VOLUME 3

WYNWOOD
STREETSCAPE MASTER PLAN

DESIGN RESOURCES (MATERIALS SPECIFICATIONS)

Prepared by:
ARQUITECTONICAGEO

Document prepared by
ArquitectonicaGEO for the City of
Miami and the Wynwood Business
Improvement District (BID).

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VOLUME 3

CONTENTS

1 UNDERGROUND UTILITIES

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Leiter, Perez & Associates, Inc.

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LAND DEVELOPMENT CONSULTANTS
ENVIRONMENTAL AND CIVIL ENGINEERS
LAND PLANNERS AND LAND SURVEYORS

SURVEYS
DESIGN
INSPECTION
PLANNING
STUDIES
ASBESTOS

WYNWOOD-Streetscape Florida Power & Light Overhead
Distribution Lines Conversion to Underground
FACILITIES (wynwoodfpl)

PROCEDURAL OUTLINE 01/09/19

I. FP&l/City of Miami (COM) Coordination MEETING.

A. FEASIBILITY/ASSESSMENT; COM MEETS FP&L AREA MANAGER.

1. Existing Facilities.
   a) Present routing/location; refer to existing Survey; update if required with FP&L.
   b) Identify existing Underground by FP&L, if any.

2. CONSTRUCTION COSTS ALTERNATIVES.
   a) FP&L constructs ductbank and pulls wires; labor and materials or:
   b) Alternative, COM constructs ductbank with FP&L list of approved contractors and purchase materials from FP&L.
      1) FP&L pulls wires, and
      2) FP&L provides materials purchased by COM.

3. COST OF REMOVAL (FP&L) OF EXISTING OVERHEAD FACILITIES TO BE INCLUDED.

II. TIME FOR COMPLETION, AS A GENERAL RULE.

A. FP&L BUILDS DUCTBANK AND INSTALLATION.

1. Time Frame Commitment; Days for installation completion; days.

B. COM INSTALLS DUCTBANK;

1. Fp&l SELLS MATERIALS.
2. Fp&l PULL WIRES.
3. Time Frame Construction Ductbank by COM; Days.

III. FP&L/COM EXECUTE AGREEMENT.

A. DOLLAR VALUE ESTABLISHED.
B. TIME FRAME ESTABLISHED.
C. PRIVATE CONTRACTOR ACCEPTED; SEE II B. above.

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Wynwoodfpl

IV. DESIGN CONSULTANT (DC) REQUIREMENTS.
These are only offered as guidelines, DC may follow his/her own procedures.

A. COM OBTAINS CONTRACTOR OR CALL FOR LOCATIONS OF UTILITIY COMPANIES.

1. Existing utilities "painted"; "Design Ticket" only provides notification.
2. Update existing Survey with new information and "paint marks".

B. "MAPPING" OF UTILITIES BY GPR, (Ground penetrating radar).

1. Proceed with "Soft Digs" via (Vacuum Soil Extraction Method).

C. EVALUATE NATURE, CHARACTER AND DEPTH OF EXISTING UTILITIES.

V. PREPARE PROPOSED ROUTE.

A. SUBMIT TO FP&L FOR APPROVAL.

1. Identify if Private Property involved/easements will be required.
2. Evaluate if Power Interruption at any time involved.
   Goal is to complete all underground new work prior to "Switch ".

B. PREPARE DESIGN DRAWINGS.

VI. CONSTRUCTION CONVEYANCE OF FACILITIES; COMPLETION.

A. " AS BUILTS " MONTHLY BASIS FOR PAYMENT TO CONTRACTOR.

1. "As Built " as Record Drawings submit to FP&l for Approval.
2. Removal of Existing Overhead.
3. Easements required? See V, A. 1. Above.

2 STRUCTURAL SOIL

Cornell University Structural Soil
Specifications

CU-Structural Soil® installation at Zuccotti Park, New York City

CU-Structural Soil®

A Comprehensive Guide

Founded in 1980 with the explicit mission of improving the quality of urban life by enhancing the functions of plants within the urban ecosystem, the Urban Horticulture Institute program integrates plant stress physiology, horticultural science, plant ecology and soil science and applies them to three broad areas of inquiry.

They are:

• The selection, evaluation and propagation of superior plants with improved tolerance of biotic and abiotic stresses, and enhanced functional uses in the disturbed landscape.

• Developing improved technologies for assessing and ameliorating site limitations to improve plant growth and development.

• Developing improved transplant technologies to insure the successful establishment of plants in the urban environment.

Compiled and edited by Bryan R. Denig

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Urban Horticulture Institute, Cornell University
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CU-Soil® is a proprietary material patented by Cornell University and marketed under the trademarked names CU-Structural Soil® or CU-Soil®. By obtaining this material from an Amereq-licensed company, it assures that the material has been produced and tested to meet research-based specifications. To find a licensed producer in your region contact Brian Kalter (bkalter@amereq.com) or Fernando Erazo (fe@amereq.com) at Amereq Inc., 19 Squadron Blvd. New City, New York 10956. (800) 832-8788

For more information on CU-Structural Soil®, see:

http://www.hort.cornell.edu/uhi/outreach/index.htm#soil

http://www.structuralsoil.com/

Contents

PART I

An Introduction to CU-Structural Soil®

The Importance of Soil

The fact that trees have difficulties surviving in urban and suburban environments is not a surprise. Urban areas are rarely designed with trees in mind. Trees are often treated as if they were afterthoughts in an environment designed and built for cars, pedestrians, buildings, roadways, sidewalks and utilities. Studies report that trees in urban areas and especially in less residential areas live an average of 20-30 years,[1] and 19-28 years from a review of 11 cities.[2] These same species could live for much longer in a forest environment.

This city tree was clearly added as an afterthought

Urban trees face a range of environmental challenges, such as increased heat loads, de-icing salts, soil and air pollution, and interference from utilities, vehicles and buildings. Yet the most significant problem that urban trees face is the scarcity of soil suitable for root growth.[3] While many of the problems urban trees face can be mitigated by planting species that are tolerant of a given challenge, there are no tree species that can tolerate the extreme soil compaction that is prevalent throughout urban and suburban landscapes.

Can smart species selection mitigate challenges of the urban landscape?

Urban Challenge	Will smart species selection help?
Insects / Diseases	Yes
Limited Space	Yes
Heat / Cold	Yes
Poor Drainage	Yes
Dry Soils	Yes (up to a point)
pH	Yes
Salt	Somewhat
Soil Compaction (physical impedance)	**No**

A large volume of uncompacted soil, with adequate drainage, aeration, and reasonable

[1] Nowak,D J, Kuroda, M and Crane, D. " Tree mortality rates and tree population projections in Baltimore, Maryland. USA" Urban Forestry and Urban Greening 2.(2004) 139-147

[2] Roman. L.A. "How many trees are enough? Tree death and the urban canopy" " Scenario Journal: Scenario 04: Building the Urban Forest.(2014)

[3] Lindsey, P. and N. Bassuk. "Redesigning the urban forest from the ground below: A new approach to specifying adequate soil volumes for street trees." *Arboricultural Journal* 16 (1992): 25-39.

fertility, is the key to the healthy growth of trees.[4,5] The upfront investment in making the soil suitable for supporting a healthy tree is paid back in full when that tree fulfills the functions for which it was planted. These functions may include shade, beauty, noise reduction, wind abatement, pollution reduction, stormwater mitigation, wildlife habitat, and the creation of civic identity. An adequate soil volume is key, considering that soils are where the nutrients, water and air are held in a balance that allows for root growth and water and nutrient acquisition. Simply put, when soils are inadequate, plant growth suffers and trees die prematurely.

The standard (but entirely inadequate) city tree pit. It's not surprising that trees in these situations have shorter lifespan.

The role of soil volume on tree growth

Human activities can severely damage soil structure. The process of construction in a city, or even the installation of a sidewalk in an otherwise rural area, necessarily dictates a high level of soil disturbance. Any construction effort requires soil excavation, cut and fill, re-grading, and soil compaction. Often heavy machinery is brought on site to accomplish this work, increasing the potential for compaction of soils.

Compaction of soil in preparation for pavement

Surface evidence of severe soil compaction

There are two critical effects of soil compaction which directly impact plant growth and limit useable rooting space:

1. Soil structure is destroyed, and the majority of large interconnected pores (macropores) are

[4] Perry, T. O. "The ecology of tree roots and the practical significance thereof." *Arboricultural Journal* 8 (1982): 197-211.

[5] Craul, P. J. *Urban Soil in Landscape Design*. New York: John Wiley & Sons, Inc., 1992.

crushed. This results in a restriction of the soil's water drainage and subsequent aeration.

2. As the macropores are crushed, soils become denser, eventually posing a physical barrier to root penetration. There are numerous accounts of urban soils being literally as "dense as bricks".[6]

Soil that is light, porous, and suitable for growing trees

Severely compacted soil that is "dense as bricks" and not conducive to tree root growth

What happens when roots encounter dense, compacted soil?

When roots encounter dense soil, they change direction, stop growing, or adapt by remaining abnormally close to the surface. This superficial rooting makes urban trees more vulnerable to drought stress and can cause pavement heaving. Also, if a dense soil becomes waterlogged, the tree roots can rot from lack of oxygen.

Trees planted in severly limited soil volumes die young unless their roots are able to break past compacted soils into an adequate volume of useable soil. This often results in dangerous sidewalk heaving.

The roots of this tree have grown through the compacted soil beneath the sidewalk, into the large volume of soil beyond. Expanding tree roots have caused the sidewalk to heave.

[6] Patterson, J. C., J. J. Murray, and J. R. Short. "The impact of urban soils on vegetation." Proc. 3rd METRIA Conference (1980): 33-56.

Tree roots heaving pavement

Thick superficial roots that have caused a sidewalk to heave.

With paving removed, it is easy to see how this tree's roots took advantage of the weak points in the pavement. While the tree survived, the expanding roots caused the pavement to fail.

Compacted soils can cause a "containerizing" effect on trees, making them especially vulnerable to wind throw

Besides limiting root growth, compacted soil drains poorly. Seen here, pooling water and a drowned tree.

In urban soils that are not covered by pavement, it is possible to break-up, amend or replace compacted soils to make them more conducive to root growth. However, where soils are covered by pavement, the needs of the tree

come in direct opposition to specifications that call for a highly compacted base on which to construct pavement. All pavements must be laid on well-draining compacted bases so that the pavement will not subside, frost heave, or otherwise prematurely require replacement. Therefore, soils that must support pavement are often too dense for root growth. It is not surprising then that urban trees surrounded by pavement have the shortest life spans of trees in cities. Unfortunately, these paved areas also tend to be those that most need trees to mitigate the heat island microclimates that exist in downtown areas.

How much soil volume does a tree need?

Everything else being equal, access to soil volume can make a substantial difference on tree growth

Even trees known to be tolerant of urban conditions such as honeylocust (Gleditsia tricanthos) suffer when given inadequate soil volumes.

Urban trees are necessary to the health and livability of our cities, but how much useable soil is necessary to allow them to fulfill their design functions? Research at Cornell's Urban Horticulture Institute (UHI) has shown that a reasonable 'rule of thumb' for most of the United States, except for the desert southwest, is to **plan for two cubic feet of soil per every square foot of crown projection.**[7] The crown projection is the area under the drip line of the tree. If the tree canopy is viewed as symmetrical, the crown projection can be calculated as the area of a circle (πr^2). For example: for a tree with a canopy diameter of 20 feet, the crown projection would be, 3.14 x 10^2, or 3.14 (100) = 314 square feet. Using the 'rule of thumb,' an estimate can be calculated that a tree with a 20 foot crown diameter needs approximately 600 cubic feet of soil to support it. Assuming a useable rooting depth of 3 feet, one way of dimensioning the space needed for this tree would be 20′ x 10′ x 3′, or 600 cubic feet. It is clear that a typical 4′ x 5′ tree opening in sidewalks, or a 6′ x 6′ tree pit, is inadequate to allow the tree to mature to this size and fulfill its function in the landscape.

This 'rule of thumb' method is a very rough way to estimate the soil volume needs of a given tree. This method is based on determining what volume of water must be available in the soil for a tree to support itself, and accounts for climatic factors such as days between rainfalls when the evaporative demand is highest. This general 'rule of thumb' is misleading about how different soil types vary in their water holding capacities. For any given tree, the minimum volume of soil needed to support it will be different depending on how much sand, silt, and clay make up the soil composition.

Another issue with this method is that it is based on crown projection, which can cause some confusion when fastigiate and narrow

[7] Lindsey, P. and N. Bassuk. "Redesigning the urban forest from the ground below: A new approach to specifying adequate soil volumes for street trees." *Arboricultural Journal* 16 (1992): 25-39.

tree cultivars are involved. For example, determining how much soil volume is needed to support a fastigiate English oak, which maintains a very narrow crown diameter, could cause confusion. In this case, it is best to decide on the intended mature size of the tree, and determine what the crown projection of a regular English oak of the same age would be. The diameter of the non-fastigiate variety is then used as a proxy to determine the necessary soil volume using the two-to-one 'rule of thumb'. Another method is to determine how tall the fastigiate tree of interest will be at maturity, and then substitute this height value in for the mature diameter when calculating the crown projection.

Yet another issue involves the presence of groundcovers, including lawn. In situations where trees are sharing their soil volume with other plants, even turfgrass, there is more competition for the water held in the soil. In such cases, it is best to try to provide additional soil volume.

The standard city tree pit – sometimes referred to in jest as a tree coffin

Where can one find enough soil?

If the soil under sidewalks and other paved areas were suitable for root growth, urban trees would potentially have access to large volumes of soil. This scenario would allow trees to grow to their mature size and perform as desired. Also, if the soil volume for each tree was connected and continuous, each tree would be able to share soil with its neighboring tree. Looking at the forest as a model, trees may be spaced reasonably close together as long as they share a large common soil volume to support their needs.

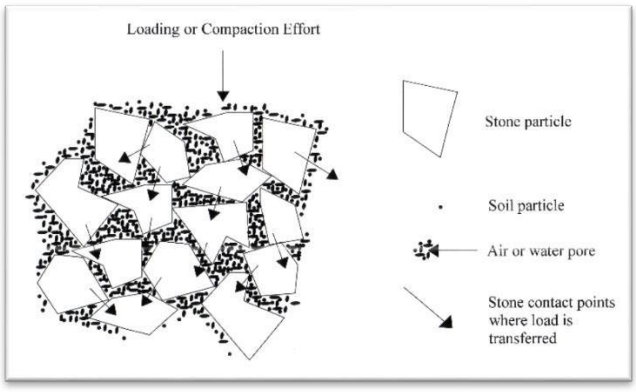
Given the limited space availability in cities, it is highly desirable to be able to have soil that meets paving engineering requirements while simultaneously allowing for unimpeded root growth under the pavement. CU-Structural Soil® is one technology that meets these requirements.

The Case for CU-Structural Soil®

What is CU-Structural Soil®?

CU-Structural Soil®, also known as CU-Soil®, is a two-part system comprised of a rigid stone "lattice" that meets engineering requirements for a load-bearing paving base, and a quantity of uncompacted soil that supports tree root growth. The primary component of this soil system is a uniformly sized, highly angular crushed stone ranging from 3/4 to 1 1/2 inches in diameter with no fine materials. When this narrowly graded stone is compacted, the stones form an open "lattice" structure with about 40 percent porosity. Friction at the points where stones come in contact with one another allow the creation of the loadbearing structure of the CU-Structural Soil®.

Uniformly sized, highly angular crushed stone



CU-Structural Soil® conceptual diagram

The second component of the system is a soil which fills the voids in the stone "lattice". As long as care is taken to not add too much soil to the mix, which would prevent the stone structure from forming, the soil in the voids will remain non-compacted and root penetrable. Since among soil textures, clay has the most water and nutrient-holding capacity, a heavy clay loam or loam, with a minimum of 20% clay, is used in the CU-Structural Soil® system. A minimum of 20% clay is also essential for an adequate cation exchange capacity. It should also have organic matter content ranging from 2%-5% to ensure nutrient and water holding while encouraging beneficial microbial activity.

With carefully chosen uniformly-graded stone and the proper stone-to-soil ratio, a medium for healthy root growth is created that also can be compacted to meet engineers' load-bearing specifications. The intention is to "suspend" the clay soil between the stones without over-filling the voids, which would compromise aeration and bearing capacity.

In addition to the stone and soil components, CU-Structural Soil® utilizes Gelscape® Tackifier as a non-toxic, non-phytotoxic tackifier. The structural soil process benefits from adding a tackifying agent to stabilize the mixing process. The tackifier allows for the stones and soil to mix uniformly and prevents separation of the materials resulting from vibration in transit, dumping, and working of the material in installation.

Gelscape® Tackifier being applied to uniformly sized crushed stone. Photo courtesy Amereq, Inc.

Close-up of angular stone with Gelscape® Tackifier applied (prior to admixing with clay loam soil)

Clay loam soil is mixed with the crushed stone. The added Gelscape® Tackifier helps it "stick" and prevents settling during construction. Photo courtesy J-V Environmental Services

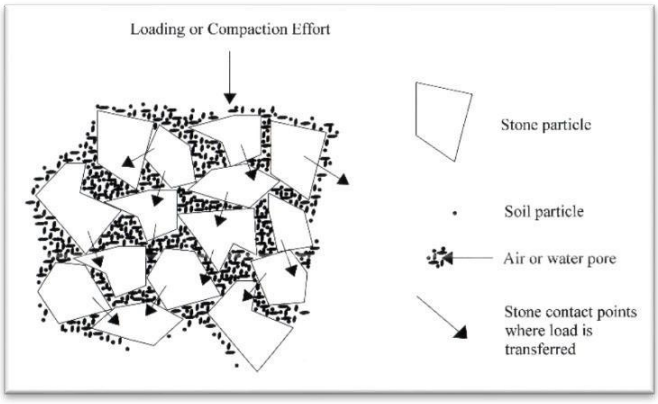
CU-Structural Soil® being delivered to project site. Photo courtesy Minick Materials Company

Compaction of CU-Structural Soil® during installation. For proper installation, CU-Structural Soil® must be compacted every 6 inches. Photo courtesy AZ Best, LLC

Closeup of CU-Structural Soil® after installation

How does it work?

The stone components of CU-Structural Soil® come together during compaction, forming a strong, load-bearing, compacted stone base suitable for paving over, while the large voids between the stones provide room for an uncompacted clay loam soil and allow for root growth and aeration of the root zone.



CU-Structural Soil® conceptual diagram

Extensive fibrous root system from a tree grown in CU-Structural Soil®

Root system of a tree grown in CU-Structural Soil® (left) compared to one grown in a regular compacted soil (right). Root systems are shown at three years post-transplant.

To be suitable as a base course that has high load-bearing ability and as a medium that supports tree growth, the ratio of stone-to-soil materials is a major consideration. If the stone voids are overly filled with soil, aeration and bearing capacity of the system are compromised. Too much soil will change the formation of the stone lattice resulting in an unacceptable decrease in bearing capacity. Not enough soil in the system limits tree growth.

Why is it Licensed?

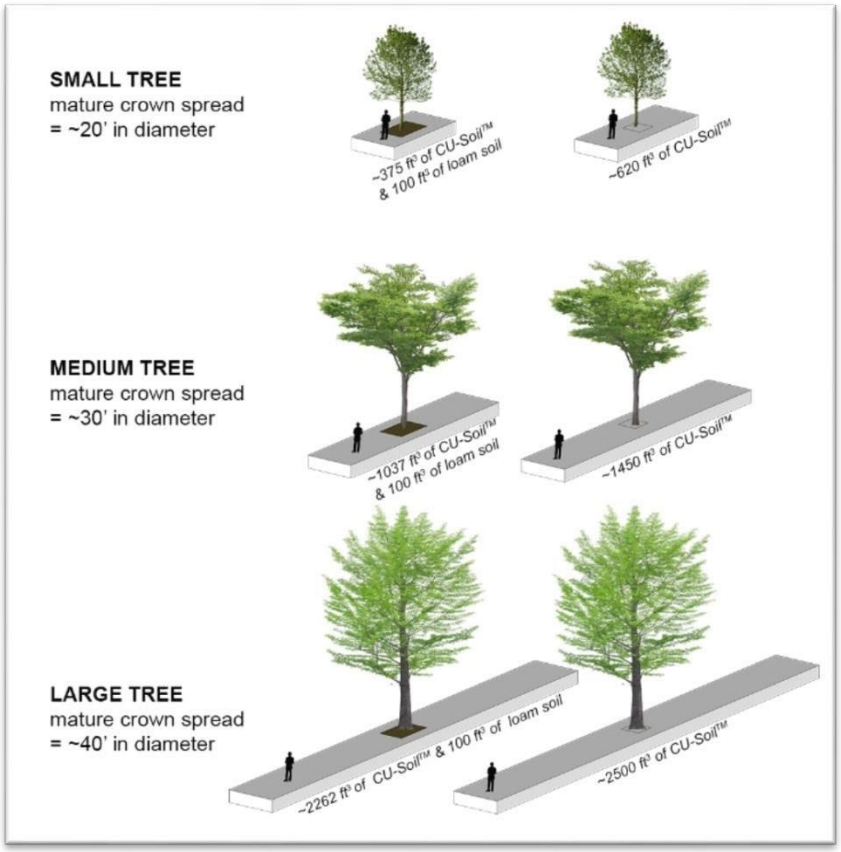
CU-Structural Soil® has been patented and licensed to qualified producers to ensure quality control; its trademarked names are CU-Structural Soil® or CU-Soil®. By obtaining this material from an Amereq, Inc.-licensed company, it assures that the material has been produced and tested to meet research-based specifications. Many individuals have employed systems termed “structural soils”, but they are not the same as CU-Structural Soil®.

Practical Matters and FAQ

What volume of CU-Soil® is needed?

Similar to naturally occurring soil types, to quickly estimate the volume of CU-Structural Soil® needed to support a mature tree, it is best to **plan for two cubic feet of CU-Soil® per every square foot of tree crown projection.**[8]

Trees growing in CU-Structural Soil® in areas that normally use irrigation to grow trees should also provide low volume drip irrigation in CU-Structural Soil® installations.



CU-Structural Soil® volumes needed to support trees of various sizes

[8] Lindsey, P. and N. Bassuk. "Redesigning the urban forest from the ground below: A new approach to specifying adequate soil volumes for street trees." *Arboricultural Journal* 16 (1992): 25-39.

What depth is needed for CU-Structural Soil®?

For typical street tree applications, a minimum depth of 24" is required, but 36" is preferred. For turf installations used with CU-Soil®, a minimum depth of 12" is recommended (please refer to the turf portion of this guide).

What is the recommended length and width for installations?

There are no established minimums. However, CU-Structural Soil® was designed to ideally go under entire pavement areas. This homogeneity ensures uniform engineering characteristics below the pavement, particularly in regard to frost heaving and drainage.

How does CU-Soil® perform over time?

The excavation of a seven-year-old installation did not show any soil migration. The pores between stones in CU-Structural Soil® are mostly filled with soil, so there are few empty spaces for soil to migrate to.

Excavation of a tree growing in CU-Structural Soil®

Over a long period of time, the soluble salts from which the hydrogel tackifier was produced, (i.e. potassium and nitrogen from the Potassium Propenoate-Propenamide Copolymer) are released. The inert hydrogel tackifier becomes a minimum part of the soil system. Beyond that, it appears that colonizing roots and other organisms will, over time, replace the spatial and tackifying roles of the hydrogel.

How does CU-Soil® prevent heaving?

As we have observed, the roots of trees grown in CU-Structural Soil® are deep down in the profile, spread over a larger area which helps prevent sidewalk heaving during expansion.

Additionally, there is no evidence of frost heave damage in the Ithaca, New York installations (which include some of the oldest CU-Soil® installations). Based on drainage testing and swell data on this extremely porous system, CU-Structural Soil® appears quite stable.

Can you add conventional soil in the tree pit and CU-Soil® under the pavement?

It is recommended to use CU-Structural Soil® under the tree ball to prevent the root ball from sinking. Planting trees directly in CU-Structural Soil® provides a firmer base for unit pavers close to the root ball than conventional soil. If the tree pit is sufficiently large, greater than 8' x 8', an uncompacted sandy loam soil could be used in the open tree pit surrounding the root ball with CU-Structural Soil® extending under the pavement.

How do you plant trees in CU-Soil®?

Planting a tree into structural soil is fairly simple. If possible, the pavement opening should be large enough to allow for buttress root formation on older trees. This opening could be paved in removable pavers or mulched. The tree is simply planted into the structural soil as it would be in a traditional soil. The roots will grow directly into the CU-Structural Soil®. If there is a large unpaved opening around the tree (at least 8' X 8'), it is possible to use a sandy loam soil in this opening and then CU-Soil® under the pavement. It is presumed that supplemental

watering will be provided for establishment as would be expected for any newly planted tree.

What about irrigation and drainage?

As would be expected in any soil, it is crucial to water the newly planted tree until it is established and possibly include additional, under pavement irrigation as part of a long-term maintenance plan as dictated by local conditions. In regions where irrigation is necessary to grow trees, low volume under pavement irrigation systems have been used successfully.

Provision for an irrigation system for trees planted in CU-Structural Soil® may be necessary and become part of a maintenance program. Given the large volume of structural soil for tree roots to explore, the need for sufficient irrigation must be determined by local as well as long-term maintenance needs. Taking into account the available moisture holding capacity, it is recommended to use CU-Soil® in larger volumes to provide similar moisture availability as traditional soils. In CU-Soil®, the total root system grows to occupy a more extensive area. Fertilizers can be dissolved into the irrigation water for nutritional management if necessary, although to date, nutrient deficiencies have not been observed in CU-Structural Soil® installations.

When the subgrade below the CU-Soil® is compacted and rendered essentially impermeable to moisture and roots or for any other reasons water saturation can become a problem, positive drainage below the tree root system is recommended. A perforated and wrapped drain pipe connected to the stormwater drainage system should be placed between the structural soil material and the compacted subgrade when needed to improve drainage.

Can CU-Soil® be used in urban areas without pavement over the root zone?

CU-Structural Soil® was designed to be used where soil compaction is required, such as under sidewalks, parking lots, medians, plazas, and low-access roads. Where soils are not required to be compacted, a good, well-draining soil should be used.

Can CU-Structural Soil® be retrofitted for use under existing trees?

CU-Structural Soil® has been utilized under and adjacent to existing trees. Several successful retrofits have been done in Ithaca, New York. Care should be taken to excavate roots with an air excavation tool and then to keep roots covered and moist until backfilling with CU-Structural Soil®, which should occur as soon as possible. Any excavation should be done under guidance from an arborist. Trees should be kept well-watered during the current and next growing season to compensate for any possible root damage.

CU-Structural Soil® quality control and installation

CU-Structural Soil® is produced by Amereq Inc.-licensed companies as needed and is preferably not stockpiled. All materials are tested by an independent soils lab. It is produced and delivered and should be installed in a timely manner. If any short-term stockpiling is required, protection from rain and contamination should be provided.

What are the oldest installations of CU-Soil®?

The two oldest installations date to 1994. There are now thousands of projects of various sizes across the United States, Canada and other countries. For more information about installations, visit www.structuralsoil.com or contact Brian Kalter at Amereq, Inc. (see below).

Obtaining CU-Structural Soil®

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PART II

How to Use CU-Structural Soil®

Growing Trees in CU-Soil®

Trees planted in a trench of CU-Structural Soil® in Campbell, CA. The photo on the right is looking up into the canopy of one of these trees. Photos courtesy TMT Enterprises, Inc.

Trees planted in standard tree pits in Campbell, CA. The photo on the right is looking up into the canopy of one of these trees. Photos courtesy TMT Enterprises, Inc.

CU-Structural Soil® was designed to provide increased soil volumes for tree roots under pavements. It can and should be used under sidewalks, parking lots, pedestrian mall pavements and low-use vehicular roads. Research at Cornell University has shown that tree roots in CU-Structural Soil® grow deep into the profile, even up to 36", away from the fluctuating temperatures at the pavement surface. Because of this, the roots are less likely to heave and crack pavement systems. This has been demonstrated by both research and real-world projects over the past 15+ years.

