ITEM 30

PORTLAND CONCRETE PAVEMENT

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30.1 DESCRIPTION

This work shall consist of a pavement and ancillary structures composed of Portland cement concrete, with or without reinforcement as specified, constructed on a prepared subgrade in accordance with these specifications and in conformity with the lines, grades, thickness and typical cross section shown on the plans or established by the **AGENCY**.

At the option of the **CONTRACTOR**, and with the **AGENCY's** concurrence, Portland Cement Concrete Pavement (PCCP) may be constructed with equipment utilizing stationary side forms or by the use of slip-form paving equipment.

30.2 MATERIALS

The concrete shall be composed of Portland cement (with or without) fly ash, fine and coarse aggregates, admixtures, and water. The ingredients are specified in sections 30.2A through 30.2F. The requirements for the mix are specified in sections 30.2G through 30.2H. The mix shall be generically known as "MGPEC PCCP Mix".

A. Portland Cement

Portland cement shall be Type I-II or Type II "medium alkali" (with a maximum alkali content of 0.8%) and shall conform to ASTM C 150.

B. Fly Ash

Fly ash for concrete shall conform to the requirements of ASTM C 618, Class C or Class F. All chemical requirements of ASTM C 618 Table 1-A shall apply, with the exception of footnote A.

The fly ash shall be limited to a maximum of 25 percent by weight of total cementious material, when used with Portland cement.

C. Fine Aggregate

Fine aggregate shall be hard, durable and uncoated particles of natural or manufactured sand or a combination thereof. It shall be essentially free from frozen material, salt, alkali, vegetable matter or other objectionable material and conform to the requirements of AASHTO M 6, including Class A criteria for deleterious substances; or conform to the requirements of ASTM C-33 using Class 4S criteria. The minimum sand equivalent, as tested in accordance with AASHTO T 176 shall be 80, unless otherwise specified. The fineness modulus shall be between 2.50 and 3.50, unless otherwise approved.
ASTM C1260 (Potential Alkali Reactivity of Aggregates) testing is also required.

D. Coarse Aggregate

Coarse aggregate shall consist of durable particles of gravel, crushed stone or combinations thereof and shall be free from frozen material, salt, alkali, vegetable matter or other objectionable material either free or as an adherent coating, and conform to the requirements of AASHTO M 80 using class A criteria; or ASTM C-33 using Class 4S criteria. ASTM C1260 (Potential Alkali Reactivity of Aggregates) testing is also required.
Grading No. 57 or 467 may be used where the pavement thickness exceeds six (6)-inches and machine pavers are used. Grading No. 67 shall be used when the pavement thickness is six (6)-inches or less.

Coarse aggregate shall conform to the grading shown in the following Table.

TABLE 30.2D-1
PCCP AGGREGATE GRADATIONS

Sieve Size	No. 67 (3/4" Nominal) % Passing	No. 57 (1" Nominal) % Passing	No. 467 Combined Grading % Passing
2 inch	- -	- -	100
11/2 inch	- -	100	95 to 100
1 inch	100	95 to 100	- -
¾ inch	90 to 100	- -	35 to 70
½ inch	- -	25 to 60	- -
3/8 inch	20 to 55	- -	10 to 30
No. 4	0 to 10	0 to 10	0 to 5
No. 8	0 to 5	0 to 5	- -
No. 200	- -	- -	- -

E. Water

Water for use in PCCP and for curing shall be free from oils, acids, organic matter or other deleterious substances and shall not contain more than 1,000 parts per million of chlorides as Cl nor more than 1,000 parts per million of sulfates as SO4. Potable water shall not require testing, but water from other sources shall be sampled and tested before use in PCCP. Tests shall be made in accordance with AASHTO T 26.

F. Admixtures

Admixtures for air entrainment, water reducers, or other uses shall be in a liquid state and conform to the requirements of ASTM C 260 or C494.

Calcium chloride is not allowed for normal use. It may be allowed (up to 2%) only for a fast-track mix (open to traffic less than 24 hours), and only when required rebar or dowels is of non-corrosive materials, upon approval by the AGENCY. The AGENCY shall consider the possible detrimental effects of the additional calcium to any on-site soil containing soluble sulfates. This may result in the lessening of future alkali reactivity protection.

G. Proportioning of Portland Cement Concrete (PCC)

The proportions of materials to be used for mix design and field placement shall produce a workable PCC having:
A slump of:
• 2" to 4" (3" ± 1") for hand pours
• or 1" to 2" (1.5" ± ½") for machine placement,
With entrained air content of:
• 5.0% to 8.0% (6.5% +/-1.5%) when using size #67 maximum coarse aggregate (3/4" nominal maximum size) in mix, or
• 4.5% to 7.5% (6.0% +/-1.5%) when using sizes # 57 or #467 maximum coarse aggregate in mix (1.0" or 1.5" nominal maximum size).

Minimum total cementious content shall be at least 610 pounds per cubic yard with a maximum of 25 percent ash substitution based on weight and a maximum water to cement ratio of 0.45.

The Portland Cement Concrete mixture shall conform to ACI 211 and 301 criteria.
A minimum of 55% coarse aggregate to total aggregate shall be used in the mix. If the mix contains a minimum of 55% of size #467 coarse aggregate, then load transfer dowels in transverse joints can be eliminated.

The field mix shall achieve a minimum 28-day compressive strength of 4,000 psi. The field mix shall achieve a flexural strength of 600 psi at 28 days. Project produced field mixes shall not normally have flexural strength as a spec, but may occasionally be tested for flexural strength. Some projects, by special provision by the **AGENCY**, may require the 600 psi flexural strength criteria be met on project produced mixes.

H. Trial Mix Design, Performance History, and Aggregates Submittals

The **CONTRACTOR** shall submit a laboratory Trial Mix Design (proportions, sources and strength data), aggregate data, and certifications for cementious materials and admixtures for each class of PCC being placed on the project. The trial mix design test data shall show the mix design material sources and proportions, actual tested slump, air content, unit weight, water/cement ratio, and laboratory 7 and 28-day compressive strength results. The laboratory Trial Mix Design mix proportions must produce at least 5,000 psi in the 28-day laboratory compressive strength test (minimum 1,000 psi over-design from the required 4,000 psi field strength). The laboratory Trial Mix Design shall also achieve a flexural strength of 700 psi at 28 days.

In lieu of laboratory Trial Mix Design data, a Field Performance History shall be accepted as proof of potential for performance provided that it meets the strength criteria set forth in ACI 301 for acceptance of concrete mixes. Each Field Performance History shall establish the mix proportions and sources of all ingredients, and data on actual field strengths, slump, air content, unit weight.

Aggregate test data shall include gradations, minus No. 200, sand equivalent, fineness modulus, specific gravity, absorption, soundness, LA abrasion per the requirements of 30.2C & 30.2D. Should the *ASTM C1260* (Potential Alkali

Reactivity of Aggregates) be greater than 0.10%, the test shall be repeated using the revised job mix materials to establish that the Potential Alkali Reactivity is less than or equal to 0.10% for the job mix. The **CONTRACTOR** shall be responsible for the design mix proportions and subsequent adjustments necessary to produce the specified concrete.

The **CONTRACTOR** shall submit a new trial mix design when a change occurs in the mix proportions, source or type of cement, fly ash or aggregate, or failure of field tests to meet the specifications. All Trial Mix Designs or Performance Histories shall be stamped and dated by a Professional Engineer licensed in Colorado. All such Designs or Histories shall be updated or re-confirmed each calendar year.

I. Joint Sealant

The joint sealant for all sawed longitudinal and transverse joints shall be a Dow Corning→ 888 or 890SL gray silicone joint sealant or an approved equal. Blocking medium shall be used below proposed joint sealant to keep the final sealant dimensions per the manufactures recommendation, by filling the lower part of the sawn the joint reservoir to ensure a nominal sealant depth. The blocking medium shall be a commercial grade non absorbing bond breaking cord (backer rod) compressible material in the form of an expanded closed-cell polyethylene foam backer rod or non-plastic rope that is compatible with the joint sealant material.

J. Expansion Joint

The polyethylene expansion joint shall be black, flexible, low density, expanded extruded polyethylene plank formed by the expansion of polyethylene base resin, extruded as a multicellular, closed cell, homogeneous foamed polyethylene. Laminations shall not be permitted.

