Introduction to Roller-Compacted Concrete Pavements

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1. APPLICATION. Procedures and criteria described here are applicable to the design and construction of roller-compacted concrete (RCC) pavement (RCCP).

2. GENERAL. Roller-compacted concrete pavement employs a concrete paving technology that involves laydown and compaction of a zero-slump concrete mixture using equipment similar to that used in placement and compaction of asphaltic concrete pavement. By using these construction techniques, the potential exists to save one-third or more of the cost of conventional concrete pavement. Although the concept and technology behind RCCP is relatively new, RCCP has already proven itself cost-effective in several projects including log-sorting yards, port facilities, heavy equipment parking areas, tank trails, and haul roads.

3. SUBGRADE AND BASE COURSE PREPARATION. The subgrade and base course should conform to the requirements outlined in the professional literature. The freeze-thaw durability of RCCP is not fully understood yet, however, marginal performance has been observed in the laboratory. For this reason, in areas where the pavement or base course might be subjected to seasonal frost action, particular attention should be given to providing a base course that will adequately drain any water that infiltrates through the pavement or subgrade. The base course should provide sufficient support to permit full consolidation of the RCCP through its entire thickness upon compaction.

4. SELECTION OF MATERIALS.

4.1 GENERAL. One of the most important factors in determining the quality and economy of concrete is the selection of a suitable aggregate source. This is as true for RCC as for conventional concrete. Aggregate for RCC should be evaluated for quality and grading, and should comply with the provisions outlined below, with the exceptions noted in the following discussion.

4.2 COARSE AGGREGATE. The coarse aggregate may consist of crushed or uncrushed gravel, recycled concrete, crushed stone, or a combination thereof. The quality of coarse aggregate used to date in RCCP has generally complied with ASTM C 33, although satisfactory RCC maybe possible with coarse aggregate not meeting these requirements. Local state highway department coarse aggregate grading limits, for example, should generally be acceptable. A primary consideration should be that, regardless of the grading limits imposed, the grading of the aggregate delivered to the project site be relatively consistent throughout the production of RCC. This is an important factor in maintaining control of the workability of the concrete mixture. The nominal maximum aggregate size normally should not exceed 3/4 inch, particularly if pavement surface texture is a consideration. When aggregate larger than 3/4 inch is used, segregation and resulting rock pockets are likely to occur.

4.3 FINE AGGREGATE. The fine aggregate may consist of natural sand, manufactured sand, or a combination of the two, and should be composed of hard, durable particles. The fine aggregate quality should generally be based on the limits given in ASTM C 33 except that consideration should be given to relaxing the maximum 5.0 percent limit of material finer than the No. 200 sieve. The amount of material passing the No. 200 sieve has been increased in Canada to 8 percent of the total weight of aggregates with acceptable results. Sands with higher quantities of nonplastic silt particles maybe beneficial as mineral filler and may allow some reduction in the amount of cement required. However, mixtures made with fine aggregates having an excessive amount of clay may have a high water demand with attendant shrinkage, cracking, and reduced strength. Determination of the specific gravity and absorption of these sands with high quantities of fines should be made according to Note 3 in ASTM C 128.

4.4 OTHER AGGREGATES. Recent experience with RCC has shown that aggregate produced for uses other than portland cement concrete may also be successfully used as aggregate for RCC. Material produced for asphalt paving and base courses have both been used effectively as RCC aggregate. These materials typically have a higher percentage of fines passing the No. 200 sieve than conventional concrete aggregates and, as a result, may produce a “tighter” pavement surface texture. Because these aggregates range in size from 3/4 inch to the No. 200 sieve, control of the grading may be more difficult due to segregation. Therefore, careful attention must be directed toward stockpile formation and subsequent handling of a single size group aggregate.

4.5 CEMENT. Any available portland cement except for Type III portland cement, any blended hydraulic cement, or combination of portland cement with pozzolan or blended hydraulic cement with pozzolan should be investigated. If sulfate exposure is a problem, either Type II, Type V, or a moderate sulfate-resistant blended hydraulic cement should be used. The use of Type III portland cement will almost never be justified or practical for use in RCC due to shortened working times with this cement.

4.6 ADMIXTURES. A proper air-void system must be provided to prevent frost damage in concrete which freezes when critically saturated. Air-entraining admixtures have not proven to be effective in creating such air-void systems in RCC even when added at dosage rates 10 times that of conventional concrete. Therefore, to compensate for an inadequate air-void system, RCCP should have a low water-cement ratio, be fully compacted, and have a well draining base under the pavement. The low water-cement ratio and good compaction provide a material with a minimum amount of freezable water in the capillaries and has low permeability. As long as the RCCP is not critically saturated, it will not be damaged by freezing and thawing. Durability for resistance to freezing and thawing of RCCP is currently being investigated. Neither water-reducing nor retarding admixtures have been shown to improve the fresh properties of RCC in limited laboratory investigations. If the use of these admixtures is proposed, such use should be based on investigations which show them to produce benefits greater than their cost.

5. MIXTURE PROPORTIONING.

5.1 GENERAL. The basic mixture proportioning procedures and properties of conventional concrete and RCC are essentially the same; however, conventional concrete cannot be reproportioned for use as RCC by any single action such as: (1) altering proportions of the mortar and concrete aggregates, (2) reducing the water content, (3) changing the water-cement ratio, or (4) increasing the fine aggregate content. Differences in mixture proportioning procedures and properties are mainly due to the relatively dry consistency of the fresh RCC and the selected use of non-conventionally graded aggregates. The primary differences in the properties of RCC are: (1) RCC generally is not air entrained, (2) RCC has a lower water content, (3) RCC has a lower paste content, and (4) RCC generally requires a higher fine aggregate content to limit segregation. A number of methods have been used to proportion RCC including those found in ACI 211.3, ACI 207.5R, and ASTM D 558. The first two of these methods follow an approach similar to that used in proportioning conventional concrete. The third method treats the material as cement stabilized soils rather than concrete and establishes a relationship between moisture and the density obtained from a particular compactive effort.