Planting a tree into CU-Structural Soil® is much like conventional planting. If possible, the pavement opening should be expandable (via removable pavers or using a mulched area) for the sake of the anticipated buttress roots of the maturing tree. CU-Structural Soil® should be used at a depth of at least 24" but preferably 36". CU-Structural Soil® can be used right up to the surface grade where there is a pavement opening that is large enough to allow for tree installation. Depending on the size of the opening, trees may be planted directly into CU-Structural Soil®.

CU-Structural Soil® under this paved sidewalk provides these street trees with a continuous large volume of usable soil. Dallas, TX. Photo courtesy Minick Materials Company

New Streetscape Tree Plantings

This new streetscape in Phoenix, Arizona provided an opportunity to incorporate a large volume of CU-Structural Soil® beneath the pavers. Photo courtesy AZ Best, LLC

New streetscape projects offer the greatest opportunity for using CU-Structural Soil®, as "thinking about the trees" can be made a priority from the very beginning of the project. Early and substantial input from a tree specialist can get the project started on the right track. By thinking about trees from the very beginning, and not merely as an afterthought, it is easier to design and construct landscapes for tree success (see Standard Design Details in Part IV: Resources).

In urban situations where tree lawns are not practical, pavement over CU-Structural Soil® allows street trees to share a large-volume, continuous strip of useable soil, as seen here in Ithaca, NY.

Trees in Plazas and Parking Lots

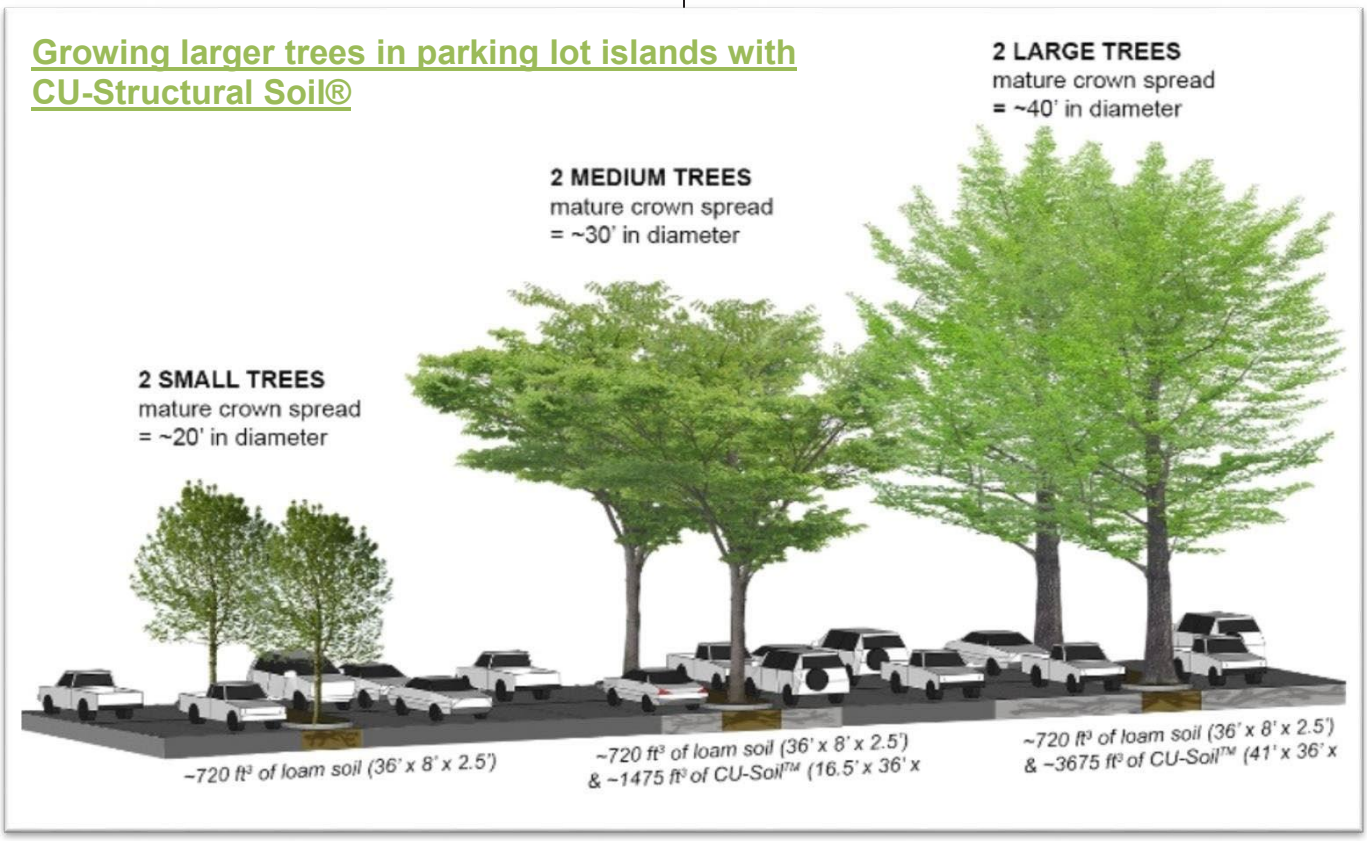
Many urban plazas sacrifice tree useable soil volume in favor of extensive paving. By utilizing CU-Structural Soil® beneath the pavers, this plaza in Ithaca, NY has thriving trees without sacrificing paved area.

Trees in parking lots, as well as paved plazas, benefit from the use of CU-Structural Soil®. Whether there is a curb or not, good, well-drained sandy loam may be used around the tree where the opening is at least 8' x 8'. This will increase water availability to the tree roots.

If the opening is smaller, CU-Structural Soil® may be used right up to the tree ball. Although it is not necessary to use an additional base course on top of CU-Structural Soil®, some engineers may want to do so, immediately under the pavement.

CU-Structural Soil® may also be used to enlarge a 'tree island' within a parking lot. With a large tree planting area, good, well-draining sandy loam can be used in the island and CU-Structural Soil® added as an unseen rooting medium under adjacent asphalt parking bays (see Standard Design Details in Part IV: Resources).

Growing larger trees in parking lot islands with CU-Structural Soil®



Freeing Existing Trees from Tree Pits Using CU-Structural Soil®

Renovation of this street and sidewalk in Ithaca, NY, provided an opportunity to use CU-Structural Soil® as a 36" base course for a replaced segment of sidewalk. This renovation allows the roots of this existing tree to escape its tree pit confines.

Street renovation projects, where lengthy sections of streets and sidewalks are entirely reconstructed, offer opportunities to "free" the roots of trees that were previously confined to tree pits.

When the sidewalk on an entire urban block is to be replaced, but the existing trees and tree pits are to remain as they are, there is potential to expand the useable soil volume by using CU-Structural Soil® as a base course for the new sidewalk pavement and also as a growing medium up to 36" deep. By doing so, it is possible to link the once isolated tree pits to one another by a continuous length of CU-Structural Soil®, and greatly increase the usable soil volume for each tree and prevent future sidewalk heaving.

Creating Break-out Zones from Narrow Tree Lawns

Removing this sidewalk section, and replacing it with one that has a CU- Soil® base, will allow tree roots to grow out from the tree lawn. Ithaca, NY

Because this tree lawn is so narrow, a sidewalk section has been removed, and a replacement will be poured on this CU- Soil® base. Ithaca, NY

Where there is an adjacent green space, whether a park or front lawn, CU-Structural Soil® may be used as a channel for roots to safely grow under sidewalk pavement and into the green space. Generally two concrete sidewalk flags are removed, the area is excavated to 24"- 36", and CU-Structural Soil® is backfilled into the area. Paving slabs are then replaced in a conventional manner (see Standard Design Details in Part IV: Resources).

Saving Existing Trees Threatened by Construction

The roots of this katsura tree were threatened by construction of a new plaza. The tree was saved due to careful planning, and the use of CU-Structural Soil® around the existing tree roots. Pavers were installed directly on top of CU-Soil®

Sometimes planned construction activity and paving projects can threaten the root systems of mature trees. When extensive paving is planned in the root zone of mature existing trees, it is possible to use CU-Structural Soil® as a means to save the threatened tree.

In preparation for new paving, the soil around existing tree roots can be excavated using a non-injurious method such as an air excavation tool. CU-Structural Soil® is then used as the base course for the new paving. Because the depth of the base course required for the pavement might mean that the paved area is "built up", on top of the tree roots, rather than "dug down" (which would destroy the roots), special design consideration must be given to the finished elevation of the final paving.

Using CU-Soil® Under Porous Pavement[9]

Stormwater concerns are receiving an increasing amount of attention from the general public, and there is currently growing interest in storing and infiltrating stormwater on site. Traditionally, solutions to this problem involved retention and detention ponds and the use of bioswales. However, these solutions require a dedicated space, which is rarely available in densely developed urban areas. Another method for storing and infiltrating stormwater on site involves using porous paving with a gravel base course that has enough void space to serve as a reservoir for captured rainwater.

Porous paving on top of CU-Structural Soil® is different than traditional porous paving installations because of the material used in the gravel reservoir underneath the pavement surface. Traditional porous pavement technology approaches the problem only from a water quantity standpoint, and usually calls for the use of uniformly sized stone in the reservoir underneath the pavement.

CU-Structural Soil® can also be used as a base for porous pavements. Such a system has two major benefits. The first is that CU-Structural Soil® is designed to be compacted, making it easy for contractors to install. Second, CU-Soil® is engineered to support healthier tree growth in the toughest of urban environments, resulting in better plant performance in and adjacent to pavements.

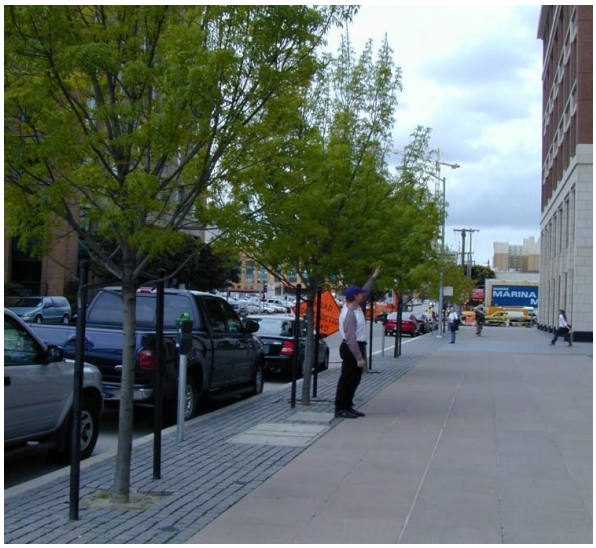
CU-Structural Soil® is a viable growing medium that supports tree growth under pavement, break-out zones, retrofitting and reducing construction damage. Given the high porosity, water infiltration is very rapid through porous pavement and structural soil. 24 inches of CU-Structural Soil® can capture 6 inches of rainfall in 24 hours. Combined with porous pavement, CU-Structural Soil® provides a reservoir for stormwater capture under pavement.

Size of Rain Event	Depth of CU-Soil® Reservoir Needed to Mitigate Rain Event
1.56”	6”
3.12”	12”
4.68”	18”
6.25”	24”
7.8”	30”
9.36”	36”

Reservoir depths and the corresponding levels of mitigated rain events based on the 26% void space within CU-Structural Soil® mix.

Permeable Pavers

If non-mortared pavers are used, a setting bed of uniformly-graded coarse sand should be used, to a depth specified by paver manufacturer specifications. To discourage rooting in this layer, a geo-textile—one that does not restrict water movement—can be used between this material and the CU-Structural Soil®.



This installation uses cobble pavers with porous joints as the covering of a continuous trench of CU-Soil®.

[9] Day, S.D. and S.B. Dickinson. Managing stormwater for urban sustainability using trees and structural soils. Virginia Polytechnic Institute and State University, Blacksburg, VA. (2008)

Water is able to infiltrate the soil, while still allowing easy pedestrian access to the cars utilizing the on-street parking. San Francisco, CA.

By having porous joints between the bricks in this paving strip, water is able to infiltrate into the CU-Soil® below. Ithaca, NY.

Porous Asphalt

A porous asphalt and CU-Soil® installation in Ithaca, NY just after construction

Porous asphalt is similar to traditional asphalt in every way but the mix specification. Unlike traditional asphalt, porous asphalt leaves out the fine particles in the mix. Leaving out these finer particles leaves gaps within the profile of the asphalt that allow water to flow through the pavement, rather than over the pavement. While porous asphalt traditionally has a crushed stone base, by substituting CU-Soil® as a stormwater reservoir it is possible to store stormwater and support tree growth.

Designing with CU-Soil® and Porous Asphalt

When using CU-Structural Soil® and porous asphalt, there are a few things that are important to keep in mind:

- Porous asphalt has its own mix specification.
- The depth of the CU-Structural Soil® reservoir underneath the porous asphalt depends on the size of the storm event that you want to mitigate.
- Infiltration rates for ground water recharge vary greatly and depend on the type of soil underneath the CU-Structural Soil® reservoir. Because of this reality, it is necessary to perform a soil test to find out the soil type and it's characteristics underneath the reservoir.
- Conventional storm drainage may be required by regulation. If this is the case, French drains or a traditional PVC drainage system may be installed below the porous asphalt surface to insure that water does not back up through the pavement profile.
- Porous asphalt needs maintenance. It should never be sealed. To keep porous asphalt porous, it should be vacuumed once every two years to remove silt and dirt particles, although this rarely occurs in practice.
- Proper sediment control measures such as silt fencing should be used during construction to keep surrounding sediment off of the porous asphalt. If not, pores in the asphalt may clog and become less effective.
- Tree planting areas should not have raised curbs. Additionally, the asphalt should be cut for the tree pits in the later stages of construction. Trees and other landscape elements should be planted last to ensure there is no damage to them during construction.

Using CU-Structural Soil® with Turf

Primarily used as a functional groundcover in residential lawns, turf grass plantings are also found in parks, playgrounds, and athletic fields. In these situations, turf is used both architecturally for providing a sense of open green space, and functionally as a protective surface for play. With careful design and installation, lawn plantings can also be used in situations that are normally not conducive to growing turf because of soil compaction resulting from high pedestrian traffic and/or occasional vehicular traffic. Examples of these situations include farmers markets, urban park lawns used for public gatherings, limited access fire lanes, and low-use parking lots.

Turf on CU-Structural Soil® at a car dealership in Birmingham, AL. Photo courtesy Southpine, Inc.

The soil in the entire median was excavated and replaced with CU-Structural Soil®, allowing the lawn median to be used as a space to display inventory. Photo courtesy Holcombe Norton Partners

In winter when the sod is dormant, the median serves as an additional storage and display space for the inventory. Photo courtesy Southpine, Inc.

Beyond supporting trees, Cornell's UHI has conducted research of planting turf on top of CU-Structural Soil®. This is in addition to streetscape and stormwater applications to create a healthy lawn that can be used in areas that receive high levels of pedestrian and/or occasional vehicular traffic, with the added benefit of mitigating stormwater. Because CU-Structural Soil® is designed to be compacted, it will withstand heavy traffic. This allows people, cars and temporary structures to safely use a turf covered surface installed on CU-Structural Soil®, without causing soil compaction that is detrimental to the health of the turf planting.

Increased water and air within the CU-Structural Soil® medium not only allows for healthier root and shoot growth of the grass, but also allows rainwater and runoff to be collected and held within the CU-Structural Soil® reservoir in large volumes until it can slowly infiltrate into the ground below the reservoir. This reduces runoff to sewer system infrastructure and also recharges the groundwater levels. While lawns are often generalized as a porous surface, different plantings can vary greatly in their capacities to mitigate stormwater, and very compacted lawns have little ability to capture and store stormwater.

On this traditional lawn corner the turf has been worn away by automotive traffic. This traffic compacts the soil and limits drainage, essentially drowning out the grass

Here, compaction and poor drainage in a traditional lawn result in large bare spots where grass once grew.

Designing and Working with Turf/CU-Soil® Systems

Compaction of CU-Structural Soil® prior to installing sod. Photo courtesy Southpine, Inc.

Turf/CU-Structural Soil® systems require entire lawn areas to have at least 12" depth of CU-Structural Soil® just below the turf surface. This homogeneity is needed to ensure uniform engineering characteristics below the lawn, particularly in regard to frost heaving and drainage and also to support proper turf growth. For new construction projects, it is relatively easy to incorporate the required depth into the design.

CU-Structural Soil® must be compacted with a vibratory or rolling compactor in 6" lifts during installation. Once installed and fully compacted, the sod should be installed directly onto the CU-Structural Soil®, and then irrigated until well rooted and established. Once established, follow local turf maintenance programs including mowing, fertilization and irrigation.

Turf/CU-Structural Soil® Systems and Stormwater

For systems where stormwater mitigation is a goal, an additional depth of CU-Structural Soil® can be used to increase the volume of stormwater that can be stored. Because the void space for CU-Structural Soil® is approximately 26%, reservoir depths between 24" to 36" will mitigate between 6.25" and 9.36" of rain in a 24 hour period.

For example, a 24" depth of CU-Structural Soil® in Ithaca, N.Y., is capable of mitigating a 100 year storm event of 6" in 24 hours. This level of mitigation is quite high, but keep in mind that precipitation is both regional and highly variable from location to location. Also, it is important to remember that if adjacent surfaces drain towards the CU-Structural Soil® installation, the stormwater demand on the system will be increased.

A depth of 24" will both support lawn plantings and mitigate a storm event up to 6.25" in 24 hours. Less than 24" will also support lawn plantings but the reservoir will be too shallow to accommodate healthy tree root growth. For

lawns that include tree plantings, a reservoir depth of 24" to 36" is recommended.

Benefits of Using CU-Structural Soil® to Remove Pollutants

An important quality of any soil is its ability to filter pollutants from surface runoff. Suspension of runoff pollutants such as oil in the soil profile allows for the biodegradation of hydrocarbons into environmentally-harmless products by microorganisms. Through this process, runoff water is filtered before it recharges the groundwater supply.

Preliminary research by Qingfu Xiao at the University of California at Davis found that CU-Structural Soil® is effective at removing the nutrients and materials found in polluted surface runoff. Further research in this area is needed, but it is expected that colonization of CU-Structural Soil® by tree roots will further enhance the removal of runoff pollutants.[10]

Turf in Parking Lots

A turf covered parking lot is not a new idea, and has been used in diverse situations in the past, such as at churches and flea markets, and is now being used at professional sports arenas like Sun Life Stadium. As these examples suggest, turf is suitable for use in parking lots that receive only occasional vehicular traffic. There are a number of recommendations for designing successful turf parking lots with CU-Structural Soil®.

- Use turf in parking areas that receive occasional vehicular traffic, such as farmers markets and the overflow parking areas on the outskirts of large lots.
- To minimize vehicular wear on the turf as much as possible, place turf only in the parking stalls and not in the driving lanes of the lot. Angled parking stalls are recommended.
- Use local stormwater data and runoff calculations to set the proper depth of the CU-Structural Soil® reservoir. Doing so will ensure the proper functioning of stormwater mitigation techniques over time.
- Soil structure underneath the reservoir will help determine infiltration and groundwater recharge rates from the reservoir into the subbase below the reservoir.
- Use additional drainage as necessary. Flooding may occur if the rate of groundwater recharge is slower than the rate that the reservoir receives both the rain and the runoff.
- Use grasses appropriate to the site conditions and specify proper post-installation maintenance. Annual fertilizer applications may be required.

[10] Day, S.D. and S.B. Dickinson. Managing stormwater for urban sustainability using trees and structural soils. Virginia Polytechnic Institute and State University, Blacksburg, VA. (2008)

Design of a Turf-covered Fire Access Lane using CU-Soil®

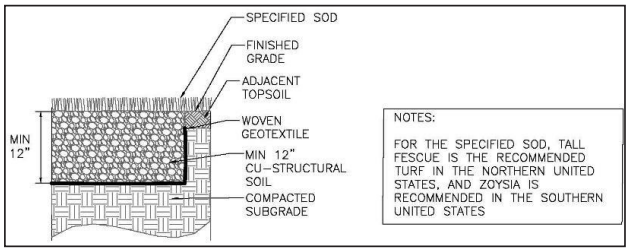
Fire lanes are access roads or lanes that are designed to accommodate rare use by emergency vehicles, but are not intended for normal vehicular traffic. Many municipalities require buildings to be accessible to emergency vehicles, and these large and heavy vehicles require certain design accommodations. A common result of these requirements is the construction of a wide, visually obtrusive paved roadway that is rarely (if ever) used.

There is great interest in using CU-Soil® to create turf-covered fire access lanes. It is possible to use CU-Soil® to support a turf-covered fire access lane rather than a traditional design based on fatigue of the pavement section. The controlling criterion is a maximum allowable deflection (i.e. soil depression) of 0.1" due to wheel loads. Although turf has been successfully grown on CU-Soil® depths as shallow as 6", **it is recommended that at least 12" of CU-Soil® be used in turf fire lane installations** to achieve this level of stability. This depth is appropriate for most types of compacted subgrades. A few soil types require greater depths of CU-Soil® due to their inherently low resilient modulus (soil stiffness). These are detailed in the table below. All other subgrade soils require 12" of CU-Soil®. For a greater explanation of these recommendations, see Design Assumptions and Modifications for Design below.

Table. Listing of subgrade types that require more than a 12" deep layer of CU-Soil® for a fire access lane.

Unified Soil Classification System (USCS) Symbol for soil subgrade	*Soil Symbol Definition*	*Resilient Modulus (soil stiffness) MR* Default (ksi)	*Minimum Thickness of CU-Soil® needed (inches)**
CH	clay of high plasticity, fat clay	4	41
MH	silt of high plasticity, elastic silt	6	27
CL	clay of low plasticity, lean clay	9	19
ML	silt	11	15

Because certain turf grasses tolerate wear better than others, for turf/CU-Soil® fire lane installations, Tall Fescue is the recommended species to use in the northern United States, while Zoysia is the recommended turf species for the southern United States. Although most fire trucks are approximately 8 feet wide, fire lanes should be designed to be at least double that width (16 feet). This width may be designed to include a heavy-duty sidewalk with a CU-Soil® base alongside the turf, or may be a turf/ CU-Soil® system by itself. Although the turf/CU-Soil® fire lane is capable of supporting a fire truck and preventing soil compaction, in certain circumstances the surface vegetation may be damaged.



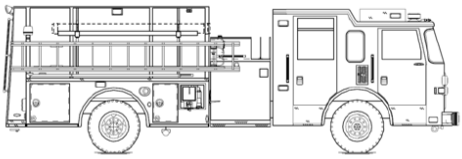
Typical section showing a turf-covered firelane using CU-Soil®

Design Assumptions

- Two layer system of CU-Soil® with turf over compacted subgrade
- The subgrade should either be undisturbed or, if reused, compacted to 95 percent Proctor density
- CU-Soil® : Minimum CBR 50 (standard for CU-Soil®)
- Subgrade soil: Varies
- Maximum 0.1 inches deflection allowed
- Fire truck dimensions

Source: *Emergency Vehicle Size and Weight Regulation Guideline* - International Fire Chiefs Association

Custom Chassis Pumper – Single Rear Axle



	Min	Max
Front GAWR	18,000	24,000
Rear GAWR	24,000	31,000
Width (in.)	98	100
Height (ft.)	9	12
Length (ft.)	30	34

Single wheel in back (worst case) with 100 psi tire pressure. During an emergency it is feasible (and may be advisable) to lower the tire pressure on extremely soft soils.

Modifications for Design

Resilient modulus (Mr) is a fundamental material property used to characterize unbound pavement materials. It is a measure of material stiffness. The greater the Mr, the more resistant the subgrade is to deformation under a load. As shown in the table below, when the Mr is low, the required thickness of CU-Soil® is greater. When the subgrade has a high Mr, less CU-Soil® is needed.

California Bearing Ratio (CBR) is another measure of material stability. It is defined as a penetration test for evaluation of the mechanical strength of road subgrades and base courses. It was developed by the California Department of Transportation before World War II. CU-Soil® is routinely tested for CBR and is specified as having a CBR of at least 50.

Resilient Modulus has been correlated with California Bearing Ratio for use in pavement design.[11] This correlation was used in the following calculations such that 50 CBR →32,000 psi

The fire lane design assumes a saturated soil with some loss of confinement versus the CBR test so an overall strength of the CU-Soil® is assumed to be about two-thirds of the value from the correlation with CBR.

CU-Soil® Design value used: 20,000 psi

For the subgrade, the design modulus is one-half the expected (default) value due to possible poor drainage conditions in the field.

[11] Source: *Guide for Mechanistic-Empirical Design of New And Rehabilitated Pavement Structures - Appendix CC-1: Correlation Of CBR Values With Soil Index Properties*, National Cooperative Highway Research Program, Transportation Research Board, National Research Council, Washington, DC 2001

CU-Soil® Thickness Needed for Typical Single Axle Fire Truck Allowing 0.1" Deflection

USCS Symbol for soil subgrade	*Resilient Modulus (soil stiffness) MR* Default (ksi)	*Thickness of CU-Soil (inches)**
CH	4	41
MH	6	27
CL	9	19
ML	11	15
SW	21	4*
SP	17	8*
SW-SC	15	10*
SW-SM	17	8*
SP-SC	15	10*
SP-SM	17	8*
SC	14	11*
SM	21	4*
GW	32	***
GP	29	***
GW-GC	24	***
GW-GM	30	***
GP-GC	23	1*
GP-GM	26	***
GC	20	5*
GM	30	***

* 12 inches is minimum for constructability, but calculated values are shown

*** Properly compacted subgrade soil can support the fire truck weight with or without the addition of the CU-Soil®

Notes on Soil Types

The Unified Soil Classification System (USCS) is one of many soil classification systems used in engineering and geology to describe the texture and grain size of a soil. The classification system can be applied to most unconsolidated materials, and is represented by a two-letter symbol. Each letter is described on the following page (with the exception of Pt):

Unified Soil Classification System (USCS)

First and/or second letters	
Letter	**Definition**
G	gravel
S	sand
M	silt
C	clay
O	organic

Second letter	
Letter	**Definition**
P	poorly graded (uniform particle sizes)
W	well-graded (diversified particle sizes)
H	high plasticity
L	low plasticity

Symbol chart

Major divisions			Group symbol	Group name
Coarse grained soils more than 50% retained on or above No.200 (0.075 mm) sieve	**gravel** > 50% of coarse fraction retained on No. 4 (4.75 mm) sieve	clean gravel <5% smaller than #200 Sieve	**GW**	well-graded gravel, fine to coarse gravel
			GP	poorly graded gravel
		gravel with >12% fines	**GM**	silty gravel
			GC	clayey gravel
	sand ≥ 50% of coarse fraction passes No.4 sieve	clean sand	**SW**	well-graded sand, fine to coarse sand
			SP	poorly graded sand
		sand with >12% fines	**SM**	silty sand
			SC	clayey sand
Fine grained soils 50% or more passing the No.200 sieve	**silt and clay liquid limit < 50**	inorganic	**ML**	silt
			CL	clay of low plasticity, lean clay
		organic	**OL**	organic silt, organic clay
	silt and clay liquid limit ≥ 50	inorganic	**MH**	silt of high plasticity, elastic silt
			CH	clay of high plasticity, fat clay
		organic	**OH**	organic clay, organic silt
Highly organic soils			**Pt**	peat

This section, "Design of a Turf-covered Fire Access Lane using CU-Soil®" created with assistance from David P. Orr, PE, PhD, Cornell Local Roads Program, Dept. of Biological and Environmental Engineering, Cornell University, Ithaca, NY 1485

Part III

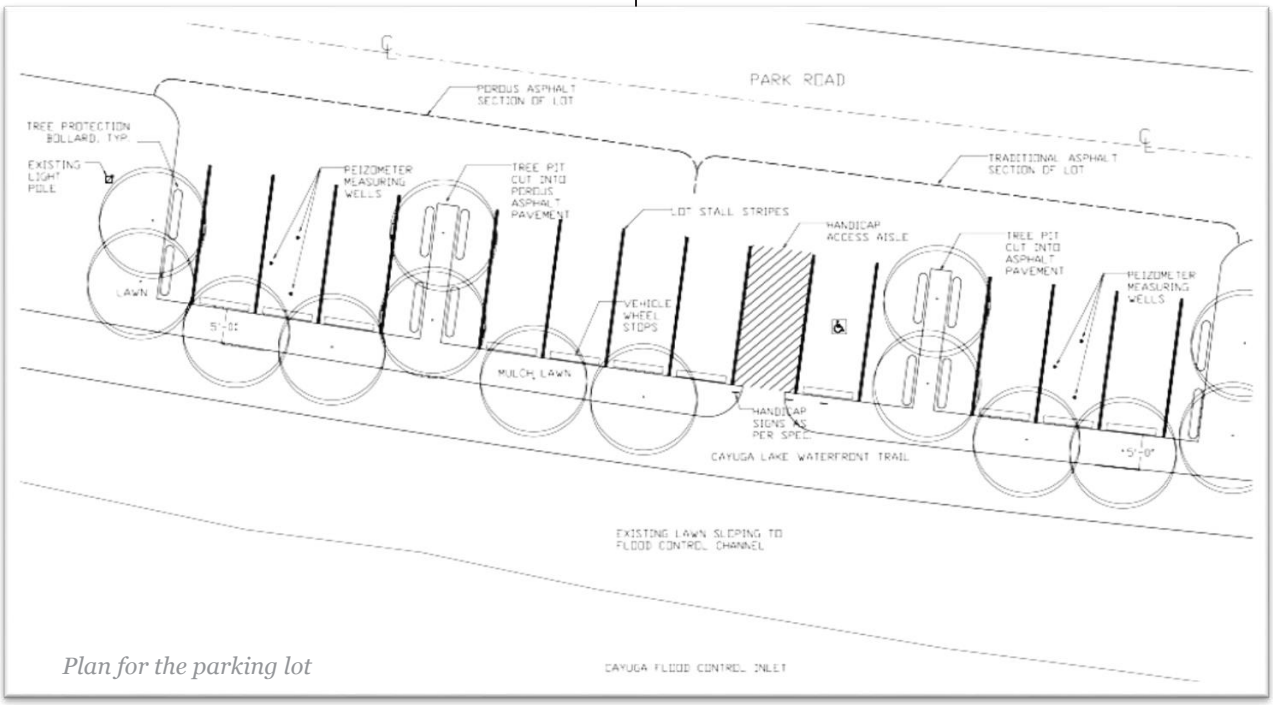
Case Studies

Porous Parking Lot, Ithaca NY

Aerial view of the site

As part of a research experiment, in 2005 a 12 car parking lot was designed and constructed in partnership with the Department of Public Works for the City of Ithaca, NY. This lot was an improvement on an existing gravel parking lot adjacent to the Flood Control Channel for the city of Ithaca.

