099, 130 PWH
11-23-2017

REPUBLIC OF THE PHILIPPINES
DEPARTMENT OF PUBLIC WORKS AND HIGHWAYS
OFFICE OF THE SECRETARY
MANILA

22 NOV 2017

DEPARTMENT ORDER)
)
No. 134)
Series of 2017)

SUBJECT: **Standard Specification on the Use of Roller-Compacted Concrete Pavement in Road Construction, Item 311 (6)**

In line with the continuing efforts to upgrade the construction technology thru adoption of successful research studies, this Department has approved the use of **Roller-Compacted Concrete Pavement in Road Construction**, subject to the specifications hereto attached.

This specification shall form part of the next revised DPWH Standard Specification for Highways, Bridges and Airports, Volume II under Item 311 Portland Cement Concrete Pavement, Pay Item 311(6) Roller-Compacted Concrete Pavement.

This Order takes effect immediately.

MARK A. VILLAR
Secretary

14.1.2 FET/RGT

Department of Public Works and Highways
Office of the Secretary
WIN7U01535

DPWH Standard Specification on The Use of Roller-Compacted Concrete Pavement in Road Construction, Item 311 (6)

1. Description

This Item shall consist of pavement of roller compacted concrete, without reinforcement, constructed on the prepared base in accordance with these Specifications and in conformity with lines and grades, thickness and typical cross-section as shown in the Plans.

The Roller Compacted Concrete (RCC) is a dry concrete mix consist of aggregate, Portland cement, other supplementary cementing materials (fly ash, slag, silica fume) and water with zero-slump. It is a highly-compacted concrete placed using high-density asphalt paver and compacted using vibratory rollers. It is constructed without forms, dowels or reinforcing steel, and does not require finishing. It has higher percentage of fine aggregates, which allows tight packing and consolidation of components.

It shall be limited to low to medium-speed (70 kph maximum) highway projects and for road networks which require fast reblocking time such as main thoroughfares and junction points.

2. Material Requirements

2.1 Portland Cement

It shall conform to the applicable requirements of Item 700, Hydraulic Cement. Portland Cement Type I meeting the requirements of AASHTO M 85 (ASTM C 150) "Standard Specification for Portland Cement" shall be used unless otherwise provided for in the Special Provisions.

Portland-Pozzolan Cement Type IP meeting the requirements of AASHTO M 240M (ASTM C 595) "Standard Specification for Blended Hydraulic Cement" shall be allowed for use.

For both Portland Cement Type I and Portland-Pozzolan Cement Type IP, trial mixes shall be done and shall meet the specification requirements of concrete. The AASHTO/ASTM provision pertinent to the use of Portland-Pozzolan Cement Type IP shall be adopted.

Different brands or the same brands from different mills shall not be mixed nor shall they be used alternately unless the mix is approved by the Engineer.

Cement which for any reason has become partially set or which contains lumps of caked cement shall be rejected. Cement salvaged from discarded or used bags shall not be used.

Samples of cement shall be obtained in accordance with AASHTO R 71 (ASTM C 183M) "Standard Practice for Sampling and Amount of Testing of Hydraulic Cement".

2.2 Aggregates

Unless otherwise approved in writing by the Engineer, the quality of aggregates shall conform to ASTM C 33M "Standard Specification for Concrete Aggregates". Aggregates may be obtained from a single source or borrow pit, or may be a blend of coarse and fine aggregates.

The aggregate shall be well graded without gradation gaps and conform to the following gradation:

Table 1. Suggested Blend Gradation

Sieve Number	Percent Passing by Weight	
	Minimum	Maximum
25 mm (1 in.)	100	100
19 mm (3/4 in.)	90	100
12.5 mm (1/2 in.)	70	90
9.5 mm (3/8 in.)	60	85
4.75 mm (No. 4)	40	65
1.18 mm (No. 16)	20	40
150 µm (No. 100)	6	18
75 µm (No. 200)	2	8

2.2.1 Fine Aggregate

It shall consist of natural sand, stone screenings or other inert materials with similar characteristics, or combinations thereof, having hard, strong and durable particles. Fine aggregate from different sources of supply shall not be mixed or stored in the same pile nor used alternately in the same class of concrete without the approval of the Engineer.

It shall not contain more than three (3) mass percent of material passing the 0.075 mm (No. 200 sieve) by washing nor more than one (1) mass percent each of clay lumps or shale. The use of beach sand will not be allowed without the approval of the Engineer.

If the fine aggregate is subjected to five (5) cycles of the sodium sulfate soundness test, the weighted loss shall not exceed 10 mass percent.

The fine aggregate shall be free from injurious amounts of organic impurities. If subjected to the colorimatic test for organic impurities and a color darker than the standard is produced, it shall be rejected. However, when tested for the effect of organic impurities on strength of mortar by AASHTO T 71, the fine aggregate may be used if the relative strength at seven (7) and 28 days is not less than 95 percent.

The fine aggregate shall be well-graded from coarse to fine and shall conform to Table 2.

Table 2. Grading Requirements for Fine Aggregate

Sieve Designation	Percent Passing by Weight
9.5 mm (3/8 in)	100
4.75 mm (No. 4)	95 – 100
2.36 mm (No. 8)	-
1.18 mm (No. 16)	45 – 80
0.600 mm (No. 30)	-
0.300 mm (No. 50)	5 – 30
0.150 mm (No. 100)	0 – 10

2.2.2 Coarse Aggregate

It shall consist of crushed stone, gravel, blast furnace slag, or other approved inert materials (coralline or dolomites) of similar characteristics, or combinations thereof, having hard, strong, durable pieces and free from any adherent coatings.

It shall consist of crushed stone, gravel, blast furnace slag, or other approved inert materials of similar characteristics, or combinations thereof, having hard, strong, durable pieces and free from any adherent coatings.

It shall contain not more than one (1) mass percent of material passing the 0.075 mm (No. 200) sieve, not more than 0.25 mass percent of clay lumps, nor more than 3.5 mass percent of soft fragments.

If the coarse aggregate is subjected to five (5) cycles of the sodium sulfate soundness test, the weighted loss shall not exceed 12 mass percent.

It shall have a mass percent of wear not exceeding 40 when tested by AASHTO T 96 "Standard Method of Test for Resistance to Degradation of Small-Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine".

