Roller compacted concrete resource guide for Indiana

Count on Concrete Indiana
# TABLE OF CONTENTS

1. PCA’s guide specification

2. PCA’s Roller Compacted Pavements for Highways and Streets

3. PCA’s Production of Roller Compacted Concrete

4. Other Agencies
   a. Columbus, Ohio
   b. St. Joe County Indiana
   c. Georgia Department of Transportation

5. Project Profiles
   a. Union County
   b. Henry County
   c. St. Joe County

6. For Additional Information

Prepared by CRT Concrete Consulting, LLC.

1.1 Description. Roller-Compacted Concrete (RCC) shall consist of aggregate, portland cement, possibly other supplementary cementing materials (fly ash, slag and silica fume) and water. RCC shall be proportioned, mixed, placed, compacted and cured in accordance with these specifications; and conform to the lines, grades, thickness, and typical cross sections shown in the Plans or otherwise established by the Engineer.

1.2 Caveat. This specification is intended to serve as a guide to format and content for normal RCC pavement construction. Most projects have features or requirements that should be incorporated in the project documents.

2. Referenced Documents

2.1 American Society for Testing and Materials (ASTM):

C 31 Practice for Making and Curing Concrete Test Specimens in the Field
C 33 Specification for Concrete Aggregates
C 39 Test Method for Compressive Strength of Cylindrical Concrete Specimens
C 42 Test Method for Obtaining and Testing Drilled Cores and Sawed Beams of Concrete
C 78 Test Method for Flexural Strength of Concrete (Using Simple Beam with Third-Point Loading)
C 150 Specification for Portland Cement
C 171 Specification for Sheet Materials for Curing Concrete
C 309 Specification for Liquid Membrane-Forming Compounds for Curing Concrete
C 494 Specification for Chemical Admixtures for Concrete
C 496 Test Method for Splitting Tensile Strength of Cylindrical Concrete Specimens
C 595 Specification for Blended Hydraulic Cements
C 618 Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use as a Mineral Admixture in Concrete
C 989 Specification for Ground Granulated Blast-Furnace Slag for Use in Concrete and Mortars
C 1040 Test Methods for Density of Unhardened and Hardened Concrete In Place by Nuclear Methods
C 1157 Performance Specification for Hydraulic Cement
C 1176 Practice for Making Roller-Compacted Concrete in Cylinder Molds Using a Vibrating Table
C 1240 Specification for Use of Silica Fume as a Mineral Admixture in Hydraulic-Cement Concrete, Mortar and Grout
C 1435 Practice for Molding Roller-Compacted Concrete in Cylinder Molds Using a Vibrating Hammer
D 977 Specification for Emulsified Asphalt
D 1557 Test Methods for laboratory Compaction Characteristics of Soil Using Modified Effort

3. Submittals

3.1 Submittal Requirements. The Contractor shall submit the following to the Engineer at least 30 days before start of any production of RCC pavement:

3.1.1 Construction schedule for all RCC related operations.

3.1.2 Paving procedures describing direction of paving operations, paving widths, planned longitudinal and transverse cold joints, and curing methods and patterns.

3.1.3 Certification for aggregate source, quality and sizing as required by the specification.

3.1.4 Certification for portland cement and supplementary cementitious materials as required by the specification.

3.1.5 Manufacturers data and specifications including capacities for equipment to be used in mixing, hauling, placing and compacting RCC.

3.1.6 Layout of plant location showing mixing plant, cement and aggregate storage, and water supply.
3.1.7 Proposed RCC Mix Design. If the proposed mix design is developed by the Contractor or there is a suggested change to the mix design, it must be submitted to the Engineer for approval at least four weeks prior to RCC construction. This mix design shall include details on aggregate gradation, cementitious materials, admixtures (if used), compressive and/or flexural strengths, and required moisture and density to be achieved.

4. Materials

4.1 General. All materials to be used for RCC pavement construction shall be approved by the Engineer based on laboratory tests or certifications of representative materials which will be used in the actual construction.

4.2 Portland Cement. Cement shall comply with the latest specifications for portland cement (ASTM C 150 and ASTM C 1157), or blended hydraulic cements (ASTM C 595 and ASTM C 1157)

4.3 Aggregates. Unless otherwise approved in writing by the Engineer, the quality of aggregates shall conform to ASTM C 33. The plasticity index of the aggregate shall not exceed five. Aggregates may be obtained from a single source or borrow pit, or may be a blend of coarse and fine aggregate. The aggregate shall be well-graded without gradation gaps and conform to the following gradation:

<table>
<thead>
<tr>
<th>Sieve Size</th>
<th>Percent passing by weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>1&quot; (25 mm)</td>
<td>100</td>
</tr>
<tr>
<td>3/4&quot; (19 mm)</td>
<td>90-100</td>
</tr>
<tr>
<td>1/2&quot; (12.5 mm)</td>
<td>70-90</td>
</tr>
<tr>
<td>3/8&quot; (9.5 mm)</td>
<td>60-85</td>
</tr>
<tr>
<td>No. 4 (4.75 mm)</td>
<td>40-60</td>
</tr>
<tr>
<td>No. 16 (1.18 mm)</td>
<td>20-40</td>
</tr>
<tr>
<td>No. 100 (150 µm)</td>
<td>6-18</td>
</tr>
<tr>
<td>No. 200 (75 µm)</td>
<td>2-8</td>
</tr>
</tbody>
</table>

4.4 Mineral Admixtures. Mineral admixtures shall conform to the requirements of ASTM C 618 (flyash), ASTM C 989 (slag) and ASTM C 1240 (silica fume). Unless specifically directed by the Engineer, total mineral admixture content including the content in blended cements shall not exceed the weight of portland cement in the RCC mix.

4.5 Chemical Admixtures. Chemical admixtures including water-reducing and retarding admixtures shall conform to ASTM C 494 and must be approved by the Engineer prior to use.

4.6 Water. Water shall be clean, clear and free of acids, salts, alkalis or organic materials that may be injurious to the quality of the concrete. Non-potable water may be considered as a source for part or all of the water, provided the mix design indicates proof that the use of such water will not have any deleterious effect on the strength and durability properties of the RCC.

4.7 Curing Compound. Concrete curing compounds shall conform to ASTM C 309 or ASTM D 977.

5. Equipment

5.1 General. All necessary equipment shall be on hand and approved by the Engineer before work will be permitted. Roller-compacted concrete shall be constructed 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.

5.2.1 Location of Plant. The mixing plant shall be located within a 30 minute haul time from the RCC placement. With prior testing and Engineer’s approval, a set retarding admixture may be used to extend the haul time.

5.2.2 Plant Capacity. The plant shall be capable of producing an RCC mixture in the proportions defined by the final approved mix design and within the specified tolerances. The capacity of the plant shall be sufficient to produce a uniform mixture at a rate compatible with the placement equipment. The volume of RCC material in the mixing chamber shall not be more than the rated capacity for dry concrete mixtures. Multiple plants shall be supplied if a single plant can not provide an uninterrupted supply of RCC to the paver(s) during peak paving operations.

5.2.3 Pugmill Plant. A pugmill plant shall be a central plant 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, mineral admixture and water. Other pugmill plant requirements are as follows:

5.2.3.1 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 or more size groups, aggregate separation must be provided at the stockpiles.

5.2.3.2 Aggregate bins shall have a feed rate controlled by a variable speed belt, or an operable gate calibrated to accurately deliver any specified quantity of material. If two or more aggregate size stockpile sources are used, the feed rate from each bin shall 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.

5.2.3.3 Plant Scales. Plant scales for any weigh box or hopper shall be either of beam or springless-dial type, and be sensitive to 0.5 per-

1. Because of the very dry consistency of RCC, the batch volume of mixed material especially for drum mixers may need to be less than the manufacturer’s rated capacity of the mixer for conventional concrete.
5.2.4.3 The amount of water entering each batch of RCC shall be measured by weight or volume. The equipment shall be capable of measuring the water to within a tolerance of plus or minus one percent and shall be equipped with an accurate gauge or dial measuring device. During batching, water shall be admitted to the mixer only through the water measuring device and then only at time of charging.

5.2.4.4 Drum mixers shall be 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.

5.2.5 Alternative Mixing Equipment. Other types of batching and mixing equipment and configurations including dry batch plants and concrete truck mixers may be used with the approval of the Engineer. The Contractor must demonstrate that the mixing equipment has the ability to produce a consistent, well-blended, non-segregated RCC mix satisfying the minimum capacity requirements of Section 5.2.2 and within the tolerance limits as specified in Section 6.3.2.

5.3 Paver.

5.3.1 RCC shall be placed with a high-density or conventional asphalt type paver subject to approval by the Engineer. The paver shall be capable of placing RCC to a minimum of 85% of the maximum wet density in accordance with ASTM D 1557 or equivalent test method. The paver shall be 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.

5.3.2 Alternative Paving Equipment. Any alternative paving equipment such as graders and dozers must be approved by the Engineer prior to use. The equipment shall be capable of producing a finished product that results in a smooth, continuous surface without segregation, excessive tearing, or rock pockets.

5.4 Compactors.

5.4.1 Self-propelled steel drum vibratory rollers having a minimum static weight of 10 tons (9.07 metric tons) shall be used for primary compaction. For final compaction either a steel drum roller, operated in a static mode, or a pneumatic-tire roller shall be utilized.

5.4.2 Walk-behind vibratory rollers or plate tampers shall be used for compacting areas inaccessible to the large rollers.

5.5 Haul Trucks. Trucks for hauling the RCC material from the plant to the paver shall have covers available to protect the material from rain or excessive evaporation. The number of trucks shall be sufficient to ensure adequate and continuous supply of RCC material to the paver.

5.6 Water Trucks. At least one water truck, or other similar equipment, shall be on-site and available for use throughout the paving and curing process. Such equipment shall be capable of evenly applying a fine spray of water to the surface of the RCC without damaging the final surface.

5.7 Inspection of Equipment. Before start-up, the Contractor's equipment shall be carefully inspected. Should any of the equipment fail to operate properly, no work shall proceed until the deficiencies are corrected.

---

cent of the maximum load required. Beam-type scales shall have a separate beam for each aggregate size, with a single telltale actuated for each beam, and a tare beam for balancing hopper. Belt scales shall be of an approved design. Standard test weights accurate to plus or minus 0.1 percent shall be provided for checking plant scales.

5.2.3.4 Cement and Mineral Admixture Material Storage. Separate and independent storage silos shall be used for portland cement and mineral admixture. Each silo must be clearly identified to avoid confusion during silo loadings. If the Contractor chooses to preblend the cementitious material he must employ blending equipment acceptable to the Engineer and demonstrate, with a testing plan, the ability to successfully produce a uniform blended material meeting the mix design requirements. Testing of the preblended cementitious material shall be done on a daily basis to assure both uniformity and proper quantities.

5.2.3.5 Cement and Mineral Admixture Feed Unit. Satisfactory means of dispensing portland cement and mineral admixture, volumetrically or by weight, shall be provided to assure a uniform and accurate quantity of cementitious material enters the mixer.

5.2.3.6 Water Control Unit. Required amount of water for the approved mix shall be measured by weight or volume. The unit shall be equipped with an accurate metering device. The water flow shall be controlled by a meter, valve or other approved regulating device to maintain uniform moisture content in the mixture.

5.2.3.7 Surge Hopper. For continuous operating pugmills, a surge hopper attached to the end of the final discharge belt shall be provided to temporarily hold the RCC discharge to allow the plant to operate continuously.

5.2.4 Rotary Central-Mix Drum Plant. A rotary drum batch mixer shall be capable of producing a homogeneous mixture, uniform in color and having all coarse aggregate coated with cementitious paste. The mixer shall be equipped with batching equipment to meet the following requirements:

5.2.4.1 The amounts of cement, mineral admixture and aggregate entering into each batch of RCC shall be measured by direct weighing equipment. Weighing equipment shall be readily adjustable to compensate for the moisture content of the aggregate or for changing the proportionate batch weights, and shall include a visible dial or equally suitable device which will accurately register the scale load from zero to full capacity. The cement and mineral admixture may be weighed separately or cumulatively in the same hopper on the same scale, provided the cement is weighed first.

5.2.4.2 Bulk cement and mineral admixture weigh hoppers shall be equipped with vibrators to operate automatically and continuously while weighing hoppers are being dumped. The weigh hopper shall have sufficient capacity to hold not less than 10 percent in excess of the cementitious material required for one batch.

5.2.4.3 The amount of water entering each batch of RCC shall be measured by weight or volume. The equipment shall be capable of
5.8 Access for Inspection and Calibration. The Engineer shall have access at all times to any plant, equipment or machinery to be used on this project in order to check calibration, scales, controls or operating adjustments.

6. Construction Requirements

6.1 Preparation of Subgrade/Subbase. Before RCC processing begins, the area to be paved shall be graded and shaped to the lines and grades as shown in the Plans or as directed by the Engineer. During this process any unsuitable soil or material shall be removed and replaced with acceptable material. The subgrade shall be uniformly compacted to a minimum of 95% of the maximum dry density in accordance with ASTM D 1557. The Contractor shall check for any soft or yielding subgrade areas by proof rolling with a loaded dump truck or pneumatic-tire roller over the entire area to be paved. All soft or yielding subgrade areas shall be corrected and made stable before RCC construction begins. If a subbase is shown on the Plans, it shall be uniformly compacted to a minimum of 95% of the maximum dry density in accordance with ASTM D 1557.

6.2 Test Section (Optional).

6.2.1 At least 30 days before the start of paving operations, the Contractor shall construct a test section using the trial mix design. This test pavement will allow the Engineer to evaluate the strength of the RCC material, methods of construction, curing process and surface conditions of the completed test pavement. The test section shall be at least 50 feet (15 meters) long and a minimum of two paver widths wide. It shall be located in a non-critical area or as indicated on the Plans. The test pavement will be constructed over an extended period to demonstrate the construction of cold joints in both a longitudinal and transverse direction, as well as fresh joint construction.

6.2.2 The equipment, materials and techniques used to construct the test section shall be that which will be used to construct the main RCC pavement.

6.2.3 During construction of the test section the Contractor will establish an optimum rolling pattern and procedure for obtaining a density of not less than 98% of the maximum wet density in accordance with ASTM D 1557 or equivalent test method. In addition, the Contractor must also demonstrate the ability to achieve a smooth, hard, uniform surface free of excessive tears, ridges, spalls and loose material.

6.2.4 Strength Testing (Optional Tests).

6.2.4.1 Field Cast Specimens. Specimens shall be prepared in accordance with ASTM D 1557, ASTM C 1435, or ASTM C 1176. Cure and transport specimens to the laboratory in accordance with ASTM C 31. Specimens shall be tested for splitting tensile strength (ASTM C 496) and compressive strength (ASTM C 39) at 7, 14, and 28 days of age. In addition, 6x6x21 in. (150x150x525 mm) beams will be sawn from the test section and flexural strength at 7, 14 and 28 days will be determined in accordance with ASTM C 78. All coring, cutting and testing of the test section shall be paid for by the Owner.

6.2.4.2 Cores and Beams. The test section shall be cured at least 5 days prior to extracting cores and beams for testing. The cores and beams shall be obtained in accordance with ASTM C 42. The cores will be tested for splitting tensile strength (ASTM C 496) and compressive strength (ASTM C 39) at 7, 14 and 28 days of age. In addition, 6x6x21 in. (150x150x525 mm) beams will be sawn from the test section and flexural strength at 7, 14 and 28 days will be determined in accordance with ASTM C 78. All coring, cutting and testing of the test section shall be paid for by the Owner.

