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USACE / NAVFAC / AFCEC / NASA **UFGS-32 13 43 (October 2011)**
Change 2 - 08/17

Preparing Activity: NAVFAC **NEW**

UNIFIED FACILITIES GUIDE SPECIFICATIONS

References are in agreement with UMRL dated July 2019
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SECTION 32 13 43

PERVIOUS CONCRETE PAVING

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SECTION 32 13 43

PERVIOUS CONCRETE PAVING
11/11

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NOTE: This guide specification covers the requirements for Pervious Portland cement concrete paving jobs such as roads, streets, sidewalks, and parking lots.

Adhere to UFC 1-300-02 Unified Facilities Guide Specifications (UFGS) Format Standard when editing this guide specification or preparing new project specification sections. Edit this guide specification for project specific requirements by adding, deleting, or revising text. For bracketed items, choose applicable item(s) or insert appropriate information.

Remove information and requirements not required in respective project, whether or not brackets are present.

Comments, suggestions and recommended changes for this guide specification are welcome and should be submitted as a Criteria Change Request (CCR).
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NOTE: The extent and location of the work to be accomplished should be indicated on the project drawings, or included in the project specifications. Precast structural concrete and portland cement pavements for airports are not included in this specification.

Porous PCCP should not be used in areas with extensive winter maintenance and in areas where high wind is common (material can be wind blown and clog the pavement pores). Additionally, this pavement should not be used where there is heavy truck traffic.
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PART 1 GENERAL

1.1 REFERENCES

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NOTE: This paragraph is used to list the publications cited in the text of the guide specification. The publications are referred to in the text by basic designation only and listed in this paragraph by organization, designation, date, and title.

Use the Reference Wizard's Check Reference feature when you add a Reference Identifier (RID) outside of the Section's Reference Article to automatically place the reference in the Reference Article. Also use the Reference Wizard's Check Reference feature to update the issue dates.

References not used in the text will automatically be deleted from this section of the project specification when you choose to reconcile references in the publish print process.

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The publications listed below form a part of this specification to the extent referenced. The publications are referred to within the text by the basic designation only.

AMERICAN CONCRETE INSTITUTE (ACI)

ACI 305R	(2010) Guide to Hot Weather Concreting
ACI 306.1	(1990; R 2002) Standard Specification for Cold Weather Concreting
ACI 522.1	(2013) Specification For Pervious Concrete Pavement

ASTM INTERNATIONAL (ASTM)

ASTM C33/C33M	(2018) Standard Specification for Concrete Aggregates
ASTM C42/C42M	(2018a) Standard Test Method for Obtaining and Testing Drilled Cores and Sawed Beams of Concrete
ASTM C94/C94M	(2018) Standard Specification for Ready-Mixed Concrete
ASTM C140/C140M	(2018a) Standard Test Methods for Sampling and Testing Concrete Masonry Units and Related Units
ASTM C150/C150M	(2018) Standard Specification for Portland Cement
ASTM C171	(2016) Standard Specification for Sheet

	Materials for Curing Concrete
ASTM C172/C172M	(2017) Standard Practice for Sampling Freshly Mixed Concrete
ASTM C174/C174M	(2017) Standard Test Method for Measuring Thickness of Concrete Elements Using Drilled Concrete Cores
ASTM C260/C260M	(2010a; R 2016) Standard Specification for Air-Entraining Admixtures for Concrete
ASTM C494/C494M	(2017) Standard Specification for Chemical Admixtures for Concrete
ASTM C595/C595M	(2018) Standard Specification for Blended Hydraulic Cements
ASTM C618	(2019) Standard Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use in Concrete
ASTM C989/C989M	(2018a) Standard Specification for Slag Cement for Use in Concrete and Mortars
ASTM C1077	(2017) Standard Practice for Agencies Testing Concrete and Concrete Aggregates for Use in Construction and Criteria for Testing Agency Evaluation
ASTM C1157/C1157M	(2017) Standard Performance Specification for Hydraulic Cement
ASTM C1260	(2014) Standard Test Method for Potential Alkali Reactivity of Aggregates (Mortar-Bar Method)
ASTM C1549	(2016) Standard Test Method for Determination of Solar Reflectance Near Ambient Temperature Using a Portable Solar Reflectometer
ASTM C1567	(2013) Standard Test Method for Potential Alkali-Silica Reactivity of Combinations of Cementitious Materials and Aggregate (Accelerated Mortar-Bar Method)
ASTM C1602/C1602M	(2018) Standard Specification for Mixing Water Used in Production of Hydraulic Cement Concrete
ASTM C1688/C1688M	(2014a) Standard Test Method For Density And Void Content Of Freshly Mixed Pervious Concrete
ASTM D6155	(2015) Nontraditional Coarse Aggregate for Bituminous Paving Mixtures

1.2 RELATED SECTIONS

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NOTE: Do not install pervious pavement systems in areas subject to high wheel loads (such as aircraft, ground support equipment, and forklifts). Consult manufacturer's recommendations for cold regions, arid regions, and regions with high wind erosion. Pervious concrete in freezing areas should be designed with adequate base thickness to ensure that water does not remain in the pavement layer during freezing conditions. Parking lots are generally good pervious pavement applications.

