

November 18, 2009

ROLLER COMPACTED CONCRETE

1. GENERAL

1.1. Description: Roller Compacted Concrete (RCC) consists of aggregate, portland cement and possibly other supplementary cementitious materials (fly ash, slag), and water. RCC is proportioned, mixed, placed, compacted, and cured in accordance with these specifications. Ensure that the RCC conforms to the lines, grades, thickness, and typical cross section shown in the plans or otherwise established by the RCE. When used as base course, it will be covered with one or more lifts of asphalt as shown on the Plans. Otherwise, the RCC will provide the final riding surface.

2. SUBMITTALS

2.1. Proposed RCC mix design: At least 45 days prior to the beginning of placing of RCC in the roadway, submit a proposed mix design to the State Materials Engineer at the SCDOT Office of Materials and Research for review. If the mix design appears satisfactory to the SCDOT, prepare and test a trial batch mixture at the Contractor's facilities to verify that the design criteria for strength are met. Perform batch mixture preparation and testing in the presence of representatives of the SCDOT Office of Materials and Research. Make no production until an approved mix design has been obtained.

3. MATERIALS

3.1. General: The RCE will approve all materials to be used for RCC construction based on laboratory tests or certifications of representative materials that will be used in the actual construction. All materials must conform to Section 700 of the *SCDOT Standard Specifications for Highway Construction*, unless otherwise modified herein.

3.2. Portland Cement, Fly Ash, and Water-Granulated Blast Furnace Slag: All cementitious material must conform to Section 501.2.1. Pozzolanic substitution for portland cement shall be allowed as specified in Section 701.4.9. If the use of silica fume is desired, have the type and usage pre-approved by the SCDOT State Materials Engineer.

3.3. Aggregates: Obtain all aggregates to be used from qualified sources appearing on the SCDOT Qualified Products Listing for aggregates. Use no aggregate where the plasticity index of the aggregate exceeds 5. Aggregates may be obtained from a single source or borrow pit, or may be a blend of fine and coarse aggregates. Use well-graded aggregate without gradation gaps and conforming to the following gradation:

<u>Sieve Size</u>	<u>Percent Passing by Weight</u>
1 inch	100
¾ inch	90-100
½ inch	70-100
3/8 inch	60-85
#4	40-60
#16	20-40
#100	6-18
#200	2-8

3.4. Water: Use only water conforming to Section 701.2.11 of the Standard Specifications.

3.5. Curing Compound: Where curing compounds are used, only those white-pigmented products shown in the current edition of SCDOT Qualified Products List 33 shall be used.

4. DESIGN STRENGTH: Use a mix design that demonstrates a compressive strength of 4000 psi within 28 days when specimens prepared according to ASTM C 1435 are tested according to AASHTO T 22. At least two sets of three cylinders will be produced, with one set being tested at 4

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days and the other at 28 days. To determine the compressive strength for a set, two of the specimens will be tested. If the weaker of the two specimens is at least 90 percent of the strength of the stronger specimen, then the two values will be averaged to determine the overall compressive strength. If the weaker specimen has less than 90 percent of the strength of the stronger specimen, then the third specimen will be broken and all three specimens will be averaged. If one individual result is much lower or much higher than the other two due to defects in the specimen, that value may be discarded at the State Materials Engineer's discretion.

5. EQUIPMENT

5.1. General: Construct roller compacted concrete with any combination of equipment that will produce a completed pavement meeting the requirements for mixing, transporting, placing, compacting, finishing, and curing as provided in this specification.

5.2. Mixing Plant: Locate the mixing plant within a thirty-minute haul time from the point of RCC placement. Use only plants capable of producing an RCC pavement mixture in the proportions defined by the final approved mix design and within the specified tolerances. The capacity of the plant must be sufficient to produce a uniform mixture at a rate compatible with the placement equipment. If the plant is unable to produce material at a rate adequate to prevent unnecessary cold joints and frequent paver stoppages, the RCE may halt production until such time that a plant of appropriate capacity is used. Have the plant inspected and approved by the SCDOT Office of Materials and Research prior to production of material under these specifications.