6.3 Mixing Process.

6.3.1 General. Except for minor variations in moisture content, the same mixture proportions shall be used for the entire project, unless otherwise stated in the project documents. The water content shall be varied by the Contractor, as necessary, to provide a consistency that is most conducive to effective placement and compaction. If during mixing there is a change in the type or source of cementitious materials, or aggregates, the mixing must be suspended, and a new mix design shall be developed.

6.3.2 Mixture Ingredient Tolerances. The mixing plant must receive the quantities of individual ingredients to within the following tolerances:

<table>
<thead>
<tr>
<th>Material</th>
<th>Variation in % by Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cementitious materials</td>
<td>+/- 2.0</td>
</tr>
<tr>
<td>Water</td>
<td>+/- 3.0</td>
</tr>
<tr>
<td>Aggregates</td>
<td>+/- 4.0</td>
</tr>
</tbody>
</table>

6.3.3 Mixing time will be that which will assure complete and uniform mixing of all ingredients. For drum mixers and dry batch facilities, the time of mixing shall be determined from uniformity test results.

6.3.4 All material must be discharged before recharging. The mixing chamber and mixer blade surfaces must be kept free of hardened RCC or other buildups. Mixer blades shall be checked routinely for wear and replaced if wear is sufficient to cause inadequate mixing.

6.3.5 Plant Calibration. Prior to commencement of RCC production, the Contractor shall carry out a complete and comprehensive calibration of the plant in accordance with the manufacturer’s recommended practice. All scales, containers and other items necessary to complete the calibration shall be provided by the Contractor. After completion of the initial calibration, the plant shall be recalibrated as directed by the Engineer.

6.3.6 Daily Reports. The Contractor shall supply daily plant records of production and quantities of materials used that day to the Engineer.

6.4 Transportation. The transportation of the RCC pavement material from the plant to the areas to be paved shall be in dump trucks fitted and equipped, when necessary, with retractable protective covers for protection from rain or excessive evaporation. The trucks shall be dumped clean with no buildup or hanging of RCC material. For paver placed RCC, the dump trucks shall deposit the RCC material

---

2. Preparation of the subgrade/subbase is frequently the responsibility of excavation/grading contractor.
directly into the hopper of the paver or into a secondary material distribution system which deposits the material into the paver hopper. Dump truck delivery must be scheduled so that RCC material is spread and compacted within the specified time limits.

6.5 Placing.
6.5.1 Condition of the Subgrade/Subbase. Prior to RCC placement, the surface of the subgrade/subbase shall be clean and free of foreign material, ponded water and frost prior to the placement of the RCC pavement mixture. The subgrade/subbase must be uniformly moist at the time of RCC placement. If sprinkling of water is required to remoisten certain areas, the method of sprinkling shall not be such that it forms mud or pools of free-standing water. Prior to placement of RCC, the subgrade/subbase shall be checked for proper density and soft or yielding areas and these areas shall be corrected as specified in Section 6.1.

6.5.2 Paver Requirements. RCC shall be placed with an approved paver as specified in Section 5.3 and shall meet the following requirements:

6.5.2.1 The quantity of RCC material in the paver shall not be allowed to approach empty between lifts. The material shall be maintained above the auger shaft at all times during paving.

6.5.2.2 The paver shall operate in a manner that will prevent segregation and produce a smooth continuous surface without tearing, pulling or shoving. The spread of the RCC shall be limited to a length that can be compacted and finished within the appropriate time limit under the prevailing air temperature, wind, and climatic conditions.

6.5.2.3 The paver shall proceed in a steady, continuous operation with minimal starts and stops. Paver speed during placement operations shall not exceed the speed necessary to ensure that minimum density requirements as specified in Section 5.3.1 are met and surface distress is minimized.

6.5.2.4 The surface of the RCC pavement once it leaves the paver shall be smooth, uniform and continuous without excessive tears, ridges or aggregate segregation.

6.5.3 Lift Thickness. Lift thickness of compacted RCC pavement shall be as indicated on the Plans. If RCC pavements are to be constructed in a thickness greater than 10 inches (250 mm), the use of two lifts shall be utilized. No lift shall be less than 4 inches (100 mm).

6.5.4 Adjacent Lane Placement. Adjacent paving lanes shall be placed within 60 minutes. If more than 60 minutes elapses between placement of adjacent lanes, the vertical joint must be considered a cold joint and shall be prepared in accordance with Section 6.8.2. At the Engineer’s discretion, this time may be increased or decreased depending on the use of set retarding admixtures or the ambient weather conditions of temperature, wind, and humidity.

6.5.5 Multiple Lift Placement. For multiple lift placement, the total pavement thickness shall be as shown on the Plans, and the Contractor shall submit his method of placement and lift thickness as part of a paving plan subject to approval by the Engineer. In multiple lift construction, the second lift must be placed within 60 minutes of the completion of the first lift. If more than 60 minutes has elapsed, the interface between the first and second lifts shall be considered a cold joint and shall be prepared in accordance with Section 6.8.3.1. At the discretion of the Engineer, this time may be increased or decreased depending on the use of set retarding admixtures or the ambient weather conditions of temperature, wind and humidity.

6.5.6 Hand Spreading. Broadcasting or fanning the RCC material across areas being compacted will not be permitted. Such additions of material 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 the spreading shall cease until the cause is determined and corrected.

6.5.8 RCC placement shall be done in a pattern so that the curing water from the previous placements will not pose a runoff problem on the fresh RCC surface or on the subbase layer.

6.5.9 Paving Inaccessible Areas. Areas inaccessible to either paver or roller may be placed by hand and compacted with equipment specified in Section 5.4.2. Compaction of these areas must satisfy minimum density requirements as specified in Section 6.7.7. An alternate and preferred method for paving inaccessible areas is to use cast-in-place, air-entrained concrete with a minimum compressive strength of 4000 psi (27 MPa) or as specified by the Engineer. In areas that may be subjected to high load transfer, the Engineer may require the cast-in-place concrete to be doweled into the RCC.

6.5.10 Placement of RCC with graders, dozers or other alternative paving equipment as specified in Section 5.3.2 shall meet the requirements of paver placed RCC where applicable.

6.6 Weather Conditions.
6.6.1 Cold Weather Precautions. RCC material shall not be placed on any surface containing frost or frozen material or when the air temperature is below 40°F (4°C), except when the air temperature is at least 35°F (2°C) and rising. When the air temperature is expected to fall below 40°F (4°C), the Contractor must present to the Engineer a detailed proposal for protecting the RCC pavement. This proposal must be accepted by the Engineer before paving operations may be resumed. A sufficient supply of protective material such as insulating blankets, plastic sheeting, straw, burlap or other suitable material shall be provided by the Contractor at his expense. The methods and materials used shall be such that a minimum temperature of 40°F (4°C) at the pavement surface will be maintained for a minimum of five days. Approval of the Contractor’s proposal for frost protection shall not relieve the Contractor of the responsibility for the quality and strength of the RCC placed during cold weather. Any RCC that freezes shall be removed and replaced at the Contractors expense.
6.7.6 Areas inaccessible to large rollers shall be treated as specified in Section 6.5.9.

6.7.7 Density Requirements. In-place field density tests shall be performed in accordance with ASTM C 1040, direct transmission, as soon as possible, but no later than 30 minutes after completion of rolling. Only wet density shall be used for evaluation. The required density shall be not less than 98% of the maximum wet density obtained by ASTM D 1557 or equivalent test method based on a moving average of five consecutive tests with no test below 96%.

6.8 Joints.

6.8.1 Fresh Vertical Joints. A vertical joint shall be considered a fresh joint when an adjacent RCC lane is placed within 60 minutes of placing the previous lane, with the time adjusted depending on use of retarders or ambient conditions. Fresh joints do not require special treatment.

6.8.2 Cold Vertical Joints. Any planned or unplanned construction joints that do not qualify as fresh joints shall be considered cold joints and shall be treated as follows:

6.8.2.1 Longitudinal and Transverse Cold Joints. Formed joints that do not meet the minimum density requirements of Section 6.7.7 and all unformed joints shall be cut vertically for the full depth. The vertical cut shall be at least 6 in (150 mm) from the exposed edge. Cold joints cut within two hours of placing may be cut with an approved wheel cutter, motor grader or other approved method provided that no significant edge raveling occurs. Cold joints cut after two hours of placement shall be saw cut 1/4 to 1/3 depth of the RCC pavement with the rest removed by hand or mechanical equipment. Any modification or substitution of the saw cutting procedure must be demonstrated to and accepted by the Engineer. All excess material from the joint cutting shall be removed.

6.8.2.2 Prior to placing fresh RCC mixture against a compacted cold vertical joint, the joint shall be thoroughly cleaned of any loose or foreign material. The vertical joint face shall be wetted and in a moist condition immediately prior to placement of the adjacent lane.

6.8.3 Fresh Horizontal Joints. For multi-layer construction a horizontal joint shall be considered a fresh joint when a subsequent RCC lift is placed within 60 minutes of placement of the previous lift. This time may be adjusted at the discretion of the Engineer depending on use of retarders or ambient weather conditions. Fresh joints do not require special treatment other than cleaning the surface of all loose material and moistening the surface prior to placement of the subsequent lift.

6.8.3.1 Horizontal Cold Lift Joints. For horizontal cold joints the surface of the lift shall be kept continuously moist and cleaned of all loose material prior to placement of the subsequent lift. The Engineer may require other action such as use of a cement slurry or mortar grout between lifts. If supplementary bonding materials are used, they shall be applied immediately prior to placement of the subsequent lift.

6.8.3.2 RCC Pavement Joints at Structures. The joints between RCC pavement and concrete structures shall be treated as cold vertical joints.

6.6.2 Hot Weather Precautions. During periods of hot weather or windy conditions, special precautions shall be taken to minimize moisture loss due to evaporation. Under conditions of excessive surface evaporation due to a combination of air temperature, relative humidity, concrete temperature and wind conditions, the Contractor must present to the Engineer a detailed proposal for minimizing moisture loss and protecting the RCC. Precautions may include cooling of aggregate stockpiles by use of a water spray, protective covers on dump trucks, temporary wind breaks to reduce wind effect, cooling of concrete mix water, and decreasing the allowable time between mixing and final compaction.

6.6.3 Rain Limitations. No placement of RCC pavement shall be done while it is raining hard enough to be detrimental to the finished product. Placement may continue during light rain or mists provided the surface of the RCC pavement is not washed-out or damaged due to tracking or pickup by dump trucks or rollers. Dump truck covers must be used during these periods. The Engineer will be the sole judge as to when placement must be stopped due to rain.

6.7.3 Rain Limitations. No placement of RCC pavement shall be done while it is raining hard enough to be detrimental to the finished product. Placement may continue during light rain or mists provided the surface of the RCC pavement is not washed-out or damaged due to tracking or pickup by dump trucks or rollers. Dump truck covers must be used during these periods. The Engineer will be the sole judge as to when placement must be stopped due to rain.

6.7.4 Longitudinal joints shall be given additional rolling as necessary to produce the specified density for the full depth of the lift and a tight smooth transition occurs across the joint. Any uneven marks left during the vibrating rolling shall be smoothed out by non-vibrating or rubber tire rolling. The surface shall be rolled until a relatively smooth, flat surface, reasonably free of tearing and cracking is obtained.

6.7.5 Speed of the rollers shall be slow enough at all times to avoid displacement of the RCC pavement. Displacement of the surface resulting from reversing or turning action of the roller shall be corrected immediately.

6.7.6 Areas inaccessible to large rollers shall be treated as specified in Section 6.5.9.
6.8.4 Control Joints (Optional). Control joints may be constructed in the RCC pavement to induce cracking at pre-selected locations. Joint locations shall be shown on the Plans or as directed by the Engineer. Early entry saws should be utilized as soon as possible behind the rolling operation and set to manufacturer’s recommendations. Conventionally cut control joints shall be saw cut to 1/4 depth of the compacted RCC pavement. Joints shall be saw cut as soon as those operations will not result in significant raveling or other damage to the RCC pavement.

6.9 Finishing.

6.9.1 Surface Smoothness. The finished surface of the RCC pavement, when tested with a 10 foot (3 meter) straight edge or crown surface template, shall not vary from the straight edge or template by more than 3/8 inch (10 mm) at any one point. When the surface smoothness is outside the specified surface tolerance the Contractor shall grind the surface to within the tolerance by use of self-propelled diamond grinders. Milling of the final surface is not acceptable, unless it is for the removal of the pavement.

6.9.2 Thickness. The thickness of the RCC pavement shall not deviate from that shown on the plans or as directed by the Engineer by more than minus 1/2 inch (12.5 mm). Pavement of insufficient thickness shall be removed and replaced the full depth. No skin patches shall be accepted.

6.9.3 When surface irregularities are outside the tolerances cited above, the contractor shall grind the surface to meet the tolerance at no additional cost to the Owner.

6.10 Curing. Immediately after final rolling and compaction testing, the surface of the RCC pavement shall be kept continuously moist for 7 days or until an approved curing method is applied.

6.10.1 Water Cure. Water cure shall be applied by water trucks equipped with misting spray nozzles, soaking hoses, sprinkler system or other means that will assure a uniform moist condition to the RCC. Application of this moisture must be done in a manner that will not wash out or damage the surface of the finished RCC pavement.

6.10.2 Curing Compound. The specified membrane curing compound shall be applied in two separate applications at right angles to one another, with the first coat being allowed to become tacky before the second is applied. This application must ensure a uniform void-free membrane across the entire RCC pavement. If the application rate is found to be excessive or insufficient, the Contractor, with approval of the Engineer, can decrease or increase the application rate to a level which achieves a void-free surface without ponding.

6.10.3 Sheet Materials. Curing paper, plastic and other sheet materials for curing RCC shall conform to ASTM C 171. The coverings shall be held securely in place and weighted to maintain a close contact with the RCC surface throughout the entire curing period. The edges of adjoining sheets shall be overlapped and held in place with sand bags, planking, pressure adhesive tape, or other Engineer-approved method.

6.11 Traffic. The Contractor shall protect the RCC from vehicular traffic during the curing period. Completed portions of the RCC pavement may be opened to traffic after seven days or as approved by the Engineer.

6.12 Maintenance. The Contractor shall maintain the RCC pavement in good condition until all work is completed and accepted. Such maintenance shall be performed by the Contractor at his own expense.

7. Measurement and Payment

7.1 Measurement. The work described in this document will be measured (1) in square yards (square meters) of completed and accepted RCC pavement as determined by the specified lines, grades and cross sections shown on the Plans and (2) in cubic yards (cubic meters) or tons (metric tons) of mixed and hauled RCC material.

7.2 Payment.

7.2.1 The work described in this document will be paid for at the contract unit price per square yard (square meter) of completed and accepted RCC pavement. The price shall include placement, compaction, curing, inspection and testing assistance and all other incidental operations. Also payment shall be made at the contract unit price per cubic yard (cubic meter) or ton (metric tons) of mixed and hauled RCC material. The price shall include mixing, hauling and all material costs. Such payment shall constitute full reimbursement for all work necessary to complete the RCC pavement.

7.2.2 Test Section. If a test section is constructed, it will be paid for on a lump sum basis. Such payment shall constitute full reimbursement for all materials, labor, equipment, mobilization, demobilization, and all other incidentals necessary to construct the Test Section in accordance with Section 6.2.
Portland Cement Association (PCA) is a not-for-profit organization and provides this publication solely for the continuing education of qualified professionals. THIS PUBLICATION SHOULD ONLY BE USED BY QUALIFIED PROFESSIONALS who possess all required license(s), who are competent to evaluate the significance and limitations of the information provided herein, and who accept total responsibility for the application of this information. OTHER READERS SHOULD OBTAIN ASSISTANCE FROM A QUALIFIED PROFESSIONAL BEFORE PROCEEDING.