5.2 ACI 207.5R METHOD. The primary consideration when using this method is proper selection of the ratio (P_v) of the air-free volume of paste (V_p) to the air-free volume of mortar (V_m). This selection is based primarily upon the grading and particle shape of the fine aggregate. The P_v affects both the compactability of the mixture and the resulting surface texture of the pavement. Ratios of 0.36 to 0.41 have been found to be satisfactory for mixtures having nominal maximum size aggregate of 3/4 or 1-1/2 inch. The fraction of fine aggregate finer than the No. 200 sieve should be included in V_p when calculations are made using P_v.

5.3 CONSISTENCY MEASUREMENTS. Since RCC has no slump, an alternative means of measuring mixture consistency must be used. Two consistency measurement methods have been used to date. One uses the Vebe apparatus as described in ACI 211.3, with the following modifications: (1) a 29-pound loose-filled sample is placed in the container and hand leveled, and (2) a total surcharge weight of 27.5 pounds is added. Consolidation is considered complete when mortar is visible around the bottom edge of the plastic surcharge disk. The second method follows the procedures generally described in ACI 207.5R. This method consists of measuring the time required to fully consolidate a sample of no-slump concrete by external vibration. Although both methods have been used successfully, the latter is more subjective and requires the use of a vibrating table having sufficient frequency and amplitude to fully consolidate the sample. Some commercially available tables have been found unsuitable without the use of a sample surcharge weight. A suggested minimum amplitude and frequency necessary to consolidate an RCC sample without using a surcharge weight are 0.0625 inch and 60 Hz, respectively.

5.4 SAMPLE FABRICATION. The strength of an RCC mixture is controlled primarily by the water-cement ratio and the degree of compaction attained. Most RCCP mixtures placed to date have had water-cement ratios ranging from 0.30 to 0.40. Laboratory strength determinations are made using fabricated flexural, compressive, and splitting tensile strength specimens. Conventional ASTM testing methods cannot be followed when fabricating these specimens due to the dry consistency of the concrete. The procedure being used is to fill cylinder molds in two layers and beam molds in a single layer, and consolidate each layer of concrete on a vibrating table. Vibration of each layer is continued until paste is discernible over the entire surface area. Use of a surcharge weight may be necessary to achieve this degree of consolidation. All specimens fabricated in the laboratory are to be cured according to ASTM C 192.

5.5 STRENGTH RESULTS. Test specimens fabricated and cured in the laboratory generally exhibit higher strengths than those cored or sawn from an RCCP. This is probably due to the higher unit weights normally obtained with the fabricated specimens and the more efficient laboratory moist curing. Laboratory test specimens generally have unit weights which are 98 to 99 percent of the theoretical (air-free) weight of the mixture, while core samples taken from RCCP normally have unit weights ranging from 95 to 98 percent of the theoretical weight. Therefore, fabrication of a companion set of test specimens having the lowest relative density allowed by the contract specifications should be considered during the laboratory mixture proportioning studies.

5.6 ASTM D 558 METHOD. Studies are currently being conducted to determine whether a proportioning method similar to ASTM D 558 is viable for RCC. Such a method would produce the optimum moisture content necessary to obtain maximum density for a particular set of materials and compaction procedures. Previous tests indicate that the optimum moisture content obtained by Method 100 (CE 55) of MILSTD 621 may produce a mixture too wet to allow efficient operation of a vibratory roller.

6. THICKNESS DESIGN.

6.1 GENERAL. The thickness design procedure for RCCP is the same as that used for conventional non-reinforced concrete pavements with no load transfer considered as outlined in the professional literature. Selected beams sawn from RCCP and tested for flexural strength indicate that the actual flexural strength of the pavement is 20 to 50 percent higher than the typical strength assumed in design for those pavements. This suggests that the thickness design for compacted RCCP should be modified based upon the 28-day strength of beams sawn from a test section constructed, using the same aggregate, cement, and construction procedure as planned for the entire work. However, until additional performance records and testing procedures are developed for RCCP, conventional pavement thickness design will be used.

6.2 LIFT THICKNESS. The maximum thickness of a lift of RCCP is governed by the ability of the pavers to place the RCCP in a smooth and continuous fashion. This maximum uncompacted thickness is usually 10 to 12 inches. The maximum uncompacted thickness can be approximated by multiplying the design thickness by 1.25, thus accounting for the reduction in thickness due to compaction. The minimum thickness of any lift should be 4 inches.

6.3 TWO-LIFT CONSTRUCTION. If the total uncompacted thickness exceeds the capacity of the paver, the RCCP should be placed in two or more lifts, thus creating a horizontal joint (or horizontal plane between the layers) in the RCCP. Sufficient bond develops at a fresh horizontal joint in RCCP (top lift placed within 1 hour of bottom lift) to allow the use of a monolithic thickness design. If the top lift is not placed within 1 hour of the bottom lift, the thickness should be designed as a rigid overlay of a rigid base pavement. The surface of the lower lift should be kept moist and clean until the upper lift is placed, and the upper lift should be placed and compacted within 1 hour of compacting the lower lift to ensure that a bond between lifts is formed. In two-lift construction, the uncompacted thickness of the first lift should be two-thirds the total uncompacted height of the RCCP (or the maximum lift thickness the paver can handle, whichever is smaller). The thinner section in the upper lift aids in creating a smoother final surface, and because of the smaller volume of material, allows the paver placing the second lift to move quicker than and follow closer behind the paver placing the first lift. Multiple lifts will be necessary if the total uncompacted thickness of the RCCP is greater than twice the maximum lift capacity of the paver.

7. TEST SECTION.

7.1 GENERAL. A test section should be constructed to determine the ability of the contractor to mix, haul, place, compact, and cure RCCP. The test section should be constructed at least one month prior to the construction of the RCCP at a location near the job site. The test section should be large enough to establish the rolling pattern for the vibratory and finish rollers, the correlation between laboratory and nuclear gage densities, and the correlation between the number of passes and relative density. The test section should contain both longitudinal and transverse cold joints and a fresh joint. A suggested minimum size is three 12- to 14-foot-wide lanes, each 150 feet long, with one and one-half lanes placed the first day and the rest placed the next day (see Fig. 1).