5.2.1. Pugmill Plant: Use only pugmill plants of the central plant type with a twin-shaft pugmill mixer, capable of batch or continuous mixing, equipped with synchronized metering devices and feeders to maintain the correct proportions of aggregate, cement, pozzolan, and water. Other pugmill plant requirements are as follows:

5.2.1.1. *Aggregate Storage:* If previously blended aggregate is furnished, storage may be in a stockpile from which it is fed directly to a conveyor feeding the mixer. If aggregate is furnished in two size groups, follow proper stockpiling techniques to ensure aggregate separation.

5.2.1.2. *Aggregate Feed Rate:* Use aggregate bins with a feed rate controlled by a variable speed belt, or an operable gate calibrated to accurately deliver any specified quantity of material. If two aggregate size stockpile sources are used, the feed rate from each bin must be readily adjustable to change aggregate proportions, when required. Feed rate controls must maintain the established proportions of aggregate from each stockpile bin when the combined aggregate delivery is increased or decreased.

5.2.1.3. *Plant Scales:* Plant scales, if utilized, for any weigh box or hopper must comply with Section 701.3.2.

5.2.1.4. *Cement and Pozzolan Material Storage:* Supply separate and independent storage silos for portland cement and pozzolan. At plants with two or more silos in which different types of cement or cementitious materials are stored, ensure that each silo has a sign at each fill inlet to reduce the potential for loading errors. Make the sign from a durable material, with minimum two-inch high by ¼-inch wide letters that are raised, indented, or cut. Ensure that the sign clearly identifies the material that is in the silo and may be easily read even when completely coated with dust. Flat signs with painted or applied letters are not acceptable.

5.2.1.5. *Preblended Portland Cement and Pozzolan:* If using preblended portland cement and pozzolan (such as fly ash or slag), employ blending equipment acceptable to the RCE and demonstrate, with a testing plan, the ability to successfully produce a uniform blended material meeting the mix design requirements. Perform testing on at least a daily basis to ensure both uniformity and proper quantities.

5.2.1.6. *Cement and Pozzolan Feed Unit:* Provide a satisfactory means of dispensing portland cement and pozzolan, volumetrically or by weight, to ensure a uniform and accurate quantity of cementitious material enters the mixer.

5.2.1.7. *Water Control Unit:* Use a water control unit capable of measuring the required amount of water for the approved mix by weight or volume. Ensure that the unit is

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equipped with an accurate metering device. Vary the amount of water to be used only with the approval of the RCE.

5.2.1.8. *Gob Hopper*: For continuous operating pugmills, provide a gob hopper attached to the end of the final discharge belt to temporarily hold the RCC discharge in order to allow the plant to operate continuously.

5.2.2. *Rotary Drum Mixer*: Provide a rotary drum batch mixer capable of producing a homogeneous mixture, uniform in color, and having all coarse aggregate coated with mortar. Equip the mixer with batching equipment to meet the following requirements:

5.2.2.1. *Weighing Equipment*: Measure the amounts of cement, pozzolan, and aggregate entering into each batch of RCC by direct weighing equipment. Use only weighing equipment that is readily adjustable in order to compensate for the moisture content of the aggregate or to change the proportionate batch weights. Include a visible dial or equally suitable device that will accurately register the scale load from zero to full capacity. The cement and pozzolan may be weighed separately or cumulatively in the same hopper on the same scale, provided the cement is weighed first.

5.2.2.2. *Weigh Hoppers*: Use only bulk cement and pozzolan weigh hoppers that are equipped with vibrators to operate automatically and continuously while weighing hoppers are being dumped. Ensure that the weigh hopper has sufficient capacity to hold not less than 10 percent in excess of the cementitious material required for one batch.

5.2.2.3. *Water Metering*: Measure the amount of water entering each batch of RCC by weight or volume. Use only equipment capable of measuring the water to within a tolerance of plus or minus one percent and equipped with an accurate gauge or dial measuring device. Vary the amount of water to be used only with the approval of the RCE. During batching, admit water to the mixer only through the water measuring device and then only at the time of charging.

5.2.2.4. *Mixing Time*: Use only drum mixers equipped with an accurate clock or timing device, capable of being locked, for visibly indicating the time of mixing after all the materials, including the water, are in the mixer.

5.2.2.5. *Recharging*: Discharge all material in the drum before recharging. Ensure that the volume of mixed material per batch does not exceed the manufacturer's rated capacity of the mixer.