PCA and its members make no express or implied warranty in connection with this publication or any information contained herein. In particular, no warranty is made of merchantability or fitness for a particular purpose. PCA and its members disclaim any product liability (including without limitation any strict liability in tort) in connection with this publication or any information contained herein.
A History of Superior Performance for Heavy-Duty Pavements

Roller-Compacted Concrete (RCC) consists of an engineered mixture of dense-graded aggregates, cement and water. This zero-slump concrete mixture, when placed with an asphalt paver and compacted to high density, provides a high-strength, durable pavement structure. RCC uses no forms, requires no conventional finishing, and needs no dowels or reinforcing steel, making it an economical choice.

Since its first use in Canada in the 1970s, RCC has been used on pavement projects throughout North America. RCC provides superior performance under conditions of heavy wheel loads, extreme climates and difficult operating conditions. Typically, the construction of heavy-duty pavements with RCC has been focused in log handling yards, intermodal terminals, freight depots and other heavy duty applications. But the past 10 years has seen an increase in using RCC to create cost-effective pavements for many conventional highway and street applications.

RCC Solves Problems Associated with Flexible Pavements

Innovative engineers and contractors have found new ways to put RCC to use to combat the problems often encountered with flexible asphalt pavements. RCC provides a rigid pavement structure that does not rut and can stand up to the abuse of heavy vehicle traffic. Excellent smoothness can be achieved with RCC pavements through the use of high-density paving equipment, surface grinding, and/or the application of thin concrete or asphalt overlays. RCC construction is fast and is competitive on an initial cost basis with asphalt pavements. Over its lifetime, RCC will exhibit significantly lower maintenance costs.

Here are some examples of how engineers are using RCC to solve their flexible pavement problems:

www.cement.org/pavements
Low-Maintenance Road System

The General Motors Saturn automobile manufacturing facility in Spring Hill, Tenn., contains a significant road network and parking areas. In 1988, the Saturn Corporation was looking for a durable pavement that would require very little maintenance. The solution: the equivalent of 18 miles (29 km) of 24-foot (7.3 m)-wide pavement was constructed with RCC, varying in thickness between six inches (150 mm) (parking areas) and 10 inches (250 mm) (loading docks). Most areas of the road network and parking lots employ RCC as the finished surface. Pavement performance has been exceptional, with virtually no maintenance performed during the first 15 years of service, and no apparent need for maintenance in the near future.

Inlay Rehabilitation

The City of Fort McMurray, Alberta, Canada, selected RCC as a pavement structure for several problem areas on one of its heaviest-traveled thoroughfares. Trucks had caused severe rutting, creating continuous maintenance problems with the existing flexible pavement. Instead of replacing the rutted sections with new asphalt, RCC was used as a more durable option. The inlays, typically using 10 inches (250 mm) of RCC overlaid with a two-inch (50 mm) asphalt traveling surface, have performed well in the several years since they were constructed: the asphalt adheres to the RCC and the pavement surface remains smooth. Most importantly, the rutting problem is solved and no maintenance has been necessary.

Road Widening

In most areas of the U.S., pavement engineers are widening and upgrading roads. In many instances, the road is widened into ditches or other areas where soil and road foundation conditions are poor. The strength and speed of construction of RCC is particularly suited to road-widening applications. The material provides a stable foundation that can be surfaced with asphalt or concrete for highway traffic and provides a long, low-maintenance life. In urban areas, traffic usually can be placed on the RCC within hours after construction, providing an excellent benefit to traffic control plans.

Shoulder Reconstruction

Georgia Department of Transportation used RCC to reconstruct shoulders on I-285 (Atlanta Beltway). The existing asphalt shoulders were badly distressed and required reconstruction. The existing shoulder was milled out, and replaced with a 10-ft (3 m) wide and eight inch (200 mm) deep section of RCC. Rumble strips were ground into the surface to conform with interstate highway safety requirements. The project included 34-shoulder miles (55 km) of RCC (Northbound and southbound outside shoulders were replaced for 17 centerline miles (27.5 km)). No surfacing was placed on the RCC because the smoothness was adequate for shoulder speeds.

Fast-Track Intersections

Intersections experience particularly tough punishment from traffic because of the stresses caused by turning movements and vehicle acceleration/deceleration. Rehabilitating busy intersections while causing only minimal interference with traffic operations is a common challenge for transportation engineers. RCC can help speed the process.

In 1994 the City of Calgary, Alberta, Canada, constructed a fast-track intersection with RCC. The asphalt had rutted and shoved, and maintenance was a continual headache. After rush hour on a Friday evening, the existing asphalt was milled out, and workers replaced the failed pavement with six-inch (150 mm) RCC inlays. (Traffic was maintained through the intersection with construction work zones.) A two-inch (50 mm) asphalt overlay, placed shortly after the RCC, sealed in the moisture, and by early Monday morning, the entire intersection was open to traffic. The superior stability of the RCC mix, as well as the protection provided by an asphalt surface during the RCC’s strength gain, allowed traffic to return to some pavement areas only eight hours old.

Industrial Access Roads

The Tennessee Department of Transportation (TDOT) regularly makes effective use of RCC for industrial access roads. TDOT maintenance personnel are called on to build roads for new industrial parks.
constructed in cooperation with local governments; these roads must offer economical construction and provide strength to withstand the heavy equipment and truck loads found in industrial areas. TDOT tried using asphalt roads, but local authorities soon faced high maintenance costs from asphalt failure. Pavement engineers have since found that RCC pavements, both surfaced and unsurfaced, cost less to install than asphalt pavements and offer far greater strength and durability.

**Residential and City Streets**

Many new residential developments use thin asphalt surfaces with aggregate base courses for their pavements, a construction method that doesn’t offer optimal support for high traffic loads generated during construction. Developers are faced with two poor choices: build the entire road prior to constructing homes, or build only the road base, saving the asphalt surface until construction is finished.

The first choice provides good construction access, but often leaves a worn-out, high maintenance road for the new residents. The second choice eventually provides residents with a new surface, but during construction, the aggregate base course must be continually graded and watered to allow proper vehicle access and dust reduction. Inclement weather often causes work slowdowns or stoppages due to wet, rutted base course material.

A third option—using RCC to construct new residential roadways—solves these problems. RCC is placed during initial site-work to serve as a working pavement and surface. Once construction is complete, a thin (one-and-a-half- to two-inch) (40-50 mm) asphalt overlay is applied, and the residents have a new, low maintenance road.

When constructing residential streets, city officials often are concerned about possible inconvenience to local residents. Pavement engineers can allay those concerns by using RCC, which allows traffic to be restored quickly. In Columbus, Ohio, several reconstruction projects in residential areas have taken advantage of RCC’s speed of construction. For these projects, the old pavement was removed, new curb and gutter installed, and an RCC base was constructed—with residents driving on the surface as soon as it was rolled to the proper density.

The City of Columbus also selected RCC pavement for reconstruction of Lane Avenue, a major arterial near the Ohio State University campus which handles over 30,000 ADT. The existing pavement was seriously distressed, and RCC was chosen because of the city’s excellent experience with RCC streets in residential areas.

The reconstructed Lane Avenue pavement consists of eight inches (200 mm) of RCC, surfaced with three inches (75 mm) of asphalt to provide smoothness for the higher speed traffic. The RCC construction was done under traffic for this four to six-lane arterial street. In some cases, traffic was placed on the RCC pavement within 24 hours after construction in order to accommodate nearby businesses.
Roller-compacted concrete has been used successfully unsurfaced. The City of Alliance, Neb., used RCC for the construction of collector streets in a residential subdivision. The RCC pavement was built to smoothness specifications that eliminated the need for an asphalt surface, and saw cuts were constructed every 27 feet (8.2 m) to enhance pavement aesthetics. This pavement has performed well for 11 years with no faulting or surface distress.

### Long-Term Performance

A study by the Portland Cement Association of RCC pavements built over the past 25 years found that the material’s long-term durability and performance is exceptional. In particular, cracks that formed shortly after construction were not found to deteriorate significantly over time, and faulting (vertical displacement along cracks or joints) was virtually nonexistent. Also, even though RCC is not air-entrained, the pavements surveyed did not show signs of deterioration due to freezing and thawing.

With excellent long-term performance, an initial construction price comparable to that of asphalt, and versatility for use in many applications, RCC pavements offer unmatched value.


### More Information

PCA offers a broad range of resources on roller-compacted concrete and soil-cement applications for pavements. Visit our Web site at [www.cement.org/pavements](http://www.cement.org/pavements) for design and construction guidelines, technical support, and research on RCC and soil-cement including cement-modified soils, cement-treated base, and full-depth reclamation.

For local support, tap into the cement industry’s network of regional groups covering the United States. Contact information is available at [www.cement.org/local](http://www.cement.org/local).

---

Unsurfaced RCC street in Alliance, NB shows little sign of wear 11 years after construction.

A smooth, durable RCC pavement can be achieved that will provide excellent performance for many years.

A key to long term performance is adequate curing. Water or concrete curing compounds are typically used.
Introduction

Definition
Roller-Compacted Concrete (RCC) takes its name from the method used to construct it. RCC refers to a stiff, zero-slump concrete mixture that is placed (typically with asphalt-type paving equipment) and then compacted with rollers.

Background
Like conventional ready mixed concrete, RCC has the same basic ingredients of cement, fine and coarse aggregates, and water. However, unlike conventional concrete, RCC is a drier material that has the consistency and feel of damp gravel. It is this low water-cement ratio and use of dense graded aggregates that gives RCC its high-strength properties, making it an ideal paving material for applications ranging from intermodal facilities and trucking terminals to parking lots, city streets, and intersections.

The main benefit of using RCC is the cost savings that result from its method of production and from its ease and speed of construction. RCC pavements do not require joints, dowels, reinforcing steel, formwork, or finishing, and are virtually maintenance-free.

Properties of RCC Mixes
The procedures for batching RCC mixes differ from those used for batching conventional concrete, due primarily to the stiff consistency of RCC and its use of densely-graded aggregate blends. The main differences in the proportioning of RCC pavement mixes as compared to conventional concrete are as follows:

- RCC has a lower water content
- RCC has a lower paste content
- RCC does not typically incorporate fibers
- RCC is not typically air-entrained, although some admixtures may be used
- RCC has a larger fine aggregate content
- RCC has a smaller maximum aggregate size

RCC must be dry enough to support the weight of a large compaction roller, yet wet enough to allow for an even distribution of the paste throughout the mix during production and placement operations.

Materials

General
The correct selection of materials is important to the production of quality RCC mixes. This knowledge of the ingredients is coupled with the construction requirements and specifications for the intended project in order to ensure an RCC mix that meets the design and performance objectives.

Aggregates
RCC uses aggregate sizes similar to those found in conventional concrete. In fact, cleaned, washed aggregates are not required for RCC, since the presence of a small quantity of non-plastic fines (2% to 8% material passing the No. 200 (75 µm) sieve) can enhance the properties of RCC. However, the blending of aggregates will be different than what the producer is used to with conventional concrete.

Table 1—PCA Recommended Gradation for RCC Mixes

<table>
<thead>
<tr>
<th>Sieve Size</th>
<th>Percent Passing by Weight Minimum</th>
<th>Percent Passing by Weight Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-in (25 mm)</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>3/4-in. (19 mm)</td>
<td>90</td>
<td>100</td>
</tr>
<tr>
<td>1/2-in. (12.5 mm)</td>
<td>70</td>
<td>90</td>
</tr>
<tr>
<td>3/8-in. (9.5 mm)</td>
<td>60</td>
<td>85</td>
</tr>
<tr>
<td>No. 4 (4.75 mm)</td>
<td>40</td>
<td>60</td>
</tr>
<tr>
<td>No. 16 (1.18 mm)</td>
<td>20</td>
<td>40</td>
</tr>
<tr>
<td>No. 100 (150 µm)</td>
<td>6</td>
<td>18</td>
</tr>
<tr>
<td>No. 200 (75 µm)</td>
<td>2</td>
<td>8</td>
</tr>
</tbody>
</table>
Coarse aggregates consist of crushed or uncrushed gravel, crushed stone, or even crushed recycled concrete while the fine aggregates consist of natural sand, manufactured sand, or a combination of the two. Crushed aggregates typically work better in RCC mixes due to the sharp interlocking edges of the particles, which help to reduce segregation, provide higher strengths, and provide better aggregate interlock at joints. Because up to 90% of the volume of a high-quality RCC mix can be comprised of coarse and fine aggregates, their durability should be evaluated through standard physical property testing such as those outlined in American Society for Testing and Materials (ASTM) C 33 or Canadian Standards Association (CSA) A23.1.

The American Concrete Institute (ACI) has established aggregate gradation limits that produce quality RCC pavement mixtures. A detailed discussion on the selection and performance of aggregate blends in RCC pavement mixes may be found in ACI 325.10R, State-of-the-Art Report on Roller-Compacted Concrete Pavements. These ACI gradation limits effectively allow the use of blends of standard size coarse aggregate. From ASTM C 33, the most common sizes used include No. 67, No. 7, No. 8, and No. 89.

ACI and the Portland Cement Association (PCA) recommend the use of dense, well-graded blends with a nominal maximum size aggregate not to exceed 1-inch (25 mm) in order to help minimize segregation and produce a smooth finished surface. Gap-graded mixes that are dominated by two or three aggregate sizes are not desirable for RCC. Additionally, the recommended gradation calls for a content of fine particles (2% to 8% passing the No. 200 (75 μm) sieve) that is typically higher than that of conventional concrete. This eliminates the need for washed aggregates in many cases and produces a mix that is stable during rolling.

In cases where washed aggregates are being used, it may be difficult to meet the specification for 2% to 8% fine particles. In cases like this, fly ash can be added to the mix to provide the desired fines content. These fines provide lubrication that helps to distribute the paste throughout the mix. However, these fines need to be non-plastic, with their plasticity index not to exceed four.

In many cases, aggregates used in typical highway construction will also meet the RCC gradation requirements mentioned above. Graded aggregate base material, crusher run material, and aggregates for hot-mix asphalt paving mixes can be used with little or no modification in RCC mixes.

Cementitious Materials
The cementitious materials including cement and pozzolan used in RCC mixes include Type I, Type IP, or Type II portland cement (ASTM C 150) or blended hydraulic cement (ASTM C 595), Class F or Class C fly ash (ASTM C 618), silica fume (ASTM C 1240), and ground granulated blast furnace slag (ASTM C 989, or CSA A3001 for all cementitious materials). The selection of the proper type and amount of cementitious materials should be based on their availability as well as the required design strength and durability of the finished RCC.

The total amount of cementitious material consisting of cement and pozzolan - often abbreviated as (C + P) - for an RCC mix is typically between 400 and 600 pounds per cubic yard (240 and 360 kilograms per cubic meter) in a wide range of proportions of these materials.

Admixtures
Chemical admixtures used in RCC mixes should conform to ASTM C 494 and should be approved by the Project Engineer prior to use. The addition of water-reducing or set-retarding (hydration-stabilizing) admixtures can delay the setting time of the cementitious materials and may be useful when there is a long haul time between the point of production and the project location. Water reducers have been successfully used with RCC to help distribute the cement paste uniformly throughout the mix and to improve workability during paving. Polycarboxylate superplasticizers have been used in dry batch plant production to improve workability and reduce mixing times, resulting in significantly increased production rates. However, a pavement test section must be constructed to verify the proper admixture to use for a particular mix.

