M.494.4

AC 150/5370-10

CHANGE 2

DATE December 28, 1978

ADVISORY CIRCULAR

CHANGE

DEPARTMENT OF TRANSPORTATION
Federal Aviation Administration
Washington, D.C.

Subject: CHANGE 2, STANDARDS FOR SPECIFYING CONSTRUCTION OF AIRPORTS -- Updates Item P-501, Portland Cement Concrete Pavement

1. PURPOSE. Item P-501, Portland Cement Concrete, has been revised to reflect recent research and current practices in the field of concrete pavement construction.

The change number and date of changed material is indicated at the top of each page.

2. PRINCIPAL CHANGES. The major changes are:

a. Elimination of design mix based on predetermined cement content. The design mix is now based only on the specified flexural strength.

b. Addition of paragraphs concerning slip-form pavement construction.

c. Optional use of pay factors for flexural strength determination.

d. Use of ASTM standards in lieu of AASHTO standards.

e. Changeover to guide specification format.

PAGE CONTROL CHART

Remove Pages	Dated	Insert Pages	Dated
319-362	10/24/74	319-362	12/28/78

William V. Vitale

WILLIAM V. VITALE
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Suggest filing this transmittal at the back of the AC. It will provide a reference authority for changes, a method of determining that all Changes have been received, and a check for determining if the AC contains the proper pages.

Initiated by: AAP-580

ITEM P-501 PORTLAND CEMENT CONCRETE PAVEMENT

1. DESCRIPTION

1.1 This work shall consist of pavement composed of portland cement concrete, [with reinforcement] [without reinforcement] constructed on a prepared subgrade or subbase course in accordance with these specifications and shall conform to the lines, grades, thicknesses, and typical cross sections shown on the plans.

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The Engineer shall specify with or without reinforcement.

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2. MATERIALS

2.1 FINE AGGREGATE. Fine aggregate for concrete shall conform to the requirements of ASTM C33 and shall meet the requirements of Table 1.

TABLE 1. GRADATION FOR FINE AGGREGATE

Sieve Designation (Square Openings)	Percentage by Weight Passing Sieves
3/8 in. (9.5 mm)	100
No. 4 (4.75 mm)	95-100
No. 8 (2.36 mm)	80-100
No. 16 (1.18 mm)	50-85
No. 30 (600 micro-m)	25-60
No. 50 (300 micro-m)	10-30
No. 100 (150 micro-m)	2-10

2.2 COARSE AGGREGATE. Coarse aggregate shall conform to the requirements of ASTM C33. Gradation shall be in accordance with Table 2.

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TABLE 2. GRADATION FOR COARSE AGGREGATE 49

Sieve Designations (square openings)		*	*
		Percentage by Weight Passing Sieves	
in.	mm	*	*
2-1/2	63	*	*
2	50.8	*	*
1-1/2	38.1	*	*
1	25.0	*	*
3/4	19.0	*	*
1/2	12.5	*	*
3/8	9.5	*	*
No. 4	4.75	*	*
No. 8	2.36	*	*

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The Engineer shall specify the aggregate to be furnished from the table shown in this note. The appropriate gradation shall be inserted into Table 2. Insert points are denoted by asterisks. Where locally available aggregates cannot be economically blended to meet the grading requirements, the gradations may be modified to fit the characteristics of such locally available aggregates.

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TABLE 2. GRADATION FOR COARSE AGGREGATE 92

Sieve Designations (square openings)		From 2" to No.4 (50.8mm - 4.75mm)		From 1-1/2" to No.4 (38.1 mm - 4.75 mm)		From 1" to No.4 (25.0mm-4.75mm)
		Percentage by Weight Passing Sieves				
in.	mm	2"-1"	1"-No.4	1-1/2"-3/4"	3/4"-No.4	1"-No.4
2-1/2	63	---	---	---	---	---
2	50.8	90-100	---	100	---	---
1-1/2	38.1	35-70	100	90-100	---	100
1	25.0	0-15	95-100	25-55	100	95-100
3/4	19.0	---	---	0-15	95-100	---
1/2	12.5	0-5	25-60	---	---	25-60
3/8	9.5	---	---	0-5	20-55	---
No. 4	4.75	---	0-10	---	0-10	0-10
No. 8	2.36	---	0-5	---	0-5	0-5

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The percentage of wear shall be no more than [**_____] when tested in accordance with [**_____.]

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The Engineer shall specify the percentage of wear. It should not exceed 40 percent. In certain cases where aggregate of this quality cannot be obtained economically, aggregate with a higher percentage of wear may be used if a satisfactory service record of at least 5 years' duration under similar conditions of service and exposure has been demonstrated. The Engineer shall specify ASTM C131 for aggregates smaller than 1 1/2 inches (38.1 mm) and ASTM C535 for aggregates larger than 3/4 inch (19.05 mm).

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Aggregates delivered to the mixer shall consist of crushed stone, crushed or uncrushed gravel, crushed slag, or natural sand. The aggregate shall be composed of sound, tough, durable particles and shall meet the requirements for deleterious substances given in ASTM C33. The aggregate in any size group shall not contain more than 8 percent by weight of flat or elongated pieces. A flat or elongated particle is one having a ratio between the maximum and the minimum dimensions of a circumscribing rectangular prism exceeding 5 to 1.

2.3 CEMENT. Cement shall conform to the requirements of [**_____,] Type [**_____.]
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The Engineer shall specify one of the following: ASTM C150 - Type I, IA, II, IIA, III, IIIA; ASTM C595 - Type IP, IP-A, IS, IS-A.
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If, for any reason, cement becomes partially set or contains lumps of caked cement, it shall be rejected. Cement salvaged from discarded or used bags shall not be used.

2.4 PREMOLDED JOINT FILLER. Premolded joint filler for expansion joints shall conform to the requirements of ASTM [**_____] and shall be punched to admit the dowels where called for on the plans. For contraction joints, the filler shall be a resin-impregnated fiberboard conforming to the physical requirements of ASTM D1752. The filler for each joint shall be furnished in a single piece for the full depth and width required for the joint, unless otherwise specified by the Engineer. When the use of more than one piece is authorized for a joint, the abutting ends shall be fastened securely and held accurately to shape by stapling or other positive fastening means satisfactory to the Engineer.
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The Engineer shall designate either ASTM D1751 or ASTM D1752.
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2.5 JOINT SEALER. The joint sealer for the joints in the concrete pavement shall meet the requirements of Item P-604 and shall be of the type(s) specified in the plans.

2.6 STEEL REINFORCEMENT. Reinforcing shall consist of [**_____] conforming to the requirements of [**_____.]

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The Engineer shall designate one of the following:

Welded steel wire fabric ASTM A185

Welded deformed steel fabric ASTM A497

Bar mats ASTM A184 or A704

Delete this section when not applicable to the project.

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2.7 DOWEL AND TIE BARS. Tie bars shall be deformed steel bars and conform to the requirements of ASTM A615 or ASTM A616, except that rail steel bars, Grade 50 or 60, shall not be used for tie bars that are to be bent or restraightened during construction. Tie bars designated as Grade 40 in ASTM A615 can be used for construction requiring bent bars.

Dowel bars shall be plain steel bars conforming to ASTM A617 and shall be free from burring or other deformation restricting slippage in the concrete. Before delivery to the construction site, a minimum of two-thirds of the length of each dowel bar shall be painted with one coat of lead or tar paint. If plastic or epoxy-coated steel dowels are used, no lead or tar paint coating is required, except when specified for a particular situation on the contract plans. Coated dowels shall conform to the requirements given in AASHTO M254.

The sleeves for dowel bars used in expansion joints shall be metal, of an approved design to cover 2 to 3 inches (50 mm to 75 mm) of the dowel, with a closed end and with a suitable stop to hold the end of the bar at least 1 inch (25 mm) from the closed end of the sleeve. Sleeves shall be of such design that they will not collapse during construction.

2.8 WATER. Water used in mixing or curing shall be as clean and free of oil, salt, acid, alkali, sugar, vegetable, or other substances injurious to the finished product as possible. Water will be tested in accordance with the requirements of AASHTO T26. Water known to be of potable quality may be used without testing.

2.9 COVER MATERIAL FOR CURING. Curing materials shall conform to one of the following specifications:

(a) Liquid membrane-forming compounds for curing concrete shall conform to the requirements of ASTM C309, Type 2.

(b) White polyethylene film for curing concrete shall conform to the requirements of ASTM C171.

(c) White burlap-polyethylene sheeting for curing concrete shall conform to the requirements of ASTM C171.

(d) Waterproof paper for curing concrete shall conform to the requirements of ASTM C171.

2.10 ADMIXTURES. The use of any material added to the concrete mix shall be approved by the Engineer. The Contractor shall submit certificates indicating that the material to be furnished meets all of the requirements indicated below. In addition, the Engineer may require the Contractor to submit complete test data from an approved laboratory showing that the material to be furnished meets all of the requirements of the cited specifications. Subsequent tests will be made of samples taken by the Engineer from the supply of the material being furnished or proposed for use on the work to determine whether the admixture is uniform in quality with that approved.

