Construction Specification 36—Roller Compacted Concrete

1. Scope
The work shall consist of furnishing all materials, tools, equipment, and mixing plant; and performing all labor for the mixing, transporting, forming, placing, compacting, and curing of roller compacted concrete (RCC) as required to install the structure(s) as shown on the drawings and designated in section 22 of this specification and the test section designated in the same section.

2. Material
Portland cement shall conform to the requirements of Material Specification 531, Portland cement. Type III Portland cement shall not be used.

Pozzolan shall conform to the requirements of Material Specification 532, Supplementary Cementitious Materials. Fly ash shall be class F unless otherwise specified. The source of pozzolan shall consistently supply material with similar chemical and physical properties.

Combined aggregates shall conform to the requirements of Material Specification 524, Aggregates for Roller Compacted Concrete, unless otherwise specified.

Water incorporated into the mix or used for curing RCC shall be clean and free from injurious amounts of oil, salt, acid, alkali, organic matter, turbidity, or other deleterious substances. Water shall conform to the requirements of ASTM C 94 except that wash water shall not be used for mixing RCC.

Water-reducing, set-retarding admixture shall conform to ASTM C 494, type D.

Curing compound shall conform to the requirements of Material Specification 534, Concrete Curing Compound. Curing compound shall be furnished in containers that have not been previously opened and that have the original manufacturer's labels attached.

Bonding mortar shall consist of cement, sand, water, and a water-reducing, set-retarding admixture to retard the set and control the consistency of the mortar. The cement, water, and admixture shall be as specified. Sand shall comply with ASTM C 33 for fine aggregate. The mortar shall be mixed in the proportions 1 part cement to 2.5 parts sand, by weight. Water content shall be sufficient to provide a spreadable consistency. In combination with the admixture, the maximum water-to-cementitious materials ratio shall be 0.45. The mortar slump shall be 7 to 9 inches when tested in accordance with ASTM C 143. The admixture shall be included at the manufacturer's recommended dosage so that the initial set time is retarded at least 3 hours when the ambient air temperature is 95 degrees Fahrenheit.

Material testing—The contractor shall test materials or provide certified test results to ensure all materials conform to the specified requirements. All nonconforming materials shall be promptly removed from the job site, including those that have been incorporated into the work.

Aggregate sampling shall be in accordance with ASTM D 75.

Aggregate samples shall be taken from stockpiles, belt feeders from bins, the mix plant feed conveyor belt(s), the mixer feed conveyer belt, or from the pug mill discharge while only aggregate is discharged from the pugmill.

When obtaining aggregate samples from stockpiles, samples shall be obtained from various parts of the stockpiles, but never from the perimeter of the lower third of the pile.
The contractor shall provide access for material sampling and performance of quality assurance testing activities at material storage sites.

**Sampling**—The contractor shall provide suitable platforms, tools, equipment, and labor necessary for obtaining representative samples of materials to be used for the contractor's quality control testing and for the Government's quality assurance testing. Samples may be taken from stockpiles, aggregate bins and feed belts, entrance to the mixer, mixer discharge, gob hopper discharge, points in transit, or the placement area.

**Material handling and processing**—Transportation of cement and pozzolan to the batching plant shall be accomplished in weather-tight trucks, conveyors, or other means that will completely and thoroughly protect the cementitious materials from exposure to moisture and contaminants.

The temperature of cement and pozzolan when delivered to the job site shall not exceed 160 degrees Fahrenheit. The temperature of the cement and pozzolan shall be determined by direct insertion of a thermometer into the material in the delivery truck. The temperature of air to transport cement into storage containers or silos shall not exceed 180 degrees Fahrenheit. It may be assumed that the temperature of the air in the transfer pipe is the same as the temperature on the outside surface of the transport pipe. The temperature of the air shall be determined by measuring the temperature on the outside of the transport pipe with a surface thermometer.

Immediately upon receipt at the job site, cement and pozzolan shall be stored in dry, weather-tight, ventilated structures. All storage facilities shall permit easy access for inspection and identification. Sufficient cement and pozzolan shall be stored onsite at all times to complete a minimum of 24 hours of placement at the planned average production rate, unless otherwise specified. Cement and pozzolan that have been stored at the site for the longest period shall be used first, unless otherwise specified.

Aggregates shall be transported to the site in two or more components that will be combined in the mix plant to meet the overall aggregate gradation. Aggregate components shall be of a gradation that will minimize segregation prior to introduction into the mixer. Aggregate components shall be stockpiled separately. Aggregates shall be handled and stockpiled in a manner to prevent intermixing between dissimilar aggregates and to prevent contamination of the aggregate. Coarse and fine aggregates shall remain separated until they are introduced into the mixing plant. For plants that mix in discrete batches, the coarse and fine aggregates shall be fed separately into the batch hopper. For mix plants that mix continuously, the coarse and fine aggregates shall remain separated until they are dropped onto the belt that delivers the aggregates to the mixing compartment. The contractor shall develop and utilize methods that reliably and consistently withdraw and transport the aggregates from the stockpile without contamination or segregation. Segregated or contaminated aggregates shall not be used in production of the RCC and shall be disposed of in locations specified in section 22.

A 2-week supply of aggregates, based on the average planned weekly production rate, shall be stockpiled at the mixing plant location or other approved location, prior to RCC production unless otherwise specified.

Sufficient water shall be available for mixing and curing to complete a minimum of 24 hours of placement at the average planned production rate.

3. **Submittals**

Manufacturer's certifications and test reports shall in no way relieve the contractor of the responsibility for furnishing materials that meet the specified requirements. Manufacturer's certifications and test reports shall be produced and dated within the 6 months preceding the delivery of the submittal. The test method used shall be noted on all
test reports. Any deviation from standard test methods shall be detailed in the test report and the reason for the deviation shall be given.

Trial mix production submittals—The submittals listed below shall be provided, in writing for approval no later than 30 days before trial mix production, unless otherwise specified. Trial mix production shall not proceed before approval of these submittals.

a. The name and qualifications of the laboratory that will perform the mix design.

b. The source(s) from which the cementitious materials will be obtained along with a certified mill test report for each type of cement, pozzolan, and/or blended cement that will be used to produce RCC. The certified mill test report shall verify that the cement, pozzolan, or blended cement conforms to the applicable material specification.

c. The source from which the aggregate will be obtained and certified test results showing that all aggregates conform to the specification.

d. The source from which the water will be obtained and the certified test results showing that water to be used in the mix conforms to ASTM C 94.

e. The source of the admixture along with certified test results showing that the admixture conforms to the specification.

RCC pre-production submittals—The submittals listed below shall be provided, in writing for approval, to the engineer. The submittal for the job mix and bonding mortar shall be furnished 30 days before delivery of any RCC or bonding mortar component materials to the site. The submittal for the plant and equipment, personnel, and test section plan shall be provided no later than 30 days before delivery of the plant or equipment to the site. RCC materials or equipment shall not be delivered to the site before approval of these submittals.

