Aggregate Filter Criteria for Green Infrastructure Facilities

Introduction

The SFPUC's Urban Watershed Management Program has developed *Green Infrastructure Typical Details and Specifications* (Typical Details) for stormwater facilities as part of SFPUC's *Stormwater Management Requirements and Design Guidelines*. The aggregate materials included in the Typical Details have been selected based on their compatibility with adjacent material layers. In the event that the specified materials are unavailable or otherwise deemed unsuitable for a specific project, this document provides general guidance on selecting and layering suitable substitute aggregate materials. Substitute materials should satisfy the filter criteria outlined below, as well as the quality criteria included in the Typical Specifications (e.g. L.A. Abrasion, fracture face, fines, organic content, etc.) and storage and drainage criteria. Information is also provided regarding geotextile fabric requirements.

Applicability

This document provides aggregate filter criteria to assist in selecting appropriate aggregate materials for use in stormwater management facilities (also known as stormwater "Best Management Practices" or "BMPs"). **These criteria should be considered guidelines, rather than requirements.** The aggregate filter criteria, which are based on generally accepted geotechnical literature[1], help the designer to:

- Evaluate what aggregates are less likely to migrate into adjacent coarser graded materials,
- Ensure that courses are underlain with a significantly more permeable material for infiltrating facilities (e.g. permeable pavement, bioretention, etc.),
- Evaluate aggregates to limit the migration of fines into underdrain perforations, and
- Incorporate geotextile fabrics requirements, as applicable.

Common uses for aggregates in stormwater BMPs include:

- **Bioretention**: choking course and gravel reservoir course
- **Permeable pavement:** gravel base course, gravel reservoir course, and, for permeable/porous unit paver applications, gravel leveling course and joint filler

NOTE: The filter criteria provided in this document are not suitable for materials with high fines content (15% or greater) or high plastic limits, nor do they address material selection at the interface with native soils. Additionally, these criteria may not address all project-specific design objectives (e.g. protect downstream infrastructure from clogging or biofouling). **To ensure these criteria are appropriate for a particular application, consult a geotechnical engineer or refer to the publications cited above.**

[1] Ferguson, B.K. Porous Pavements - Integrative Studies in Water Management & Land Dev. 2005.
Cedergren, H.R. Seepage, Drainage, and Flow Nets, 3rd Edition. 1989.
U.S. Army Corps of Engineers. Seepage Analysis and Control for Dams, Appendix D. Engineering Manual 1110-2-1901. 1986. Revised 1993.
United States Department of Agriculture/Natural Resources Conservation Service. Gradation Design of Sand and Gravel Filters (Chapter 26). National Engineering Handbook Part 633. October 1994.

San Francisco Water Power Sewer
Services of the San Francisco Public Utilities Commission

Aggregate Layering Criteria

In general, the Criteria 1 and 2, the "bridging criteria," should be met for each aggregate interface in the facility to prevent movement of soil particles into or through adjacent materials[2]:

Criterion 1: $D_{15} / d_{85} \leq 5$ where,

> **D_{15}** is the particle size (diameter) for the coarser material at which 15 percent of the material is finer.
>
> **d_{85}** is the particle size (diameter) for the finer material at which 85 percent of the material is finer.

Criterion 2: $D_{50} / d_{50} \leq 25$ where,

> **D_{50}** is the particle size (diameter) for the coarser material at which 50 percent of the material is finer.
>
> **d_{50}** is the particle size (diameter) for the finer material at which 50 percent of the material is finer.

In addition to the bridging criteria, it is also recommended for infiltrating facilities (e.g. permeable pavement, bioretention, etc.) that the selected gravel base and/or gravel reservoir material be sufficiently more permeable than any overlying courses. Criterion 3 can be used to evaluate the relative permeability of the two layers.

Criterion 3: $20 \geq D_{15} / d_{15} \geq 5$ where,

> **D_{15}** is the particle size (diameter) for the coarser material at which 15 percent of the material is finer.
>
> **d_{15}** is the particle size (diameter) for the finer material at which 15 percent of the material is finer.

The final two criteria, Criteria 4 and 5, apply to each aggregate material used within the facility individually (i.e., regardless of adjacent material properties). Criterion 4 provides restrictions on a material's coefficient of uniformity to prevent gap-graded and/or very poorly graded materials from being used in the pavement section.

Criterion 4: $6 \geq D_{60} / D_{10} \geq 2$ (Coefficient of Uniformity) where,

> **D_{60}** is the particle size (diameter) at which 60 percent of the material is finer.
>
> **D_{10}** is the particle size (diameter) at which 10 percent of the material is finer.