The joint material shall conform to the following physical property requirements:

- Compression, psi; when tested in accordance with ASTM Designation D 1056 except that compressive strength shall be determined at 10 percent and 80 percent deflection:
    - Less than 10 psi at 10 percent deflection
    - Less than 125 psi at 80 percent deflection

- Water absorption when tested in accordance with ASTM Designation C 272 using conditioning procedure 4.1.1 at a temperature of 50º ± 3 degrees Centigrade:
    - Less than 0.5 % by volume

- Density when tested in accordance with ASTM Designation D 1564:
    - 2.6 ± 0.2 pounds per cubic foot

- Size: Thickness shall be 1 inch, +1/2 inch, -0 inch and full depth of the slab. Width shall be sufficient to fill the joint without laminating to within 1/2 inch below the finished surface of the PCCP.

Regardless of the type of joint filler used, the joint shall be clean and free from all loose material, dirt, dust, grease, oil, or other foreign matter and shall be smooth and surface dry prior to installation of the filler.

K. Curing Compound or Combination Cure/Sealer

Allowable curing compound types and specification shall vary depending upon when an expected snow or freeze condition may occur, or when de-icing materials will be soon used.

1. For PCCP placed between April 1 through September 14:

For normal PCCP, related flatwork, sidewalks, and vertical surfaces, white-pigmented curing compound conforming to ASTM C-309 Type 2, (white pigmented dye) shall be used unless another method conforming to ACI 308, Section 2, is approved by the **AGENCY** in writing. For colored concrete, products must meet ASTM C-309 Type 1 (clear) or 1-D (fugitive dye).

2. For PCCP placed between September 15 and March 31:

A combination cure-sealer shall be used for PCCP and other related flatwork, sidewalks, and vertical surfaces placed during these dates, or when the AGENCY predicts an event where they expect to receive snow, freezing conditions and/or the need for use of de-icing materials within 28 days after concrete is placed. Provide adequate texture to surfaces prior to applying the cure-seal, as the solvent based product has a high gloss finish and can pose visual distractions to drivers at night time if applied to smooth concrete surfaces.

The combination cure-seal products for PCCP, related flatwork, sidewalks, and vertical surfaces must meet ASTM C-1315 Type II, Class B (pigmented, some yellowing allowed). For colored concrete, products must meet ASTM C-1315 Type I, Class A (clear, non-yellowing). The compound must be an acrylic copolymer type, non-freezing solvent based, with a minimum of 25% solids content. Compound must be VOC compliant in accordance with EPA 40 CFR Part 59. The final gloss appearance will serve as proof of application.

The contractor shall use a sealer that when applied according to manufactures recommendations will not adversely affect the skid resistance of the pavement. The use of cure-Sealer shall not be a substitute for best cold weather curing practices according to ACI 308.

3. Submittal & Pre-qualification

The **CONTRACTOR** shall submit manufacturer's literature that shall include surface preparation, application instructions, recommendations and storage and handling requirements.

The applicator must have prior experience applying specified product or similar products, or have manufacturer's representative on site ensuring that preparation and application are performed correctly.

The **CONTRACTOR** shall deliver the approved product in factory sealed and numbered container. Store drums in cool dry area and protected from freezing.

4. Application

The **CONTRACTOR** shall be responsible to protect the concrete being cured from the elements, traffic, and vandalism. Those surfaces covered by forms shall be similarly treated after the forms are removed. Inadequate protection by the **CONTRACTOR** shall be cause for suspension of concreting operations and replacement of the affected concrete at no expense to the **AGENCY.**

The **CONTRACTOR** shall examine concrete surfaces that are to receive curing and sealing compound. The **CONTRACTOR** shall notify **AGENCY** if surfaces are not acceptable. Unacceptable conditions include, but are not limited to, cracked, curled, or spalled concrete surfaces. The **CONTRACTOR** shall not begin surface preparation or application until unacceptable conditions are corrected.

Clean surface of substances that might interfere with penetration or performance of concrete curing and sealing compound. Remove oil, existing curing compounds, laitance, and other substances that could prevent adhesion or penetration of concrete sealers. If necessary, the **CONTRACTOR** shall clean surface with a concrete cleaner. Protect adjoining work, including sealant bond surfaces, from spillage or blow-over of concrete sealer. Cover adjoining and nearby surfaces comprised of aluminum and glass if there is the possibility of concrete sealer being deposited on surfaces. Cover live plants and grass.

Curing and Cure-Sealing compound should be applied to freshly placed concrete as soon as the surface water has dissipated and/or immediately upon removal of formwork. Apply compound at uniform coverage rate in accordance with manufacturer's instructions with a low-pressure sprayer. If using preform pavement markings, apply pavement markings first, cover pavement marking, and then apply sealer. Do not dilute curing and sealing compound. Protect horizontal surfaces from traffic until curing and sealing compound has cured.

30.3 EQUIPMENT

A. General

Equipment and tools necessary for handling materials and performing all parts of the work must have adequate capacity and be in good mechanical condition. This equipment shall be on the site, available for inspection and testing, before paving operations are started. All equipment, tools, and machinery shall be maintained in a satisfactory working condition.

The **CONTRACTOR** shall provide equipment of such capacity that the paver shall operate continuously or at a constant rate of production insofar as feasible. In the event that any piece of equipment does not have sufficient capacity to keep pace with the other operations, the **AGENCY** may limit the size of the batch or otherwise limit the rate of production to prevent poor workmanship, overloading of equipment, or frequent delays.

Any equipment operating entirely or partially on the pavement, regardless of the age of the pavement, shall be equipped so that only rubber-tired wheels shall come in contact with the pavement.

Equipment shall be approved by the **AGENCY**. AII equipment and machinery shall be kept in good working order, free of leaks and properly muffled. All taxes, licenses, and fees shall have been paid and proper licenses and permits shall be posted as required by law.

B. Vibrators

The rate of vibration shall be not less than 3,500 vibrations per minute for surface vibrators and 5,000 vibrations per minute for internal vibrators. For hand vibration, the amplitude of vibration shall be sufficient to be perceptible on the surface of the concrete more than one (1) foot from the vibrating element. The **CONTRACTOR** shall furnish a tachometer or other suitable device for measuring and indicating the actual frequency of vibrations.

Vibrators shall not rest on new pavements or side forms. Power to the vibrators shall be so connected that vibration shall cease when the forward or backward motion of the machine is stopped.

C. Concrete Saw

The **CONTRACTOR** shall provide sawing equipment adequate in number of units and power to complete the sawing with a diamond edge saw blade or an abrasive wheel to the required dimensions. The **CONTRACTOR** shall provide at least one standby saw that is also in good working order. An ample supply of saw blades shall be maintained at the site of the work at all times during sawing operations.

D. Forms

Forms shall be of such section and of sufficient rigidity, both in the form and in the interlocking connection with the adjoining forms, that springing shall not occur under the weight of the subgrading and paving equipment or from the pressure of the pavement when placed. The **CONTRACTOR** shall provide sufficient forms so that there shall be no delay in placing the pavement due to lack of forms. Form sections shall be straight, free from warps, bends, indentations, or other defects. Defective forms shall be removed from the work.

E. Slip-Forms

Slip-form paving equipment shall be equipped with traveling side forms of sufficient dimensions, shape, and strength to support the PCCP laterally for a sufficient length of time during placement to produce pavement of the required cross section.

No abrupt changes in longitudinal alignment of the pavement shall be permitted. The horizontal deviation shall not exceed 0.1 foot from the alignment established by the **AGENCY**.

30.4 CONSTRUCTION

A. Preparation of Grade

The subgrade shall be moist at the time of placing PCC. Sprinkling shall be such that mud and pools of water shall not be formed. At the time of placing the PCC, the grade shall not be muddy, soft, yielding, or frozen. Subgrades shall be prepared, proof rolled and accepted in accordance with Item 3, Embankment.

B. Setting Forms

Before placing side forms, the underlying material shall be at the proper grade. Side forms shall have full bearing upon the foundation throughout their length and width of the form base and shall be placed to the required grade and alignment of the edge of the finished pavement. They shall be so supported that they shall not deviate vertically at any time more than 1/8 inch from the grade established by the **AGENCY**.

