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USACE / NAVFAC / AFCEC / NASA **UFGS-32 13 43 (May 2020)**

Preparing Activity: NAVFAC **Superseding**
UFGS-32 13 43 (November 2011)

UNIFIED FACILITIES GUIDE SPECIFICATIONS

References are in agreement with UMRL dated July 2022
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DIVISION 32 - EXTERIOR IMPROVEMENTS

SECTION 32 13 43

PERVIOUS CONCRETE PAVING

05/20

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SECTION 32 13 43

PERVIOUS CONCRETE PAVING
05/20

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NOTE: This guide specification covers the requirements for Pervious Portland cement concrete paving 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: Pervious concrete is a near-zero-slump, open-graded material consisting of portland cement, coarse aggregate, little or no fine aggregate, admixtures, and water. The combination of these ingredients produces a hardened material with connected pores that allow water to pass through easily. Pervious concrete is recognized as a sustainable building material, as it reduces storm water runoff, improves storm water quality, may recharge groundwater supplies, and can reduce the impact of the urban heat island (albedo) effect.

NOTE: The extent and location of the work to be accomplished should be indicated on the project drawings, or included in the project

specifications. Pervious portland cement pavements for airfields are not included in this specification.

Pervious concrete paving may be used on site pavements, provided there is documented evidence of successful past performance for similar applications. Parking lots are generally good pervious pavement applications. Typical thicknesses range from 150 to 250 mm 6 to 10 inches.

Permeable pavements may not be used in areas where there is potential to contaminate existing soils, such as fuel areas, industrial storage, marina, vehicle maintenance or service areas. Do not install pervious pavement systems in areas subject to high wheel loads (such as aircraft, ground support equipment, forklifts, and heavy truck traffic) or the special military vehicles listed in UFC 3-201-01, paragraph 4-1.

Consult industry practice 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.

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PART 1 GENERAL

1.1 UNIT PRICES

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NOTE: Delete this paragraph when the work is covered by a lump-sum contract price.

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1.1.1 Measurement

Measure the quantity of pervious concrete paving, completed and accepted,in [square][cubic] meters [square][cubic] yards.[Determine the volume of pervious concrete paving, in place and accepted, by the average job thickness obtained in accordance with paragraph FIELD QUALITY CONTROL and the dimensions indicated.]

1.1.2 Payment

The quantity of completed and accepted pervious concrete paving will be paid for at the contract unit price, which will constitute full compensation for the construction and completion of the pervious concrete paving, including the test section, and the furnishing of all other necessary labor and incidentals.

1.2 REFERENCES

****

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 305.1	(2014) Specification for 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	(2020) Standard Test Method for Obtaining and Testing Drilled Cores and Sawed Beams of Concrete
ASTM C88	(2018) Standard Test Method for Soundness of Aggregates by Use of Sodium Sulfate or Magnesium Sulfate
ASTM C150/C150M	(2021) Standard Specification for Portland Cement
ASTM C171	(2020) Standard Specification for Sheet Materials for Curing Concrete
ASTM C172/C172M	(2017) Standard Practice for Sampling Freshly Mixed Concrete
ASTM C260/C260M	(2010a; R 2016) Standard Specification for Air-Entraining Admixtures for Concrete
ASTM C494/C494M	(2019) Standard Specification for Chemical Admixtures for Concrete

ASTM C595/C595M	(2021) 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 C1260	(2021) Standard Test Method for Potential Alkali Reactivity of Aggregates (Mortar-Bar Method)
ASTM C1542/C1542M	(2019) Standard Test Method for Measuring Length of Concrete Cores
ASTM C1549	(2016) Standard Test Method for Determination of Solar Reflectance Near Ambient Temperature Using a Portable Solar Reflectometer
ASTM C1567	(2021) 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 C1701/C1701M	(2017a) Standard Test Method for Infiltration Rate of In Place Pervious Concrete
ASTM C1754/C1754M	(2012) Standard Test Method for Density and Void Content of Hardened Pervious Concrete
ASTM D6155	(2019) Nontraditional Coarse Aggregate for Bituminous Paving Mixtures

NATIONAL READY MIXED CONCRETE ASSOCIATION (NRMCA)

NRMCA QC 3	(2015) Quality Control Manual: Section 3, Plant Certifications Checklist: Certification of Ready Mixed Concrete Production Facilities

1.3 SUBMITTALS

****

NOTE: Review Submittal Description (SD) definitions in Section 01 33 00 SUBMITTAL PROCEDURES and edit the following list, and corresponding submittal items in the text, to reflect only the submittals required for the project. The Guide Specification technical editors have classified 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 Army projects, fill in the empty brackets following the "G" classification, with a code of up to three characters 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" classification indicates submittals required as proof of compliance for sustainability Guiding Principles Validation or Third Party Certification and as described in Section 01 33 00 SUBMITTAL PROCEDURES.