If the slag is used, its density shall not be less than 1120 kg/m^3. The gradation of the coarse aggregate shall conform to Table 3.

Only one grading specification shall be used from any one source.

Table 3. Grading Requirements for Coarse Aggregate

Sieve Size	Mass Percent Passing
25 mm (1 in.)	100
19 mm (3/4 in.)	90-100
12.5 mm (1/2 in.)	70-90
9.5 mm (3/8 in.)	60-85
4.75 mm (No. 4)	40-65

2.3 Water

Water quality shall be determined and tested in accordance with and meet the requirements of ASTM C 1602M "Standard Specification for Mixing Water Used in the Production of Hydraulic Cement Concrete".

Water used in mixing, curing or other designated application shall be reasonably clean and free of oil, salt, acid, alkali, grass or other substances injurious to the finished product. Water will be tested in accordance with and shall meet the requirements of Item 714, Water. Water which is drinkable may be used without test. Where the source of water is shallow, the intake shall be so enclosed as to exclude silt, mud, grass or other foreign materials.

2.4 Reinforcing Steel

RCC pavement, unlike conventional concrete pavement, cannot be reinforced with steel nor include dowel bars to provide joint load transfer because steel reinforcement will hinder compaction effort of equipment on the pavement section. Joint load transfer must rely on aggregate interlock and base support for long-term joint performance.

2.5 Joint Fillers

Poured joint fillers shall be mixed asphalt and mineral or rubber filler conforming to the applicable requirements of Item 705, Joint Materials.

Preformed joint filler shall conform to the applicable requirements of Item 705. It shall be punched to admit the dowels where called for in the Plans. The filler for each joint shall be furnished in a single piece for the full depth and width required for the joint.

2.6 Cementitious Materials

In addition to cement and pozzolan used in RCC mixes, the other cementitious materials if specified or permitted, such as fly ash, shall meet the required design strength and durability requirements of the finished RCC, not exceeding twenty percent partial replacement of Roller compacted in concrete mix and shall be based on its availability. It shall conform to the requirements of ASTM C 618 "Standard Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use as a Mineral Admixture in Concrete".

2.7 Admixture

Chemical admixtures such as water-reducing, set-retarding and set-accelerating admixture shall conform to ASTM C 494M "Standard Specification for Chemical Admixtures for Concrete" and must be approved by the Engineer prior to use.

Superplasticizers (Polycarboxylate) can be used in dry batch plant production to improve workability and reduce mixing time, but a pavement test section must be constructed to verify the proper admixture to use for a particular mix.

Extensive laboratory and field test must be conducted prior to any use of admixtures to determine the effectiveness and proper dosage rates.

Admixture/s may be added to the concrete mix to produce some desired modifications to the properties of concrete if necessary, but not as partial replacement of cement.

2.8 Curing Materials

Curing materials shall conform to the following requirements as specified:

Curing Materials	Standard	Description
a) Burlap cloth	AASHTO M 182	"Standard Specification for Burlap Cloth Made for Jute or Kenaf and Cotton Mats"
b) Liquid membrane forming compounds	ASTM C 309	"Standard Specification for Liquid Membrane-Forming Compounds for Curing Concrete"
c) Sheeting (film) materials	AASHTO M 171	"Standard Specification for Sheet Materials for Curing Concrete"

Cotton mats and waterproof paper can be used.

2.9 Storage of Cement and Aggregate

All cement shall be stored, immediately upon delivery at the Site, in weatherproof building which will protect the cement from dampness. The floor shall be raised from the ground. The buildings shall be placed in locations approved by the Engineer. Provisions for storage shall be ample, and the shipments of cement as received shall be separately stored in such a manner as to allow the earliest deliveries to be used first and to provide easy access for identification and inspection of each shipment. Storage buildings shall have capacity for storage of a sufficient quantity of cement to allow sampling at least 12 days before the cement is to be used. Bulk cement, if used, shall be transferred to elevated air tight and weatherproof bins. Stored cement shall meet the test requirements at any time after storage when retest is ordered by the Engineer. At the time of use, all cement shall be free-flowing and free of lumps.

The handling and storing of concrete aggregates shall be such as to prevent segregation or the inclusion of foreign materials. The Engineer may require that aggregates be stored on separate platforms at satisfactory locations.

In order to secure greater uniformity of concrete mix, the Engineer may require that the coarse aggregate be separated into two or more sizes. Different sizes of aggregate shall be stored in separate bins or in separate stockpiles sufficiently removed from each other to prevent the material at the edges of the piles from becoming intermixed.

2.10 Proportioning, Consistency and Strength of Concrete

The Contractor shall prepare the design mix based on the soil compaction method as indicated in ACI 327R -14 "Guide to Roller-Compacted Concrete Pavements". The Engineer shall determine from laboratory tests of the materials to be used, the cement content and the proportions of aggregate and water that will produce workable concrete with zero slump that will achieve the required density with optimal compaction effort, a flexural strength of not less than 3.8 MPa when tested by the third-point method or 4.5 MPa when tested by the mid-point method at 14 days in accordance with AASHTO T 97 "Standard Method of Test for Flexural Strength of Concrete (Using Simple Beam with Third-Point Loading" and T 177 "Standard Method of Test for Flexural Strength of Concrete (Using Simple Beam with Center-Point Loading", respectively; or a compressive strength of 24.1 MPa for cores taken at 14 days and tested in accordance with AASHTO T 24M "Standard Method of Test for Obtaining and Testing Drilled Cores and Sawed Beams of Concrete" and durable enough to endure in the given environment.

The mix design shall be submitted to the Engineer for approval and shall be accompanied with certified test data from an approved laboratory demonstrating the adequacy of the mix design. A change in the source of materials during the progress of work may necessitate a new design mix.

The Contractor shall prepare the design mix based on:

Table 4. RCC Mix Design

Component	Percent Composition (by Volume)
Cement	10 %
Water	13 %
Air	1.5 %
Fine Aggregate	35 %
Coarse Aggregate	40.5 %

Alternately, dense and well-graded coarse and fine aggregates shall comprise the 75 to 85 percent of RCC mixture by volume.