(a) Pozzolanic Admixtures. Pozzolanic admixtures shall be fly ash or raw or calcined material pozzolans meeting the requirements of ASTM C618 with the exception of loss of ignition, where the maximum should be less than 6 percent.

(b) Air-Entraining Admixtures. Air-entraining admixtures shall meet the requirements of ASTM C260 and shall be added to the mixer in the amount necessary to produce the specified air content. The air-entrainment agent and the water reducer admixture shall be compatible.

(c) Water-Reducing Admixtures. Water-reducing, set-controlling admixtures shall meet the requirements of ASTM C494, Type A, water-reducing or Type D, water-reducing and retarding. Water-reducing admixtures shall be added at the mixer separately from air-entraining admixtures in accordance with the manufacturer's printed instructions.

3. CONSTRUCTION METHODS

3.1 EQUIPMENT. Equipment and tools necessary for handling materials and performing all parts of the work shall be approved by the Engineer as to design, capacity, and mechanical condition. The equipment shall be at the job site before the start of construction operations for examination and approval.

(a) Batching Plant and Equipment.

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(1) General. The batching plant shall include bins, weighing hoppers, and scales for the fine aggregate and coarse aggregate. If bulk cement is used, a bin, hopper, and separate scale for cement shall be included. The weighing hoppers shall be properly sealed and vented to preclude dusting during operation.

(2) Bins and hopper. Bins with adequate separate compartments for fine aggregate and coarse aggregate shall be provided in the batching plant. Each compartment shall discharge efficiently and freely into the weighing hopper. Means of control shall be provided so that, as the quantity desired in the weighing hopper is approached, the material may be added slowly and shut off with precision. A port or other opening for removing an overload of any one of the several materials from the hopper shall be provided. Weighing hoppers shall be constructed to eliminate accumulations of materials and to discharge fully.

(3) Scales. The scales for weighing aggregates and cement shall be of either the beam or the springless dial type. They shall be accurate within 0.5 percent throughout their range of use. When beam-type scales are used, provisions such as a "telltale" dial shall be made for indicating to the operator that the required load in the weighing hopper is being approached. A device on the weighing beams shall clearly indicate critical position. Poises shall be designed to be locked in any position and to prevent unauthorized change. The weight beam and "telltale" device shall be in full view of the operator while charging the hopper, and the operator shall have convenient access to all controls.

Scales shall be inspected and sealed as often as the Engineer may deem necessary to assure their continued accuracy. The Contractor shall have on hand not less than ten 50-pound (23 kg) weights for testing of all scales when directed by the Engineer.

(b) Mixers.

(1) General. Concrete may be mixed at a central plant, or wholly or in part in truck mixers. Each mixer shall have attached in a prominent place a manufacturer's nameplate showing the capacity of the drum in terms of volume of mixed concrete and the speed of rotation of the mixing drum or blades.

A device accurate within 3 percent and satisfactory to the Engineer shall be provided at the mixer for determining the amount of air-entraining agent or other admixture to be added to each batch requiring such admixtures.

Mixers shall be examined daily for the accumulation of hard concrete or mortar and the wear of blades.

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(2) Central plant mixer. Mixing shall be in an approved mixer capable of combining the aggregates, cement, and water into a thoroughly mixed and uniform mass within the specified mixing period, and of discharging the mixture without segregation. Central plant mixers shall be equipped with an acceptable timing device that will not permit the batch to be discharged until the specified mixing time has elapsed. The water system for a central mixer shall be either a calibrated measuring tank or a meter and shall not necessarily be an integral part of the mixer.

The mixers shall be examined daily for changes in condition due to accumulation of hard concrete or mortar or wear of blades. The pickup and throwover blades shall be replaced when they have worn down 3/4 inch (19 mm) or more. The Contractor shall have a copy of the manufacturer's design on hand showing dimensions and arrangement of blades in reference to original height and depth.

(3) Truck mixers and truck agitators. Truck mixers used for mixing and hauling concrete and truck agitators used for hauling central-mixed concrete shall conform to the requirements of ASTM C94.

(4) Nonagitator trucks. Nonagitating hauling equipment shall conform to the requirements of ASTM C94.

(c) Finishing Equipment.

(1) Finishing machine. The finishing machine shall be equipped with one or more oscillating-type transverse screeds.

(2) Vibrators. For side-form construction, vibrators may be either the surface pan type for pavements less than 8 inches (20 cm) thick or the internal type with either immersed tube or multiple spuds, for the full width of the concrete slab. They may be attached to the spreader or the finishing machine, or they may be mounted on a separate carriage. They shall not come in contact with the joint, load-transfer devices, subgrade, or side forms. The frequency of the surface vibrators shall not be less than 3,500 vibrations per minute, and the frequency of the internal type shall not be less than 7,000 vibrations per minute for spud vibrators. When spud-type internal vibrators are used adjacent to the side forms, they shall have a frequency of not less than 3,500 vibrations per minute. Hand vibrators should be used to consolidate the concrete along forms and other isolated areas.

For slip-form construction, the paver shall vibrate the concrete for the full width and depth of the strip of pavement being placed. Vibration shall be accomplished by internal vibrators with a frequency range variable between 7,000 and 12,000

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vibrations per minute. The amplitude of vibration shall be between 0.025 (0.6 mm) and 0.06 (1.5 mm) inches.

The number, spacing, frequency, and eccentric weights shall be provided as necessary to achieve an acceptable concrete density and finishing quality. Adequate power to operate all vibrators at the weight and frequency required for a satisfactory finish shall be available on the paver. The internal vibrators may be supplemented by vibrating screeds operating on the surface of the concrete. The frequency of surface vibrators shall not be less than 3,500 vibrations per minute. The Contractor shall furnish a tachometer or other suitable device for measuring the frequency of the vibrators. The vibrators and tamping elements shall be automatically controlled so that they shall be stopped as forward motion ceases. Any override switch shall be of the spring-loaded, momentary contact type.

(d) Concrete Saw. When sawing of joints is specified, the Contractor shall provide sawing equipment adequate in number of units and power to complete the sawing to the required dimensions and at the required rate. The Contractor shall provide at least one standby saw in good working order. An ample supply of saw blades shall be maintained at the site of the work at all times during sawing operations. The Contractor shall provide adequate artificial lighting facilities for night sawing. All of this equipment shall be on the job both before and at all times during concrete placement.

(e) Forms. Straight side forms shall be made of steel having a thickness of not less than 7/32 inch (6 mm) and shall be furnished in sections not less than 10 feet (3 m) in length. Forms shall have a depth equal to the prescribed edge thickness of the concrete without horizontal joint, and a base width equal to the depth of the forms. Flexible or curved forms of proper radius shall be used for curves of 100-foot (31 m) radius or less. Flexible or curved forms shall be of a design acceptable to the Engineer. Forms shall be provided with adequate devices for secure settings so that when in place they will withstand, without visible spring or settlement, the impact and vibration of the consolidating and finishing equipment. Flange braces shall extend outward on the base not less than two-thirds the height of the form. Forms with battered top surfaces and bent, twisted, or broken forms shall be removed from the work. Repaired forms shall not be used until inspected and approved. Built-up forms shall not be used, except as approved by the Engineer. The top face of the form shall not vary from a true plane more than 1/8 inch (3 mm) in 10 feet (3 m), and the upstanding leg shall not vary more than 1/4 inch (6 mm). The forms shall contain provisions for locking the ends of abutting sections together tightly for secure setting.

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(f) Slip-form Pavers. The paver shall be fully energized, self-propelled, and designed for the specific purpose of placing, consolidating, and finishing the concrete pavement, true to grade, tolerances, and cross section. It shall be of sufficient weight and power to construct the maximum specified concrete paving lane width as shown in the plans, at adequate forward speed, without transverse, longitudinal or vertical instability or without displacement. The paver should be equipped with electronic or hydraulic horizontal and vertical control devices.

3.2 FORM SETTING. Forms shall be set sufficiently in advance of the concrete placement to insure continuous paving operation. After the forms have been set to correct grade, the grade shall be thoroughly tamped, either mechanically or by hand, at both the inside and outside edges of the base of the forms. Forms shall be staked into place with not less than 3 pins for each 10-foot (3 m) section. A pin shall be placed at each side of every joint.

Form sections shall be tightly locked and shall be free from play or movement in any direction. The forms shall not deviate from true line by more than 1/4 inch (6 mm) at any joint. Forms shall be so set that they will withstand, without visible spring or settlement, the impact and vibration of the consolidating and finishing equipment. Forms shall be cleaned and oiled prior to the placing of concrete.

The alignment and grade elevations of the forms shall be checked and corrections made by the Contractor immediately before placing the concrete. When any form has been disturbed or any grade has become unstable, the form shall be reset and rechecked.