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Pervious pavement systems must use Section 32 11 20 [BASE COURSE FOR RIGID][AND][SUBBASES FOR FLEXIBLE] PAVING in addition to this section.

1.3 SUBMITTALS

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NOTE: Review Submittal Description (SD) definitions in Section 01 33 00 SUBMITTAL PROCEDURES and edit the following list to reflect only the submittals required for the project.

The Guide Specification technical editors have designated those items that require Government approval, due to their complexity or criticality, with a "G." Generally, other submittal items can be reviewed by the Contractor's Quality Control System. Only add a "G" to an item, if the submittal is sufficiently important or complex in context of the project.

For submittals requiring Government approval on Army projects, a code of up to three characters within the submittal tags may be used following the "G" designation to indicate the approving authority. Codes for Army projects using the Resident Management System (RMS) are: "AE" for Architect-Engineer; "DO" for District Office (Engineering Division or other organization in the District Office); "AO" for Area Office; "RO" for Resident Office; and "PO" for Project Office. Codes following the "G" typically are not used for Navy, Air Force, and NASA projects.

The "S" following a submittal item indicates that the submittal is required for the Sustainability eNotebook to fulfill federally mandated sustainable requirements in accordance with Section 01 33 29 SUSTAINABILITY REPORTING. Locate the "S" submittal under the SD number that best describes the submittal item.

Choose the first bracketed item for Navy, Air Force and NASA projects, or choose the second bracketed item for Army projects.

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Government approval is required for submittals with a "G" designation; submittals not having a "G" designation are [for Contractor Quality Control approval.][for information only. When used, a designation following the "G" designation identifies the office that will review the submittal for the Government.] Submittals with an "S" are for inclusion in the Sustainability eNotebook, in conformance with Section 01 33 29 SUSTAINABILITY REPORTING. Submit the following in accordance with Section 01 33 00 SUBMITTAL PROCEDURES:

SD-03 Product Data

Curing Materials

Admixtures

Fine Aggregates

Coarse Aggregates

Cementitious Materials

[Albedo

] SD-04 Samples

[Field-Constructed Mockup

] SD-05 Design Data

Concrete Mix Design

SD-06 Test Reports

Aggregate Tests

Cementitious Materials

Concrete Density Tests

SD-07 Certificates

Ready-mixed Concrete Plant

Ready-mixed Concrete Truck

Batch Tickets

Cementitious Materials

1.4 DELIVERY AND STORAGE

ASTM C94/C94M.

1.5 QUALITY ASSURANCE

1.5.1 Ready-mixed Concrete Plant and Ready-mixed Concrete Truck

Unless otherwise approved by the Contracting Officer, ready mixed pervious concrete must be produced and provided by a National Ready-Mix Concrete Association (NRMCA) certified plant. If a volumetric mobile mixer is used to produce the pervious concrete, rather than ready-mixed pervious concrete, the mixer(s) must conform to the standards of the Volumetric Mixer Manufacturers Bureau (VMMB). Verification must be made by a current VMMB conformance plate affixed to the volumetric mixer equipment.

1.5.2 Contractor Qualifications

Unless waived by the Contracting Officer, the Contractor must meet one of the following criteria:

a. Contractor must have at least one National Ready Mixed Concrete Association (NRMCA) certified pervious concrete craftsman on site, overseeing each placement crew during all concrete placement.

b. Contractor must have no less than three NRMCA certified pervious concrete installers, who must be on site working as members of each placement crew during all concrete placement.

1.5.3 Required Information

Submit copies of laboratory test reports showing that the mix has been successfully tested to produce concrete with the properties specified and that mix will be suitable for the job conditions. The laboratory test reports must include mill test and all other tests for cementitious materials, aggregates, and admixtures. Provide maximum nominal aggregate size, combined aggregate gradation analysis, percentage retained and passing sieve, and a graph of percentage retained verses sieve size. Submit test reports must be submitted along with the concrete mix design. Sampling and testing of materials, concrete mix design, sampling and testing in the field must be performed by a commercial testing laboratory which conforms to ASTM C1077. The laboratory must be approved in writing by the Contracting Officer.