Job mix

a. A certified statement of materials, mix proportions (reported for saturated surface dry aggregate), theoretical air-free density (TAFD), moisture/density curves (wet density only), Vebe time, air content, unit weight of mix in air pot just prior to testing air content, and all compressive strength test results for each of the three mixes required in the development of the RCC job mix.

b. Gradation of each of the aggregate component and combined aggregates used in each mix developed in the mix design program.

c. The compacted bulk density and voids in each of the aggregate components and combined aggregates used in each mix developed in the mix design program.

d. A statement of materials and mix proportions used in each mix developed in the mix design program.

e. A statement of materials and mix proportions proposed to be used in manufacturing the RCC job mix.

Bonding mortar

a. A statement of materials and mix proportions to be used in manufacturing the bonding mortar.

Plant and equipment

a. The planned RCC component material production, transportation, and storage and temperature control procedures. Anticipated peak production capacity, normal production capacity, and onsite storage volumes shall be included in the plan.

b. Mixing plant manufacturer’s data and operating instructions and the plant layout to include a schematic drawing of the plant and materials storage with a narrative description providing its peak capacity, normal
anticipated production rate, and results of the most recent uniformity tests conducted within the previous 12 months. The proposed location of the mixing plant relative to the placement site(s) shall be provided.

c. A narrative description and a layout of the equipment and methods to be used for delivering and depositing RCC at the placement site(s).

d. The type and expected number of pieces of equipment required for all placing, spreading, and compaction of the RCC.

e. The plan for obtaining the specified vertical surfaces.

f. The method and procedure for curing of the in-place RCC, including the type of curing compound if used.

g. The method and procedure that will be implemented to provide protection of RCC from temperature extremes, including the type of external heating equipment and insulating materials to be used.

Personnel

a. The names and qualifications of the supervisor and plant operator who will direct the batching, mixing, and placing of RCC.

Test section plan

a. The contractor's proposed location for the test section and equipment, materials, personnel, and methods to construct the test section as specified. The submittal shall include plans for the pre- and post-test section briefings.

Test section submittals—Within 24-hours of completing the tests or test section, the following information shall be transmitted to the engineer in writing.

a. Results of moisture and density tests used to compute the apparent maximum density (AMD). Include the results of all density tests made of RCC in the test section.

b. Lift maps of the test section.

c. Results of compressive strength tests.

d. Air content and unit weight of RCC.

e. Production plan that includes RCC production methods, materials, plant, equipment, and personnel as modified based on the results from the performance of the test section that have been documented to produce RCC that meets the requirements of the specification.

Unless otherwise specified, 7 days prior to beginning RCC production, submit a final written plan for RCC production methods, materials, plant, equipment, and personnel that will produce RCC that meets the requirements of this specification.

RCC production submittals—The following submittals shall be provided in writing within 24 hours after delivery tickets, records, or test results are produced, unless otherwise specified.

a. Delivery tickets for cement and pozzolan shall include the source, date manufactured or produced, type or class, contractor's name, project name, and a certification that the material meets the specification requirements.

b. Delivery tickets for aggregates shall include the source, material description, date, and certification that the material meets the specification requirements.

c. Delivery tickets for bonding mortar shall include name and location of batch plant, ticket number, load and truck number, date, destination, class of cementitious materials, mix proportions, quantity of bonding mortar, time mixer drum charged with cement, and recording of revolution counter (transit-mixed concrete). If bonding mortar is produced on site, the above required information shall be provided as applicable.
d. Records of climatic conditions shall be collected on a daily basis and reported on a weekly basis.

e. Mix plant production records and summary of daily material use and RCC produced shall be submitted before the start of the next production shift. Production records shall include a comparison of actual materials used to the approved job mix.

f. Results of RCC moisture and wet density tests.

g. Results of uniformity tests.

h. Results of compressive strength tests.

i. Results of RCC temperature tests.

j. Lift maps shall be submitted before the start of the next production shift.

4. Personnel

There shall be a supervisor who is responsible for all aspects of the RCC operation and a plant operator who is solely responsible for batching and mixing. The supervisor and the plant operator shall have responsible experience on at least one previous RCC job in the same position for which they are being considered for the current job.

There shall be at least one person whose sole responsibility is the oversight of the RCC curing activities.

5. RCC mix design

The contractor shall be responsible for the mix design and selection of all materials to be used in the design mix. The materials and proportions so stated, when approved, shall constitute the job mix. The job mix(s) shall be prepared to meet the quality, consistency, and strength of the RCC specified.

The contractor shall conduct the mix design program at a materials testing laboratory staffed by American Concrete Institute (ACI) Certified Grade II Concrete Laboratory Testing Technicians.

**Trial mix design parameters**—The aggregate gradation shall be as specified. The bulk density and voids in each of the aggregate components and the combined aggregate shall be determined according to ASTM C 29.

The density, relative density, and absorption shall be determined according to ASTM C 127 for coarse aggregate and ASTM C 128 for fine aggregate.

The air content of each mix shall be determined according to ASTM C 231. The volume and tare weight of the air pot shall be determined according to ASTM C 138. After consolidating the RCC in the air pot and just prior to testing to determine the air content, the weight of the RCC and pot shall be determined according to ASTM C 138. The density of the RCC that is consolidated in the pot at the time of testing shall be computed.

The minimum compressive strength for the RCC job mix shall be as specified in section 22 of this specification.

Unless otherwise specified in section 22:

- A minimum of three separate mixes shall be developed in the laboratory.
- Pozzolan(s) shall comprise at least 20 percent (by volume), but shall not exceed 50 percent (by volume) of the cementitious materials.
- The remainder of the cementitious materials shall be comprised of Portland cement.
- A compaction curve (wet density only) shall be developed for each mix to determine the water content that corresponds to the maximum wet density of each mix. Compaction tests shall be performed in accordance with ASTM D 1557, adapted as follows:
The mold specified for Method C shall be used.

All mix components shall be included.

When the maximum size aggregate in the mix is larger than 3/4 inch, place the material in three layers into the mold and compact each layer with 94 blows of the hammer.

- A Vebe test shall be performed on each trial mix design to determine the Vebe consistency time in seconds and the wet density in pounds per cubic foot. The Vebe test shall be performed according to ASTM C 1170. The Vebe consistency time shall range from a minimum of 15 seconds to a maximum of 30 seconds.

**Theoretical air free density** — The theoretical air free density (TAFD) shall be computed for each of the three laboratory mixes in the mix design program. The TAFD is the maximum wet density that can be attained for a specific mix assuming there is no air (entrapped or entrained) in the mix. The TAFD shall be computed by dividing the sum of the individual weights of the mix components by the sum of the individual absolute volumes of the mix components. The absolute volume is the volume of the solid matter in the particles, exclusive of the volume of voids between the particles. The absolute volume of each mix component is determined as per ACI 211. The saturated surface dry weight and density of the aggregate shall be used when computing the TAFD.