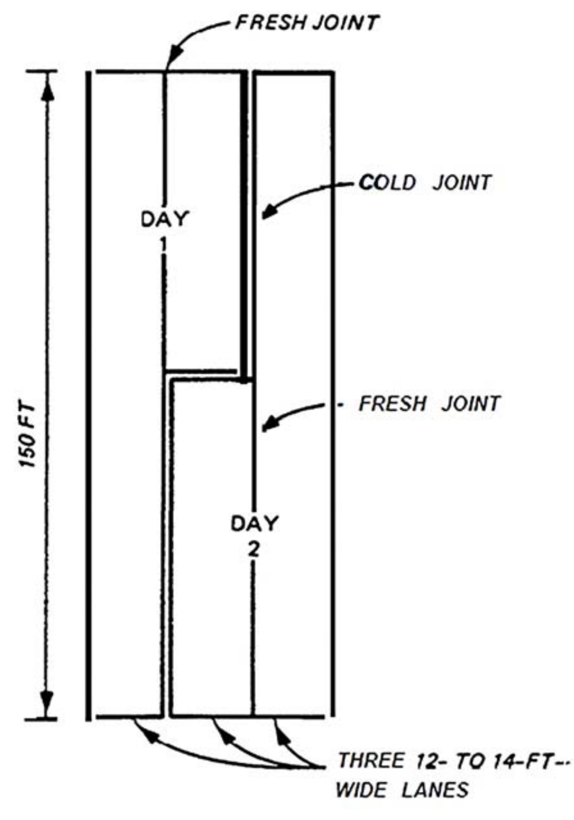

Figure 1

Typical layout for RCCP test section

7.2 OPTIMUM NUMBER OF ROLLING PASSES. During the test strip construction, a nuclear gage operated in the direct transmission mode and standardized with a calibration block should be used to determine the optimum number of passes with the vibratory roller to reach maximum density. The density should be measured by inserting the nuclear gage probe into the same hole after each pass of the vibratory roller. The hole should be made with an instrument specifically designed for this purpose, and should be formed using the same method throughout the test section and main construction. This rolling and measuring procedure should be continued until there is less than a 1 percent change in successive readings. These data may be used in conjunction with correlation between the nuclear gage and the laboratory density to determine the minimum number of passes needed to achieve or slightly exceed the specified density in the RCCP construction. However, a minimum of four vibratory passes should be used, and this minimum will probably prevail in most cases.

7.3 NUCLEAR GAGE/LABORATORY DENSITY CORRELATION. After a reasonable estimate is made of the optimum number of passes needed for compaction, a correlation between the value of in situ RCCP density as measured with the nuclear gage and the value obtained by weighing a sample of the RCCP in air and water should also be determined. This should be accomplished by measuring the final compacted density (after four or more passes with the vibratory roller) in 10 locations with the nuclear gage, which has been standardized with a calibration block. The measurement should be made by inserting the probe the full depth of the lane. Then, at 7 days, a pair of cores should be taken on either side of the remaining nuclear gage holes (within a 1- to 3-foot radius from the hole) and the density of the cores measured in the laboratory by weighing them in air and water. For each of the 10 holes, the average of the pair of the laboratory densities should be compared with their corresponding nuclear gage density, and a constant relationship between the nuclear gage and laboratory densities developed by averaging the algebraic differences in these readings. This difference should be combined with future field readings to obtain an adjusted reading which can be compared to the specified density. In the past a specified density of 96 percent of theoretical weight as defined in ASTM C 138 has been achieved. If the adjusted nuclear gage density is less than the specified density, additional passes should be made on the fresh RCCP until the specified density is reached. Two nuclear density gages should be calibrated (using the same holes) during the test section construction so that an extra one is available during final construction.

7.4 STRENGTH TESTS. Ten cores and beams should be taken from the test section after 28 days to determine a correlation between flexural strength and splitting tensile strength and/or compressive strength of the RCCP. This reduces the amount of sawing necessary to obtain samples during further construction. Although both the splitting tensile and compressive strength data would be useful for historical reference, only one of these tests is needed for quality control testing of the RCCP construction. After the correlation is determined, the appropriate splitting tensile and/or compressive strength that correlates to the specified design flexural strength should be used in any further quality control testing.

8. BATCHING, MIXING, AND TRANSPORTING. RCCP needs a vigorous mixing action to disperse the relatively small amount of water evenly throughout the matrix. This action has been best achieved by using a twin-shaft pugmill mixer commonly used in asphaltic concrete mixing. Batching of the concrete may be accomplished successfully in either a continuous mixing or a weigh-batch asphalt plant. The continuous mixing plant is recommended for batching RCC because it is easier to transport to the site, takes less time to set up, and has a greater output capacity than the weigh-batch plant. The weigh-batch plant allows more accurate control over the proportions of material in each batch, but generally does not have enough output capacity for larger paving jobs. The output of the plant should be such that the smooth, continuous operation of the paver(s) is not interrupted, and for all but the smallest jobs (1,000 square yards or smaller), the capacity of the plant should be no less than 250 tons per hour. The output (or production) of the plant should not be greater than the laydown capacity of the paver(s) nor greater than the rolling capacity of the rollers. The plant should be located as close as possible to the paving site, but in no case should the haul time between the batch plant and the paver(s) exceed 15 minutes. The RCC should be hauled from the mixer to the paver(s) in dump trucks. These trucks should be equipped with protective covers to guard against adverse environmental effects on the RCC, such as rain, or extreme cold or heat. The truck should dump the concrete directly into the paver hopper.