Set-accelerating admixtures can also be used if the intent is to speed the setting time of the RCC, such as when opening a project early to traffic. Because of the dry nature of RCC and the difficulty of getting uniform distribution, fibers are typically not used. Additionally, air-entraining admixtures have not been used extensively in RCC, since acceptable freeze/thaw durability can be achieved without air entrainment. Entraining air at the mixing plant has also been found to be difficult. Whenever any admixtures are being considered, extensive laboratory and field testing should be conducted to determine the effectiveness and proper dosage rates.

Water
While the quantity of mixing water is considerably reduced for RCC, its quality should meet the same requirements as for conventional concrete mixes. The quantity of water is typically between 150 and 200 pounds per cubic yard (90 and 120 kilograms per cubic meter). Water to total cementitious ratios - expressed as W/(C + P) - for RCC pavement mixes generally fall between 0.30 and 0.45. W/(C + P) ratios in this range have the greatest positive influence on the final strength of the RCC, with 28-day unconfined compressive strengths typically exceeding 6,000 psi (41 MPa).

Mix Design

General
Just as in material selection, the correct proportioning of the raw materials is critical to the production of quality RCC mixes. The mix design process should not be approached as one of trial and error, but rather a systematic procedure based on the aggregates, water, and cementitious materials used in the mix.

Several methods currently exist for proportioning RCC mixes for pavements; however, there is not one commonly accepted method. The main RCC proportioning methods include those based on
remaining voids after the aggregates have reached their maximum optimal mix should have just enough paste to completely fill any workability requirements. It is based on the assumption that an optimal mix should have just enough paste to coat the aggregates in the mix and to fill in the voids between them.

Proportioning by Use of Concrete Consistency Tests
Proportioning methods that use concrete consistency tests normally require the establishment of specific mixture parameters—such as the amount of aggregate, the amount of water, or the amount of cementitious materials—and then adjust one of these parameters in order to meet a required level of consistency, workability, or strength. By following this method, each ingredient in the mixture can be optimized in order to obtain the desired fresh and hardened RCC properties.

In order to determine the sufficient minimal paste volume, a series of trial mortar mixtures with varying water/binder and sand/cementitious ratios is prepared and cast, measuring the density of each mixture. For an established water/binder ratio, a certain sand/cementitious ratio will result in the optimum mixture density. This water/binder ratio is selected to meet the required design strength. After determining these water/binder and sand/cementitious ratios, the coarse and fine aggregate proportions are adjusted in order to achieve a certain workability.

Proportioning by Use of the Solid Suspension Model
In recent years, a more theoretical and fundamental approach to RCC mix design proportioning has been introduced, called the solid suspension model. This proportioning method is used to determine the proportions of each of the dry solid ingredients (cement, fly ash, silica fume, sand, and coarse aggregate) that optimize the dry packing density of a given RCC mixture. Using this optimized dry packing density, the amount of water necessary to entirely fill the void spaces between the dry ingredients can then be easily calculated.

By knowing certain material characteristics such as gradation, specific gravity, and void content for each of the dry solid ingredients, reliable computer simulations can be run using this model. In fact, the systematic use of this proportioning method has yielded results very similar to those obtained using the concrete consistency tests mentioned earlier. The main advantage of the solid suspension model is that it can be used to recalculate very quickly the optimum proportions of an RCC mixture without having to prepare a large number of laboratory trial batches.

Proportioning by Use of the Optimal Paste Volume Method
Originally developed to prepare RCC mixes for dams and other large structures, the optimal paste volume method has lately been used for the proportioning of non-air-entrained RCC pavement mixes as well. Because the workability of an RCC mix is one of its main requirements, this method stresses a mix design that will meet specified workability requirements. It is based on the assumption that an optimal mix should have just enough paste to completely fill any remaining voids after the aggregates have reached their maximum density under compaction.

The optimal paste volume method has three major steps. The first step is to select an aggregate gradation that contains a minimal volume of voids for a given compaction energy. In the second step, the volume of remaining voids is used to adjust the volumetric dosage of paste in order to obtain the required workability. The third and final step involves the selection of the W/(C + P) ratio and the proportions of cement and any other cementitious materials that will produce a paste with enough binding capacity to satisfy the strength requirements of the project.

Proportioning by Use of Soil Compaction Tests
This proportioning method involves establishing a relationship between the density and moisture content of an RCC mix by compacting samples over a range of moisture contents as described in the section of this document titled Moisture-Density Relationship. Moisture-density tests are conducted and moisture-density curves are established over a range of cementitious material contents. Strength test specimens are then prepared by compacting specimens at the optimum moisture content for each particular cementitious material content. From these tests, a plot of strength versus cementitious material content is established to select the minimum cementitious materials content that will meet the design requirements.

Moisture-Density Relationship
A moisture-density test is used to determine the optimum moisture content and maximum density of RCC mixtures. The modified Proctor compaction test (ASTM D 1557) is a common and familiar procedure for most geotechnical and materials testing laboratories to perform. Figure 1 shows a typical compaction curve from the modified Proctor test. If the mix is too dry, there is not enough moisture available to lubricate the particles into a denser formation. If the mix is too wet, the excess moisture pushes the particles apart. The moisture content at which maximum density is achieved should be selected for mix design and field quality control.

For a given project, the objective of the moisture-density testing is to establish a maximum unit weight of the RCC mix which will be used as the target density to which the mix must be compacted. The optimum moisture content will facilitate compaction and provide the best opportunity to achieve maximum compaction and density. Since density is an important factor in the strength and durability of RCC, required minimum density levels are always included in project specifications.

Usually the requirement is a minimum of 98% of the maximum total density. Because the moisture content in the field will typically not vary much from optimum, most specifications will indicate required density in terms of wet or total density.

The most commonly used method to determine density in the field is through the use of a nuclear density gauge. This device measures both the wet density and the moisture content of RCC. However, the moisture measurements made from nuclear gauges can be affected by cement hydration, and should be verified with other methods of determining water content. This effect on moisture content measurements is one reason most RCC construction specifications reference
wet density instead of dry density. Moisture content determination constitutes an important part of RCC quality control because the information is used in evaluating the compaction efficiency and material behaviors; therefore, accurate moisture measurement is critical.

Proportioning by use of soil compaction testing is the most commonly used method of mix design and is further explained in detail in the sections following.

**Aggregates.** With fine and coarse aggregates comprising up to 90 percent of the volume of an RCC pavement mix, the first step is to properly choose the aggregates that will be used. The dense, well-graded aggregates incorporated in an RCC mix are selected based upon the recommended aggregate gradation specifications previously mentioned.

**Water.** The second step is to select the proper water (moisture) content for the RCC mix. Unlike conventional concrete, the W/(C + P) ratio is not used as the primary design objective. It is important to remember that water content is based on the maximum compaction density of the RCC mix and the construction requirements of the project. Water content is also dependent on the use of chemical admixtures.

The water content ($w$) is usually expressed as a percentage (by weight) of the total solids in the mix:

$$\text{water content, } w (\%) = \frac{\text{weight of water in mix}}{\text{weight of oven-dry aggregates + cementitious material}} \times 100$$

For quality control purposes, it is important that the producer monitor the moisture of aggregates in bins and stockpiles. The amount of water added at the plant will depend upon the amount of moisture (above oven-dry) already in the aggregate stockpiles. (Note that the moisture content is based on oven-dry aggregates and not saturated surface dry aggregates, which are typically referenced in conventional concrete.) Water should be adjusted accordingly at the plant so that the moisture conditions of the aggregate accurately meet the water requirements of the RCC mix.

**Cementitious Materials.**
The third and final step is to select the proper amounts of cementitious materials to be incorporated into the RCC mix. Prepared samples (cylinders) are cast and tested for compression (ASTM C 39) and splitting tensile strength (ASTM C 496, or CSA A23.2 for both) in accordance with the project specifications. Specifications relating to flexural strength (or modulus of rupture) are usually converted to equivalent estimates based on compressive strength.

Cementitious content ($c + p$) may occasionally be expressed in terms of percentage of the mixture rather than in pounds per cubic yard ($\text{kg/m}^3$). When this is the case, the percent of cementitious material (by weight) is based on the total solids in the mixture and is determined as follows:

$$\text{cementitious content, } c + p (\%) = \frac{\text{weight of cementitious material in mix}}{\text{weight of oven-dry aggregates + cementitious material}} \times 100$$

---

**Figure 1—Typical Moisture-Density Curve for RCC Mixes.**

**Figure 2—Moisture Conditions of Aggregate.**
Cylinder Preparation
Because RCC is very stiff, dry-rodding of concrete cylinders provides inadequate consolidation; therefore, RCC cylinders are prepared using either the modified Proctor procedure (ASTM D 1557) or the vibratory hammer method (ASTM C 1435).

Production

Mixing Equipment
RCC can be produced in any type of equipment that will provide uniform mixing of the cement, aggregates, and water. Obviously, the size and nature of the project will dictate which production method to use.

- **Transit Mixers**—While transit mixers (either standard or front-discharge) are capable of producing a quality product and providing more local availability of RCC, their slower mixing and discharge times are tailored for production on a smaller scale.

- **Tilt Drum Mixers**—By far the most common central mixing unit, tilt drum mixers (either portable or permanent) have regional availability coupled with fast, quality-consistent production capabilities, making them suitable for most RCC projects.

- **Mobile Truck Mixers**—Versatility and speed are advantages of mobile truck mixers since all components—aggregates, cement, and water—are stored in separate compartments on the truck unit.
• **Horizontal Shaft Mixers**—Whether single-shaft or dual-shaft, portable or permanent, continuous flow (as in a pugmill) or compulsory batch, spiral ribbon or paddle, horizontal shaft mixers provide the most intense and fastest mixing action, making them the best choice for larger and high production-oriented projects.

**Batching and Mixing**

The required mixing time for RCC will depend on a number of factors including the size of the batch, the gradation of the mix, the W/(C + P) ratio, and the type of mixing equipment employed. Because of the very dry consistency of RCC, the batch volume of mixed material for transit and tilt drum mixers is oftentimes less than the manufacturer’s rated capacity of the mixer for conventional concrete. Sample mixing times and maximum batch sizes for five types of mixing units are summarized in Table 2.

For larger RCC paving projects, the horizontal shaft mixers are most commonly used because they are easily transported and erected at the job site, can produce a relatively large amount of material, and provide excellent mixing efficiency. For smaller projects, tilt drum mixers, transit mixers, and mobile truck mixers are sufficient. The central mix plant that produces the RCC mix should be located as near to the paving project as possible in order to minimize haul time.

Whichever mixing method is employed, it is imperative that RCC be mixed vigorously in order to evenly distribute the small amount of water present in the mix. Because of its zero-slump and low paste content, the key to producing a strong, durable RCC mix rests in the careful proportioning and vigorous mixing of all the ingredients.

Successfully proportioned and mixed RCC looks and feels like damp gravel. Proper moisture content is critical to achieve adequate compaction and long-term performance. Acceptable moisture contents can vary within a narrow range of plus or minus 1/2 percent. To monitor the moisture content at the plant, samples of the mixed RCC should be tested as part of routine quality control.

**Table 2—Recommended Mixing Times and Batch Sizes for RCC.**

<table>
<thead>
<tr>
<th>Mixer Type</th>
<th>Mixing Time</th>
<th>Batch Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transit</td>
<td>4 to 5 minutes *</td>
<td>70% to 100% of drum capacity</td>
</tr>
<tr>
<td>Tilt Drum</td>
<td>2 to 4 minutes</td>
<td>70% to 100% of drum capacity</td>
</tr>
<tr>
<td>Horizontal Compulsory</td>
<td>20 to 60 seconds</td>
<td>up to 12 yd$^3$ (9.2 m$^3$)</td>
</tr>
<tr>
<td>Mobile Truck Mixer</td>
<td>Continuous</td>
<td>12 yd$^3$ (9.2 m$^3$) capacity; variable production up to 75 yd$^3$ (57 m$^3$) per hour</td>
</tr>
<tr>
<td>Horizontal Continuous Flow</td>
<td>Continuous</td>
<td>up to 250 yd$^3$/hr (190 m$^3$/hr)</td>
</tr>
</tbody>
</table>

* assuming a mixing speed of 20 revolutions per minute
Production Levels
The construction sequences from production to compaction must be coordinated so that there is a continuous operation with no delays in any of the construction phases. Mixing, transporting, placing, and compaction must be planned accordingly. It is extremely important that the rate of RCC production at the plant be able to keep up with the speed of construction at the site, as a continuous supply of fresh RCC material to the pavement placement machinery is necessary in order to produce a quality product. If production does not keep pace with construction, the stopping and starting actions of the paving machinery can potentially result in problems with segregation of material, surface undulations, inadequate compaction, and poor final ride quality.

As an example, consider the rate of plant production that would be necessary in order to keep up with the following field paving operations:

- pavement width = 20 feet (6.1 m)
- pavement thickness = 8 inches (200 mm)
- unit weight of RCC material = 150 pounds per cubic foot (2400 kg per cu m)
- speed of paving operations = 4 feet (1.2 m) per minute

\[
\text{Rate of production} = (20 \text{ ft})(8 \text{ in})(150 \text{ pcf})(4 \text{ fpm})(60 \text{ min}) = 480,000 \text{ pounds (218,000 kg) per hour} = 240 \text{ tons (218 metric tons) per hour (or 120 cu yd (92 cu m) per hour)}
\]

Using this example, the rate of RCC production at the plant would have to be at least 120 cubic yards (92 cubic meters) per hour in order to keep the paving equipment in the field moving at a constant speed.

Transportation
General
Regardless of the mixing and batching method chosen, the RCC mix is almost always transported to the job site in dump trucks. These dump trucks should be equipped with covers in order to protect the RCC mix from the elements and to ensure efficient placement. While RCC can be produced directly into dump trucks from tilt drum and horizontal shaft mixers, the use of transit mixers involves the additional step of discharging into a dump truck for delivery. Because of the very dry consistency of RCC, the use of fluidizing admixtures is recommended when mixing or hauling RCC in transit mixers.

References

Bibliography
Further Help
For assistance with your RCC project, visit the PCA web site at www.cement.org/rcc. Also, the following useful publications can be ordered through the web site or by calling PCA Publications at 800.868.6733.

The Right Choice for Tough Duty (PL397)
Roller-Compacted Concrete Pavements—A Study of Long Term Performance (RP366)
Structural Design of Roller-Compacted Concrete for Industrial Pavements (IS233)
RCPPave (Computer Program Software for Thickness Design of Roller-Compacted Concrete Pavement) (MC043)
The Right Choice for Tough Duty (Video on mini-CD, CD034) (Video in VHS Format, VC396)
Frost Durability of Roller-Compacted Concrete Pavements (RD135)
Guide Specification for Construction of Roller-Compacted Concrete Pavements (IS009)
Roller-Compacted Concrete Density: Principles and Practices (IS541)
Frost Durability of Roller-Compacted Concrete Pavements: Research Synopsis (IS692)

Portland Cement Association ("PCA") is a not-for-profit organization and provides this publication solely for the continuing education of qualified professionals. THIS PUBLICATION SHOULD ONLY BE USED BY QUALIFIED PROFESSIONALS who possess all required license(s), who are competent to evaluate the significance and limitations of the information provided herein, and who accept total responsibility for the application of this information. OTHER READERS SHOULD OBTAIN ASSISTANCE FROM A QUALIFIED PROFESSIONAL BEFORE PROCEEDING.