**Laboratory compressive strength** — Fifteen compressive strength cylinders from each RCC mixture shall be prepared in accordance with ASTM C 1176 or C 1435 and weighed to determine the density of the RCC within each cylinder. Any cylinder that weighs less than 98 percent of the weight of the heaviest cylinder shall be discarded and another cylinder prepared and weighed until all 15 cylinders have a weight that is at least 98 percent of that of the heaviest cylinder. The water content of each mixture, from which cylinders are made, shall be within 0.5 percent of the water content that corresponds to the maximum wet density determined in accordance with ASTM D 1557. Three cylinders from each RCC mixture shall be tested at 7, 14, 28, 90, and 180 days for compressive strength in accordance with ASTM C 39.

The average of the two closest 28-day strength values shall represent the 28-day compressive strength of the mix. The 28-day compressive strength of at least one of the mix designs shall be 75 percent to 100 percent of the specified strength. The 28-day compressive strength of at least one of the mix designs shall be 100 percent to 125 percent of the specified strength. The 28-day compressive strength of the remaining mix design shall approximate the specified strength.

The cementitious materials content that will be used for the job mix will be based on the results of the 28-day compressive strengths of the three laboratory mix designs. The 28-day compressive strengths of each of the three laboratory mix designs will be plotted to form a curve showing the relationship of the cementitious materials content to the 28-day compressive strength of the laboratory mix designs. A cementitious material content shall be selected from this curve corresponding to the 28-day compressive strength specified in section 22. The proposed job mix shall be proportioned to contain the selected cementitious materials content and shall be submitted for approval.

After the job mix has been approved, neither the source, character, or grading of the aggregates; nor the source mill, type, brand, or quantity of the cement; nor the source, type, or quantity of the pozzolan; nor the type, brand, or quantity of the chemical admixture(s) used shall be changed without approval. Changes to the approved job mix will require submittal and approval of a new job mix that complies with the requirements of this specification.

6. **Test section**

Prior to RCC production the contractor shall construct a test section as part of the RCC placement operations. RCC production is defined as the mixing of RCC to be incorporated into the work and the placing and compacting of
RCC, to the specified density, within the specified lines and grades of the structure(s). Unless otherwise specified in section 22, the test section shall be installed at an approved location proposed by the contractor. If the contractor constructs the test section in a location that will be incorporated into the RCC structure, it shall be located in a noncritical part of the structure, and it shall be removed if it fails to meet the requirements of this specification. If the contractor constructs the test section in a location that will not be incorporated into the structure, the contractor shall remove and dispose of the test section upon completion of the testing requirements unless otherwise specified.

All RCC that is incorporated into the structure and placed prior to determining the AMD shall be compacted to a density that is at least 96 percent of the TAFD. All RCC incorporated into the structure after the AMD is determined shall be compacted to specification requirements.

The test section shall be used to demonstrate all techniques, materials, plant and equipment, and personnel to be used for RCC construction and quality control. Additional techniques, materials, equipment, and personnel shall be demonstrated in the test section as specified in section 22. Information gained will be used to evaluate the practical effectiveness of all techniques, materials, plant and equipment, and personnel to make minor adjustments to the mix and to determine the AMD of the approved job mix. The contractor shall allow for numerous stops and starts to facilitate the testing that is required to determine the AMD.

The test section shall be of sufficient size to allow the complete RCC placement and compaction operation to be conducted with the equipment operating at normal operating speeds.

When the test section is placed on soil, a minimum of two 12-inch lifts shall be placed, and tests for determining the AMD shall be conducted on the uppermost lift.

A section shall be constructed to determine the adequacy of the procedures implemented to construct vertical surfaces. Any surface that is not horizontal is, within this specification, considered to be a vertical surface. Unless otherwise specified in section 22, the tolerance of vertical surfaces shall conform to the requirements of section 18. The finish and appearance of formed and unformed vertical surfaces shall comply with the requirements specified in section 17.

The contractor and engineer shall conduct the pre-test section briefing to review the field status related to the preparedness, capability, and readiness of the contractor to construct the test section according to the approved plan. After test section construction and before RCC production, the contractor and engineer shall conduct the post-test section briefing to discuss adjustments to the techniques, materials, plant, equipment, and personnel that will be used in RCC production. The contractor shall submit in writing a final plan for RCC production methods, materials, plant, equipment, and personnel that will produce RCC that meets the requirements of this specification. Unless otherwise specified, the plan shall be submitted no later than 7 days prior to beginning RCC production. Written approval of the plan shall be required prior to beginning RCC production.

**Apparent maximum density**—AMD is the maximum RCC density of the approved job mix that can be attained by compacting the RCC with the production roller defined in section 13 of this specification. The AMD shall be greater than or equal to 98 percent of the TAFD. The AMD of the RCC shall be determined from the test section.

To determine the AMD, the RCC lift shall be compacted by successive passes of the production roller over the entire lift surface. (Note: The act of rolling forward past a point and then rolling in reverse past the same point is considered two passes.) Between passes of the production roller, in-place wet density tests (ASTM C 1040) shall be made at a depth of 12 inches. Density tests shall be initiated after the second pass of the production roller. A
minimum of two density tests shall be performed at a depth of 12 inches and at approved locations. Successive passes of the production roller, followed by density tests at the 12-inch depth, shall be made until the density of the lift no longer increases. When it appears that continued compaction will not increase the density, make two more passes of the production roller, each followed by a density test to document that the density is no longer increasing. Once it has been determined that the density measurement at the 12-inch depth is no longer increasing, density tests shall be taken in two locations at depths of 2, 4, 6, 8, 10, and 12 inches. If the maximum and minimum density values obtained in one test hole vary more than 2 percent of the maximum value obtained at that test hole, the contractor shall modify operations until this variation is no more than 2 percent.

When the density of the lift no longer increases and the density measurements taken at the specified depths vary no more than 2 percent of the highest value measured at one location, the density shall be measured at the 10-inch depth at six approved locations. If more than one of these density measurements results in values less than 96 percent of the TAFD, the contractor shall modify operations and repeat the process for determining the AMD. The AMD shall be the average of the in-place density test values that are greater than or equal to 96 percent of the TAFD of the job mix. If the AMD is less than 98 percent of the TAFD of the job mix, the contractor shall modify operations to attain an AMD that is at least 98 percent of the TAFD.

If a new job mix is approved during production of RCC, a new TAFD will be computed and a new AMD will be determined as previously specified.

Air content and density—The air content of the mix shall be determined according to ASTM C 231. The volume and tare weight of the air pot shall be determined according to ASTM C 138. After consolidating the RCC in the air pot and just prior to testing to determine the air content, the weight of the RCC and pot shall be determined according to ASTM C 138. The density of the RCC that is consolidated in the pot at the time of testing shall be computed.

Compressive strength tests—Fifteen compressive strength cylinders shall be prepared from the mix in accordance with ASTM C 1176 or C 1435 and weighed to determine the density of the RCC within each cylinder. Any cylinder that weighs less than 98 percent of the weight of the heaviest cylinder shall be discarded and another cylinder prepared and weighed until all 15 cylinders have a weight that is at least 98 percent of that of the heaviest cylinder. Three cylinders shall be tested at 7, 14, 28, 90, and 180 days, respectively, for compressive strength in accordance with ASTM C 39.