9. PLACING. For most pavement applications, RCCP should be placed with an asphalt paver or similar equipment. The paver should be equipped with automatic grade-control devices such as a traveling ski or electronic stringline grade-control device. A paver having a vibratory screed or one equipped with a tamping bar is recommended to provide a satisfactory surface texture and some initial compaction when the RCCP is placed. Necessary adjustments on the paver to handle the RCC include enlarging the feeding gates between the feed hopper and screed to accommodate the large volume of stiff material moving through the paver, and adjusting the spreading screws in front of the screed to insure that the RCC is spread uniformly across the width of the paving lane. Care should be taken to keep the paver hopper from becoming empty to prevent any gaps or other discontinuities from forming in the pavement. The concrete should be placed and compacted within 45 minutes after water has been added to the batch. When paving adjacent lanes, the new concrete should be placed within 90 minutes of placing the first lane (forming a “fresh” joint), unless procedures for cold joint construction are followed. The height of the screed should be set even with the uncompacted height of the adjacent lane, thus allowing simultaneous compaction of the edges of the adjacent lanes into a fresh joint. When paving rectangular section, paving should be in the short direction in order to minimize the length and number of cold longitudinal and transverse joints. Two or more pavers operating in echelon may reduce the number of cold joints by one half or greater, and are especially recommended in road construction where the entire width of the road can be placed at the same time.

10. COMPACTION.

10.1 GENERAL. RCCP is best compacted with a dual-drum (10-ton static weight) vibratory roller making four or more passes over the surface to achieve the design density (one back-and-forth motion is two passes). Table 1 describes vibratory rollers that have been used on five recent RCCP projects. To achieve a higher quality pavement, the primary compaction should be followed with two or more passes of a 20-ton pneumatic-tired roller (90 psi minimum tire pressure) to close up any surface voids or cracks. The use of a dual-drum static (nonvibratory) roller may be required to remove any roller marks left by the vibratory or pneumatic-tired roller. A single-drum (10-ton) vibratory roller has been used successfully to compact RCCP, but may require the use of a pneumatic-tired or dual-drum static roller to remove tire marks.

10.2 PROPER TIME FOR ROLLING. Ideally, the consistency of the RCCP when placed should be such that it may be compacted immediately after placement without undue displacement of the RCCP. However, no more than 10 minutes should pass between placing and the beginning of the rolling procedure. The rolling should be completed within 45 minutes of the time that water was added at the mixing plant. A good indication that the RCCP is ready for compaction is found by making one or two static passes on the RCCP within 1 foot of the edge of the lane before vibrating begins and observing the material during these two passes to ensure that undue displacement does not occur. If the RCCP is too wet or too dry for compaction upon placing, the water content should be adjusted at the plant. Only minor changes in water content from the design mix should be made; otherwise, a new mix design may be needed. With practice, the roller operator should be able to tell whether the consistency of the RCCP is satisfactory for compaction.

Job	Construction Date	Type Roller	Shipping Weight lb	Static Drum Weight lb	Drum Width in.	Weight/in. width lb/in.	Frequency Range vibrational min	Amplitude Range in.	Maximum Compacted Lift Thickness in.
Ft. Stewart, CA	July 1983	Tampo RS-28 (Single drum)	18,750	10,750	84.0	128.0	1,100 1,500	0.063	10.0
Ft. Hood, TX	July 1984	Tampo RS-188A (Double drum)	30,750	16,000	84.0	190.5	2,200	0.029 0.016	10.5
Ft. Lewis, WA	Nov 1984	Tampo RS-28A (Single drum)	19,250	11,300	84.0	134.5	1,500 1,700	0.020 0.061	8.5
Port of Tacoma, WA	April 1985	Dynapac CC50A (Double drum)	31,385	15,692	84.0	186.8	2,400	0.016 0.032	9.0
Portland International Airport	Aug 1985	ABG Puma 168A (Single drum)	16,755	7,275	65	111.9	2,000 3,000	0.075 0.029	7.0

Table 1

Vibratory rollers used in RCCP construction

10.3 ROLLING PATTERN. After making the static passes, the vibratory roller should make four vibratory passes on the RCCP using the following pattern: two passes on the exterior edge of the first paving lane (the perimeter of the parking area or the edge of a road) so that the rolling wheel extends over the edge of the pavement 1 to 2 inches (done to "confine" the RCCP to help prevent excessive lateral displacement of the lane upon further rolling), followed by two passes within 12 to 18 inches of the interior edge. This will leave an uncompacted edge to set the height of the screed for an adjacent lane, and allows both lanes of the fresh joint to be compacted simultaneously. Any remaining uncompacted material in the center of the lane should be compacted with two passes of the roller. This pattern should be repeated once to make a total of four passes on the lane, or more if the specified density is not achieved (see Fig. 2). If the interior edge will be used to form a cold joint, it should be rolled exactly as the exterior edge was rolled, taking care to maintain a level surface at the joint and not round the edge. When the adjacent lane is placed, two passes should be made about 12 to 18 inches from the outer edge of the lane (again, to confine the concrete) followed by two passes on the fresh joint. The first two passes should extend 1 to 2 inches over the outer edge of this adjacent lane if the lane will form an outer edge of the completed pavement. Any remaining uncompacted material in the lane should be rolled with two passes of the roller. This pattern should be repeated to make a total of four passes over the RCCP.

Additional passes may be necessary along the fresh joint to ensure smoothness and density across the joint (see Fig. 3).

