DESIGNER NOTE: The specifications below are based on the best available information. Designer should modify the specifications to satisfy project-specific constraints.

DESIGNER NOTE: Green text corresponds to notes to the designer. Blue text corresponds to requirements taken directly from ACI 522.1.

1. general
	1. SUMMARY
		1. This section includes:
			1. Pervious Concrete
			2. Pavement Base
			3. Geotextile for Soil Separation
		2. Related Sections:

DESIGNER NOTE: The designer should list any additional specification sections which relate to the pervious concrete work (i.e., temporary erosion control, utilities, earthwork, etc.)

* 1. STANDARDS AND CODES
		1. Reference Standards This section incorporates by reference the latest versions of the following documents. These references are a part of this section as specified and modified.

|  |  |
| --- | --- |
| Reference | Title |
| Caltrans | Standard Specifications |
| San Francisco DPW | Engineering Standard Specifications |
| AASHTO | Standards of the American Association of State Highway and Transportation Officials, 1998 or latest edition |
| ACI 522.1 | Specifications for Pervious Concrete Pavement |
| ACI 301 | Specifications for Structural Concrete |
| ACI 305.1 | Standard Specifications for Hot Weather Concreting |
| ACI 306.1 | Standard Specifications for Cold Weather Concreting |
| ACI 308.1 | Standard Specifications for Curing Concrete |
| ASTM | Annual Book of ASTM Standards, American Society for Testing and Materials, Philadelphia, PA, 1997 or latest edition. |

* 1. REFERENCES

DESIGNER NOTE: Designer to provide references to related industry manuals and guidance and all project specific documents (e.g., geotechnical report).

* 1. SUBMITTALS
		1. Bid Submittals: The Contractor shall submit to the Owner the following as part of the bid proposal:
			1. National Ready Mix Concrete Association (NRMCA) Pervious Concrete Contractor Certifications and project experience as specified in Section 1.05.A for the crew assigned to this project.

DESIGNER NOTE: The designer should incorporate by reference these requirements in Division 00 of the Specifications.

* + 1. Pre-Installation Submittals: The Contractor shall submit to the Engineer the following a minimum of 20 calendar days prior to the construction of the pervious cement concrete pavement:
			1. NRMCA Certifications for the batch plant to be used in the production of pervious concrete for this project.
			2. Proposed mix design including the following:
				1. Batch weights of all constituents.
				2. Portland cement type and brand.
				3. Non-Portland cement pozzolan type and source.
				4. Microfiber brand and type.
				5. Admixture type and brand.
				6. Aggregate source(s), gradation(s), LA abrasion, and cleanness value(s).

No concrete shall be placed until the Engineer has provided written acceptance of the mix design per Section 1.05.B.

* + - 1. Source certificates, gradations, R-values, LA abrasion, and cleanness values of aggregates for base and reservoir course materials performed within one (1) month of product delivery to site.

DESIGNER NOTE: Consider revising acceptable age of sieve test depending on scale of project. On a larger project it may be appropriate to require testing by an independent lab with samples taken at the supplier’s yard from the stockpile to be used for the project.

* + - 1. Product data sheets for all proposed admixtures and geotextiles.
			2. A detailed plan of the proposed paving pattern and sequencing (if applicable) showing the location and type (saw cut or rolled in plastic concrete) of all planned joints. No deviation from the jointing pattern shown on the Plans will be allowed without written approval of the Engineer.
			3. A detailed procedure for the production, transportation, placement, protection, curing, and temperature monitoring of concrete for hot and/or cold weather, unless written approval of the Engineer waiving the requirement is received.
			4. Field technician qualifications as specified in Section 1.05.A.
			5. Testing agency qualifications as specified in Section 1.05.A.
			6. Density of fresh pervious concrete, length of cores, and density of cores for one (1) reference panel. Reference panel shall be placed, jointed, cured, and tested as specified in Section 1.05.D.1 and be within tolerance of the required thickness defined by the Contract Documents.
	1. QUALITY CONTROL AND QUALITY ASSURANCE
		1. General: Test and inspect concrete materials and operations as Work progresses as described in this section. Failure to detect defective Work or materials at any time will not prevent rejection if a defect is discovered later, nor shall it constitute final acceptance.
			1. Contractor and Personnel Qualifications
				1. Contractor qualification: Unless otherwise approved by Engineer, Contractor shall provide evidence of employment for one (1) NRMCA certified Pervious Concrete Installer and four (4) NRMCA certified Pervious Concrete Technicians who must be on site, working as members of each placement crew, during all concrete placement.

For all projects where the total pervious concrete pavement area exceeds 2,000 square feet (sf), the Contractor shall provide evidence of employment for at least one (1) NRMCA certified Pervious Concrete Craftsman who must be onsite, working as part of the placement crew, during all concrete placement. Additionally, for every 10,000 sf of pavement area over 2,000 sf, one (1) additional NRMCA certified Pervious Concrete Installer is required on site, working as part of the placement crew.

The Contractor shall provide documentation showing three (3) successful pervious concrete projects completed in the last three (3) years collectively totaling more than 20,000 square feet. Documentation shall include name and address of project, and contact information for project owner.

DESIGNER NOTE: The designer should adjust as required based on the availability of qualified bidders and the size of the project.

* + - * 1. Field technician qualification: Field tests of concrete required in the responsibilities of the testing agency shall be performed by an individual certified as both an NRMCA Certified Pervious Concrete Technician, or equivalent, and an ACI Concrete Field Testing Technician – Grade I, or equivalent.

DESIGNER NOTE: The designer should adjust as required based on the availability of qualified personnel and the size of the project.