1.5.4 Batch Tickets

ASTM C94/C94M. Submit mandatory batch ticket information for each load of ready-mixed concrete.

[1.5.5 Field-Constructed Mockup

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NOTE: Pervious pavement (permeable pavement) is a permeable surface with an underlying stone reservoir to temporarily store surface runoff before it infiltrates into the subsoil. This permeable surface replaces traditional pavement, allowing parking lot storm water to infiltrate directly and receive water quality treatment. Pervious asphalt and concrete may appear to be similar to traditional pavement from the surface, but are manufactured without "fine" materials, and incorporate void spaces to allow infiltration.

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Install a minimum 37 square meters 400 square feet to demonstrate typical joints, surface finish, texture, color, permeability, thickness, density, and standard of workmanship. Test panels must be placed using the mixture proportions, materials, and equipment as proposed for the project. Test mock up panels in accordance with requirements in subpart FIELD QUALITY CONTROL.

When a test panel is does not meet one or more of the requirements, the test panel must be rejected, removed, and replaced at the Contractor's expense. If the test panels are acceptable, they may be incorporated into the project with the approval of the Contracting Officer.

]PART 2 PRODUCTS

2.1 MATERIALS

2.1.1 Cementitious Materials

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NOTE: ASTM C595 covers three kinds of blended hydraulic cements. The three types are as follows:

1. Portland Blast - Furnace Slag Cement (Type IS).

2. Portland - Pozzolan Cement (Types IP and P).

3. Ternary blended Cement (Type IT).

For sulfate resistance consider using types IS (MS) or IP (MS), II, and V.

Types IS-A, IP-A, PA, SA, and PM-A are air-entrained cements but should not be specified because of inability to control air content and lack of uniformity.

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NOTE: Cement is 10 to 15 percent of concrete, but is more energy intensive than the other constituents. Use the minimum amount of cement required for a project to produce quality concrete. Fly ash is commonly used as a replacement for portland cement but typically replaces less than 40 percent of the cement; it needs to be tested extensively for compatibility and performance if the fly ash is intended to replace 40 percent or more of the cement. Include the last sentence of the following paragraph if fly ash replaces 40 percent of portland cement.

Coal fly ash, slag, cenospheres, and silica fumes are EPA designated recovered products to be ingredients in concrete and cement. Use materials with recycled content where appropriate for use. The following section allows a percentage range of non-portland cement materials to be used. The

Contractor must incorporate these other non-cement materials based on local availability and mixes available at local plants. A resource that can be used for additional information on recovered materials used in cement and concrete is the "Comprehensive Procurement Guidelines (CPG)" page within the EPA's website at http://www.epa.gov.

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Cementitious materials in concrete mix must be 20 to 50 percent non-portland cement pozzolanic materials by weight.[Provide test data demonstrating compatibility and performance of concrete satisfactory to Contracting Officer.]

2.1.1.1 Cement

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NOTE: A maximum alkali content of 0.40 percent is more desirable and should be used where available. However, the availability of low alkali cement is extremely limited and is not economically feasible in most cases. Therefore the use of low alkali cement is not required.

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ASTM C150/C150M, Type I or II [III, for high early concrete] [or V] [low alkali]or ASTM C595/C595M, Type IS, IP, or P [MS] [MH] [mortar expansion] or ASTM C1157/C1157M [MS] [HS] [R].

2.1.1.2 Fly Ash and Pozzolan

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NOTE: Fly ash, pozzolan, and slag cement may produce uneven discoloration of the concrete during the early stages of construction, depending upon the type of curing provided. Fly ash or pozzolan meeting the specified test results, which are more stringent than ASTM C618, should provide acceptable end results.

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ASTM C618, Type C, F, or N. Fly ash certificates must include test results in accordance with ASTM C618.

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NOTE: A maximum calcium oxide content of 2 percent is more desirable but not required.

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2.1.1.3 Slag

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NOTE: GGBFS Grade 120 is more desirable but Grade 100 is allowed.

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ASTM C989/C989M, Slag Cement (formerly Ground Granulated Blast Furnace Slag) Grade 100 or 120. Certificates must include test results in accordance with ASTM C989/C989M.

2.1.2 Water

Water must conform to ASTM C1602/C1602M. Do not use hot water unless approved by the Contracting Officer.