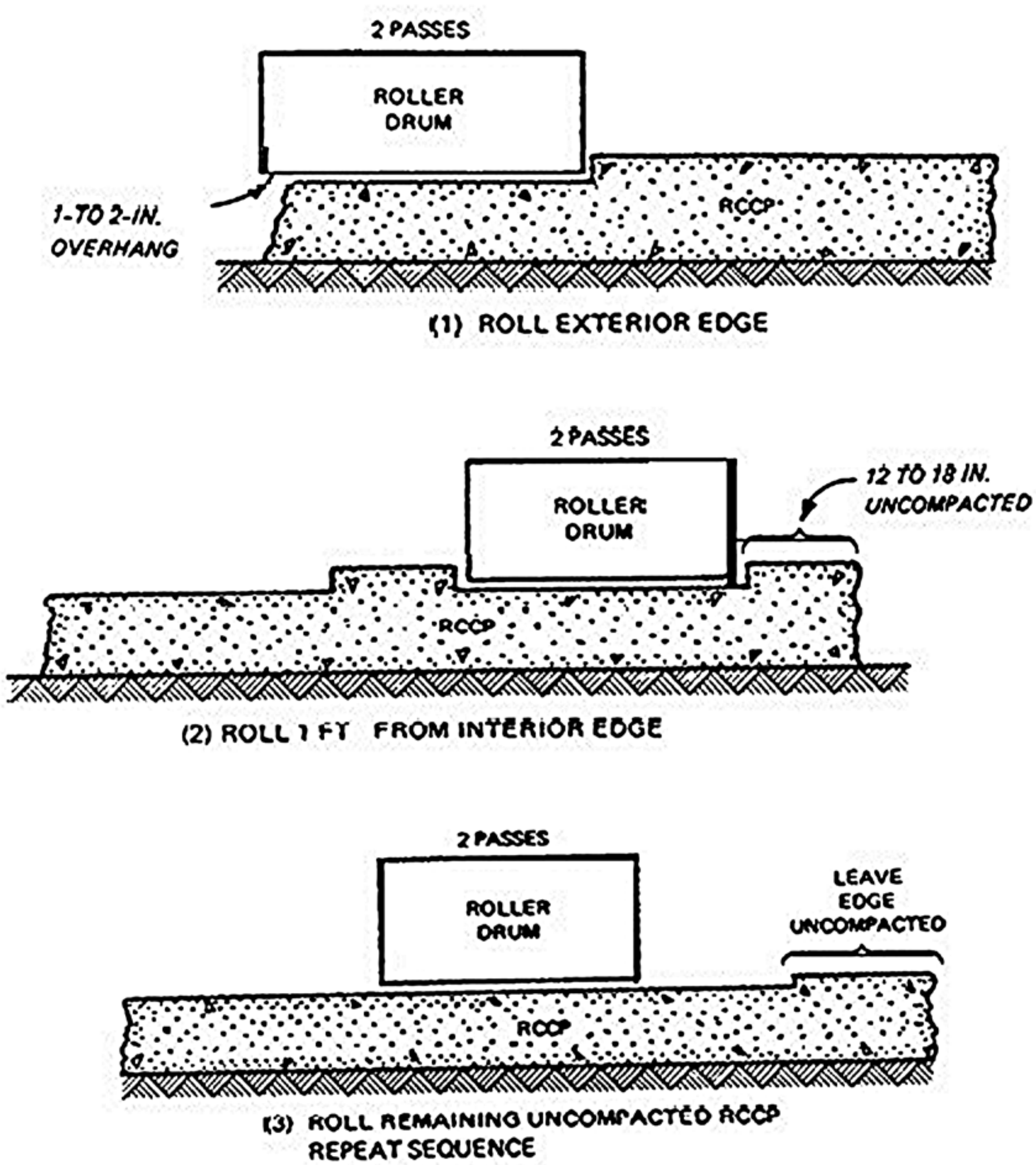

Figure 2

Compaction of first paving lane

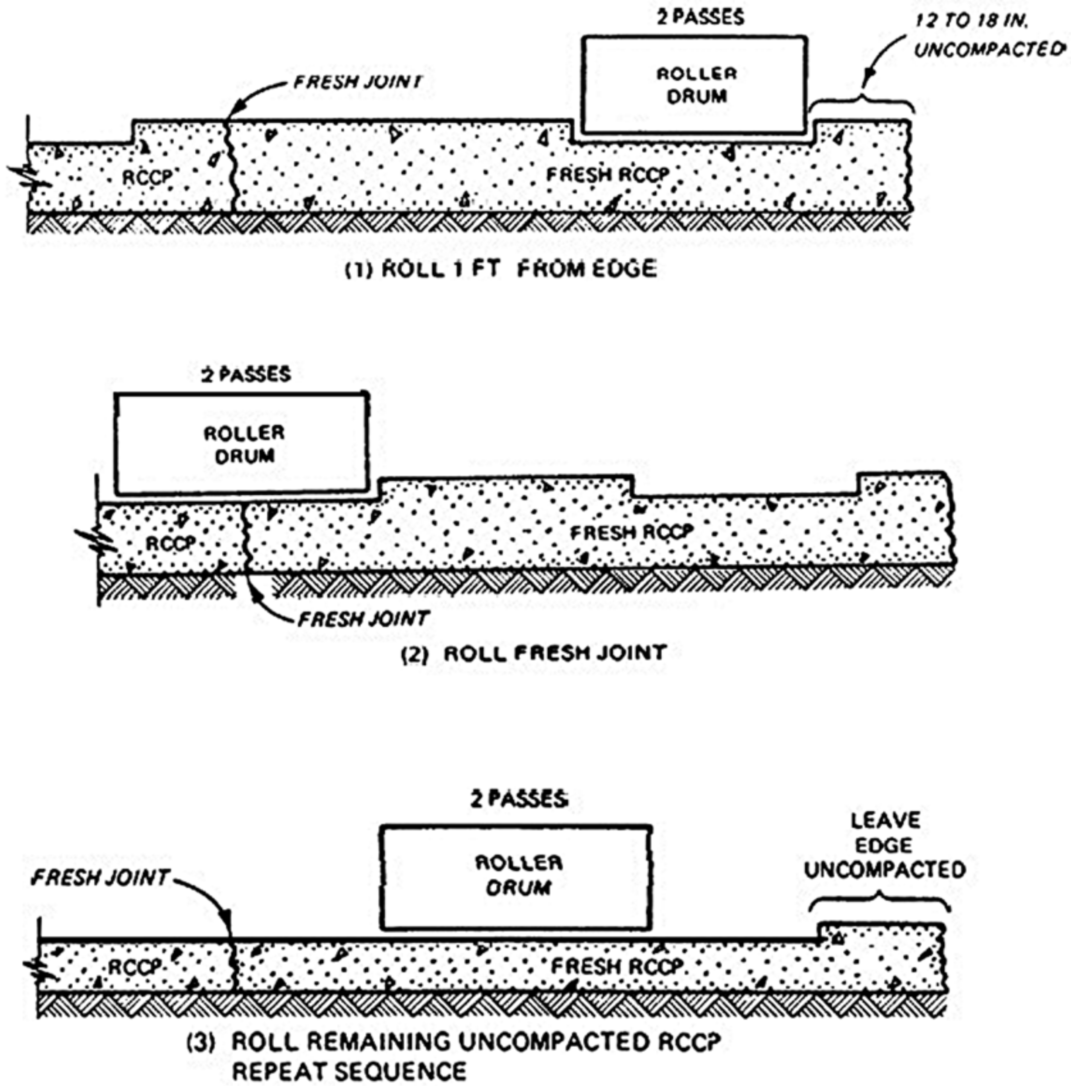

Figure 3

Compaction of interior paving lanes

10.4 COMPACTING THE END OF A LANE. When the end of a lane is reached, the roller should roll off the end of the lane, rounding off the end in the process. This rounded end should be trimmed with a motor grader or with shovels to form a vertical face through the entire depth of the pavement. An alternative method involves confining the uncompacted end of the lane with a crosstie or beam anchored to the base course, thereby forming a vertical face at the end of the lane after compaction.