* + - * 1. Testing agency qualification: Agencies that perform testing on concrete materials shall meet the requirements of ASTM C1077 and provide evidence of employment for at least one (1) NRMCA Certified Pervious Concrete Technician, responsible for testing, or providing direct oversight of testing, of all concrete materials. Agencies inspecting the Work shall meet the requirements of ASTM E329. Testing agencies performing the testing shall be accepted by the Engineer before performing any Work.
				2. Batch plant qualification: Batch plant used for pervious concrete shall be a semi-automatic or automatic batching plant with a current NRMCA certification.

DESIGNER NOTE: Volumetric (truck mounted) Site Mixed Mobile Mixers may be used at the designer’s discretion. Mixing operations should be per manufactures directions. Designer should specify certification and calibration requirements for Volumetric Mobile Mixers including, but not limited to:

* Proof of Volumetric Mixer Manufacturer Bureau (VMMB) certification, compliance with VMMB 100-01 Volumetric Mixer Standards, and associated VMMB rating plate, or equal
* Provisions for calibration of Volumetric Mobile Mixers performed with aggregate manufactured for the project and recalibrated with each restocked stockpile

Additionally, the designer should specify required quality control measures to ensure aggregates, cementitious material, and admixtures are free from contamination from deleterious material or other stockpiles/storage containers, protected from damage by equipment, vehicles, or weather, and properly batched in lieu of batch ticket (e.g., labeling of aggregate bins to ensure correct aggregate is fed into appropriate mixer material compartment.

* + 1. Approved Mix Design: Once accepted by the Engineer, the mix design meeting the criteria specified in Section 2.01.F shall become the Approved Mix Design and shall not be modified in any way. The Approved Mix Design shall be determined from information submitted under Section 1.04 and from results of reference panel testing as described in Section 1.05.D.1.

Modifications to the Approved Mix Design will not be allowed and any modified mix placed in the Work will be rejected. Proposed modifications to the Approved Mix Design shall be submitted as a new mix design and shall require a new reference panel to validate the proposed mix design and determine the new Approved Mix Design. If accepted by the Engineer, the new mix design shall become the Approved Mix Design. The requirement for a new reference panel may be waived at the discretion of the Engineer. Only one (1) Approved Mix Design shall be valid at any time. Admixture and water dosages may be modified as needed to maintain mix properties.

* + 1. Responsibilities of Contractor
			1. Pre-Placement Conference: A mandatory pre-placement conference will take place including at a minimum the Engineer, the Owner, general contractor, pervious concrete installer, concrete supplier, and field testing agency representative. The document Checklist for the Concrete Pre-Construction Conference (available from the National Ready Mix Concrete Association) will be used to review all materials, personnel qualifications, concrete production, delivery, maintaining moisture retention of fresh mixture, preparation, placing, curing (including timing, placement, and securing of curing cover), jointing, testing procedures, and responsibilities. Meeting emphasis will be on how pervious concrete differs from conventional concrete.
			2. Reference Panel: For installations over 500 square feet, place reference panels on the project site, on a subgrade and base prepared as specified, using the material and construction requirements for pavement in this Specification. Each panel must have a surface area of at least 225 square feet, and a width and thickness as specified for the pavement in the Contract Documents. The Engineer shall observe and accept each element of the pervious concrete construction. Construction and evaluation of the reference panel(s) will occur as follows:
				1. Notify the Engineer at least ten (10) Working Days before installing pervious concrete reference panel.
				2. Coordinate the location of the reference panel with the Engineer.
				3. Notify the Engineer when each element of the reference panel is ready for inspection.
				4. Remove, replace, and dispose of any unsatisfactory portions of reference panel as determined by the Engineer and at no additional cost to the Owner.
				5. Retain and maintain approved reference panels during construction in an undisturbed condition as a standard for judging completed portions of the final installations.

Approved reference panels may remain as final installations of the Work at the discretion of the Engineer. If not retained, the reference panel shall be removed and disposed of at no additional cost to the Owner.

* + - 1. Testing facilitation: Owner’s use of testing services will not relieve Contractor of the responsibility to furnish materials and construction in full compliance with the Contract Documents. Unless otherwise specified in the Contract Documents, Contractor shall assume the following duties and responsibilities:
				1. Furnish the materials to be tested, including concrete cores.
				2. Furnish any necessary labor to assist Owner’s testing agency in obtaining and handling samples, including concrete cores, at the project site or at the source of materials.
				3. Provide measures to collect slurry and debris during coring operation in order to avoid sealing adjacent pavement.
				4. Fill core holes in accordance with Section 1.05.D.2.
				5. Advise Owner’s testing agency at least 24 hours in advance of operations to allow for completion of quality tests and for assignment of personnel.
			2. Pressure wash testing: Before final acceptance by the Engineer, the Contractor shall pressure wash the pervious concrete. Pressure washing shall be provided and completed by using portable washer equipment working at a minimum of 3,000 psi at 2.0 to 2.5 gpm. The nozzle shall be a zero degree nozzle and be held a maximum of three (3) inches off the concrete surface. The Contractor shall pressure test three (3) locations per lot or as determined by the Engineer. Any sections of pervious concrete that breaks up or ravels shall be removed and replaced with acceptable pervious concrete to the nearest joints. The Engineer will reject the concrete if the pressure washing dislodges aggregate particles from more than two (2) percent of the pervious concrete in a single panel (joint to joint).

The Contractor shall decide, after placing the pervious concrete, when to perform the quality assurance pressure wash testing for the acceptance.

DESIGNER NOTE: The designer should consider requiring verification of subgrade infiltration rate and provision to increase reservoir course depth based on results.

* + 1. Testing
			1. Reference Panel: Testing for the reference panel shall adhere to the requirements for testing of Pavement per Section 1.05.D.2 for approval by the Engineer. Each test shall meet the acceptance criteria for Reference Panel as defined in Section 1.05.E.1.

The Engineer shall inspect and approve the reference panel prior to the placement of additional pervious concrete.

Failure to install acceptable reference panels of pervious concrete will indicate an unqualified installer.

Production sections of this Work shall not be placed until achieving a complete reference panel that fully complies with the Plans and Specifications and has written acceptance issued by the Engineer.