2.1.3 Aggregate Tests

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Use materials with recycled content where appropriate for use. Verify suitability, availability within the region, cost effectiveness and adequate competition (including verification of bracketed percentages included in this guide specification) before specifying product recycled content requirements.
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Coarse aggregate must consist of crushed or uncrushed gravel, crushed stone, or a combination thereof.[Coarse aggregate must contain a minimum of [25][_____] percent recycled porcelain, concrete, stone, or other recycled material complying with ASTM D6155.] Aggregates, as delivered to the mixers, must consist of clean, hard, uncoated particles. Coarse aggregate must be washed. Washing must be sufficient to remove dust and other coatings. Fine aggregate must consist of natural sand, manufactured sand, or a combination of the two, and must be composed of clean, hard, durable particles. Both coarse and fine aggregates must meet the requirements of ASTM C33/C33M.

2.1.3.1 Alkali Reactivity Test

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NOTE: While not wholly conclusive, petrographic examination (ASTM C295/C295M) and the Chemical Test Method (ASTM C28/C28M) are valuable indicators. However, chemical test results may not be correct for aggregates containing carbonates of calcium, magnesium or ferrous iron, such as calcite, dolomite, magnesite or siderite; or silicates of magnesium such as serpentine. The Concrete Prism Test (ASTM C1293) is also a valuable indicator. ASTM C1293 is ineffective in hot and humid climates. However, none of the methods above constitutes a substitute for the modified ASTM C1260.
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NOTE: The most important rocks and mineral known to be deleteriously reactive with the alkalies in Portland cement are listed in ASTM C33 (and ASTM C294). However, this list is not inclusive, and particles having a glassy or micro-crystalline structure should be considered suspect. Reactive aggregates are widespread in the United States, being especially common in the western half and southeastern portions. However, generalizations concerning area distribution of reactive aggregates should not be relied upon for important work. Contract documents for important concrete projects

should include provisions for preventing such aggregate being used, if possible, or requiring their use exclusively with low-alkali cements, suitable blended cements, or pozzolanic admixtures as available and as required to avoid deleterious effects on the concrete.

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NOTE: It is recommended that the various types of aggregates also be evaluated separately, in accordance with the original ASTM C1260, to ascertain the specific reactivity of each aggregate.

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Aggregates to be used in all concrete in projects over 9290 SM 100,000 SF in size must be evaluated and tested by the Contractor for alkali-aggregate reactivity in accordance with ASTM C1260. The types of aggregates must be evaluated in a combination which matches the proposed mix design (including Class F fly ash or GGBF slag), utilizing ASTM C1567. Test results of the combination must have a measured expansion of less than 0.08 percent at 28 days. Should the test data indicate an expansion of greater than 0.08 percent, the aggregate(s) must be rejected and new aggregate sources must be submitted for retesting or may submit additional test results incorporating Lithium Nitrate for consideration.

ASTM C1260 must be modified as follows to include one of the following options:

a. Utilize the low alkali Portland cement and Class F fly ash in combination for the test proportioning. The laboratory must use the contractor's proposed percentage of cement and fly ash.

b. Utilize the low alkali Portland cement and ground granulated blast furnace (GGBF) slag in combination for the test proportioning. The laboratory must use the contractor's proposed percentage of cement and GGBF.

c. Utilize the low alkali Portland cement and Class F fly ash and ground granulated blast furnace (GGBF) slag in combination for the test proportioning. The laboratory must use the contractor's proposed percentage of cement, fly ash and GGBF.

2.1.3.2 Fine Aggregates

ASTM C33/C33M.

2.1.3.3 Coarse Aggregates

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NOTE: For pervious concrete, use No.67 (3/4 inch to No.4), No.8 (3/8 inch to No.16) or No.89 (3/8 inch to No. 50) so as to provide 15 percent to 20 percent optimum void factor in hardened concrete.

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a. Gradation: ASTM C33/C33M,[#67][#8][#89].

b. Quality: ASTM C33/C33M, Class 4M or 4S, depending on weathering region.

c. Alkali-Silica Reactivity: Test in accordance with ASTM C1260, as specified in ASTM C33/C33M, Appendix XI. Aggregates failing to meet the expansion limit of 0.08 percent at 16 days after casting must be replaced or mitigated using fly ash, pozzolan, or slag in accordance with ASTM C1567.

2.1.4 Admixtures

ASTM C494/C494M: Type A, water reducing; Type B, retarding; and Type D, water-reducing and retarding, except acceptance must be based on 28 day physical properties. Do not use calcium chloride admixtures. Where not shown or specified, the use of admixtures is subject to written approval of the Contracting Officer.

ASTM C260/C260M: Air-entraining.

2.1.5 Curing Materials

2.1.5.1 Polyethylene Sheet

ASTM C171, 0.15 mm 0.006 inch clear or white opaque polyethylene cut to a minimum of 600 mm 24 inches wider than full placement width, for curing of pervious concrete.