Unless otherwise specified in section 22 of this specification, the contractor shall extract 10 intact vertical core samples, in accordance with ASTM C 42, from a portion of the test section that has been placed to the specified density and cured in accordance with this specification. Core specimens shall be taken 13 days after the RCC is placed. The contractor shall test two samples at 14, 28, 56, 90, and 180 days, respectively, for compressive strength in accordance with ASTM C 42. Cores shall have a minimum length equal to one lift thickness and a nominal diameter of 6 inches.

7. Mix plant
The plant shall either be a batch-type pugmill or a continuous-flow pugmill. The pugmill shall be a twin shaft paddle-type mixer and shall have adequate capacity to produce a uniform RCC mix at a rate that will conform to the production schedule. The plant shall have a minimum capacity of 100 tons per hour.

The plant shall have demonstrated satisfactory reliable performance on similar mixes on other RCC projects with little or no down time because of mixer breakdown or other production-related problems, excluding normal maintenance. Satisfactory reliable performance of the proposed plant shall be documented by mixer uniformity tests from recent production work showing that the plant produced a mix of similar proportions that met the requirements for production rate and uniformity set forth in this specification.

The results of uniformity tests that are conducted after the plant is set up and calibrated may be substituted for documentation of reliable past plant performance. RCC produced during uniformity tests required herein shall not be incorporated into the test section or any permanent structure.
The contractor shall perform trial runs of the mixing and proportioning equipment, including uniformity tests if required.

**Accuracy.** Facilities shall be provided for the accurate measurement and control of each of the materials entering the RCC mix. Delivery of materials as they are discharged from the mixer and from any gob hoppers shall be within the tolerances shown in table 36–1.

<table>
<thead>
<tr>
<th>Material</th>
<th>Tolerance</th>
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<tbody>
<tr>
<td>Pozzolan, mass</td>
<td>± 2 %</td>
</tr>
<tr>
<td>Cement, mass</td>
<td>± 2 %</td>
</tr>
<tr>
<td>Aggregate, mass</td>
<td>± 3 %</td>
</tr>
<tr>
<td>Water, mass or volume</td>
<td>± 2 %</td>
</tr>
<tr>
<td>Chemical admixture, mass or volume</td>
<td>± 3 %</td>
</tr>
</tbody>
</table>

Component monitoring systems. The systems that meter individual mix components shall be interlocked with the plant control and shall warn the operator and shut down the plant if any component is not feeding into the mixing chamber.

Aggregate bins. A separate bin shall be provided for each gradation of aggregate supplied for the RCC mix. The bins and associated conveyors shall be capable of discharging and conveying the aggregates at a uniform rate without clogging, under all conditions.

Portland cement and pozzolan silos. All onsite storage facilities and connection hoses shall be properly labeled with readily visible signage. The storage silo(s) shall be weather tight to prevent moisture and contaminants from accessing the portland cement and pozzolan. Blended cement/pozzolan products mixed by the cement manufacturer are permitted. Silos shall be capable of dispensing at a uniform rate without clogging or bridging of the materials.

Portland cement, pozzolan, and aggregate feed. For a continuous-flow pugmill, the portland cement, pozzolan, and aggregates shall be uniformly, continuously, and simultaneously fed into the mixing mechanism at the appropriate ratios. Each bin opening shall be provided with a gate that can be maintained at the necessary opening size to consistently provide the correct feed rate. The bins shall be of sufficient size to assure a uniform flow of aggregate at a constant rate. Portland cement and pozzolan shall be fed continuously by a feed device that is adjustable to ensure a uniform flow of cement and pozzolan at a constant rate for proportions established by the approved job mix. Feed device(s) shall be capable of gradual adjustment while in operation.

Water dispenser. A suitable water facility shall be provided that is capable of metering and dispensing the mix water within the specified tolerances. The mechanism for delivering water to the mixers shall be free from leakage. The meter shall measure the weight of water being added in pounds per unit time for continuous-flow pugmills, and weight per batch for batch-type pugmills. The valve shall be capable of gradual adjustment during the mixing process to compensate for varying moisture contents in the aggregates.

Admixture dispenser. The liquid admixture dispensing system shall be capable of metering and dispensing within the specified tolerances. The dispenser shall be designed and installed in such a manner that will permit convenient checking of its accuracy and will assure uniform distribution of the liquid admixture with water to the materials entering the mixer. The system shall be leak-free and designed and installed to prevent backflow or siphoning.
Mixing mechanism. The mixing mechanism shall be capable of combining the materials into a uniform mixture and discharging this mixture without segregation. The mixing mechanism shall produce a mix that meets the uniformity requirements listed in table 36–2.

Uniformity tests. When a continuous-flow pugmill is used, the three samples for obtaining uniformity tests shall be taken from RCC produced near the beginning, the middle, and the end of a production run lasting a minimum of 1 minute. When a batch-type pugmill is used, the samples shall be taken from RCC produced from three separate batches. Each batch shall be similar in size, be produced by charging the mixer in a similar manner, be mixed at the same mixing speed and mix retention time as the other two batches, and be representative of a normal production run.

<table>
<thead>
<tr>
<th>Test</th>
<th>Allowable max. difference (^1)</th>
<th>ASTM standard</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water content of full mix (% by weight)</td>
<td>10%</td>
<td>C 566</td>
</tr>
<tr>
<td>(Select one of the ASTM standard tests listed)</td>
<td></td>
<td>D 2216</td>
</tr>
<tr>
<td></td>
<td></td>
<td>D 3017</td>
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<td></td>
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<td>D 4643</td>
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<td></td>
<td></td>
<td>D 4959</td>
</tr>
<tr>
<td>Coarse aggregate content (% by weight)</td>
<td>10%</td>
<td>C 685 (annex)</td>
</tr>
<tr>
<td>Density (lb/ft(^3)) of full mix</td>
<td>2%</td>
<td>C 1170, C 1176, C 1435</td>
</tr>
<tr>
<td>Compressive strength at 14 days (lb/in(^2))</td>
<td>15%</td>
<td>C 39 (^2)</td>
</tr>
</tbody>
</table>

\(^1\) The allowable maximum difference = 100 multiplied by the (maximum value – minimum value) divided by the average of three tests.

\(^2\) Cylinders shall be made in accordance with ASTM Standard C 1176 or C 1435.

Mix record. The mix plant shall be capable of continually producing an RCC mix record. The record shall show the weight of portland cement, pozzolan, water, aggregate, and weight or volume of chemical admixture that is processed through the plant during a specific time interval. The time interval shall not exceed 30 minutes. The aggregate shall be reported in terms of saturated surface dry weight processed through the plant during a specific time interval. The RCC mix record shall be produced at all times when the plant is producing a mix. The aggregate moisture shall be tested daily whenever RCC is being produced. The mix plant record shall include the aggregate moisture content tests upon which the batch proportions are based.