The completed and accepted reference panels shall be maintained and protected throughout the duration of the Work and may not be demolished and disposed of without written permission from the Engineer. If a reference panel is incorporated into the Work, it shall remain in place and be accepted as a single lot.

Unless otherwise determined by the Engineer, density testing of fresh concrete and hardened cores will be used to validate the mix design per the design criteria set forth in Section 1.04.B and the acceptance criteria in Section 1.05.E.1.

The average fresh density and average hardened density of the cores shall be the densities used for the Approved Mix Design.

* + - 1. Pavement: The following testing shall be conducted for approval by the Engineer for each reference panel and each lot of pervious concrete placed, where a lot is defined as the lesser of one (1) day’s production or 5,000 square feet of pervious concrete, in place, unless otherwise specified below:
				1. Density testing of at least one (1) cubic foot of fresh concrete in accordance with ASTM C1688.
				2. Thickness testing of three (3), four‑ (4)‑inch hardened concrete cores in accordance with ASTM C174 and adhering to the following requirements:

Removed not less than seven (7) days after placement of pervious concrete.

Location selected in accordance with ASTM D3665.

Cut in accordance with ASTM C42.

* + - * 1. Density and void content testing of the three (3) hardened concrete cores extracted for thickness testing and trimmed to produce flat core ends per ASTM C42 paragraph 7.4.1 and 7.4.2. Samples shall be tested in accordance with ASTM C1754.
				2. Surface infiltration tests per ASTM C1701 and at the frequency described below.

Three (3) test locations per 10,000 square feet of pervious concrete, in place

One (1) additional test location per 5,000 square feet of pervious concrete, or fraction thereof, in place

DESIGNER NOTE: Designer to specify the number and location(s) of required post construction infiltration tests.

Core holes shall be filled with solid concrete, pre-blended grout, or pervious concrete and shall match adjacent pavement color, and grade. At the Engineer’s discretion, a sacrificial panel for cores may be required or allowed.

Each test shall meet the acceptance criteria for Pavement as defined in Section 1.05.E.2.

* + 1. Acceptance
			1. Reference Panel: Acceptance of the reference panel will be based on the criteria for acceptance of Pavement per Section 1.05.E.2 with the following deviations:
				1. Fresh Density: The fresh density shall be within or equal to five (5) pounds per cubic foot of the average fresh density of the three (3) samples.
			2. Pavement: Acceptance of a lot of pervious concrete will be based on the following criteria:
				1. Smoothness: Pervious concrete pavement smoothness shall be checked with a 10‑foot straightedge. Vertical measurement should be taken between the pavement’s determined plane and straight edge, discounting surface void and roughness irregularities, in a direction perpendicular and parallel to the centerline. The finished pavement shall be uniform to a degree such that no variations greater than 3/8‑inch are present between the straight edge and pavement surface over a distance of at least 6 inches.
				2. Grade: Pervious concrete shall be true to designed spot elevations plus or minus ½ inch and shall not deviate from designed slope more than ¼ inch in ten (10) feet. Where abutting existing facilities such as sidewalks, walkways, curbs, driveways or other pavements, the pervious concrete shall be flush.
				3. Line: Pervious concrete margins shall be true to designed lines plus or minus ½ inch at any point.
				4. Slope: Pervious concrete shall be sloped as shown on the Plans. Slope shall be consistent to within 1/4 inch in ten (10) feet.
				5. Thickness: Each core sample shall be equal to the minimum section depth or more as specified on the Plans.
				6. Hardened Density: The density of the core samples for each lot shall be within +/- five (5) percent of the average density of the three core samples from the accepted reference panel.
				7. Void Content: The total void content of the core samples for each reference panel and lot shall be twenty (20) percent, plus or minus five (5) percent, in place, as constructed.
				8. Infiltration Rate: The average of all surface infiltration tests shall be greater than 250 inches per hour with no single test less than 100 inches per hour.

DESIGNER NOTE: The designer should adjust infiltration rates to reflect project specific conditions such as anticipated sediment loading based on pavement use (e.g., vehicular, pedestrian) and design run-on from adjacent surfaces. The recommended criteria are as follows:

* For permeable pavement that will accept run-on from adjacent impervious and/or pervious surfaces OR pavement that will be subject to vehicular traffic:
	+ The average of all surface infiltration tests shall be greater than 250 inches per hour with no single test less than 100 inches per hour
* For permeable pavement not subject to run-on OR vehicular traffic:
	+ The average of all surface infiltration tests shall be greater than 100 inches per hour with no single test less than 75 inches per hour
		- * 1. Fresh Density: The fresh density shall be within or equal to five (5) pounds per cubic foot of the fresh density indicated by the Approved Mix Design.
				2. Batch Ticket: Each load of pervious concrete transported to the location of placement shall have a Batch Ticket delivered with the load. Batch Tickets shall be provided upon request for each load and shall be in accordance with ASTM C94, with the following additions:

Batch weights of all constituents in the mix, including cement, aggregate, admixtures, water, and fibers

Signature of responsible representative of the concrete producer, affirming the accuracy of the information provided

* + - * 1. Appearance: Each lot of finished pervious concrete will be inspected for appearance by the Engineer after completion of pressure wash testing per Section 1.05.C.4. The pervious concrete shall have a consistent surface texture, shall have no more than five (5) percent of the surface area within each panel (joint to joint) filled with paste, shall be free of ridges or other surface imperfections, shall have joints that are in the specified location and are constructed per specification, shall be free of cracks and shall not be raveled.

A panel will be considered raveled if aggregate is dislodged from a contiguous area of the pavement surface or longitudinally along a joint exceeding five times the nominal maximum aggregate size in any direction OR if aggregate particles are dislodged from more than two (2) percent of the pervious concrete within each panel (joint to joint). Raveling occurring during pressure wash testing (as defined in 1.05.C.4) or during the first three (3) months after installation is subject to complete removal and replacement of affected panels with acceptable pervious concrete at the Owner’s discretion and Contractor’s expense. Requirement to replace affected panels shall continue until three (3) months after the date of replacement. Written notification of defects is the sole responsibility of the Owner.