[2.1.6 Edge Restraints

Edge restraints for pervious systems must be [concrete][_____].

]2.2 CONCRETE PAVEMENT

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NOTE: The urban heat island effect forms as vegetation is replaced by low reflectivity materials such as dark colored paving. These surfaces absorb, rather than reflect, the sun's heat, causing surface temperatures and urban ambient temperatures to be one to 6 degrees C 2 to 10 degrees F hotter than surrounding rural areas.

Mitigation of heat island effect is not required by UFC 1-200-02 but may be desired for sustainability reasons. The albedo requirements below for roads and parking lot paving are most beneficial in ASHRAE climate zones 1 through 5. Retain the following section when needed to meet project requirements.
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[2.2.1 Albedo

Provide system with a minimum initial Solar Reflectance of at least 0.33 and a 3-year aged of 0.28 as tested in accordance with ASTM C1549.

]2.3 CONTRACTOR-FURNISHED MIX DESIGN

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NOTE: Flexural strength tests do not apply to pervious concrete. Pervious concrete is air-entrained per manufacturer's recommendations for

freeze thaw durability. However, due to the open void structure of the material, air content cannot be measured by standard ASTM test procedures.

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NOTE: Coordinate with Contracting Officer for mix design requirement to satisfy project albedo and permeability needs.

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Contractor-furnished concrete mix must be designed in accordance with ACI 522.1 except as modified herein.

The water/cementitious materials ratio must be 0.26-0.40. The air voids must be 18 to 22 percent, as measured in accordance with ASTM C1688/C1688M.

PART 3 EXECUTION

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NOTE: Dowel bars and reinforcement are not used in pervious concrete applications.

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3.1 PREPARATION FOR PERVIOUS SYSTEMS

Verify compacted subgrade, granular base or stabilized soil is acceptable and ready to support paving and imposed loads. Subgrade compaction must not exceed 94 percent of modified proctor. Install edge restraints per the drawings and manufacturer's recommendations.

3.2 FORMS

3.2.1 Construction

Construct forms to be removable without damaging the concrete.

3.2.2 Coating

Before placing the concrete, coat the contact surfaces of forms with a non-staining mineral oil, non-staining form coating compound, or two coats of nitro-cellulose lacquer.[When using existing pavement as a form, clean existing concrete, but do not apply form release agent to previously placed concrete.]

3.2.3 Grade and Alignment

Check and correct grade elevations and alignment of the forms immediately before placing the concrete.

3.3 MEASURING, MIXING, CONVEYING, AND PLACING CONCRETE

3.3.1 Measuring

ASTM C94/C94M.

3.3.2 Mixing

ASTM C94/C94M, except as modified herein. Begin mixing immediately after

cement has been added to aggregates. When the air temperature is greater than 29.4 degrees C 85 degrees F, place concrete within 60 minutes. With the approval of the Contracting Officer, a hydration stabilizer admixture meeting the requirements of ASTM C494/C494M Type D, may be used to extend the placement time to 90 minutes. Additional water may be added to enhance workability up to a level acceptable to the contractor without causing paste drain or exceeding the specified water-cement ratio.

3.3.3 Conveying

ASTM C94/C94M, pervious concrete may not be placed by pumping.

3.3.4 Placing

Placement of pervious concrete should comply with guidelines set in ACI 522.1, except as modified herein. Do not exceed a free vertical drop of 1.5 m 5 feet. Deposit concrete either directly from the transporting equipment or by conveyor onto the pre-wetted subgrade or subbase, unless otherwise specified. Do not place concrete on frozen subgrade or subbase. Deposit the concrete between the forms to an approximately uniform height. Spread the concrete using a come-along, square ended shovel, or rake. Do not allow foot traffic on the fresh concrete. Strike off the concrete between forms using a form-riding paving machine or vibrating screed. Other strike off devices may be used with the approval of the contracting officer. Place concrete continuously at a uniform rate, with a minimum amount of segregation, without damage to the grade and without unscheduled stops except for equipment failure or other emergencies. If this occurs within 3 m 10 feet of a previously placed expansion joint, remove concrete back to joint, repair any damage to grade, install a construction joint and continue placing concrete only after cause of the stop has been corrected. Do not use steel trowels or power finishing equipment. Finish the pavement to the elevations and thickness specified or indicated and compact the fresh concrete to meet the requirements of final finish as described herein. Compact the concrete along the slab edges with hand tools. Compact concrete to a dense, pervious surface. Edge top surface to a radius of not less than 6 mm 1/4 inch, where required.Construct the pavement to comply with the following tolerances:

a. Elevation: plus 19 mm; minus 0 mm plus 3/4 inch; minus 0 inch

b. Thickness: plus 37 mm; minus 6 mm plus 1.5 inches; minus 1/4 inch

c. Contraction joint depth: plus 6 mm; minus 0 mm plus 1/4 inch; minus 0 inch

Mechanically sweep pavement before testing hardened concrete for compliance tolerances.