The quantity of water is typically between 90 and 120 kilograms per cubic meter. The water to total cementitious ratio, expressed as W/(C+P), for RCC pavement mix shall generally fall between 0.30 and 0.45 W/(C+P) ratio, where the greatest positive influence on the final strength of the RCC, with 28-day unconfined compressive strengths typically exceeding 41 MPa.

The total cementitious material content including the content in blended cements, unless specifically directed by the Engineer, shall not exceed the weight of Portland cement in the RCC mix and shall fall between the 240 and 360 kilograms per cubic meter in a wide range of proportions of these materials.

The mixture shall have the consistency of damp, dense-graded aggregates, which is relatively dry and stiff with almost zero slump.

Table 5. Properties of Roller Compacted Concrete Pavement

Properties	Affecting Factors	Specifications
Flexural Strength*	Raw Materials, Mix Design	3000 KPa to 5,500 KPa @ 3 days
Compaction	Mix Design and Paver Set-up alignment	98% (min)
Skid Resistance	Mix Design, Aggregates Properties, Curing, Surface Texture, Surface Condition	55 (min)
Surface Texture	Finishing	0.5
International Roughness Index (IRI)	Continuous Concrete supplies and Dump Trucks Specification	3.0 (max)

*Flexural strength shall conform to design requirement.

To achieve smooth pavements with values for International Roughness Index (IRI) of not more than 3.0 m/km, the Contractor shall consider tightening the ranges and tolerances of mix design components to produce a more consistent mix, and include revised target values in the Contractor's Quality Control Plan and Method Statement.

3. Construction Requirements

3.1 Quality Control of Roller Compacted Concrete

3.1.1 General

The Contractor shall be responsible for the quality control of all materials during the handling, blending, and mixing and placement operations.

Experienced and qualified personnel shall perform all batching or mixing operation for the concrete mix, and shall be present at the plant and job site to control the concrete productions whenever the plant is in operation.

3.1.2 Quality Control Plan

The Contractor shall furnish the Engineer a Quality Control Plan detailing his production control procedures and the type and frequency of sampling and testing to ensure that the concrete produced complies with the Specifications. The test method that may be used for making specimens and determining densities of laboratory-produced RCC mixtures shall be in accordance to ASTM C 1800M "Standard Test Method for Determining Density of Roller-Compacted Concrete Specimens Using the Gyratory Compactor".

The Engineer shall be provided free access to recent plant production records, and if requested, informational copies of mix design, materials certifications and sampling and testing reports.

3.1.3 Quality Control Testing

The Contractor shall perform all sampling, testing and inspection necessary to assure quality control of the component materials and the concrete.

The Contractor shall be responsible for determining the gradation of fine and coarse aggregates and for testing the concrete mixture for moisture content, temperature. He shall conduct his operations so as to produce a mix conforming to the approved mix design.

3.1.4 Documentation

The Contractor shall maintain adequate records of all inspections and tests. The records shall indicate the nature and number of observations made, the number and type of deficiencies found, the quantities approved and rejected, and nature of any corrective action taken.

The Engineer may take independent assurance samples at random location for acceptance purposes as he deems necessary.

3.2 Equipment

Equipment and tools necessary for handling materials and performing all parts of the work shall be approved by the Engineer as to design, capacity and mechanical condition. The equipment shall be at the jobsite sufficiently ahead of the start of construction operations to be examined thoroughly and approved.

3.2.1 Mixing Plant

Obtain the Engineer's approval of the mixing plant before starting RCC production. Use a mixing plant capable of producing a homogeneous RCC mixture in the proportions defined in the approved mixture design and conforming to the tolerances specified in ASTM C 94 "Standard Specification for Ready-Mixed Concrete" for batch mixing plants or ASTM C 685 "Standard Specification for Concrete Made by Volumetric Batching and Continuous Mixing" for continuous mixing plants.

Use a plant with production capacity sufficient to produce a uniform RCC mixture at a rate compatible with the placement operation. The Engineer can halt operations if the plant is unable to produce the RCC mixture sufficiently in quality or quantity, until operations are adjusted or a plant meeting all requirements is obtained.

3.2.1.1 Pugmill Plant

Pugmill plants shall be central plant type with a twin-shaft pugmill mixer, capable of continuous mixing.

Provide synchronized metering devices and feeders to dispense the correct proportions of aggregate, cement, supplementary cementing materials, and water for continuous mixing within the tolerance requirements of ASTM C 685 depending on plant type.

Provide a surge or gob hopper attached to the final discharge belt to temporarily hold the mixed RCC, in order to minimize segregation when loading into haul trucks, and to allow the plant to operate continuously.

3.2.1.2 Batching Plant and Equipment

3.2.1.2.1 General

The batching shall include bins, weighing hoppers, and scales for the fine aggregate and for each size of coarse aggregate. If cement is used in bulk, a bin, a hopper, and separate scale for cement shall be included. The weighing hopper shall be properly sealed and vented to preclude dusting operation. The batch plant shall be equipped with a suitable non-resettable batch counter which will correctly indicate the number of batches proportioned.

3.2.1.2.2 Bins and Hoppers

Bins with adequate separate compartments for fine aggregate and for each size of coarse aggregate shall be provided in the batching plant.

3.2.1.2.3 Scales

Scales for weighing aggregates and cement shall be of either the beam type or the springless-dial type. They shall be accurate within one-half percent throughout the range of use. Poises shall be designed to be locked in any position and to prevent unauthorized change.

Scales shall be inspected and sealed as often as the Engineer may deem necessary to assure their continued accuracy.

3.2.1.2.4 Automatic Weighing Devices

Unless otherwise allowed on the Contract, batching plants shall be equipped with automatic weighing devices of an approved type to proportion aggregates and bulk cement.

3.2.2 Paving Machine

Obtain the Engineer's approval of the paving equipment before starting RCC placement. RCC is placed using asphalt pavers equipped with a high-density screed capable of placing the RCC material to a minimum of ninety percent of the reference density required in accordance with ASTM D 1557 "Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Modified Effort 56,000 ft-lbf/ft^3 (2,700 kN-m/m^3)" or equivalent test method, prior to any additional compaction. Ensure that the paver is of suitable weight and stability, equipped to spread, compact, and place the RCC mixture to the required thickness, cross slope, edge and

surface texture. Use of graders, bulldozers, or any equipment that does not provide compaction during paving shall not be permitted, except as required for areas inaccessible to a paving machine or requiring odd-shapes upon approval of the Engineer.