DESIGNER NOTE: The designer should incorporate by reference these requirements in Division 00 of the Specifications.

* + - * 1. Conformance to Approved Mix Design: The pervious concrete used shall conform to the Approved Mix Design within the limits set forth in ASTM C94.
			1. Required Inspections: Notify the Engineer at least 48 hours prior to required inspections specified in Sections 3.02, 3.03, and 3.04.B.
1. PRODUCTS

DESIGNER NOTE: Designers should maximize the use of regionally available materials.

* 1. PERVIOUS CONCRETE

DESIGNER NOTE: No reinforcing bars or tie bars will be used in the installation of pervious concrete.

Pervious Concrete shall comply with ASTM C94, except sections 4.2, 6.1.2, 6.1.3, 6.1.4, 6.1.5, 7, 8, 16, 17, 18, 19, 20 and the requirements specified herein. The volume of fresh concrete in a given batch shall be determined from the total mass of the batch divided by the design density of the concrete. The total mass of the batch shall be determined as the net mass of the concrete in the batch as delivered, including the total mixing water as defined in ASTM C94 Paragraph 9.3.

* + 1. Cement: Cement in the mix design shall conform to the requirements for Portland Cement or Blended Hydraulic Cement as specified herein:
			1. Portland Cement: Portland Cement shall meet the requirements of ASTM C150 Type I, II, or V Portland cement.
			2. Blended Hydraulic Cement: Blended Hydraulic Cement shall be Type IP or IS Cement conforming to ASTM C595. Type IP(X), Portland Pozzolan Cement, and IS(X) where (X) dictates pozzolan and slag percentage, respectively, shall be Portland Cement and Pozzolan. The pozzolan shall be limited to fly ash or ground granulated blast furnace slag.

The fly ash or ground granulated blast furnace slag constituent content in the finished cement shall not vary more than plus or minus 5 percent by weight of the finished cement from the certified value.

* + - 1. Supplementary cementitious material shall be as specified herein:
				1. Fly Ash: Fly ash shall conform to the requirements of ASTM C618, Class F or C.
				2. Slag Cement: Slag cement shall meet the requirements of ASTM C989, Grade 100 or Grade 120.
				3. Silica Fume: Silica fume shall meet the requirements of ASTM C1240.
		1. Aggregates: Aggregates shall conform to ASTM C33 except as specified herein, unless otherwise approved by the Engineer.
			1. Aggregate Gradation tested in accordance with ASTM C136 at least once per 300 cubic yards of concrete.

|  |  |
| --- | --- |
| Sieve1 | Percent Passing by Weight |
| Coarse Aggregate | Fine Aggregate |
| ASTM No. 7 | ASTM No. 8 | ASTM No. 89 | ASTM No. 9 |
| 2 inch | – | – | – | – | – |
| 1 1/2 inch | – | – | – | – | – |
| 1 inch | – | – | – | – | – |
| 3/4 inch | 100 | – | – | – | – |
| 1/2 inch | 90 to 100 | 100 | 100 | – | – |
| 3/8 inch | 40 to 70 | 85 to 100 | 90 to 100 | 100 | 100 |
| No. 4 | 0 to 15 | 10 to 30 | 22 to 55 | 85 to 100 | 95 to 100 |
| No. 8 | 0 to 5 | 0 to 10 | 5 to 30 | 10 to 40 | 80 to 100 |
| No. 16 | – | 0 to 5 | 0 to 10 | 0 to 10 | 50 to 85 |
| No. 30 | – | – | 0 to 5 | 0 to 5 | 25 to 60 |
| No. 50 | – | – | – | – | 5 to 30 |
| No. 100 | – | – | – | – | 0 to 10 |
| No. 200 | – | – | – | – | 0 to 3 |

1 Sieve provided in nominal size square openings or United States Standard Sieve Series sizes.

In individual tests, a variation of 4 percent under the minimum percentages or over the maximum percentages will be allowed. The average of three successive tests shall be within the percentages stated above. Aggregate shall contain no pieces larger than two times the maximum sieve size for the specified grading measured along the line of greatest dimension.

* + - 1. Coarse Aggregate
				1. LA Abrasion: 35 percent (maximum) tested in accordance with ASTM C131 at least once per 300 cubic yards of concrete.
				2. Cleanness Value: 75 (minimum) tested in accordance with California Test 227 at least once per 300 cubic yard of concrete.
			2. Acceptance of grading and quality of the aggregate may be based on samples taken from stockpiles at the concrete plant or a submitted gradation report at the discretion of the Engineer. The point of acceptance will be determined in the field by the Engineer.
		1. Admixtures
			1. Air Entraining Admixtures: Air entraining admixtures shall meet the requirements of ASTM C260.
			2. Water Reducing Admixtures: Water reducing admixtures shall meet the requirements of ASTM C494, Type A.
			3. Hydration Stabilizing Admixtures: Hydration stabilizing admixtures shall meet the requirements of ASTM C494, Type B or Type D.
			4. Superplasticizers: Superplasticizers and retarders shall meet the requirements of ASTM C494, Type F or Type G and ASTM C1017, Type 1.
			5. Viscosity Modifying Admixtures: Viscosity modifying admixtures may be used if approved by the Engineer.
			6. Color Pigment: Color pigment shall meet the requirements of ASTM C979 for integrally colored concrete. Pigments shall be color stable, non-fading, and resistant to lime and other alkalis.

DESIGNER NOTE: Designer to specify color, as indicated by manufacturer’s designation, architect’s sample, etc. with provision for approved equal color.