3.3.5 Cold Weather

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NOTE: Accelerators should not be used with pervious concrete.
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Do not place concrete when ambient temperature is below 5 degrees C 40 degrees F or when concrete is likely to be subjected to freezing temperatures within 24 hours without approval from the contracting officer. If approval is granted, heat concrete materials so that the

temperature of the concrete at placement is between 18 and 29 degrees C 65 and 80 degrees F. Methods of heating materials are subject to approval by the Contracting Officer. Do not use heated mixing water. Follow practices found in ACI 306.1.

3.3.6 Hot Weather

Maintain required concrete temperature in accordance with Figure 2.1.5 in ACI 305R to prevent evaporation rate from exceeding 0.98 kg of water per square meter 0.2 pound of water per square foot of exposed concrete per hour. Cool ingredients before mixing or use other suitable means to control concrete temperature and prevent rapid drying of newly placed concrete. After placement, use fog spray, apply monomolecular film, or use other suitable means to reduce the evaporation rate. Start curing within 20 minutes of concrete discharge. Cool underlying material by sprinkling lightly with water before placing concrete.

3.4 PAVING

[Install pervious paving system in accordance with manufacturer's recommendations and as indicated. Install surface elevation of the paving system 3 to 6 mm 1/8 to 1/4 inch above adjacent drainage inlets, concrete collars, or channels. Manufacturer's recommendations must take precedence over the specifications in the event of conflicting requirements between the two.]Pavement must be constructed with paving and finishing equipment utilizing [fixed forms].

3.4.1 Consolidation

Surface vibration must be automatically controlled so that it must be stops immediately as forward motion ceases. Excessive vibration must not be permitted. Concrete in small, odd-shaped slabs or in locations inaccessible to the paver mounted vibration equipment must be tamped. Vibrators must not be used to transport or spread the concrete.

3.4.2 Operation

When paving between or adjacent to previously constructed pavement (fill-in lanes), provisions must be made to prevent damage to the previously constructed pavement, including keeping the existing pavement surface free of any debris.

3.4.3 Required Results

The paving equipment must be operated to produce a thoroughly consolidated slab throughout, true to line and grade within specified tolerances. The paver-finishing operation must produce a surface finish free of irregularities, tears, and any other discontinuities. The equipment and its operation must produce a finished surface requiring no hand finishing, other than the use of jointing tools, except in very infrequent instances. No water, other than true fog sprays (mist), must be applied to the concrete surface during paving and finishing.

3.4.4 Fixed Form Paving

Forms must be steel, except that wood forms may be used for curves having a radius of 45 m 150 feet or less, and for fillets. Forms may be built up with metal or wood, added only to the base, to provide an increase in depth of not more than 25 percent. The base width of the form must be not

less than eight-tenths of the vertical height of the form, except that forms 200 mm 8 inches or less in vertical height must have a base width not less than the vertical height of the form. Wood forms for curves and fillets must be adequate in strength and rigidly braced. Forms must be set on firm material cut true to grade so that each form section when placed will be firmly in contact with the underlying layer for its entire base. Forms must not be set on blocks or on built-up spots of underlying material.[Prior to setting forms for paving operations, the Contractor must demonstrate the proposed form setting procedures at an approved location and must not proceed further until the proposed method is approved.] Forms must remain in place at least 12 hours after the concrete has been placed. Forms must be removed without damaging the concrete.

3.4.5 Slip Form Paving

When approved for use by the Contracting Officer, the slipform paver must shape the concrete to the specified and indicated cross section in one pass, and must finish the surface and edges so that only a minimum amount of hand finishing is required.

3.5 FINISHING CONCRETE

Start finishing operations immediately after placement of concrete. Use finishing machine, except hand finishing may be used in emergencies and for concrete slabs in inaccessible locations or of such shapes or sizes that machine finishing is impracticable. Finish pavement surface on both sides of a joint to the same grade. Finish formed joints from a securely supported transverse bridge. Provide hand finishing equipment for use at all times. Transverse and longitudinal surface tolerances must be no more than 6 mm in 3 m 1/4 inch in 10 feet.