This new 150' x 18' parking lot was divided in half, with the southern half of the lot using a 3" porous asphalt surface, while the northern half used a 3" layer of medium-duty traditional impervious asphalt surface. The entire lot was excavated to a depth of 2' and CU-Structural Soil® was used as the new 2' base course for the entire lot.



Plan for the parking lot

CU Structural Soil® was used as a 2' deep base course for the entire parking lot

In the middle of each pavement profile type (porous or impervious asphalt), 3' wide tree pits were cut, running the entire 18' width of the lot to the shoulder of the adjacent roadway. Within each tree pit, two bare root 1.5" caliper Accolade Elms (*Ulmus japonica x Ulmus wilsoniana* 'Accolade') were installed. Eight other Accolade Elms of the same size were planted within a 2' adjacency surrounding the parking lot with four of these adjacent to the porous asphalt profile and four of these adjacent to the traditional asphalt profile

The saw-cut planting bed with holes dug in the CU-Soil® for tree planting.

Planting the bareroot elms directly into CU-Soil® in 2005

The finished parking lot

Spring 2006

Growth as of 2009

Growth as of 2014

McCarren Park, Brooklyn NY

In 1997, a streetscape project adjacent to McCarren Park in Brooklyn, NY, included CU-Structural Soil® in the design. On one side of the street, CU-Soil® was used as a 24" base course for the entire length and width of the sidewalk, with regularly spaced tree pits that included removable permeable stone pavers.

The trees planted on the other side of the street were placed in a standard tree lawn, allowing for easy growth comparisons to be made over the years.

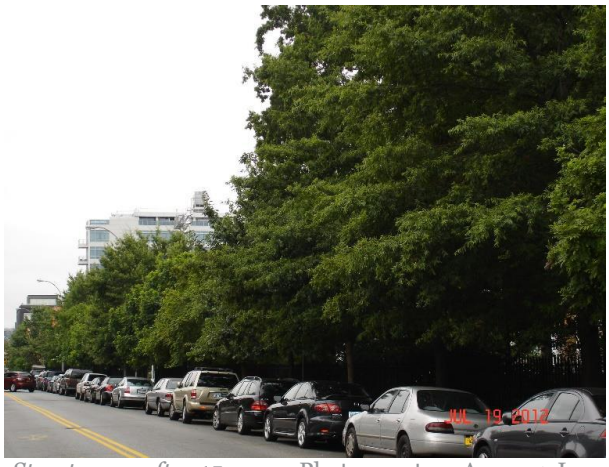
After 17 years of observation the trees growing in CU-Soil® are comparable to those growing in the tree lawn across the street. Ground penetrating radar data suggests that the tree roots have thoroughly colonized the CU-Soil® profile.

One of the trees planted in the tree lawn. The trees visible across the street are planted in a continuous trench of CU-Structural Soil®

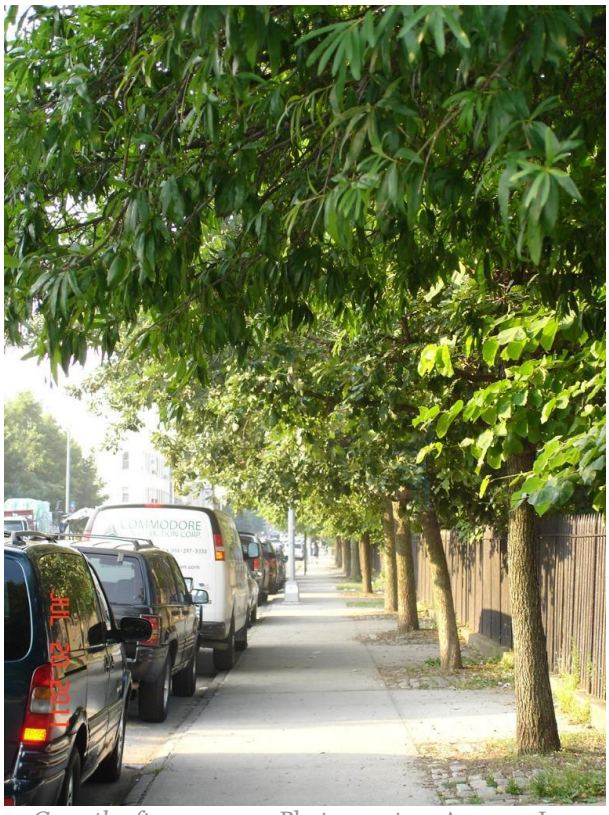
Growth after 3 years

Growth after 9 years. Photo courtesy Amereq, Inc.

Streetscape after 10 years. Photo courtesy Amereq, Inc.



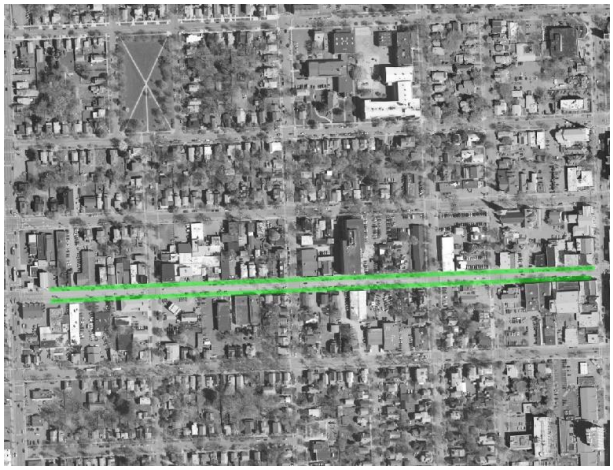
Streetscape after 15 years. Photo courtesy Amereq, Inc.



Growth after 14 years. Photo courtesy Amereq, Inc.

Streetscape after 17 years. Photo courtesy Amereq, Inc.

W. State Street, Ithaca NY



Extents of the W. State Street project

A 1999 project to retrofit many blocks of W. State Street in Ithaca, NY provided an opportunity to create block-long continuous trenches of CU-Structural Soil® in the newly constructed streetscape. There were a number of mature trees growing in existing tree pits that were kept during the project. CU-Soil® was constructed right up to the existing tree pits on either side. This effectively freed the roots of the mature tree from the cramped tree pit, and allowed them to explore the lengthy trenches of CU-Soil®. New tree pits were also created.

In this project, in many areas, the species used for the new tree plantings were chosen in order to maintain visual similarity with the existing trees.

Installation of the new sidewalk on a base of CU-Soil®. This picture also shows an existing mature tree

Growth after 10 years. The two trees on the right are mature Zelkovas that were preserved during the retrofitting. The two new trees on the left are Homestead elms that were planted following the retrofitting.

A typical tree pit on W. State Street. The colored concrete sections correspond with the extents of the CU-Soil® volume.

Green Street, Ithaca NY

Location of the project. The green line represents a continuous trench of CU-Soil®

A project in 2003 involved redoing a streetscape in downtown Ithaca, NY. The site, Green Street, is one of the most urban sites in Ithaca. It sees high volumes of vehicular traffic and serves as a major bus station, meaning that the street trees here are constantly exposed to exhaust from idling buses. The design uses an 8' wide by 24" deep trench of CU-Soil® that provides a continuous soil volume that is shared among all of the trees.

The trees planted here are an interesting aspect of the project. These trees are Chinkapin Oak (*Quercus muehlenbergii*), a tall-growing species that is rarely used as a street tree, but is notable because of its incredible tolerance to highly alkaline soils. The growth and health of these trees attest to this species' ability to withstand difficult urban stresses.

Green Street is one of the busiest streets in Ithaca, and the site of a bus station. The trees are constantly exposed to the exhaust from idling buses.

A continuous trench of CU-Soil® connects each tree pit to one another

Aerial view in 2014, eleven years after planting.

Growth as of 2006, three years after planting.

Growth as of 2014, eleven years after planting.

Mann Library, Ithaca NY

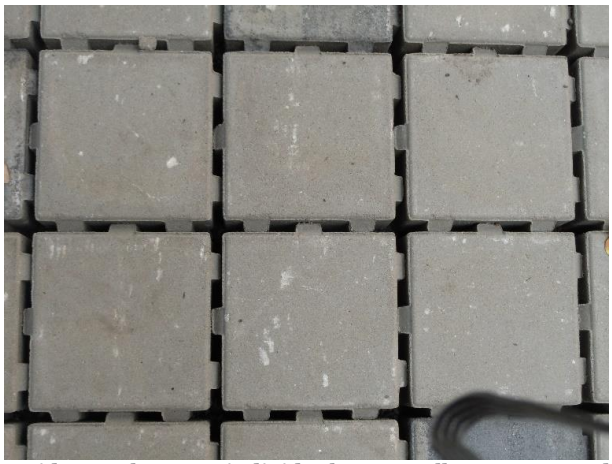
An academic building renovation and a plan for a newly paved plaza space threatened a mature Katsura Tree (*Cercidiphyllum japonicum*) on the Cornell University campus. The standard method for installing a new paved area, which involves excavating down into the soil 18" or more, would have destroyed much of the tree's root system and led to its demise.

Working with the designers during the initial stages of design, it was found that CU-Soil® could play a role in saving the tree. Rather than using the standard methods, the paved plaza space was built on top of the existing tree root-system, which experienced very little damage during construction. In 2014, soil was first cleared from the tree roots using a minimally invasive air excavation tool. On top of the newly exposed roots, CU-Soil® was placed and compacted to form the base course for the plaza. On top of this, pavers with an open, porous joint were installed. This project provides a unique example of how CU-Soil® can be utilized to save mature trees when new paving threatens their root systems.

Soil around the roots was excavated using an air excavation tool

12"-15" of CU-Soil® was placed on top of the exposed roots and compacted for use as a base course for the paving

Permeable pavers were installed over the CU-Soil® and mature tree roots



Void space between individual pavers allows water and air to infiltrate

The nearly finished plaza space

Car Dealership Turf Median, Birmingham, AL

Turf on CU-Structural Soil® has been successfully used at a car dealership in Birmingham, AL. At this installation, the soil in an entire median was excavated and replaced with CU-Structural Soil® and sod was placed on top. After installation, the entire median can properly withstand the compaction from the weight of the cars and serves as a flexible open space for the dealership, providing additional space to display inventory, or as overflow parking.

Installation and compaction of the CU- Soil®. Photo courtesy Southpine, Inc.

The finished installation. Photo courtesy Southpine, Inc.

The turf median is used as a parking and display space. Photo courtesy Holcombe Norton Partners

The turf median in winter. Photo courtesy Southpine, Inc.

PART IV

Resources

Installation Specifications

1.1 GENERAL

A. The work of this section consists of all structural soil work and related items as indicated on the drawings or as specified herein and includes, but is not limited to, the following:

CU-Soil® is a proprietary material patented by Cornell University and marketed under the registered trademark, CU-Structural Soil®. Only licensed companies are authorized to produce this material, meeting the specifications described in this text. For a list of licensed CU-Soil® producers, call AMEREQ, INC. at 800-832-8788.

1.2 DELIVERY, STORAGE AND HANDLING

A. Delivered CU-Structural Soil® shall be at or near optimum compaction moisture content as determined by AASHTO T 99 (ASTM D 698) and should not be placed in frozen, wet or muddy sites.

B. Protect CU-Structural Soil® from exposure to excess water and from erosion at all times. Do not store CU-Soil® unprotected. Do not allow excess water to enter site prior to compaction. If water is introduced into the CU-Soil® after grading, allow water to drain to optimum compaction moisture content.

1.3 EXAMINATION OF CONDITIONS

A. All areas to receive CU-Structural Soil® shall be inspected by the installing contractor before starting work and all defects such as incorrect grading, compaction, and inadequate drainage shall be reported to the engineer prior to beginning this work.

1.4 QUALITY ASSURANCE

A. Qualifications of installing contractor: The work of this section should be performed by a contracting firm which has a minimum of five years experience. Proof of this experience shall be submitted as per paragraph, SAMPLES and SUBMITTALS, of this section.

1.5 UNDERGROUND UTILITIES AND SUBSURFACE CONDITIONS

A. The installing contractor shall notify the engineer of any subsurface conditions which will affect the contractor's ability to install the CU-Soil®.

B. The installing contractor shall locate and confirm the location of all underground utility lines and structures prior to the start of any excavation.

C. The installing contractor shall repair any underground utilities or foundations damaged during the

progress of this work.

1.6 SITE PREPARATION

A. Do not proceed with the installation of the CU-Structural Soil® material until all walls, curb footings and utility work in the area have been installed. For site elements dependent on CU-Structural Soil® for foundation support, postpone installation of such elements until immediately after the installation of CU-Structural Soil®.

B. Install subsurface drain lines as shown on the plan drawings prior to installation of CU-Structural Soil® material.

C. Excavate and compact the proposed subgrade to depths, slopes and widths as shown on the drawings. Maintain all required angles of repose of the adjacent materials as shown on the drawings. Do not over excavate compacted subgrades of adjacent pavement or structures.

D. Confirm that the subgrade is at the proper elevation and compacted as required. Subgrade elevations shall slope parallel to the finished grade and/or toward the subsurface drain lines as shown on the drawings.

E. Clear the excavation of all construction debris, trash, rubble and any foreign material. In the event that fuels, oils, concrete washout silts or other material harmful to plants have been spilled into the subgrade material, excavate the soil sufficiently to remove the harmful material. Fill any over excavation with approved fill and compact to the required subgrade compaction.

F. Do not proceed with the installation of CU-Structural Soil® until all utility work in the area has been installed. All subsurface drainage systems shall be operational prior to installation of CU-Structural Soil®.

G. Protect adjacent walls, walks and utilities from damage. Use ½" plywood and/or plastic sheeting as directed to cover existing concrete, metal and masonry work and other items as directed during the progress of the work.

   1. Clean up all trash and any soil or dirt spilled on any paved surface at the end of each working day.

   2. Any damage to the paving or architectural work caused by the installing contractor shall be repaired, as directed by the engineer.

H. Maintain all silt and sediment control devices required by applicable regulations. Provide adequate methods to assure that trucks and other equipment do not track soil from the site onto adjacent property and the public right of way.

1.7 WATER

A. The installing contractor shall be responsible to furnish his own supply of water (if needed) free of impurities, to the site.

1.8 INSTALLATION OF CU-STRUCTURAL SOIL® MATERIAL

A. Install CU-Structural Soil® in 6 inch lifts and compact each lift.

B. Compact all materials to at least 95% Proctor Density from a standard compaction curve AASHTO T 99 (ASTM D 698). No compaction shall occur when moisture content exceeds maximum as listed herein. Delay compaction if moisture content exceeds maximum allowable and protect CU-Structural Soil® during delays in compaction with plastic or plywood as directed by the engineer.

C. Bring CU-Structural Soil® to finished grades as shown on the drawings. Immediately protect the CU-Structural Soil® from contamination by toxic materials, trash, debris, water containing cement, clay, silt or materials that will alter the particle size distribution of the mix with plastic or plywood as directed by the engineer.

D. The engineer may periodically check the material being delivered, prior to installation for color and texture consistency with the approved sample provided by the installing contractor as part of the submittal for CU-Structural Soil®. If the engineer determines that the delivered CU-Soil® varies significantly from the approved samples, the engineer shall contact the licensed producer.

E. Engineer shall ensure that the delivered structural soil was produced by the approved CU-Soil® licensee by inspecting weight tickets showing source of material.

F. CU-Soil® should not be stockpiled long-term. Any CU-Soil® not installed immediately should be protected by a tarp or other waterproof covering.

1.9 FINE GRADING

A. After the initial placement and rough grading of the CU-Structural Soil® but prior to the start of fine grading, the installing contractor shall request review of the rough grading by the engineer. The installing contractor shall set sufficient grade stakes for checking the finished grades.

B. Adjust the finish grades to meet field conditions as directed.

Provide smooth transitions between slopes of different gradients and direction.
Fill all dips with CU-Soil® and remove any bumps in the overall plane of the slope.

a. The tolerance for dips and bumps in CU-Structural Soil® areas shall be a 3” deviation from the plane in 10’.

All fine grading shall be inspected and approved by the engineer prior to the installation of other items to be placed on the CU-Structural Soil®.

C. The engineer will inspect the work upon the request of the installing contractor. Request for inspection shall be received by the engineer at least 10 days before the anticipated date of inspection.

1.10 ACCEPTANCE STANDARDS

A. The engineer will inspect the work upon the request of the installing contractor. Request for inspection shall be received by the engineer at least 10 days before the anticipated date of inspection.

1.11 CLEAN-UP

A. Upon completion of the CU-Structural Soil® installation operations, clean areas within the contract limits. Remove all excess fills, soils and mix stockpiles and legally dispose of all waste materials, trash and debris. Remove all tools and equipment and provide a clean, clear site. Sweep, do not wash, all paving and other exposed surfaces of dirt and mud until the paving has been installed over the CU-Structural Soil® material. Do no washing until finished materials covering CU-Structural Soil® material are in place.

END OF SECTION

Choosing Trees Appropriate for use in CU-Structural Soil®

As in any street tree planting, it is important to choose species that can withstand the conditions they will encounter in an urban setting. Drought tolerant tree species are recommended for planting in CU-Structural Soil®, which has an available water holding capacity of between 7-12%. The crushed stone component of the CU-Soil® whether limestone, granite, or other aggregate, will ultimately influence soil pH, and this has to be taken into consideration when selecting tree species. CU-Structural Soil® made with limestone generally ends up with a soil pH of about 8.0, regardless of the soil pH when the material was first mixed. For many parts of the country, this is not unusually high, and is especially common in urban areas. Using aggregates that do not influence pH, such as granite, may not affect pH as quickly, but the soil pH value will continue to increase as adjacent concrete slowly breaks down. A CU-Structural Soil® system provides an opportunity for choosing alkaline-tolerant species that require good drainage and are somewhat drought tolerant. As with any planting, local climate will greatly affect what tree species are suitable.

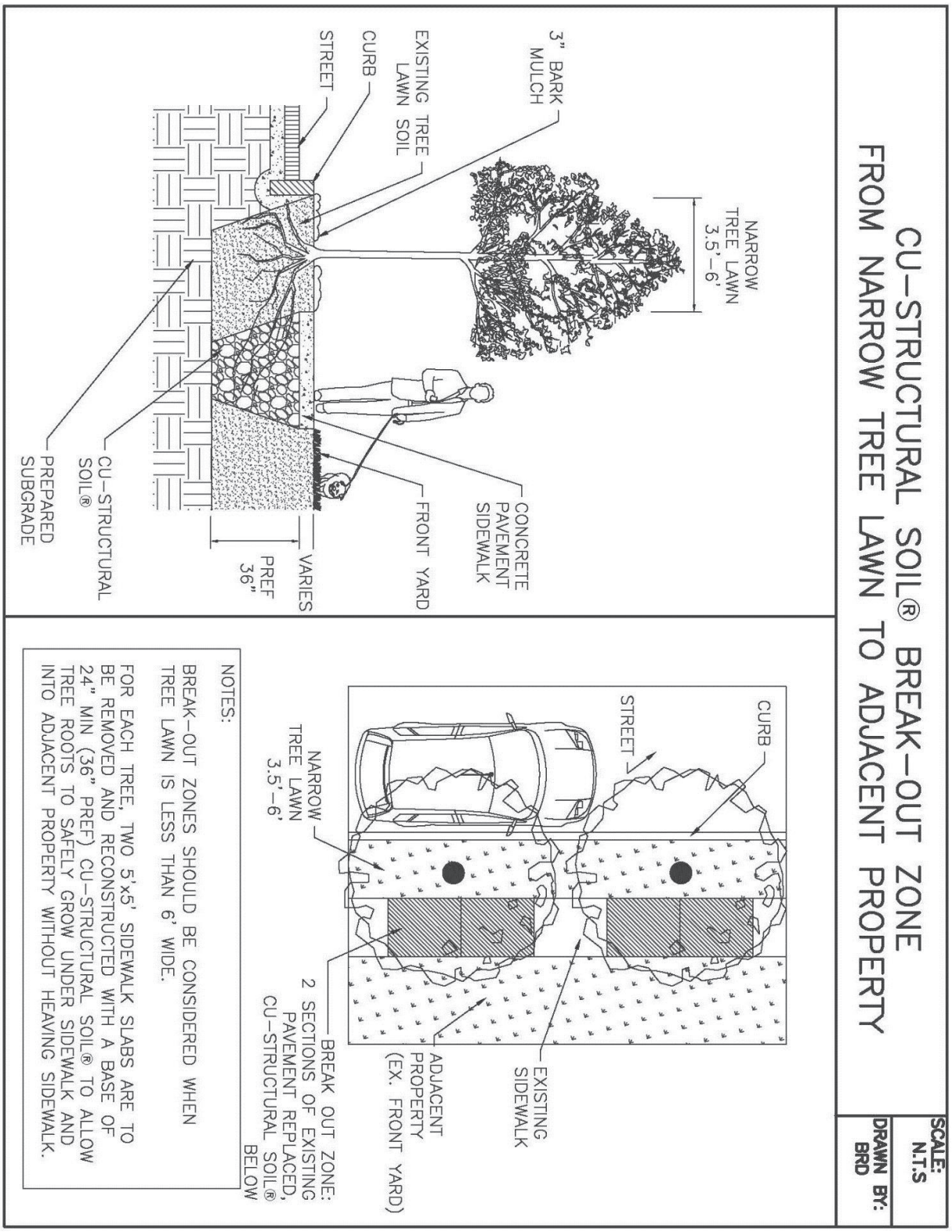
As an example, the following list of trees are both alkaline and drought tolerant. These species are suitable for Ithaca, New York, and other similar temperate climates. This list is just to provide a sampling. These species are certainly not the only species that are suitable for growing in a CU-Structural Soil® system. New trees in CU-Soil® must be watered for the first several years until they become established on the site. Lindens (*Tilia* spp.) in particular may need supplemental water in the first three years.