The maximum vertical deviation of the top of any individual side form, including joints, shall not exceed 1/8 inch from a 12-foot straightedge, nor shall the inside face vary more than 1/4 inch from a 12-foot straightedge. Stake pockets and interlocking devices shall be in such condition that they shall prevent movement of the form.

Side forms shall be staked firmly by means of steel stakes at each end of the section and at intermediate points not more than 5 feet apart and shall be so designed that stakes may be driven through the base of the form. Forms shall be provided with means for locking stakes in position. Side form sections shall be laid with an expansion gap of approximately 1/8-inch. The stakes used in staking side forms shall be of sufficient length so that the side forms shall be held firmly in place. Any lateral movement of forms greater than 1/4 inch while supporting moving equipment shall be considered as evidence that the steel stakes do not hold the side forms firmly in place and the **CONTRACTOR** at his expense shall provide longer stakes. Immediately in advance of placing pavement and after all subgrade operations are completed, side forms shall be trued and maintained to the required line and grade for a distance sufficient to prevent delay in placing the pavement. Side forms shall remain in place until the day after placing the pavement, and in all cases until the edge of the pavement no longer requires the protection of the forms. When allowed, if the contractor removes forms prior to seven days, he shall apply curing compound to the exposed surface.

Side forms shall be thoroughly cleaned and oiled each time they are used and before pavement is placed against them.

C. Reinforcement

PCCP shall be reinforced at structure approaches and other locations as shown on the plans or directed by the AGENCY, and as specified in this section. Any PCCP that carries heavy traffic loads, 1,000,000 ESALS or greater, shall have smooth dowels inserted in the transverse joints. Also, use if the PCC mix has less than 55% coarse aggregate to total aggregate

TABLE 30.4C-1

Pavement Thickness (T)	Tie Bar Size	Dowel Bar Diameter
T ≤ 8 in.	No. 4	1 in.
8 in. ≤ T ≤ 10 in.	No.5	1.25 in.
10 in. ≤ T ≤ 14 in.	No.6	1.5 in.

Bar reinforcement shall be held accurately and firmly in position during the placing and compacting of the PCCP without sagging by means of supporting devices which shall be left in place. The supports shall be specifically manufactured for the purpose and each support shall be capable of supporting a vertical load of 200 pounds. Spacing of tie bars shall typically be 30 inches on center and dowel bars at 24 inches on center, unless otherwise shown on the plans. Vertical placement shall be at mid thickness.

D. Mixing

All PCC shall be homogeneous and thoroughly mixed in appearance, and there shall be no lumps or other evidence of undispersed cement. Concrete shall be plant mixed concrete, which meets the requirements of AASHTO M 157.

E. Placing PCCP

PCCP shall not be placed on frozen ground, nor shall it be mixed or placed when air temperatures are expected to fall below 35° F unless adequate means are taken to insure the surface of the concrete does not fall below 40° F until the concrete meets a minimum strength of 2,500 psi.

The **CONTRACTOR** shall make adequate advance arrangements for preventing delay in delivery and placing of the PCCP. An interval of more than 45 minutes between placing of any two consecutive batches or loads shall constitute cause for stopping paving operations. The **CONTRACTOR** shall make a construction joint at his expense and as directed by the **AGENCY**, in the concrete already placed. Resumption of paving operations must be approved by the **AGENCY**, after adjustments to the operations by the **CONTRACTOR**.

Unless otherwise specified, PCCP shall be placed in 12-foot traffic lane widths separated by construction joints as shown on the plans, or, at the option of the **CONTRACTOR** and with the **AGENCY's** concurrence, the PCCP may be placed monolithically two or more lanes wide without a construction joint, but with a longitudinal weakened plane joint at each traffic lane line. Any PCC showing improper proportions of materials, including water, shall not be used in the pavement and any such unsatisfactory PCCP shall be removed and disposed of by the **CONTRACTOR** at his expense.

The **CONTRACTOR** shall protect freshly placed PCCP from damage by any cause; see Sec 30.7 for additional information. Any damage that had occurred shall be repaired at the **CONTRACTOR's** expense. Concrete work shall be adequately barricaded in all directions to protect the work. Equipment that damages the subgrade or base shall not be allowed.

Expansion joint material shall be protected while depositing fresh PCC.

F. Spreading, Compacting, and Shaping

1. Form Construction

The PCC shall be distributed uniformly with a mechanical spreader. The placed PCC shall be vibrated, screeded, and tamped by a machine or machines. Any delay in excess of 15 minutes in vibrating, screeding, and tamping shall constitute cause for stopping the placement of PCC until the machines performing such work are again in proper position in the paving train.

The screeds shall be adjusted to an elevation slightly above grade so that when properly consolidated and finished, the completed surface of the pavement shall be at the established grade, true to the cross section shown on the plans, and free from porous areas. The tops of the forms or the adjacent pavement and the contact surface of the crawler tracks or wheels shall be kept clean by effective devices attached to the machine. The travel of the machine shall be maintained true without lift, wobble, or other variation tending to affect precision screeding. During each pass of the machine, a roll of PCC shall be maintained ahead of the front screed for the entire width of pavement being placed and except when making an expansion joint, the machine shall not be operated beyond that point where the roll of PCC can be maintained.

PCC required to be placed in widths less than a traffic lane may be compacted and shaped by a powered mechanical compacting and shaping machine, supplemented by hand methods as necessary. Where hand compaction is performed, the tamper shall be constructed of heavy plank which length exceeds the width of pavement by a minimum of 1 foot; shall be covered with a heavy strip of metal for a tamping surface; and shall be stiffened adequately to maintain the required shape during use. For PCC production in excess of 40 cubic yards per hour, and where all compaction is performed by hand methods, not less than two tampers shall be used.

The hand tamper shall be used with a combined tamping and longitudinal motion raising it from the side form and dropping it to consolidate the PCC. A surplus of PCC shall be kept in front of the hand tamper and tamping shall continue until the required cross section is obtained and the mortar flushes slightly to the surface.

Where hand compaction is performed on grades in excess of 5 percent, a light strike board constructed similar to the heavy tamper shall be used following the heavy tamper or tampers to correct any displacement caused by gravity flow of the PCC.

2. Slip-Form Construction

The **CONTRACTOR** shall establish references at reasonable intervals or both sides of the roadway, for line and grade control of the placing operations. The **CONTRACTOR** shall furnish, place, maintain, remove and dispose of such supports, wire devices, and materials as may be required to provide continuous line and grade reference controls to the placing machine or paver. The slip-form paver shall be equipped with a control system, which shall automatically sense and simultaneously control the laying or trimming of the materials to the specified longitudinal and lateral grade, from both sides of the roadway. The control systems shall be automatically actuated from an independent line, and grade control references through a system of mechanical sensors or sensor directed devices, which shall maintain the equipment at the proper transverse slope and at the proper elevation to obtain the required thickness and surface. The material placed shall be subject to the smoothness and thickness tolerances.

Slip-form paving equipment shall spread, consolidate, screed, and float-finish the freshly placed PCC in such a manner that a minimum of finishing with a hand float, as specified herein, shall be required to provide a dense and homogeneous pavement. The PCC shall be distributed uniformly into final position by the slip-form paver without delay.

The PCCP, for the full paving width, shall be effectively consolidated by internal vibration with transverse vibrating units or a series of equally spaced longitudinal vibrating units. If a series of longitudinal vibrating units are used, they shall be equally spaced at intervals not to exceed 30 inches, measured center to center.

When PCC is being placed adjacent to an existing pavement, that part of the equipment which is supported on the existing pavement shall be equipped with protective pads on crawler tracks or rubber-tired wheels on which the bearing surface shall be offset to run a sufficient distance from the edge of the pavement to avoid breaking or cracking the pavement edge.

At locations inaccessible to slip-form paving equipment, PCCP shall be placed by methods and equipment conforming to the requirements for placing PCC in widths less than a traffic lane as specified in 30.4F1. Locations inaccessible to the slip-form paving equipment shall be finished by the hand float method.

30.5 FINISHING

A. General

Placing of PCC shall cease at such time that finishing operations cannot be completed during daylight hours or when sufficient illumination that duplicates daylight is available. Necessary workmen shall remain at work long enough to complete the finishing and curing of the pavement.