A summary shift record shall be provided. The record shall include the total quantity of each constituent in the mix, total quantity of RCC produced, and a comparison of the quantity of each constituent mixed per cubic yard to that of the job mix.

Noise pollution. The plant shall be operated to comply with all applicable regulations pertaining to noise pollution.

Pollution control. The plant shall be operated to comply with all applicable regulations pertaining to air and water quality.

8. Mixing
The plant shall be operated according to the manufacturer’s recommendations. The mixing mechanism shall be maintained in satisfactory operating condition and shall be cleaned after each production run. All supply bins and silos shall be kept sufficiently full to ensure a uniform and constant flow of all materials.
All RCC produced from the beginning of startup shall be disposed of at the location(s) specified in section 22 of this specification until a uniform mix of the required proportions is consistently being discharged from the mixer.

After a batch-type pugmill has been calibrated and has produced the job mix with the specified uniformity, the mix retention time shall not be reduced.

**Uniformity**—RCC uniformity shall be monitored by continuous visual inspection by the plant operator and by periodic visual inspection by contractor quality control personnel. The mix shall be visually inspected for uniformity by contractor quality control personnel at the beginning of each production run and at least once each hour during the production run. If it becomes apparent that the mixer is not producing a uniform mix of the proportions specified, RCC production shall be promptly discontinued until the problem(s) that caused the uniformity problem are discovered and corrected.

If a uniformity problem is suspected, the contractor shall conduct the tests listed in table 36–2, determine the maximum difference and compare to the allowable maximum difference, and take appropriate corrective measure(s).

Adjustments shall be made to the mixing plant as necessary to obtain the required uniformity and consistency of the RCC mix when uniformity test results indicate that the requirements for uniformity are not being met. The production and placement of RCC may proceed without waiting for the compressive strength results if the results of the other three tests listed in table 36–2 are within the allowable maximum difference and the issues that caused a uniformity problem are resolved.

### 9. Conveying

The RCC mix shall be conveyed from mixer to placement area as rapidly as practicable by methods that prevent segregation, contamination, and loss of water. The total length of time from the end of mixing until the RCC has been placed, spread, and compacted shall not exceed 45 minutes.

The contractor shall provide baffles to limit free fall of mixed RCC to a maximum of 5 feet at the discharge end of conveyors, within hoppers, and at other locations where the potential for segregation may occur. Chutes that tend to cause segregation, such as an inclined chute, will not be permitted.

**Communications**—Telephone, radio, or other voice communication shall be provided between all interim storage hoppers, the batch plant control, and the placement locations. The contractor shall provide the Government inspector the same form of communication.

**Temporary storage containers**—Gob hoppers shall be used for storage wherever the mixed RCC is temporarily accumulated prior to being loaded into hauling equipment and when direct conveyor systems do not otherwise provide continuous delivery to the final placement location. Gob hoppers shall be configured to allow free flow of RCC without segregation or choking.

**Conveyor belts**—The conveyor system design and layout shall provide for adequate capacity, speed, reach, and pivot points to convey RCC to all placement areas.

Conveyor belts shall be designed, erected, operated, and maintained in a manner that meets production requirements and does not segregate materials. RCC shall not be exposed on any belt for a period exceeding 5 minutes without being protected from the drying elements of wind and sun. RCC shall not be exposed on any belt during rainfall unless it is protected from the rain.

**Hauling equipment**—Equipment shall be maintained in good operating condition and shall not be permitted onto the RCC surface when vehicle fluids are leaking or when there is a potential for contamination to the RCC.
RCC may be hauled using trucks, front-end loaders, or scrapers. Hauling equipment that rut, score, mar, or indent the RCC surface shall not be operated directly on previously compacted RCC surfaces. Hauling equipment shall not track mud or other contaminants onto previously placed RCC and shall not be operated directly on uncompacted RCC. All hauling vehicles shall be operated in a manner that prevents tight turns, sudden stops, or other actions that cause damage or displacement to previously compacted RCC. The contractor shall implement necessary measures to prevent contamination or damage of the previously compacted RCC.

10. Weather

**Adverse weather**—In adverse weather (heavy rain, severe cold, heavy snow, and hot temperature) where the conditions specified herein for RCC construction cannot be maintained, an interruption in placing operations shall be required.

**Weather station**—The contractor shall install and maintain a weather station onsite at all times during performance of the test section and the production and placement of RCC. The weather station shall be located at an approved location near the RCC structure. The weather station shall record wind speed, ambient temperature, humidity, and the rate and cumulative volume of rainfall. A record of climatic conditions at the designated location including wind speed, ambient temperature, humidity, and rainfall rate and volume shall be recorded daily.

**Wet weather placement**—RCC shall be protected from rainfall induced erosion and shall not be placed during rainfall events at a rate equal to or greater than 0.1 inch in 20 minutes. Placement during a light mist may continue when covered belt conveyors rather than hauling vehicles are used to convey the mix. Placement of RCC will not be permitted when rainwater accumulates on compacted RCC surfaces.

**Cold weather placement**—RCC shall not be placed when the ambient air temperature drops below 35 degrees Fahrenheit or the temperature of the RCC mix is less than 40 degrees Fahrenheit.

**Hot weather placement**—The maximum temperature of the RCC at time of placement shall be as specified in section 22. After placing, but prior to compaction, the temperature of the mix shall be determined according to ASTM C 1064. When the RCC temperature is within two degrees of the specified limit it shall be measured every hour. Introduction of chilled water and/or ice, shading and/or cooling of the aggregates, or other measures may be required in the production of RCC to maintain the RCC temperature within the specified requirements. If the RCC temperature exceeds the maximum specified temperature, RCC placement shall be suspended until cooler weather or additional measures to reduce the RCC temperature results in a reduction of the placement temperature of the RCC to or below the specified maximum temperature.

11. Foundation preparation

Prior to the start of RCC placement, the foundation shall be excavated or filled to the specified lines and grades as shown on the drawings. The foundation shall be free of standing water and any organic or loose materials. All surfaces where RCC installation is specified shall be damp and have a surface temperature not less than 35 degrees Fahrenheit at time of placement. Placement of RCC on mud, dried earth, uncompacted fill, standing water, or frozen subgrade is not permitted.

**Earthen foundations**—Earthen foundation surfaces shall be prepared by adjusting the moisture content and compacting the foundation. The moisture content, depth, and degree of compaction required shall be as specified in section 22. If the earthen foundation is allowed to dry after compaction, it shall be moistened prior to placing RCC. The foundation surface shall be firm and damp.
Rock foundations—Rock foundations shall be cleaned and prepared as specified in Construction Specification 63, Treatment of Rock Surfaces. The slope of the finished foundation surface shall not be steeper than one horizontal to one vertical. Rock surfaces shall be damp at the time of RCC placement.

12. Placing and spreading
The placement of RCC into the structure shall be performed in a virtually continuous non-stop operation.