Botanic Name	Common Name
Acer campestre	Hedge Maple
Acer miyabei	Miyabe Maple
Acer truncatum	Painted Maple
Celtis occidentalis	Hackberry
Cercis canadensis	Redbud
Crataegus crus-galli	Cockspur Hawthorn
Crataegus phaenopyrum	Washington Hawthorn
Crataegus viridis	Green Hawthorn
Eucommia ulmoides	Hardy Rubber Tree
Ginkgo biloba	Ginkgo
Gleditsia triacanthos	Honey Locust
Gymnocladus dioicus	Kentucky Coffee Tree
Koelreuteria paniculata	Goldenrain tree
Maclura pomifera	Osage Orange
Malus spp.	Crabapple

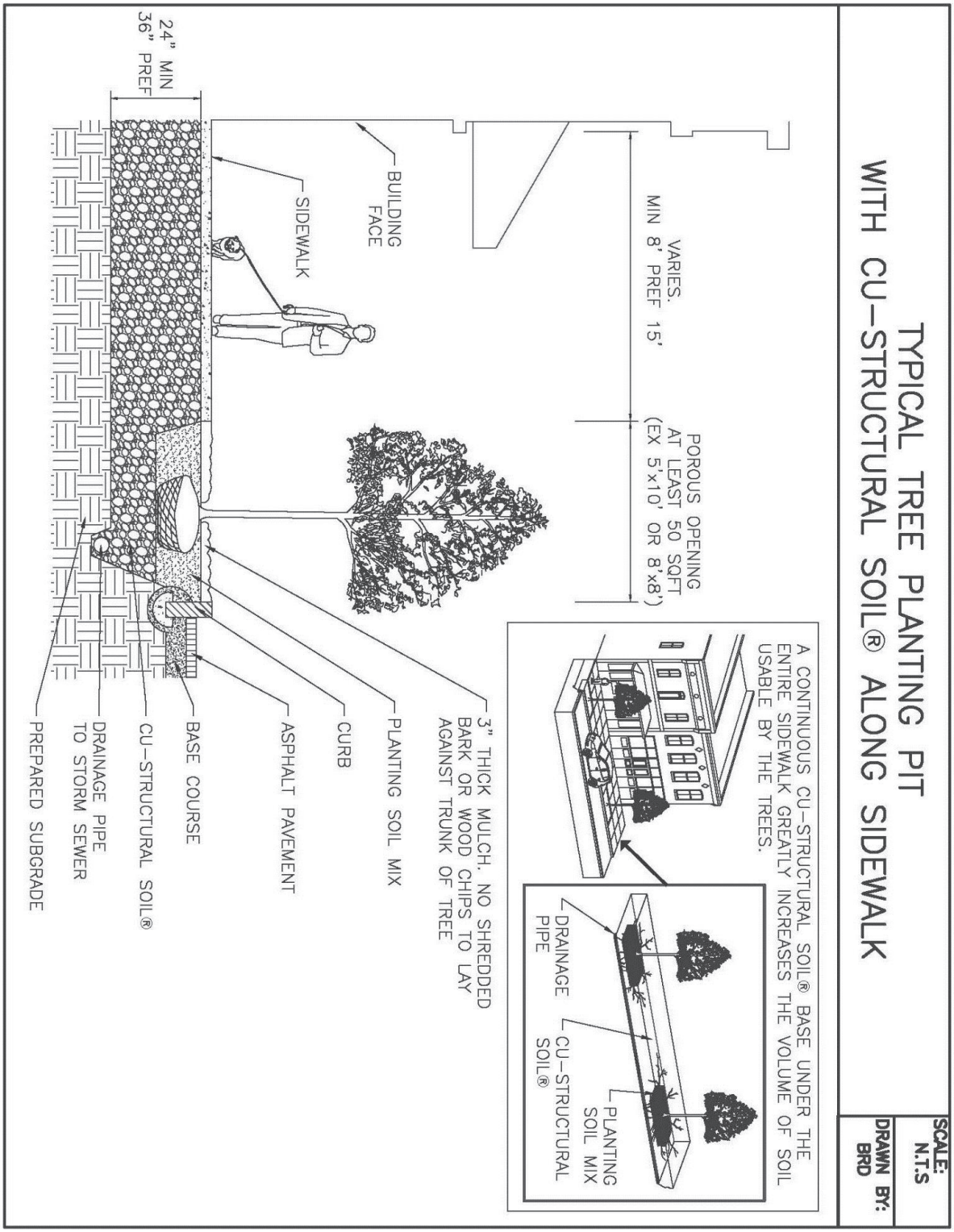
Botanic Name	Common Name
Platanus x *acerifolia*	London Plane
Pyrus calleryana	Callery Pear
Quercus macrocarpa	Mossy Cup Oak
Quercus muehlenbergii	Chinkapin Oak
Quercus robur	English Oak
Robinia pseudacacia	Black Locust
Styphnolobium japonicum	Japanese Pagoda Tree
Syringa reticulata	Japanese Tree Lilac
Tilia cordata	Littleleaf Linden
Tilia tomentosa	Silver Linden
Tilia x *euchlora*	Crimean Linden
Ulmus parvifolia	Lace Bark Elm
Ulmus spp.	Elm Hybrids
Zelkova serrata	Japanese Zelkova

Standard Design Details

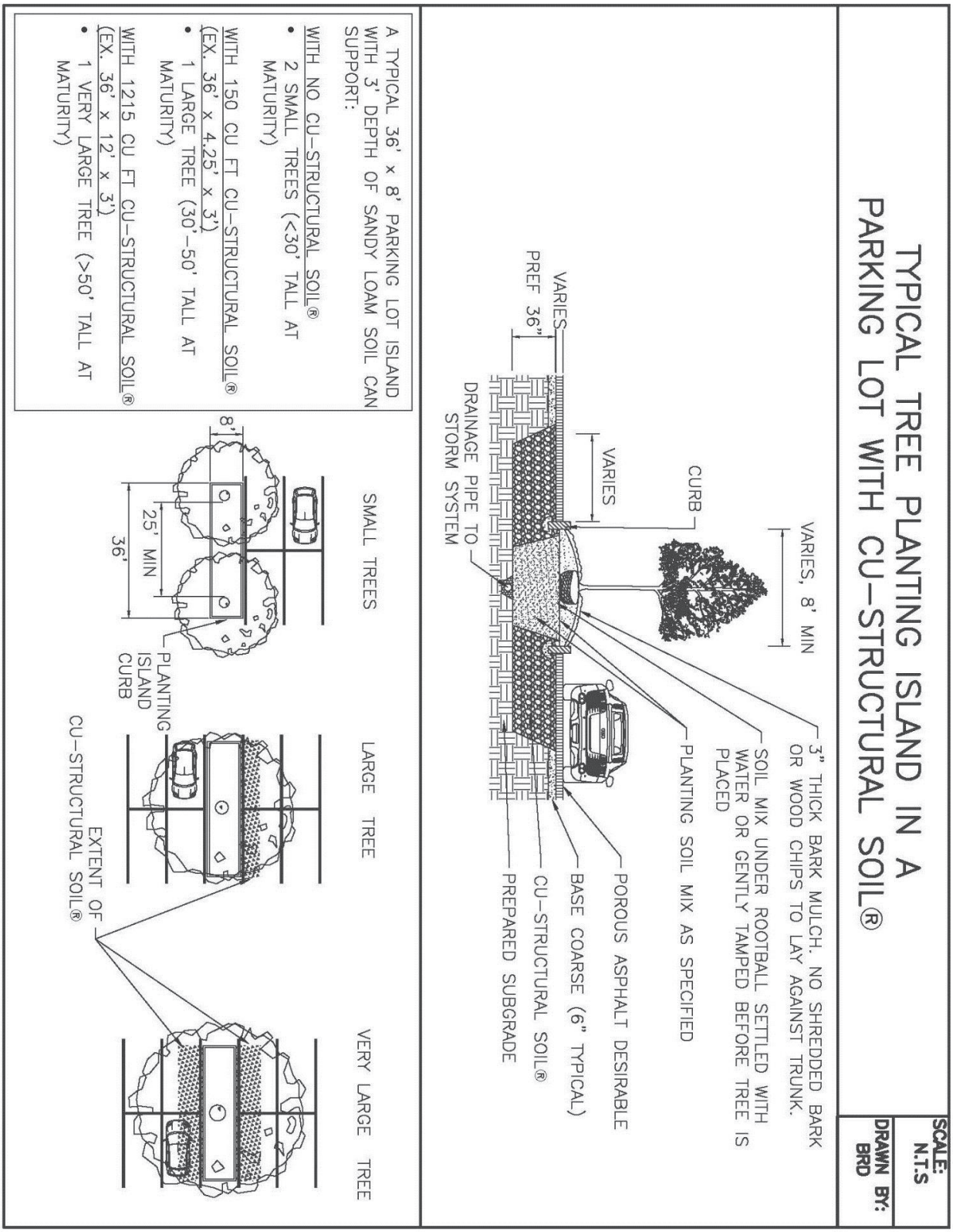
CU-Structural Soil® Break-out Zone from Narrow Tree Lawn to Adjacent Property



Typical Tree Planting Pit with CU-Structural Soil® along Sidewalk



Typical Tree Planting Island in a Parking Lot with CU-Structural Soil®



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3 PERVIOUS CONCRETE

Specifications

Guide Specification for Materials and Construction of Pervious Concrete Pavement Parking Lots

January 2017

National Ready Mixed Concrete Association • 900 Spring Street, Silver Spring, MD 20910 • 888-84-NRMCA • www.nrmca.org

Disclaimer

The information contained herein is provided for use by professional personnel who are competent to evaluate the significance and limitations of the information provided and who will accept total responsibility for the application of this information. The project Engineer of Record is responsible for the review and acceptance of the materials and construction specifications. The recommended specification requirements, criteria, and language herein reflect the professional knowledge and experience of the National Ready Mixed Concrete Association (NRMCA). However, NRMCA makes no representations or warranties concerning the fitness of this information for any particular application or installation and DISCLAIMS any and all RESPONSIBILITY and LIABILITY for the accuracy of and the application of the information provided to the full extent of the law.

Introduction

The following specification has been developed for use by owners and their design consultants to define material and construction requirements, criteria, and expectations of material suppliers and construction contractors. The definitions, test methods, and quality requirements are considered current state of the practice for the industry at the time of publication. This document is a recommended guide specification and has not been developed through a consensus process typical of industry standards that can be referenced. It should not be incorporated by reference in project specifications or contract documents.

Jointed unreinforced concrete parking lots may be designed using various methods; however, NRMCA recommends using the American Concrete Institute (ACI) procedure 330R-08 *Guide for the Design and Construction of Concrete Parking Lots* which specifically addresses the unique loading conditions, durability considerations, and joint layout patterns inherent to parking lots.

This specification is based off of the ACI 522.1-13, Specification for Pervious Concrete Pavement.

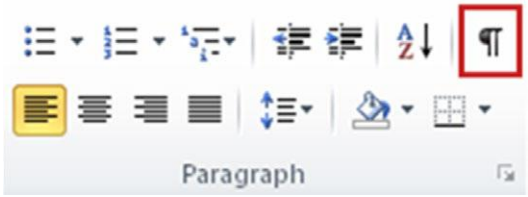
ACI 330R-08 and 522.1-13 can be obtained from ACI at www.concrete.org.

Notes to Specifier

1. Prior to use on a project, this guide specification should be thoroughly reviewed by the Project Engineer of Record for applicability to the specific project and local conditions. It is intended that the language contained herein will be modified, as necessary, to fit within the project contractual conditions and local preferences and that the referenced test methods will be modified accordingly.

2. All references to NRMCA on the cover page and in the main document header should be removed prior to incorporation into the final project specifications by the Engineer of Record or their representative.

3. The specification includes hidden text throughout which provides guidance to the specifier regarding the applicability or use of a section/subsection. Hidden text may be shown or hidden with the use of the Show/Hide button to see notes about optional language and what should be removed from the specification if it is not applicable. Hidden text is indicated as blue text. The hidden text should not be shown in the final project specification. The Show/Hide button in Microsoft Word is highlighted below. Print options can suppress printing of hidden text.



4. There are several locations where the engineer of record needs to input information specific to the project for which this specification is being issued. Without modifying these locations, this specification is incomplete. Locations identified as <**bold text**> indicate required information to be completed by the specifier. Locations identified as [**bold text]** generally indicate choices between one or more options to be selected by the specifier. The specifier is responsible for removing or inserting these for the final project specification. The engineer can also add other clauses as is typical for local practice and standard of care.

5. NRMCA requests feedback regarding this guide specification in terms of clarity of the language, constructability, and specification criteria/parameters. Feedback may be emailed to Publications@nrmca.org. Please include the specification title, revision number, and section/subsection number pertinent to your comment(s).

PERVIOUS CONCRETE PAVEMENT

PART I - GENERAL

1.01 CONTRACT CONDITIONS

Work of this Section is bound by the Contract Conditions, bound herewith, in addition to this Specification and accompanying Drawings.

1.02 SUMMARY

A. Description

The work of this Section includes subgrade preparation and installation of Portland Cement Pervious Pavement.

B. Related Sections

1. Section 01300 – Submittals
2. Section 02225 – Excavation, Backfilling and Compacting
3. Section 02233 – Aggregate Base Course
4. Section 03300 – Cast-in-Place Concrete

C. Measurement

1. Portland cement concrete pervious pavement, by square foot OR square yard, of the depth specified, placed to the lines and grades shown on the Contract Drawings.

No measurement will be made for:

2. Extra thickness of pervious pavement, as discovered in the field through testing.
3. Cutting concrete joints, joint materials, and/or joint sealant, used in the construction of Portland cement pervious concrete pavements.

D. Payment

Portland Cement Pervious Concrete Pavement will be paid for per square foot OR square yard of the depth and type specified, which price will be payment in full for furnishing all labor, materials, tools, equipment and incidentals, and doing all Work necessary to complete the Portland cement pervious concrete pavement, as specified, including: Furnishing and installing curing materials, cutting concrete joints (sawcut or plastic), thickened edges of concrete at joints if specified, joint material, joint sealant (if specified), used in construction of Portland cement pervious concrete pavement.

1.03 REFERENCES

A. Annual Book of ASTM Standards, 1997; American Society for Testing and Materials, Philadelphia, PA.
B. Standards of the American Association of State Highway and Transportation Officials (AASHTO).
C. American Society of Testing and Materials ASTM C 29 “Test for Unit Weight and Voids in Aggregate.”

D. American Concrete Institute (ACI) 522.1-08 "Specification for Pervious Concrete Pavements."
E. American Concrete Institute (ACI) 306R – latest edition "Cold Weather Concreting."
F. ASTM C 33 "Specification for Concrete Aggregates."ASTM C 42 "Test Method for Obtaining and Testing Drilled Cores and Sawed Beams of Concrete
G. ASTM C 117 "Test Method for Material Finer than 75 μm (No. 200) Sieve in Mineral Aggregates by Washing."
H. ASTM C 140 "Methods of Sampling and Testing Concrete Masonry Units."
I. ASTM C 150 "Specifications for Portland Cement" (Types I or II only).
J. ASTM C 172 "Practice for Sampling Fresh Concrete."
K. ASTM C 260 "Specification for Air-Entraining Admixtures for Concrete."
L. ASTM E 329 "Standard Recommended Practice for Inspection and Testing Agencies for Concrete, Steel and Bituminous Materials as used in Construction."
M. ASTM D 448 "Specification for Standard Sizes of coarse Aggregate for Highway Construction.
N. ASTM C 494 "Specification for Chemical Admixtures for Concrete."
O. ASTM C 595 "Specifications for Blended Hydraulic Cements" (Types IP or IS only).
P. ASTM C 618 "Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for use as a Mineral Admixture in Portland Cement Concrete."
Q. ASTM C 989 "Specification for Ground Granulated Blast-Furnace Slag for use in Concrete and Mortars."
R. ASTM C 1077 "Practice for Laboratories Testing Concrete and concrete Aggregates for use in Construction and Criteria Laboratory Evaluation."
S. ASTM C1116 "Standard Specification for Fiber Reinforced Concrete"
T. ASTM D 1557 "Tests for Moisture-Density Relations of Soils and Soil Aggregate Mixtures using 10 Pound Rammer and 18-inch Drop"
U. ASTM C 1688 "Standard Test Method for Density and Void Content of Freshly Mixed Pervious Concrete."
V. ASTM C 1701 **"**Standard Test Method for Infiltration Rate of In Place Pervious Concrete."
W. ASTM C1754 / C1754M - 12 "Standard Test Method for Density and Void Content of Hardened Pervious Concrete."

1.04 SUBMITTALS

A. See Section 01300- Administrative Requirements, for submittal procedures.
B. Concrete Mix Design
C. NRMCA Certifications of the contractor and ready mixed concrete producer as described in section 1.06 below.

1.05 QUALITY ASSURANCE

A. Perform work of this section in accordance with ACI 522 except as modified herein.
B. Follow recommendations of ACI 306R when concreting during cold weather with the exception of the following:
    1. Do not place pervious concrete unless the temperature is above 32 degrees F for seven (7) consecutive calendar days, unless otherwise permitted in writing by the Engineer.

C. Use adequate numbers of skilled workmen who are thoroughly trained and experienced in the necessary crafts and who are completely familiar with the specified requirements and the methods needed for proper performance of the work in this section.

1.06 CONTRACTOR QUALIFICATIONS

A. The Contractor shall employ no less than one National Ready Mixed Concrete Association (NRMCA) Certified Pervious Concrete Craftsman who must be on site, overseeing each placement crew during all concrete placement, or the Contractor shall employ no less than three (3) NRMCA Certified Pervious Concrete Installers, who shall be on site working as members of each placement crew during all concrete placement unless otherwise specified. Alternative documentation of qualifications shall be permitted when approved by the Architect/Engineer. Prior to award of the contract, the placing contractor shall furnish Owner/Engineer a statement attesting to qualifications and experience and the following:

1. A minimum of 3 completed projects, total square footage to exceed 10,000 SF with addresses.
2. Unit weight acceptance data.
3. In-Situ pavement test results including void content and unit weight.
4. Sample of Product (i.e. core or test panel)

B. If the placing contractor and concrete producer have insufficient experience with Portland Cement pervious concrete pavement (less than 3 successful jobs), the placing contractor shall either:

1. Retain an experienced consultant or NRMCA Certified Pervious Craftsman to monitor production, handling, and placement operations at the contractor's expense, or
2. Receive permission in writing from the Engineer or Owner of the acceptance of the contractor's experience on past projects as sufficient.
3. The Owner and/or Contractor may contact the NRMCA for information on qualified/NRMCA certified contractors and personnel. Contact Shawnita Dickens, sdickens@nrmca.org, 240-485-1154

C. Test Panels: Regardless of qualification, Contractor is to place, joint and cure two test panels, each to be a minimum of 200 sq. ft. at the required project thickness to demonstrate to the Architect's and Owner's satisfaction that in-place unit weights can be achieved and a satisfactory pavement can be installed at the site location.
D. Test panels may be placed at any of the specified Portland Cement pervious locations on the project or at another test site. Test panels shall be tested for thickness in accordance with ASTM C 42; and void structure and unit weight in accordance with ASTM C 1688.
E. Satisfactory performance of the test panels will be determined by:

1. Compacted thickness no less than ¼" of specified thickness.
2. Void Structure: 15% minimum; 23% maximum.
3. Unit weight plus or minus 5 pcf of the design unit weight.
4. If measured void structure falls below 13% or if measured thickness is greater than ¼" less than the specified thickness of if measured weight falls less than 5 pcf below unit weight, the test panel shall be removed at the contractor's expense and disposed of in an approved landfill.

F. If the test panel meets the above-mentioned requirements, it can be left in-place and included in the completed work.

1.07 PROJECT CONDITIONS

A. Protection of Existing Improvements

1. Protect adjacent work from splashing of paving materials. Remove all stains from exposed surfaces of paving, structures, and grounds. Remove all waste and spillage.
2. Do not damage or disturb existing improvements or vegetation. Provide suitable protection where required before starting work and maintain protection throughout the course of the work.
3. Restore damaged improvements, including existing paving on or adjacent to the site that has been damaged as a result of construction work, to their original condition or repair as directed to the satisfaction of the Owner, and authority having jurisdiction at no additional cost.

B. Safety and Traffic Control

1. Notify and cooperate with local authorities and other organizations having Jurisdiction when construction work will interfere with existing roads and traffic.
2. Provide temporary barriers, signs, warning lights, flagmen, and other protections as required to assure the safety of persons and vehicles around the construction area and to organize the smooth flow of traffic. Costs for said traffic control are to be included in the price of installation of the Pervious Concrete.

C. Weather Limitations

1. Follow recommendations of ACI 522 when concreting during cold weather with the exception of the following: Do not place pervious concrete unless the temperature is above 32 degrees F for seven (7) consecutive calendar days, unless otherwise permitted in writing by the Engineer.

1.08 PRE PAVING CONFERENCE

A pre-paving conference with the engineer shall be held two (2) days prior to beginning placing the pervious concrete. The contractor shall have the pervious concrete consultant, ready mix supplier, the foreman and the entire concrete crew that will form and place the concrete in attendance at this meeting.

PART 2 - PRODUCTS

2.01 CONCRETE MIX DESIGN

Contractor shall furnish a proposed mix design with proportions of materials prior to commencement of work. **The data shall include void content and unit weight as determined in accordance with ASTM C 1688.**

2.02 STORMWATER STORAGE/INFILTRATION BEDS

A. Coarse aggregates shall meet the size and grading requirements as defined in Standard Sizes of Coarse Aggregate, Table 4, AASHTO Specifications, Part I, 13th Ed., 1982, or later, unless otherwise specified.
B. Coarse aggregate for groundwater recharge bed shall be between 2-1/2" to 3/4", uniformly graded crushed coarse aggregate, with a wash loss of no more than 0.5%, AASHTO size number 2 thru 57 per Table 4, AASHTO Specifications, Part I, 13th Ed., 1982, or later.
C. Use only one selected size of stone – multiple layers of different sized stones (such as a choker course) is not required for pervious concrete.
D. Non-woven filter fabric shall be Propex PERC™ Pervious Concrete Infiltration Fabric or approved equal.
E. Impervious liner – shall be Permalon, PLY-X 150, or approved equal.

2.03 PORTLAND CEMENT PERVIOUS CONCRETE

A. Cement: Portland Cement Type I or II conforming to ASTM C 150 or Portland Cement Type IP or IS conforming to ASTM C 595. Slag or Flyash may be used as part of the total cementitious content.
B. Aggregate:
    1. For most applications (parking lots, driveways, sidewalks), use 3/8" washed, crushed coarse aggregate with a minimum void content per ASTM C29 of 40%.
    2. For sidewalks and trails, an optional size of aggregate may be used, #9 (1/4") washed, crushed coarse aggregate with a minimum void content per ASTM C29 of 40%.
    3. Industrial/heavy duty pavements where ADA requirements are not needed, use #57 (3/4") or larger, washed, crushed coarse aggregate with a minimum void content per ASTM C29 of 40%.
    4. If other gradations of aggregate are to be used, submit data on proposed material to owner for approval.

C. Admixtures and Reinforcement: The following admixtures may be used as needed:
    1. A hydration stabilizer that meets the requirements of ASTM C 494 Type B Retarding or Type D Water Reducing/Retarding admixtures. This stabilizer suspends cement hydration by forming a protective barrier around the cementitious particles, which delays the particles initial set.
    2. Air Entraining Agent – ASTM C 260 may be used to improve resistance to freeze/thaw cycles.
    3. A viscosity modifier - Used to reduce paste drain down caused by using a dirty aggregate
    4. Synthetic fibers per ASTM C1116 - Standard Specification for Fiber Reinforced Concrete, if specified, either:
        i. Monofilament polypropylene / polyethylene blend dosed at the rate of 2 to 3 pounds per cubic yard
            a) Specific Gravity 0.92
            b) Fiber Length 2"
            c) Tensile Strength 87-94 ksi (600-650 MPa)
            d) Modulus of Elasticity 725 ksi (5.0 GPa)
            e) Aspect Ratio 74
        ii. Cellulose fibers dosed at the rate of 3 pounds per cubic yard

D. Water: Potable water shall be used. DO NOT USE HOT WATER IN PERVIOUS CONCRETE.

E. Proportions:
   5. Cement Content: For pavements subjected to vehicular traffic loading, the total cementitious material shall not be less than 500 lbs. per cu. yd. For other pavement areas not subject to vehicular traffic loading, the total cementitious material shall not be less than 450 lbs. per cu. yd.
   6. Aggregate Content: the volume of aggregate per cu. yd. shall be equal to 27 cu. ft. when calculated as a function of the unit weight determined in accordance with ASTM C 1688.
      i. An aggregate/cement ratio range of 4:1 to 4.5:1.
      ii. A unit weight range of 105 lbs/cu. ft. to 140 lbs/cu. ft. per ASTM C 1688.
      iii. Voids of 15% to 23%.
   7. Admixtures: Shall be used in accordance with the manufacturer's instructions and recommendations.
   8. Mix Water: Mix water shall be such that the cement paste displays a wet metallic sheen without causing the paste to flow from the aggregate. (Mix water yielding a cement paste with a dull-dry appearance has insufficient water for hydration).
      i. **Water cement ratios should range from 0.29 to 0.35**.
      ii. Insufficient water results in inconsistency in the mix and poor bond strength.
      iii. High water content results in the paste sealing the void system primarily at the bottom and poor surface bond.

PART 3 – EXECUTION

Owner shall be notified at least 24 hours prior to all recharge bed and pervious paving work.

1.01 INSTALLATION

A. Subgrade Preparation
   1. Existing subgrade under bed areas shall **NOT** be compacted or subject to excessive construction equipment traffic prior to stone bed placement.
   2. Where erosion of subgrade has caused accumulation of fine materials and/or surface ponding, this material shall be removed with light equipment and the underlying soils scarified to a minimum depth of 6 inches with a York rake or equivalent and light tractor.
   3. Bring subgrade of stone recharge bed to line, grade, and elevations required.
   4. Fill and lightly regrade any areas damaged by erosion, ponding, or traffic compaction before the placing of stone.

B. Recharge Bed Installation
   1. Upon completion of subgrade work, the Engineer shall be notified and shall inspect at his discretion before proceeding with recharge bed installation.
   2. Filter fabric, pipe, and recharge bed aggregate shall be placed immediately after approval of subgrade preparation. Any accumulation of debris or sediment which has taken place after approval of subgrade shall be removed prior to installation of filter fabric at no extra cost to the Owner.
   3. Place filter fabric in accordance with manufacturer's standards and recommendations. Adjacent strips of filter fabric shall overlap a minimum of sixteen inches (16"). Secure

fabric at least two feet (2') outside of bed and take steps necessary to prevent any runoff or sediment from entering the storage bed.

4. If an impervious liner is specified. place impervious liner over geo-textile extending six feet (6') beyond toe of slope face at building face, secure as recommended by manufacturer.
5. Install coarse aggregate in 6 inch maximum lifts. Lightly compact each layer with equipment, keeping equipment movement over storage bed subgrades to a minimum.
6. Install aggregate to grades required on the drawings.
7. Following placement of bed aggregate, the filter fabric shall be folded back along all bed edges to protect from sediment washout along bed edges. At least a two foot (2") strip shall be used to protect beds from adjacent bare soil. This edge strip shall remain in place until all bare soils contiguous to beds are stabilized and vegetated. In addition, hay bales shall be placed at the toe of slopes which may be adjacent to beds to further prevent sediment from washing into beds during site development. As the site is fully stabilized, excess filter fabric along the bed edges can be cut back to gravel edge.

1.02 PORTLAND CEMENT PERVIOUS PAVEMENT CONCRETE MIXING, HAULING AND PLACING

A. Mix Time: Central mixed concrete shall be mixed for a minimum of two (2) minutes after introduction of all materials into mixer. Truck mixers shall be operated at the speed designated as mixing speed by the manufacturer for 75 to 100 revolutions (or 3 to 5 minutes) of the drum.
B. Transportation: The Portland Cement aggregate mixture may be transported by ready mix trucks or dump trucks or mixed on site and should be used within one (1) hour of the introduction of mix water, unless otherwise approved by an engineer. This time can be increased to 120 minutes when utilizing the hydration stabilizer specified above at the proper dosage rate, unless otherwise approved by an engineer.
C. Each truck should not haul more than two (2) loads before being cycled to another type concrete, unless delivered by dump truck or if a stabilizing hydration agent is used in the pervious concrete mix design or if field experience proves that there is no significant concrete buildup in concrete mixer after delivery.
D. Prior to placing concrete, the subbase shall be soaked and in a wet condition (no ponding of water) at time of placement. Failure to provide a moist subbase will result in a reduction in strength of the pavement.
E. Discharge shall be a continuous operation and shall be completed as quickly as possible. If consolidation occurs during concrete discharge, placement shall be halted and wet concrete removed.
F. Concrete shall be deposited as close to its final position as practicable and such that fresh concrete enters the mass of previously placed concrete.
G. Placing and Finishing Equipment: Unless otherwise approved by the Owner or Engineer in writing, the Contractor shall provide mechanical equipment of either slipform or form riding with a following compactive unit that will provide a minimum of 10 psi vertical force.
H. The pervious concrete pavement will be placed to the required cross section and shall not deviate more than +/- 3/8 inch in 10 feet from profile grade.
I. If placing equipment does not provide the minimum specified vertical force, a full width roller or other full width compaction device that provides sufficient compactive effort shall be used immediately following the strike-off operation.

J. Strike off the pervious concrete 1/2" to 3/4" above the final grade prior to compaction, if needed, by using either slip-form, form riding vibrating screed, form riding aluminum roller screed or laser screed. Strike off may be done by hand for sidewalks. Care must be taken to avoid filling voids in the concrete.
K. The Contractor will be restricted to pavement placement widths of a maximum of fifteen (15') feet unless the Contractor can demonstrate competence to provide pavement placement widths greater than the maximum specified to the satisfaction of the Owner.

3.03 CURING

A. Curing procedures shall be complete within 20 minutes after the final placement operations if polyethylene sheeting is used.

    1. The pavement surface must be covered with a layer of six (6) mil thick polyethylene sheeting.

        i. PRIOR TO THE ARRIVAL OF THE CONCRETE, remove the plastic sheeting from the box, unfold, measure, and cut to size. Roll the plastic onto a PVC pipe that is of sufficient length to span the forms.
        ii. Plastic can now be rolled onto the finished pavement is an efficient manner.

    2. On hot weather days, the pavement surface shall be covered with a minimum .20 mil thick polyethylene sheet (painters plastic) or other approved covering material prior to final cross rolling of the surface and then covered with a layer of four to six (4 – 6) mil thick polyethylene sheeting. Prior to covering, an evaporative reducer shall be sprayed above the surface when required due to ambient conditions (high temperature, high wind, and low humidity).

B. The cover shall overlap by 18 inches all exposed edges and shall be secured (without using dirt or stone) to prevent dislocation due to winds or adjacent traffic conditions.