3.2.3 Compaction Equipment

Self-propelled 10T vibratory dual steel drum and/or pneumatic rollers capable of providing primary and final compaction efforts necessary to meet the in-place density requirement of ninety-eight percent minimum shall be used as appropriate, and in a manner comparable to the test strip demonstration. Furnish each drum on steel drum vibratory rollers with a properly operating scraper and brush. Only operate steel drum vibratory rollers in static mode for final compaction. Never operate a roller or paver in vibratory mode when the equipment is not in motion.

Walk-behind vibratory rollers or plate tampers shall be used only for compacting areas inaccessible to larger rollers.

3.2.4 Dump Trucks

Dump trucks shall be used for transporting the RCC material from the plant to the paver. Trucks shall be clean and equipped with open-bed with retractable protective covers to protect the RCC material from rain, evaporation, heat and other detrimental weather conditions. A sufficient number of trucks shall be provided to ensure adequate and continuous supply of RCC material to the paver. Adequate size and clearance height must be established through inspection to determine the compatibility of the truck with the paving machine. No part of the truck must hit the paving machine at any moment during the laying operation.

3.2.5 Water Truck

Water truck or other similar equipment shall be on-site and available for use throughout the paving and curing process. The truck or device shall be equipped with a spray bar capable of evenly applying a fine spray of water to the RCC, subgrade or subbase surface without damage.

3.2.6 Concrete Saw

The Contractor shall provide concrete saws that are capable of sawing new RCC for crack control with minimal raveling and to the depth shown on the plans. Saw cutting shall first be tested on sample areas starting at 24 hours after laying to see if raveling will occur during cutting. Test cuts shall be done at one (1) hour interval until desired quality is achieved or until 48 hours. All saw shall be equipped with blade guards and guides or devices to control alignment and depth.

The Contractor shall provide sawing equipment in adequate number of units and power to complete the sawing with a water-cooled diamond edge saw blade or an abrasive wheel to

the required dimensions and at the required rate. He shall provide at least one (1) stand-by saw in good working condition and with an ample supply of saw blades.

3.3 Preparation of Grade

After the subgrade of base has been placed and compacted to the required density, the areas which will support the paving machine and the grade on which the pavement is to be constructed shall be trimmed to the proper elevation by means of a properly designed machine extending the prepared work areas compacted at least 60 cm beyond each edge of the proposed concrete pavement. If loss of density results from the trimming operations, it shall be restored by additional compaction before concrete is placed. If any traffic is allowed to use the prepared subgrade or base, the surface shall be checked and corrected immediately ahead of the placing concrete.

The subgrade or base shall be uniformly moist when the concrete is placed and shall conform to the requirements specified in Item 105-Subgrade Preparation and Part D-Subbase and Base Course of the DPWH Standard Specifications for Highways, Bridges, and Airports, Volume II.

3.4 Setting of the String Line / Guide Lines

3.4.1 Setting of the String lines

String lines shall be used to guide the paver in laying RCC in grade, lift thickness and alignment and must be installed with enough clearance as to not be disturbed during laying operations. String lines to be used shall be sufficiently tough under tension. String lines shall be set sufficiently in advance of the point where concrete is being laid. After the string lines have been set to correct grade, the grade shall be thoroughly tamped, mechanically or by hand, at both the inside and outside edges of the base of the string lines. The string lines shall not deviate from true line by more than one (1) cm at any point.

3.4.2 Grade and Alignment

The alignment and grade elevations of the string lines shall be checked and corrections made by the Contractor immediately before RCC laying. Testing as to crown and elevation with reference to the design, prior to placing of concrete can be made by means of holding an approved template in a vertical position and moved backward and forward along the string lines.

When any string lines have been disturbed or any grade has become unstable, the string lines shall be reset and rechecked.

3.5 Conditioning of Subgrade or Base Course

When string lines have been securely set to grade, the subgrade or base course shall be brought to proper cross-section. High areas shall be trimmed to proper elevation. Low areas

shall be filled and compacted to a condition similar to that of surrounding grade. The finished grade shall be maintained in a smooth and compacted condition until the pavement is placed.

Unless waterproof subgrade or base course cover material is specified, the subgrade or base course shall be uniformly moist when the concrete is placed. If it subsequently becomes too dry, the subgrade or base course shall be sprinkled, but the method of sprinkling shall not be such as to form mud or pools of water.

3.6 Test Specimens

As work progresses, at least one (1) set consisting of three (3) concrete beam test specimens, 150 mm x 150 mm x 525 mm shall be taken from each 270 m^2 of pavement for 280 mm depth or 250 m^2 of pavement for 300 mm depth, or fraction thereof placed each day (whenever applicable). Each set of specimens shall represent the volume of concrete not exceeding 75 m^3 placed each day. Test specimens shall be made under the supervision of the Engineer, and the Contractor shall provide all concrete and other facilities necessary in making the test specimens and shall protect them from damage by construction operations. Cylinder samples shall not be used as substitute for determining the adequacy of the strength of concrete.

The beams shall be made by modifying the method described ASTM C 1435M "Standard Practice for Molding Roller-Compacted Concrete in Cylinder Molds Using a Vibrating Hammer", cured and tested in accordance with AASHTO T 23 "Standard Method of Test for Making and Curing Concrete Test Specimens in the Field"' and AASHTO T 97 "Standard Method of Test for Flexural Strength of Concrete (Using Simple Beam with Third-Point Loading)".

3.7 Joints

Joints shall be constructed of the type and dimensions, and at the locations required by the Plans or Special Provisions. All joints shall be protected from the intrusion of injurious foreign material until sealed.

3.7.1 Longitudinal Joint

Longitudinal joints shall be cut straight and aligned to full depth with all excess materials removed. The sawed area shall be thoroughly cleaned before paving the adjacent section. The longitudinal joints shall be continuous. There shall be no gaps in either transverse or longitudinal joints at the intersection of the joints.

Longitudinal sawed joints shall be cut by means of approved concrete saws to the depth, width and line shown on the Plans. Suitable guide lines or devices shall be used to assure cutting the longitudinal joint on the true line. The longitudinal joint shall be sawed before the end of the curing period or shortly thereafter and before any equipment or vehicles are allowed on the pavement. If required, the joint shall immediately be filled with approved joint sealer.