5.3. *Paver*: Place RCC with a high-density asphalt-type paver subject to approval by the RCE. Use only pavers equipped with compacting devices capable of producing an RCC pavement with a minimum of 90 percent of the maximum density in accordance with AASHTO T 180, Method D prior to any additional compaction. Ensure that the paver is of suitable weight and stability to spread and finish the RCC material, without segregation, to the required thickness, smoothness, surface texture, cross-section, and grade.

5.4. *Compactors*: Use self-propelled steel drum vibratory rollers having a minimum static weight of 10 tons for primary compaction. For final compaction, use either a steel drum roller, operated in a static mode, or a rubber-tired roller of equal or greater weight. Only use walk-behind vibratory rollers or plate tampers for compacting areas inaccessible to large rollers.

5.5. *Haul Trucks*: Use trucks for hauling the RCC material from the plant to the paver with covers available to protect the material from inclement weather. To ensure adequate and continuous supply of RCC material to the paver, have a sufficient number of trucks. If the number of trucks is inadequate to prevent frequent starts and stops of the paver, cease production until additional trucks are obtained.

5.6. *Water Trucks*: Keep at least one water truck, or other similar equipment, on-site and available for use throughout the paving and curing process. Equip such equipment with a spreader pipe containing fog spray nozzles capable of evenly applying a fine spray of water to the surface of the RCC without damaging the final surface.

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- 5.7. Inspection of Equipment: Before start-up, the Contractor's equipment will be carefully inspected. Should any of the equipment fail to operate properly, cease work until the deficiencies are corrected.
- 5.8. Access for Inspection and Calibration: Provide the RCE or RCE's representative access at all times for any plant, equipment, or machinery to be used in order to check calibration, scales, controls, or operating adjustments.

6. CONSTRUCTION REQUIREMENTS

- 6.1. Preparation of Subgrade: Before the RCC processing begins, prepare the subgrade in accordance with Section 208 of the SCDOT Standard Specifications.
- 6.2. Quality Control Test Specimens: For each day's production, up to 1500 cubic yards of mix produced, prepare at least three sets of test specimens in accordance with ASTM C 1435 under the direct observation of the RCE or RCE's representative. A set of specimens consists of three cylinders. Make an additional three sets for each additional 1500 cubic yards or fraction thereof. Cure and transport the specimens to the Contractor's (or mix producer's) Office of Materials and Research-approved laboratory in accordance with ASTM C 31. Test two cylinders for compressive strength in accordance with ASTM C 39 at 3 days, 7 days, and 28 days under the direct observation of the RCE or RCE's representative. If the measured compressive strength between two cylinders varies by more than 10 percent of the stronger cylinder, test the third cylinder and average the results of the three cylinders. Otherwise, average the measured compressive strengths of the two cylinders tested at 28 days to determine the compressive strength of the lot. Retain the compressive strength test results for inspection by the RCE.

If the compressive strength measured at 3 days indicates that the 28-day compressive strength will be less than 3500 psi, investigate the potential causes of the low strengths and report to the RCE within 24 hours. If the compressive strength measured at 3 days indicates 28-day compressive strengths less than 3200 psi, immediately stop production and notify the RCE. Do not resume production until the cause of the discrepancy has been determined to the satisfaction of the RCE. The RCE may adjust compressive strength targets at 3 days as production continues based on field experience.

- 6.3. Mixing Process: Use the same mixture for the entire project unless otherwise stated in the project documents. If, during production, the source of portland cement, pozzolan, or aggregates is changed, then suspend production and submit a new mix design to the RCE for approval. Do not exceed the manufacturer's rated capacity for dry concrete mixtures in the mixing chamber. Keep the sides of the mixer and mixer blades free of hardened RCC or other buildups. Routinely check mixer blades for wear and replace if wear is sufficient to cause inadequate mixing.
 - 6.3.1. *Mixing Time*: Use a mixing time adequate to ensure a thorough and complete mixing of all materials. Do not allow the mixing time, after all materials including water are in the mixer, to be less than 1½ minutes for one cubic yard and 20 seconds for each additional cubic yard.
 - 6.3.2. *Mixture Ingredient Tolerances*: Ensure that the mixing plant receives the quantities of individual ingredients to within the following tolerances:

Material	Variation by Weight
Cementitious Materials	± 2.0%
Water	± 3.0%
Aggregates	± 4.0%

- 6.3.3. *Plant Calibration*: Prior to commencement of RCC production, carry out a complete and comprehensive calibration of the plant in accordance with the manufacturer's recommended

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practice. Provide all scales, containers, and other items necessary to complete the calibration. After completion of the initial calibration, calibrate the plant periodically as directed by the RCE. Plants listed on SCDOT Qualified Product List 28 at the time of RCC production are exempt from this requirement, although the SCDOT reserves the right to require additional calibration if variation in mixture quantities are suspected.