    1. Secure plastic to forms with staples or nails.
    2. Overlap plastic sheeting as roof tiles to prevent rainwater from infiltrating the pervious concrete until it has sufficiently cured.
    3. Prevent wind from billowing up the middle of the plastic by placing wood 2"x4" or rebar across the plastic spanning the form.

C. Cure Time: **7 days minimum**.

D. No truck traffic shall be allowed for **10 days**; no passenger car/light trucks for **7 days**; and no pedestrian traffic for **48 hours**.

3.04 JOINTING

A. Control (contraction) joints shall be installed as indicated by plans. They shall be installed at a depth of the 1/3 to 1/4 the thickness of the pavement.
B. These joints are to be saw cut.

C. For saw cuts, the procedure should begin as soon as the pavement has hardened sufficiently to prevent raveling and uncontrolled cracking (normally after curing), minimum of 36 hours after placement.
D. Possible complications from saw cutting include:
    1. Removal of plastic to perform saw cutting will cause pervious concrete to hydrate too quickly. If plastic is removed to accommodate saw cutting, re-hydrating of pervious concrete by spraying concrete with water and keep concrete wet until plastic can be reapplied. THIS IS REQUIRED.
    2. Sawing pervious concrete too early can damage concrete surface.
E. Transverse constructions joints shall be installed whenever placing is suspended a sufficient length of time that concrete may begin to harden (over 20 minutes).
F. Isolation (expansion) joints should be used in structure widths exceeding thirty (30) feet or at seventy five (75) feet on sidewalks or when pavement is abutting slabs or other adjoining structures.
G. Expansion joint material shall be K-form screed rail or approved equal.
H. To reduce raveling, if transverse or isolation joints are used, or where pervious concrete meets impervious pavement, extra compaction may be necessary.
I. Additional installation specifications for the pervious concrete provided by the material source and engineer shall be followed strictly.

3.05 PERVIOUS PAVEMENT CONCRETE TESTING, INSPECTION, AND ACCEPTANCE

A. The owner will retain an independent testing laboratory.
B. The testing laboratory shall conform to the applicable requirements of ASTM E 329 “Standard Recommended Practice for Inspection and Testing Agencies for Concrete, Steel, and Bituminous Materials as Used in Construction” and ASTM C 1077 “Standard Practice for Testing Concrete and Concrete Aggregates for use in Construction, and Criteria for Laboratory Evaluation” and shall be inspected and accredited by the Construction Materials Engineering Council, Inc. or by an equivalent recognized national authority.
C. The Agent of the testing laboratory performing field sampling and testing of concrete shall be certified by the American Concrete Institute as a Concrete Field Testing Technician Grade I, or by a recognized state or national authority for an equivalent level of competence.
D. Testing and Acceptance:

    1. A minimum of 1 gradation test of the subgrade is required every 5,000 square feet to determine percent passing the No. 200 sieve per ASTM C 117.
    2. A minimum of one test for each load of pervious concrete in accordance with ASTM C 1688 to verify unit weight shall be conducted. Delivered unit weights are to be determined in accordance with ASTM C 1688 using a 0.25 cubic foot cylindrical metal measure. The measure is to be filled and compacted in accordance with ASTM C 1688. The unit weight of the delivered concrete shall be +/- 5 pcf of the design unit weight.
    3. Test panels shall have two cores taken from each panel in accordance to ASTM C 42 at a minimum of seven (7) days after placement of the pervious concrete. The cores shall be measured for thickness, void content and unit weight in accordance with ASTM C1754. Range of satisfactory unit weight values are +/- 5% pcf of the design unit weight.
    4. After a minimum of seven (7) days following each placement, three cores shall be taken in accordance with ASTM C 42. The cores shall be measured for thickness, void content and unit weight determined as described above for test panels. Core holes shall be filled

with concrete meeting the pervious design or other concrete material as permitted by the owner.

E. Maintenance: There shall be a maintenance plan submitted by the owner to prevent the clogging of the pervious concrete pavement which shall include periodic testing for flowability by the pervious concrete installer prior to the pervious concrete being opened to service, in accordance with ASTM C 1701 - Standard Test Method for Infiltration Rate of In Place Pervious Concrete, with flow rates reported in writing to the owner and again at six (6), twelve (12) eighteen (18) and twenty-four (24) months and again report the results in writing to the owner. It is the contractor's responsibility to help the owner to develop a maintenance plan. The owner must have a plan and methods to restore flowability if the flow rate drops below 75% of the original rate. Acceptable methods to restore levels of flowability are either to vacuum or powerwash the pervious concrete sections.

4 BONDED RUBBER MULCH

EasyGrass | Artificial Grass and Turf Supplier and Installer
14181 SW 143 Court, Miami, Florida 33186 | P:305.234.5800 | www.easygrass.net

REFER TO VOLUME 1 FOR BONDED RUBBER MULCH COLOR STANDARDS PER STREET TYPE.

EASY MULCH CO

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Architects First Choice Product Specifications for…

EASY MULCH:
Rubberized Anti-Fatigue Attenuated Walking and Exercise Trail Surfacing

DESIGN CRITERIA:

a.) The Surface System shall have been marketed by name within the United States for at least ten (5) years.

b.) The installation of the Surfacing specified herein and indicated on the Drawings shall be performed by an organization who can furnish supporting evidence of rubberized surfacing installation experience, a company regularly engaged in this type of work on a full time basis for a period of not less than 5 years.

c.) The installation of the Surfacing must be executed by experienced mechanical applicators who are factory trained and approved Rainbow Turf installation contractors.

d.) The raw materials used to formulate the bonded rubberized surfacing and the mechanical installation methodologies used to manufacture the finished product must validated by the customer prior to surfacing being installed.

e) An authorized factory trained representative of Easy Mulch must approve and endorse in person the authenticity and correctness of the completed surfacing once installed, whose signed authorization must appear on certificates of completion used for payment submittals.

f) Bonded rubber surfacing must be mechanically applied and fully compacted while installing to manufacturers installation specifications.

SUBMITTALS:

a.) Samples:
1.) Submit Samples of the following for approval by the Engineer.
a.) 12 inch x 12 inch samples of 1 ½" of surfacing material compacted and compressed to 1".

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PRODUCT TESTING MANDATED:

a.) ***Shock Absorbency:*** *When tested in accordance with ASTM F-1292, the surface shall not impart to the head form upon impact, a peak deceleration exceeding 200 times the acceleration due to Gravity (200 G's). Drop height used in this test shall be at 4'. Successful attenuated testing passes must be documented a poured in place material depth of 1 ½".*

b.) ***Slip Resistance****: Wet dynamic reading shall not be less than 40 when tested in accordance with ASTM E 303, using British Portable Skid Resistance Tester.*

c.) ***Flammability:*** *Minimum Critical radiant flux of 0.22 Watts/CM2 when tested in accordance with ASTM E 648.*

1) *Particulate Rubber Particles must successfully pass ASTM standard CFR 1630 for flammability of carpet and rugs.*

d) ***Rubber Buffing Material****: Passes Long-Strand Water Permeability per USTC Test Procedure*

1) *Rubber Buffing Long-Strand Material Passes ASTM E 303 Test for Skid Resistance*
2) *Rubber Buffing Long-Strand Material Passes ASTM D412-98a Test for Tensile & Elongation Properties*
3) *Rubber Buffing Long-Strand Material Passes ASTM C501-84 (96) Test for Abrasive Wear*
4) *Rubber Buffing Passes Accelerated U.V. Colored Buffing Test Rating a 'No Change when exposed to 420 AFU's – Testing Methodology AATCC 16E for loose-particle Rubber Buffing*
5) *Buffing Material Passes Accelerated Wear Test Rating when bonded by Urethane showing 'No Change' of 20,000 foot counts – Testing Methodology CRI TM-101 for rubber bluffing bounded together as a solid surface as a rubber walking surface.*

e) ***Water Leaching Test****: Passes Department of Health SW-846 test method for the chemical analysis and evaluation of water and solid waste materials.*

SITE CONDITIONS:

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a.) Manufacturer's current installation methodologies and procedures must be used and adhered to on the Project.

b.) Proceed with work of this section only after substrate construction and penetrating work has been compacted to 90+% of dry density.

c.) Do not proceed with work during inclement weather. Comply with manufacturer's recommendations for application and curing under specific climatic conditions.

e.) Conditions of substrates with respect to structural performance shall be evaluated and approved by a Factory Representative prior to applying the surfacing.

f.) At the time of application ambient air temperature shall be 40 Degrees Fahrenheit or greater and remain so during the duration of the product installation.

g.) Adjacent Material along with the rubberized surfacing shall be protected and secured by the customer during the installation process, while curing from weather and other site related damaging.

SITE PREPARATION GENERAL:

a.) A 90+% Compacted Sub-Straight is required over the base material is required for the installation of Easy Mulch pathway surfacing. Optional use of Geo-Textile membrane fabric for weed-blocking may be preferred.

SUB – BASE
CONSTRUCTION SPECIFICATIONS

A solid sub-surface such as concrete or asphalt is the preferred for Standardized EASY MULCH rubberized surfacing installations.
The following information is provided herein a brief guideline. It is important to note that proper installation of the aggregate sub-surface is one of the most critical and most often overlooked aspects of a rubberized surfacing project. Due diligence is recommended when preparing the sub-surface or selecting a sub-surface contractor.

1. Evaluate existing drainage. If the installation area is lower than the adjacent grades and collects water or if there are standing puddles on the sub-surface, a sub-surface water drain system must be installed. It is recommended that an individual with drainage experience such as a soil or civil engineer inspects the site prior to commencement of the installation.

2. Remove topsoil until solid, packed and stable sub-soil is visible and level. (Test sub-soil for rebound). If sub soil is of poor quality then there is a possibility that geo-textile cloth may be necessary between the sub-soil and the granular sub-surface.

3. An installation retainer edge is sometimes needed. Various edging options are available including, rubber flex curbs, wood, plastic and concrete boarder edging can be installed both above and below grade.

4. Install 4-8 inches of "Granular A" aggregate (terminology varies by region). Contact local soil engineers for detailed local aggregate specifications and performance expectations. Granular A shall consist of crushed rock composed of hard, fractured fragments free of clay coatings.
Granular A shall be produced from bed rock gravel, cobbles or boulders of uniform quality. Granular A may also contain a blend or combination of crushed gravel, sand and fines produced from naturally formed deposits, crushed slag produced from air-cooled iron blast furnace or nickel slag, reclaimed Portland cement concrete or reclaimed asphalt pavement material. Install material in 3 to 4" layers.

5. Rolling Packer – It is critical that the base be properly compacted. Without adequate sub-surface compaction the planarity of finished surface will change as the sub-surface planarity changes. Use a rolling vibrating packer or equivalent to reach 95% standard proctor density.
Complete multiple passes in both directions. Assist packing by wetting aggregate if necessary.

6. This portion is dependent on region and aggregate materials obtained locally. Level sub-surface aggregate to +- ¼" over 10' measured in any direction. To ensure proper grade install ½" of ¼" minus granite screenings or "chips and dust" over the final compacted and leveled sub-surface. This material is used to fill in any undulations in grade of the packed aggregate. Pack material as stated above.

7. Extend granular base 3-4" past edge of installation. When no solid retainer edge is going to be used at the edge of the installation, then the granular base must be sloped off at a 4" rise in 12" run. Slope for 12 linear inches or until the packed subsurface is 4" below finished grade of the adjacent surfacing. This prevents a tripping hazard in the event the adjacent
loose fill surface erodes and exposes the edge of the resilient surface.

8. Base surface slope to be 2% in order to ensure adequate water drainage.

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9. Inspect final packed aggregate base. It is important to carefully inspect any base supplied by an outside contractor.

MATERIALS:

Primer: *Single component moisture cured Rainbow Turf AR 55200 polyurethane primer.*

Binder: *An elastic polyurethane pre-polymer with minimal odor, excellent weathering and binding characteristics. The use of AR 55200 Urethane is specific to and required for this project. Supplier must verify the use supply of urethane specified for this project. No "as equal" urethane bonding agent substitutions are permitted. The AR 55200 is supplied by Easy Mulch, LLC. Toll Free (800)988-6156.*

Rubber Buffing RT 3125: *RT # 3125 colored rubber buffing particles are used for purpose of mechanically compacted rubber trail surfacing and it's proprietary sizing is class sized specific to; and for use of and to manufacture bonded rubber trail surfacing. RT 3125 Rubber Buffing consists of100% recycled tire-buffing product is color pigmented by way and use of iron oxide pigments. RT #3125 Rubber Buffing material may be sourced by calling Easy Mulch, LLC. Toll Free (800)988-6156. No as equal raw material substitutions will be accepted.*

The body and proportionate formulation of RT #3125 of Rubber Buffing consists of rubber particles ranging in size from 1/2" to 2" that when mixed to proper proportion meet or exceeds the following basic criteria in addition to the product testing mandated for the product specified.

1) Rubber Buffing Material is Non-Toxic
2) Rubber Buffing Material is Anti-Fungal
3) Rubber Buffing Material is Non-Absorbent
4) Rubber Buffing to Avert Nesting of Insects
5) Rubber Buffing is consistent of proportionate Long-Strand Particles
6) Rubber Buffing is 100% free of wire, and cotton/polyester contaminates

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WARRANTY:

a.) *Provide a written warranty stating that work executed under this Section will be free from defects of materials and workmanship for a period of two years from date of Substantial Completion, whereby the integrity of the bonded surfacing remains attenuated.*

b.) *The Warranty shall be supplied in writing, and honored by Contractor. Contractor shall Warranty removal and replacement of materials as required repairing or replacing PIP surfacing.*

c.) *Customer testimonials which can document ten (5) years of tenured experience are required and must be submitted; inclusive of the bidders proposal bid package.*

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MIAMI, FL 33186

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5 DETECTABLE WARNING PLATE

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DURALAST® Detectable Warning Plates

DURALAST® Detectable Warnings
Durable, Reliable, Proven!

DURALAST Cast Iron Detectable Warnings
DURALAST® Detectable Warning Plates help warn the blind or visually impaired of the approaching street. Engineered to outlast the sidewalk, this long-lasting cast iron product withstands rigorous urban conditions, such as snow plows, street cleaning machines, and vehicular traffic. Lower your maintenance and product life cycle costs by using DURALAST Detectable Warnings—your Americans with Disabilities Act (ADA) compliant, Accessibility for Ontarians with Disabilities Act (AODA) compliant, and environmentally friendly solution.

Resistant to the elements
Cast iron's inherent resistance to the elements, snow plows, and snow melting chemicals make it a natural fit for severe climates.

- Long-wearing cast iron
- Impervious to vehicular and snow plow traffic
- Corrosion resistant
- Permanently embedded into concrete
- 10 year limited warranty

DURALAST® Detectable Warning Plates

Product Features

Durable and Cost Effective
· Over 500 times more durable than composite
· Engineered to outlast the sidewalk — long-lasting and corrosion resistant
· Easy to install
· Maintenance free
· 10 year limited warranty

Made in the USA from Recycled Materials
· Eligible to earn LEED® points in the Materials and Resources category
· Cast iron is an environmentally responsible product that is completely recyclable after its useful life

Americans With Disabilities Act (ADA) Compliant
· Natural finish meets color contrast requirements
· Slip resistant textured surface – greater than 0.8 coefficient of friction
· DOT approved (contact your local Sales Representative for specification approvals)
· Bolting ensures compliance during installation

Accessibility for Ontarians with Disabilities Act (AODA) Compliant

Product Data

Product Testing
Maintenance free cast iron detectable warnings are designed to fully comply with the American Disabilities Act Accessibility Guidelines (ADAAG). Contact your local sales representative for other independent laboratory tests and research studies.

Product Durability—Wear Resistance
Independent lab test* demonstrates DURALAST® Detectable Warning Plates durability. Per ASTM C501-84 standards, an independent third party laboratory test was conducted to determine the wear index values of DURALAST Detectable Warning Plates versus a competing composite surface. Test results indicate that DURALAST plates are over 500 times more wear resistant than composites. Additional impact testing on DURALAST cast iron plates proves they are more resilient to the demanding installation environments of these products.

Test Results

Physical Properties	Results	Specification
Slip Resistance	1.10 Dry / 1.06 Wet	ASTM C-1028
Wear Resistance (Abrasion)	7333	ASTM C-501-84
Impact Resistance	>238 Newtons	ASTM D-1709
Adhesion to Concrete (Bond Strength)	>5000 lbs	ASTM D-482
Tensile Strength	35,000 PSI	ASTM A-48
Design Compliance	Fully Compliant	ADAAG

Over 500 times more durable than composite!

7333
DURALAST wear index

13.7
Composite Tile wear index

*Testing performed by 3rd party, ABIC Testing Laboratories, Inc.

Sizes and Installation

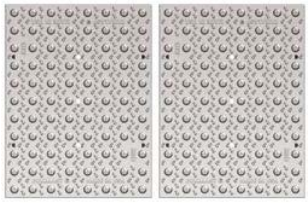
Standard Sizes

Standard Sizes

Size	Product Number
18" x 24"	00700561
24" x 24"	00700571
30" x 24"	00700721

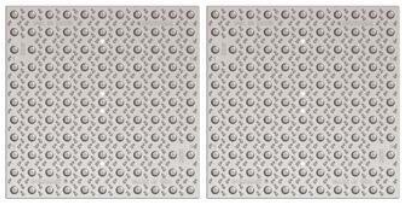
Sizes for Your Application

3' Ramp
00700561C01



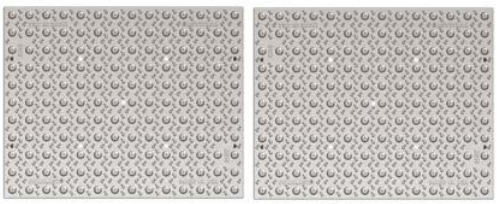
18" x 24" 18" x 24"

4' Ramp
00700571C01



24" x 24" 24" x 24"

5' Ramp
00700721C01

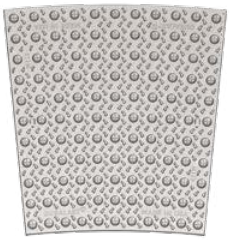


30" x 24" 30" x 24"

Radial Sizes

Radial Sizes

Radius	Product Number
10'	00700611
15'	00700615
17 1/2'	00700617
20'	00700621
25'	00700625
30'	00700631
35'	00700635



Radial plates are designed to fit your unique curb line.

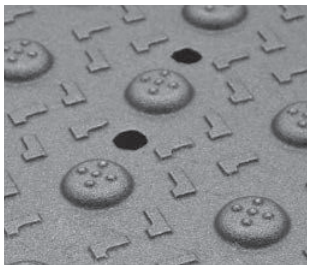
Installation Instructions

Optional: Hand-tighten plates together with stainless steel bolts. This helps ensure proper installation and compliance.

Step 1: Set cast iron Detectable Warning Plate into wet concrete in accordance with ADAAG (American Disabilities Act and Accessibility Guidelines).

Step 2: Tamp plate thoroughly with rubber mallet until concrete seeps through vent holes.

Step 3: Clean off excess concrete from the plate and finish concrete around the plate.



DURALAST® Detectable Warning Plates

Finish Options

EJ recommends specifying cast iron products in their natural state to minimize any unnecessary environmental impact. DURALAST products are also offered in black asphalt dip. Contact your local sales representative for powder coating or special requests. Natural finish meets color contrast requirements for ADA compliance.

Natural Finish
Uncoated

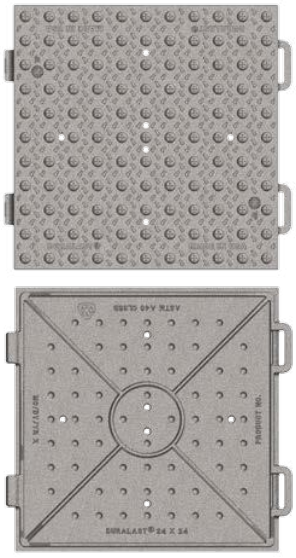
Black Asphaltic Dip Finish
Coated

New I-LOK™ Interlocking Plates

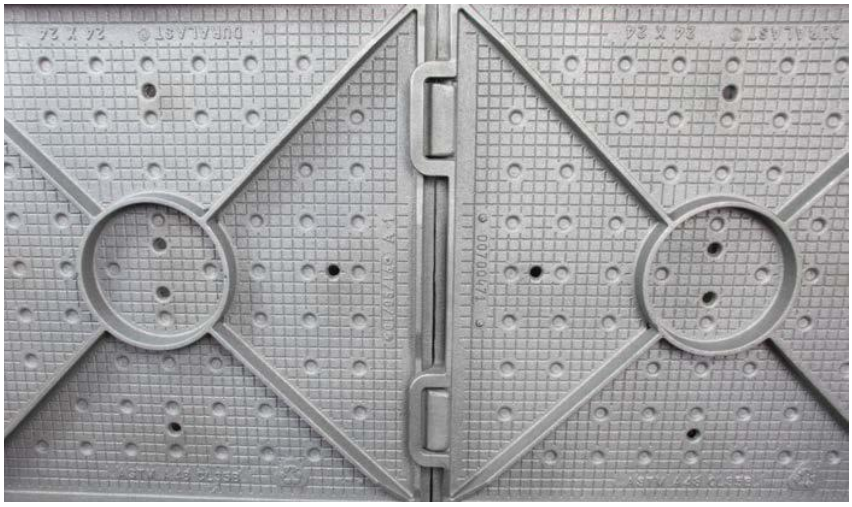
In addition to the standard DURALAST detectable warning plates, EJ now offers the new I-LOK interlocking plate design.

Save time during the installation by eliminating the need to bolt plates together. Simply connect and set.

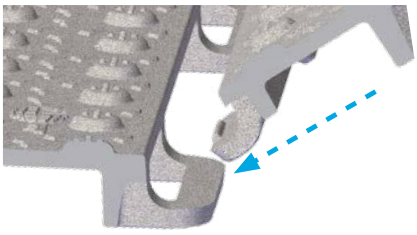
Benefits
· No extra tools or hardware required
· Reduced setup time
· Uniform installation



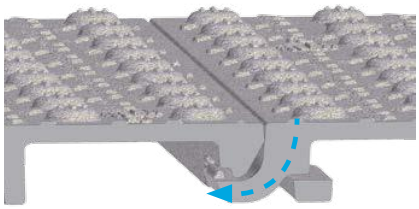
Check with your EJ representative for available sizes.



24" x 24" (00700471) shown



Connect plates together by inserting both hook ends into the handles at 45 degree angle.



Once the plate is lowered, it will be engaged and interlock the plates together. Interlocked plates can be easily moved together and uniformly set in concrete.

ejco.com
800 626 4653

Americas
800 626 4653
231 536 2261

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and Africa
+33 (0)344 08 28 00

Asia-Pacific
+61 (0)7 3216 5000

EJ
301 Spring Street
PO Box 439
East Jordan, MI 49727
800 626 4653
231 536 2261
us.sales@ejco.com

Registered Mark(s)

DURALAST®

DURALAST AM 0316

6 THERMOPLASTIC FOR ROAD MARKING

Ennis-Flint | Traffic Safety Solutions
P:800.331.8118 | www.ennisflintamericas.com

DecoMark®
A TrafficScapes™ Solution by Ennis-Flint

DecoMark® Marking Design Guidelines

DecoMark® markings are durable, typically interconnected, surface-applied preformed thermoplastic surface signage and logo markings, suitable for application on asphalt and concrete pavement substrates. DecoMark markings are created using custom cut solid color pieces of preformed thermoplastic to create the desired marking. The pieces are assembled and glued together on the back so that they come in preassembled segments for ease of application, typically 2'x3' (.6m x .91m) sheets, depending on the marking's size.

Design and Colors

- When replicating a customer's marking design, we will make every effort to replicate it as closely as possible; however, modifications may be necessary.
- Every line, element, or space within the marking should have a minimum width of 1/2" (12.7mm) wide or wider in order for us to manufacture, cut, and assemble a custom design into a complete DecoMark marking.
Note that these tolerances are for narrow areas of larger material pieces that make up a marking. Depending on the marking's design and complexity, we reserve the right to require wider tolerances where necessary to manufacture certain markings.
- Unless very large, design elements with sharp points will likely have the tip of the sharp point(s) rounded to prevent breakage during manufacturing and assembly.
- There are 33 standard colors available for DecoMark markings.
- Custom colors are not available in DecoMark.
- Gradient shading design coloration is not possible in DecoMark preformed thermoplastic material.
- DecoMark is not a printed media that can simply be printed to a durable "sticker" and applied.

To get a better understanding of the material, design capabilities and the application process, it will be helpful to watch the videos and review the photo gallery on our DecoMark webpage at: www.ennisflintamericas.com. There are two videos available on the "Videos" tab in the middle of the page, and the photo gallery of some of our past markings is available at the link in the upper right-hand corner.

Material Thickness

Two thicknesses are available for DecoMark Regulatory Surface Signage with ViziGrip® surface treatment, 90 and 125 mils (2.3mm and 3.2mm). 90 mil (2.3mm) material is typically used in bike and pedestrian areas, while 125 mil (3.2mm) material is most often used in roadways or areas exposed to vehicular traffic. DecoMark SK Non-Reflective Logos are only available in 125 mil (3.2mm) thickness for enhanced durability and maximized service life.

Intellectual Property

Ennis-Flint makes every effort to respect others' intellectual property, so any registered, trademarked, or copyrighted logo, symbol, or brand name that we are to replicate must have a letter of permission from the brand owner or authorized representative accompany the request.

Pricing

Custom item pricing is based on design complexity/intricacy, marking size, number of colors, quantity needed, and material thickness.

Details needed to quote pricing for a custom item:
Design: (Emailed drawing file, image, sketch, etc.)
The image should be of high resolution and print quality so that it can be evaluated properly. Vector design files using solid colors are ideal when available. We can accept CAD files (.DWG or .DXF), .PDF, .JPG, .TIF and .AI file types.
Description/Notes: (Only if any deviations from image submitted)
Dimensions: (Very Important)
Colors: (If not clear on the image submitted)
Quantity: (If an exact quantity is not known, please indicate an approximate amount.)
Mil Thickness: 90 mil (2.3mm) is typically used for regulatory surface signage in bike and pedestrian areas, while 125 mil (3.2mm) is used in roadways and other areas subject to vehicular traffic. DecoMark SK Logos are only available in 125 mil (3.2mm).

DecoMark markings are more economical if there are multiples of the same design ordered because the price per marking will be less than if only ordering a single marking, due to the design and set up expenses being amortized over multiple markings, instead of being charged to a single marking, if only one is desired.

Submittal Drawings
- Once the price has been accepted and an order placed for the markings, Ennis-Flint will prepare a submittal drawing for approval by the customer.
- No production will begin until the submittal drawing is approved in writing.
- Should a submittal drawing be required before the order is placed, Ennis-Flint reserves the right to charge an up-front design fee for submittal drawing creation. This amount will be applied toward the invoice for the markings when they are ordered, so it is not an additional charge above the quoted price.

Application
- A two-component epoxy sealer is applied to the pavement prior to the placement and heating of the marking.
- Each DecoMark marking consists of cut and preassembled pieces or sheets (depending on size) of preformed thermoplastic and must be heated until molten when applied to the pavement.
- The marking material's colors may change slightly when heated to a molten state during application.
- Any browning of the material from heating should wear away within a week or so of being opened to traffic.

Marking Functionality
TrafficScapes™ products (including DecoMark) are functional pavement markings designed to provide streetscape enhancement, promote safety awareness and calm traffic. The initial aesthetic properties of applied markings will be affected by traffic, weather, chemicals, and other environmental factors over time.

DecoMark®

A TrafficScapes® Solution by Ennis-Flint

Interconnected, Surface-Applied Preformed Thermoplastic Logos and Surface Signage for Asphalt and Concrete

Maximize traffic guidance, increase brand awareness, enhance community pride, and promote school spirit with durable preformed thermoplastic horizontal surface signage that is engineered to last 6 to 8 times longer than paint, and even longer in areas with only pedestrian traffic. DecoMark® design and color combinations are virtually endless.