B. Hand Float Method

The surface of the PCCP shall be finished smooth and true to grade with two wooden or magnesium floats 8 feet long, 1 inch thick and 4 inches wide, rigidly ribbed and with adjusting screws between the rib and float bars at not more than 2-foot center, to ensure a true and flat surface on the underside at all times. Each float shall be operated from the side of the pavement and the float shall be parallel with the centerline of the pavement. The edge of the float shall be used to cut down all high areas, and the material so removed shall be floated into the depressions until a true surface is obtained. Each successive passage of the float shall just lap the previous path. Upon completion of the passage, the float shall be brought back and the overlap between the two passages smoothed.

The floats shall be operated as far back of the tamping machine as the PCC remains workable and the number of passes shall be sufficient to remove all perceptible inequalities.

C. Edging

After the preliminary finishing has been completed, the edges of an initial pavement lane shall be rounded to a 1/2-inch radius. Transverse construction joints, expansion joints, and joints adjacent to an existing pavement shall be rounded to a 1/4 inch radius.

D. Texture

In advance of the curing operations, the pavement shall be textured with a drag strip of burlap or other device, which shall produce scoring parallel to the centerline. The burlap drag shall consist of one or more pieces of burlap fastened to a cross member riding on the subgrade or side forms by means of wheels or skids to form a continuous strip of burlap the full width of the pavement. Drags shall be maintained clean and free from encrusted mortar. Drags that cannot be cleaned shall be discarded and new drags substituted. Completed pavement that, in the opinion of the **AGENCY**, is found to have a surface texture that does not provide satisfactory skid resistance shall be ground or scored by abrasive means to provide a surface texture satisfactory to the AGENCY, at the **CONTRACTOR's** expense.

E. Tining

The **AGENCY** may require tining to form groves on the PCCP surface, as shown on design plans. In advance of curing operations, the PCCP shall be first textured with a drag strip of burlap or similar device. If the **AGENCY** requires, tining with a mechanical spring steel tine device, will be required and which shall form grooves as shown on the plans. In lieu of Plan details, the tines shall be rectangular in cross section, 3/32 to 1/8 inch wide, and 4 to 5 inches long. Tines shall be spaced 3/4 inches center to center and be of sufficient thickness and

resilience to result in grooves 1/8 to 1/4 inch deep in the finished PCCP. The speed of the tine machine shall be slow enough so that the tines shall penetrate the surface to the desired depth, yet fast enough so, the machine can keep up with paving operations. A 1-inch gap shall be left between each tine strip to prevent overlapping the tined surface and producing a weak surface area.

30.6 JOINTS

A. General

Joints in pavement shall be designated as longitudinal and transverse construction joints, transverse expansion joints, and longitudinal and transverse contraction joints, and shall be constructed as shown on the plans and in accordance with the following provisions.

Construction joints are those made by placing fresh PCC against hardened PCCP at planned locations. PCCP on both sides of longitudinal construction joints shall be connected with tie bars as shown on the plans. PCCP on both sides of transverse construction joints shall be connected with dowel bars as shown on the plans.

All transverse joints shall be constructed at the angle to the centerline of the pavement shown on the plans and the faces of all joints both transverse and longitudinal shall be perpendicular to the surface of the pavement.

All sawed joints shall be clean, free of all foreign material, and sealed after completion of shoulder work and prior to acceptance of the project or portion of the work.

Tie bars shall be required for all longitudinal joints and shall be placed as specified on the plans.

B. Joint Layout

The **CONTRACTOR** shall propose a joint layout for approval by the **AGENCY**. Panel width should match lane width, with joints on lane lines whenever possible. Recommended panel width is 12 feet, and maximum panel width should be 14 feet.

C. Weakened Plane Joints

Sawed *TRANSVERSE* weakened plane joints shall be formed by cutting the pavement with a power driven saw at the locations shown on the plans. The grooves for transverse weakened plane joints shall be saw cut to the dimensions shown on the plans for “transverse weakened plane joint.” (Recommended saw depth of 1/3 the pavement thickness for joints with steel reinforcement, and 1/4 the pavement thickness for joints without steel reinforcement.)

Sawed *LONGITUDINAL* weakened plane joints shall be formed by cutting the pavement with a power driven saw at all lane lines. The grooves for longitudinal weakened plane joints shall be saw cut to the dimensions shown on the plans for “longitudinal weakened plane joint”.

The sawed joint shall go through the pavement edge at full depth of cut. The time of sawing shall be determined by the **CONTRACTOR** to prevent uncontrolled cracking and raveling from the sawing. Every other planned transverse weakened plane joint in the initial lane of PCCP and the first joint immediately after the transverse joint shall be sawed within 24 hours after the PCCP has been placed, unless otherwise authorized by the **AGENCY**. The remaining longitudinal and transverse weakened plane joints shall be saw cut, before uncontrolled Volunteer cracking occurs and within 48 hours and before permitting the **CONTRACTOR's** traffic or public traffic to use the pavement.

In succeeding lanes of the PCCP, transverse joints opposite those which have opened in the initial lane, shall be sawed within 24 hours after the PCC has been placed.

No transverse sawing shall be done within 5 feet of transverse uncontrolled cracks. If a transverse uncontrolled crack falls within 5 feet of the location of a proposed sawed joint, the sawed joint shall be omitted. Non-conforming sawed joints shall not be paid for. Cracks shall be routed and sealed at the **CONTRACTOR's** expense.

When the pavement is cured by means of a curing seal, all portions of the seal which have been disturbed by sawing operations shall be restored by spraying the areas with additional approved curing seal.

D. Joint Sealing

Sawed longitudinal, transverse weakened plane joints and construction joints shall be sealed with joint sealant material meeting the requirements of 30.2I. The joint shall conform to the details shown on the plans. After saw cutting, the joint shall be cleaned by low-pressure water flushing to remove the slurry. Prior to sealing, the joint shall be cleaned per joint sealant manufacturer's recommendations. Immediately prior to sealing, joints shall be blown using a minimum air pressure of 100 psi. All joints shall be clean and dry prior to sealing. Prior to placing the joint sealant, a commercial quality non-absorptive blocking medium or bond breaker cord (backer rod) shall be placed in the joint to the depth shown on the plans. The silicone joint sealant material shall then be installed in accordance with the manufacturer's recommendations.

It shall be the **CONTRACTOR's** responsibility to prevent spills or excess sealant material from coming in contact with the horizontal surface of the PCCP on either side of the joint. Any such spills or excess material shall be removed to the satisfaction of the **AGENCY** at the **CONTRACTOR's** expense.
Silicone joint sealant shall be tested with the field adhesion test as follows:
These simple screening procedures may help detect application problems such as improper cleaning, use of improper primer, poor primer application, or improper joint configuration.

- Make a knife cut horizontally from one side of the joint to the other.
- Make two vertical cuts (from the horizontal cut) approximately 3 inches (76.2 mm) long, at both sides of the joint.
- Place a 1-inch (25.4 mm) mark on the sealant tab.
- Grasp the 2-inch (50.8-mm) piece of sealant firmly just beyond the 1-inch (25.4 mm) mark and pull at a 90° angle.

- If dissimilar substrates are being sealed, check the adhesion of sealant to each substrate separately. This is accomplished by extending the vertical cut along one side of the joint, checking adhesion to the opposite side and then repeating for the other surface.
- The adhesion test is considered passing when 1 inch (25.4 mm) of sealant is elongated to 4 inches (101.6 mm) without bond loss.

E. Transverse Expansion Joints

Transverse expansion joints shall be formed at structure approaches as shown on the plans and as specified herein. Transverse expansion joints shall be formed by means of joint filler strips meeting the requirements of 30.2J. The joint strips shall be firmly supported in position by metal holders and end supports. The supports shall be held firmly in position and shall remain in place after completion of the pavement.

The metal holders shall be fabricated of sheet steel not less than 16 gauge. They shall be in the form of a deep channel, extending down on both sides of the joint strip to a depth of not less than 3/8 inch. They shall be slotted and cut away as necessary, to allow the PCC to make contact with the joint strip at close intervals. The ends of the holders shall be spread to admit the end supports.