* + 1. Water: Clean potable water or water conforming to ASTM C1602 shall be used in the mix design and on the jobsite. The use of hot water is not permitted.

DESIGNER NOTE: Hot water in practice is only used in freezing ambient temperatures to bring the mix to a normal temperature. Unlikely for contractors to want to use hot water, but may be considered for projects outside the City.

* + 1. Microfibers and Macrofibers: Microfibers shall conform to the requirements of ASTM C1116, Type III and shall be monofilament and ½ inch in length. Macrofibers shall conform to the requirements of ASTM C1116, Type III and shall be monofilament.
		2. Mix Design:
			1. General: The Contractor shall propose a mix design for pervious concrete and shall submit the mix design to the Engineer for acceptance prior to constructing the reference panels. Pervious concrete shall not be placed in the reference panels without a mix design that has been reviewed and accepted by the Engineer.
			2. Mix Design Criteria: The Contractor shall include the following elements and results of the described procedures in the proposed mix design:
				1. The cementitious content, including pozzolans if used, shall be a minimum of 480 and a maximum of 600 pounds per cubic yard.
				2. The mix may incorporate up to 5 percent fine aggregate, by weight.
				3. The mix shall incorporate a hydration stabilizing admixture.
				4. The mix may incorporate microfibers, macrofibers or fibers per Manufacturer’s recommendations.
				5. The mix shall be designed to meet the acceptance criteria for Void Content per Section 1.05.E.2.g as determined by the testing methods specified in Section 1.05.D.
				6. The water/cement ratio shall be between 0.27 and 0.35.
				7. Up to 50 percent of cementitious material in the mix, by weight, may be fly ash, slag cement, or a combination of silica fume and either or both of the above, with silica fume not exceeding 10 percent.

Deviations from this mix design, such as the use of internal curing admixtures, cementitious content outside of the range specified, or finer aggregate gradations may be permitted at the sole discretion of the Engineer provided the Contractor can demonstrate the viability of the mix design through past successful installations or sound science.

* 1. PAVEMENT BASE
		1. Pavement Base Material shall consist of clean, mechanically crushed stone, substantially free from adherent coatings. Materials shall be washed thoroughly to remove clay, organic matter, extraneous debris, or objectionable materials. Recycled materials or round river gravel are not permitted. Material shall be obtained only from a source(s) approved by the Engineer. Written requests for source approval shall be submitted to the Engineer not less than Working 10 days prior to the intended use of the Material. Should the proposed source be one that the Engineer has no history of Material performance with, the Engineer reserves the right to take preliminary samples at the proposed source, and make preliminary tests, to first determine acceptability of the new source and then perform the applicable Material approval testing. Continued approval of a source is contingent upon the Materials from that source continuing to meet Contract requirements. Materials shall meet the Standard Specifications for grading and quality for use in the Work; however, allowable exceptions may be specified in the Contract. The Engineer shall reserve the right to sample and test Material at any time including at the source.
		2. Pavement Base shall consist of up to two (2) layers as specified on the Plans and included herein:
			1. “Base Course” shall be ASTM No. 3 (modified) or ASTM No. 57 (modified) stone per Section 2.02.C.

DESIGNER NOTE: This layer of the pavement base is intended to provide structural (load bearing) capacity to the pavement.

* + - 1. “Reservoir Course” shall be ASTM No. 2 (modified), ASTM No. 3 (modified), or ASTM No. 57 (modified) stone per Section 2.02.C.

DESIGNER NOTE: This layer of the pavement base is intended to provide storage and drainage of the pavement, structural support, and a capillary break. The materials specified should be crushed, clean, washed rock to provide the desired structural capacity, maintain good drainage, function as a capillary barrier, and minimize clogging of the subgrade due to export of fines.

DESIGNER NOTE: If the designer chooses to specify materials that differ from those provided herein, the designer should check their filter criteria to evaluate the likelihood of finer-graded material migration into underlying courser graded materials or reduction in permeability relative to the underlying material. Refer to the SFPUC aggregate filter criteria guidance document for information on selecting appropriate alternate materials.

* + 1. Pavement Base Material shall meet the following specifications for grading and quality.
			1. Aggregate Gradation tested in accordance with ASTM C136 at least once per 500 cubic yards of base material.

| Sieve1 | Percent Passing by Weight |
| --- | --- |
| ASTM No. 2 (modified) | ASTM No. 3 (modified) | ASTM No. 8 (modified) | ASTM No. 57 (modified) |
| 3 inch | 100 | – | – | – |
| 2 1/2 inch | 90 to 100 | 100 | – | – |
| 2 inch | 35 to 70 | 90 to 100 | – | – |
| 1 1/2 inch | 0 to 15 | 35 to 70 | – | 100 |
| 1 inch | – | 0 to 15 | – | 95 to 100 |
| 3/4 inch | 0 to 5 | – | – | – |
| 1/2 inch | – | 0 to 5 | 100 | 25 to 60 |
| 3/8 inch | – | – | 85 to 100 | – |
| No. 4 | – | – | 10 to 30 | 0 to 10 |
| No. 8 | – | – | 0 to 10 | 0 to 5 |
| No. 16 | – | – | 0 to 5 | – |
| No. 1002 | 0 to 2 | 0 to 2 | 0 to 2 | 0 to 2 |

1 Sieve provided in nominal size square openings or United States Standard Sieve Series sizes.

2 Gradation modified from ASTM for portion passing the No. 100 sieve.

* + - 1. L.A. Abrasion: 30 percent (maximum) tested in accordance with ASTM C131.
			2. Cleanness Value: 75 (minimum) tested in accordance with California Test 227 at least once per 500 cubic yards of base material.
			3. Crushed Particles: 90 percent (minimum) with two (2) or more fractured faces tested in accordance with California Test 205.
			4. The combined portion of Material retained on the U.S. No. 4 sieve shall not contain more than 0.1 percent wood waste by weight. The portion of Material passing a U.S. No. 10 sieve shall not have wood waste that results in more than 250 parts per million of organic matter by calorimetric tests when tested. The color shall be measured after the sample has been in the test solution for 1 hour.
	1. GEOTEXTILE FOR SOIL SEPARATION

DESIGNER NOTE: Geotextile is not typically required under permeable pavement applications unless recommended by a geotechnical engineer. Geotextile can be placed vertically for material separation between side walls of reservoir course and native soil.