10.5 PROPER ROLLER OPERATION. During the course of the vibratory compaction, the roller should never stop on the pavement in the vibratory mode. Instead, the vibrator should be turned on only after the roller is in motion and should be turned off several feet before the roller stops moving. The stopping points of successive rolling passes should be staggered to avoid forming a depression in the RCCP surface. The roller should be operated at the proper speed, amplitude, and frequency to achieve optimum compaction. The best compaction will probably occur at a high amplitude and low frequency (because of the thick lifts) and at a speed not exceeding 2 miles per hour.

10.6 FINISH ROLLING. The vibratory compaction should be followed immediately with two or more passes of the pneumatic-tired roller so that the surface voids and fissures close to form a tight surface texture. This rolling may be followed by a light dual-drum roller to remove any roller marks on the surface, but this will probably not be necessary. It is very important that all exposed surfaces of the RCCP be kept moist with a light water spray after the rolling process until the curing procedure is implemented.

11. COLD JOINTS.

11.1 GENERAL. A cold joint in RCCP is analogous to a construction joint in conventional concrete pavement. It is formed between two adjacent lanes of RCCP when the first lane has hardened to such an extent that the uncompacted edge cannot be consolidated with the fresher second lane. This happens when there is some time delay between placement of adjacent lanes such as at the end of the day's construction. This hardening may take from one to several hours depending on properties of the concrete and environmental conditions. Nevertheless, the adjacent lane should be placed against the first lane within 90 minutes or be considered a cold joint.

11.2 COLD JOINT CONSTRUCTION. Before placing fresh concrete against hardened in-place pavement to form a longitudinal cold joint, the edge of the in-place pavement should be trimmed back to sound concrete to form a vertical face along the edge. This vertical face should be dampened before the placement of the fresh lane begins. The height of the screed should be set to an elevation approximately 25 percent higher than the desired thickness of the compacted concrete. The screed should overlap the edge of the hardened concrete lane 2 or 3 inches. The excess fresh concrete should be pushed back to the edge of the fresh concrete lane with rakes or lutes and rounded off so that a minimal amount of fresh material is left on the surface of the hardened concrete after compaction. The loose material should not be broadcast over the area to be compacted; this may leave a rough surface texture after rolling. The edge of the fresh lane adjacent to the hardened concrete should be rolled first, with about 1 foot of the roller on the fresh concrete, to form a smooth longitudinal joint (see Fig. 4). Transverse cold joints are constructed in a similar manner. After cutting back the rounded-off edge and wetting the vertical face, the paver is backed into place and the screed set to the proper elevation using shims sitting on top of the hardened concrete. The excess material should be pushed back as mentioned before, and a static pass made in the transverse direction across the first 1 foot of the freshly placed lane. The joint should be carefully rolled to ensure a smooth transition across the joint.