During placing and compacting the PCC, the joint holder and end supports shall be secured as to ensure against movement of the joint strip and to keep the top edge of the joint strip approximately 1/2 inch below the surface of the finished pavement. After the PCCP has been placed and consolidation completed, the metal holder may be removed and a suitable shallow metal channel substituted which shall fit snugly over the top edge of the joint strip and shall remain there until the joint is edged.

Filler shall extend 1/2 inch less than full width of the PCCP being placed. After the side forms have been removed, any PCC, which has flowed around the ends of the joint filler, shall be removed.

The new PCCP shall be saw cut at locations as shown on the plans for placement of the polyethylene joint filler. Forming of the open joint and subsequently removing the forms to allow placement of the joint filler shall not be permitted. The joint shall be saw cut full width of the PCCP and full depth and shall be 1 inch wide with a tolerance of +0 inches and minus 1/8 inch between joint faces. Remove all PCC between the cuts and thoroughly clean the open joint with compressed air.

The polyethylene joint filler shall conform to the requirements of Item 30.6E. The height of the polyethylene joint filler shall be such that the top surface of the installed filler is 1/2 inch below the finished surface of the PCCP. The width of the joint filler shall be 1 inch. Prior to inserting the filler into the open joint, all sides of the material which shall be in contact with PCCP shall be coated with a joint lubricant and adhesive recommended by the manufacturer of the filler material.

30.7 TOLERANCES

A. Smoothness

Upon completion of the pavement, any points that are high in excess of the 10' straightedge tolerance of 1/4-inch maximum longitudinal and 1/4-inch maximum transverse shall be removed by diamond grinding.

The profile index requirements herein shall not apply to the pavement within 30 feet of either end of a bridge or intersection. The finished surface of such pavement shall, however meet all other requirements in this section.

Equipment that consistently produces a finished surface having a profile index of 12 inches per mile or less shall be used. Should the profile index exceed the rate of 12 inches per mile, for reasons other than to match perimeter conditions, the paving operations shall be discontinued until other means and equipment are proposed for trial by the **CONTRACTOR** and are approved by the **AGENCY**. Such revised methods and equipment shall be discontinued if they do not produce a finished surface having a profile index of 12 inches per mile or less per Colorado Procedure CP 72 (0.2 inches Blanking Band) profilograph.

In addition to the requirement for average profile index, all areas representing high points having deviations in excess of 0.5 inch in 25 ft. as defined in the following paragraph, shall be reduced by abrasive means until such deviations as indicated by reruns of the profilograph do not exceed 0.5 inch in 25 ft. The deviations in excess of 0.5 inch in 25 ft. shall be determined by measurement of the profilograph.

After grinding has been completed to reduce all individual deviations in excess of 0.5 inch as provided in the above paragraph, additional grinding shall be performed if necessary to reduce the profile index, as measured by the profilograph to 12 inches per mile, or less, in any 0.1 mile section along any line parallel to the edge of the pavement.

Additional grinding shall be performed as necessary to extend the ground area laterally to the nearest lane line or edge of pavement and longitudinally so that the grinding begins and ends at lines perpendicular to the pavement centerline within any one ground area. It is the intent of this requirement that all ground areas be neat rectangular areas of uniform texture.

The **CONTRACTOR** shall be responsible for providing a CDOT certified profilograph and trained operator.

B. Pavement Thickness

It is the intent of the specifications that PCCP shall be constructed in accordance with the thickness requirements of the plans and specifications. Thickness measurements shall be made at the rate of not less than one measurement for each 500 linear feet of traffic lane, or fraction thereof, of pavement placed. Insufficient thickness from 0.20 to 0.60 inches shall be price reduced for each lot of 500-foot lane feet, in accordance to Section 30.9.
If the pavement is deficient by more than 0.6 inches, additional measurements shall be made to identify the limits of the deficiency. The area in question shall

be entirely bordered by longitudinal or transverse joints and pavement edges. After the deficient area is identified, the **AGENCY** shall determine as to whether the PCCP shall remain in place or be removed in accordance with the following procedures:

- The **CONTRACTOR** shall, at his expense, remove and replace the PCCP in the area determined by the **AGENCY** with new PCCP meeting the thickness requirements. Subgrade shall be lowered as necessary to meet full thickness requirements.

- The **CONTRACTOR** shall leave the deficient section of PCCP in place without payment, if it meets all of the other requirements as determined by the AGENCY.

C. Compressive Strength

When a compressive strength test falls below the specified 28-day compressive strength, a determination shall be made by the **AGENCY** to whether the PCCP shall be removed and replaced or allowed to remain in place. This determination shall be based on ACI 301, sections 1.6.5.3, 1.6.6.3, and 1.6.7.3, except that the Testing Agency shall be mutually agreed upon by the **AGENCY** and the **CONTRACTOR**. If after review, the **AGENCY** allows the PCCP to remain in place a price reduction for each lot of 100 cubic yards shall be in accordance with Section 30.8.

D. Repair of Defective Concrete Pavement

Defective concrete pavement shall be repaired or replaced at the **CONTRACTOR's** expense. This corrective work shall be accomplished prior to joint sealing and final smoothness measurement. Defective concrete pavement replaced after smoothness measurement shall be retested for final smoothness. The **CONTRACTOR's** corrective work plan shall be approved prior to performing the work. When necessary, the extent of defects shall be determined by the inspection of cores at the **CONTRACTOR's** expense. The following conditions shall require removal and replacement:

- Pavement slabs containing multiple cracks through the full depth of the slab that separate the slab into three or more parts.
- Pavement slabs having a single diagonal crack that intersects the longitudinal and transverse joint.
- Pavement slabs containing honeycombed areas.
- Pavement slabs containing more than one void greater in depth than half the pavement thickness.
- Pavement slabs containing a cumulative surface area of moderate and severe voids, as defined below, greater than one percent of the slab's total area.
- Pavement slabs containing 20 or more severe voids as defined below.

A void is a defect in a slab caused by air pockets, clay balls, clumps of sand, cement or reinforcing fibers caused by incomplete mixing or foreign materials such as cans, rags, bottles, etc. The defect shall be considered a moderate void when the largest dimension, height, width, or length is at least 13 mm (1/2 inch)

but no more than 50 mm (2 inch). The defect shall be considered a severe void when the largest dimension, height, width, or length is greater than 50 mm (2 inch). The defect shall be considered an extreme void when the largest dimension, height, width or length is greater than 1/3 the thickness of the pavement.

Concrete slabs that are determined by the **AGENCY** to be acceptable if repaired shall have voids filled using materials and methods approved by the **AGENCY**.

Cracks penetrating the full depth of the pavement shall be routed and sealed. The top of the crack shall be routed to a minimum depth of 20 mm (3/4 inch) and a width not less than 10 mm (3/8 inch) nor more than 15 mm (5/8 inch) by means of a grooving machine. The routing machine shall be capable of following the path of the crack and widening the top of the crack to the required section without spalling or damaging the concrete. Loose and fractured concrete shall be removed and the crack shall be cleaned and sealed in accordance with section 30.6D requirements. Cracks that are determined by the **AGENCY** to be tight and do not penetrate the full depth of the pavement shall be left undisturbed.

30.8 CURING

A. General

All PCCP must be cured and protected from weather and temperature extremes for a minimum of 72 hours.

B. Curing Compound Method

The curing compound shall not be applied until all patching and surface finishing, except grinding, has been completed. When deemed necessary by the AGENCY during periods of hot weather, fogging of the PCCP with water shall be continued after curing compound is applied until a cooling effect is no longer required.

Refer to section 30.111 for selecting a curing compound to be used between April 1st and September 14th, and selecting a combination cure-seal to be used between September 15th and March 31st, or when use of de-icing materials may likely be applied to PCCP less than 28 days old.

All PCCP, except colored PCCP, shall be cured with a white pigmented curing compound applied uniformly with adequate coverage according to manufacturer's recommendations. A fugitive dye or clear curing compound shall be used on colored PCCP. Surfaces of the PCCP, which are exposed to the air, shall be sprayed uniformly to obtain total coverage of the PCCP surfaces. The rate of application for an approved curing compound shall be 1 gallon per 150 square feet $\pm$ 50 square feet Curing compound must be uniformly applied, resulting in a visually well-painted surface. Power operated spraying equipment for application of curing compound shall be equipped with an operational pressure gauge and means of controlling the pressure.