* + 1. Geotextile shall be woven, consisting only of long chain polymeric fibers or yarns formed into a stable network such that the fibers or yarns retain their position relative to each other during handling, placement, and design service life. At least 95 percent by weight of the material shall be polyolefins or polyesters. The material shall be free from defects or tears. The geotextile shall also be free of any treatment or coating which might adversely alter its hydraulic or physical properties after installation. The geotextile shall conform to the properties specified herein:

|  |  |  |
| --- | --- | --- |
| Geotextile Property | Test Method | Requirement |
| Grab Tensile Strength, minimum in weakest direction | ASTM D4632 | 200 lbs/in |
| Apparent Opening Size (AOS) | ASTM D4751 | 40 to 50 |
| Ultraviolet (UV) Radiation Stability, minimum strength retained after 500 hours in weatherometer | ASTM D4355 | 50%  |
| Flow Rate, minimum | ASTM D4491 | 140 gal/min/ft2 |

DESIGNER NOTE: The designer should consider including specifications for signage and pavement markings in this section.

1. EXECUTION
	1. GENERAL
		1. Prevent runoff from adjacent pervious and impervious surfaces from entering the permeable pavement area (e.g., stabilize adjacent areas, flow diversion) until authorization is given by the Engineer/Landscape Architect. For capital projects, redevelopment projects, and any project where the permeable pavement is in the public ROW (i.e., with an SFPW encroachment permit), refer to SFPUC Specification Section 01 57 29 Temporary Protection of Green Infrastructure Facilities.
		2. Exclude equipment from permeable pavement areas that have been excavated to subgrade. No equipment shall operate on subgrade within the facility once excavation has begun, including during and after excavation. Equipment may operate on the placed aggregate surface.
		3. Prevent foreign materials and substances, such as silt laden run-off, construction debris, etc. from entering or being stored in the facility at any point during construction.
		4. Do not dump materials or substances except the aggregate within the permeable pavement area. Any foreign materials or substances shall be removed prior to aggregate placement.
	2. SUBGRADE PREPARATION AND PROTECTION
		1. Construct subgrade to +/- ¾ inch of the grades and slopes specified on the Plans.
		2. Grading of subgrade shall be with low ground pressure equipment when within six (6) inches of final subgrade elevation.
		3. Compact subgrade to 90 percent (+/- 2 percent) of the maximum dry density per standard Proctor test (ASTM D698), or as directed by the Geotechnical Engineer. Determination of in-place density shall be made using a nuclear gauge per ASTM D6939.

DESIGNER NOTE: The designer should set compaction requirements based on consideration of site specific geotechnical properties of the native soil (e.g., permeability, stiffness) and performance requirements for the pavement section (e.g., traffic loading, infiltration, cost).

* + 1. Areas of the subgrade which are over-compacted, as determined by the Geotechnical Engineer, shall be ripped/tilled to a depth of 12 inches (minimum) or as directed by the Geotechnical Engineer and shall be recompacted in accordance with Section 3.02.C. Contractor shall locate all utilities within pavement footprint prior to ripping and re-compacting subgrade.
		2. Proof-roll prepared subgrade with loaded dump truck, remove soft spots, and replace with permeable structural fill as directed by the Engineer to achieve uniform subgrade.

DESIGNER NOTE: Other subgrade verification methods may be required if site conditions limit proof rolling. Consult with geotechnical engineer for acceptable methods.

* + 1. After compaction and proof roll, scarify subgrade ¼‑ to ½‑inch deep by hand rake. Once scarified, materials or equipment shall not be permitted within the prepared subgrade area so as to avoid recompaction or clogging of the scarified subgrade.
		2. The subgrade shall be protected from over-compaction or contamination by silty run-off or other contaminants.
			1. Provide physical barriers or direct traffic to eliminate unnecessary vehicular traffic on the subgrade during construction in accordance with SFMTA and SFDPW ordinances and specifications.
			2. Provide flow diversion and erosion control measures to protect the permeable pavement area from sedimentation until the upstream catchment area is thoroughly stabilized.
		3. Areas of subgrade over-compacted by construction traffic or other impacts by the Contractor or Subcontractors shall be ripped/tilled and re-compacted in accordance with Section 3.02.D. All work and materials required to correct over-compacted subgrade, including utility locates within the pavement footprint, shall be at the Contractor’s expense.
		4. Areas of subgrade contaminated by the accumulation of silty material following rains or other debris or contamination shall be removed and disposed at the Contractor’s expense.
		5. The subgrade shall be inspected and accepted by the Engineer prior to placement of the geotextile or pavement base.
		6. Place geotextile, if required, on scarified subgrade. Care shall be taken to provide full coverage and to prevent the geotextile from being torn. Damaged geotextile shall be repaired as indicated by the manufacturer and to the satisfaction of the Engineer at no additional cost to the Owner. Overlaps of the geotextile shall be a minimum of one (1) foot or to the manufacturer’s recommendation, whichever is greater.

DESIGNER NOTE: The use of geotextile under permeable pavement systems should be avoided unless required by the project geotechnical engineer as it can be prone to subsurface clogging.

* 1. PAVEMENT BASE
		1. Construct pavement base to the lines, grades, and thicknesses shown on the Plans.
		2. Place the pavement base so as to prevent loaded dump trucks from driving directly on the prepared subgrade.
		3. Compact pavement base, in six (6) inch (maximum) lifts, by making a minimum of three passes over the pavement base material with a ten (10) ton vibratory roller, or as directed by the Geotechnical Engineer. The first two (2) passes (minimum) shall be in vibratory mode. Acceptance of the pavement base will be based on Engineer’s observation that compaction has achieved an unyielding surface. Compaction equipment shall be accepted by the Engineer prior to use.