3.7.2 Transverse Contraction Joint/Weakened Joint

When shown on the Plans, it shall consist of planes of weakness created by forming or cutting grooves in the surface of the pavement. Sawed Contraction Joint shall be created by sawing grooves in the surface of the pavement of the width not more than six (6) mm, depth should be at one-third (1/3) of the concrete thickness, and at the spacing and lines shown on the Plans, with an approved concrete saw. After each joint is sawed, it shall be thoroughly cleaned including the adjacent concrete surface.

Sawing of the joint shall commence as soon as the concrete has hardened sufficiently to permit sawing without excessive raveling, usually 24 hours to 48 hours. All joints shall be sawed before uncontrolled shrinkage cracking takes place. If necessary, the sawing operations shall be carried on during the day or night, regardless of weather conditions. The sawing of any joint shall be omitted if crack occurs at or near the joint location prior to the time of sawing. Sawing shall be discounted when a crack develops ahead of the saw. In general, all joints should be sawed in sequence.

3.7.3 Transverse Construction Joint

It shall be constructed when there is an interruption of more than 30 minutes in the concreting operations. No transverse joint shall be constructed within 1.50 m of a contraction joint, or plane of weakness. If sufficient concrete has been mixed at the time of interruption to form a slab of at least 1.5 m long, the excess concrete from the last preceding joint shall be removed and disposed off as directed.

3.7.4 Load Transfer Device

RCC pavement, unlike conventional concrete pavement, cannot be reinforced with steel nor include dowel bars to provide joint load transfer because steel reinforcement will hinder compaction effort of equipment on the pavement section. Joint load transfer must rely on aggregate interlock and base support for long-term joint performance.

3.7.5 Pavement Thickness

RCC shall be placed in lifts of 101.6 mm (4 in.) minimum to 203.2 mm (8 in.) maximum or 254 mm (10 in.) maximum, if heavy pavers are used.

The avoidance of the reinforcement is considered in the thickness of the section, and compensated with thicker sections if needed.

Table 6. Pavement Thickness

Category	Thickness	Vehicle	Application
Low Traffic Thickness	100 – 150 mm	Light weight vehicles, pick up and occasionally heavy weight trucks	Residential & secondary roads Parking
Medium Traffic Thickness	150 – 230 mm	Medium weight trucks, occasionally buses & heavy weight trucks	Industrial areas Farm to market Parking
Heavy Traffic Thickness	200 – 330 mm	Medium to heavy weight trucks	Primary roads Industrial parking

3.8 Trial Construction (Test Strips)

The Contractor shall conduct test strips that will be used to validate the design, method of construction, curing process, joint construction, and field and laboratory testing of RCC for any given project. The test strip shall be done prior to the actual paving operation. The test strip should be constructed on an approved compacted base course using the same materials and construction techniques that are proposed for the actual project. The test strip for the project can be in non-production areas and can be left in place if satisfactory. The location of the trial section shall be shown on the project drawings or located by agreement. and should be long enough to provide adequate evaluation of the design and construction methods and should be a minimum of two paver widths wide.

The equipment, placing, compaction procedures and joint forming methods shall initially conform to the preliminary method statement, but during the trial these may be varied if they do not achieve the specified requirements, e.g. the in-situ plastic density; surface finish. Any variations of method shall be recorded and the preliminary method statement modified to reflect this experience. The trial shall include the formation of a longitudinal joint and if used, a contraction joint. This trial section shall be constructed over an extended time period to demonstrate the constructability at the specified or agreed time limits for joint/second layer construction.

On both diagonals of the trial area a series of nuclear density measurements shall be taken starting at 300 mm from each corner to assess the uniformity of compaction and the achievement of ninety-eight percent of the plastic density at the maximum dry density or of the intended plastic density of supply.

3.9 Transport to site

RCC mix shall be transported to site in non-agitating vehicles fully covered with sheeting to prevent premature drying of the RCC or water gain from rain or other sources. Each delivery shall be fully discharged. The maximum time between batching and delivery shall not exceed 60 minutes except where another time has been agreed as being technically appropriate, such as when the RCC contains a retarder.

3.10 Placing of Roller Compacted Concrete

RCC placement shall follow the laying sequence approved by concerned parties with consideration to equipment clearance and mobility of the heavy equipment to be used.

3.10.1 Base Conditioning

Prior to RCC placement, the prepared base shall first be moistened using appropriate sprayer that will not create pools of water and muddy the surface. All deleterious materials should be removed. When placing RCC adjacent to existing RCC pavement, the construction joint must be cut to the full depth and all excess and debris removed.

3.10.2 Laying Sequence

RCC shall be placed with a heavy-duty, self-propelled asphalt paving machine, utilizing high-density single- or double-tamper bar screed to initially consolidate the mixture to a slab of uniform thickness.

The paver will then be positioned on the starting point and be setup to correct grade and level. The area where the paver hopper is facing should be cleared for backing of the dump trucks.

The dump trucks carrying the RCC mix should be adequately covered to prevent loss of moisture from the mix. Upon arrival, all deliveries shall be checked for moisture content and loading and unloading time shall be recorded. Concrete samples will be obtained to test later.

The dump truck will then unload the RCC mix to the paver hopper and will move in tandem with the paver. All RCC material shall be completely unloaded from each batch. The laid RCC will then be checked for initial compaction by in-place density determination in accordance with AASHTO T 191 "Standard Method of Test for Density of Soil In-Place by the Sand-Cone Method" or any equivalent method approved by the Engineer.

Primary compaction shall be done by use of the approved steel drum roller in static mode within 15 minutes of placement. After which, the pneumatic tire roller or steel drum roller shall do the final compaction. The RCC shall be compacted to ninety-eight percent of the maximum dry density determined in accordance with AASHTO T 180, Method D. "Standard Method of Test for Moisture-Density Relations of Soils Using a 4.54-kg Rammer and a 457-mm Drop". An in-place density determination in accordance with AASHTO T 191 or any equivalent method approved by the Engineer shall be conducted to check the final compaction.