All equipment used on the RCC fill shall be maintained in good operating condition at all times. Equipment shall not drip or spill oil or other contaminants onto the RCC. Any equipment that contaminates the RCC mixture shall be promptly removed from contact with the RCC and repaired or replaced. Any contaminated RCC mixture shall be removed and replaced.

Placing and spreading shall be performed with equipment that does not mar or contaminate the surface of the compacted RCC. Track-type equipment shall not operate directly on compacted RCC unless the tracks are equipped with rubber pads. Equipment used to deposit, spread, or compact shall not turn on previously compacted RCC.

Layout of the placement area—The RCC shall be spread in level lifts across the entire area of the structure. The direction of RCC placement shall be parallel to the long axis of the structure so that the number of lanes and the number of edge joints are minimized. Transverse joints of adjacent lanes shall be offset by no less than 20 feet horizontally.

Placing—RCC mix, bonding mortar, Portland cement, neat cement grout, or concrete shall not be placed on previously placed layers that have not been compacted to the specified density.

Roller compacted concrete mix shall be deposited as near to its final location as possible. When haul vehicle delivery is used, depositing shall be accomplished with a dump-spread action while the placing vehicle is moving. Belt placement shall discharge with a spreading action that does not segregate the material. RCC shall not be deposited directly against formwork or other vertical surfaces. Piles that form when placing RCC shall not contact forms or vertical surfaces. Neither the discharge height nor the pile height of RCC shall exceed 5 feet.

Spreading—Spreading of the RCC shall be completed within 10 minutes following depositing. RCC shall be spread into an uncompacted, uniform lift thickness that can be compacted to produce a lift of the specified thickness and density. In areas requiring special compaction, it may be necessary to deposit, spread, and compact the RCC in several layers to produce a lift of the specified thickness and density.

Equipment shall not operate directly on any surface that has been cleaned and prepared to receive a subsequent lift of RCC.

Spreading of RCC material shall be performed with a track-type bulldozer in a manner that will not cause damage to previously compacted RCC.

With RCC placement at or near its final location, spreading will typically be limited to leveling the RCC into uniform lifts. In isolated or confined placement locations, the RCC may be deposited and spread up to a maximum distance of 50 feet provided segregation does not occur, specified spreading time is not exceeded and the time specified between mixing and a completion of compaction is not exceeded. The contractor shall conduct placing and spreading operations in a manner that will prevent segregation of RCC.

If segregation of RCC occurs during the spreading operation, it shall be corrected by immediately reworking the RCC. Reworking shall be performed using techniques that do not damage previously compacted RCC. This may require removing the RCC from the lift surface to accomplish reworking, then transporting the mix back onto the
surface after mix uniformity has been achieved. If reworking the RCC does not produce a uniform mix, the segregated RCC shall be wasted and replaced.

If a uniformity problem is suspected, uniformity tests shall be performed from material taken from the placement area following spreading of the material and/or other points in the RCC production process as required to identify the source of the problem. Three individual samples of the material shall be taken at the sample location at intervals of 5 minutes or more. Uniformity tests shall be conducted in accordance with table 36–2. The maximum difference between the resulting values shall be compared to the allowable maximum difference and appropriate corrective measure(s) shall be employed.

13. Compaction
The entire surface area of each RCC lift shall be compacted to the specified density, as determined from the apparent maximum density (AMD) specified in section 6, with adequate compaction overlap to assure complete compaction of the RCC.

The in-place wet density of the compacted RCC measured at a depth of 10 inches shall not be less than 98 percent of the AMD.

Uniformity of density shall be achieved within each lift. The difference between density measurements at any two depths shall not exceed 2 percent of the greater of the two values.

The wet density of the compacted RCC shall be tested in accordance with ASTM C 1040. The moisture content of the compacted RCC shall be tested in accordance with ASTM D 3017. Unless otherwise specified in section 22, a minimum of three moisture and density tests will be performed on each lift of RCC with no less than one density measurement and moisture measurement for each 100 cubic yards of RCC compacted.

Production compaction shall be performed with production rollers as defined in this section. RCC compacted with production rollers shall be compacted in single lifts that are 12 inches thick (plus/minus one inch) after the specified density has been achieved.

Production rollers shall consist of single or double drum, large, self-propelled vibratory rollers. The roller(s) shall transmit a centrifugal force to the surface through a smooth steel drum(s) by means of revolving weights, eccentric shafts, or other equivalent methods. Production rollers shall impart a centrifugal force of at least 450 pounds per inch of drum width at the operating frequency during compaction. Production rollers shall operate at a vibrating frequency of at least 1,500 vibrations per minute and have a drum diameter of 4 to 6 feet and a drum width of 5 to 8 feet. The amplitude of vibration of the roller shall be between 0.03 and 0.07 inch. The roller shall not travel at greater than 2 feet per second during the compaction operation.

Production rollers shall be operated in open areas where they can compact RCC to the specified density within the specified time and without damage to the structure, forms, foundation, or appurtenances.

Rollers shall be only operated in the vibratory mode while actively compacting the RCC. After the RCC has been deposited and spread, rollers may be operated in static mode to smooth and/or firm up the surface, but shall operate in the vibratory mode to compact the RCC to the specified density. Compaction shall be completed with the roller operated in the static mode, as necessary, to achieve the specified density near the surface of the lift.
The contractor shall select the combination of frequency of vibration, amplitude of vibration, and speed of operation that result in the specified density at the fastest production rate while meeting all other requirements.

Placement and compaction of RCC shall be completed without damaging the structure, other structures, forms, foundation, or other embedded appurtenances. Any appurtenance damaged by the compaction process will be repaired or removed and replaced at the contractor's expense.

Special compaction techniques shall be performed using special compaction rollers and power tampers in areas where production rollers cannot maneuver or will cause damage to the structure, forms, foundation, or appurtenances. RCC shall be deposited, spread, and compacted in 4 or 6 inch thick layers as required to obtain uniform specified density throughout the 12-inch lift with limited compaction to avoid drying the surface.

The individual layers that compose one lift shall be deposited, spread, and compacted within 1 hour from the time the first layer within that lift is placed.

Special compaction rollers shall be vibratory rollers that are capable of operating in confined areas and adjacent to forms, foundation, or appurtenances without damage to the RCC structure or appurtenances. Special compaction rollers shall produce a centrifugal force of at least 150 pounds per linear inch of drum width for each drum of a double drum unit and 300 pounds per linear inch of drum width for a single drum unit. Special compaction rollers shall be operated at a speed less than 2 feet per second during the compaction operation.

Power tampers shall develop a force per blow of at least 3,500 pounds per square foot. The maximum layer thickness to be compacted by power tampers shall be plus or minus 6 inches after the specified density has been achieved.

The contractor shall maintain at least one special compaction roller and two tampers in operating condition at the site during RCC placement.

Manually directed vibratory plate compactors may be used to shape, smooth, and level the surface, but shall not be used as a substitute for vibratory rollers and power tampers.

14. Record testing

Unless otherwise specified in section 22, one set of RCC cylinders for compressive strength tests shall be obtained for each 1,000 cubic yards of RCC placed to be used for compressive strength testing.