The curing compound shall be applied immediately after the moisture sheen begins to disappear from the surface, but before any drying shrinkage or craze

cracks begin to appear. In the event of any delay in the application of curing compound, application of water with an atomizing nozzle shall be started immediately and shall be continued until the application of the compound is resumed or started.

Evaporation inhibitors may also be used to extend the surface workability. Evaporation inhibitors shall be a mono-molecular film such as Dayton J-74 or Master Builders Confilm or equivalent. These are poly vinyl alcohols that do not change the water cement ratio, but by being hydrophobic they drive the water back into the slab and thus inhibit evaporation. Widely used, and part of every contractor's tool kit in the summer. Should the film of compound be damaged from any causes before the expiration of 72 hours after the PCCP is placed, the damaged portion shall be repaired immediately with additional compound.

C. Protection of Pavement during Inclement Weather

The **CONTRACTOR** shall protect newly placed PCCP from any detrimental precipitation and weather. The **CONTRACTOR** may choose to proceed with PCCP placement during marginal weather, but they do so at their own risk of later removal. Concrete damaged due to changing weather conditions shall be repaired, or removed and replaced as determined by the **AGENCY**, and at the **CONTRACTOR's** expense.

Placing PCCP shall be stopped and newly placed PCCP to be covered before:

- The quantity of RAINFALL is sufficient to cause a flow or wash the surface.
- The quantity of PRECIPITATION or FOREIGN SUBSTANCES might impact the strength or durability
- The quantity of wind could cause surface drying leading to cracking.

The **CONTRACTOR** must protect pavement from damage due to the above mentioned causes. Failure to properly protect concrete may constitute cause for removal and replacement of defective pavement. Plastic film is preferred for surface and edge protection to limit water intrusion or surface drying..

Rain damage varies considerably depending on rainfall intensity, duration, and protective measures taken by the contractor. Covering and side forms placed by the contractor afford sufficient protection to unhardened concrete in some cases. In other cases, surface and edges may erode to such a degree that removal and replacement of the slab is the only solution. If the concrete is still plastic and is damaged by rain, the damaged surface may be dug out and replaced with fresh concrete. It is not acceptable to refinish the damaged surface without first removing the damaged concrete.

All PCCP shall be protected from freezing or frost for a period of 5 days after placing. The temperature of the surface of the concrete shall not be allowed to drop below 40° F during this period. The **CONTRACTOR** shall show, by evidence of using recording internal or surface mounted external concrete temperature devices, that all slab top, side, and face surfaces were cured at or above the minimum 40°F during the 5-day period. Any evidence of curing below this temperature, such as a 'leaf pattern' on surfaces or inside cracks, shall be investigated. The concrete compressive strength must be deemed to be at or

above the required minimum 2,500 psi strength prior to opening to traffic, and able to reach the required 28 day strength.

D. Damage Analysis

All PCCP, which the **AGENCY** suspects might be damaged, shall be assessed for suitability by mutual agreement with the **CONTRACTOR**. **CONTRACTOR** shall provide **AGENCY** with approved experts in assessment, and shall replace or repair any damaged PCCP at the **CONTRACTOR's** expense, as approved by the **AGENCY**.

In the event that the **CONTRACTOR** does not agree with removal and replacement, the **CONTRACTOR** may elect, at his own expense, to send cores to an experienced petrographer for analysis of the concrete's water-cement ratio, air content, air-void spacing factor, and general appearance using ASTM C 856. The number of cores and the core locations should be approved by the **AGENCY** prior to submittal. A petrographic examination of cores taken from the concrete does provide helpful information to determine the extent of the damage. A petrographer can indicate how deep any damage extends and provide recommendations for effective repair, such as diamond grinding. If a general petrographic evaluation does not answer all of the questions on the concrete's durability to the satisfaction of the **AGENCY**, a more detailed analysis of the air-void system using ASTM D 457 should be performed. Surface scaling tests should also be conducted in accordance with ASTM C 672. Rain damaged concrete shall need to be removed if it is determined by the **AGENCY** to be non-durable in terms of abrasion, skid resistance, or freezing & thawing.

E. Open to Traffic

No traffic or **CONTRACTOR's** equipment shall be permitted on the pavement until the strength requirement has been reached. Criteria shall be at least 2,500 psi for PCCP over 8" thick, and the design field strength (4,000psi) for PCCP less than or equal to 8" thick. See Appendix 30 for using the maturity method to predict opening strength.

30.9 PRICE REDUCTIONS

Insufficient thickness and compressive strength shall be subjected to removal and replacement or price reduction at the following rates:

TABLE 30.9-1

Thickness PRICE REDUCTIONS

Average Thickness Deficiency (inches)	Price Reduction *
0.00 to 0.20	0
0.21 to 0.30	10
0.31 to 0.40	15
0.41 to 0.50	25
0.51 to 0.60	30

*Price reduction is equal to the full price of the entire pavement system. Price reductions reflect the reduction in lifespan of the facility resulting from the deficiency.

TABLE 30.9-2
STRENGTH PRICE REDUCTIONS

Percent of Specified 28 – Day Compressive Strength *	Price Reduction **
100	0
95	0
94	3
93	6
92	9
91	12
90	15
89	18
88	21
87	24
86	27
85	30

*Strengths less than 85 percent of the design strength shall be removed and replaced.
**Price reduction is equal to the full price of the entire pavement system. Price reductions reflect the reduction in lifespan of the facility resulting from the deficiency.

30.10 MEASUREMENT

A. PCCP

The number of square yards of PCCP to be measured for payment shall be determined using field quantities mutually agreed upon by the **CONTRACTOR** and the **AGENCY**.

B. Expansion Joints

The "expansion joint (saw cut)" shall be measured for payment by the linear foot.

C. Sawed Transverse and Longitudinal Weakened Plane Joints

The length of sawed transverse and longitudinal weakened plane joints shall be measured for payment by the linear foot of the transverse and longitudinal weakened plane joints actually sawed. Volunteer or uncontrolled cracks shall not be included in the length of transverse or longitudinal weakened plane joints measured for payment. Joint sealant and bond breaker placed in sawed transverse and longitudinal weakened plane joints shall not be measured or paid for directly, and shall be included in the contract unit price bid per linear foot for the joint.

D. Tie Bars and Dowels

Tie bars and dowels shall not be measured or paid for separately.

30.11 TESTING AND INSPECTION

Testing of Portland Cement Concrete Pavement shall be performed in accordance with Table 30.11-1.

TABLE 30.11-1
QC SCHEDULE FOR MINIMUM MATERIALS SAMPLING AND TESTING
FOR ITEM 30 - PORTLAND CEMENT CONCRETE PAVEMENT
QA testing may be less frequent than that require for QC testing

Test Type	Test Standard	Minimum Frequency of Tests
Compressive Strength	ASTM C 39	One set* per 100 cubic yards (minimum of one/day)
Air Content	ASTM C 231	One test per each first three trucks, then one for every five trucks **
Slump	ASTM C 143	One test per each first three trucks, then one for every five trucks **
Temperature	ASTM C 1064	One test with every air and slump test.
Thickness	ASTM C 174	One core test per 500 linear feet per lane
Unit Weight	ASTM C 138	One per air content test
Joint Sealant Pull Test	See Section 11.6.3	One per 1,000 linear feet of joints

*One set consists of at least 4 cylinders
**If out of specification test all until in specification

Field testing shall be performed by ACI certified field testers. The **AGENCY** shall determine who is responsible for performing QA testing, and the **CONTRACTOR** shall be responsible for QC testing.

30.12 PAYMENT

The accepted quantities measured in Section 30.10 shall be paid for at the contract unit price bid as follows:

Bid item 30.12-1 PCCP shall be full compensation per square yard placed. All PCCP shall include PCC, water, mixing, hauling, placing, tie bars, dowels, finishing, curing, pavement protection, QC testing, repairs, and incidentals necessary for doing all the work as shown on the plans or established by the **AGENCY**.

There shall be no direct payment for grooving the PCCP surface with tines and all work involved shall be considered included in the contract bid prices for other items of work.

There shall be no direct payment for Profilograph measurement to the PCCP surface, all work involved shall be included in the contract bid prices as shown on the plans or when established by the **AGENCY**.