3.10.3 Curing

Immediately after compaction, curing compound shall be uniformly applied throughout the laid RCC and covered for protection. Moisture loss must be prevented when there is a delay in application of curing compound by using fine spray of water. Unless otherwise specified, curing shall be done in accordance with one of the methods included in Subsection 3.12,

Curing. The curing media shall be applied at the appropriate time and shall be applied uniformly and completely to all surfaces and edges of the pavement.

3.10.4 Joints

All joints shall be constructed in accordance with Subsection 3.13, Sealing of Joints.

3.10.5 Protection Against Rain

In order that the concrete may be properly protected against rain before the concrete is sufficiently hardened, the Contractor will be required to have available at all times, materials for the protection of the edges and surface of the unhardened concrete. Such protective materials shall consist of standard metal forms or wood planks having a nominal thickness of not less than 50 mm and a nominal width of not less than the thickness of the pavement at its edge for the protection of the pavement edges, and covering material such as burlap or cotton mats, curing paper or plastic sheeting materials for the protection of the surface of the pavement. When rain appears imminent, all paving operations shall stop and all available personnel shall begin placing forms against the sides of the pavement and covering the surface of the unhardened concrete with the protective covering.

3.10.6 Straight-edge Testing and Surface Correction

During the paving operation, the surface of the concrete shall be tested for trueness with a 300 cm long straight-edge. For this purpose, the Contractor shall furnish and use an accurate 300-cm straight-edge swung from handles 100 cm longer than one-half (½) the width of the slab. The straight-edge shall be held in contact with the surface in successive positions parallel to the road center line and the whole area gone over from one side of the slab to the other as necessary.
Advances along the road shall be in successive stages of not more than one-half (½) the length of the straight-edge. Any depressions found shall be marked and repaired with methodology agreed upon and approved by Engineer at a later time. High areas shall be scraped down and compacted sufficiently to finish provided that RCC material is still fresh otherwise these areas shall be marked and repaired with methodology agreed upon and approved by Engineer at a later time.

Special attention shall be given to assure that the surface across joints meets the requirements for smoothness, all overlapping RCC mix on adjacent sections shall be removed and finished. Straight-edge testing and surface corrections shall continue until the entire surface is found to be free from observable departures from the straight-edge and the slab conforms to the required grade and cross-section.

3.11 Surface Test

Paved shoulders shall be subjected to surface test using a 3-m straight-edge. All areas within the carriageway shall be subjected to surface test using an approved profiling system. The profiling system shall qualify as Class 1 roughness measurement device and shall conform to

the latest version ASTM E 950M "Standard Test Method for Measuring the Longitudinal Profile of Traveled Surfaces with an Accelerometer Established Inertial Profiling Reference".

The components of the profiling system shall be validated on regular basis per manufacturer's recommendations to ensure that the system is properly calibrated Validation reports shall be generated, for presentation to the Engineer, confirming that the validations are current and within tolerances specified by the manufacturer.

The acceptable International Roughness Index (IRI) for concrete pavements shall be not more than 3.0 m/km for National Primary Road, measured in 100 meter sections, at the time of completion.

The road surface for test shall be cleaned of loose or deleterious material by brooming or other approved means prior to any testing. Survey shall only be conducted on dry pavement surfaces only. Wide-beam lasers are recommended for textured surfaces like diamond ground, diamond grooved or tyned surfaces where they yield lower IRI values than single point or spot lasers.

A test segment with a length of 500 meters will be selected at site for repeatability test prior to data collection. The repeatability test shall be witnessed by the authorized representative of the Contractor and the Project Engineer. Five profile runs will be made on the test segment for repeatability test. The profile runs for repeatability are acceptable if the average IRI of the two wheel/paths satisfy the following criteria:

a. The IRI values of each of the five (5) runs are within one percent of the mean IRI of the selected runs.
b. The standard deviation of IRI of the selected runs are within two percent of the mean IRI

If the runs do not meet the above criteria, the Profiling Team shall determine if the variability between runs are due to operator or equipment error, and make additional runs until five (5) runs free of equipment or operator errors are obtained. Where necessary an accuracy calibration test shall be conducted in comparison with a Class 1 Profiler (SS1 Walking Profiler CS8800 or similar) to resolve said errors.

If the IRI values from the profile runs (for repeatability) meet the above criteria, three (3) runs per lane per site should be conducted for acceptance measurement. The IRI value for the lane shall be the average IRI of the two wheel paths for the three (3) runs combined.

If the IRI value of the whole concrete pavement meets the required value regardless if there are areas found to have exceeded the required IRI value, no correction shall be required, provided that the areas with exceedance have an IRI value within the tolerance limit of 0.5m/km.

However, if the IRI value of the whole concrete pavement falls beyond the prescribed IRI of 3.0 m/km for National Primary Roads and exceeds the allowable tolerance, the Contractor

may opt to undertake corrective action, otherwise, pay adjustment. The completed concrete pavement shall be accepted on a LOT basis. A LOT shall be considered as 100 linear meters of a lane of pavement. If the length of the last LOT is less than 100 m, it shall be considered as a separate lot LOT disincentive pay/pay deduction will be calculated as described in the Table 7:

Table 7. Pay Adjustment Table
IRI Acceptance Tolerance

LOT IRI Value (m/km)	LOT Pay Adjustment, % of Item Cost
3.50 and below	100%
3.51 to 4.00	90%
4.01 to 4.50	70%
4.51 to 5.00	55%
5.01 to 5.50	35%
5.51 to 6.00	15%
Above 6.00	0%

If the contractor undertakes corrective action, further IRI Survey will be conducted to validate if the pavement irregularities had been eliminated. Only one IRI survey will be done after the corrective action takes place. If the IRI value of the whole concrete pavement meets the prescribed IRI value of 3.0 m/km for National Primary Road and any 100 m sections exceeding the prescribed value are within the allowable tolerance after correction, no reduction in payment will be made; otherwise, pay adjustment shall be made based on the above Pay Adjustment Table.

3.12 Curing

Refer to Item 311.3.15, Curing of the DPWH Standard Specifications for Highways, Bridges and Airports, Volume II.

3.13 Sealing Joints

Joints shall be sealed with asphalt sealant soon after completion of the curing period and before the pavement is opened to traffic, including the Contractor's equipment. Just prior to sealing, each joint shall be thoroughly cleaned of all foreign materials including membrane curing compound and the joint faces shall be clean and surface dry when the seal is applied.