Each set shall consist of 15 compressive strength cylinders prepared in accordance with ASTM C 1176 or C 1435 and weighed to determine the density of the RCC within each cylinder. Any cylinder that weighs less than 98 percent of the weight of the heaviest cylinder shall be discarded and another cylinder prepared and weighed until all 15 cylinders have a weight that is at least 98 percent of that of the heaviest cylinder. Three cylinders shall be tested for compressive strength in accordance with ASTM C 39 at 7, 14, 28, 90, and 180 days, respectively, after the specimens are molded.

Unless otherwise specified in section 22 of this specification, the contractor shall extract two sets of vertical core RCC samples in accordance with ASTM C 42. Each set shall be sampled from RCC that has been placed in the structure at no less than 1 week apart. Each set shall contain eight intact cores taken from the structure at approved locations. Cores shall have a minimum length equal to one lift thickness and a nominal diameter of 6 inches. Core specimens shall be obtained no earlier than 20 days after placement. The contractor shall test two samples at 28, 56, 90, and 180 days, respectively, after placement for compressive strength in accordance with ASTM C 42.
15. Lift joints
The term joint, as used in this specification, applies to all surfaces that will eventually be covered by RCC mix, bonding mortar, Portland cement, neat cement grout, or conventional concrete.

The joint treatment method shall be as specified in section 22.

Joint condition—Three potential joint conditions will exist during construction: fresh joint, intermediate joint, and cold joint. The condition of a joint shall be defined on the basis of joint maturity or time of exposure. Joint maturity is defined as the product of the average RCC surface temperature (AST) in degrees Fahrenheit and the time of exposure (TE) in hours. Joint maturity is expressed in degree-hours (deg F-hr) and is calculated as:

\[
\text{Joint maturity in deg F-hr} = (\text{AST}) \times (\text{TE}).
\]

The TE shall be the period, expressed to the nearest quarter hour, beginning when the compaction of RCC is completed and ending when covered by the subsequent placement of RCC, bonding mortar, Portland cement, neat cement grout, or conventional concrete.

Whenever the joint condition is defined on the basis of joint maturity, the AST shall be determined hourly during the exposure period by measuring the RCC surface temperature at various locations with a surface thermometer. The temperature shall be measured in degrees Fahrenheit and the temperature readings averaged to determine the AST.

A fresh joint is defined as a joint having maturity of 400 deg F-hr or less. In lieu of determining the joint maturity, a fresh joint may be defined as a joint with a TE of 4 hours or less.

An intermediate joint is defined as a joint having a maturity greater than 400 deg F-hr, but less than or equal to 1,600 deg F-hr. In lieu of determining the joint maturity, an intermediate joint may be defined as a joint with a TE of more than 4 hours, but less than 16 hours.

A cold joint is defined as a joint having a maturity of over 1,600 deg F-hr. In lieu of determining the joint maturity, a cold joint may be defined as a joint with a TE of 16 hours or more.

Joint treatment—All joint surfaces shall be kept continuously moist, clean, and uncontaminated until placement of succeeding RCC lifts. Water that ponds on a finished surface shall be removed prior to placing RCC.

The surface of previously placed RCC shall be free of soil, dust, or other contaminants prior to being covered with joint treatment material or another layer or lift of RCC. Cleaning of previously placed RCC lifts shall be accomplished by pressurized water and/or air or other methods provided that the surface of the in-place layer is not damaged by the cleaning operation.

The contractor shall have a pressure washer and a blowpipe onsite capable of delivering a combined air-water mixture, with the ability to adjust the pressure, volume, and proportion of air and water.

Edge joints that are exposed for more than 30 minutes shall be trimmed back no less than 9 inches to an RCC surface, that has been compacted to the specified density and beveled at a slope of one horizontal to one vertical. Immediately before placing RCC against a trimmed surface, the joint condition shall be determined and the specified joint treatment shall be applied.

Any surface to be covered with RCC, a bonding material or conventional concrete that is damaged to the extent that over 25 percent of the exposed coarse aggregate is undercut shall be treated as a cold joint. Coarse aggregate with less than half of it surface area remaining embedded and bonded to the RCC is considered undercut.
All RCC materials removed by cleaning, brooming, smoothing, beveling, or trimming layers shall be collected and removed from the structure.

**Treatment Method I.** Remove any loose materials and contaminants from the lift joint surface. The lift joint surface shall be cleaned using moderate-pressure air immediately before spreading the next RCC lift. Maintain the surface in a moistened condition.

**Treatment Method II.** Perform Treatment Method I. Before the placement of RCC on the joint surface, uniformly distribute a layer of dry Portland cement over the surface. The Portland cement shall be applied at a rate of 0.5 to 1 pound per square foot of surface. The amount of water applied to the lift surface before, during, or after distributing the cement shall be of sufficient quantity to dampen all of the cement. The ratio of water to cement shall be limited to that which will produce a tacky paste. Water applied after the cement is distributed shall be applied in a fine mist to prevent the displacement of cement. The cement shall be applied immediately ahead of placing the next layer or lift of RCC. The cement shall not be exposed on the surface more than 10 minutes before being covered with RCC. Portland cement paste that does not meet these requirements shall be removed from the structure and disposed of, and the treatment method shall be repeated.

**Treatment Method III.** Perform Treatment Method I. Before the placement of RCC, the joint surface shall be covered with a layer of the bonding mortar specified in section 2. The thickness of the bonding mortar shall be 0.25 to 0.5 inch. The bonding mortar shall be covered with the next layer or lift of RCC while the mortar is still fluid. In no case shall the bonding mortar remain uncovered for more than 30 minutes. Bonding mortar shall be placed in a manner that will avoid segregation. Bonding mortar that does not meet these requirements shall be removed from the structure and disposed of, and the treatment method shall be repeated.

16. **Curing and protection**

**Curing**—Curing of RCC shall begin immediately after compaction. All exposed and completed RCC surfaces shall be cured for a minimum of 14 days at or above 40 degrees Fahrenheit following placement. All repairs including that required to fill holes associated with form anchorages and coring shall be cured for a minimum of 7 days at or above 40 degrees Fahrenheit following repair.

If the RCC is wet cured, the RCC shall be maintained in a continuously damp condition for the entire curing period. The continuous application of water supplemented by the use of a saturated cover material or an impermeable covering shall be required to obtain the continuously damp condition. The application of water or cover material shall not erode, mar, or otherwise damage the RCC. Plastic or paper covering shall meet the requirements of ASTM C 171. Only white or reflective coverings shall be used during hot weather as defined by ACI 305.