All grinding and re-grooving of the PCCP that is necessary to meet the requirements of these specifications shall be accomplished solely at the **CONTRACTOR's** expense and no additional payment shall be allowed.

Bid item 30.12-2 Expansion Joint (Saw Cut) shall be full compensation by the linear foot placed. All Expansion Joint shall include sawing, cleaning, furnishing expansion material, placing bond breaker, and the joint sealer,

Bid item 30.12-3 Sawed Transverse and Longitudinal Weakened Plane Joints shall be full compensation by the linear foot placed. All Expansion Joint shall include sawing, cleaning, furnishing, placing the bond breaker, and the joint sealer,

Item	Description	Payment
30.12-1	Portland Cement Concrete Pavement	$/square yard
30.12-2	Expansion Joint (Saw Cut)	$/linear foot
30.12-3	Sawed Transverse and Longitudinal/Weakened Plane Joints	$/linear foot

30.13 WHITETOPPING

A. General

Whitetopping is a concrete overlay of existing asphalt pavement. When loaded by vehicles, the new concrete overlay behaves like a new concrete pavement on a firm base course. All the previous specification shall apply including the following. Concrete for whitetopping (concrete overlay) shall conform to the requirements for "MGPEC PCCP Mix" concrete as specified in subsection 11.2 with the following exception: "MGPEC PCCP Mix" pavement for whitetopping shall contain a minimum of 55% coarse aggregate. Coarse aggregate shall be AASHTO M43 size 67.

B. Asphalt Surface Preparation

Mill existing asphalt surface to the depth indicated on the Project Drawings using self-propelled milling equipment having an effective means for preventing dust

from escaping into the air. The recommended minimum depth of asphalt base remaining after milling shall be 4". All material removed becomes the property of the **CONTRACTOR** unless otherwise designated in the Contract Documents.

Surface Milling: The milled surface shall be full-width. No concrete shall be placed on un-milled surface or on exposed base. If base is exposed, the **CONTRACTOR** shall submit a plan to correct the exposed base surface and proceed with corrective action after the **AGENCY** approves the plan.

Surface Cleaning: The initial cleaning of the milled surface shall be accomplished by brooming the surface using a mechanical broom surface shall be further cleaned by the use of pressure cleaning to insure that all dust, grit, and foreign material is removed from the surface. The area shall be protected as necessary to prevent contamination until placement. When areas are not adequately protected, additional cleaning will be required prior to placement of concrete overlay as directed by the **AGENCY**. Milled surface will not be open to traffic.

Remove all loose foreign material from asphalt surface with compressed air, by brooming or other methods immediately prior to placing concrete.

Do not place concrete when the asphalt surface temperature is less than 10° C (50°F).

C. Whitetopping Placement

Whitetopping shall be placed in accordance with the following additional requirements:
The Contractor shall receive delivery tickets, monitor, and maintain yield to achieve the minimum thickness. Copy of tickets to be delivered to the engineer at the end of each days paving.

Deposit concrete directly onto the prepared asphalt that has been physically saturated with water prior to placement. Other methods of conveying the concrete may be used when accepted by the **AGENCY**.

Moisture Coat: After the surface has been milled, cleaned, and accepted, and prior to the concrete overlay placement, a light wetting of the surface will be required. This should be accomplished just ahead of the concrete overlay placement by spraying with a fine mist without allowing ponding on the surface. No asphalt surface shall be allowed to dry prior to concrete overlay placement.

D. Exclusions to Normal PCCP

Dowel bars will not be required for whitetopping (concrete overlay).

E. Method of Measurement

1. Asphalt Surface Preparation

The area of asphalt surface preparation shall be computed by the **AGENCY** in square yards from measurements of the locations.

2. PCCP (Whitetopping)

The area of concrete overlay placement shall be computed by the **AGENCY** in square yards from measurement of the locations.

F. Basis of Payment

1. Asphalt Surface Preparation

Payment shall be made at the contract price per square yard for asphalt surface preparation. This shall include full compensation for removal and disposal of material.

2. PCCP(Whitetopping)

For the concrete overlay constructed, payment shall be made at the contract price per square yard. This shall be full compensation for furnishing all materials, and for proportioning, mixing, delivery of concrete to the paving site, all labor, equipment and materials to place, finish, texture, cure the concrete, and to saw or form and seal the joints, in accordance with the Contract Documents.

Item	Description	Payment
30.13-1	Asphalt Surface Preparation	$/square yard
30.13-2	Portland Cement Concrete Pavement-Whitetopping	$/square yard

Appendix 30
Maturity (Time-Temperature) and Strength Relationship

Maturity-Strength Relationship testing may be used as a tool to obtain strengths in making decisions when to open the roadway pavement to traffic (or allow design loads on the concrete), particularly when early opening is desired or required by the Agency. This is a two-step procedure. First, a relationship must be established between the maturity values and the concrete strength as measured by destructive methods (that are, through testing of beams or cylinders). The development of the maturity-strength curve shall be done at the beginning of construction using project materials and the project proportioning and mixing equipment. The second step is the instrumentation of the concrete to be measured. Temperature probes are installed in the concrete and the temperature is measured. From those measurements, along with the age at which the measurements were taken, maturity values are determined. A maturity meter or temperature-measuring device and a computer or calculator may also be used to determine the maturity values. The contractor and the agency shall jointly develop a plan for performing the maturity testing. The plan shall include:

1. The contractor shall be responsible for the development of the maturity curve. The curve development shall be monitored by the contracting agency.
2. The temperature monitoring process of the constructed pavement or structure shall be the responsibility of the contractor and shall be monitored by the contracting AGENCY. Determining that sufficient strength has been achieved shall remain the responsibility of the AGENCY. The contractor shall provide documentation of maturity testing before a pavement section may be opened to traffic, a structure may be loaded, or the forms may be removed.

THE MATURITY-STRENGTH CONCEPT

Detailed procedures for maturity testing can be found in ASTM C 1074.

The hydration of cement and gain in strength of the concrete is dependent on both curing time and temperature. Thus, the strength of the concrete may be expressed as some function of time and temperature. This information can then be used to determine the strength of concrete without conducting physical tests. The time-temperature function commonly used is the maturity concept proposed by Nurse-Saul (ASTM C1074),

$$M(t) = \Sigma\ [(Ta - T0)\ \Delta t] \qquad \text{Equation 1}$$

where:

M (t) = temperature-time factor (TTF) at time t (degree-days or degree-hours)
Δt = time interval (days or hours)
Ta = average concrete temperature during time interval (°C or °F)
T0 = datum temperature at which it is assumed that concrete ceases to gain strength with time; the value of -10°C (14°F) is most commonly used.

The other maturity function is used to compute equivalent age at a specific temperature proposed by Freiesleben - Pedersonas follows:

$$te = \Sigma e^{-Q(1/Ta-1/Ts)} \Delta t \qquad \text{Equation 2}$$

where:

te = equivalent age at a specified temperature Ts , days or hours
Q = activation energy divided by the gas constant, °K
Ta = average temperature of concrete during time interval Δt, °K
Ts = specified temperature, °K
Δt = time interval, days or hours

ESTABLISHMENT OF MATURITY-STRENGTH RELATIONSHIP

Precaution: When the concrete temperature is below 10°C (50°F), maturity strength development shall cause over extended TTF values. Development of strength maturity relationship should be performed on concrete with temperatures above 10°C (50°F). When air temperatures are expected to fall below 4°C (40°F), place the beams on a piece of foam board or plywood to prevent the cold ground from lowering beam temperatures. Placing insulation over the beams to retain heat may also be warranted. To establish a maturity-strength relationship for a concrete mix, a maturity meter or a thermal meter and a hydraulic testing machine are needed. The following procedure shall be used: (Note: Before using any maturity meter, check to be sure the datum temperature is set to 0°C.)