The sealing material shall be applied to each joint opening to conform to the details shown on the Plans or as directed by the Engineer. Material for seal applied hot shall be stirred during heating so that localized overheating does not occur. The pouring shall be done in such a manner that the material will not be spilled on the exposed surfaces of the concrete. The use of sand or similar material as a cover for the seal will not be permitted.

Preformed elastomeric gaskets for sealing joints shall be of the cross-sectional dimensions shown on the Plans. Seals shall be installed by suitable tools, without elongation and secured in placed with an approved lubricant adhesive which shall cover both sides of the concrete

joints. The seals shall be installed in a compressive condition and shall at time of placement be below the level of the pavement surface by approximately six (6) mm.

The seals shall be in one piece for the full width of each transverse joint.

3.14 Protection of Pavement

The Contractor shall protect the pavement and its appurtenances against both public traffic, and traffic caused by his own employees and agents. This shall include watchmen to direct traffic, and the erection of and maintenance of warning signs, lights, pavement bridges or cross-overs, etc. The Plans or Special Provisions will indicate the location and type of device or facility required to protect the work and provide adequately for traffic.

All boreholes after thickness and/or strength determinations of newly constructed asphalt and concrete pavements shall be immediately filled/restored with the prescribed concrete/asphalt mix after completion of the drilling works.

Any damage to the pavement, occurring prior to final acceptance, shall be repaired or the pavement be replaced.

3.15 Acceptance of Concrete

No acceptance and final payment shall be made for the completed concrete pavement unless core test for thickness determination is conducted, except for Barangay Roads where the Implementing Office is allowed to waive such test, and for National Primary Roads where the concrete pavement shall also meet the International Road Roughness (IRR) criteria at the time of completion. The concrete pavement shall only be considered accepted if it meets the specified IRI value at the time of completion.

The strength level of the concrete will be considered satisfactory if the averages of all sets of three (3) consecutive strength test results equal or exceed the specified strength, fc' and no individual strength test result is deficient by more than fifteen percent of the specified strength, fc'. A set shall consist of a minimum of three (3) concrete beam specimens.

Concrete deemed to be not acceptable using the above criteria may be rejected unless the Contractor can provide evidence, by means of core tests, that the quality of concrete represented by failed test results is acceptable in place. At least three (3) representative cores shall be taken from each member or area of concrete in place that is considered deficient. The location of cores shall be determined by the Engineer so that there will be at least impairment of strength of the structure. The obtaining and testing of drilled cores shall be in accordance with AASHTO T 24 "Standard Method of Test for Obtaining and Testing Drilled Cores and Sawed Beams of Concrete".

Concrete in the area represented by the cores will be considered adequate if the average strength of the cores is equal to at least eighty-five percent of, and if no single core is less than seventy-five percent of, the specified strength, fc'.

If the strength of control specimens does not meet the requirements of this Subsection, and it is not feasible or not advisable to obtain cores from the structure due to structural considerations, payment of the concrete will be made at an adjusted price due to strength deficiency of concrete specimens as specified hereunder:

Table 8. Payment Adjustment

Deficiency in Strength of Concrete Specimens, Percent (%)	Percent (%) of Contract Price Allowed
Less than 5	100
5 to less than 10	80
10 to less than 15	70
15 to less than 20	60
20 to less than 25	50
25 or more	0

3.16 Opening to Traffic

The Engineer will decide when the pavement may be opened to traffic. The road will not be opened to traffic until test specimens molded and cured in accordance with AASHTO T 23 "Standard Method of Test for Making and Curing Concrete Test Specimens in the Field" have attained the minimum strength requirements in Subsection 2.10 Proportioning, Consistency and Strength of Concrete. If such tests are not conducted prior to the specified age the pavement shall not be operated to traffic until 14 days after the concrete was placed. Before opening to traffic, the pavement shall be cleaned and joint sealing completed.

3.17 Tolerance in Pavement Thickness

3.17.1 General

The thickness of the pavement will be determined by measurement of cores from the completed pavement in accordance with AASHTO T 148 "Standard Method of Test for Measuring Length of Drilled Concrete Cores".
The completed pavement shall be accepted on a lot basis. A lot shall be considered as 1,000 linear meters of pavement when a single traffic lane is poured or 500 linear meters when two (2) lanes are poured concurrently. The last unit in each slab constitutes a lot in itself when its length is at least one-half (½) of the normal lot length. If the length of the last unit is shorter than one-half (½) of the normal lot length, it shall be included in the previous lot.

Other areas such as intersections, entrances, crossovers, ramp, etc., will be grouped together to form a lot. Small irregular areas may be included with other unit areas to form a lot.

Each lot will be divided into five (5) equal segments and one core will be obtained from each segment in accordance with AASHTO T 24M "Standard Method of Test for Obtaining and Testing Drilled Cores and Sawed Beams of Concrete".

3.17.2 Pavement Thickness

It is the intent of this Specification that the pavement has a uniform thickness as called for on the Plans for the average of each lot as defined. After the pavement has met all surface smoothness requirements, cores for thickness measurements will be taken.

In calculating the average thickness of the pavement, individual measurements which are in excess of the specified thickness by more than five (5) mm will be considered as the specified thickness plus five (5) mm and measurement which are less than the specified thickness by more than 25 mm shall not be included in the average. When the average thickness for the lot is deficient, the contract unit price will be adjusted for thickness in accordance with Subsection 3.17.3, Adjustment for Thickness.

Individual areas within a segment found deficient in thickness by more than 25 mm shall be evaluated by the Engineer, and if in his judgment, the deficient areas warrant removal, they shall be removed and replaced by the Contractor with pavement of the specified thickness at his entire expense. However, if the evaluation of the Engineer is that the deficient area should not be removed and replaced, such area will not be paid.

When the measurement of any core is less than the specified thickness by more than 25 mm, the actual thickness of the pavement in this area will be determined by taking additional cores at no less than five (5) m intervals parallel to the center line in each direction from the affected location until a core is found in each direction, which is not deficient in thickness by more than 25 mm. The area of slab for which no payment will be made shall be the product of the paving width multiplied by the distance along the center line of the road between transverse sections found not deficient in thickness by more than 25 mm. The thickness of the remainder of the segment to be used to get the average thickness of each lot shall be determined by taking the average thickness of additional cores which are not deficient by more than 25 mm.