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" or "S" classification. Submittals not having a "G" or "S" classification are [for Contractor Quality Control approval.][for information only. When used, a code following the "G" classification identifies the office that will review the submittal for the Government.] Submit the following in accordance with Section 01 33 00 SUBMITTAL PROCEDURES:

SD-03 Product Data

Curing Materials

SD-04 Samples

Test Section

SD-05 Design Data

Mix Design Report; G[, [_____]]

SD-06 Test Reports

Concrete Density Tests

Field Infiltration Tests

Surface Smoothness

Core Thickness

Plan Grade

SD-07 Certificates

NRMCA Certificate Of Conformance

1.4 QUALITY CONTROL

1.4.1 NRMCA Certificate of Conformance

Provide a batching and mixing plant consisting of a stationary-type central mix plant, including permanent installations and portable or relocatable plants installed on stable foundations. Provide a plant designed and operated to produce concrete within the specified tolerances, with a minimum capacity of 200 cubic meters 250 cubic yards [_____] per hour. Submit NRMCA Certificate of Conformance that conforms to the requirements of NRMCA QC 3 including provisions addressing:

1. Material Storage and Handling

2. Batching Equipment

3. Central Mixer

4. Ticketing System

5. Delivery System

1.4.2 Qualifications

1.4.2.1 Laboratory Accreditation

Perform sampling and testing using an approved commercial testing laboratory or on-site facility that is accredited in accordance with ASTM C1077. Maintain this certification for the duration of the project.

1.4.2.2 Field Technicians

Provide field technicians meeting one of the following criteria:

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

b. Provide no less than three NRMCA certified pervious concrete installers on site working as members of each placement crew during all concrete placement.

1.5 DELIVERY AND STORAGE

In accordance with ACI 522.1

1.6 ACCEPTANCE

1.6.1 Tolerances

Acceptance of pervious concrete paving is based on compliance with the tolerances presented in Table 1. Remove and replace pervious concrete paving represented by the failing tests or submit repair plan for approval.

TABLE 1

Attribute	Tolerance
TEST SECTION	
Fresh Density	plus/minus 80 kg/cm 5 lb/cf of approved mix design value
Core Length (avg 3)	plus 37.5 mm 1.5 inches minus 19 mm 3/8 inch
Core Length (ind)	minus 19 mm 3/4 inch
FRESH CONCRETE	
Fresh Density	plus/minus 80 kg/cm 5 lb/cf of approved mix design value
FINISHED PAVEMENT	
Core Length (avg 3)	plus 37.5 mm 1.5 inches minus 19 mm 3/8 inch
Core Length (ind)	minus 19 mm 3/4 inch
Hardened Density	plus/minus 5 percent of test section value
Grade	plus/minus 15 mm 0.05 foot from plan
Grade at Drainage Structures	plus 3 to 6 mm 1/8 to 1/4 inch above plan
Smoothness	6 mm1/4 inch longitudinal and transverse
Surface Finish	Free of irregularities, tears, and discontinuities

1.6.2 Test Section

Construct a minimum 37 square meters 400 square feet test section to demonstrate typical joints, surface finish, texture, color, infiltration rate, thickness, density, and standard of workmanship. Place test section using the mixture proportions, materials, and equipment as proposed for the project. Test in accordance with requirements in subpart FIELD QUALITY CONTROL.

When a test section does not meet one or more of the tolerances in Table 1, remove and replace the test section. If the test section is acceptable, it may be incorporated into the project.

PART 2 PRODUCTS

2.1 MATERIALS

2.1.1 Cementitious Materials

****

NOTE: Coal fly ash and slag 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 supplementary cementitious materials (SCM). Consult agency Subject Matter Expert (SME) for guidance on choice.

Select first sentence in brackets to require the use of SCMs. Select the second option in brackets to permit the use of SCMs.

****

[Provide cementitious materials in concrete mix with 20 to 50 percent non-portland cement pozzolanic materials by weight.] [Provide cementitious materials consisting of portland cement, [blended cement] or only portland cement in combination with supplementary cementitious materials (SCM), that conform to appropriate specifications listed below. New submittals are required when the cementitious materials sources or types change.]