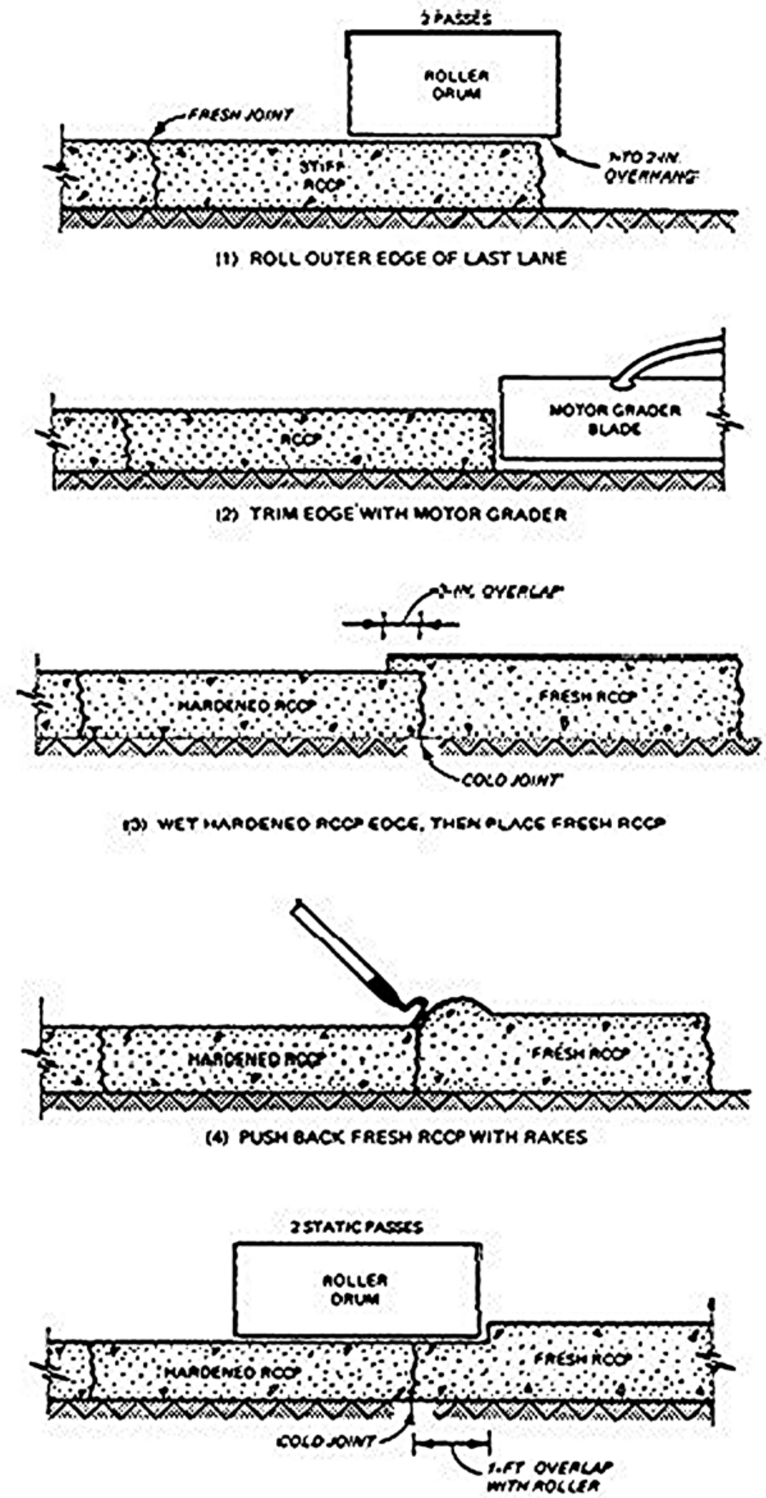

Figure 4

Cold Joint Construction

11.3 SAWING. The sawing of contraction joints in RCCP has proven to be unnecessary in past projects. Cracks were allowed to form naturally in all of the Canadian-built RCCP, and virtually no distress has been observed at the cracks. These pavements have endured over 7 years of very heavy loads and numerous freeze-thaw cycles. Attempts to saw joints at Fort Hood and Fort Lewis produced a ragged edge along the saw cut where pieces of cement paste and aggregate were kicked out by the saw blade. Until a suitable method is developed for sawing joints in RCCP, this method should not be used.

11.4 LOAD-TRANSFER DEVICES. The stiff consistency of RCCP does not lend itself to application of load transfer devices such as dowels or keyed joints, although dowels were used in cold joint construction at Fort Stewart. There, the dowels were driven into the RCCP before final set, and the adjacent fresh lane was carefully worked around the dowels by hand. Until an efficient method is developed to insert and align dowels properly in RCCP, the use of dowels should be limited.

11.5 VERTICAL JOINTS IN TWO-LIFT CONSTRUCTION. In two-lift construction, care should be taken to align the cold transverse and longitudinal joints in the upper and lower lifts to form a uniform, vertical face through the depth of the pavement along the joint. If the edge of the upper lift is not even with the edge of the lower lift, the lower lift should be cut back even with the edge of the upper lift (see Fig. 5).

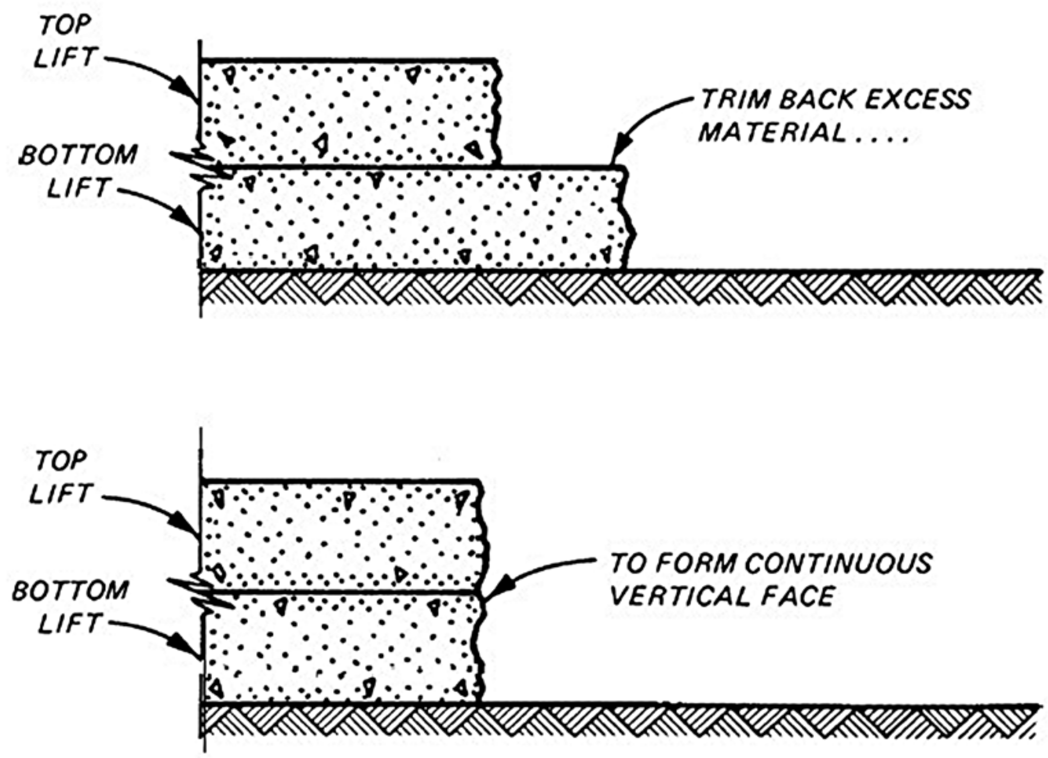

Figure 5

Two-lift cold joint

12. CURING.

12.1 GENERAL. Because of the low water content used in an RCCP mixture, a combination of moist curing and membrane curing is recommended to prevent drying and scaling of the RCCP surface. The pavement surface should be kept continuously moist after final rolling for at least 24 hours by means of a water spray truck, sprinkler (fog spray) system, or wet burlap or cotton mat covering. If burlap mats are used, they should be thoroughly wetted, placed on the RCCP so that the entire surface and exposed edges are covered, and kept continuously wet. After the initial moist curing period, the RCCP should be cured until it is at least 7 days old by one of the following methods: water-spray curing, burlap or cotton mat covering, or membrane-forming curing material. The curing material may be a white pigmented membrane curing compound or an asphalt emulsion. The curing compound or emulsion must form a continuous void-free membrane and should be maintained in that condition throughout the curing period. An irrigation sprinkler system has been used to cure RCCP in Canada and at Fort Lewis, but caution should be exercised so that the fines in the surface of the RCCP are not washed away by excessive spraying.