USES AND LOCATIONS

- Custom Logos
- Sidewalk Accents
- Directional Markings
- Informational Markings
- Trail Markings
- Toll Lane Markings
- Streets and Highways
- Business Parks
- Parking Lots
- University Campuses
- Driveways
- and more...

PERFORMANCE-BASED FEATURES AND BENEFITS

- High skid/slip resistant for safety. As material wears, new anti-skid elements are exposed.
- Lasts 6 to 8 times longer than paint with a clean, crisp appearance
- ADA compliant - Pedestrian and wheelchair friendly surface
- Eliminates the maintenance and safety concerns of loose pavers
- Precut, interconnected shapes and colors; easy to handle
- All preformed thermoplastic materials are made at Ennis-Flint's manufacturing facility which is ISO 9001:2015 certified for design, development and manufacturing of preformed thermoplastic. Quality, value and long-term performance are built into the marking. Anti-skid elements are added at time of manufacturing for optimized application at the jobsite.

Whether a basic two-color directional message or a multi-colored custom logo, each design begins with a CAD drawing linked to a stringent manufacturing process. At the time of installation, the applicator will find pre-cut sheets of interconnected material with application instructions and a diagram for proper layout. The sheets of DecoMark® material are easily lifted and positioned onto an asphalt or concrete surface for application with a propane heat torch or large heater.

STANDARD COLORS

COLONIAL BRICK	BRICK RED	DARK BRICK RED	COCOA	OLIVE GREEN	SYG	LEMON YELLOW
SALMON	HERITAGE RED	RED	GREEN	KELLY GREEN	LIGHT GREEN	YELLOW
CINNAMON	CHESTNUT	ORANGE	TEAL	LT. BLUE	SKY BLUE	LIGHT GREY
SAND	SIENNA	PINK	BLUE	BLACK	FIELD GREY	GREY
TAN	KHAKI	LILAC	PURPLE	TERRACOTTA	BURNT ORANGE	WHITE
SONOMA SAND	SANTA FE CLAY					

ENNIS-FLINT
The Mark of Traffic Safety®

TrafficScapes®

Surface Systems for Enhanced Safety

CROSSWALKS • MEDIANS • ISLANDS • ROUNDABOUTS • ENTRYWAYS • LOGOS

TrafficScapes® is a portfolio of preformed thermoplastic pavement marking materials engineered for durability, safety, and aesthetics for the streetscape and traffic calming market. Each product offers its own unique application and performance approach to streetscape projects where shared roadway safety and aesthetic appeal need to work in conjunction.

TrafficPatterns® by Ennis-Flint

INTERCONNECTED

TrafficPatternsLT® by Ennis-Flint

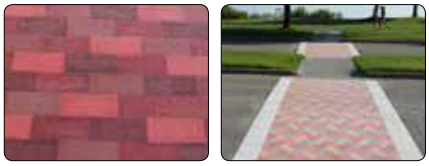
OVERLAY

DecoMark® by Ennis-Flint

SURFACE SIGNS

TrafficPatternsGF® by Ennis-Flint

GROUT FREE



TrafficPatternsXD® by Ennis-Flint

IMPRESSED

DuraTherm® by Ennis-Flint

INLAID

When used on public roadways and private properties open to public travel, decorative crosswalks require proper demarcation with white linear boundaries according to the Manual on Uniform Traffic Control Devices (MUTCD).

800.331.8118 • www.ennisflint.com • sales@ennisflint.com

7 STANDARD BENCH

mmcité
www.mmcite.com

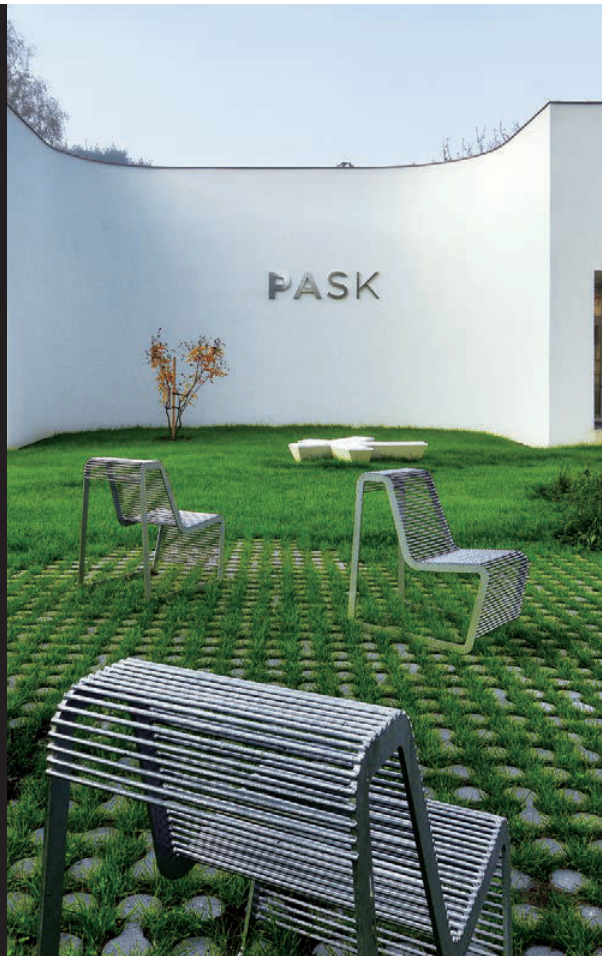
limpido

EN Fine but strong structure, made of steel rounds, contours an exquisite silhouette and creates a backed or backless bench. In the park, on a historical square or nearby any contemporary architecture, the transparent appearance of this bench excels.
Steel weldment treated with zinc coating and powder coating. Firmly ground-mounted.

FR La structure fine et solide en ronds d'acier enserre un profil aux formes élaborées, elle constitue le banc avec ou sans dossier. Dans un parc, sur une place historique ou près d'une architecture contemporaine, l'effet transparent et presque irréel de cette gamme va dominer.
Structure en acier galvanisé, thermolaqué suivant les coloris de la gamme. Fixation au sol robuste.

DE Die zarte aber zugleich robuste Struktur der Stahlrundstäbe folgt dem formschönen Profil und bildet eine exquisite Parkbank mit oder ohne Rückenlehne. Im Park, auf dem historischen Stadtplatz oder in der Nähe zeitgenössischer Architektur kommt der transparente, fast übersinnliche Effekt dieser Bankserie perfekt zur Geltung.
Verschweißte, verzinkte und mit Pulvereinbrennlack beschichtete Stahlkonstruktion. Fest im Boden verankert.

Design: Roman Vrtiška



152 153
limpido

$790 - $1,560 each

LLP205 / 226

mmcite.com

Park bench
Banc de parc
Parkbank

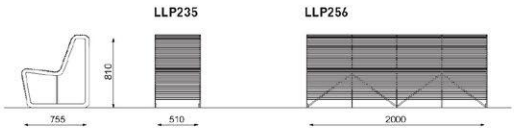
steel structure, seat made of steel rounds
structure en acier, assise en ronds d'acier
Stahlkonstruktion, Sitzfläche aus Rundstahl

LLP235 / 256

mmcite.com

Park bench with backrest
Banc de parc avec dossier
Parkbank mit Lehne

steel structure, seat and backrest made of steel rounds
structure en acier, assise et dossier en ronds d'acier
Stahlkonstruktion, Sitzfläche und Rückenlehne aus Rundstahl

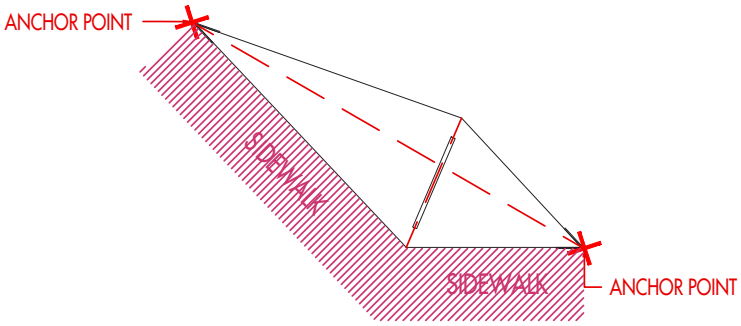


8 'W' BENCH

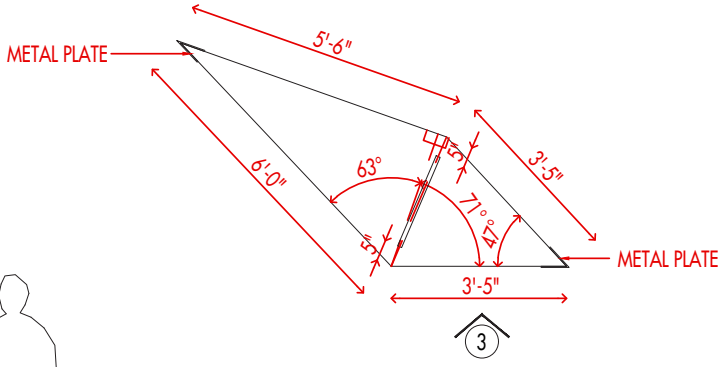
Cuellar Architecture USA, LLC | Natural Stone Custom Products
355 Alhambra Cir. Suite 1000, Coral Gables, FL 33132 | P:832.830.2747 | www.cuellarstone.com

1

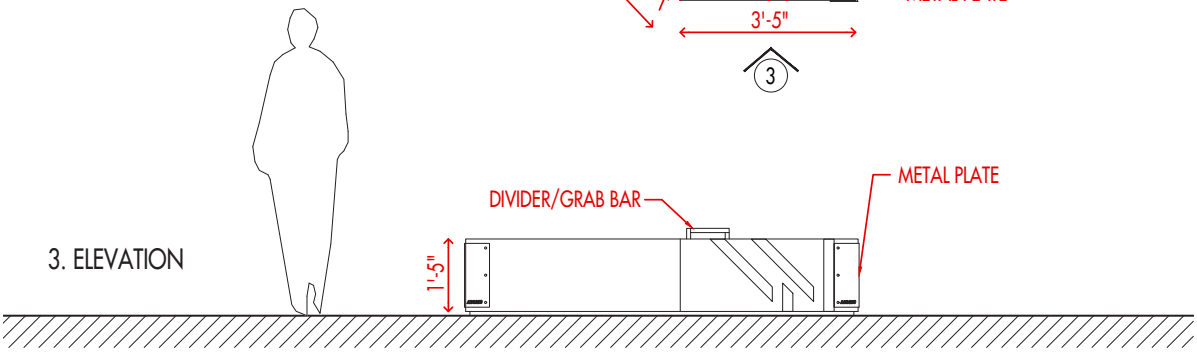
1. ORIENTATION PLAN



2. DIMENSIONS PLAN



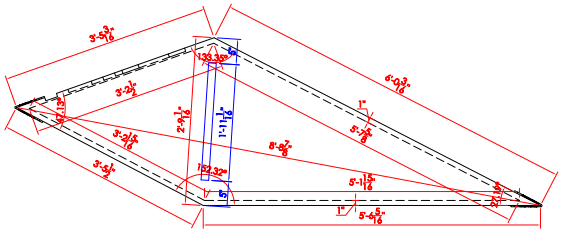
3. ELEVATION



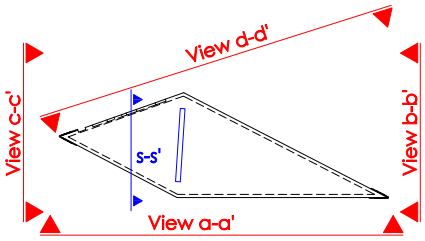
4. PERSPECTIVE

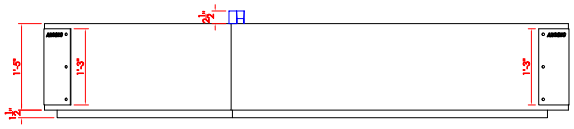
1

Order nº	WYNWOOD - CUSTOM BENCHES	Material: GRANITE	Finish: ROUGH SAND BL	Legend:	
Description	PLANS, VIEWS & DETAILS. BENCH 2	Draw nº: 02 Scale: S/E	Date: 11/10/2019	Visible face: ▶	Streak direction: ⤴

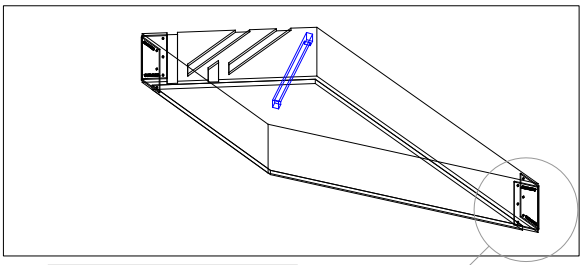


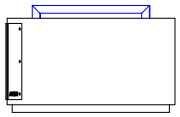
BENCH 01



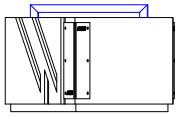


View a-a'

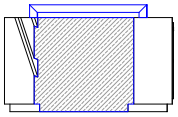




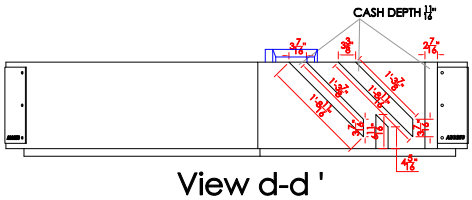
View b-b'



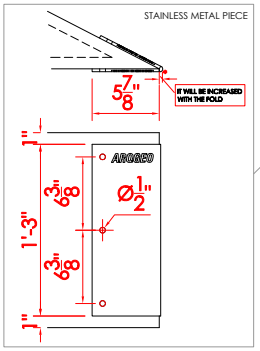
View c-c'



Section S-S'



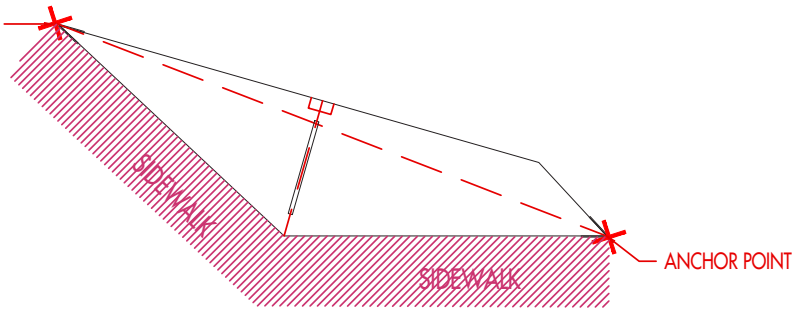
View d-d '



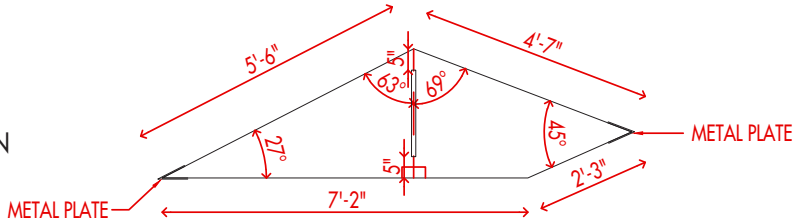
CUELLAR STONE 1958

2

1. ORIENTATION PLAN

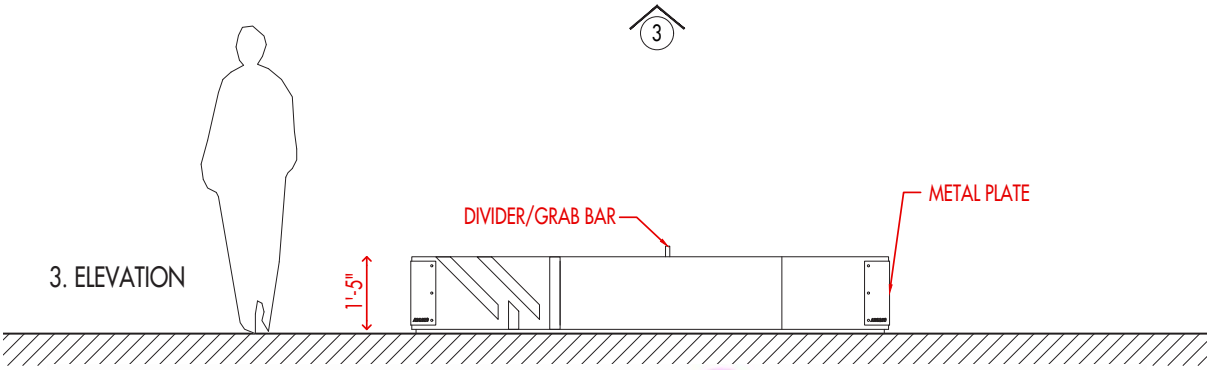


2. DIMENSIONS PLAN



3

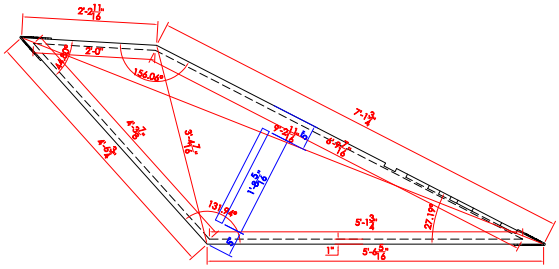
3. ELEVATION



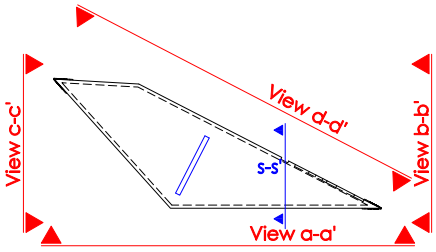
4. PERSPECTIVE

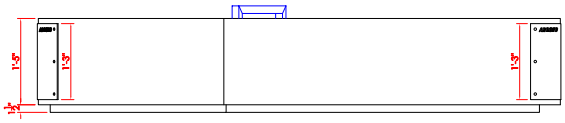
2

Order nº	WYNWOOD - CUSTOM BENCHES	Material: GRANITE	Finish: ROUGH SAND BL	Legend:
Description	PLANS, VIEWS & DETAILS. BENCH 3	Draw nº: 03 Scale: S/E	Date: 11/10/2019	Visible face: ▶ Streak direction: ⤴

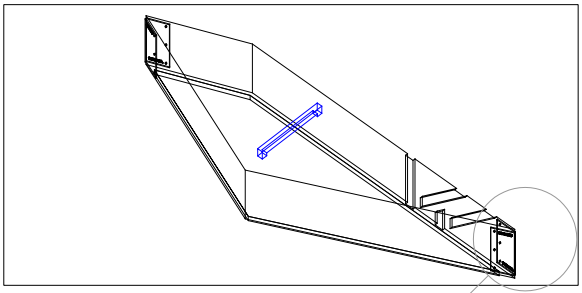


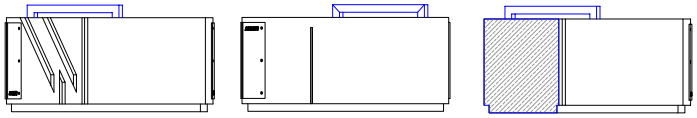
BENCH 02



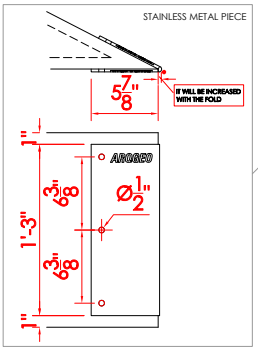


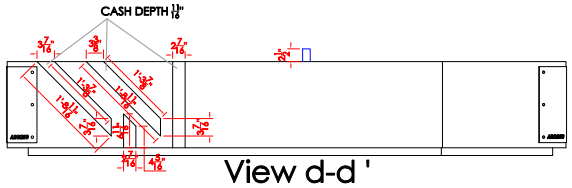
View a-a'





View b-b' View c-c' Section S-S'



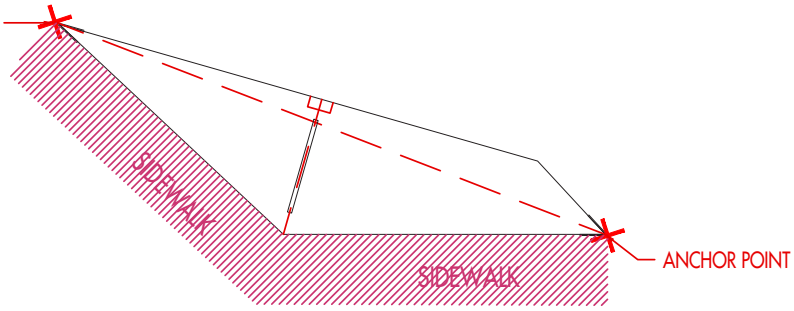


View d-d '

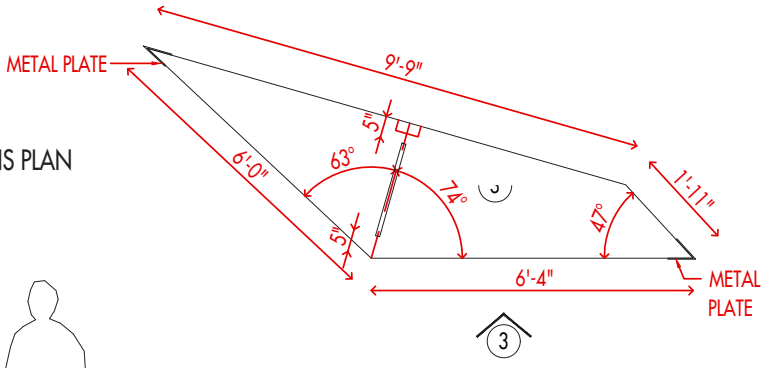
CUELLAR STONE 1958

3

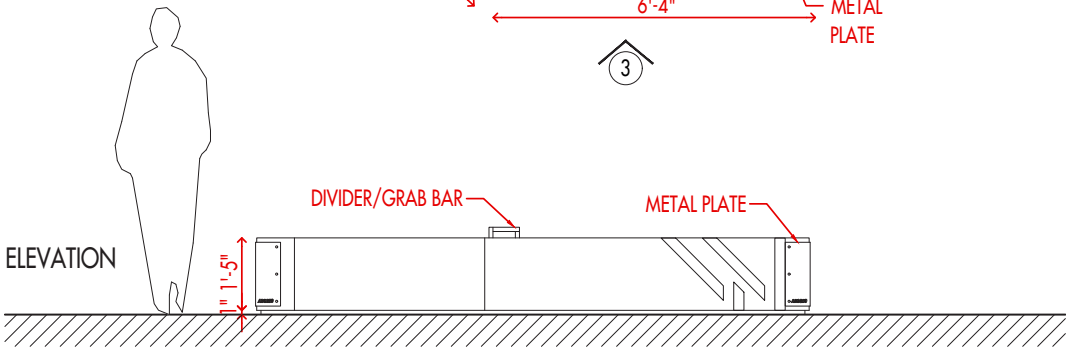
1. ORIENTATION PLAN



2. DIMENSIONS PLAN



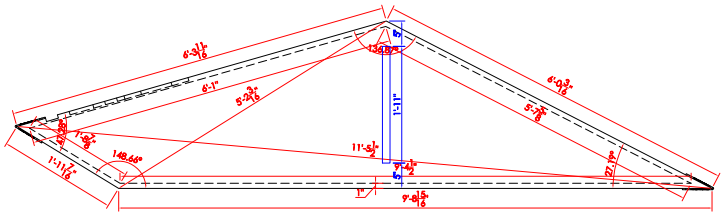
3. ELEVATION



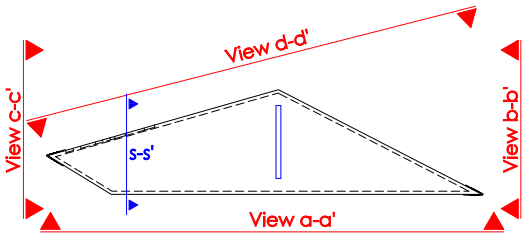
4. PERSPECTIVE

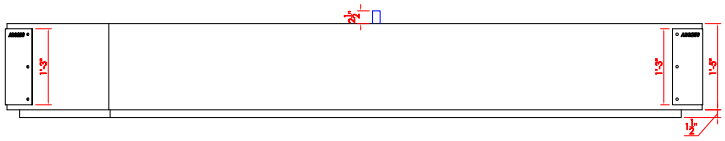
3

Order nº	WYNWOOD - CUSTOM BENCHES	Material: GRANITE		Finish: ROUGH SAND BL	Legend:
Description	PLANS, VIEWS & DETAILS. BENCH 1	Draw nº: 01	Scale: S/E	Date: 11/10/2019	Visible face: ▶ Streak direction: ⤴

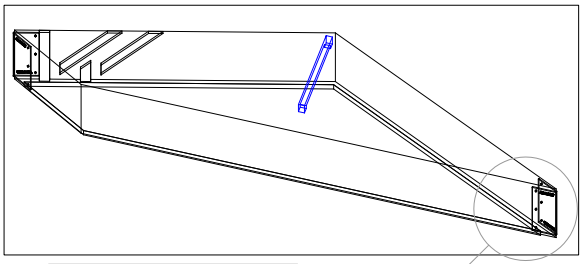


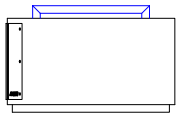
BENCH 03



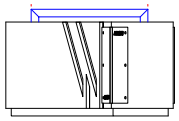


View a-a'

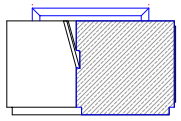




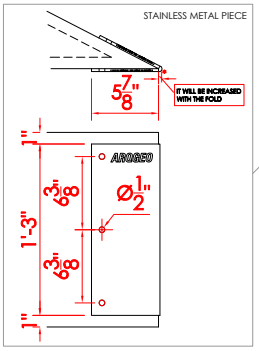
View b-b'

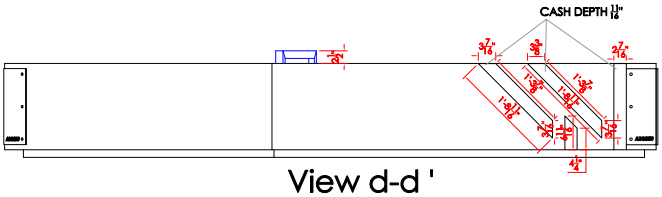


View c-c'



Section S-S'





View d-d '

CUELLAR STONE 1958

9 STANDARD LITTER RECEPTACLE

Architectural Products + Site Furnishings | Manufacturer
P:786.574.8109 | www.architecturalproducts.p-ls.com

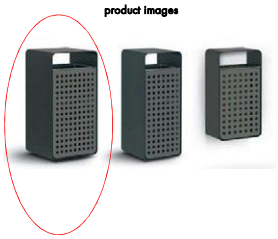
architectural products
a division of Power & Lighting Systems, Inc.
site furnishings

https://www.architecturalproducts.p-ls.com/

PRODUCT & MATERIAL DATA

WYNWOOD STREETSCAPE MASTER PLAN SITE FURNISHINGS
prepared for ARQUITECTONICA GEO attn. Ana Faria-Delfino
PRICING VALID UNTIL 12/19/19

prepared by **sheryl sinclair** | 786-574-8109 | **ssinclair@p-ls.com**

product images	type	qty	product description	unit cost	
		**	METALCO 0024684 BOX IRON LITTER RECEPTACLE WITH POWDER COATED STEEL SIDES & POWDER COATED PERFORATED DETAIL ON DOOR & BACK SIDES 135lt/ 36 gallon capacity *METALCO'S BOX IRON Litter Receptacle, Designed by Staubach & Kuckertz, is made of a robust sheet metal structure & features a perforated door detail with a spring steel blade slam-lock opening mechanism. Equipped with steel ring to secure inner waste liner. Custom graphics available (Serigraphy or Adhesive Stickers, not included)*	$1,892.00	**

PRODUCT & MATERIAL NOTES FOR METALCO BOX IRON LITTER RECEPTACLES

1. Unit pricing includes TRI-PLEX Zinc Primer for Powder Coated Steel & ANTI-GRAFFITI Treatment
2. See BOX SOLID Data Sheet & Drawings
3. See RAL Color Selections for POWDER COATED Steel ('Wrinkle" or 'Sable' finish included; Matt or Glossy Finish + 5% surcharge; Custom RAL $400.00 flat fee)
4. Select RAL for Door & Back & RAL for Sides (1 or 2 RAL selections included)
5. See BOX Litter Receptacle Installation Data
6. Also available in Wall Mounted 50lt & 100lt capacities
7. Unit pricing does not include freight

12-16 WEEK LEAD TIME ON STANDARD PRODUCTS UPON RECEIPT OF PURCHASE ORDER & SUBMITTALS

ADDITIONAL NOTES

PROVIDED BY OTHERS UNLESS OTHERWISE NOTED: RECEIPT/UNLOADING OF MATERIALS, PREVAILING WAGES, PERMITS, STATE OR LOCAL APPROVALS, PERFORMANCE BONDS, ENGINEERING, TESTING, SITE PREPARATION, BORDERS, SAFETY SURFACING, STORAGE, SECURITY OF MERCHANDISE OR EQUIPMENT, LANDSCAPING, MECHANICAL EQUIPMENT

UNLESS NOTED, UNIT PRICING DOES NOT INCLUDE SALES TAX

OCEAN AND/OR AIR FREIGHT NOT INCLUDED IN UNIT PRICING

PAYMENT TERMS

50% DEPOSIT REQUIRED WITH PURCHASE ORDER. BALANCE DUE UPON RELEASE OF ORDER FROM METALCO TO FREIGHT CARRIER

PAYABLE TO:

PRECISION OUTDOOR LIGHTING
attn. Architectural Products Division | Sheryl Sinclair
3832 SHIPPING AVENUE
MIAMI, FL 33146

DELIVERY NOTES

AT TIME OF DELIVERY, ALL APPARENT DAMAGE MUST BE NOTED BY THE RECIPIENT ON DELIVERY RECEIPT & ACKNOWLEDGED BY FREIGHT CARRIER'S AGENT FOR THE SUBMITTAL OF VALID FREIGHT CLAIMS & PRODUCT REPLACEMENT

REMOVE ALL PLASTIC WRAPPING & PACKAGING WITHIN 24 HOURS OF DELIVERY TO PREVENT TRAPPED CONDENSATION ON MATERIAL SURFACES, WHICH COULD CAUSE IRREPARABLE DAMAGE TO FINISHES

CONTACT

Sheryl Sinclair, Division Manager | 786-574-8109 | ssinclair@p-ls.com

BOX IRON

STAUBACH & KUCKERTZ

The Box Iron litter bin, is made of a powder coated steel frame with a perforated powder coated steel door, and is opened via a spring steel blade slam-lock. The litter bin is equipped with a steel ring to hold a waste bag.