2.1.1.1 Portland Cement

ASTM C150/C150M, Type I or II [or V] [low alkali].

2.1.1.2 Blended Cement

Provide blended cement conforming to ASTM C595/C595M, Type IP or IS, including the optional requirement for mortar expansion [and sulfate soundness]. Provide pozzolan added to the Type IP blend consisting of ASTM C618 Class F or Class N and that is interground with the cement clinker. Include in written statement from the manufacturer that the amount of pozzolan in the finished cement does not vary more than plus or minus 5 percent by mass of the finished cement from lot to lot or within a lot. Do not permit the percentage and type of mineral admixture used in the blend to change from that submitted for the aggregate evaluation and mixture proportioning. The requirements of paragraph SUPPLEMENTARY CEMENTITIOUS MATERIALS (SCM) CONTENT do not apply to the SCM content of blended cement.

2.1.1.3 Fly Ash and Pozzolan

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NOTE: Class C fly ash is not permitted for paving concrete. Use loss on ignition not exceeding 3 percent for frost areas to reduce carbon interference with air entraining admixture.

****

ASTM C618, Type F or N, including the optional requirement for uniformity, with a loss on ignition not exceeding [3] [6] percent. Provide Class F fly ash for use in mitigating Alkali-Silica Reactivity with a total equivalent alkali content less than 3 percent.

2.1.1.4 Ultra Fine Fly Ash and Ultra Fine Pozzolan

Provide Ultra Fine Fly Ash (UFFA) and Ultra Fine Pozzolan (UFP) that conforms to ASTM C618, Class F or N, and the following additional requirements:

a. The strength activity index at 28 days of age of at least 95 percent of the control specimens.

b. The average particle size not exceeding 6 microns.

2.1.1.5 Slag

ASTM C989/C989M, Slag Cement (formerly Ground Granulated Blast Furnace Slag) Grade 100 or 120.

2.1.1.6 Supplementary Cementitious Material (SCM) Content

****

NOTE: Select first sentence in brackets for mandatory use of SCMs. Select second sentence in brackets of optional use of SCMs. Consult agency SME for guidance on choice.

****

[Provide a concrete mix that contains one of the SCMs listed in Table 2 within the range specified therein, whether or not the aggregates are found to be reactive in accordance with paragraph ALKALI REACTIVITY TEST.] [Use of one of the SCMs listed below is optional, unless the SCM is required to mitigate ASR.]

TABLE 2
SUPPLEMENTARY CEMENTITIOUS MATERIALS CONTENT

Supplementary Cementitious Material	Minimum Content (percent)	Maximum Content (percent)
Class N Pozzolan and Class F Fly Ash		
$SiO_2 + Al_2O_3 + Fe_2O_3$ greater than 70 percent	25	35
$SiO_2 + A1_2O_3 + Fe_2O_3$ greater than 80 percent	20	35
$SiO_2 + A1_2O_3 + Fe_2O_3$ greater than 90 percent	15	35
UFFA and UFP	7	16
Slag Cement	40	50

2.1.2 Water

Water conforming to ASTM C1602/C1602M.

2.1.3 Aggregates

2.1.3.1 Durability

Evaluate and test all aggregates to be used in all concrete for durability in accordance with ASTM C88. Provide fine and coarse aggregates with a maximum of 18 percent loss when subjected to 5 cycles using Magnesium Sulfate or a maximum of 12 percent loss when subjected to 5 cycles using Sodium Sulfate.

2.1.3.2 Alkali Reactivity Test

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NOTE: Documentation of alkali reactivity testing is required for all aggregate sources.

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Evaluate the fine and coarse aggregates separately, using ASTM C1260. Reject individual aggregates with test results that indicate an expansion of greater than 0.10 percent at 16 days after casting, or perform additional testing as follows: utilize the proposed low alkali portland cement, blended cement, and SCM in combination with each individual aggregate in accordance with ASTM C1567. Determine the quantity that meets all the requirements of these specifications and that lowers the expansion equal to or less than 0.10 percent at 16 days after casting. Base the mixture proportioning on the highest percentage of SCM required to mitigate ASR-reactivity. If any of the above options does not lower the expansion to less than 0.10 percent at 16 days after casting, reject the aggregate(s) and submit new aggregate sources for retesting. Submit the results of testing for evaluation and acceptance.