PCA AND ITS MEMBERS MAKE NO EXPRESS OR IMPLIED WARRANTY WITH RESPECT TO THIS PUBLICATION OR ANY INFORMATION CONTAINED HEREIN. IN PARTICULAR, NO WARRANTY IS MADE OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE. PCA AND ITS MEMBERS DISCLAIM ANY PRODUCT LIABILITY (INCLUDING WITHOUT LIMITATION ANY STRICT LIABILITY IN TORT) IN CONNECTION WITH THIS PUBLICATION OR ANY INFORMATION CONTAINED HEREIN.
CITY OF COLUMBUS
PUBLIC SERVICE DEPARTMENT
TRANSPORTATION DIVISION

SUPPLEMENTAL SPECIFICATION 1523
ROLLER COMPACTED CONCRETE PAVEMENTS (RCC)

APRIL 15, 2006

1523.01 Description
1523.02 Materials Requirements
1523.03 Mix Design
1523.04 Equipment
1523.05 Placing RCC
1523.06 Compaction and Finishing
1523.07 Small Areas
1523.08 Joints
1523.09 Curing
1523.10 Tolerances
1523.11 Quality Assurance and Control
1523.12 Defective RCC
1523.13 Asphalt Surfacing / Opening to Traffic
1523.14 Warranty
1523.15 Basis of Payment
1523.01 Description

This Supplement outlines the requirements for production and construction of Roller Compacted Concrete (R.C.C.) pavement for City streets. In addition to this supplement, items 305, 306, 401, 407, 451, and 700 of the City of Columbus Construction and Material Specifications (CMSC) apply where applicable.

1523.02 Materials Requirements

All materials to be used shall be from approved sources as documented on the “Approved Materials List” on file in the City’s testing laboratory.


Fly Ash: Fly Ash shall conform to ASTM C 618 Class F and section 705.13 of the CMSC.

Aggregates: Fine and course aggregates shall meet the requirements of section 703.02 of the CMSC for Portland Cement Concrete, item 305 and 306. The aggregates shall be well graded to conform to the following composite gradation.

<table>
<thead>
<tr>
<th>Sieve Size</th>
<th>Percent Passing</th>
</tr>
</thead>
<tbody>
<tr>
<td>1&quot;</td>
<td>100</td>
</tr>
<tr>
<td>3/4&quot;</td>
<td>90 – 100</td>
</tr>
<tr>
<td>1/2&quot;</td>
<td>70 – 90</td>
</tr>
<tr>
<td>3/8&quot;</td>
<td>60 - 85</td>
</tr>
<tr>
<td>#4</td>
<td>40 – 70</td>
</tr>
<tr>
<td>#16</td>
<td>20 – 40</td>
</tr>
<tr>
<td>#100</td>
<td>5 – 20</td>
</tr>
<tr>
<td>#200</td>
<td>2 - 8</td>
</tr>
</tbody>
</table>

Water: Clean, potable and free from oil, acid, and strong alkalies or organic materials.

Admixtures (other than fly ash): Meet applicable ASTM standards.

1523.03 Mix Design

The Contractor/Supplier shall develop an R.C.C. mixture proportioned in accordance with this specification and procedures discussed in ACI 325.10R-95 “State-of-the-Art Report on Roller-Compacted Concrete Pavements” sections 4.2 and 4.3. Once the mix has been designed, certified test data shall be submitted in accordance with Section
101.10 of the CMSC from a recognized testing laboratory that shows the proposed mix design will meet the following requirements.

- **Compressive Strength, Cylinders:** 3500 psi @ 28 days
- **Flexural Strength, Beams:** 500 psi @ 14 days
- **Splitting Tensile Strength, Cores:** 400 psi @ 14 days

The minimum Cementitious Material shall be 350 pounds per C.Y.

Fly Ash may only be used between April 1 and November 1 unless otherwise authorized by the Project Engineer.

### 1523.04 Equipment

**Mixing Plants:** Mixing plants shall be of a design that can produce an R.C.C. pavement mixture of the proportions defined in the approved mix design and within the specified tolerances in ASTM C 94 and ASTM C 685. The mixing plant may be a Central-Mix Drum or a Stationary Continuous-Mixing Twin-Shaft Pugmill mixer. The plant shall have a minimum manufacturer’s rated capacity of 200 tons per hour.

**Paver:** RCC shall be placed with a high-density or conventional asphalt type paver subject to approval by the Engineer. The paver shall be capable of placing RCC to a minimum of 85% of the maximum wet density in accordance with ASTM D 1557 or equivalent test method. The paver shall be 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.

**Alternative Paving Equipment.** In areas not accessible to paving machines, alternative paving equipment including graders and dozers may be used, if approved by the Engineer. The equipment shall be capable of producing a finished product that results in a smooth, continuous surface without segregation, excessive tearing, or rock pockets. Work in areas inaccessible to paving machines will be performed according to 1523.07 of these specifications.

**Pneumatic Rollers:** Pneumatic rollers shall be self-propelled, with overlapping tire positions capable of providing full compaction in a single pass. Static weight shall be no less than 10 tons, or more than 20 tons. Tire configuration shall be 5 front and 6 rear.

**Vibratory Rollers:** Vibratory rollers shall be self-propelled, double drum, steel wheel vibratory rollers having a static weight of at least 10 tons. Each roller drum shall be equipped with a properly operating scraper and brush. The rollers shall transmit a dynamic impact to the surface through smooth steel drums by means of revolving weights, eccentric shafts or other equivalent methods. The roller drum shall be between 4 and 5-1/2 foot in diameter and 5-1/2 to 8 feet in width.
Finish Rollers: Finish rollers shall be self-propelled, double drum, steel wheel rollers having a static weight of between 3 and 10 tons. Each drum shall be equipped with a properly operating scraper and brush. A single drum vibrator roller with a vulcanized rubber coating may be utilized for finish rolling, at the approval of the engineer.

Equipment for Vertical Cuts in R.C.C. Pavement: To cut vertical joints in fresh R.C.C. pavement, equipment such as a wheel cutter or other approved equipment capable of cutting vertically, the full depth of the layer, shall be used. If the Contractor waits until the R.C.C. hardens to make vertical cuts, concrete sawing equipment shall be used to make the vertical cuts.

1523.05 Placing RCC

Cold Weather Limitations: R.C.C. shall not be placed on any surface containing frost or frozen material. R.C.C. shall only be placed when the ambient temperature is a minimum of 35°F and rising, unless the procedures set forth in section 451.061 “Depositing and Curing Concrete During Cold Weather”, of the Construction and Material Specifications, are strictly adhered to. Conformance will be closely monitored and stringently enforced.

Hot Weather Precautions: During periods of hot weather or windy conditions, special precautions shall be taken to minimize moisture loss due to evaporation. Precautions may include cooling of aggregate stockpiles by the use of a water spray, protective covers on dump trucks, temporary windbreaks to reduce wind velocity, cooling of concrete mix water, decreasing the allowable time between mixing and final compaction, and keeping the surface of the newly placed R.C.C. pavement damp with a light spray during compaction and finishing operations.

Rain Limitations: No placement of R.C.C. pavement shall be done while it is raining hard enough to be detrimental to the finished product. Placement may continue during light rain or mist provided the surface of the R.C.C. pavement is not eroded or washed. Dump truck covers must be used during these periods. The Engineer will be the sole judge as to when placement must be stopped due to rain.

Subgrade Preparation: Prepare the subgrade according to Section 204 of the CMSC. If required, construct a granular base according to Section 304.

Moisten the surface of the subgrade or base without creating mud or ponding water, to minimize absorption of water from R.C.C. mix to be deposited.

Transporting: Transport the R.C.C. mixture to the site in dump trucks with boxes cleaned out before loading and provided with protective covers properly secured in place until discharge. The trucks shall dump directly into the hopper of the paver unless placement is by hand as directed by the Engineer. Hauling over the freshly placed R.C.C. will not be permitted.
Continuity: Co-ordinate R.C.C. delivery so the mix can be spread and rolled within the specified time limit and to ensure uniform progress of the paver until the paving operation is complete. The time between mixing, and compacting shall not exceed ninety (90) minutes, for all RCC placed, provided that the temperature of the RCC does not exceed 90 degrees (F). This time limit may be increased or decreased by the Engineer dependent upon ambient conditions of temperature and humidity.

Spreading: Spread the material to a sufficient depth that will produce the specified thickness when compacted and conform to the required cross-sections and grade. Operate the paver in a manner that will prevent segregation and will produce a smooth continuous surface without tearing, pulling or shoving. Placing of the R.C.C. mix shall be done in a pattern so that the water from previously placed R.C.C. will not affect the fresh surface or subgrade. Where required, broadcasting or fanning of R.C.C. must be performed immediately behind the paver. Any R.C.C. surface that has been compacted “rolled” but is not cured, must be scarified at least one inch deep prior to broadcasting fresh R.C.C. over the top. Broadcasting must be completed in the allotted time within these specifications.

Segregation: If segregation occurs, suspend the paving operation until the cause is determined and corrected. Rake off segregated coarse aggregate before rolling. Broadcasting or fanning of R.C.C. mixture onto areas being compacted is not permitted.

Placing Adjacent Lanes: All R.C.C. on both sides of the longitudinal joint formed by placing an adjacent lane, must be compacted within 90 minutes of plant mixing, unless a cold joint is provided.

**1523.06 Compaction and Finishing**

Required Density: The Contractor is responsible for achieving 98% of the maximum wet density, as determined in the laboratory according to ASTM D 1557.

Start of Rolling: Begin compaction operations within fifteen (15) minutes after spreading of the R.C.C. mix. Any additional delay will result in the coring of the affected area at the Contractors expense to ensure that it meets the requirements of this specification.

Rolling Pattern: Establish a rolling pattern that will achieve the required density with a minimum number of roller passes.

Vibratory Rolling: During vibratory compaction, the roller shall not be started, stopped, or left standing in vibratory mode. Stagger the stopping point of successive rolling passes to avoid forming depressions on the surface.
Surface Check: Continually check the R.C.C. surface while still plastic to ensure surface and grade tolerances are met. Immediately correct excessive variations in accordance with the spreading requirements.

Finish Rolling: Remove any roller marks on the surface using a steel drum roller in static mode.

Lane Edge: Each edge of each lane shall be constructed with a vertical or a 15-degree from vertical configuration.

1523.07 Small Areas

Spread RCC mix by hand in areas not accessible by the paver, as directed by the Engineer.

Compact the mix to the required density using suitable walk-behind vibratory compaction equipment. The vibratory equipment must have a minimum centrifugal force of 2,200 pounds and/or 70 pounds per square inch. Compaction of these areas must be performed immediately after placement of the R.C.C. in order to avoid moisture loss.

1523.08 Joints

Fresh Joint: A fresh joint is made when R.C.C. on both sides of the joint are compacted within 90 minutes of plant mixing. Ensure that the contact face is moist and not segregated. Before rolling, hand-finish the joint as necessary to produce a tight surface. Roll extra passes as necessary to achieve the required density and smoothness in the joint area.

Cold Joint: A cold joint is made when either side of the joint is not compacted within 90 minutes of plant mixing. Sawcut the edge of previous lane back to sound R.C.C. to form a vertical face. Trimming by grader blade may be permitted if done at the end of the workday or the first thing the following day. Place fresh grout on the vertical face just before placing fresh R.C.C. against it. Before rolling, hand-finish the joint as necessary to produce a tight surface. Roll extra passes as necessary to achieve the required density and smoothness in the joint area. Every effort shall be made to maintain longitudinal joints as a fresh joint as described in “Fresh Joint” above.

Transverse Joint: May be a Fresh Joint or Cold Joint as described above. They shall be spaced at a maximum of 30 foot intervals, or at intervals directed by the Engineer and cut to a depth 1/3 of the specified pavement thickness.

Longitudinal Joint: Leave the outer 12 to 18 in. of the paving lane uncompacted during the initial rolling operation. This uncompacted edge is then used to set the height of the paver screed for paving the adjacent lane. After the adjacent lane is placed, the
joint is compacted by centering the roller drum over the joint and compacting the adjacent lane edges simultaneously.

1523.09 Curing

R.C.C. without Asphalt Surfacing applied within 72 hours: Keep the R.C.C. surface continuously moist by water, fog spray, wet burlap, or an approved membrane-forming curing compound, or polyethylene sheeting for a period of 7 days. Apply curing compound at 1-1/2 times the rate specified by the manufacturer.

R.C.C. with Asphalt Surfacing applied within 72 hours: Immediately after final rolling, apply an asphalt emulsion per item 407 of the CMS. Apply at 1-1/2 times the rate specified by the manufacturer.

1523.10 Tolerances

R.C.C. pavement construction shall be subject to Section 451 of the CMSC.

1523.11 Quality Assurance and Control

Responsibility: Testing at the plant and the paving site is the responsibility of the Contractor or Developer and shall be performed by a private Independent Testing Laboratory approved by the City. The Contractor and Supplier shall provide safe and convenient access, acceptable to the Engineer, for the inspection and sampling of the R.C.C. and constituent materials, at both the production plant and the paving site, and shall cooperate in the inspection and sampling process at all times.

Test Strip: The contractor shall construct a test section of a thickness equal to the design thickness with at least 100 tons of R.C.C. The test strip will be used to resolve anticipated problems with equipment, mix behavior, compaction, and/or strength characteristics. The test strip shall be constructed at a location chosen by the contractor at least 30 days before the start of paving operations. The contractor shall cooperate fully with the Engineer during construction and testing of the test strip. During construction of the test section, the Contractor will establish an optimum rolling pattern and procedure for obtaining a density of not less than 98% of the maximum wet density in accordance with ASTM D 1557. In addition, the Contractor must also demonstrate the ability to achieve a smooth, hard, uniform surface free of excessive tears, ridges, spalls and loose material. After completion of the test section, beams and cores will be extracted to verify mix compliance. This will be performed by the Independent Testing Laboratory, at the expense of the Contractor. During the trial placement, the City's Testing Personnel shall calibrate their nuclear density gauges in accordance with ASTM C 1040, with a sample of the test section mix. Moisture readings of the gauge shall be calibrated using oven dry samples of the plant-mixed R.C.C. If all aspects of the test strip have been previously satisfied, the engineer may waive this requirement on a project-by-project basis.
**Pre-placement:** The Contractor shall ensure quality control at the plant, by controlling materials, obtaining test samples and ensuring segregation is not occurring while loading haul trucks.

The private Testing Laboratory will develop a moisture/density relationship of the actual job materials in accordance with ASTM D 1557. Optimum moisture content, maximum dry and wet densities will be established.

Compressive Strength Testing: During the mix design development, the Independent Testing Laboratory shall produce six (6" x 12") diameter cylinders, in accordance with ASTM C 1435, to perform a 28 day compressive strength test of the material to verify mix conformance. Handling and curing shall be in accordance with ASTM C 31. The Engineer may require additional tests at different ages. Compressive strength testing shall be in accordance with ASTM C 39.

**During Placement:** The Contractor, in cooperation with the Independent Testing Laboratory, shall ensure that compaction and grade specifications are met and time limits are adhered to.

Field Density: The City’s Testing Laboratory shall perform density testing of the R.C.C. in accordance with ASTM C 1040, direct transmission mode, as soon as possible, but no more than 30 minutes, after completion of rolling. Only wet density shall be used for evaluation. The required density shall be a minimum of 98% of the maximum wet density. At least 5 tests shall be performed for each 250 cubic yards placed. The Contractor shall be responsible for verifying required densities are achieved by the paver.

If density tests indicate that the material does not meet the required density, the Engineer, in collaboration with the Contractor and the City’s Testing Laboratory, shall determine the source of the problem, whether mix properties, segregation, or gauge calibration. If mix properties have changed, or the concerns cannot be resolved, placement shall be suspended until the problem is corrected.