DESIGNER NOTE: For areas or sites that cannot accommodate a vibratory roller compactor, consider allowing compaction of pavement base with a 13,500 lbf (60 kN) minimum vibratory plate compactor with a compaction indicator. At least two passes should be made over each lift of the aggregates.

* + 1. Pavement base shall be true to the designed grade and slope, +/- 0.05 feet, after compaction for each layer. In the event of low spots, additional material shall be added and recompacted. In the event of high spots, excess material shall be removed and the area recompacted.
		2. The pavement base shall be protected from over-compaction or contamination by silty run-off or other contaminants.
			1. Provide physical barriers or direct traffic to eliminate unnecessary vehicular traffic on the pavement base during construction in accordance with SFMTA and SFDPW ordinances and specifications.
			2. Provide flow diversion and erosion control measures to protect the permeable pavement area from sedimentation until the upstream catchment area is thoroughly stabilized.
		3. Any damage to the pavement base (including contamination by silty run-off) shall be repaired to the satisfaction of the Engineer at the Contractor’s expense. Contaminated pavement base shall be removed and replaced to the limits as determined by the Engineer.
		4. The pavement base shall be inspected and accepted by the Engineer prior to placing any pervious concrete.

DESIGNER NOTE: Consider developing a testing plan for the required testing and inspection of the pavement base. Verification of the in place density/compaction of the open graded base materials is typically not possible with the use of a nuclear densometer due to nature of these materials. Therefore, other means to verify these materials are firm and unyielding (such as observation of the compaction process by a geotechnical engineer) are necessary.

DESIGNER NOTE: Consider requiring the Contractor to compact aggregates without crushing them.

* 1. MIXING, PLACEMENT & CURING OF PERVIOUS CONCRETE
		1. Pervious concrete formwork
			1. Forms shall be made of steel or wood and shall be in good condition, clean, and capable of being anchored in place so as to ensure pavement placement true to the grades, lines and slopes as specified on the Plans.
			2. Forms that are bent, warped, unclean, or otherwise deemed inadequate by the Engineer shall not be used.
			3. Existing curbs, structures, or the vertical face of previously placed pervious concrete may be used as a form.
			4. Set, align, and brace forms to satisfy the lines, grades, and slopes on the Plans.
			5. Apply form-release agent to the form face immediately before placing concrete, if used.

DESIGNER NOTE: Placement without the use of form release agents encouraged in MS4 areas to reduce potential water quality issues.

* + - 1. No pervious concrete shall be placed until the forms are inspected and accepted by the Engineer.
			2. Slip forming is an acceptable method for placement of pervious concrete.
		1. Batching, mixing, and delivery
			1. Pervious concrete shall be batched and centrally mixed at a batching plant meeting the requirements set forth in Section 1.06.A.4. Pervious concrete shall not be shrink mixed or transit mixed.
			2. Begin mixing immediately after cement has been added to aggregates. Batch and mix concrete in compliance with ASTM C94, with the following exceptions:
				1. Placement of concrete shall occur no more than 60 minutes from the time water or aggregate is added to the cement unless a hydration-stabilizing admixture is used.
				2. Hydration stabilizers shall be used if time from batching to placement is expected to exceed 60 minutes. The appropriate dosage rate shall be determined by the ready-mix concrete producer or contractor to allow for the necessary fresh properties required for placement of concrete as determined by the contractor. Placement shall cease immediately if the concrete mix becomes unworkable. Loss of the wet metallic sheen, combined with slowing discharge from the ready-mix truck and a rapid rise in concrete temperature are indications of loss of workability.

Additional water may be added on site, but the fresh density must still meet the requirements of Section 2.01.F.2 after water addition.

* + 1. Placing and consolidation
			1. Pervious concrete shall not be placed on standing water or frozen pavement base.
			2. In hot and or dry conditions, prior to placement of the pervious concrete, moisten sub-base aggregate to provide a dampened condition at the time concrete is placed. If initial application of water is absorbed within a few minutes, apply a second application of water just before installing pervious concrete.
			3. Place pervious concrete on the prepared pavement base as close to its final position as possible, either directly from the transporting equipment or by conveyor, unless otherwise specified. Spread the concrete using mechanized equipment or hand tools, without segregation.
			4. Strike off concrete between forms using a form riding paving machine or roller screed at the appropriate height, as determined by the Contractor, to allow for compaction to finished grade. Equipment used for striking off the pervious concrete shall leave a smooth surface, free of ridges or other imperfections, without drawing excessive paste to the surface. Vibratory screeds are not permitted. Other strike-off devices may be used when accepted by the Engineer.
			5. Provide secondary compaction of pervious concrete with purpose-built cross roller, float pan, or alternate method approved by the Engineer. Rollers shall be of sufficient weight and width to compact the fresh pervious concrete to grade, leaving a smooth surface, free of ridges or other imperfections, without drawing excessive paste to the surface. Compacted pervious concrete shall meet the acceptance criteria for Smoothness set forth in Section 1.05.E.2.
			6. Contractor’s personnel shall take care to avoid foot traffic in the pervious concrete to prevent non-uniform compaction and to keep contaminated material from entering the pavement mix. Foot traffic on the fresh concrete shall not be allowed after it has been struck off.
			7. Place pervious concrete continuously. When discharge from a truck is complete or stops, and there will be a gap in time before the next truck arrives or placement continues, cover the placed material, including the leading edge, until the next truck arrives. If the gap in time between trucks is 15 minutes or more, a header shall be placed between the forms and a construction joint formed. The construction joint shall be located at a contraction joint location, unless otherwise approved by the Engineer. The pervious concrete shall be compacted and finished to the header before placement may continue. Upon resuming placement, the header may be carefully removed and a construction joint formed at that location. Any sloughing or sagging of the previously placed pervious concrete at the header location shall be corrected prior to placing new pervious concrete against the joint.
		2. Edging: Edging of the top surface shall be completed in plastic concrete to a radius of not less than 1.5 times the nominal size of the aggregate. Defects shall be repaired immediately.
		3. Jointing: Joints shall be of three (3) types: construction, contraction, and isolation. Wherever possible, the angle between intersecting joints shall be between 80 and 100 degrees. Construct joints at the locations and to the horizontal dimensions indicated on the Plans.
			1. Construction Joints: Construction joints shall be formed at the end of a day’s work or when necessary to stop production for any reason.
				1. Construction joints shall be located as near as possible to the location of a planned contraction or isolation joint.
				2. Construction joints are to be formed by placing a header between the forms, at right angles, to the full depth of the finished pervious concrete, and set to the height of the forms. Pervious concrete shall be placed against the header and compacted and finished as normal, including edging.
				3. Upon resuming paving, the header shall be carefully removed and new pervious concrete placed directly against the existing pervious concrete. The new pervious concrete shall be compacted and finished against the hardened pervious concrete as if it were a form.
				4. If an isolation joint is planned at this location, then the premolded joint filler shall be placed against the existing pervious concrete and the new pervious concrete shall be placed against the premolded joint filler. The joint shall be tooled on both sides of the premolded joint filler.
			2. Contraction Joints: Contraction joints shall be used to control random cracking.
				1. Contraction joints shall be a minimum depth of 1/4 of the pervious concrete thickness, up to a maximum required depth of 1 and 1/4 inches, and shall have a joint width of no more than 1/8 inch.
				2. Contraction joints shall be placed every 15 feet unless otherwise shown on the Plans.