12.2 MOIST CURING. Continuous moist curing of the RCCP for at least 7 days should be considered if frost resistance is a concern. Preliminary results of laboratory freezing and thawing tests indicate that RCCP which has a sufficiently low water-cement ratio and has been moist cured for an extended period tends to be more frost-resistant. The improved frost resistance may be due to more complete hydration resulting in a reduction in fractional volume of freezable water at saturation.

12.3 EARLY LOADING. All vehicular traffic should be kept off the RCCP for at least 14 days. If it is absolutely necessary, a water-spraying truck and membrane-spraying truck may be driven onto the RCCP before that age, but this practice should be kept to a minimum.

13. QUALITY CONTROL/ASSURANCE.

13.1 GENERAL. Quality control and quality assurance consist of testing of materials going into the concrete; checking the plant calibration regularly; measuring the in-place density of the RCCP using a nuclear density gage; checking the smoothness of the finished RCCP with a straightedge; taking core samples from the RCCP for measurement of density, strength, and thickness; and, if desired, fabricating RCC cylinders and beams.

13.2 TESTS AT PLANT. Moisture contents of the fine and coarse aggregates should be determined daily as necessary and appropriate changes made in the amount of mixing water. Washed gradation tests should normally be performed on the combined aggregates three times per day: in the morning, at midday, and in the afternoon. The samples should be taken from the conveyor before the cement or fly ash is added to the combined aggregates. The amount of materials passing the No. 100 sieve should be determined during this analysis. After each gradation test, a washout test according to procedures in ASTM C 685 may be performed on the combined dry ingredients on samples taken from the conveyor belt between the cement and fly ash hoppers and the pugmill. By washing the dry ingredients over the No. 4 and No. 100 sieves and weighing the material in each size category, the approximate proportions of coarse aggregate, fine aggregate, and cement and fly ash combined may be determined and checked against predetermined limits.

13.3 FIELD DENSITY TESTS. Field density tests should be performed on the RCCP using a nuclear density gage operated in the direct transmission mode according to ASTM D 2922. At least one field reading should be taken every 100 feet of each paving lane. The readings should be taken as closely behind the rolling operation as possible. The reading should be adjusted using the correlation determined in the test section construction and checked against a specified density. Areas that indicate a deficient density should be rolled again with the vibratory roller until the specified density is achieved.

13.4 OBTAINING CORE SAMPLES. The acceptance criteria for the strength, density, and thickness of RCCP shall be based on appropriate tests conducted on cores taken from the RCCP. Cores should be taken from the RCCP when the pavement is 7 days old. One core should be taken at every fifth nuclear gage density test site, within a 1- to 3-foot radius of the test hole. The density and thickness of the core should be measured, and the core should be field cured under conditions similar to the RCCP curing conditions. The cores should be tested for splitting tensile strength (ASTM C 496) when they are 28 days old.

13.5 SMOOTHNESS. The finished surface of the RCCP should not vary more than 3/8 inch from the testing edge of a 10-foot straightedge. Smoothness should be checked as closely behind the finish roller as possible, and any excessive variations in the surface shall be corrected with the finish roller. Particular attention should be paid to the smoothness across fresh and cold joints because this is usually a critical area for surface variations. A skilled vibratory roller operator is essential in minimizing smoothness problems. The final surface texture of the RCCP should resemble that of an asphalt concrete pavement surface.

13.6 CYLINDER AND BEAM FABRICATION. The fabrication of cylinders and beams during RCCP construction would be highly desirable as an aid to the coring operation in checking the RCCP strength and density, and as a means of establishing a data base for developing future quality control criteria. If fabricated cylinders and beams are to be used as a quality control aid during construction, a correlation between their strength and density and that obtained from cores and sawed beams should be made during test section construction.

13.7 METHOD OF CYLINDER AND BEAM FABRICATION. Cylinders and beams should be fabricated in the field by filling cylinder molds in two layers and beam molds in a single layer and consolidating each layer of concrete on a vibrating table. Four beams (one group) should be fabricated during each shift of construction, two to be tested at 14 days and two at 28 days. The beams should be tested for flexural strength according to ASTM C 78. Eight cylinders (one group) should be fabricated for every 300 cubic yards (225 cubic meters) of RCC placed, with one group coming from the same batch of RCC used in the beams. Two cylinders should be tested each at 7, 14, 28, and 90 days. The cylinders should be tested for splitting tensile strength according to ASTM C 496.

13.8 INSPECTORS. Inspections are vital in the quality control operations. At least one inspector should be stationed at the mixing plant and at the jobsite to ensure that a quality pavement is being built. At the mixing plant, the inspector should check mixing times occasionally and spot-check the consistency and appearance of the mix coming out of the plant. He should also coordinate the aggregate moisture content tests, the gradation tests, calibration of the plant, and washout tests to see that they are performed properly and at the right frequency. At the jobsite, the inspector should make sure that the base course and cold joints are moistened before the RCC is placed against them and that the RCC is placed and compacted within the proper time limitations. He should check the paver operation to ensure that proper grade control is continuously maintained, and to make sure no gaps or discontinuities are left in the pavement before rolling. The inspector should make sure the roller begins compaction at the proper time and that the proper rolling pattern and number of passes is used. He should make sure adequate smoothness across joints is achieved and that the surface texture is tight after final rolling. The final compacted thickness of the RCCP should be spot-checked by the inspector and corrected accordingly, if appropriate. He should make sure that the curing procedures are implemented as specified. The inspector should also ensure that all exposed surfaces of the RCCP are kept moist at all times and that the curing compound, if used, is applied properly and in a continuous fashion. He should also coordinate the nuclear gage density test, the coring procedures, cylinder and beam fabrication, and the surface smoothness test to see that they are performed properly and at the required frequency.