1. Cast a minimum of twelve- (12) 6-in. x 6 in. x 20-in. beams. Test the entrained air content and slump of the concrete being used to cast the beams. Record these values. The concrete shall meet specifications. Since there is a direct relationship between w/c ratio and strength, the concrete used to develop the maturity-strength relationship shall be at the maximum w/c ratio expected during production. The beams shall be cast from a batch of at least 3 cu. yd.
2. Embed a thermocouple wire near each end of a test beam (when flexural strength is to be determined) to monitor the temperature. This beam shall be the last to be tested. A probe shall be inserted near each beam end to the approximate mid-depth and such that they are approximately 3 in. from each side and each end. Loop the wire around the beam box handles to prevent the wire from being inadvertently pulled out of the beam. The average of the two readings shall be used in the development of the maturity-strength curve. When the maturity thermal meter is used, the measured temperature should be substituted into Equation 2 to obtain values of maturity. When a maturity meter is used, the meter computes the values. Twelve (12) test specimens shall be tested as described in #4 below.
3. Cast, cure, and test the beams at the plant site. This shall allow a maturity meter to be protected from the weather and theft. The meter can be stored in a lab trailer or vehicle with the probes run outside to the beam in the sandpit. The beams shall be covered with plastic immediately after casting and prior to form removal. If possible, wet burlap should be placed over the surface of the beams under the plastic. The forms shall be removed the following day. Cure all beams in a pit of wet sand after form removal, until they are tested.
4. Determine maturity values and strength at four different ages. Test three specimens for strength at each age and calculate the average strength at each age. The maturity value shall be calculated from a temperature reading at the time the specimen is tested for strength. When the thermal meter is used, the

temperature used to calculate the maturity shall be determined at 2- to 3-hour intervals for the first 24 to 36 hours and at least twice per day thereafter. The tests shall be spaced such that they are performed at somewhat consistent intervals of time and span a range in strength that includes the opening strength desired. The table below gives suggested maturity values for each test of three standard mixture classes. This is only a guide and may need to be modified, depending on specific mixtures and conditions.

Sample of Approximate Maturity Values (TTF)

	Test 1	Test 2	Test 3	Test 4
A Mix	750	1500	2500	3500
B Mix	1500	3500	5500	7500
C Mix	750	1500	2500	3500
D Mix	600	1200	2000	3000

These values assume opening strength for pavements of 500 psi for the A, B, and C mixtures, and a five-hour opening for the D mixture with calcium chloride. If the maturity curve is intended for use in determining the time to begin joint sawing, testing must begin at lower maturity values.
The first test (Test 1), for Class C mixes, normally would be performed at an age of approximately twelve (12) hours when hot, summer temperatures prevail. During cooler conditions, the first test may be performed at the beginning of the day following the casting of test specimens. Additional test specimens may be cast at a later time and tested at earlier ages to add data to the strength-maturity relationship as an aid to determining the appropriate time to saw.

5. Plot the measured strength against the corresponding values of maturity at different ages, as determined by the maturity meter or by hand methods. The TTF number corresponding to the opening strength or the flexural loading strength/form removal strength of the structure shall be used to determine when the pavement has reached opening strength or the structure has reached the required loading strength.

FIELD PROCEDURE

Equipment

1. 2 - 6 in. x 6 in. x 20 in. beam molds
2. 1 each shovel (square point), rubber hammer or equivalent, and wood float or equivalent
3. 1 each hydraulic testing machine - center point leading flexural
4. 1 each maturity meter
5. 1 each hand-held thermometer
6. Type T thermocouple wire
7. Connectors

Placement of the Temperature Probes
Strip the coating from each end of the two wires and twist the ends together before inserting them into the fresh concrete.

For pavements, insert the temperature probe into the concrete until the end is at approximately the pavement mid-depth and 1.6 feet from the edge of the pavement. The wire ends are the points at which the temperature measurement is taken. Insertion may be accomplished by attaching the wire ends to a wooden dowel and embedding it into the slab. Check to ensure the concrete is consolidated around the dowel. The portion of the dowel that protrudes above the pavement should be cut or broken off after the testing is completed.

Probes may be placed at any point along the pavement slab. A minimum of two probes shall be placed in each day's placement. On days when there is a large difference between daytime high temperatures and nighttime low temperatures, placing additional probes near the beginning of the day's run and at a point near the midday, location would provide helpful information. This would be helpful to those sawing the pavement as well as those determining the opening time. It has been found that the concrete does not always gain strength at the same rate. Therefore, the concrete placed during the middle of the day can gain strength faster than the concrete placed at the beginning of the day. For structures, a minimum of two probes shall be attached to the reinforcing steel near the edge at the upper corner of the exposed surface. The probe should be wrapped around the rebar and taped with approximately 1 to 2 inches extending below the rebar to prevent the probe from damage and removal during concrete placement. The rebar should also be taped 2 to 3 inches on both sides of the probe location to prevent contact with the reinforcing steel.

Data Collection
The other probe wire ends, not placed in the concrete, shall be connected to a plug, unless the temperature-measuring device must be connected to the probe directly with bare wires. The plug is then inserted into the maturity meter or thermal meter. Normally a thermal meter can be used to collect field data. Be careful to connect the copper wire to the copper plug prong (+).

When a thermal meter is used, the wire is connected to the meter each time a temperature is taken. Then the wire is disconnected and the value recorded. Do not disconnect the wire from the maturity meter until the test is completed. The data collection must be uninterrupted. In addition, the maturity meter must be protected from rain or water. If water finds its way inside the meter, permanent damage shall result.

Once the wires are placed, an initial temperature of the concrete shall be taken and recorded, when a thermal meter is being used. Temperature readings should be taken in the morning and late afternoon, when one first arrives on the project and before one leaves for the day, as a minimum for standard A, B, and C mixtures. For the fast-setting mixtures, readings should be taken every few hours, depending on weather conditions and mixture. If a maturity meter is being used, it should be connected to the probe as soon as possible to begin data collection.

Measuring the Maturity

The maturity number can be read directly from the maturity meter or calculated from the temperature readings obtained by the thermal meter. This number is then used to enter the strength-maturity chart that was established as described above and strength is then determined. Note: An instruction sheet shall accompany each maturity meter. It is important to follow these instructions to initialize the instrument.

Implementation

For pavements, when used at the contractor's option, it is the intent of the procedure to use the maturity method to open the pavement to traffic from the very first day of paving, including the days of development of new curves. Pavement placed on the first day during development of the strength-maturity curve may be opened when either of the following criteria has been met:

1. The TTF of the slab, or structure, meets or exceed the opening TTF as determined by the strength-maturity curve being developed.
2. At a particular test age, the average strength of the three beams used for development of the strength-maturity curve meets or exceeds the required opening strength.

For structures, since maturity is to be used on units exposed to flexural loading, the maturity curve should be developed early in the project during placement of concrete exposed to compressive stress. If this is not possible, concrete placed on the same day as development of the strength-maturity curve may be loaded at a particular age using either of the first day placement criteria required for pavements.

Validation

Once per month, validation tests shall be conducted to determine if concrete strength is being represented by the current maturity curve. Cast and cure three (3) beams using the same procedure and manner as used to develop the current maturity curve. Test all three beams as close as possible to the maturity value determined to represent the opening strength of the pavement or the flexural loading strength or form removal strength of the structure.

For pavements, if the average of these tests is within ±50 psi of the original curve at the TTF that the validation beams were tested, the original curve shall be considered validated. If the average value is less than 50 psi of the original maturity curve at the TTF the validation beams were tested, a new maturity curve shall be developed. If the average value is greater than 50 psi of the original maturity curve at the TTF the validation beams were tested, a new maturity curve may be developed.

For structures, if the average of these tests is greater than the original curve at the TTF the validation beams were tested, the original curve shall be considered validated. If the average value is less than the original maturity curve at the TTF the validation beams was tested, a new maturity curve shall be developed.

This validation procedure is intended to be similar to the assurance procedure in that it is not an acceptance test, but merely a check. If the test results indicate a new curve must be developed, this should be done in a timely manner. The curve currently being used shall be continued until new beams can be cast and at that point, the implementation procedure described above shall be followed.

Factors Requiring a New Curve

Changes in material sources, proportions, and mixing equipment all affect the maturity value of a given concrete mixture. If the w/c ratio of the production concrete exceeds the w/c ratio of the concrete used to develop the strength-maturity curve by more than 0.02, a new curve shall be developed. Therefore, development of a new maturity curve is generally required for any change to a concrete mix.

Development of a new maturity curve due to material source or proportion changes in a concrete mix may be waived by use of the validation procedure. If the average strength is greater than the original maturity curve at the TTF the validation beams were tested, a new curve shall not be required. A new curve shall be required if the average strength is less than the original curve at the TTF the validation beams were tested.