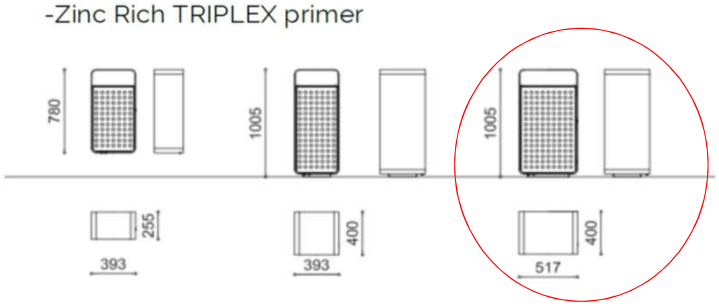
MATERIAL & FINISH
-Powder Coated Steel

DIMENSIONS
-393x255mm H=780mm
-393x400mm H=1005mm
-517x400mm H=1005mm

CAPACITY
-50lt
-100lt
-135lt

FOOTING
-Surface Mount (Anchors Not Supplied)
-Wall Mount (50lt only)

OPTIONS
-Anti-Graffiti Treatment
-Zinc Rich TRIPLEX primer



metalco id

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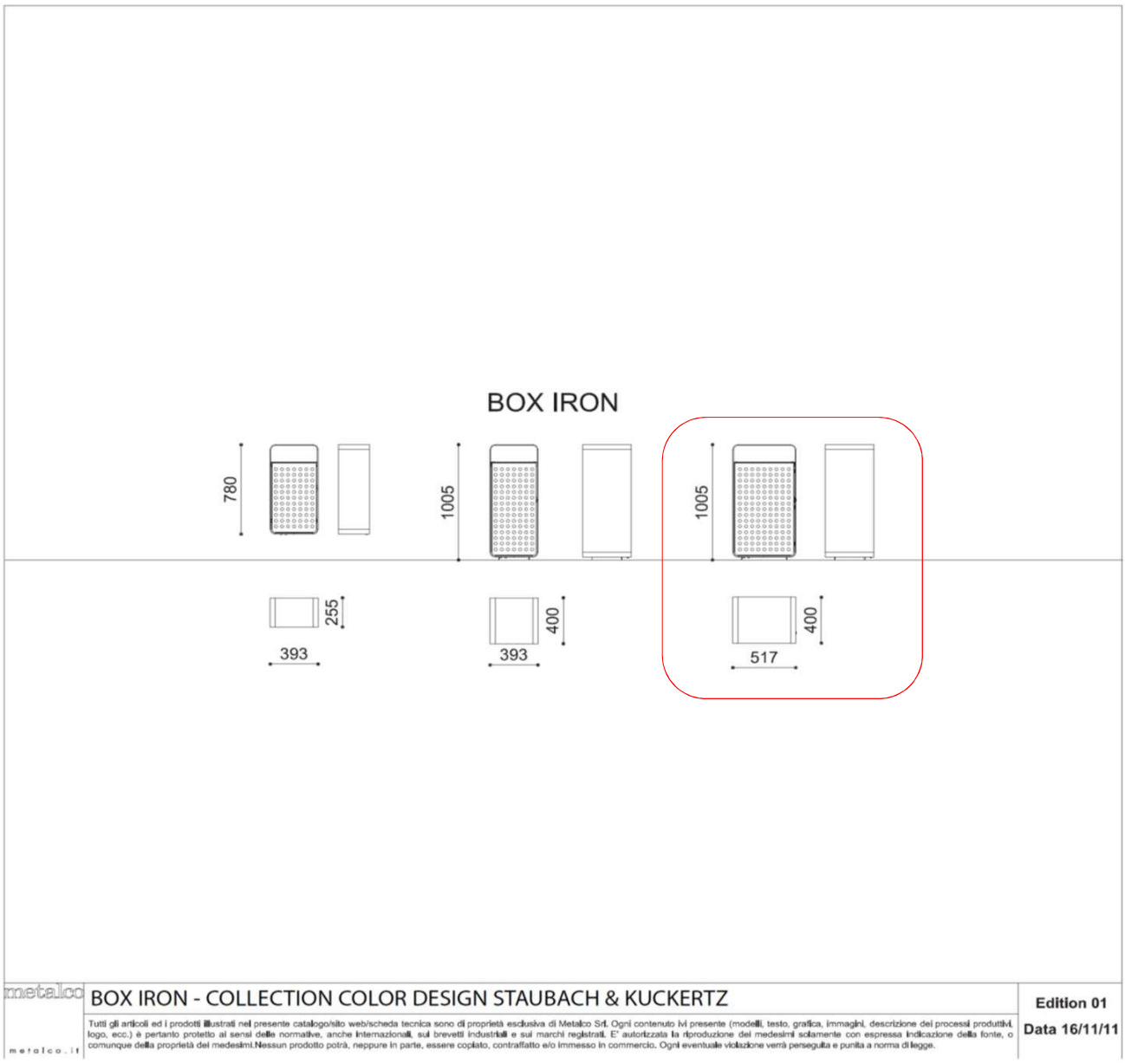
BOX IRON
780
1005
1005
255
400
400
393
393
517
metalco
metalco.it
BOX IRON - COLLECTION COLOR DESIGN STAUBACH & KUCKERTZ
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Edition 01
Data 16/11/11

Powder Coated Steel and Aluminum

Galvanization on steel

For coated steel products, Metalco uses alternatively three galvanizing systems:

- hot-dip galvanizing
- sendzimir galvanization
- cold galvanization

Metalco selects the galvanizing system most suitable for the thickness and/or shape and/or manufacturing process of each article.

Coating on steel and aluminum

1. Preparation (Sandblasting or manual sanding)
2. Alkaline degreasing
3. Rinsing with water system
4. Rinsing with demineralized water
5. Passivation film-forming
6. Drying with hot air 160°C
7. Application of epoxy primer zinc*
8. Polymerization in the over 185°C*
9. Cooling*
10. Application of electrostatic pure powder polyester
11. Polymerization in the oven 185°C
12. Cooling
13. Final Test

(*) only on request and/or on cast iron components.

Metalco's standard treatment is polyester powder coated paint with a wrinkled matte effect. Only on request, if it's possible, products can be coated with a glossy finish for an additional charge.

Wrinkled Finish (With different levels of embossing)

Sable Finish (Subject to price surcharge)

These images are merely indicative; please refer to physical sample.

The reproduction of colors on computer monitors and in print is not a true RAL match. To compare the relative RAL colors use a commercial RAL card.

It is very important to follow the manufacturer's **"Care and Maintenance"** guide to retain your product's warranty. In case of any doubt about the proper maintenance procedure, please contact id created, Inc. for support.

metalco id

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877.690.7755
info@idcreated.com
idcreated.com

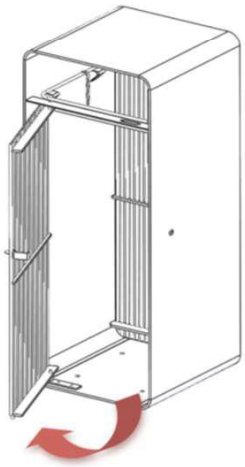
metalco GROUP	**MOUNTING INSTRUCTIONS** **BOX LITTER BIN**	

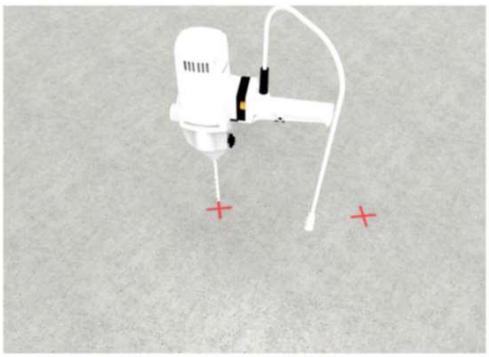
To mount the BOX litter bin you will need the following tools:

1. Hammer drill with plug drill for concrete: diam. 8 / 10 mm
2. Iron hammer
3. Hex wrenches
4. Triangular key supplied

You will use the following screws:

- (4) anchors M8 or M10 x 100/120mm



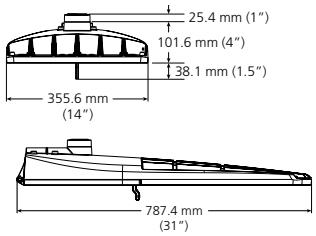


1. Place the litter bin and open the door with the supplied key.
2. Make four holes with the hammer drill in correspondence to the base holes for M8 or M10 anchors.
3. Double check alignment and insert the M8/M10 anchors in the holes.
4. Re-close the door.

10 STANDARD TYPE 1 ROADWAY LIGHT POST

Florida Power and Light Catalogue | AEL - American Electric Lighting
www.americanelectriclighting.acuitybrands.com

FPL CATALOGUE SELECTION



Effective Projected Area (EPA)
The EPA for the ATB2 is 0.78 sq. ft.,
Approx. Wt. = 21 lbs. (9.53 kg)

MANUFACTURER	AEL
PRODUCT	ATB2
COLOR	Gray
POLE OPTIONS	6 & 7
LIGHT PATTERN	4

Standard
Concrete

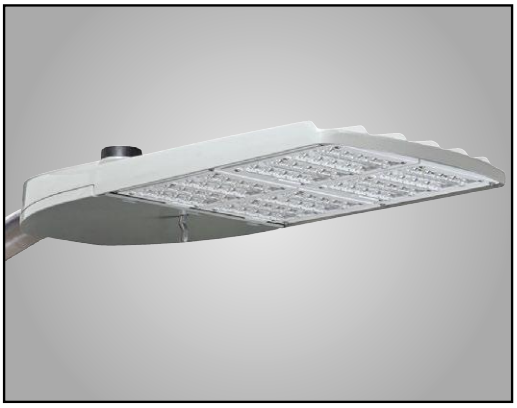
7

Arm Mount
30' (22'6" MH)
35' (27'6" MH)
40' (30'" MH)
45' (35' MH)

Autobahn Series ATB2
Roadway Lighting

Consistent with LEED® goals & Green Globes™ criteria for light pollution reduction

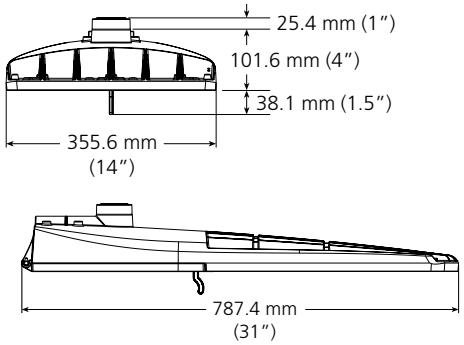
PRODUCT OVERVIEW



Applications:

Roadways
Off ramps
Residential streets
Parking lots

DIMENSIONS



Effective Projected Area (EPA)
The EPA for the ATB2 is 0.78 sq. ft.,
Approx. Wt. = 21 lbs. (9.53 kg)

STANDARDS

DesignLights Consortium® (DLC) qualified product. Not all versions of this product may be DLC qualified. Please check the DLC Qualified Products List at www.designlights.org/QPL to confirm which versions are qualified.

Color temperatures of ≤ 3000K must be specified for International Dark-Sky Association certification.

Rated for -40°C to 40°C ambient.
CSA Certified to U.S. and Canadian standards
Complies with ANSI: C136.2, C136.10, C136.14, C136.31, C136.15, C136.37

Features:

OPTICAL

Same Light: Performance is comparable to 250-400W HPS roadway luminaires.

White Light: Correlated color temperature - 4000K, 70 CRI minimum, 3000K, 70CRI minimum or optional 5000K, 70 CRI minimum.

Unique IP66 rated LED light engines provided 0% uplight and restrict backlight to within sidewalk depth, providing optimal application coverage and optimal pole spacing.

Available in Type II, III, IV, & V roadway distributions.

ELECTRICAL

Expected Life: LED light engines are rated >100,000 hours at 25°C, L70. Electronic driver has an expected life of 100,000 hours at a 25°C ambient.

Lower Energy: Saves an average of 40-60% over comparable HPS platforms.

Robust Surge Protection: Three different surge protection options provide a minimum of ANSI C136.2 10kV/5kA protection. 20kV/10kA protection is also available.

MECHANICAL

Easy to Maintain: Includes standard AEL lineman-friendly features such as tool-less entry, 3 station terminal block and quick disconnects. Bubble level located inside the electrical compartment for easy leveling at installation.

Rugged die-cast aluminum housing is polyester powder-coated for durability and corrosion resistance. Rigorous five-stage pre-treating and painting process yields a finish that achieves a scribe creepage rating of 7 (per ASTM D1654) after over 5000 hours exposure to salt fog chamber (operated per ASTM B117).

Four-bolt mast arm mount is adjustable for arms from 1-1/4" to 2" (1-5/8" to 2-3/8" O.D.) diameter and provides a 3G vibration rating per ANSI C136.

Wildlife shield is cast into the housing (not a separate piece).

CONTROLS

NEMA 3 Pin photocontrol receptacle is standard, with the Acuity designed ANSI 7 Pin receptacle optionally available.

Premium solid state locking sale photocontrol - PCSS (10 year rated life). Extreme long life sold state locking style photocontrol - PCLL (20 year rated life).

Mulit-level dimming available to provide scheduled dimming as specified by the customer.

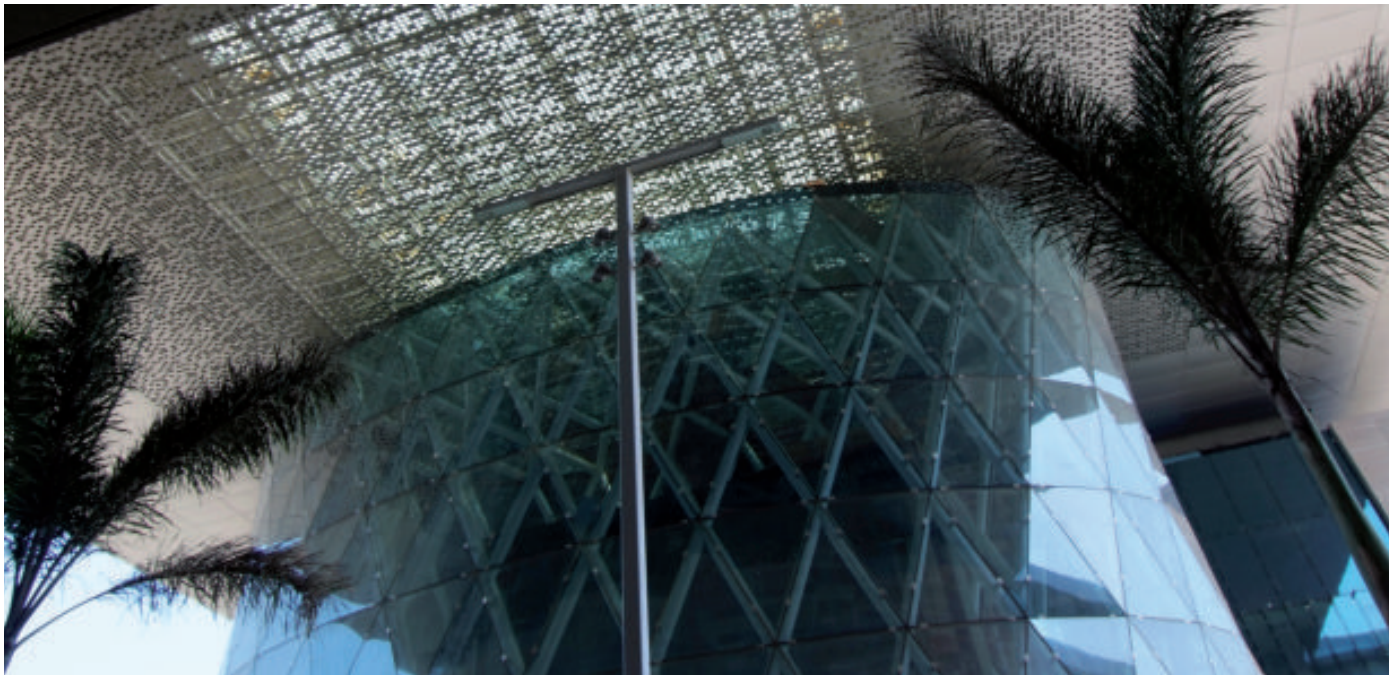
Optional onboard Adjustable Output module allows the light output and input wattage to be modified to meet site specific requirements, and can also allow a single fixture to be flexibly applied in many different applications.

Note: Specifications subject to change without notice.

11 STANDARD TYPE 2 PEDESTRIAN LIGHT POST

Hess America | Lighting Manufacturer
P: 864.487.3535 | www.hessamerica.com

BLACK MATTE



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Leuven . Belgium

LINEA

LINEA

149

LINEA

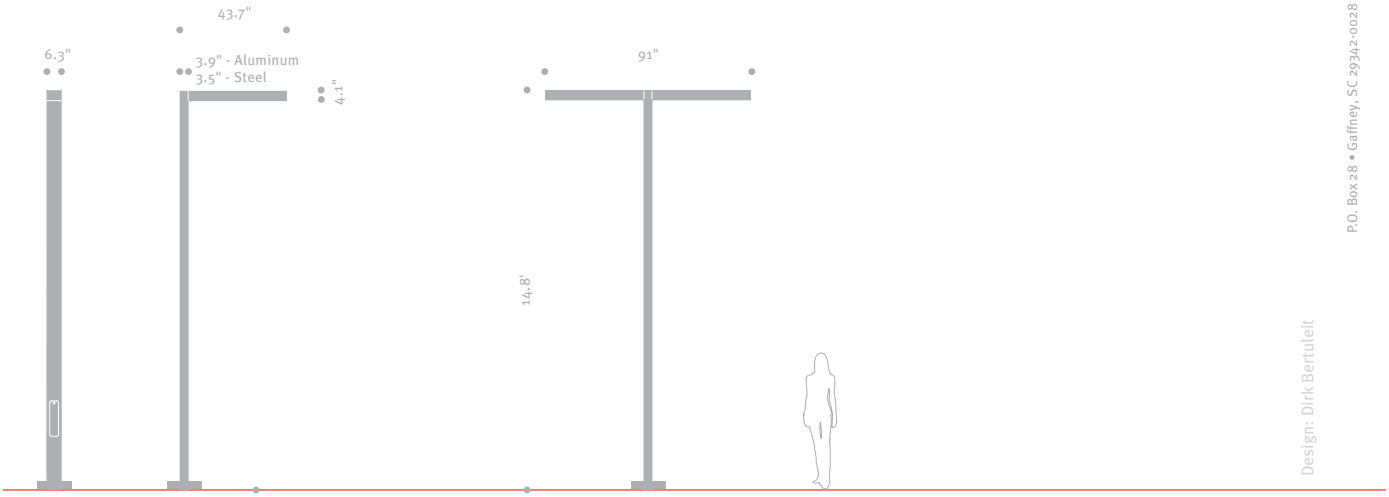
www.hessamerica.com

Phone: 864.487.3535 • Fax: 864.487.3175 • www.hessamerica.com
P.O. Box 28 • Gaffney, SC 29342-0028

L I N E A 4 5 0 . Pole Mounted Luminaire

LINEA´s minimalist profile adds subtle accent to contemporary architecture. It is available in single, twin, or bi-level mounting configurations to meet a variety of site, area, or pathway lighting requirements. Rectangular luminaire fabricated from extruded aluminum transitions seamlessly to the pole with matching rectangular profile. Frameless clear tempered glass lens with single quarter-turn fastener provides tool-less access for relamping. Optional matte glass lens is available on request. Straight rectangular pole is available in aluminum or steel. Steel pole is hot-dip galvanized prior to being finished in finely textured paint. All hardware is stainless steel. Standard colors; matte silver grey metallic or graphite grey. Special colors available. CSA certified for Wet Locations.

Model	Pole	Lamp
LN450	15' Straight Rectangular	LED / 150 MH / 70 MH



LN450

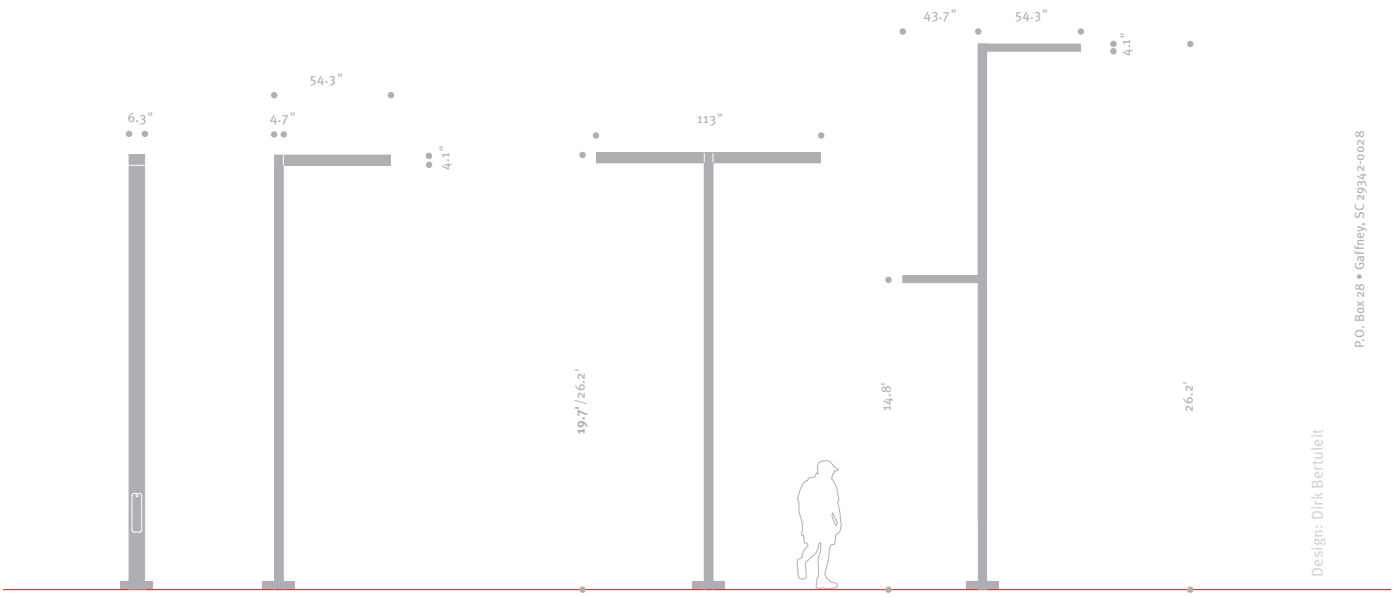
Design: Dirk Bertuleit

LINEA

Phone: 864.487.3535 • Fax: 864.487.3175 • www.hessamerica.com
P.O. Box 28 • Gaffney, SC 29342-0028

LINEA 600/800. Pole Mounted Luminaire

Model	Pole	Lamp
LN600	20' Straight Rectangular	LED / 150 MH / 70 MH
LN800	26' Straight Rectangular	LED / 150 MH / 70 MH
LN800	26' Bi-Level Straight Rectangular	LED / 150 MH / 70 MH



Design: Dirk Bertuleit

12 STANDARD TYPE 3 PEDESTRIAN LIGHT POST

Landscape Forms | Designer/Manufacturer
P: 800.521.2546 | www.landscapeforms.com

BLACK MATTE

landscapeforms®

ARNE

Product Data Sheet

Arne's formal simplicity has international appeal and complements both traditional and contemporary architecture. Inspired by the work of renowned Danish architect and designer Arne Jacobsen, Arne offers multiple functions and styles for a range of applications. This versatile luminaire can be wall mounted, suspended from a cable for catenary applications, or fixed to a pole or column. Arne provides full 360° rotation and tilt capabilities to efficiently light all aspects of the environment, from walkways and architectural structures, to monuments and landscapes.

General Description

- Pole, catenary, or wall mounting options
- Pole and wall mount brackets provide tilt and roll capabilities
- Offered in 5 standard pole heights (4.2m, 5.0m, 5.8m, 7.6m, 9.2m)
- Poles for catenary applications can be custom engineered for each project (cable not included)
- Available in 18 and 36 LED configurations
- Multiple drive currents and distribution types
- Mounting template and anchor hardware included
- Zero up-light, International Dark-Sky approved
- UL Listed, suitable for wet locations

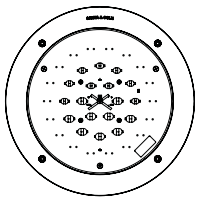
Electrical

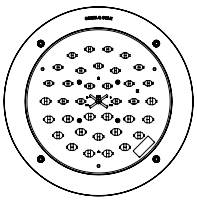
120V-277V 50/60 Hz, Class 2 integrated dimmable driver. 1-10V dimming interface is standard, DALI compatible dimming interface available upon request. Arne ships prewired and fully assembled. Reference the installation guide for the wiring diagram and other electrical support information.