6.3.4. *Daily Reports*: Supply daily plant records of production and quantities of materials used that day to the RCE. These records may be used as a check on plant calibration.

6.4. Transportation: Transport the RCC pavement material from the plant to the areas to be paved in dump trucks equipped with retractable protective covers for protection from rain or excessive evaporation. Ensure that the trucks are dumped clean with no buildup or hanging of RCC material in the corners. Have the dump trucks deposit the RCC material directly into the hopper of the paver or into a secondary material distribution system that deposits the material into the paver hopper. Dump truck delivery must be timed and scheduled so that RCC material is spread and compacted within the specified time limits.

6.5. Placing:

6.5.1. *Subbase Condition*: Prior to RCC placement, ensure that the surface of the subbase is clean and free of foreign material, ponded water, and frost. Ensure that the subbase is uniformly moist at the time of RCC placement. If sprinkling of water is required to remoisten certain areas, ensure that the method of sprinkling will not form mud or pools of freestanding water. Correct soft or yielding subbase areas prior to placement of RCC as specified in Section 6.1 above.

6.5.2. *Weather Conditions*:

6.5.2.1. *Cold Weather Precautions*: Employ cold weather precautions as detailed in Section 501.4.6 of the Standard Specifications.

6.5.2.2. *Hot Weather Precautions*: During periods of hot weather or windy conditions, take special precautions to minimize moisture loss due to evaporation. Cooling of aggregate stockpiles by shading or the use of a fine mist may be required. Protective covers may be required on dump trucks. Keep the surface of the newly placed RCC pavement continuously moist.

6.5.2.3. *Rain Limitations*: Conduct no placement of RCC pavement during rain conditions sufficient to be detrimental to the finished product. Placement may continue during light rain or mists provided the surface of the RCC pavement is not eroded or damaged in any way. Use dump truck covers during these periods. The RCE may terminate paving at any time when, in the RCE's judgement, the rain is detrimental to the finished product.

6.5.3. *Paver Requirements*: Place all RCC with an approved paver as specified in Section 5.3 and also meet the following requirements:

6.5.3.1. *Filling the Paver*: Do not allow the quantity of RCC material in the paver to approach empty between loads. Maintain the material above the auger at all times during paving.

6.5.3.2. *Stopping the Paver*: Ensure that the paver proceeds in a steady, continuous operation with minimal starts and stops, except to begin a new lane. Maximum paver speed during laydown is 10 feet per minute. Higher paver speeds may be allowed at the discretion of the RCE if the higher speeds may be obtained without distress to the final product or cause additional starts and stops.

6.5.3.3. *Surface Condition*: Ensure that the surface of the RCC pavement is smooth, uniform, and continuous without excessive tears, ridges, or aggregate segregation once it leaves the paver.

6.5.4. *Inaccessible Areas*: Pave all areas inaccessible to either roller or paver with cast-in-place concrete meeting the compressive strength requirements of these specifications.

6.5.5. *Adjacent Lane Paving*: Place adjacent paving lanes within 60 minutes. If more than 60 minutes elapses between placement of adjacent lanes, the vertical joint must be considered a cold joint and prepared in accordance with Section 6.7 below. At the discretion of the RCE, this time may be increased or decreased depending on ambient conditions of

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temperature, wind, and humidity. Multiple pavers may be used in tandem to reduce the occurrence of cold joints.

6.5.6. *Hand Spreading*: Broadcasting or fanning the RCC material across areas being compacted is not permissible. Such additions of materials may only be done immediately behind the paver and before any compaction has taken place. Any segregated coarse aggregate shall be removed from the surface before rolling.