3.3 CONDITIONING OF UNDERLYING COURSE, SLIP-FORM CONSTRUCTION. The compacted subgrade or subbase on which the pavement will be placed shall be widened approximately 3 feet (1 m) to extend beyond the paving machine track to support the paver without any noticeable displacement. After the subgrade or subbase has been placed and compacted to the required density, the areas which will support the paving machine and the area to be paved shall be trimmed to the proper elevation and profile by means of a properly designed machine. The grade of the subbase on which the concrete pavement is to be placed shall be controlled automatically by steel guide wires erected and maintained by the Contractor. If the density of the base is disturbed by the trimming operations, it shall be corrected by additional compaction before the concrete is placed except when stabilized subbases are being constructed. If damage occurs on a stabilized subbase, it shall be corrected full depth by the Contractor or the damaged areas filled with concrete integral with the pavement. The grading operations should be delayed as long as possible and immediately precede paving insofar as practical,

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particularly if the base course is subjected to haul traffic. If traffic is allowed to use the prepared grade, the grade shall be checked and corrected immediately before the placement of concrete. The prepared grade shall be well moistened with water, without saturating, immediately ahead of concrete placement to prevent rapid loss of moisture from concrete. In cold weather the underlying subbase shall be protected so that it will be entirely free of frost when concrete is placed.
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Stabilized subbase is required to accommodate dual tandem gear aircraft with gross weights in excess of 200,000 pounds (90700 kg).
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3.4 CONDITIONING OF UNDERLYING COURSE, SIDE-FORM CONSTRUCTION. The prepared grade shall be well moistened with water, without saturating, immediately ahead of concrete placement to prevent rapid loss of moisture from the concrete. Ruts or depressions in the subgrade or subbase caused by hauling or usage of other equipment shall be filled as they develop with suitable material (not with concrete or concrete aggregates) and thoroughly compacted by rolling. If damage occurs to a stabilized subbase, it shall be corrected full depth by the Contractor, or the damaged areas filled with concrete integral with the pavement. A multiple-pin templet weighing not less than 1,000 pounds (454 kg) per 20 feet (6.1 m) or other approved templet shall be provided and operated on the forms immediately in advance of the placing of the concrete. The templet shall be propelled only by hand and not attached to a tractor or other power unit. Templets shall be adjustable so that they may be set and maintained at the correct contour of the underlying course. The adjustment and operation of the templet shall be such as will provide an accurate retest of the grade before placing the concrete thereon. All excess material shall be removed. Low areas may be filled and compacted to a condition similar to that of the surrounding grade, or filled with concrete integral with the pavement. In cold weather, the underlying subbase shall be protected so that it will be entirely free from frost when the concrete is placed. The use of chemicals to eliminate frost in the underlying material will not be permitted. The templet shall be maintained in accurate adjustment, at all times by the Contractor, and should be checked daily. The work described under the foregoing paragraphs does not constitute a regular subgrading operation, but rather a final accurate check of the underlying course.

3.5 HANDLING, MEASURING, AND BATCHING MATERIAL. The batch plant site, layout, equipment, and provisions for transporting material shall assure a continuous supply of material to the work. Stockpiles shall be built up in layers of not more than 3 feet (1

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m) in thickness. Each layer shall be completely in place before beginning the next layer and shall not be allowed to "cone" down over the next lower layer. Aggregates from different sources and of different grading shall not be stockpiled together. Improperly placed stockpiles will not be accepted by the Engineer.

Aggregates shall be handled from stockpiles or other sources to the batching plant in such manner to secure the specified grading of the material. Aggregates that have become segregated or mixed with earth or foreign material shall not be used. All aggregates produced or handled by hydraulic methods, and washed aggregates, shall be stockpiled or binned for draining at least 12 hours before being batched. Rail shipments requiring more than 12 hours will be accepted as adequate binning only if the car bodies permit free drainage. The fine aggregate and coarse aggregate shall be separately weighed into hoppers in the respective amounts set by the Engineer in the job mix. Cement shall be measured by weight. Separate scales and hopper, with a device to positively indicate the complete discharge of the batch of cement into the batch box or container, shall be used for weighing the cement.

When required by the contract or when permitted, batching plants shall be equipped to proportion aggregates and bulk cement, by weight, automatically using interlocked proportioning devices of an approved type. When bulk cement is used, the Contractor shall use a suitable method of handling the cement from weighing hopper to transporting container or into the batch itself for transportation to the mixer, such as a chute, boot, or other approved device, to prevent loss of cement. The device shall be arranged to provide positive assurance of the actual presence in each batch of the entire cement content specified.

When cement is placed in contact with the aggregates, batches may be rejected unless mixed within 1 1/2 hours of such contact. Batching shall be conducted so that the results in the weights of each material required will be within a tolerance of 1 percent for cement and 2 percent for aggregates.

Water may be measured either by volume or by weight. The accuracy of measuring the water shall be within plus or minus 1 percent of required amounts. Unless the water is to be weighed, the water-measuring equipment shall include an auxiliary tank from which the measuring tank shall be filled. The measuring tank shall be equipped with an outside tap and valve to provide for checking the setting, unless other means are provided for readily and accurately determining the amount of water in the tank. The volume of the auxiliary tank shall be at least equal to that of the measuring tank.

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Methods and equipment for adding air-entraining agent or other admixtures to the batch, when required, shall be approved by the Engineer. All admixtures shall be measured into the mixer with an accuracy of plus or minus 3 percent.

3.6 PROPORTIONS. Proportioning requirements for concrete shall be designed for a flexural strength of [**_____.]
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The Engineer shall designate the design flexural strength. The minimum flexural strength allowable for airport pavements is 600 psi (4136 kPa) and the minimum allowable cement content is 5.2 bags of cement per cubic yard. Higher flexural strengths should be specified when local materials make this economically feasible.
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Prior to the start of paving operations and after approval of all material to be used in the concrete, the Contractor shall submit test data showing the proportions and actual flexural strength obtained from the concrete. Flexural strength shall be as specified at 28 days using test specimens prepared in accordance with ASTM C31 and tested in accordance with ASTM C78. The mix determined shall be workable concrete having a slump for side-form concrete between 1 and 2 inches (25 mm and 50 mm) as determined by ASTM C143. For vibrated slip-form concrete, the slump shall be between 1/2 inch (13 mm) and 1 1/2 inches (38 mm).
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Low slump concrete is a necessity for slip-form pavement, particularly for pavement with keyways or for pavement in excess of 10 inches (25 cm) thick.
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The minimum cement content shall be maintained to produce concrete of suitable durability and workability. The maximum water-cement ratio specified for concrete shall not be exceeded. Entrained air shall be required to increase durability and provide workability.

For slip-form construction, a high degree of uniformity in the plastic concrete is required. Caution should be exercised in establishing the air-entrainment percentage, as excessive air entrainment will aggravate edge slumping and insufficient air entrainment will result in poor concrete durability. Batches with slump in excess of 1 1/2 inches (38 mm) shall be wasted. Some edge slump of the wet concrete behind the side form on the paving machine will occur, even with low slump concrete. This may continue, though very slowly, until initial set has taken

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place. Provision for adequate compensating adjustment in the side form and in the final screed must be incorporated in the paver.

The cement content shall not be less than 5.2 sacks per cubic yard nor shall the water-cement ratio, including free surface moisture on the aggregates but not including moisture absorbed by the aggregates, be more than 6 gallons per sack of cement. The cement content shall be determined in accordance with ASTM C138.

Air-entraining admixture shall be added in such a manner that will insure uniform distribution of the agent throughout the batch. The air content of freshly mixed air-entrained concrete shall be based upon trial mixes with the materials to be used in the work adjusted to produce concrete of the required plasticity and workability. The percentage of air entrainment in the mix shall be [**_____] percent plus or minus 1 1/2 percentage points. Air content shall be determined by testing in accordance with ASTM C231 for gravel and stone coarse aggregate and ASTM C173 for slag and other highly porous coarse aggregate.
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The Engineer shall specify the appropriate air content as determined from the table in this note.

ENTRAINED AIR TOLERANCES

Maximum Size Coarse Aggregate	Air Content Percent by Volume
1 1/2 in. (38.1 mm), 2 in. (51 mm), 2 1/2 in. (63 mm)	5 1/2
3/4 in. (19.1 mm), 1 in. (25.0 mm)	6
3/8 in. (9.5 mm), 1/2 in. (12.5 mm)	7 1/2

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3.7 FIELD TEST SPECIMENS. Concrete samples shall be furnished by the Contractor and shall be taken in the field to determine the consistency, air content, and strength of the concrete. Flexural test beams shall be made each day that the concrete is placed. Each group of test beams shall be molded from the same batch of concrete and shall consist of a sufficient number of specimens to provide two flexural strength tests at each test age. One group of specimens will be made during the first half of each shift, and the other during the last portion of the shift. The specimens shall be made in accordance with ASTM C31. However, at the start of paving operations and when the aggregate

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source, aggregate characteristics, or mix design is changed, additional groups of test beams may be required until the Engineer is satisfied that the concrete mixture being used complies with the strength requirements of these specifications. Test ages will be 7 days and 28 days.