**After Placement:** The City’s Testing Laboratory shall core at least nine (9) 3 1/2 inch diameter cylindrical specimens from the interior of the slab for compliance verification. Length measurements of the cores and compressive strength testing shall be in accordance with ASTM C 42. The actual number of cores will be determined as defined in section 451.16 of the CMSC. Testing will be conducted as follows:

Compressive Strength Testing: Three (3) of the cores obtained for thickness verification will be tested for compressive strength at 28 days.

Splitting Tensile Strength: Three (3) of the cores obtained for thickness verification will be tested for splitting tensile strength at 14 days.
Density Test: The three (3) core samples obtained for splitting tensile strength will also be tested for density PCF.

The remaining three cores will be held for backup testing and/or further review as necessary.

Flexural Strength Testing: At the option of the project Engineer, the Contractor/Independent Testing Laboratory shall cut at least three (3) rectangular beams from the interior of the slab, in accordance with ASTM C 42, to perform a 14 day flexural strength test of the material. Additional tests at different ages may be required by the Engineer.

1523.12 Defective RCC

Repairs: All repairs are subject to the Engineers approval. Correct deficiencies while R.C.C. is still plastic; otherwise do repairs after seven (7) days. After seven (7) days, the R.C.C. shall be removed by saw cutting full depth before removal. Replace the R.C.C. utilizing a Cast-in-Place concrete meeting the requirements of section 499; Class B or E Concrete as directed by project Engineer. The new concrete shall be doweled into the existing R.C.C. utilizing epoxy coated reinforcing bars unless the RCC option is utilized.

Remove and replace R.C.C. if determined deficient in thickness by following the procedure set forth in section 451.16 of CMSC.

Any R.C.C. pavement found to be of unacceptable thickness, or deficient in any testing done according to 1523.11, may be subject to removal and replacement by the contractor, at no cost to the City, including removal and replacement of any intermediate and surface asphalt courses.

Grind off high surface variations to a finish acceptable to the Engineer.

Filling of low areas with fresh R.C.C. is not permitted.

If asphalt surfacing is specified, low areas shall be made up with additional surfacing material without extra payment.

1523.13 Asphalt Surfacing / Opening to Traffic

The R.C.C. pavement may be asphalt surfaced as specified on the plans once the requirements of Section 1523.06 have been met and all transverse contraction joints have been constructed.

If the R.C.C. pavement is not to be asphalt surfaced immediately, all traffic shall be restricted from using the R.C.C. until seven (7) days has elapsed or all strength requirements of Section 1523.03 have been met. At any time prior to the expiration of
the above mentioned seven (7) day period, the R.C.C. may be asphalt surfaced as specified on the plans and then opened to traffic.

1523.14 Warranty

Pavement constructed according to this specification shall be guaranteed by the developer/owner for a period not less than two (2) years from date of acceptance of the street by the City Engineer.

1523.15 Basis of Payment

The accepted quantities of R.C.C. pavement will be paid for at the contract unit price per square yard (square meter), which price and payment shall be full compensation for furnishing and placing all materials including reinforcing steel, dowels, and joint materials.

No additional payment over the unit contract bid price will be made for any pavement which has an average thickness in excess of that shown on the plans.

Payment for accepted quantities, complete in place, will be paid for at the contract price for item Supplemental Specification 1523.

<table>
<thead>
<tr>
<th>Item</th>
<th>Unit</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1523</td>
<td>Square Yard</td>
<td>Roller Compacted Concrete</td>
</tr>
<tr>
<td></td>
<td>(Square Meter)</td>
<td></td>
</tr>
</tbody>
</table>
ROLLER COMPACTED CONCRETE

1 General Provisions
1.1 Description. Roller Compacted Concrete (RCC) shall consist of aggregate, Portland cement, possibly other supplementary cementing materials (fly ash, slag and silica fume) and water. RCC shall be proportioned, mixed, placed, compacted and cured in accordance with these specifications; and conform to the lines, grades, thickness, and typical cross sections shown in the Plans or otherwise established by the Engineer.

2 Referenced Documents
2.1 American Society for Testing and Materials (ASTM): C 31, C 39, C 42, C 78, C 150, C 171, C 309, C 494, C 496, C 595, C 618, C 989, C 1040, C 1157, C 1176, C 1240, C 1435, D 977, D 1557

3 Submittals
3.1 Submittal Requirements. The Contractor shall submit the following to the Engineer at least 30 days before start of any production of RCC pavement.

3.1.1 Construction Schedule for all RCC related operations.

3.1.2 Paving procedures describing direction of paving operations, paving widths, planned longitudinal and transverse cold joints, and curing methods and patterns.

3.1.3 Proposed RCC Mix Design. If the proposed mix design is developed by the Contractor or there is a suggested change to the mix design, it must be submitted to the Engineer for approval at least four weeks prior to RCC construction. This mix design shall include details on aggregate gradation, cementitious materials, admixtures (if used), compressive and/or flexural strengths, and required moisture and density to be achieved.

4 Materials
4.1 General. All materials to be used for RCC pavement construction shall be approved by the Engineer based on laboratory tests or certifications of representative materials which will be used in the actual construction.

4.2 Portland Cement. Cement shall comply with the latest specifications for Portland cement (ASTM C 150 and ASTM C 1157), or blended hydraulic cements (ASTM C 595 and ASTM C 1157).

4.3 Aggregates. Unless otherwise approved in writing by the Engineer, the quality of aggregates shall conform to ASTM C 33. The plasticity index of the aggregates shall not exceed five. Aggregates may be obtained from a single source or borrow pit, or may be a blend of coarse and fine aggregate. The aggregate shall be well-graded without gradation gaps and conform to the following gradation:

<table>
<thead>
<tr>
<th>Sieve Size</th>
<th>Percent Passing by Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>1” (25 mm)</td>
<td>100</td>
</tr>
<tr>
<td>¾” (19 mm)</td>
<td>90-100</td>
</tr>
<tr>
<td>⅝” (12.5 mm)</td>
<td>70-90</td>
</tr>
<tr>
<td>3/8” (9.5 mm)</td>
<td>60-85</td>
</tr>
<tr>
<td>No. 4 (4.75 mm)</td>
<td>40-60</td>
</tr>
</tbody>
</table>
4.4 Mineral Admixtures. Mineral admixtures shall conform to the requirements of ASTM C 618 (fly ash), ASTM C 989 (slag) and ASTM C 1240 (silica fume). Unless specifically directed by the Engineer, total mineral admixture content including the content in blended cements shall not exceed the weight of Portland cement in the RCC mix.

4.5 Chemical Admixtures. Chemical admixtures including water-reducing and retarding admixtures shall conform to ASTM C 494 and must be approved by the Engineer prior to use.

4.6 Water. Water shall be clean, clear and free of acids, salts, alkalis or organic materials that may be injurious to the quality of the concrete. Non-potable water may be considered as a source for part or all of the water, providing the mix design indicates proof that the use of such water will not have any deleterious effect on the strength and durability properties of the RCC.

4.7 Curing Compound. Concrete curing compounds shall conform to ASTM C 309 or ASTM D 977.

5. **Equipment**

5.1 General. All necessary equipment shall be on hand and approved by the Engineer before work will be permitted. Roller compacted concrete shall be constructed 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 Plant.

5.2.1 Location of Plant. The plant shall be located within a 30 minute haul time form the RCC placement. With prior testing and Engineer’s approval, a set retarding admixture may be used to extend the haul time.

5.2.2 Plant Capacity. The plant shall be capable of producing an RCC mixture in the proportions defined by the final approved mix design and within the specified tolerances. The capacity of the plant shall be sufficient to produce a uniform mixture at a rate compatible with the placement equipment. The volume of RCC material in the mixing chamber shall not be more than the rated capacity for dry concrete mixtures. Multiple plants shall be supplied if a single plant can not provide an uninterrupted supply of RCC to the paver(s) during peak paving operations.

5.3 Paver

5.3.1 RCC shall be placed with a conventional asphalt type paver. The paver shall be capable of placing RCC to a minimum of 85% of the maximum wet density in accordance with ASTM D 1557 or equivalent test method. The paver shall be 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
5.4.1 Self-propelled self drum vibratory rollers having a minimum static weight of 10 tons shall be used for primary compaction. For final compaction either a steel drum roller, operated in a static mode, or pneumatic-tire roller shall be utilized.

5.5 Haul Trucks. Trucks for hauling the RCC material from the plant to the paver shall have covers available to protect the material from rain or excessive evaporation. The number of trucks shall be sufficient to ensure adequate and continuous supply of RCC material to the paver.

5.6 Water Trucks. At least one water truck, or other similar equipment, shall be on-site and available for use throughout the paving and curing process. Such equipment shall be capable of evenly applying a fine spray of water to the surface of the RCC without damaging the final surface.

6 Construction Requirements
6.1 Preparation of Subgrade/Subbase. Before RCC processing begins, the area to be paved shall be graded and shaped to the lines and grades as shown in the Plans or as directed by the Engineer. During this process any unsuitable soil or material shall be removed and replaced with acceptable material. The subgrade shall be uniformly compacted to a minimum of 95% of the maximum dry density in accordance with ASTM D 1557. The Contractor shall check for any soft or yielding subgrade areas by proof rolling over the entire area to be paved. All soft or yielding subgrade areas shall be corrected and made stable before RCC construction begins. If a subbase is shown on the Plans, it shall be uniformly compacted to a minimum of 95% of the maximum dry density in accordance with ASTM D 1557.

6.2 Mixing Process
6.2.1 General. Except for minor variations in moisture content, the same mixture proportions shall be used for the entire project, unless otherwise stated in the project documents. The water content shall be varied by the Contractor, as necessary, to provide a consistency that is most conducive to effective placement and compaction. If during mixing there is a change in the type or source of cementitious materials, or aggregates, the mixing must be suspended, and a new mix design shall be developed.

6.2.2 Mixture Ingredient Tolerances. The mixing plant must receive the quantities of individual ingredients to within the following tolerances:

<table>
<thead>
<tr>
<th>Material</th>
<th>Variation in % by Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cementitious materials</td>
<td>+/- 2.0</td>
</tr>
<tr>
<td>Water</td>
<td>+/- 3.0</td>
</tr>
<tr>
<td>Aggregates</td>
<td>+/- 4.0</td>
</tr>
</tbody>
</table>

6.2.3 Mixing Time will be that which will assure complete and uniform mixing of all ingredients. For drum mixers and dry batch facilities, the time of mixing shall be determined from uniformity test results.

6.2.4 All material must be discharged before recharging. The mixing chamber and mixer blade surfaces must be kept free of hardened RCC or other buildups. Mixer blades shall be checked routinely for wear and replaced if wear is sufficient to cause inadequate mixing.
6.3 Transportation. The transportation of the RCC pavement material from the plant to the areas to be paved shall be in dump trucks fitted and equipped, when necessary, with retractable protective covers for protection from rain or excessive evaporation. The trucks shall be dumped clean with no buildup or hanging of RCC material. For paver placed RCC, the dump trucks shall deposit the RCC material directly into the hopper of the paver or into a secondary material distribution system which deposits the material into the paver hopper. Dump truck delivery must be scheduled so that RCC material is spread and compacted within the specified time limits.

6.4 Placing.

6.4.1 Condition of Subgrade/Subbase. Prior to RCC placement, the surface of the subgrade/subbase shall be clean and free of foreign material, ponded water and frost prior to the placement of the RCC pavement mixture. The subgrade/subbase must be uniformly moist at the time of RCC placement. If sprinkling of water is required to remoisten certain areas, the method of sprinkling shall not be such that it forms mud or pools of free standing water. Prior to placement of RCC, the subgrade/subbase shall be checked for proper density and soft or yielding areas and these areas shall be corrected as specified in Section 6.1.

6.4.2 Paver Requirements. RCC shall be placed with an approved paver as specified in Section 5.3 and shall meet the following requirements:

6.4.2.1 The quantity of RCC material in the paver shall not be allowed to approach empty between loads. The material shall be maintained above the auger shaft at all times during paving.

6.4.2.2 The paver shall operate in a manner that will prevent segregation and produce a smooth continuous surface without tearing, pulling or shoving. The spread of the RCC shall be limited to a length that can be compacted and finished within the appropriate time limit under the prevailing air temperature, wind, and climatic conditions.

6.4.2.3 The paver shall proceed in a steady, continuous operation with minimal starts and stops. Paver speed during placement operations shall not exceed the speed necessary to ensure that minimum density requirements as specified in Section 5.3.1 are met and surface distress is minimized.

6.4.2.4 The surface of the RCC pavement once it leaves the paver shall be smooth, uniform and continuous without excessive tears, ridges or aggregate segregation.

6.5 Lift Thickness. Lift Thickness of compacted RCC pavement shall be as indicated on the Plans. If RCC pavements are to be constructed in a thickness greater than 10 inches, the use of two lifts shall be utilized. No lift shall be less than 4 inches.

6.5.4 Adjacent Lane Placement. Adjacent lanes shall be placed within 60 minutes. If more than 60 minutes elapses between placement of adjacent lanes, the vertical joint must be considered a cold joint and shall be prepared in accordance with Section 6.8.2. At the Engineer’s discretion, this time may be increased or decrease depending on the use of set retarding admixtures or the ambient weather conditions of temperature, wind, and humidity.
6.5.5 Hand Spreading. Broadcasting or fanning the RCC material across areas being compacted will not be permitted. Such additions of material 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.

6.5.6 RCC placement shall be done in a pattern so that the curing water from the previous placements will not pose a runoff problem on the fresh RCC surface or on the subbase layer.

6.6 Weather Conditions.

6.6.1 Cold Weather Precautions. RCC material shall not be placed on any surface containing frost or frozen material or when the air temperature is below 40°F, except when the air temperature is at least 35°F and rising. When the air temperature is expected to fall below 40°F, the Contractor must present to the Engineer a detailed proposal for protecting the RCC pavement. This proposal must be accepted by the Engineer before paving operations may be resumed. A sufficient supply of protective material such as insulating blankets, plastic sheeting, straw, burlap or other suitable material shall be provided by the Contractor at his expense. The methods and materials used shall be such that a minimum temperature of 40°F at the pavement surface will be maintained for a minimum of five days. Approval of the Contractor’s proposal for frost protection shall not relieve the Contractor of the responsibility for the quality and strength of the RCC placed during cold weather. Any RCC that freezes shall be removed and replaced at the Contractor’s expense.

6.6.2 Hot Weather Precautions. During periods of hot weather or windy conditions, special precautions shall be taken to minimize moisture loss due to evaporation. Under conditions of excessive surface evaporation due to a combination of air temperature, relative humidity, concrete temperature and wind conditions, the Contractor must present to the Engineer a detailed proposal for minimizing moisture loss and protecting the RCC. Precautions may include cooling of aggregate stockpiles by use of a water spray, protective covers on dump trucks, temporary wind breaks to reduce wind effect, cooling of concrete mix water, and decreasing the allowable time between mixing and final compaction.

6.6.3 Rain Limitations. No placement of RCC pavement shall be done while it is raining hard enough to be detrimental to the finished product. Placement may continue during light rain or mists provided the surface of the RCC pavement is not washed-out or damaged due to tracking or pickup by dump trucks or rollers. Dump truck covers must be used during these periods. The Engineer will be the sole judge as to when placement must be stopped due to rain.

6.7 Compaction

6.7.1 Compaction shall begin immediately behind the placement process and shall be completed within 60 minutes of the start of plant mixing. The time may be increased or decreased at the discretion of the Engineer depending on use of set retarding admixtures or ambient weather conditions of temperature, wind and humidity.