6.5.7. *Segregation*: If segregation occurs in the RCC during paving operations, placement shall cease until the cause is determined and corrected to the satisfaction of the RCE. If the segregation is judged by the RCE to be severe, remove and replace the segregated area at no additional cost to the Department.

6.6. Compaction:

6.6.1. *Time to Compaction Start*: Ensure that compaction begins with the placement process and is completed within 60 minutes of the start of the mixing at the plant. The time may be increased or decreased at the discretion of the RCE depending on ambient conditions of temperature and humidity. Do not permit delays in rolling unless approved by the RCE. Plan operations and supply sufficient equipment to ensure that these criteria are met.

6.6.2. *Rolling*: Determine the sequence and number of passes by vibratory and non-vibratory rollers to obtain the specified density and surface finish. Only operate rollers in the vibratory mode while in motion. Rubber-tire rollers may be used for final compaction. Use additional rollers if specific density requirements are not obtained or if placing operations get ahead of the rolling operations.

6.6.3. *Rolling Longitudinal and Transverse Joints*: Do not operate the roller within 2 feet of the edge of a freshly placed lane until the adjacent lane is placed. Then, roll both edges of the two lanes together within the allowable time. If a cold joint is planned, then roll the complete lane and follow cold joint procedures as specified in Section 6.7 below.

6.6.4. *Inaccessible Areas*: Compact areas inaccessible to large rollers using walk-behind rollers or hand tampers.

6.6.5. *Density Requirements*: Field density tests will be performed in accordance with SC-T-33 as soon as possible, but no later than 30 minutes after the completion of the rolling. Only wet density is used for evaluation. The required minimum density is 98 percent of the maximum laboratory density obtained according to AASHTO T 180 (Method D). The in-place density and moisture content may be determined with a nuclear moisture-density gauge. The gauge will be calibrated for moisture content at the beginning of the work and at any time during the work. RCC properly placed and compacted, but not meeting the density requirements, shall be cored and tested at the Contractor's expense. If the tested area achieves 28-day design strength, it will be paid at the full unit price. If the tested area indicates strength less than 3500 psi but greater than 3150 psi, payment will be made as follows:

Compressive Strength (psi)	Price Reduction (percent of unit bid price)
3300-3499	5
3150-3299	15

If the cores indicate strengths less than 3150 psi at 28 days or longer, the Department will evaluate the results and may reject the affected area and require removal and replacement or elect to pay at a reduced rate.

6.7. Joints:

6.7.1. *Fresh Vertical Joints*: A joint is considered a fresh joint when an adjacent RCC lane is placed within 60 minutes of placing the previous lane or as specified by the RCE based on ambient conditions. Fresh joints do not require special treatment.