The flexural strength of the concrete shall meet the following requirements: (1) the average of any 4 consecutive strength tests, tested at the end of 28 days, shall have an average flexural strength equal to or greater than the specified flexural strength; (2) not more than 20 percent of the beams tested at the end of 28 days shall have a flexural strength less than the specified strength. Specimens which are obviously defective shall not be considered in the determination of the strength. When it appears that the test specimens will fail to conform to the requirements for strength, the Engineer shall have the right to order changes in the concrete sufficient to increase the strength to meet these requirements. When a satisfactory relationship between 7-day and 28-day strengths has been established and approved, the 7-day test results may be used as an indication of the 28-day strengths. However, the 7-day test results will not replace the results of the 28-day tests if the 28-day results fall below the requirement.

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Compressive strength tests offer some degree of correlation with flexural strength tests and may be used to obtain approximations of flexural strength. However, they must not be used for project acceptance. The specimens shall be tested in accordance with ASTM C39.

An alternate method of accepting concrete for flexural strength is on a lot basis. A lot will consist of [**_____] square yards or cubic yards and will be divided into four equal sublots. One test will be made for each sublot. Random samples will be taken from the plastic concrete at the site in accordance with accepted statistical procedures.

The concrete shall be sampled in accordance with ASTM C172. Flexural strength specimens shall be made in accordance with ASTM C31 and tested in accordance with ASTM C78.

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The lot will be accepted without adjustment in payment if the average 28-day flexural strength, based on four acceptance tests of the lot, is greater than or equal to the acceptance limit shown under the 1.00 pay factor in the table in this note. If the average strength does not meet this limit, the Contractor may elect to leave the lot in place at a reduced unit price determined in accordance with the table. If the average 28-day flexural strength of the lot fails to attain the lower acceptance limit shown for a 0.70 pay factor, the Engineer may order the removal of all the concrete in the lot. The pay factor for concrete which is allowed to remain in place when the pay factor is outside the 0.70 limit will be 0.50.

The Engineer shall specify the lot size in the specifications.

PAY FACTOR SCHEDULE FOR FLEXURAL STRENGTH AT 28 DAYS

Pay Factor	Acceptance Limits Average Flexural Strength (4 tests)
1.00	greater than M +0.120 R
0.95	M to M +0.115 R
0.70	M -0.090 R to M -0.005 R

Where: M = Modulus of Rupture (specified 28 day flexural strength)

R = the range of a sample of size N=4; the difference between the largest and smallest test

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ı MIXING CONCRETE. The concrete may be mixed at the work
:e, in a central mix plant or in truck mixers. The mixer shall
of an approved type and capacity. Mixing time shall be
ısured from the time all materials, except water, are emptied
:o the drum. Ready-mixed concrete shall be mixed and delivered
accordance with the requirements of ASTM C94, except that the
ıimum required revolutions of the mixing speed for transit
ıed concrete may be reduced to not less than that recommended
the mixer manufacturer. The number of revolutions recommended
the mixer manufacturer shall be indicated on the
ıufacturer's serial plate attached to the mixer. The
ıtractor shall furnish test data acceptable to the Engineer
:ifying that the make and model of the mixer will produce
:form concrete conforming to the provisions of ASTM C94 at the
luced number of revolutions shown on the serial plate.

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When mixed at the work site or in a central mixing plant, the mixing time shall not be less than 50 seconds nor more than 90 seconds. Mixing time ends when the discharge chute opens. Transfer time in multiple drum mixers is included in mixing time. The contents of an individual mixer drum shall be removed before a succeeding batch is emptied therein.

The mixer shall be operated at the drum speed as shown on the manufacturer's nameplate on the approved mixer. Any concrete mixed less than the specified time shall be discarded at the Contractor's expense. The volume of concrete mixed per batch shall not exceed the mixer's nominal capacity in cubic feet (cubic meters), as shown on the manufacturer's standard rating plate on the mixer. An overload up to 10 percent above the mixer's nominal capacity may be permitted provided concrete test data for segregation and uniform consistency are satisfactory, and provided no spillage of concrete takes place. The batch shall be charged into the drum so that a portion of the mixing water shall enter in advance of the cement and aggregates. The flow of water shall be uniform, and all water shall be in the drum by the end of the first 15 seconds of the mixing period. The throat of the drum shall be kept free of such accumulations as may restrict the free flow of materials into the drum.

Mixed concrete from the central mixing plant shall be transported in truck mixers, truck agitators, or nonagitating trucks. The time elapsing from the time water is added to the mix until the concrete is deposited in place at the work site shall not exceed 30 minutes when the concrete is hauled in nonagitating trucks, nor 60 minutes when the concrete is hauled in truck mixers or truck agitators. Retempering concrete by adding water or by other means will not be permitted, except when concrete is delivered in transit mixers. With transit mixers additional water may be added to the batch materials and additional mixing performed to increase the slump to meet the specified requirements, if permitted by the Engineer. All these operations must be performed within 45 minutes after the initial mixing operations and the water-cement ratio must not be exceeded. Admixtures for increasing the workability or for accelerating the set will be permitted only when specified for in the contract.

3.9 LIMITATIONS OF MIXING. No concrete shall be mixed, placed, or finished when the natural light is insufficient, unless an adequate and approved artificial lighting system is operated.

Unless authorized in writing by the Engineer, mixing and concreting operations shall be discontinued when a descending air temperature in the shade and away from artificial heat reaches 40 degrees F (4 degrees C) and shall not be resumed until an ascending air temperature in the shade and away from artificial heat reaches 35 degrees F (2 degrees C).

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When concreting is authorized during cold weather, the aggregates may be heated by either steam or dry heat prior to being placed in the mixer. The apparatus used shall heat the mass uniformly and shall be arranged to preclude the possible occurrence of overheated areas which might be detrimental to the materials. Unless otherwise authorized, the temperature of the mixed concrete shall not be less than 50 degrees F (10 degrees C) at the time of placement in the forms.

If the air temperature is 35 degrees F (2 degrees C) or less at the time of placing concrete, the Engineer may require the water and/or the aggregates to be heated to not less than 70 degrees F (21 degrees C) nor more than 150 degrees F (66 degrees C). Concrete shall not be placed on frozen subgrade nor shall frozen aggregates by used in the concrete.

During periods of warm weather when the maximum daily air temperature exceeds 85 degrees F (30 degrees C), the following precautions should be taken. The forms and/or the underlying material shall be sprinkled with water immediately before placing the concrete. The concrete shall be placed at the coolest temperature practicable, and in no case shall the temperature of the concrete when placed exceed 90 degrees F (32 degrees C). The aggregates and/or mixing water shall be cooled as necessary to maintain the concrete temperature at or not more than the specified maximum.

3.10 PLACING CONCRETE.

(a) Side-form Method. For the side-form method, the concrete shall be deposited on the moistened grade to require as little rehandling as possible. Unless truck mixers, truck agitators, or nonagitating hauling equipment are equipped with means for discharge of concrete without segregation of the materials, the concrete shall be unloaded into an approved spreading device and mechanically spread on the grade to prevent segregation of the materials. Placing shall be continuous between transverse joints without the use of intermediate bulkheads. Necessary hand spreading shall be done with shovels -- not rakes. Workmen shall not be allowed to walk in the freshly mixed concrete with boots or shoes coated with earth or foreign substances.

When concrete is to be placed adjoining a previously constructed lane of pavement and when mechanical equipment will be operated upon the existing lane of pavement, the concrete shall be at least 7 days old and at a flexural strength approved by the Engineer. If only finishing equipment is carried on the existing lane, paving in adjoining lanes may be permitted after 3 days, if approved by the Engineer.

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Concrete shall be thoroughly consolidated against and along the faces of all forms and along the full length and on both sides of all joint assemblies by means of vibrators inserted in the concrete. Vibrators shall not be permitted to come in contact with a joint assembly, the grade, or a side form. In no case shall the vibrator be operated longer than 15 seconds in any one location, nor shall the vibrators be used to move the concrete.

Concrete shall be deposited as near to expansion and contraction joints as possible without disturbing them but shall not be dumped from the discharge bucket or hopper onto a joint assembly unless the hopper is well centered on the joint assembly.

Should any concrete materials fall on or be worked into the surface of a completed slab, they shall be removed immediately by approved methods.

(b) Slip-form Method. For the slip-form method, the concrete shall be placed with an approved crawler-mounted, slip-form paver designed to spread, consolidate, and shape the freshly placed concrete in one complete pass of the machine so that a minimum of hand finishing will be necessary to provide a dense and homogeneous pavement in conformance with requirements of the plans and specifications. The concrete should be placed directly on top of the joint assemblies to prevent them from moving when the paver moves over them. Side forms and finishing screeds shall be adjustable to the extent required to produce the specified pavement edge and surface tolerance. The side forms shall be of dimensions, shape, and strength to support the concrete laterally for a sufficient length of time so that no appreciable edge slumping will occur. Final finishing shall be accomplished while the concrete is still in the plastic state.