6.7.2 Rolling. The Contractor shall determine the sequence and number of passed by vibratory and non-vibratory rolling to obtain the minimum specified density and surface finish. Rollers shall only be operated in the vibratory mode while moving.
6.7.3 Rolling Longitudinal and Transverse Joints. The roller shall not operate within 12 inches of the edge of a freshly placed lane until the adjacent lane is placed. Then both edges of the two lanes shall be rolled together within the allowable time. If a cold joint is planned, the complete lane shall be roller and cold joint procedures, as specified in Section 6.8.2 shall be followed.

6.7.4 Longitudinal joints shall be given additional rolling as necessary to produce the specified density for the full depth of the lift and a tight smooth transition occurs across the joint. Any uneven marks left during the vibrating rolling shall be smoothed out by a non-vibrating or rubber tire rolling. The surface shall be rolled until a relatively smooth, flat surface, reasonably free of tearing and cracking is obtained.

6.7.5 Speed of the rollers shall be slow enough at all times to avoid displacement of the RCC pavement. Displacement of the surface resulting from reversing or turning action of the roller shall be corrected immediately.

6.7.6 Areas inaccessible to large roller shall be treated as specified in Section 6.5.9.

6.7.7 Density Requirements. In-place field density tests shall be performed in accordance with ASTM C 1040, direct transmission, as soon as possible, but no later than 30 minutes after completion of rolling. Only wet density shall be used for evaluation. The required density shall be not less than 98% of the maximum wet density obtained by ASTM D 1557 or equivalent test method based on a moving average of five consecutive tests with no test below 96%.

6.8 Joints

6.8.1 Fresh Vertical Joints. A vertical joint shall be considered a fresh joint when an adjacent RCC lane is placed within 60 minutes of placing the previous lane, with the time adjusted depending on use of retarders or ambient conditions. Fresh joints do not require special treatment.

6.8.2 Cold Vertical Joints. Any planned or unplanned construction joints that do not qualify as fresh joints shall be considered cold joints and shall be treated as follows:

6.8.2.1 Longitudinal and Transverse Cold Joints. Formed joints that do not meet the minimum density requirements of Section 6.7.7 and all unformed joints shall be cut vertically for the full depth. The vertical cuts shall be at least 6 in from the exposed edge. Cold joints cut within two hours of placement may be cut with an approved wheel cutter, motor grader or other approved method provided that no significant edge raveling occurs. Cold joints cut after two hours of placement shall be saw cut ¼ to 1/3 depth of the RCC pavement with the rest removed by hand or mechanical equipment. Any modification or substitution of the saw cutting procedure must be demonstrated to and accepted by the Engineer. All excess material from the joint cutting shall be removed.

6.8.2.2 Prior to placing fresh RCC mixture against a compacted cold vertical joint, the joint shall be thoroughly cleaned of any loose or foreign material. The vertical joint face shall be wetted and in a moist condition immediately prior to placement of the adjacent lane.
6.8.3 Fresh Horizontal Joints. For multi-layer construction a horizontal joint shall be considered a fresh joint when a subsequent RCC lift is placed within 60 minutes of placement of the previous lift. This time may be adjusted at the discretion of the Engineer depending on use of retarders or ambient weather conditions. Fresh joints do not require special treatment other than cleaning the surface of all loose material and moistening the surface prior to placement of the subsequent lift.

6.8.3.1 Horizontal Cold Lift Joints. For horizontal cold joints the surface of the lift shall be kept continuously moist and cleaned of all loose material prior to placement of the subsequent lift. The Engineer may require other action such as use of a cement slurry or mortar grout between lifts. If supplementary bonding materials are used, they shall be applied immediately prior to placement of the subsequent lift.

6.8.3.2 RCC Pavement Joints at Structures. The joints between RCC pavement and concrete structures shall be treated as cold joints.

6.8.4 Control Joints (Optional). Control joints may be constructed in the RCC pavement to induce cracking at pre-selected locations. Joint locations shall be shown on the Plans or as directed by the Engineer. Early entry saws should be utilized as soon as possible behind the rolling operation and set to manufacturer’s recommendations. Conventionally cut control joints shall be saw cut to ¼ depth of the compacted RCC pavement. Joints shall be saw cut as soon as those operations will not result in significant raveling or other damage to the RCC pavement.

6.9 Finishing.

6.9.1 Surface Smoothness. The finished surface of the RCC pavement, when tested with a 10 foot straight edge or crown surface template, shall not vary from the straight edge or template by more than 3/8 inch at any one point. When the surface smoothness is outside the specified surface tolerance the Contractor shall grind the surface to within the tolerance by use of self-propelled diamond grinders. Milling of the final surface is not acceptable, unless it is for the removal of the pavement.

6.9.2 Thickness. The thickness of the RCC pavement shall not deviate from that shown on the plans or as directed by the Engineer by more than minus ½ inch. Pavement of insufficient thickness shall be removed and replaced the full depth. No skin patches shall be accepted.

6.9.3 When surface irregularities are outside the tolerances cited above, the contractor shall grind the surface to meet the tolerance at no additional cost to the Owner.

6.10 Curing. Immediately after final rolling and compaction testing, the surface of the RCC pavement shall be kept continuously moist for 7 days or until an approved curing method is applied.

6.10.1 Water Cure. Water cure shall be applied by water trucks equipped with misting spray nozzles, soaking hoses, sprinkler system or other means that will assure a uniform moist condition to the RCC. Application of this moisture must be done in a manner that will not wash out or damage the surface of the finished RCC pavement.
6.10.2 Curing Compound. The specified membrane curing compound shall be applied in two separate applications at right angles to one another, with the first coat being allowed to become tacky before the second is applied. This application must ensure a uniform void-free membrane across the entire RCC pavement. If the application rate is found to be excessive or insufficient, the Contractor, with approval of the Engineer, can decrease or increase the application rate to a level which achieves a void-free surface without ponding.

6.11 Traffic. The Contractor shall protect the RCC from vehicular traffic during the curing period. Completed portions of the RCC pavement may be opened to traffic after seven days or as approved by the Engineer.

6.12 Maintenance. The Contractor shall maintain the RCC pavement in good condition until all work is completed and accepted. Such maintenance shall be performed by the Contractor at his own expense.

7 Measurement and Payment
7.1 Measurement. The work described in this document will be measured (1) in square yards of completed and accepted RCC pavement as determined by the specified lines, grades and cross sections shown on the Plans and (2) in cubic yards or tons of mixed and hauled RCC material.

7.2 Payment.
7.2.1 The work described in this document will be paid for at the contract unit price per square yard of completed and accepted RCC pavement. The price shall include placement, compaction, curing, inspection and testing assistance and all other incidental operations. Also payment shall be made at the contract unit price per cubic yard or ton of mixed and hauled RCC materials. The price shall include mixing, hauling and all material costs. Such payment shall constitute full reimbursement for all work necessary to complete the RCC pavement.
Georgia Department of Transportation
State of Georgia
Section 442—Roller Compacted Concrete Pavement

442.1 General Description
This work includes constructing pavement composed of Roller Compacted Concrete (RCC) on a prepared subgrade or subbase course. Follow the requirements of these Specifications and conform to the lines, grades, thickness, and cross sections shown on the Plans or as directed by the Engineer.

442.1.01 Definitions
General Provisions 101 through 150.

442.1.02 Related References
A. Standard Specifications
   Section 106—Control of Materials
   Section 430—Portland Cement Concrete Pavement
   Section 500—Concrete Structures

B. Referenced Documents
   ASTM C 1435
   AASHTO T 22
   AASHTO T 180, Method D
   QPL 10
   GDT 59

442.1.03 Submittals
Submit the following to the Engineer at least 35 days before start of any production of RCC:

A. Concrete Mix Design
   Submit a mix design prepared by a qualified testing laboratory. The Engineer will transmit the design to the Office of Materials and Research for approval.
   Include details on aggregate gradation, cementitious materials, admixtures (if used), compressive strengths, required moisture and density to be achieved and quantities of individual materials per cubic yard for the mix design.

B. Paving Plan
   Submit paving procedures describing direction of paving operations, paving widths, planned longitudinal and transverse cold joints, curing methods and patterns and description of all equipment.

442.2 Materials
Ensure that materials meet the requirements of the following Specifications:

<table>
<thead>
<tr>
<th>Material</th>
<th>Section</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coarse Aggregate, Class A or B Crushed Stone or Gravel</td>
<td>800</td>
</tr>
<tr>
<td>Fine Aggregate, Size No. 10</td>
<td>801.2.02</td>
</tr>
</tbody>
</table>
A. **Fly Ash**

   Ensure the use of fly ash conforms to Subsection 430.2.A.1, 2 and 4, “Fly Ash” and that the fly ash mix conforms to Subsection 442.3.06, “Quality Acceptance”.

B. **Granulated Iron Blast-Furnace Slag**

   Ensure the use of slag conforms to Subsection 430.2.B.1, 2 and 4, “Granulated Blast-Furnace Slag” and that the slag mix conforms to Subsection 442.3.06, “Quality Acceptance”.

C. **Composition of RCC**

   1. **Aggregates**

   Use aggregates manufactured to meet the gradation at the quarry or blended at the plant site to produce the desired results. Use aggregates that are well graded without gradation gaps and conform to the following gradation:

<table>
<thead>
<tr>
<th>Sieve Size</th>
<th>Percent Passing By Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 in (25 mm)</td>
<td>100</td>
</tr>
<tr>
<td>3/4 in (19 mm)</td>
<td>90 – 100</td>
</tr>
<tr>
<td>1/2 in (12.5 mm)</td>
<td>70 – 100</td>
</tr>
<tr>
<td>3/8 in (9.5 mm)</td>
<td>60 – 85</td>
</tr>
<tr>
<td>No. 4 (4.75 mm)</td>
<td>40 – 60</td>
</tr>
<tr>
<td>No. 16 (1.18 mm)</td>
<td>20 – 40</td>
</tr>
<tr>
<td>No. 100 (150 µm)</td>
<td>6 – 18</td>
</tr>
<tr>
<td>No. 200 (75 µm)</td>
<td>2 – 8</td>
</tr>
</tbody>
</table>

   Produce evidence that the proportions have the potential for strength development at 28 days as required in Subsection 442.3.06.B, “Approval of Mix Design Proportions”.

### 442.3 Construction Requirements

#### 442.3.01 Personnel

General Provisions 101 through 150.

#### 442.3.02 Equipment

Provide equipment and tools to construct RCC that will produce a completed pavement meeting the requirements for mixing, transporting, placing, compacting, finishing, and curing as provided in this specification. All equipment will be on hand and approved by the Engineer before work can proceed.
A. Mixing Plant

Produce an RCC pavement mixture in the proportions defined by the approved mix design and within the specified tolerances.

Capacity of the plant will be sufficient to produce a uniform mixture at a rate compatible with the placement equipment.

1. Pugmill Plant
   a. Pugmill plant shall be a central plant with a twin shaft pugmill mixer, capable of batch or continuous mixing.
   b. Equip plant with synchronized metering devices and feeders to maintain the correct proportions of aggregates, cement, fly ash and water.
   c. The pugmill plant will also meet the following:
      1) Aggregate Storage
         a. If previously blended aggregate is furnished, storage may be in a stockpile from which it is fed directly to a conveyor feeding mixer.
         b. If aggregate is furnished in two size groups, aggregate separation must be provided at the stockpile.
      2) Aggregate Bins
         a. Control feed rate by a variable speed belt or operate gate calibrated to accurately deliver any specified quantity of material.
         b. If two aggregate size stockpile sources are used, the feed rate from each bin shall be readily adjustable to change aggregate proportions, when required.
         c. Feed rate controls must maintain the established proportions of aggregate from each stockpile bin when the combined aggregate delivery is increased or decreased.
      3) Plant Scales
         a. If utilized, for any weigh box or hopper will be either of beam or springless dial type, and be sensitive to 0.5 percent of the maximum load required.
         b. Provide beam-type scales that have a separate beam for each aggregate size, with a single telltale actuated for each beam, and a tare beam for balancing hopper.
         c. Belt scales will be of an approved design.
         d. Provide standard weights accurate to plus or minus 0.1 percent for checking plant scales.
      4) Cement, Fly Ash or Slag Material Storage
         a. Provide separate and independent storage silos for Portland cement, fly ash or slag.
         b. Identify clearly each silo to avoid confusion during silo loading.
      5) Cement, Fly Ash or Slag Feed Unit
         To assure a uniform and accurate quantity of cementitious materials enters the mixer, provide satisfactory means of dispensing Portland cement, fly ash or slag, volumetrically or by weight.
      6) Water Control Unit
         a. Measure by weight or volume the required amount of water for the approved mix.
         b. Equip the unit with an accurate metering device.
         c. Keep RCC mixture at optimum moisture by having the rate of water added adjustable.
      7) Gob Hopper
         For continuous operating pugmills, attach a gob hopper to the end of the final discharge belt to temporarily hold the RCC discharge to allow the plant to operate continuously.
2. Central Mix Batch Plant
   Central mix batch plant may be used in RCC work meeting the requirements of Subsection 500.3.04.E of the Specifications.

3. Dry Batch Plant
   a. A dry batch plant meeting the requirements of Subsection 500.3.04.E of the Specifications may be used on projects with less than 5000 cubic yards of RCC.
   b. RCC may be mixed at a central point or wholly or in part in truck mixers as provided in Subsection 500.3.04.E of the Specifications.

B. Paver
   Place RCC with an asphalt paver meeting the following requirements:
   1. Equip the paver with compacting devices capable of producing a RCC pavement with a minimum of 90% of the maximum density in accordance with AASHTO T 180, Method D.
   2. Spread and finish the RCC material without segregation, to the required thickness, smoothness, surface texture, cross-section and grade using a paver of suitable weight and stability.

C. Compactors
   1. For primary compaction, use self-propelled smooth steel drum vibratory rollers having minimum weight of 10 tons (9.07 Mg).
   2. For finish rolling as required for final compaction or for removing roller marks, use a steel drum roller, operating in static mode, a rubber tired roller or combination roller.
   3. For compacting areas inaccessible to large rollers, use walk-behind vibratory rollers or plate tampers.

D. Haul Trucks
   1. Provide sufficient number of trucks to ensure adequate and continuous supply of RCC material to paver.
   2. Equip trucks hauling RCC material from the plant to the paver with covers to protect the material from inclement weather and to reduce evaporation losses.

E. Water Trucks
   1. Throughout the paving and curing process, have at least one water truck or other similar equipment on-site and available.
   2. Equip the water truck with a spreader pipe containing fog nozzles capable of evenly applying a fine mist of water to the surface of the RCC without damaging the final surface.

442.3.03 Preparation
Prepare the subgrade/subbase as required by the Plans and Specifications before placing the RCC.
Ensure that the foundation immediately under the RCC pavement and the areas supporting the paving equipment will not contribute to deficient pavement thickness or excessive yield losses.

442.3.04 Fabrication
General Provisions 101 through 150.

442.3.05 Construction
A. Mixing RCC
   Use the same mix design and materials for the entire project. If the source of cement, fly ash, slag, or aggregates is changed, suspend construction and submit a new mix design to the Engineer for approval.
1. Mixing Time
   a. Assure complete and uniform mixing of all ingredients.
   b. The volume of RCC material in the mixing chamber should not exceed the manufacturer’s rated capacity for dry concrete mixtures.
   c. Keep sides of the mixer and mixer blade surfaces free of hardened RCC and other materials.
   d. Check mixer blades routinely for wear and replace if wear is sufficient to cause inadequate mixing.