3.5.1 Side Form Finishing

Strike off and screed concrete to the required [crown] [slope] and cross-section by a power-driven transverse finishing machine. Transverse rotating tube or pipe are not permitted unless approved by the Contracting Officer. Elevation of concrete must be such that, when consolidated and finished, pavement surface will be adequately consolidated and at the required grade. Equip finishing machine with two screeds which are readily and accurately adjustable for changes in pavement [crown] [slope] and compensation for wear and other causes. When using a static roller for consolidation, the roller must be stiffened to prevent flexing and warping straightness tolerance must be 6 mm in 3 m 0.25 inch in 10 feet. Make as many passes over each area of pavement and at such intervals as necessary to give proper compaction, retention of coarse aggregate near the finished surface, and a surface of uniform texture, true to grade and [crown] [slope]. Do not permit excessive operation over an area, which will result in an excess of mortar and water being brought to the surface.

3.5.1.1 Equipment Operation

Maintain the travel of machine on the forms without lifting, wobbling, or other variation of the machine which tend to affect the precision of concrete finish. Keep the tops of the forms clean by a device attached to the machine. During the first pass of the finishing machine, maintain a uniform ridge of concrete ahead of the front screed for its entire length.

3.5.1.2 Joint Finish

Before concrete is hardened, correct edge slump of pavement, exclusive of edge rounding, in excess of 6 mm 0.25 in. Finish concrete surface on each side of construction joints to the same plane, and correct deviations before newly placed concrete has hardened.

3.5.1.3 Hand Finishing

Strike-off and screed surface of concrete to elevations slightly above finish grade so that when concrete is consolidated and finished pavement surface is at the indicated elevation. Vibrate entire surface until required compaction and reduction of surface voids is secured with a strike-off template.

3.5.1.4 Longitudinal Floating

After initial consolidation, further smooth and consolidate concrete by means of hand-operated longitudinal rollers. Use rollers that are not less than 1.82 m 6 feet long and 200 mm 8 inches in diameter and stiffened to prevent flexing and warping.

3.5.2 Edging

Immediately after consolidation and jointing, carefully finish slab edges, including edges at formed joints, with an edge having a radius of not less than 6 mm 0.25 inch. Clean by removing loose fragments and soupy mortar from corners or edges of slabs which have crumbled and areas which lack sufficient mortar for proper finishing. Refill voids solidly with a mixture of suitable proportions and consistency and refinish. Remove unnecessary tool marks and edges. Remaining edges must be smooth and true to line.[Install edge restraints of pervious systems per the drawings and manufacturer's recommendations.]

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NOTE: Drawings should clearly show all pavement joints. If the jointing plan on the project drawings is not compatible with the contractor's placement sequence, the contractor may submit a plan shop drawing indicating joint locations.

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3.5.3 Jointing

Construct joints at the locations, depths, and width dimensions indicated on the project drawings or the approved shop drawings. Tool contraction joints in fresh concrete immediately after the concrete has been compacted to the specified depth and width. Do not sawcut joints. Extend expansion joints through the full depth of the pavement. Cut expansion material flush to grade after concrete has fully hardened and provide joint filler material as indicated or as approved on the shop drawings.

3.5.3.1 Joint Layout Drawings

If jointing requirements on the project drawings are not compatible with the proposed placement sequence, submit a joint layout plan shop drawing to the Contracting Officer for approval. No work must be allowed to start until the joint layout plan is approved. The joint layout plan must indicate and describe in the detail the proposed jointing plan for

contraction joints, expansion joints, and construction joints, in accordance with the following:

a. Indicate locations of contraction joints, construction joints, and expansion joints. Spacing between contraction joints must not exceed 4.5 m 15 feet unless noted otherwise or approved by the Contracting Officer.

b. The larger dimension of a panel must not exceed 125 percent of the smaller dimension.

c. The minimum angle between two intersecting joints must be 80 degrees, unless noted otherwise or approved by the Contracting Officer.

d. Joints must intersect pavement-free edges at a 90 degree angle the pavement edge and must extend straight for a minimum of 450 mm 1.5 feet from the pavement edge, where possible.

e. Align joints of adjacent panels.

f. Align joints in attached curbs with joints in pavement when possible.

g. Ensure joint depth, widths, and dimensions are specified.

h. Minimum contraction joint depth must be one-fourth of the pavement thickness. The minimum joint width must be 3 mm 1/8 inch.

i. Use expansion joints only where pavement abuts buildings, foundations, manholes, and other fixed objects.

3.6 CURING AND PROTECTION

Curing of pervious concrete must be in accordance with ACI 522.1. Protect concrete adequately from injurious action by sun, rain, flowing water, [frost,] mechanical injury, tire marks and oil stains, and do not allow it to dry out from the time it is placed until the expiration of the minimum curing periods specified herein. Use White-Polyethylene Sheet, except as specified otherwise herein. Do not use membrane-forming compound. Maintain temperature of air next to concrete above 5 degrees C 40 degrees F for the full curing periods.