It is the intent of the specification to produce a high quality, dense, long lasting, and smooth pavement suitable for the high speed operations of roughness-sensitive heavy jet aircraft. This requires that all joints, and particularly all longitudinal joints, meet the specified tolerance throughout their length. The Engineer will designate the paving lanes in an apron, taxiway, or the outer runway paving lanes to be used for the initial paving operations. In the event that slumping or sloughing occurs behind the paver or if there are any other structural or surface defects which, in the opinion of the Engineer, cannot be corrected within permissible tolerances, the Engineer may halt paving operations until proper adjustment of the equipment or procedures have been made. In the event that satisfactory procedures and pavement are not achieved after not more than 2,000 lineal feet (600 m) of single lane paving, the Contractor shall complete the balance of the work with the use of standard metal forms and the formed method of placing and curing.

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3.11 STRIKE-OFF OF CONCRETE AND PLACEMENT OF REINFORCEMENT. Following the placing of the concrete, it shall be struck off to conform to the cross section shown on the plans and to an elevation such that when the concrete is properly consolidated and finished, the surface of the pavement shall be at the elevation shown on the plans. When reinforced concrete pavement is placed in two layers, the bottom layer shall be struck off to such length and depth that the sheet of reinforcing steel fabric or bar mat may be laid full length on the concrete in its final position without further manipulation. The reinforcement shall then be placed directly upon the concrete, after which the top layer of the concrete shall be placed, struck off, and screeded. If any portion of the bottom layer of concrete has been placed more than 30 minutes without being covered with the top layer or if initial set has taken place, it shall be removed and replaced with freshly mixed concrete at the Contractor's expense. When reinforced concrete is placed in one layer, the reinforcement may be positioned in advance of concrete placement or it may be placed in plastic concrete by mechanical or vibratory means after spreading.

Reinforcing steel, at the time concrete is placed, shall be free of mud, oil, or other organic matter that may adversely affect or reduce bond. Reinforcing steel with rust, mill scale, or a combination of both will be considered satisfactory, provided the minimum dimensions, weight, and tensile properties of a hand wire-brushed test specimen are not less than the applicable ASTM specification requirements.

3.12 JOINTS.

(a) General.

(1) Longitudinal and transverse joints. Longitudinal and transverse joints shall be constructed as indicated on the plans and in accordance with these requirements. All joints shall be constructed true to line with their faces perpendicular to the surface of the pavement. Joints shall not vary more than 1/2 inch (13 mm) from a true line or from their designated position. The vertical surface of the pavement adjacent to all expansion joints shall be finished to a true plane and edged to a radius of 1/4 inch (6 mm) or as shown on the plans. The surface across the joints shall be tested with a 10-foot (3 m) straightedge as the joints are finished and any irregularities in excess of 1/4 inch (6 mm) shall be corrected before the concrete has hardened. When required, keyways shall be accurately formed with a template of metal or wood. The gauge or thickness of the material in the template shall be such that the full keyway, as specified, is formed and is in the correct location. Transverse joints shall be at right angles to the centerline of the pavement and shall extend the full width of the slab. The transverse

joints in succeeding lanes shall be placed in line with similar joints in the first lane. All joints shall be so prepared, finished, or cut to provide a groove of the width and depth shown on the plans.

(2) Tie bars. Tie bars shall consist of deformed bars installed principally in longitudinal joints as shown on the plans. Tie bars shall be placed at right angles to the centerline of the concrete slab and shall be spaced at intervals of 30 inches (76 cm), unless otherwise specified. They shall be held in position parallel to the pavement surface and midway between the surfaces of the slab. When tie bars extend into an unpaved lane, they may be bent at right angles against the form at longitudinal construction joints, unless threaded bolt or other assembled tie bars are specified. These bars shall not be painted, greased, or enclosed in sleeves.

(3) Dowel bars. Dowel bars or other load-transfer units of an approved type shall be placed across transverse or other joints in the manner as specified on the plans. They shall be of the dimensions and spacings as shown and held rigidly in the middle of the slab depth in the proper horizontal and vertical alignment by an approved assembly device to be left permanently in place. The dowel or load-transfer and joint devices shall be rigid enough to permit complete assembly as a unit ready to be lifted and placed into position. A metal, or other type, dowel expansion cap or sleeve shall be furnished for each dowel bar used with expansion joints. These caps shall be substantial enough to prevent collapse and shall be placed on the ends of the dowels as shown on the plans. The caps or sleeves shall fit the dowel bar tightly and the closed end shall be watertight. The portion of each dowel painted with rust preventative paint, as required under Section 501-2.7, shall be thoroughly coated with asphalt MC-70, or an approved lubricant, to prevent the concrete from binding to that portion of the dowel. If free-sliding plastic-coated or epoxy-coated steel dowels are used, a lubrication bond breaker shall be used except when approved pullout tests indicate it is not necessary. In lieu of using dowel assemblies at contraction joints, dowel bars may be placed in the full thickness of pavement by a mechanical device approved by the Engineer.

(4) Slip-form construction. For slip-form construction, the following shall apply: When keyed construction joints are called for, a sheet metal keyway liner shall be required. The liner may remain in place permanently and become part of the keyed joint and shall be galvanized, copper clad, or of similar rust-resistant material, of sufficient stiffness to support the upper keyway flange. Two-piece hook bolts may be installed in either the male or female side of the keyed joint providing the installation is made without distorting the keyed

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dimensions or causing edge slump. If a bent tie bar installation is used, the tie bars shall be inserted through the sheet metal keyway liner only on the female side of the joint. The bent tie bar installation may cause breaking of some small amount of laitance where the bar goes through the liner when the exposed portion of the bar is bent for extension into the adjacent lane. In no case shall a bent tie bar installation for male keyways be permitted which will require chipping away of concrete to perform the straightening of the tie bar. Alternate methods of bar installation may be approved by the Engineer if the keyway can be formed to a tolerance of 1/4 inch (6 mm) in any dimension and without distortion or slumping of the top of the male flange. Transverse joints with dowels will require particular care to insure the dowels are accurately placed and not disturbed during concrete placement. Transverse dowels will require use of an apparatus to firmly hold the dowels perpendicular to the joint and parallel to the slab surface. During the concrete placement operation, it is advisable to place plastic concrete directly on the dowel assembly immediately prior to passage of the paver to help maintain dowel alignment. In lieu of using dowel assemblies at contraction joints, dowel bars may be placed in the full thickness of pavement by a mechanical device approved by the Engineer.

(b) Installation. The top of an assembled joint device shall be set at the proper distance below the pavement surface and the elevation shall be checked. Such devices shall be set to the required position and line and shall be securely held in place by stakes or other means during the pouring and finishing of the concrete. The premolded joint material shall be placed and held in a vertical position; if constructed in sections, there shall be no offsets between adjacent units. Dowel bars shall be checked for exact position and alignment as soon as the joint device is staked in place, and the device shall be tested to determine whether it is firmly supported. The maximum permissible tolerance on dowel bar alignment in each plane, horizontal and vertical, shall not exceed 2 percent or 1/4 inch (6 mm) per foot of a dowel bar. The most effective way to obtain proper alignment is with well-fabricated dowel baskets and dowel assemblies. In lieu of using dowel assemblies at contraction joints, dowel bars may be placed in the full thickness of pavement by mechanical device approved by the Engineer.

When joints in concrete pavements are sawed, the joints shall be cut as shown on the plans. Equipment shall be as described in Section 501-3.1. The circular cutter shall be capable of cutting a groove in a straight line and shall produce a slot at least 1/8 inch (3 mm) wide and to the depth shown on the plans. When shown on the plans or required by the specifications, the top portion of the slot or groove shall be widened by means of a second shallower cut or by suitable and approved beveling to provide

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adequate space for joint sealers. Sawing of the joints shall commence as soon as the concrete has hardened sufficiently to permit cutting without chipping, spalling, or tearing. Sawing shall be carried on both during the day and night as required. The joints shall be sawed at the required spacing consecutively in sequence of the concrete placement, unless otherwise approved by the Engineer.

(c) Longitudinal Joints.