2. Mixing Ingredient Tolerances
   Ensure that mixing plant receive the quantities of individual ingredients to within the following tolerances:

<table>
<thead>
<tr>
<th>Material</th>
<th>Variation by Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cementitious Materials</td>
<td>± 2.0%</td>
</tr>
<tr>
<td>Water</td>
<td>± 3.0%</td>
</tr>
<tr>
<td>Aggregates</td>
<td>± 4.0%</td>
</tr>
</tbody>
</table>

3. Plant Calibration
   a. Prior to RCC production, provide a complete and comprehensive calibration of the plant in accordance to the manufacturer’s recommendation.
   b. Concrete batch plants currently listed on QPL 10, the calibration requirement is waived.

Supply daily plant records of production and quantities of materials used that day to the Engineer. These records may be used as a check on plant calibration.

B. Transporting RCC
   Transport RCC pavement material from the plant to the paver as follows:
   1. Use dump trucks fitted with retractable protective covers for protection from inclement weather or excessive evaporation.
   2. Dump the trucks clean with no buildup or hanging of RCC material in the corners.
   3. Deposit the RCC material directly into the hopper of the paver or secondary distribution system which deposits the material into the paver hopper.

C. Placing RCC
   1. Subgrade/Subbase Condition
      a. Keep subgrade/subbase surface clean and free of foreign material, ponded water and frost prior to RCC placement.
      b. Uniformly moisten subgrade/subbase at the time of RCC placement.
      c. If the subbase becomes dry, uniformly water, but the method of watering used will not form mud or pools of freestanding water.
   2. Paver Requirements
      a. Adjust the paver and regulate the speed to prevent segregation and provide a surface course that is smooth and continuous without tears and pulling. Limit the spread of the RCC to a length that can be compacted and finished within the appropriate time limit under the prevailing air temperature, wind, and climatic conditions.
      b. Proceed in a steady, continuous operation with minimal starts and stops.
      c. Regulate speed to assure a constant supply of RCC material in the hopper.
      d. Maintain RCC material above the auger shaft at all times during paving.
3. **Lift Thickness**
   Construct pavements greater than 10 in (250 mm) in two lifts of equal thickness.

4. **Adjacent Lane Placement**
   a. Place adjacent paving lanes within 60 minutes.
   b. If more than 60 minutes has elapsed between placements of adjacent lanes, the vertical joint will be considered a cold joint. Prepare the cold joint in accordance with Subsection 442.3.05.E.2, “Cold Vertical Joints”.
   c. At the discretion of the Engineer, this time may be increased or decreased depending on the use of set retarding admixtures or the ambient weather conditions of temperature, wind, and humidity.

5. **Multiple Lift Placement**
   a. The thickness of each lift will meet the requirements of Subsection 442.3.05.C.3, “Lift Thickness”.
   b. Place second lift within 60 minutes of the completion of the first lift.
   c. If more than 60 minutes has elapsed, the interface between the first and second lift will be considered a cold joint. Prepare cold joint in accordance with Subsection 442.3.05.E.4, “Horizontal Cold Lift Joints”.
   d. At the discretion of the Engineer, this time may be increased or decreased depending on the use of set retarding admixtures or the ambient weather conditions of temperature, wind, and humidity.
   e. To reduce the opportunity for cold joints to develop, the use of multiple pavers in tandem formation is advantageous.

6. **Hand Spreading**
   a. Limit hand spreading, broadcasting, or fanning to immediately behind the paver and before compaction.
   b. Remove any segregated coarse aggregate from the surface before compaction.

7. **Segregation**
   a. If segregation occurs in the RCC during paving operations, cease the spreading until the cause is determined and corrected to the satisfaction of the Engineer.
   b. If the Engineer determines the segregation to be severe, remove and replace the segregated area at no additional cost.

Place RCC in a pattern so that the curing water from the previous placements will not pose a runoff problem on the fresh RCC surface or on the subbase layer.

**D. Compacting**

1. Immediately begin compaction behind the placement of RCC material and complete within 60 minutes of the start of mixing at the plant.

2. This time may be increased or decreased depending on the use of set retarding admixtures or ambient weather conditions of temperature, wind and humidity.

3. Plan operations and supply sufficient rollers to ensure these criteria are met.

4. Determine the sequence and number of passes by vibratory and non-vibratory rolling to obtain the specified density and surface finish.

5. Operation of rollers in the vibratory mode while stopped or reversing direction is not allowed.

6. Using rubber tire rollers for final compaction to knead and seal the surface is permissible.

7. **Rolling Longitudinal and Transverse Joints:**
   a. Do not operate roller within 12 in. (300 mm) of the edge of a freshly placed lane until the adjacent lane is placed.
   b. Within the allowable time roll together both edges of the two lanes.
c. When a cold joint is planned, roll the complete lane and follow cold joint procedures as specified in Subsection 442.3.05.E.2, “Cold Vertical Joints”.

d. Provide additional rolling for longitudinal joints with a vibratory roller as necessary to produce the specified density for the full depth of the lift and provide a tight smooth transition across the joint.

e. Smooth out any uneven marks left during the vibratory rolling utilizing a non-vibratory or rubber tire roller.

f. Roll until a smooth, flat surface, free of tearing and cracking is obtained.

g. Avoid displacement of RCC pavement by operating the speed of the rollers slow enough at all times.

h. Correct any displacement of RCC pavement resulting from reverse direction of the roller or from any other causes.

8. Density Requirements:

a. Perform in-place field density tests in accordance with GDT-59, direct transmission, as soon as possible, but no later than 30 minutes after completion of rolling. Only wet density will be used for evaluation.

b. In-place field density will be not less than 98% of the average maximum laboratory density obtained according to AASHTO T 180, Method D, based on a moving average of five consecutive tests, with no test below 95%.

c. RCC properly placed and compacted, but not meeting these requirements will be cored and tested at no additional cost.

d. If tested area achieves the 28 day design strength as outlined in Subsection 442.3.06.D, “Concrete Strength Acceptance”, it will be paid for at full price.

e. Areas that fail the strength test will be removed and replaced at no additional cost.

E. Joints

1. Fresh Vertical Joints:

a. A vertical joint is considered a fresh joint when an adjacent RCC lane is placed within 60 minutes of placing the previous lane, with time adjusted depending on use of retarders or ambient conditions. Fresh joints will not require the treatment specified for cold joints.

b. Construct joints to assure continuous bond between new and previously placed lanes.

2. Cold Vertical Joints:

| Note: Vertical joints that are constructed utilizing a drop extension or edging shoe are exempt from the following requirement when placed up to 15 degrees from vertical. |

a. Cold joints are any planned or unplanned construction joint in the RCC pavement that does not qualify as fresh joints.

Treat longitudinal and transverse cold joints as followed:

1) Cut the joint vertically full depth. Cut vertically at least 6 in. (150 mm) from the exposed edge.

2) The edge of cold joints cut within 2 hours of placing the RCC pavement may be cut with an approved wheel cutter, or motor grader or other approved method provided that no edge raveling occurs.

3) Edges of cold joints cut after 2 hours of placing the RCC pavement, cut to 1/4 to 1/3 of the depth of the RCC pavement and excess material removed.

4) If the excess material cannot be removed without causing tearing and raveling, cut full depth.

b. Clean the joint of any loose or foreign material prior to placing fresh RCC material against a compacted cold vertical joint.

c. Before placement of fresh RCC, wet the compacted cold joint to prevent excess loss of moisture.
3. Fresh Horizontal Joints
   a. For multi-layer construction, a horizontal joint is considered a fresh joint when an subsequent RCC lift is placed within 60 minutes of placing the previous lift, with time adjusted depending on use of retarders or ambient weather conditions.
   b. Clean the surface of all loose material and moisten the surface prior to placement of the subsequent lift.

4. Horizontal Cold Lift Joints
   a. For horizontal cold joints, clean all loose material and moisten the surface prior to placement of the subsequent lift.
   b. The Engineer or Plans may require use of a cement slurry or grout between lifts. If required, apply supplementary bonding materials immediately prior to placement of the subsequent lift.

5. Control Joints:
   Joint locations shall be shown on the Plans or as directed by the Engineer.
   a. Early entry saws should be utilized as soon as possible behind the rolling operation and set to the manufacturer’s recommendation.
   b. Saw cut control joints to 1/4 depth of the compacted RCC pavement.
   c. Saw as soon as possible without causing raveling or other damage to the pavement, but no later than 18 hours after placement.

6. Joints at Structures
   Treat joints between RCC pavement and concrete structures as cold vertical joints.

F. Finishing
   1. The finished surface of the RCC pavement, when tested with a 10 foot (3 m) straight edge or crown surface template, will not vary by more than 1/4 inch (6 mm) at any one point.
   2. When the surface smoothness is outside of the specified tolerance, grind the surface to within the tolerance by use of self-propelled diamond grinders at no additional cost.
   3. Milling to obtain a final riding surface is not acceptable.

G. Curing
   Immediately after final rolling and compaction testing, keep the surface of the RCC pavement continuously moist for 7 days or until an approved curing method is applied.
   1. Water Cure:
      a. Apply water cure using water truck equipped with misting spray nozzles, soaking hoses, sprinkler system or other means that will assure a uniform moist condition to the RCC.
      b. Apply moisture in a manner that will not wash out or damage the surface of the finished RCC pavement.
   2. Curing Compound:
      a. Apply curing compound as specified in Subsection 430.3.05.L.1 of the Specifications.
      b. Ensure the application provides a uniform void-free membrane across the entire RCC pavement surface.
   3. White Polyethylene Sheeting
      Use sheet material as specified in Subsection 430.05.L.2 of the Specifications

H. Sealing Joints
   If required by the Plans or directed by the Engineer, seal joints in accordance to Subsection 430.3.05.M, “Seal the Joints” of the Specifications.
I. Permitting Traffic on Pavement

Before using the pavement as a haul road for loaded or unloaded vehicles:

1. Protect the RCC from vehicular traffic during the curing period.
2. Ensure that compressive strength tests show the RCC has developed at least 2000 psi (14 MPa) and is at least 4 days old.
3. If required by the Plans or directed by the Engineer, seal the joints before permitting vehicles or equipment on the pavement.

442.3.06 Quality Acceptance

A. Concrete Mixing

Ensure mixing of RCC conforms to the requirements of Subsection 442.3.05.A, “Mixing RCC”.

B. Approval of Mix Design Proportions

The Office of Materials and Research will review concrete mix designs and will verify compressive strength development.

The Department will approve material combinations and mix designs using approved materials and complying with Subsection 442.2, “Materials” and the following:

1. Compressive Strength
   Prepare and test 6 cylinders according to ASTM C 1435 and AASHTO T 22 to determine the 28 day compressive strength for RCC.
   The mix design will demonstrate a compressive strength of 4000 psi (28 MPa) at 28 days.

C. Thickness

The Engineer will designate pavement areas to be examined for depth measurement compliance with the Plan and Specifications.

The Engineer will evaluate areas deficient by more than 1/2 in (13 mm) thick. If the Engineer requires removal, remove and replace the pavement in full cross sections according to Plan requirements. The Engineer may require a reduction in payment if removal and replacement is not required.

D. Concrete Strength Acceptance

RCC pavement not meeting density requirements outlined in Subsection 442.3.05.D.8, “Density Requirements” will be accepted based on compressive strength development at 28 days. The compressive strength value shall be at least 3,500 psi (25 MPa).

442.3.07 Contractor Warranty and Maintenance

General Provisions 101 through 150.

442.4 Measurement

The work to be paid for under this Item is the number of square yards (meters) of RCC pavement completed and accepted as measured in place as determined by the specified lines, grades and cross sections shown on the Plans.

442.4.01

General Provisions 101 through 150.

442.5 Payment

The work will be paid for at the Contract Unit Price per square yard (meter). Payment is full compensation for providing materials, equipment, and labor, mixing, transporting, handling, placing, compaction and providing incidental to complete the work.

Payment will be made under:
442.5.01 Adjustments

The Contract Unit Price per square yard (meter) of RCC pavement will be adjusted for RCC pavement accepted with a 28 day compressive strength or thickness deficiency.
UNION COUNTY, INDIANA
CLIFTON ROAD

Location: Clifton Road
Owner: Union County
Designer: Union County
Contractor: Union County
RCC Supplier: imi

Length: 1/8 mile
Width: 24'
Depth: 6"
Constructed: October 2007
HENRY COUNTY, INDIANA
ACCESS ROAD

Location: Access Road
Owner: Hayes Landfill
Designer: IRMCA
Contractor: Henry County
RCC Supplier: Busters Concrete Products

Length: 100 FT
Width: 12’
Depth: Variable
Constructed: January 2008
# First Run

<table>
<thead>
<tr>
<th>Lift (in)</th>
<th>Wet Density (pcf)</th>
<th>Dry Density (pcf)</th>
<th>Moisture (%)</th>
<th>Proctor (%)</th>
<th>Roller (y/n)</th>
<th># Passes w/o Vibrator</th>
<th># Passes w/ Vibrator</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>117.8</td>
<td>109.7</td>
<td>7.4</td>
<td>74</td>
<td>No</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>9</td>
<td>116.1</td>
<td>109.4</td>
<td>6.2</td>
<td>74</td>
<td>No</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>6</td>
<td>144.9</td>
<td>136.5</td>
<td>6.2</td>
<td>92</td>
<td>Yes</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>6</td>
<td>148.8</td>
<td>138.8</td>
<td>7.3</td>
<td>94</td>
<td>Yes</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>8</td>
<td>147.4</td>
<td>137.8</td>
<td>7</td>
<td>93</td>
<td>yes</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>8</td>
<td>161.9</td>
<td>151.3</td>
<td>7</td>
<td>102</td>
<td>Yes</td>
<td>2</td>
<td>1</td>
</tr>
</tbody>
</table>
# Second Run

<table>
<thead>
<tr>
<th>Lift (in)</th>
<th>Wet Density (pcf)</th>
<th>Dry Density (pcf)</th>
<th>Moisture (%)</th>
<th>Proctor (%)</th>
<th>Roller (y/n)</th>
<th># Passes w/o Vibrator</th>
<th># Passes w/ Vibrator</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>118.7</td>
<td>111.9</td>
<td>6</td>
<td>76</td>
<td>No</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>9</td>
<td>114.4</td>
<td>108.6</td>
<td>5.3</td>
<td>73</td>
<td>No</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>6</td>
<td>143.1</td>
<td>135.2</td>
<td>5.8</td>
<td>91</td>
<td>Yes</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>9</td>
<td>138.9</td>
<td>131.6</td>
<td>5.5</td>
<td>89</td>
<td>Yes</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>9</td>
<td>147.3</td>
<td>138.9</td>
<td>6</td>
<td>94</td>
<td>Yes</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>6</td>
<td>153.2</td>
<td>145.2</td>
<td>5.5</td>
<td>98</td>
<td>Yes</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>6*</td>
<td>149.0</td>
<td>140.1</td>
<td>6.3</td>
<td>95</td>
<td>Yes</td>
<td>0</td>
<td>2</td>
</tr>
</tbody>
</table>

* Test at joint
Location: St. Thomas Street
Owner: St. Joseph County
Designer: St. Joseph County.
Contractor: Walsh & Kelly
RCC Supplier: Kuert Concrete

Size: 2,638 sy
Depth: 5”
4” of asphalt was milled out and replaced with RCC
Road Closure was 24 hours
Constructed: July 2008
FOR FURTHER INFORMATION:

Indiana Ready Mixed Concrete Association
3500 Depauw Boulevard, Suite 1081
Indianapolis, Indiana 46268
Phone 317-872-6302
FAX 317-872-6313
E-mail: jlarson@irmca.com
www.irmca.com

Indiana Chapter
American Concrete Pavement Association
One North Capitol Avenue, Suite 480
Indianapolis, Indiana 46204
Phone 317-634-8989
FAX 317-634-8988
E-mail: plong@pavement.com
www.pavement.com