Criterion 5 restricts the maximum particle size (smallest sieve requiring 100 percent passing) to minimize segregation and bridging of larger particles during placement of materials.

Criterion 5: Maximum particle size ≤ 3 inches

[2] Criteria 1 and 2 are applicable for all materials with gradation curves approximately parallel. Where gradation curves are not approximately parallel, the filter design is based on filtration tests. (Cedergren 1989).

Criteria for Aggregates Surrounding Underdrains

Where an underdrain is proposed within an aggregate layer, or aggregate is used as a filter blanket around an underdrain pipe, the following criteria may be used to limit migration of fines into the pipe:

- **For pipes with slotted perforations**, D_{85} of the adjacent aggregate material should be larger than 1.5 times the width of the slotted perforations AND D_{15} of the adjacent aggregate material should be larger than the width of the slotted perforations.
- **For pipes with circular perforations**, D_{85} of the adjacent aggregate material should be larger than 2.0 times the diameter of the perforations AND D_{15} of the adjacent aggregate material should be larger than the diameter of the perforations.

Geotextile Fabric Requirements

Geotextile fabric **shall not** be used between aggregate layering due to the risk of clogging. Geotextile is not typically required in green Infrastructure facilities unless recommended by a geotechnical engineer for soil separation from native subgrade or sidewalls. If recommended, geotextile fabric shall meet the following requirements:

- 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 in the following table.

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/ft^2

Aggregate Layering Example

The following is an example of a filter criteria calculation for the nationally accepted permeable unit paver section. See Figure 1 below for the pavement section materials and layering.

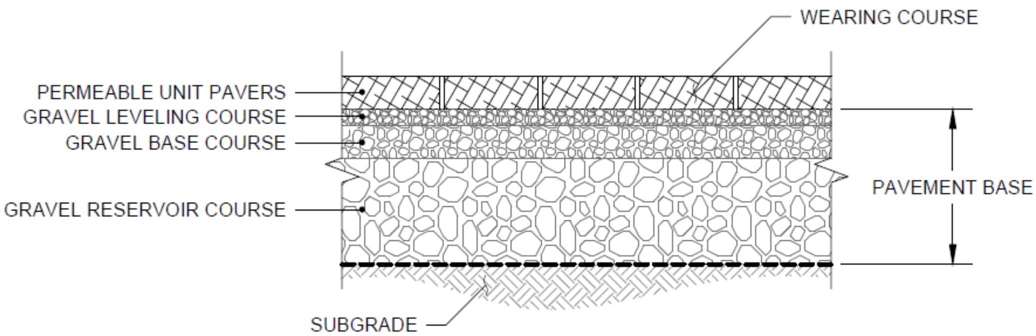

Figure 1. Typical Permeable Unit Paver Section

The typical permeable unit pavers section uses ASTM No 8 stone for the gravel leveling course and ASTM No. 57 stone for the gravel base course. The evaluation below represents the filter criteria for these materials:

1. Calculate D_{15}, D_{85}, $D_{50,}$ $D_{60,}$ and $D_{10,}$ for both materials.

   For this example, assume the following characteristics:

ASTM No. 8:	$D_{10} = 0.10$	ASTM No. 57:	$D_{10} = 0.35$
	$D_{15} = 0.15$		$D_{15} = 0.40$
	$D_{50} = 0.25$		$D_{50} = 0.55$
	$D_{60} = 0.27$		$D_{60} = 0.70$
	$D_{85} = 0.35$		$D_{85} = 0.90$

2. Check Criterion 1.

   For this example, ASTM No. 8 is the finer material:

   $D_{15} / d_{85} = 0.40 / 0.35 = 1.14 \leq 5$ ➔ OK

3. Check Criterion 2.

   $D_{50} / d_{50} = 0.55 / 0.25 = 2.2 \leq 25$ ➔ OK

4. Check Criterion 3.

   $D_{15} / d_{15} = 0.40 / 0.15 = 2.7 < 5$ ➔ FAIL[3]

5. Check Criterion 4.

   ASTM No. 57 Coefficient of Uniformity = $D_{60} / D_{10} = 0.70 / 0.35 = 2.0 \geq 2$ AND ≤ 6 ➔ OK

   ASTM No. 8 Coefficient of Uniformity = $D_{60} / D_{10} = 0.27 / 0.10 = 2.7 \geq 2$ AND ≤ 6 ➔ OK

6. Check Criterion 5.

   Smallest sieve with 100 percent passing ≤ 3 inches ➔ OK

[3] The aggregate filter criteria provided in this should be considered guidelines, rather than requirements. The designed should use their professional judgment in specifying adjacent aggregate layers.