DESIGNER NOTE: Designer should consider size and aspect ratio of panels when locating joints.

* + - * 1. Plastic Formed Joints: Contraction joints may be formed in the plastic concrete using a roller designed for this purpose or by other methods accepted by the Engineer.

Rollers shall have sufficient weight to produce the joint and shall not otherwise damage or mar the surface.

Joints shall be tooled on both sides of the joint with a radius not less than 1.5 times the nominal size of the aggregate.

* + - * 1. Saw Cut Joints: At the option of the Contractor, contraction joints may be saw cut provided joints are early-entry dry-cut type.

Joints shall be cut using purpose built early-entry saw cutting equipment.

Saw cutting shall not be performed during the curing period.

Saw cut joints shall be installed no later than the same day the curing plastic is removed.

Remove cuttings from surface immediately after saw cutting of joints.

If shrinkage cracking is likely to be a concern during the curing period, plastic formed joints should be installed to relieve slab stress.

* + - 1. Isolation Joints: Isolation joints shall be used where the pervious concrete abuts existing facilities or where shown on the Plans.
				1. Isolation joints shall continue through the depth of the pervious concrete using a 3/8 inch premolded joint filler.
				2. Isolation joints may be formed by inserting the premolded joint filler into the plastic concrete or by forming a construction joint and affixing the premolded joint filler against one side of the joint and placing fresh pervious concrete against it.
				3. Isolation joints and filler shall be flush with the surrounding pervious concrete and shall not deviate from the acceptance criteria for Grade as specified in Section 1.05.E.2.
				4. The edges of the pervious concrete on either side of the premolded joint filler shall be hand tooled to a radius not less than 1/4 inch.
		1. Curing
			1. Begin curing within 20 minutes or as soon as possible after concrete is discharged from the truck to attain the proper moisture level as indicated by cement paste with a wet metallic sheen, unless otherwise specified or approved by the Engineer.
			2. Completely cover the pavement surface and all exposed edges with a minimum six‑ (6)‑mil-thick white polyethylene sheet, unless otherwise specified or approved by the Engineer. No wetted burlap or cloth shall be used.
			3. Thoroughly secure a polyethylene sheet at all exterior edges and interior laps without using soil. The method of securing the cover material shall prevent wind from removing the sheet and from blowing under the sheet across the surface of the concrete.
			4. Curing compound shall not be used on any pervious cement concrete surface.
			5. Cure pavement for a minimum of 7 uninterrupted days, unless otherwise specified or approved by the Engineer.
			6. With the exception of saw cutting equipment, all traffic shall be kept off of the pervious concrete during the curing period.
			7. Any testing for acceptance shall not occur until the end of the curing period.
		2. Cold-weather construction
			1. Protect concrete from freezing and record concrete temperature no less than twice per 24‑hour period in accordance with ACI 306.1.
	1. OPENING TO TRAFFIC
		1. No traffic shall be allowed on the pervious cement concrete pavement for 10 days.
		2. Once open to traffic, measures must be maintained to prohibit any construction related impacts on the pervious concrete pavement surface. No construction equipment, trucks or material staging is allowed on the completed pervious concrete pavement at any time after installation and curing.
	2. PROTECTION OF PAVEMENT
		1. Cured and exposed pervious cement concrete pavement surface shall be kept clean and free of clogging debris and soils from the Contractor’s operations and all upstream and adjacent debris. Neither construction equipment nor staging shall be allowed on the cured an exposed pervious cement concrete pavement surface. If debris or soils contaminate the pervious pavement voids, the pavement shall be cleaned at the Contractor’s expense and to the satisfaction of the Engineer. If pervious cement concrete pavement cannot be unclogged, it shall be removed and replaced at the Contractor’s expense and to the satisfaction of the Engineer.
	3. REJECTION
		1. Pervious concrete that does not meet the acceptance criteria set forth in Section 1.05.E.2 will be rejected by the Engineer on a lot-by-lot basis. Pervious concrete that has been rejected by the Engineer or the Contractor shall be removed and replaced at no additional cost to the Owner.

END OF SECTION