(1) Construction. Longitudinal construction joints necessary for lane construction shall be formed against suitable side forms (usually made of steel) with or without keyways, as indicated in the plans. Wooden forms may be used under special conditions, when approved by the Engineer. When the concrete is placed using slip-form pavers, the keyway shall be formed in the plastic concrete by means of preformed metal keyway liners which are inserted during the slip-form operations to form the female side of the key and which may be left in place. The dimensions of the keyway forms shall not vary more than plus or minus 1/4 inch (3 mm) from the dimensions indicated and shall not deviate more than plus or minus 1/4 inch (6 mm) from the mid-depth of the pavement. A male keyway may be used providing the keyway and edge tolerances are met. Where butt-type joints with dowels are designated, the dowels for this type shall be painted and greased. The edges of the joint shall be finished with a grooving tool or edging tool, and a space or slot shall be formed along the joint of the dimensions, as indicated, to receive the joint sealing material. Longitudinal construction joints shall be sawed to provide a groove at the top conforming to the details and dimensions indicated on the plans. Provisions shall be made for the installation of tie bars as noted on the plans.

(2) Contraction or weakened-plane type. The longitudinal groove formed or sawed in the top of the slab shall be installed where indicated on the drawings. The groove shall be formed in the plastic concrete with suitable tools or material to obtain the width and depth specified, or it shall be sawed with approved equipment in the hardened concrete to the dimensions required. When the groove is formed in plastic concrete, it shall be true to line with not more than 1/4-inch (6 mm) variation in 10 feet (3 m); it shall be uniform in width and depth; and the sides of the groove shall be finished even and smooth with an edging tool. If an insert material is used, the installation and edge finish shall be according to the manufacturer's instructions. The sawed groove shall be straight and of uniform width and depth. In either case, the groove shall be clean cut so that spalling will be avoided at intersections with transverse joints. Tie bars shall be installed across these joints where indicated on the plans.

(3) Expansion. Longitudinal expansion joints shall be installed as indicated on the plans. The premolded filler, of the thickness as shown on the plans, shall extend for the full depth and width of the slab at the joint, except for space for sealant at the top of the slab. The filler shall be securely staked or fastened into position perpendicular to the proposed finished surface. A metal cap shall be provided to protect the top edge of the filler and to permit the concrete to be placed and finished. After the concrete has been placed and struck off, the cap shall be carefully withdrawn leaving the space over the premolded filler. The edges of the joint shall be finished and tooled while the concrete is still plastic.

(d) Transverse Joints.

(1) Expansion. Transverse expansion joints shall be installed at the locations and spacing as shown on the plans. The joints shall be installed at right angles to the centerline and perpendicular to the surface of the pavement. The joints shall be installed and finished to insure complete separation of the slabs. Expansion joints shall be of a premolded type conforming to these specifications and with the plans and shall be the full width of the pavement strip.

All concrete shall be cleaned from the top of the joint material. Before the pavement is opened to traffic, this space shall be swept clean and filled with approved joint sealing material.

All devices used for the installation of expansion joints shall be approved by the Engineer. They shall be easily removable without disturbing the concrete and held in proper transverse and vertical alignment. Immediately after forms are removed, any concrete bridging the joint space at the ends shall be removed for the full width and depth of the joint.

When specified, expansion joints shall be equipped with dowels of the dimensions and at the spacing and location indicated on the plans. The dowels shall be firmly supported in place and accurately aligned parallel to the subgrade and the centerline of the pavement by means of a dowel assembly which will remain in the pavement and will ensure that the dowels are not displaced during construction.

Other types of load-transfer devices may be used, when approved by the Engineer.

(2) Contraction. Transverse contraction joints, weakened-plane joints, or both, shall be installed at the locations and spacing as shown on the plans. These joints will be installed by forming a groove or cleft in the top of the slab while the concrete is still plastic or by sawing a groove into

the concrete surface after the concrete has hardened in the same manner as specified in Section 501-3.12(c)(2). Dowel bar assemblies shall be installed, when required, as shown on the plans.

(3) Construction. Transverse construction joints shall be installed at the end of each day's placing operations and at any other points within a paving lane when concrete placement is interrupted for more than 30 minutes or it appears that the concrete will obtain its initial set before fresh concrete arrives. When the installation of the joint can be planned in advance, it shall be located at a contraction or expansion joint. The joint shall not be allowed within 8 feet (2.4 m) of a regular spaced transverse joint. If the pouring of the concrete has been stopped, causing a joint to fall within this limit, it shall not be installed, and the fresh placed concrete shall be removed back to the 8 foot (2.4 m) limit.

3.13 FINAL STRIKE-OFF, CONSOLIDATION, AND FINISHING.

(a) Sequence. The sequence of operations shall be the strike-off and consolidation, floating and removal of laitance, straightedging, and final surface finish. The addition of superficial water to the surface of the concrete to assist in finishing operations generally will not be permitted. If the application of water to the surface is permitted, it shall be applied as a fog spray by means of approved spray equipment.

(b) Finishing at Joints. The concrete adjacent to joints shall be compacted or firmly placed without voids or segregation against the joint material; it shall be firmly placed without voids or segregation under and around all load-transfer devices, joint assembly units, and other features designed to extend into the pavement. Concrete adjacent to joints shall be mechanically vibrated as required in Section 501-3.10. After the concrete has been placed and vibrated adjacent to the joints, the finishing machine shall be operated in a manner to avoid damage or misalignment of joints. If uninterrupted operations of the finishing machine, to, over, and beyond the joints, cause segregation of concrete, damage to, or misalignment of the joints, the finishing machine shall be stopped when the screed is approximately 8 inches (20 cm) from the joint. Segregated concrete shall be removed from the front of and off the joint; the screed shall be lifted and set directly on top of the joint, and the forward motion of the finishing machine shall be resumed. Thereafter, the finishing machine may be run over the joint without lifting the screed, provided there is no segregated concrete immediately between the joint and the screed or on top of the joint.

(c) Machine Finishing. The concrete shall be spread as soon as it is placed, and it shall be struck off and screeded by an approved finishing machine. The machine shall go over each area as many times and at such intervals as necessary to give the proper consolidation and to leave a surface of uniform texture. Excessive operation over a given area shall be avoided. When side forms are used, the tops of the forms shall be kept clean by an effective device attached to the machine, and the travel of the machine on the forms shall be maintained true without lift, wobbling, or other variation tending to affect the precision finish. During the first pass of the finishing machine, a uniform ridge of concrete shall be maintained ahead of the front screed for its entire length. When in operation, the screed shall be moved forward with a combined longitudinal and transverse shearing motion, always moving in the direction in which the work is progressing, and so manipulated that neither end is raised from the side forms during the striking-off process. If necessary, this shall be repeated until the surface is of uniform texture, true to grade and cross section, and free from porous areas.

(d) Hand Finishing. Hand finishing methods will not be permitted, except under the following conditions: In the event of breakdown of the mechanical equipment, hand methods may be used to finish the concrete already deposited on the grade; in areas of narrow widths or of irregular dimensions where operation of the mechanical equipment is impractical. Concrete, as soon as placed, shall be struck off and screeded. An approved portable screed shall be used. A second screed shall be provided for striking off the bottom layer of concrete when reinforcement is used.

The screed for the surface shall be at least 2 feet (0.6m) longer than the maximum width of the slab to be struck off. It shall be of approved design, sufficiently rigid to retain its shape, and shall be constructed either of metal or of other suitable material covered with metal. Consolidation shall be attained by the use of a suitable vibrator.

(e) Floating. After the concrete has been struck off and consolidated, it shall be further smoothed, trued, and consolidated by means of a longitudinal float, using one of the following methods:

(1) Hand Method. The hand-operated longitudinal float shall not be less than 12 feet (3.6 m) in length and 6 inches (15 cm) in width, properly stiffened to prevent flexibility and warping. The longitudinal float, operated from foot bridges resting on the side forms and spanning but not touching the concrete, shall be worked with a sawing motion, while held in a floating position parallel to the pavement centerline and passing

gradually from one side of the pavement to the other. Forward movement along the centerline of the pavement shall be in successive advances of not more than one-half the length of the float. Any excess water or soupy material shall be wasted over the pavement edge on each pass.

(2) Mechanical method. The Contractor may use a machine composed of a cutting and smoothing float(s), suspended from and guided by a rigid frame. The frame shall be carried by four or more visible wheels riding on, and constantly in contact with, the side forms or pavement subgrade. If necessary, long-handled floats having blades not less than 5 feet (1.5 m) in length and 6 inches (1.5 cm) in width may be used to smooth and fill in open-textured areas in the pavement. Long-handled floats shall not be used to float the entire surface of the pavement in lieu of mechanical methods. When strike-off and consolidation are done by hand and the crown of the pavement will not permit the use of the longitudinal float, the surface shall be floated transversely by means of a long-handled float. Care shall be taken not to work the crown out of the pavement during the operation. After floating, any excess water and laitance shall be removed from the surface of the pavement by a straightedge 10 feet (3 m) or more in length. Successive drags shall be lapped one-half the length of the blade.