3.6.1 White-Polyethylene Sheet

Begin curing within 20 minutes of concrete discharge unless longer working time is accepted by the Contracting Officer. Lay sheets directly on concrete surface and overlap 300 mm 12 inches. Make sheeting not less than 600 mm 24 inches wider than concrete surface to be cured, and weight down on the edges, without using soil or debris, and over the transverse laps to form closed joints. Repair or replace sheets when damaged during curing. Check daily to assure sheets are soundly in place. If moisture evaporates, re-saturate concrete and replace polyethylene on pavement (re-saturation and re-placing must take no longer than 10 minutes per sheet). Leave sheeting on concrete surface to be cured for at least seven days.

3.7 FIELD QUALITY CONTROL

3.7.1 Sampling

The Contractor's approved laboratory must collect samples of fresh concrete in accordance with ASTM C172/C172M during each working day as required to perform tests specified herein.

3.7.2 Consistency Tests

The Contractor's approved laboratory must perform concrete density tests on the fresh concrete in accordance with ASTM C1688/C1688M. Take samples for density determination from concrete during placement. Perform tests at the beginning of a concrete placement operation and and for each batch (minimum) or every 40 cubic meters 50 cubic yards (maximum) of concrete to ensure that specification requirements are met. The fresh density must be within plus or minus 80 K/CM 5 lb/CF of the accepted fresh density from the submitted mixture proportions.

3.7.3 Sample Cores

After a minimum of seven days following each placement, three cores must be taken at random per the Contracting Officer's discretion. Core hardened concrete panels in accordance with ASTM C42/C42M Test thickness and density of the cores in accordance with ASTM C174/C174M and paragraph 9.3 of ASTM C140/C140M, respectively. Tolerance for thickness and density reported as the average of three cores of each test panel must be as follows:

a. The average compacted thickness must not be more than 6 mm 0.25 in less than the specified thickness.

b. The average compacted thickness must not exceed the specified thickness by more than 38 mm 1.5 in.

c. The average hardened density must be within plus or minus 5 percent of the accepted hardened density of the test panels.

Core holes must be filled with regular concrete or pre-mixed grout.

3.7.4 Surface Testing

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NOTE: Drawings should clearly show all pavement joint intersection elevations, and specific required deviations from a plane surface for such special features as crowns, drainage inlets, etc.

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Surface testing for surface smoothness [, edge slump] and plan grade must be performed as indicated below by the Testing Laboratory. The measurements must be properly referenced in accordance with paving lane identification and stationing, and a report given to the Contracting Officer within 24 hours after measurement is made. A final report of surface testing, signed by a Registered Engineer, containing all surface measurements and a description of all actions taken to correct deficiencies, must be provided to the Contracting Officer upon conclusion of surface testing.

3.7.4.1 Surface Smoothness Requirements

The finished surfaces of the pavements must have no abrupt change of 3 mm 1/8 inch or more, and [all pavements must be within the tolerances specified when checked with a 4 meter 12 foot straightedge: 5 mm 1/5 inch longitudinal and 6.5 mm 1/4 inch transverse directions for roads and streets and 6.5 mm 1/4 inch for both directions for other concrete surfaces, such as parking areas.][variations in final pervious surface must not exceed [10][_____] mm [3/8][_____] inch under a 3.0 m 10 foot straightedge.]

3.7.4.2 Surface Smoothness Testing Method

The surface of the pavement must be tested with the straightedge to identify all surface irregularities exceeding the tolerances specified above. The entire area of the pavement must be tested in both a longitudinal and a transverse direction on parallel lines approximately 4.5 m 15 feet apart. The straightedge must be held in contact with the surface and moved ahead one-half the length of the straightedge for each successive measurement. The amount of surface irregularity must be determined by placing the straightedge on the pavement surface and allowing it to rest upon the two highest spots covered by its length and measuring the maximum gap between the straightedge and the pavement surface, in the area between these two high points. Measurement of the gap must be made with a steel spacer bar of rectangular section the same thickness as the allowable gap, and width of four times the nominal maximum aggregate size.

3.7.5 Plan Grade Testing and Conformance

The surfaces must not vary more than 18 mm 0.75 inch above or 0.0 m 0.0 feet below the plan grade line or elevation indicated. Each pavement category must be checked for conformance with plan grade requirements by running lines of levels at intervals to determine the elevation at each joint intersection.

3.7.6 Open To Traffic

Do not open the pavement to vehicular traffic until the concrete has cured at least 14 days or until the pavement is accepted by the Contracting Officer.

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