the line and grade of the new patch and existing shoulder.

2-736H Reinforcement

Smooth welded-steel-wire fabric is used in full-depth patches. The reinforcement is placed at a depth of 3 ± ½ in. (75 ± 13 mm) as measured from the top of the slab. A minimum clearance of 2½ in. (60 mm) from the slab edges and dowel bars must be maintained.

2-736I Placement and Finishing

Concrete is placed in accordance with Article 4.01 of the Standard Specifications. Concrete placement is restricted to the late afternoon or evening during the summer months, or as directed by the Engineer. The limitation minimizes the effect of the daily expansion of adjacent slabs. The concrete mix is placed evenly to a level slightly above the adjacent pavement surface. The use of a continuous mobile mixer to facilitate patching operations, if using a proprietary rapid-setting concrete mixture, may be permitted with the approval of the Engineer.

2-736J Consolidation

Vibration must be used to thoroughly consolidate the concrete throughout the entire patch area. An approved spud-type vibrator or pan vibrator is used to consolidate the concrete. Vibrators must be capable of transmitting 10,000 to 15,000 vibrations per minute. Internal vibration must be used to consolidate the concrete beneath the reinforcing steel. Utmost care must be exercised to ensure that the concrete around the dowel bars and slab edges has been properly consolidated.

Vibrating plates or vibrating screeds must be used on the surface of all concrete pavement replacements for strike-off and consolidation. After the concrete is finished to a level slightly above the existing pavement surface, the vibrating plate or screed is drawn over the surface at a uniform speed, without stopping, to finish the surface smooth and even with the adjacent concrete. The type of screed or plate must be approved by the Engineer.

2-736K Strike-off and Finishing

The surface is struck off to finished grade with a steel or wooden template, and floated to a smooth finish. Addition of water to facilitate the finishing of the patch surface is not permitted. Finishing operations must be completed before initial set takes place. Patches less than 10 ft. (3 m) long (measured in direction of travel) are screeded parallel to the centerline. Patches greater than 10 ft. (3 m) long (measured in direction of travel) are screeded perpendicular to the centerline.
2-736L **Surface Tolerances**

The surface profile of the patch must not vary more than 1/8 in. (3 mm) in 10 ft. (3 m) when a 10 ft. (3 m) straightedge is placed on a surface at any angle. Sags or depressions in the surface of the patch area that exceed the tolerance are repaired at the expense of the contractor. High areas are ground down at the expense of the contractor by approved machinery as directed by the Engineer.

2-736M **Joint Sealing**

Joints are formed and sealed as shown on the plans. Joint sealing must be completed within five days after concrete placement. Joint sealant reservoirs are formed and filled with approved sealant. The reservoirs are thoroughly cleaned with water and dried with compressed air. An approved sealant is applied in accordance with Articles M.03.01-8a and 4.01.03-F.6(f) of the *Standard Specifications* and as shown on the plans.

2-736N **Curing**

Concrete for pavement and high-early-strength portland cement concrete are maintained with liquid curing compound as specified in Article 4.01.03–F.7(a) of the *Standard Specifications*. In addition, an insulating curing blanket with a minimum thermal insulation value of R-3.5 must be placed over the patch if high early strength is required or if the ambient and existing concrete surface temperature is expected to drop below 50 °F (10 °C). Curing of rapid-setting concrete must be in accordance with the manufacturer's recommendations.

2-736O **Testing**

Any newly placed concrete patch having a hollow sound if chain dragged or sounded with a hammer must be replaced by the contractor in accordance with the contract documents.

The Inspector makes test cylinders in accordance with Article 4.01.03–I of the *Standard Specifications*. Additional cylinders are made to ensure the concrete has attained the required compressive strength prior to opening to traffic.

2-736P **Opening to Traffic**

Traffic will be allowed on areas of the roadway where the contractor has placed and finished full-depth concrete patches after the material meets the following criteria.

- Concrete for pavement must conform to Article 4.01.03–J of the *Standard Specifications*.
- High-early-strength Portland cement concrete and rapid-setting concrete must attain a minimum compressive strength of 1,800 psi (12,400 kPa).