3.17.3 Adjustment for Thickness

When the average thickness of the pavement per lot is deficient, payment for the lot shall be adjusted as follows:

Table 9. Payment Adjustment

Deficiency in the Average Thickness per lot (mm)	Percent (%) of Contract Price per Lot
0 – 5	100% payment
6 – 10	95% payment
11 – 15	85% payment
16 – 20	70% payment
21 – 25	50% payment
More than 25	Remove and replace/ No payment

+ No acceptance and final payment shall be made on completed pavement unless core test for thickness determination is conducted, except for Barangay Roads where the implementing office is allowed to waive such test.

4. Method of Measurement

The area to be paid for under this Item shall be the number of square meters (m^2) of concrete placed and accepted in the completed pavement and completed pavement with wire mesh. The width for measurements will be the width from outside edge to outside edge of completed pavement as placed in accordance with the Plans or as otherwise required by the Engineer in writing. The length will be measured horizontally along the center line of each roadway or ramp. Any curb and gutter placed shall not be included in the area of concrete pavement measured.

5. Basis of Payment

The accepted quantity, measured as prescribed in Section 4, Method of Measurement, shall be paid for at the contract unit price for Roller compacted Concrete Pavement which price and payment shall be full compensation for preparation of roadbed and finishing of shoulders, unless otherwise provided by the Special Provisions, furnishing all materials, for mixing, placing, finishing and curing all concrete, for furnishing and placing all joint materials, for sawing weakened plane joints, for fitting the prefabricated center metal joint, for facilitating and controlling traffic, and for furnishing all labor, equipment, tools and incidentals necessary to complete the Item.

Payment will be made under:

Pay Item Number	Description	Unit of Measurement
311 (6)a1	Roller Compacted Concrete Pavement, 0.15 thick, 14 days	Square Meter
311 (6)a2	Roller Compacted Concrete Pavement, 0.15 thick, 7 days	Square Meter
311 (6)a3	Roller Compacted Concrete Pavement, 0.15 thick, 3 days	Square Meter
311 (6)b1	Roller Compacted Concrete Pavement, 0.20 thick, 14 days	Square Meter
311 (6)b2	Roller Compacted Concrete Pavement, 0.20 thick, 7 days	Square Meter
311 (6)b3	Roller Compacted Concrete Pavement, 0.20 thick, 3 days	Square Meter
311 (6)c1	Roller Compacted Concrete Pavement, 0.23 thick, 14 days	Square Meter
311 (6)c2	Roller Compacted Concrete Pavement, 0.23 thick, 7 days	Square Meter
311 (6)c3	Roller Compacted Concrete Pavement, 0.23 thick, 3 days	Square Meter
311 (6)d1	Roller Compacted Concrete Pavement, 0.25 thick, 14 days	Square Meter
311 (6)d2	Roller Compacted Concrete Pavement, 0.25 thick, 7 days	Square Meter
311 (6)d3	Roller Compacted Concrete Pavement, 0.25 thick, 3 days	Square Meter

Pay Item Number	Description	Unit of Measurement
311 (6)e1	Roller Compacted Concrete Pavement, 0.28 thick, 14 days	Square Meter
311 (6)e2	Roller Compacted Concrete Pavement, 0.28 thick, 7 days	Square Meter
311 (6)e3	Roller Compacted Concrete Pavement, 0.28 thick, 3 days	Square Meter
311 (6)f1	Roller Compacted Concrete Pavement, 0.30 thick, 14 days	Square Meter
311 (6)f2	Roller Compacted Concrete Pavement, 0.30 thick, 7 days	Square Meter
311 (6)f3	Roller Compacted Concrete Pavement, 0.30 thick, 3 days	Square Meter

References:

1. DPWH Standard Specifications Vol. II Roads, Highways and Airports 2013
2. AASHTO "Standard Specifications for Transportation Materials and Methods of Sampling and Testing, Part I-Specifications and Part II-Tests.
3. ASTM C 31 Practice for Making and Curing Concrete Test Specimens in the Field
4. ASTM C 33 Specification for Concrete Aggregates
5. ASTM C 39 Test Method for Compressive Strength of Cylindrical Concrete Specimens
6. ASTM C 42 Test Method for Obtaining and Testing Drilled Cores and Sawed Beams of Concrete
7. ASTM C 78 Test Method for Flexural Strength of Concrete (Using Simple Beam with Third-Point Loading)
8. ASTM C 150 Specification for Portland Cement
9. ASTM C 171 Specification for Sheet Materials for Curing Concrete
10. ASTM C 309 Specification for Liquid Membrane-Forming Compounds for Curing Concrete
11. ASTM C 494 Specification for Chemical Admixtures for Concrete
12. ASTM C 496 Test Method for Splitting Tensile Strength of Cylindrical Concrete Specimens
13. ASTM C 595 Specification for Blended Hydraulic Cements
14. ASTM C 618 Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use as a Mineral Admixture in Concrete
15. ASTM C 989 Specification for Ground Granulated Blast-Furnace Slag for Use in Concrete and Mortars
16. ASTM C 1040 Test Methods for Density of Unhardened and Hardened Concrete In Place by Nuclear Methods
17. ASTM C 1157 Performance Specification for Hydraulic Cement
18. ASTM C 1176 Practice for Making Roller-Compacted Concrete in Cylinder Molds Using a Vibrating Table
19. ASTM C 1240 Specification for Use of Silica Fume as a Mineral Admixture in Hydraulic-Cement Concrete, Mortar and Grout
20. ASTM C 1435 Practice for Molding Roller-Compacted Concrete in Cylinder Molds Using a Vibrating Hammer
21. ASTM D 977 Specification for Emulsified Asphalt
22. ASTM D 1557 Test Methods for laboratory Compaction Characteristics of Soil Using Modified Effort
23. ACI 327R -14 Guide to Roller-Compacted Concrete Pavements
24. PCA Guide Specification for Construction of Roller-Compacted Concrete Pavements
25. ACPA Guide Specification: Roller-Compacted Concrete Pavements as Exposed Wearing Surface