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- 6.7.2. *Cold Vertical Joints*: Any planned or unplanned construction joints that do not qualify as fresh joints are considered cold joints. Prior to placing fresh RCC mixture against a compacted cold vertical joint, thoroughly clean the cold joint of loose or foreign material. Wet the vertical joint face and maintain it in a moist condition immediately prior to placement of the adjacent lane.
- 6.7.2.1. *Sawing Cold Vertical Joints*: For uncompacted surfaces or slopes more than 15 degrees from the vertical, cut the joint vertically for the full depth. Within 2 hours of final compaction, the edge of a cold joint may be cut with approved mechanical equipment. For edges cut after 2 hours, sawcut to the full depth of the pavement. Demonstrate any modification or substitution of the sawcutting procedure to the RCE for approval prior to use. In no case allow cutting of the edge to cause raveling or tearing of the surface. Moisten the cut edge immediately prior to placement of the adjacent lane.
- 6.7.3. *RCC Pavement Joints at Structures*: Line structures such as manholes, valves, or concrete curb and gutter with joint filler as defined in Section 501.2.6.1 of the Standard Specifications.
- 6.7.4. *Control Joints*: Construct transverse contraction joints in the RCC pavement by sawing. At the option of the Contractor, soft-cut or green-cut saws may be utilized as soon as possible behind the rolling operation and set to manufacturer's recommendations. Conventional cut saws must be used as soon as the sawing operation will not result in raveling or other damage to the RCC pavement, but not more than 18 hours after RCC placement. Cut all joints to 1/4 the depth of the RCC pavement to a single saw blade width. Joints should be spaced at intervals equal to 24 times the nominal pavement thickness unless otherwise indicated on the Plans or directed by the RCE. (For example, for an 8-inch RCC pavement, cut joints at 16-foot intervals.)
- 6.8. *Finishing*: Ensure that the finished surface of the RCC pavement, when tested with a 10-foot straightedge or crown surface template, does not vary from the straightedge or template by more than 1/4 inch at any one point and shall be within 5/8 inch of the specified finished grade. When surface irregularities are outside these tolerances, diamond-grind the surface to meet the tolerance at no additional cost to the SCDOT.
- 6.9. *Curing*: Immediately after final rolling and compaction testing, keep the surface of the RCC pavement continuously moist until an approved curing compound, a suitable prime coat, or a layer of asphalt concrete is applied or for 72 hours after placement, whichever comes first.
- 6.9.1. *Water Cure*: Apply water cure by water trucks equipped with fog spray nozzles, soaking hoses, sprinkling system, or other means such that a uniform moist condition on the surface of the RCC is ensured. Apply this moisture in a manner that will not erode or damage the surface of the finished RCC pavement.
- 6.9.2. *Curing Compound*: Do not use curing compounds when the RCC material is to be promptly covered with asphalt. Apply curing compound as indicated in Section 501.4.11 of the Standard Specifications, except that the minimum rate of curing compound application is 0.09 gallons per square yard (11 square yards per gallon) unless a higher rate is specified by the curing compound manufacturer.
- 6.10. *Traffic*: Protect the RCC from vehicular traffic during the curing period. Completed portions of the RCC pavement may be opened to automotive and light truck traffic as soon as the strength is sufficient to prevent visible damage to the RCC. The pavement may be opened to unrestricted traffic after 12 hours. However, if the temperature drops below 40° F, then the period of time the temperature is below 40° F will be added to the minimum time to opening. Temperature will be based on the hourly ambient air temperature reported by the nearest National Weather Service station.
- 6.11. *Maintenance*: Maintain the RCC pavement in good condition until all work is completed and accepted. Perform such maintenance at no additional cost to the SCDOT.

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- 6.12. Thickness: Provide and operate equipment capable of extracting a small (approximately 1 inch diameter or greater) core to determine the pavement thickness. Extract samples in the presence of the RCE or RCE's representative unless otherwise directed. Repair the core holes using a packaged quick set repair mortar such as SikaQuick 1000 or approved equivalent or a Class 4000 or better ready mix concrete. Rod and neatly strike off the repair material.
- 6.13. Thickness Tolerance - The thickness of the completed RCC is measured at staggered intervals not to exceed 250 feet in length for two-lane roads. Measure the core to the nearest 1/8 inch at three different, evenly spaced locations and record the average. Where the RCC is deficient by more than 1/2 inch, correct such areas by removal and replacement. Where the measured thickness is more than 1/2 inch thicker than shown on the Plans, it is considered as the specified thickness, plus 1/2 inch. The average job thickness is the average of the depth measurements determined as specified above. Should this average thickness be more than 1/4 inch below the specified thickness, an adjusted unit price is used in calculating payment. This adjusted contract unit price bears the same ratio to the contract unit price as the square of the average thickness bears to the square of the specified thickness. When the contract includes more than one road, each road is considered separately.

7. MEASUREMENT AND PAYMENT

- 7.1. Measurement: The quantity measured for payment under this supplemental specification is the number of square yards of RCC Pavement completed and accepted, and measured in place along the surface of normal width of through-lane pavement. Pavement constructed outside the area designated to be paved will be disregarded in computing the number of square yards. Construction of control joints will not be measured separately and no direct payment will be made for this work.
- 7.2. Basis of Payment: The quantity, as measured above, will be paid for at the contract unit price for RCC Pavement, of the thickness specified, which price and payment will be full compensation for furnishing all materials, equipment, tools, labor, and incidentals necessary to satisfactorily complete the work. Pavement that is deficient in thickness, but is permitted to be left in place, will be paid at the reduced unit price as provided in Section 6.13. No compensation will be allowed for the materials or labor involved in the removal of defective material.

Payment includes all direct and indirect costs and expenses required to complete the work. Payment will be made under:

Roller Compacted Concrete Pavement - Square Yard