(f) Straight-edge Testing and Surface Correction. After the pavement has been struck off and consolidated and while the concrete is still plastic, it shall be tested for trueness with a 16-foot (4.8 m) straightedge. For this purpose the Contractor shall furnish and use an accurate 16-foot (4.8 m) straightedge swung from handles 3 feet (0.4 m) longer than one-half the width of the slab. The straightedge shall be held in contact with the surface in successive positions parallel to the centerline and the whole area gone over from one side of the slab to the other, as necessary. Advancing shall be in successive stages of not more than one-half the length of the straightedge. Any excess water and laitance shall be removed from the surface of the pavement. Any depressions shall be immediately filled with freshly mixed concrete, struck off, consolidated, and refinished. High areas shall be cut down and refinished. Special attention shall be given to assure that the surface across joints meets the requirements for smoothness. Straightedge testing and surface corrections shall continue until the entire surface is found to be free from observable departures from the straightedge and until the slab conforms to the required grade and cross section. The use of long-handled wood floats shall be confined to a minimum; they may be used only in emergencies and in areas not accessible to finishing equipment.

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3.14 SURFACE TEXTURE. The surface of the pavement shall be finished with either a broom or burlap drag finish for all newly constructed concrete pavements.

(a) Brush or Broom Finish. If the pavement surface texture is to be a type of brush or broom finish, it shall be applied when the water sheen has practically disappeared. The equipment shall operate transversely across the pavement surface, providing corrugations that are uniform in appearance and approximately 1/16 of an inch (2 mm) in depth. It is important that the texturing equipment not tear or unduly roughen the pavement surface during the operation. Any imperfections resulting from the texturing operation shall be corrected.

(b) Burlap Drag Finish. If a burlap drag is used to texture the pavement surface, it shall be at least 15 ounces per square yard (555 grams per square meter). To obtain a rough-textured surface, the transverse threads of the burlap should be removed approximately 1 foot (0.3 m) from the trailing edge. A heavy buildup of grout on the burlap threads produces the desired wide sweeping longitudinal striations on the pavement surface. The corrugations shall be uniform in appearance and approximately 1/16 of an inch (2 mm) in depth.

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Several methods are available for providing skid resistant runway pavement surfaces. They are saw-cut grooves, and grooves or wire combed texture constructed in plastic concrete. In all cases, either a broom, brush, or burlap finish in the plastic concrete pavement shall be provided prior to construction of the skid surface treatment. The Engineer shall specify one of the above methods if a skid resistant surface is required.

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3.15 SKID RESISTANT SURFACES. A skid resistant surface shall be provided by construction of [**_____.]

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The Engineer shall specify either sawcut grooves, plastic grooves, or wire combing and include one of the following paragraphs in the specification:

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Sawcut Grooves. For new concrete pavements that have hardened, transverse grooves shall be saw-cut in the pavement forming a 1/4 inch (6 mm) by 1/4 inch (6 mm) by 1-1/4 inches (31 mm) configuration. The grooves shall be continuous for the entire runway length. They shall be saw-cut transversely in the runway pavement to within 10 feet (3 m) of the runway pavement edge to allow adequate space for equipment operation. The maximum transverse saw-cut grooves shall not exceed 130 feet (40 m). The tolerances for the saw-cut grooves shall meet the following:

Alignment tolerance.

Plus or minus 1 1/2 inches (38 mm) in alignment for 75 feet (23 m).

Groove tolerance.

Minimum depth 3/16 inch (5 mm).

Maximum depth 5/16 inch (8 mm).

Minimum width 3/16 inch (5 mm).

Maximum width 5/16 inch (8 mm).

Center-to-center spacing.

Minimum spacing 1 1/4 inches (31 mm).

Maximum spacing 2 inches (50 mm).

Saw-cut grooves shall not be closer than 3 inches (76 mm) to transverse paving joints. Grooves may be continued through longitudinal construction joints. Cleanup of waste material shall be continuous during the grooving operation. Waste material may be disposed of by either flushing with water, sweeping, or vacuuming. Waste material must not be allowed to enter the airport storm or sanitary sewer system.

Plastic grooves. The grooves formed in the plastic concrete shall be 1/4 inch (6 mm) by 1/4 inch (6 mm) by 1-1/4 inches (31 mm). The grooves shall be continuous for the entire runway length and width. The tolerances for the grooves formed in plastic concrete shall meet the following:

Alignment tolerance.

Plus or minus 3 inches (76 mm) in alignment for 75 feet (23 m).

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Groove tolerance. 1692

Minimum depth 1/8 inch (3 mm). 1694

Maximum depth 3/8 inch (10 mm). 1696

Minimum width 1/8 inch (3 mm). 1698

Maximum width 3/8 inch (10 mm). 1700

Center-to-center spacing. 1702

Minimum spacing 1 1/4 inches (31 mm). 1704

Maximum spacing 2 inches (50 mm). 1706

Wire Combing. The wire combing technique shall use steel combs or tines of various dimensions to form groove-like texture in the plastic concrete pavement and shall provide grooves that are approximately 1/8 inch (3 mm) by 1/8 inch (3 mm) spaced 1/2 inch (13 mm) center-to-center. 1708 1709 1710 1711 1711

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3.16 SURFACE TEST. As soon as the concrete has hardened sufficiently, the pavement surface shall be tested with a 16-foot (5 m) straightedge or other specified device. Areas in a slab showing high spots of more than 1/4 inch (6 mm) but not exceeding 1/2 inch (13 mm) in 16 feet (5 m) shall be marked and immediately ground down with an approved grinding machine to an elevation that will fall within the tolerance of 1/4 inch (6 mm) or less. Where the departure from correct cross section exceeds 1/2 inch (13 mm), the pavement shall be removed and replaced at the expense of the Contractor when so directed by the Engineer. 1718 1719 1721 1722 1723 1724 1724 1725 1726 1727

Any area or section so removed shall not be less than 10 feet (3 m) in length nor less than the full width of the lane involved. When it is necessary to remove and replace a section of pavement, any remaining portion of the slab adjacent to the joints that is less than 10 feet (3 m) in length shall also be removed and replaced. 1729 1730 1731 1732 1733 1733

3.17 CURING. Immediately after the finishing operations have been completed and marring of the concrete will not occur, the entire surface of the newly placed concrete shall be cured in accordance with one of the methods below. In all cases in which curing requires the use of water, the curing shall have prior right to all water supply or supplies. Failure to provide sufficient cover material of whatever kind the Contractor may elect to use, or lack of water to adequately take care of both curing and other requirements, shall be cause for immediate 1736 1738 1738 1740 1741 1742 1743 1744 1745

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suspension of concreting operations. The concrete shall not be left exposed for more than 1/2 hour during the curing period. The following are alternate approved methods for curing concrete pavements.

(a) Impervious Membrane Method. The entire surface of the pavement shall be sprayed uniformly with white pigmented curing compound immediately after the finishing of the surface and before the set of the concrete has taken place. The curing compound shall not be applied during rainfall. Curing compound shall be applied by mechanical sprayers under pressure at the rate of 1 gallon (4 liters) to not more than 150 square feet (14 square meters). The spraying equipment shall be of the fully atomizing type equipped with a tank agitator. At the time of use, the compound shall be in a thoroughly mixed condition with the pigment uniformly dispersed throughout the vehicle. During application the compound shall be stirred continuously by effective mechanical means. Hand spraying of odd widths or shapes and concrete surfaces exposed by the removal of forms will be permitted. Curing compound shall not be applied to the inside faces of joints to be sealed, but approved means shall be used to insure proper curing for 72 hours. The curing compound shall be of such character that the film will harden within 30 minutes after application. Should the film become damaged from any cause within the required curing period, the damaged portions shall be repaired immediately with additional compound. Upon removal of side forms, the sides of the exposed slabs shall be protected immediately to provide a curing treatment equal to that provided for the surface.

(b) Polyethylene Films. The top surface and sides of the pavement shall be entirely covered with polyethylene sheeting. The units shall be lapped at least 18 inches (457 mm). The sheeting shall be placed and weighted to cause it to remain in contact with the surface covered. The sheeting shall have dimensions that will extend at least twice the thickness of the pavement beyond the edges of the pavement. Unless otherwise specified, the sheeting shall be maintained in place for 72 hours after the concrete has been placed.

(c) Waterproof Paper. The top surface and sides of the pavement shall be entirely covered with waterproofed paper. The units shall be lapped at least 18 inches (457 mm). The paper shall be placed and weighted to cause it to remain in contact with the surface covered. The paper shall have dimensions that will extend at least twice the thickness of the pavement beyond the edges of the slab. The surface of the pavement shall be thoroughly wetted prior to placing of the paper. Unless otherwise specified, the paper shall be maintained in place for 72 hours after the concrete has been placed.

(d) White Burlap-Polyethylene Sheets. The surface of the pavement shall be entirely covered with the sheeting. The sheeting used shall be such length (or width) that it will extend at least twice the thickness of the pavement beyond the edges of the slab. The sheeting shall be placed so that the entire surface and both edges of the slab are completely covered. The sheeting shall be placed and weighted to remain in contact with the surface covered, and the covering shall be maintained fully wetted and in position for 72 hours after the concrete has been placed.