In lieu of wet curing, RCC that will not be covered with subsequent joint treatment, RCC, or conventional concrete may be treated with a curing compound as specified in section 2, unless otherwise specified in section 22. Areas to be cured with curing compound shall be kept continuously moist until curing compound is applied. Curing compound shall be thoroughly mixed before applying and be agitated during application. A continuously agitating pressure sprayer shall be used to apply the curing compound at a uniform rate of not less than double the curing compound manufacturer's recommended rate for conventional concrete curing. Manual hand pump sprayers shall not be used. A brush or paint roller shall be used in areas that are near unmasked surfaces that will be covered with subsequent joint treatment, RCC, or conventional concrete. The curing compound shall form a uniform, continuous, adherent film that shall not check, crack, or peel and shall be free from pinholes or other imperfections. Multiple applications of curing compound may be necessary to achieve the specified coverage. When multiple applications are required, the second application shall be applied at a 90 degree angle to the first application. During
the curing period, curing compound shall be reapplied 7 days after the initial application. In areas where the curing compound is damaged, it shall be reapplied immediately.

Curing compound shall not be applied to areas that are to be repaired or patched. Areas to be repaired or patched shall be kept continuously moist until the repair is made. Curing compound or wet curing shall then be implemented to conform to curing requirements specified herein. Any curing compound applied to areas that are to be repaired or patched shall be removed prior to applying the repair material.

Regardless of the curing method used, curing activities shall not be discontinued or interrupted until the RCC has remained at or above 40 degrees Fahrenheit for a total of 14 days. This will require extending the curing period by the number of days that the RCC temperature drops below 40 degrees Fahrenheit during the curing period.

**Protection**—The temperature of RCC shall be maintained at or above 35 degrees Fahrenheit from the time the RCC is placed until 7 days after the curing period. When ambient temperatures are expected to be below 32 degrees Fahrenheit, measures shall be implemented to protect the RCC from freezing. The protection shall remain in place until ambient temperatures remain continuously above 35 degrees Fahrenheit for 24 hours. Protective measures shall not hinder the specified curing of the RCC.

RCC shall be protected from damage by precipitation, vehicular traffic, or other causes.

**17. Vertical surfaces**

Unless otherwise specified in section 22, all formed RCC vertical surfaces that are subject to exposure shall be finished to ensure a minimum of 80 percent of the surface area is free from honeycomb or other voids and is uniform in appearance.

Forming is not required for vertical RCC surfaces that are not subject to permanent exposure.

The finish and appearance of unformed vertical surfaces shall comply with the requirements specified in section 22.

**18. Tolerances**

Any variation in the face or surface of the finished RCC shall be within the tolerances stated herein.

The structure(s) shall be constructed to the lines and grades depicted on the drawings.

The thickness of compacted lifts of RCC shall be 12 inches plus or minus 1 inch.

The allowable tolerance of all exposed formed surfaces shall be plus or minus 0.1 foot from specified line. Abrupt changes shall not exceed 0.05 foot in any exposed formed surface.

Limit gradual overbuild of exposed unformed RCC faces to 0.5 foot. Under build will not be allowed.

Do not exceed 0.1 foot in 10 feet variation in an unformed, exposed RCC face as measured in a straight line along the length and height of the face, or 0.5 foot over the entire length of the structure. Abrupt changes shall be less than 0.1 foot.

The elevation of any horizontal RCC surface shall be plus or minus 0.1 foot of the specified grade except that the elevation of a finished top of dam or spillway crest shall be no more than 0.1 foot above the specified elevation.
19. Repair of RCC

**Repair or replacement**—The contractor shall repair or replace RCC that does not meet the requirements of this specification. Before starting any repair or replacement work, the contractor shall prepare a written plan for the repair or replacement. The primary reference for material and repair methods for the plan shall be the appropriate sections of the American Concrete Institute's Manual of Concrete Inspection. The repair plan shall be submitted for review and approval at least 10 days before any repair or replacement work.

**Patching**—All form bolts, metal ties, and similar forming restraints shall be removed to a depth of 1 inch below the surface of the RCC and their cavities repaired unless otherwise specifically permitted or specified in section 22. Small cavities large air holes, minor honeycombed areas, holes created from test coring, and other superficial imperfections that require patching to meet the specified finish requirement shall be thoroughly cleaned and filled. Holes left by bolts or straps that passes through the RCC shall be filled solid with a dense, well-bonded nonshrink patching material. Dry-pack mortar and replacement concrete shall follow the appropriate procedure detailed in the Repair and Maintenance chapter of the Concrete Manual, Bureau of Reclamation, U.S. Department of the Interior. Proprietary patching material shall be appropriate for the type of repair used within the manufacturer’s recommended limits and applied according to the manufacturer's recommendations.

When proprietary patching material is proposed in the plan, the manufacturer's data sheets and written recommendations shall be included in the plan.

Repair material or replacement concrete shall have properties, color, and texture similar to and compatible with the concrete being repaired or replaced.

Curing of repaired or replaced concrete shall be started immediately after finish work is completed as specified in section 16 or as specified by the manufacturer of proprietary compounds.

20. Cleanup of spillage

All loose gravel and uncompacted RCC material shall be removed from the structure for disposal in approved location(s) or as specified in section 22 and shall not be recycled into the RCC mix.

21. Measurement and payment

For items of work for which specific unit prices are established in the contract, the volume of RCC is measured and computed to the nearest cubic yard by the method of average cross-sectional end areas. Unless otherwise specified in section 22, no deduction in volume is made for embedded items, such as, but not limited to conduits, inlet structures, outlet structures, embankment drains, sand diaphragm and outlet, and their appurtenances.

The volume of RCC shall be determined by measuring from the surface of the foundation when approved for RCC placement to the specified neatlines of the completed RCC structures, unless otherwise specified in section 22.

If the test section is not incorporated into the RCC structure, the volume of RCC placed into the construction of the test section will be added to the volume computation of the completed RCC structure to determine the total volume of RCC for payment. If the test section is incorporated into the RCC structure, no addition volume of RCC shall be included for payment.

When the test section is paid for under a separate bid item, the test section will not be measured for payment. Payment will be made at the contract lump sum price for the test section and will constitute full compensation for the completion of the test section including any removal and disposal as applicable.
Payment for the RCC, for which a specific unit price is established in the contract, will be computed to the nearest cubic yard. Payment shall constitute full compensation for furnishing all labor, materials (except cementitious materials), equipment, tools transportation, and all other items necessary and incidental to the construction and removal of the test section and construction of the RCC structure, including joint treatment, trimming and removal, repair, replacement, patching, curing, protection, site clean up, and disposal of spillage and waste materials. Payment for treatment of rock foundation surfaces, if any, shall not be included in the payment for RCC. Payment will not be made for RCC material that is wasted or rejected for failure to comply with this specification.

Payment for each cementitious component of the RCC, for which a separate bid item is included in the contract, shall include the quantity incorporated into the RCC structure and test section. This quantity shall be computed based on statement of delivery tickets. Payment will not be made for any cementitious materials not incorporated into the structure(s) or test section.

Payment for the cementitious materials for which specific unit prices are established in the contract will be to the nearest 0.1 ton of cementitious materials.

Compensation for any item of work described in the contract, but not listed in the bid schedule will be included in the payment for the item of work to which it is made subsidiary. Such items and the items to which they are made subsidiary are identified in section 22.

22. **Items of work and construction details**