2.1.3.3 Fine Aggregates

Provide fine aggregate conforming to the quality and grading requirements of ASTM C33/C33M.

2.1.3.4 Coarse Aggregates

****

NOTE: 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.

Select sentence in brackets for mandatory use of recycled materials. Consult agency SME for guidance.

****

Provide coarse aggregate consisting of crushed or uncrushed gravel, crushed stone, or a combination thereof meeting the requirements of ASTM C33/C33M[.][and containing a minimum of [25][_____] percent recycled porcelain, concrete, stone, or other recycled material complying with ASTM D6155.] Deliver aggregates to the mixers consisting of clean, hard, uncoated particles. Wash aggregate sufficient to remove dust and other coatings.

****

NOTE: For pervious concrete, use No.67 (19 mm to 4.75 mm) (3/4 inch to No.4), No. 7 (12.5 mm to 4.75 mm) (1/2 inch to No. 4), No.8 (9.5 mm to 1.2 mm) (3/8 inch to No.16) or No.89 (9.5 mm to 0.30 mm) (3/8 inch to No. 50) to provide 15 percent to 20 percent optimum void factor in hardened concrete.

Gradations No. 8 and No. 89 are commonly used for parking lot and pedestrian walkway applications.

The larger aggregate (No. 67) provides a more pervious pavement structure, but with a rougher surface finish and is less suited for pedestrian areas. Gradation No 67 is recommended for vehicle pavements.

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a. Gradation: ASTM C33/C33M,#67 [#7] [#8] [#89].

****

NOTE: Select class 4M for exterior concrete exposed to frequent wetting in moderate weathering regions. Select class 4S for exterior concrete exposed to frequent wetting in severe weathering regions.

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b. Quality: ASTM C33/C33M, Class [4M] [4S].

2.1.4 Chemical Admixtures

2.1.4.1 Water Reducing and Retarding Admixtures

ASTM C494/C494M: Type A, water reducing; Type B, retarding; Type C, accelerating; Type D, water-reducing and retarding; and Type E, water reducing and accelerating. Acceptance is based on 28 day physical properties. Do not use calcium chloride admixtures.

2.1.4.2 Air Entraining Admixture

Air entraining admixture conforming to ASTM C260/C260M.

2.1.4.3 Hydration Retarding Admixture

Hydration retarding admixture conforming to ASTM C494/C494M, Type B, retarding, or Type D, water-reducing and retarding.

2.1.5 Curing Materials

2.1.5.1 Polyethylene Sheet

Provide curing materials conforming to 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

Provide edge restraints consisting of concrete curb sections [_____].

2.1.7 Riser Strips

Provide wood strips of thickness to accommodate the initial strike off and consolidation of the pervious concrete.

2.2 MIX DESIGN

****

NOTE: 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.

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 bracketed sentence when needed to include solar reflectance criteria.

****

Design pervious concrete mix in accordance with ACI 522.1 to meet the following criteria: the water/cementitious materials ratio within the range of 0.26-0.40 and the air voids of freshly mixed pervious concrete within the range of 18 to 22 percent, as measured in accordance with ASTM C1688/C1688M. Provide air entrainment in freeze-thaw environments.[Provide system with a minimum initial Solar Reflectance of at least 0.33 as tested in accordance with ASTM C1549.]

2.2.1 Mix Design Report

Perform trial design batches, mixture proportioning studies, testing, and include test results demonstrating that the proposed mixture proportions produce pervious concrete of the qualities indicated. Submit test results in a mix design report to include:

a. Aggregate gradations and plots.

b. Aggregate quality test results, including deleterious materials and ASR tests.

c. Mill certificates for cement and supplemental cementitious materials.

d. Certified test results for all admixtures.

e. Recommended proportions and volumes for proposed mixture.

f. Water/cementitious materials ratio and air voids.

g. Narrative discussing methodology on how the mix design was developed.

2.2.2 Mix Verification

Mix verification tests may be performed by the Government. Provide quantities of cementitious materials, aggregates and admixtures as requested. Verification tests may be conducted on the proposed mix design proportions to confirm the fresh concrete air voids content. An existing mix design may be submitted if developed within the previous 12 months.

2.3 EQUIPMENT

All plant, equipment, and tools used in the performance of the work will be subject to approval before the work is started. Maintain all plant, equipment, and tools in satisfactory working condition at all times.

2.3.1 Compaction Equipment

2.3.1.1 Pipe Roller

A steel pipe roller or a motorized or hydraulically actuated rotating tube screed spanning the width of the section placed.