(e) Curing in Cold Weather. When the average daily temperature is below 40 degrees F (4 degrees C), curing shall consist of covering the newly laid pavement with not less than 12 inches (30 cm) of loose, dry hay or straw, or equivalent protective curing authorized by the Engineer, which shall be retained in place for 10 days. The hay or straw shall be secured to avoid being blown away. Admixture for curing or temperature control may be used only when authorized by the Engineer.

When concrete is being placed and the air temperature may be expected to drop below 35 degrees F (2 degrees C), a sufficient supply of straw, hay, grass, or other suitable blanketing material such as burlap or polyethylene shall be provided along the work. Any time the temperature may be expected to reach the freezing point during the day or night, the material so provided shall be spread over the pavement to a sufficient depth to prevent freezing of the concrete. The period of time such protection shall be maintained shall not be less than 10 days. A minimum of 3 days is required when high, early strength concrete is used. The Contractor shall be responsible for the quality and strength of the concrete placed during cold weather, and any concrete injured by frost action shall be removed and replaced at the Contractor's expense.

3.18 REMOVING FORMS. Unless otherwise specified, forms shall not be removed from freshly placed concrete until it has set for at least 12 hours, except where auxiliary forms are used temporarily in widened areas. Forms shall be removed carefully to avoid damage to the pavement. After the forms have been removed, the sides of the slab shall be cured as outlined in one of the methods indicated in Section 501-3.17. Major honeycombed areas shall be considered as defective work and shall be removed and replaced. Any area or section so removed shall not be less than 10 feet (3 m) in length nor less than the full width of the lane involved. When it is necessary to remove and replace a section of pavement, any remaining portion of the slab adjacent to the joints that is less than 10 feet (3 m) in length shall also be removed and replaced.

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3.19 SEALING JOINTS. The joints in the pavement shall be sealed in accordance with Item P-605. 1863 1863

3.20 PROTECTION OF PAVEMENT. The Contractor shall protect the pavement and its appurtenances against both public traffic and traffic caused by the Contractor's employees and agents. This shall include watchmen to direct traffic and the erection and maintenance of warning signs, lights, pavement bridges, or crossovers, etc. The plans or special provisions will indicate the location and type of device or facility required to protect the work and provide adequately for traffic. Any damage to the pavement occurring prior to final acceptance shall be repaired or the pavement replaced at the Contractor's expense. In order that the concrete be properly protected against the effects of rain before the concrete is sufficiently hardened, the Contractor will be required to have available at all time materials for the protection of the edges and surfaces of the unhardened concrete. Such protective materials shall consist of rolled polyethylene sheeting at least 4 mils (0.1 mm) thick of sufficient length and width to cover the plastic concrete slab and any edges. The sheeting may be mounted on either the paver or a separate movable bridge from which it can be unrolled without dragging over the plastic concrete surface. When rain appears imminent, all paving operations shall stop and all available personnel shall begin covering the surface of the unhardened concrete with the protective covering. 1866 1867 1868 1868 1872 1874 1875 1877 1878 1879 1880 1881 1882 1882 1883 1884 1886 1886 1887 1890 1891 1891 1892

3.21 OPENING TO TRAFFIC. The Engineer shall decide when the pavement shall be opened to traffic. The pavement will not be opened to traffic until test specimens molded and cured in accordance with ASTM C31 have attained a flexural strength of 550 pounds per square inch (3792 kPa) when tested in accordance with ASTM C78. If such tests are not conducted, the pavement shall not be opened to traffic until 14 days after the concrete was placed. Prior to opening to traffic, the pavement shall be cleaned. 1895 1896 1897 1898 1899 1901 1902 1904 1904

3.22 SURFACE TOLERANCES. Extreme care must be exercised in all phases of the operation to assure the pavement will pass the specified tolerances. The following tolerances are applicable: 1907 1908 1909

(a) Lateral deviation from established alignment of the pavement edge shall not exceed plus or minus 0.10 foot (30 mm) in any lane. 1911 1912 1912

(b) Vertical deviation from established grade shall not exceed plus or minus 0.04 foot (12 mm) at any point. 1914 1915

(c) Surface smoothness deviations shall not exceed 1/4 inch (6 mm) from a 16-foot (5 m) straightedge placed in any direction, 1917 1918

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including placement along and spanning any pavement joint or edge.

3.23 TOLERANCE IN PAVEMENT THICKNESS. Concrete will be accepted for thickness on a lot basis. A lot will consist of [**_____] square yards (cubic yards). One core shall be taken at random by the Engineer in each lot. When the measurement of the core from a lot is not deficient more than 0.2 inch (5 mm) from the plan thickness, full payment will be made. When such measurement is deficient more than 0.2 inch (5 mm) and not more than 1.0 inch (25 mm) from the plan thickness, two additional cores shall be taken at random and used in determining the average thickness for that lot. An adjusted unit price, as provided in Paragraph 501-5.2, will be paid for the lot. The thickness of the pavement shall be determined by average caliper measurement of cores tested in accordance with ASTM C174.

In calculating the average thickness of the pavement, measurements which are in excess of the specified thickness by more than 0.2 inch (5 mm) shall be considered as the specified thickness plus 0.2 inch (5 mm), and measurements which are less than the specified thickness by more than 1.0 inch (25 mm) shall not be included in the average.

When the measurement of any core is less than the specified thickness by more than 1.0 inch (25 mm), the actual thickness of the pavement in this area shall be determined by taking additional cores at not less than 10-foot (3 m) intervals parallel to the centerline in each direction from the affected location, until in each direction a core is found which is not deficient by more than 1.0 inch (25 mm). Areas found deficient in thickness by more than 1.0 inch (25 mm) shall be evaluated by the Engineer and, if the deficient areas warrant removal, they shall be removed and replaced with concrete of the thickness shown on the plans. Exploratory cores for deficient thickness will not be used in averages for adjusted unit price. Core holes shall be filled with non-shrink grout.
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The lot size shall be equal to that specified for flexural strength determinations under 501-3.7 (alternate method) and should not exceed a day's pour.
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4. METHOD OF MEASUREMENT 1976

4.1 The quantity to be paid for shall be the number of square yards (square meters) of either plain or reinforced pavement as specified, in place, completed and accepted, less deductions as hereinafter required for deficient thickness. 1978 1979 1982 1982

5. BASIS OF PAYMENT 1984

5.1 General. The accepted quantities of concrete pavement will be paid for at the contract unit price per square yard (square meters) which price and payment shall be full compensation for furnishing and placing all materials, including any dowels, steel reinforcement and joint material texturing, except for saw-cut grooving, provided, however, that for any pavement found deficient in thickness by more than 0.2 inch (5 mm), but not more than 1.0 inch (25 mm) only the reduced price stipulated below shall be paid. 1987 1988 1989 1991 1992 1995 1997 1998 1998

No additional payment over the unit contract bid price shall be made for any pavement which has an average thickness in excess of that shown on the plans. 2000 2001 2002

Payment will be made under: 2004

Item P-501-5.1	Portland Cement Concrete Pavement - per square yard (per square meter).	2007 2007
Item P-501-5.1	Saw-Cut Grooving -- per square foot (per square meter).	2010 2010

5.2 Price adjustment 2012

(a) Thickness adjustment. Where the average thickness of pavement is deficient in thickness by more than 0.2 inch (5 mm) but not more than 1.0 inch (25 mm), payment will be made at an adjusted price as specified in Table 3. 2015 2016 2017 2017

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TABLE 3. PAVEMENT DEFICIENCY 2019

Deficiency in Thickness Determined by Cores (Average of 3 tests)			Proportional Part of Contract Price Allowed (Percent)
inches		mm	
0.00 to 0.20	0.00	to 5	100
0.21 to 0.30	5	to 8	80
0.31 to 0.40	8	to 10	72
0.41 to 0.50	10	to 13	68
0.51 to 0.75	13	to 19	57
0.76 to 1.00	19	to 25	50

When the thickness of pavement is deficient by more than 1 inch (25 mm) and, in the judgment of the Engineer, the area of such deficiency should not be removed and replaced, there shall be no payment for the area retained.

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The following optional paragraph applies when concrete is accepted for flexural strength as described under Notes to the Engineer in Paragraph 501-3.7. Delete paragraph below if not applicable.

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(b) Flexural Strength Adjustment. When any pay factor for a lot of concrete is less than 1.0, payment for the material in that lot shall be made at a reduced price arrived at by multiplying the contract price per unit of measurement by the appropriate pay factor. If pay factors for pavement thickness deficiency and flexural strength deficiency are both used for any given lot, the reduced price will be determined by successively multiplying the contract unit price by both pay factors.

6. TESTING AND MATERIAL REQUIREMENTS

6.1 TESTS

ASTM C31	Making and Curing Concrete Test Specimens in the Field
ASTM C39	Compressive Strength of Cylindrical Concrete Specimens

U.S. GOVERNMENT PRINTING OFFICE: 1979-281-568/8