2.3.1.2 Plate Compactor

Compact small areas using a standard soil plate compactor that has a base area of at least 0.2 square meters two square feet and exerts a minimum of 69 kPa 10 psi vertical pressure on the pavement surface (through a temporary cover of 19 mm 3/8 inch thick plywood).

2.3.2 Vibratory Screed

Truss mounted vibratory screed, adjustable in length to span the paving lane. Provide capability to adjust the vibration along the screed length and compact the full depth of the pervious concrete thickness.

2.3.3 Jointing Tool

Provide a jointing tool consisting of a "pizza cutter roller" to which a beveled fin with a minimum depth of 1/4 the thickness of the slab has been welded around the circumference of a steel roller.

2.3.4 Concrete Saw

Provide equipment for sawing joints and for other sawing of concrete consisting of standard diamond-type concrete saws mounted on a wheeled chassis which can be easily guided to follow the required alignment. Provide diamond tipped blades. Provide spares as required to maintain the required sawing rate.

2.3.5 Straightedge

Furnish one 4 m 12 foot straightedge constructed of aluminum or magnesium alloy, having blades of box or box-girder cross section with flat bottom, adequately reinforced to insure rigidity and accuracy. Provide handles for operation on the pavement.

PART 3 EXECUTION

3.1 PREPARATION FOR PERVIOUS PAVING

Verify the underlying material, upon which pervious concrete is to be placed is clean, damp, and free from debris, waste concrete or cement, frost, ice, and standing or running water. Correct soft, yielding areas and ruts or other irregularities in the surface. Loosen material in the affected areas and remove unsatisfactory material. Add approved select material where directed. Shape the area to line, grade, and cross section, and compact to the specified density.[Conform Subgrade to Section 31 00 00 EARTHWORK.][Conform Base course to Section 32 11 20

[BASE COURSE FOR RIGID][AND][SUBBASE] [SELECT-MATERIAL] [FOR FLEXIBLE PAVING].] Rework and compact any underlying material disturbed by construction operations to specified density immediately in front of the pervious concrete placement.

3.2 WEATHER LIMITATIONS

3.2.1 Inclement Weather

Do not commence placing operations when heavy rain or other damaging weather conditions appear imminent. At all times when placing pervious concrete, maintain on-site sufficient waterproof cover and means to rapidly place it over all unhardened concrete or concrete that might be damaged by rain. Suspend placement of concrete whenever rain, high winds, or other damaging weather commences to damage the surface or texture of the placed unhardened concrete, washes cement out of the concrete, or changes the water content of the surface concrete. Immediately cover and protect all unhardened concrete from the rain or other damaging weather. Completely remove and replace any area damaged by rain or other weather full depth.

3.2.2 Cold Weather

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. 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. Do not use heated mixing water. Follow practices found in ACI 306.1.

3.2.3 Hot Weather

Maintain required concrete temperature in accordance with ACI 305.1 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 or 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.

3.3 CONCRETE PRODUCTION

Batch, mix, and deliver pervious concrete in accordance with ACI 522.1.

3.4 PAVING

3.4.1 Paving Plan

Submit for approval a paving plan identifying the following items:

a. A description of the placing and protection methods proposed when concrete is to be placed in or exposed to hot, cold, or rainy weather conditions.

b. A detailed paving sequence plan and proposed paving pattern showing all planned construction joints.

c. Plan and equipment proposed to control alignment of formed or sawn joints within the specified tolerances.

3.4.2 Placing

Comply with guidelines set in ACI 522.1 for placement of pervious concrete, 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. Do not allow foot traffic on the fresh concrete. Place concrete continuously at a uniform rate, 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. Spread the concrete using a come-along, square ended shovel, or rake. Strike off the concrete between forms using a vibrating screed. Other strike off devices may be submitted for Government approval. Remove riser strips immediately after strike off operations are complete.

3.4.3 Fixed Form Paving

Use steel forms, 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. Provide forms with the base width of the form not less than eight-tenths of the vertical height of the form, except that for forms 200 mm 8 inches or less in vertical height, provide forms with a base width not less than the vertical height of the form. Provide wood forms for curves and fillets that are adequate in strength and rigidly braced. Provide forms and anchors suitable to resist lateral pressures from compaction. Set forms 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. Do not set forms on blocks or on built-up spots of underlying material.[Prior to setting forms for paving operations, demonstrate the proposed form setting procedures at an approved location and do not proceed further until the proposed method is approved.] Maintain forms in place at least 12 hours after the concrete has been placed. Remove forms without damaging the concrete.

3.4.4 Operation

When paving between or adjacent to previously constructed pavement, make provisions to prevent damage to the previously constructed pavement, including keeping the existing pavement surface free of any debris.

3.4.5 Compaction

Automatically control surface vibration so that it stops immediately as forward motion ceases. Do not permit excessive vibration. Tamp concrete in small, odd-shaped slabs or in locations inaccessible to the paver mounted vibration equipment. Do not use vibrators to transport or spread the concrete. After initial compaction, further smooth and compact 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. Operate the paving equipment to produce a thoroughly compacted concrete layer throughout, requiring no hand finishing, other than the use of jointing tools, except in very infrequent instances.

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. Provide hand finishing equipment for use at all times.

3.5.1 Fixed Form Finishing

Strike off and screed concrete to the required [crown] [slope] and cross-section. When using a static roller for consolidation, stiffen the roller to prevent flexing and warping. 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 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.

3.5.2 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.[Install edge restraints of pervious systems per the drawings and manufacturer's recommendations.]

3.5.3 Jointing

Construct joints at the locations, depths, and width dimensions indicated on the project drawings or the approved shop drawings. Saw cut or use the jointing tool to form contraction joints in fresh concrete immediately after the concrete has been compacted to the specified depth and width. 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.

3.6 CURING

Cure pervious concrete for a minimum of 7 days. 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. 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 approved. 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 (limit re-saturation and re-placing no longer than 10 minutes per sheet).

3.7 FIELD QUALITY CONTROL

3.7.1 Sampling

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

Conduct 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 for each batch (minimum) or every 40 cubic meters 50 cubic yards (maximum) of concrete to ensure that specification requirements are met.

3.7.3 Sample Cores

After a minimum of seven days following each placement, take three cores at random locations. Core hardened concrete panels in accordance with ASTM C42/C42M. Test thickness and density of the cores in accordance with ASTM C1542/C1542M and ASTM C1754/C1754M Drying Method B, respectively. Compute the tolerance for core thickness and density reported as the average of three cores of each test panel. Fill core holes with regular concrete or pre-mixed grout.

3.7.4 Field Infiltration Tests

After the curing period is complete, determine the infiltration rate of the pervious concrete in accordance with ASTM C1701/C1701M. Locate field infiltration tests at three random locations for each 930 square meters 10000 square feet of pervious concrete surface area. Determine the location of each test using GPS or other methods suitable to repeat testing during the life of the pavement. Submit the test results For Information Only.

3.7.5 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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Perform surface testing for surface smoothness and plan grade as indicated below. Reference the measurements in accordance with paving lane

identification and stationing, and submit a report within 24 hours after measurement is made. Upon conclusion of surface testing, submit 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. Mechanically sweep pavement before testing hardened concrete for compliance tolerances.

3.7.5.1 Surface Smoothness Requirements

Provide the finished surfaces of the pavements with no abrupt change of 3 mm 1/8 inch or more, and within the tolerances specified in Table 1 when checked with a 4 meter 12 foot straightedge.

3.7.5.2 Surface Smoothness Testing Method

Test the surface of the pavement with the straightedge to identify all surface irregularities exceeding the tolerances specified above. Test the entire area of the pavement in both a longitudinal and a transverse direction on parallel lines approximately 4.5 m 15 feet apart. Hold the straightedge in contact with the surface and move ahead one-half the length of the straightedge for each successive measurement. Determine the amount of surface irregularity 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. Make the measurement of the gap 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.

3.7.6 Plan Grade Testing and Conformance

Check each pavement category for conformance with plan grade requirements by running lines of levels to determine the elevation at locations on the pavement surface 4.5 meters 15 feet on center.

3.8 Pavement Protection

Protect the pavement against all damage prior to final acceptance of the work. Do not stockpile aggregates, landscaping materials, or other construction materials on pervious concrete pavements. Keep all new and existing pervious pavement carrying construction traffic or equipment completely clean, and clean up spillage of concrete or other materials immediately upon occurrence. Remove dust, leaves and debris with a leaf blower or dry vacuum.

3.9 Open To Traffic

Do not open the pavement to vehicular traffic until the concrete has cured at least 7 uninterrupted days during which the ambient temperature has exceeded 13 deg C 55 deg F or until the pavement is accepted.

-- End of Section --