Arne

Housing: Die-cast aluminum
Lens: Tempered glass (clear or opal / diffused)
Light Source: 18/36 Cree XPG2 LEDs
Color Temperature: 3000K, 4000K
Power Supply: 120V-277V
Dimming: 1-10V (DALI available upon request)
Protection Class: IP66
Weight: 18 lbs (luminaire only)
EPA: .577 ft^2

LED Configurations





Distributions

Wideflood

Flood

Medium

Spot

TII+II

TII

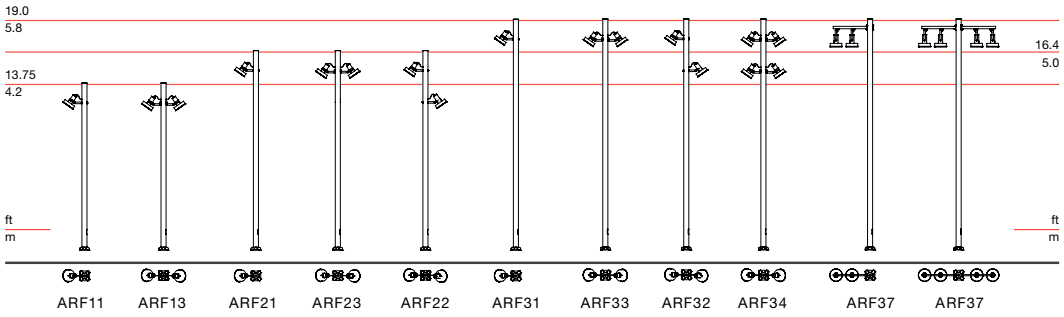
TIII

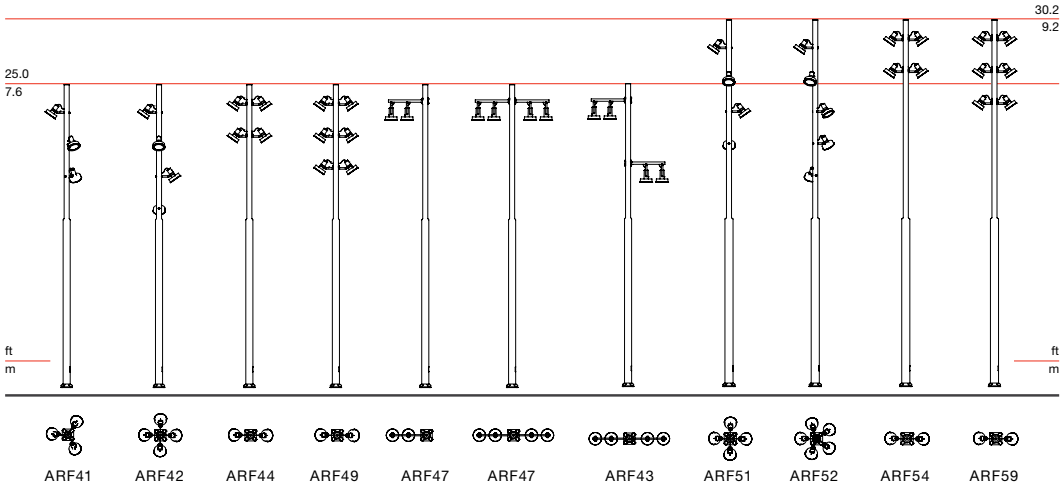
TIV

landscapeforms®

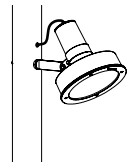
ARNE

Product Data Sheet

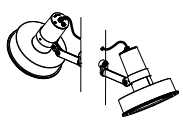




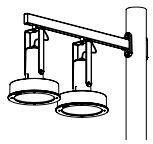
Arne Column Mount



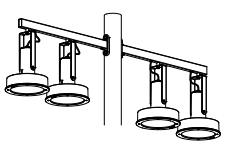
Single Column



Double Column

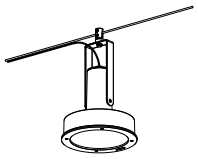


Single Arm

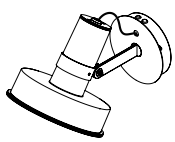


Double Arm

Arne Catenary Mount



Arne Wall Mount



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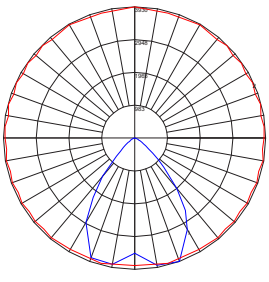
Product Data Sheet

Performance Data for Flood Distributions

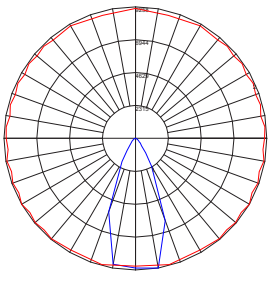
						Wide Flood (WF) *NEMA Type 6H x 6V*		Flood (F) *NEMA Type 5H x 5V*		Medium (M) *NEMA Type 4H x 4V*	
Model	**Lamp Power**	**System Power**	**LED Quantity**	**CCT**	**Drive Current**	**Lumens***	**Efficacy***	**Lumens***	**Efficacy***	**Lumens***	**Efficacy***
ARP18A1xx	18	22	18	3000K 80 CRI	350	2211	100	2385	108	2331	106
ARP18B1xx	26	32			500	3115	97	3361	105	3284	103
ARP18C1xx	36	42			700	4033	96	4352	104	4252	101
ARP18A2xx	18	22		4000K 70 CRI	350	2608	119	2814	128	2750	125
ARP18B2xx	26	32			500	3675	115	3966	124	3875	121
ARP18C2xx	36	42			700	4759	113	5135	122	5017	119
ARP36A1xx	36	40	36	3000K 80 CRI	350	4186	105	4517	113	4413	110
ARP36B1xx	51	59			500	5805	98	6264	106	6120	104
ARP36C1xx	72	85			700	7517	88	8111	95	7925	93
ARP36A2xx	36	40		4000K 70 CRI	350	4939	123	5329	133	5207	130
ARP36B2xx	51	59			500	6849	116	7391	125	7221	122
ARP36C2xx	72	85			700	8869	104	9570	113	9350	110

*Apply 0.925 multiplier for opal / diffused lens option.

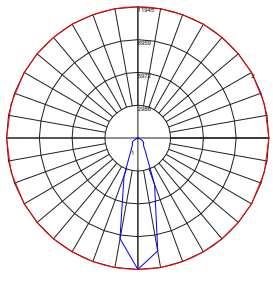
Wide Flood (WF)
Beam Angle 75H x 75V



Flood (F)
Beam Angle 45H x 45V



Medium (M)
Beam Angle 35H x 35V



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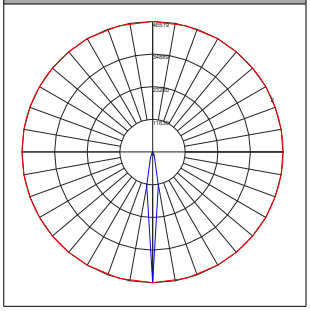
Product Data Sheet

Performance Data for Flood Distributions (cont.)

						Spot (S) *NEMA Type 3H x 3V*	
Model	**Lamp Power**	**System Power**	**LED Quantity**	**CCT**	**Drive Current**	**Lumens***	**Efficacy***
ARP18A1xx	18	22	18	3000K 80 CRI	350	2287	104
ARP18B1xx	26	32			500	3223	101
ARP18C1xx	36	42			700	4174	99
ARP18A2xx	18	22		4000K 70 CRI	350	2699	123
ARP18B2xx	26	32			500	3803	19
ARP18C2xx	36	42			700	4924	117
ARP36A1xx	36	40	36	3000K 80 CRI	350	4331	108
ARP36B1xx	51	59			500	6007	102
ARP36C1xx	72	85			700	7778	92
ARP36A2xx	36	40		4000K 70 CRI	350	5110	128
ARP36B2xx	51	59			500	7087	120
ARP36C2xx	72	85			700	9177	108

*Apply 0.925 multiplier for opal / diffused lens option.

Spot (S)
Beam Angle 15H x 15V



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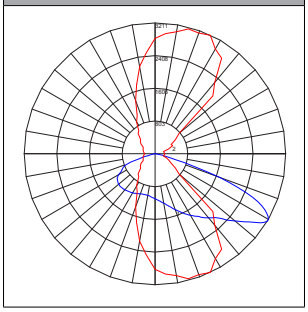
Product Data Sheet

Performance Data for Asymmetrical Distributions

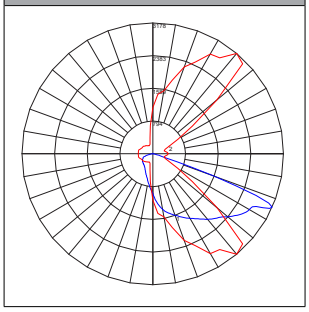
						Type II (TII) *IES Type II*		Type III (TIII) *IES Type III*		Type IV (TIV) *IES Type IV*	
Model	**Lamp Power**	**System Power**	**LED Quantity**	**CCT**	**Drive Current**	**Lumens***	**Efficacy***	**Lumens***	**Efficacy***	**Lumens***	**Efficacy***
ARP18A1xx	18	22	18	3000K 80 CRI	350	2114	96	1991	90	2036	93
ARP18B1xx	26	32			500	2980	93	2805	88	2869	90
ARP18C1xx	36	42			700	3858	92	3632	86	3714	88
ARP18A2xx	18	22		4000K 70 CRI	350	2495	113	2349	107	2402	109
ARP18B2xx	26	32			500	3516	110	3310	103	3384	106
ARP18C2xx	36	42			700	4552	108	4286	102	4382	104
ARP36A1xx	36	40	36	3000K 80 CRI	350	4004	100	3770	94	3855	96
ARP36B1xx	51	59			500	5553	94	5228	89	5346	91
ARP36C1xx	72	85			700	7190	85	6769	80	6922	81
ARP36A2xx	36	40		4000K 70 CRI	350	4724	118	4448	111	4548	114
ARP36B2xx	51	59			500	6552	111	6168	105	6307	107
ARP36C2xx	72	85			700	8483	100	7987	94	8167	96

*Apply 0.925 multiplier for opal / diffused lens option.

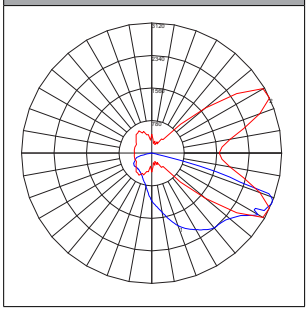
Type II (TII)
IES Type II



Type III (TIII)
IES Type III



Type IV (TIV)
IES Type IV



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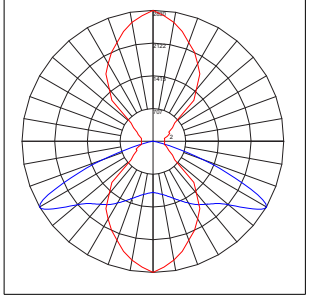
Product Data Sheet

Performance Data for Asymmetrical Distributions (cont.)

						Type II + II --	
Model	**Lamp Power**	**System Power**	**LED Quantity**	**CCT**	**Drive Current**	**Lumens***	**Efficacy***
ARP18A1xx	18	22	18	3000K 80 CRI	350	2114	96
ARP18B1xx	26	32			500	2980	92
ARP18C1xx	36	42			700	3858	92
ARP18A2xx	18	22		4000K 70 CRI	350	2495	113
ARP18B2xx	26	32			500	3516	110
ARP18C2xx	36	42			700	4552	108
ARP36A1xx	36	40	36	3000K 80 CRI	350	4004	100
ARP36B1xx	51	59			500	5553	94
ARP36C1xx	72	85			700	7190	85
ARP36A2xx	36	40		4000K 70 CRI	350	4724	118
ARP36B2xx	51	59			500	6552	111
ARP36C2xx	72	85			700	8483	100

*Apply 0.925 multiplier for opal / diffused lens option.

Type II + II
Beam Angle 90H x 60V



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ARNE

Product Data Sheet

Finish

The Arne luminaire is aluminum extrusion with a natural aluminum powdercoat finish offered by Santa & Cole. The Pangard II® powdercoat finish on poles is offered exclusively by Landscape Forms. Reference the materials sheet for additional information.

Product Modifications

Don't see what you are looking for? Our goal is to partner with you as the designer to manufacture solutions needed for the space you are creating. We offer the option to modify our standard product to meet certain design specifications or needs. Contact your local Landscape Forms representative to learn more about these offerings.

Product Specifications

Ready to place an order or receive a quote for your project? Reference the Arne specification sheet available here.

Warranty

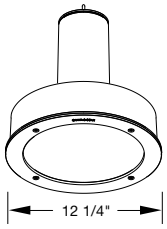
Santa & Cole guarantees the composition and performance features of all material that shape the product for a period of three years. Electrical components including LED boards and electronic drivers are guaranteed for a period of five years.

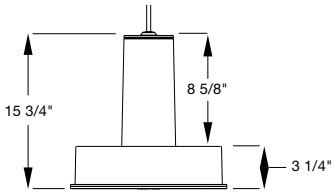
Other

UL Listed, CE, RoHS Compliant, Dark-Sky Approved

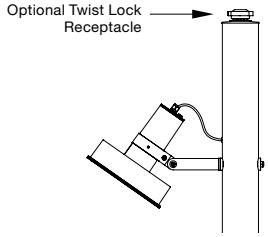
3000K and warmer

Arne is designed by Santa & Cole Urbidermis

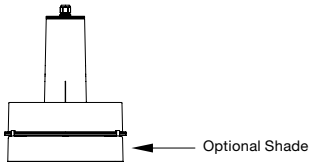




Twist Lock Receptacle



Accessory



Landscape Forms, Inc. | 800.521.2546 | F 269.381.3455 | 7800 E. Michigan Ave., Kalamazoo, MI 49048

13 STANDARD BIKE RACK

mmcité
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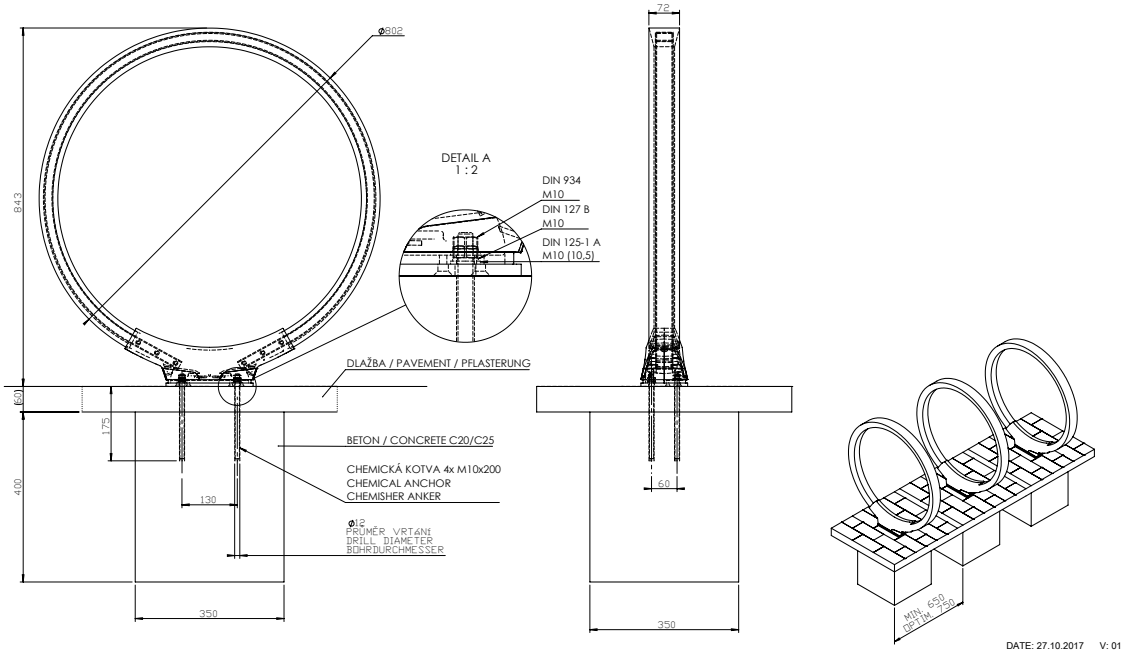
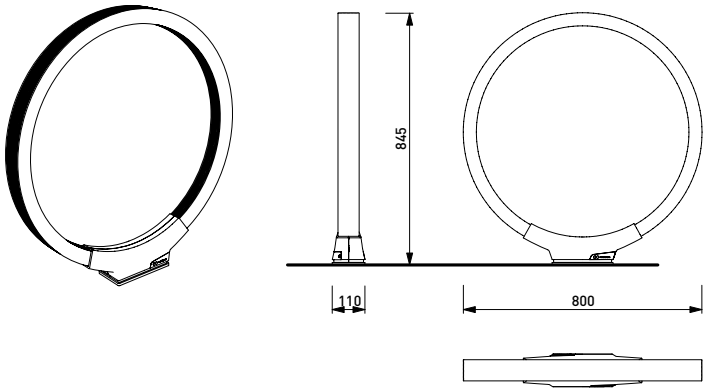


DATE: 27.10.2017 V: 01
minimal load-bearing capacity of the soil 150kPa
dimmensions in mm

GMZ110 - GOMEZ - FOUNDATION

mmcite.com

ILLUSTRATIVE PHOTO



DATE: 30. 10. 2017 V: 01
dimensions in mm

GMZ110 - GOMEZ

Rozměry výrobků mají informativní charakter. Výrobce si vyhrazuje právo na změnu technické specifikace bez předchozího upozornění. Rozměry spodní stavby a způsob osazení výrobku jsou závazné. Rozteče kotev rozměřovat dle rozměrů dodaného výrobku.
All product sizes have an informative character. The producer reserves the right to amend the technical specification at any time without previous warning. The size of foundantion baseplate and the method of mounting of the product are imperative. Anchor spacing measure out by measurements of supplied product.
Die Abmessungen der Produkte sind informativ. Der Hersteller behält sich das Recht an Änderungen der technischen Spezifikationen vor, ohne vorher darauf hinzuweisen. Abmessungen der Fundamentierung – Unterbau und Art des Produkteinbaus sind verbindlich. Ankerabstand gemäß der gelieferten Produktabmessungen dimensionieren.
Dimensions des produits sont à titre informatif seulement. Le fabricant se réserve le droit de modifier les spécifications techniques sans préavis. Dimensions des fondations et manière de l'implantation du produit sont obligatoire. Ancre écartement dimensions à partir des dimensions du produit livré.
Las dimensiones de los productos tienen carácter informativo. El fabricante se reserva el derecho de cambio de la especificación técnica sin aviso previo. Tanto las dimensiones de las bases de cimentación como el sistema de fijación son inalterables. Hay que medir el espaciamiento de anclajes según las dimensiones del producto suministrado.

mmcite.com

Bicycle stand

Structure type:	aluminium alloy casts with a rubber hoop reinforced with steel profile.
Coating:	casts are treated with powder coating.
Body:	aluminium alloy casts.
	Total height approx. 840 mm, width 72 mm.
Colour options:	shades of polyester powder coatings in the fine matt finish, standardly provided by mmcité.
	Other shades according to the RAL color chart are available upon request.
Anchoring:	anchoring onto the paving or into concrete foundation using M10 threaded rods.
	All street furniture elements must be properly anchored according to the producer´s technical instructions. The manufacturer declines responsibility for any damages caused by careless use or by non-compliance with the instructions.
Weight:	GMZ110 12.5 kg
Option:	different than standard colour of aluminium cast.

DATE: 10.11.2017 V:01
TECHNICAL SPECIFICATIONS

GOMEZ GMZ110

mmcite.com

14 PARKLETS

Vestre | Designer/Manufacturer
175 Varick Street, New York, NY 10014 | P: 212.634.9658 | www.vestre.se

vestre

Parklets_2.0

$8,200 each

Parklets 2.0 urban flooring extends pavements and provides more free space for people and plants. The series consists of six complete modules which can quickly be placed in a street area, and moved if wished. The modules have adjustable feet, so they can be adapted to different situations and height levels. Parklets 2.0 is suitable for projects where former parking areas are to be converted into social zones.

Parklets 2.0 are free-standing, and can be positioned individually or joined together. The signature plates provide an even transition from existing pavements. The steel details are hot-dip galvanised (901) and designed for long-term use. Choose from nearly 200 different RAL colours for powder coating (900). All screws and fittings are supplied in acid-resistant or stainless steel.

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N-0801 Oslo
Norway
+47 23 00 78 40
+47 23 00 78 41
www.vestre.com
post@vestre.com

Vestre AB
Bergebyvägen 27
685 34 Torsby
Sweden
+46 (0)560 688877
+46 (0)560 10250
www.vestre.se
info@vestre.com

As standard, Parklets 2.0 come with high-quality, PEFC-certified pine from Scandinavia. Standard products in hot-dip galvanised, powder-coated steel are also available with wooden details in Kebony Radiata. Other types of wood are available on request.

Technical information

Models and combinations

Anchorage

F - Flexible

Materials and treatment

Timber

Pine treated with linseed oil
Kebony ®

Metal

901 Steel hot-dip galvanised
900 Powder-coated steel

RAL Colors

Designer recommends

- RAL-6011
- RAL-6021
- RAL-7003
- RAL-1023
- RAL-6034
- RAL-2009
- RAL-9002
- RAL-7015
- RAL-6002

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Bergebyvägen 27
685 34 Torsby
Sweden

+46 (0)560 688877
+46 (0)560 10250
www.vestre.se
info@vestre.com

15 CYCLE TRACK

ZICLA | Manufacturer
P: +34.932.242.731 | info@zicla.com | www.zicla.com

ZICLA®

Ramon Turró 100-104 ~ 4º 3ª
08005 Barcelona (Spa)

info@zicla.com
+34 932 242 731

zicla.com

Zebra® Cycle Lane Separator

Robust and innovative separator with reflective strips that give great visibility. Rounded form.

100% Recycled Plastic

Recycled PVC. Electrical cable sheathing, hoses, synthetic textiles.

Characteristics

High shock absorption.
Due to flexibility of the material and absence of sharp edges.

High mechanical strength.
Due to structure and design of the material, featuring a 3-point pavement anchor system.

High visibility day and night.
Due to retroreflective microspheres.

High resistance to weathering.
Due to the material used.

Made in.
EU

1st year of production.
2008

Design registration.
Ohim
000974142-0001
Ohim
002463877-0001/2/3
Turk Patent Institusu
2014 08314
The United States Copyright
TX 7-918-855
United States Design Patent
US D741, 739 S
Inapi Chile
D.I. 8.057
Argentina
92786
China
201730354160.0

Awards.
2009 Design for Recycling
PREMI
Best Recycled Product 2011. 2nd place.
epro
Certificates.
"Design for all, Good practice".

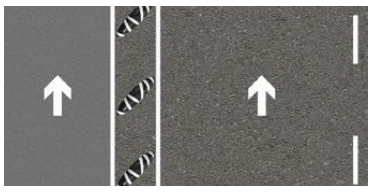
Eco-label.
DGQA.
The Emblem of Guarantee of Environmental Quality

CO_2 saving.
Compared to virgin material.
Zebra 5.
7.7 lb of CO_2 eq per unit
Zebra 9.
12.5 lb of CO_2 eq per unit
Zebra 13.
37.4 lb of CO_2 eq per unit

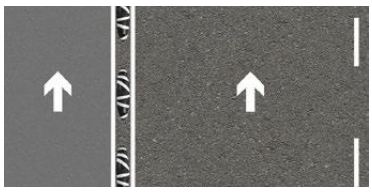
Carbon footprint.
1.5 lb of CO_2 eq per lb

Design.
Curro Claret

Positioning options

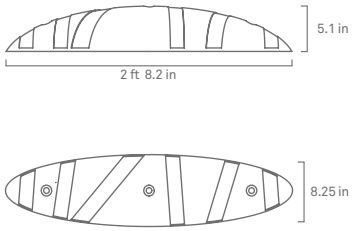


Oblique



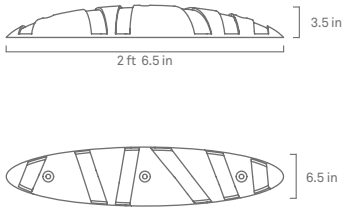
Parallel

Zebra 13



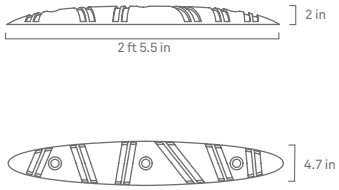
Weight	19 lb
Length	2 ft 8.2 in
Height	5.1 in
Width	8.25 in
Color	Black

Zebra 9



Weight	11 lb
Length	2 ft 6.5 in
Height	3.5 in
Width	6.5 in
Color	Black

Zebra 5



Weight	5 lb
Length	2 ft 5.5 in
Height	2 in
Width	4.7 in
Color	Black

Spacing between elements

Recommended spacing	Maximum spacing allowed
4.3 ft	8.6 ft

Spacing of over 8.6 feet between the separators poses a great risk for both cyclists and other road users.

Testing

Properties	Unit	Regulation	Value
Hardness	ShD	ASTM D2240	41
Tensile strength	MPa	ASTM D638	10.2
Elongation at break	%	ASTM D638	101
Tear resistance	kN/m	ASTM D624	27.2
Taber abrasion loss	mg/1,000 cycles	ASTM D4060	262
Lightfastness		ASTM G154	Excellent
Resistance to acids		ASTM D471	Excellent
Resistance to bases		ASTM D471	Excellent
Reaction to fire		UL94	V-0
Density	g/cm^3	ASTM D792	1.25

16 BIOSWALE MAINTENANCE PLAN

EPA
United States
Environmental Protection
Agency

Operation and Maintenance of Green Infrastructure Receiving Runoff from Roads and Parking Lots

Technical Memorandum

September 2016

Great Lakes RESTORATION

Funding for this project was provided by the Great Lakes Restoration Initiative administered by the United States Environmental Protection Agency—Great Lakes National Program Office.

This report was developed under EPA Contract No. EP-BPA-13-R5-0001 by Tetra Tech, Inc.

Operation and Maintenance of Green Infrastructure Receiving Runoff from Roads and Parking Lots
Technical Memorandum

Operation and maintenance is a challenge that when not addressed properly can lead to failure of green infrastructure and high costs associated with restoration. This memorandum addresses common operation and maintenance questions and provides recommendations for evaluating the need and providing maintenance for green infrastructure, specifically bioretention and bioswales, that serves highly impervious roadways and parking lots.

Green infrastructure (GI) involves the use of vegetation and porous materials to restore some of the natural processes required to treat stormwater runoff at the source. GI tends to have vegetation, be relatively small and distributed, and contain fewer structural components than more conventional stormwater practices. GI requires routine operation and maintenance to uphold the desired performance and aesthetic quality as well as ensure performance throughout its expected lifetime.

Runoff from roads and parking lots often contains high nutrient loads compared to other impervious surfaces and is also a source of sediment, heavy metals, and organic compounds (e.g., polycyclic aromatic hydrocarbons, or PAHs). Concentrated flow from roads and parking lots causes stream degradation, flooding, and other hydrologic impacts. These conditions emphasize the importance of maintaining GI receiving runoff from these surfaces.

Stormwater managers have been installing vegetated infiltration practices such as bioswales and bioretention for decades now. While some studies exist, limited research is available on how operation and maintenance affects performance of these practices. Key issues and challenges include:

- How to determine if maintenance is needed
- Inspection frequency
- Triggers for maintenance
- Disposal of materials

The purpose of this memorandum is to illustrate what is known about each challenge listed above and provide operation and maintenance recommendations. All stormwater control measures (SCMs)—not just GI—need operation and maintenance. If not properly operated and maintained, performance can decline, eventually leading to failure. The following series of photos provides several examples of failure due to insufficient operation and maintenance.

Tetra Tech

Bioswale treating runoff from urban parking lot (Cleveland, OH).

Operation and Maintenance of Green Infrastructure Receiving Runoff from Roads and Parking Lots
Technical Memorandum

All photos: Bill Lord, NCSU BAE Stormwater Engineering Group

Examples of failing bioretention and swales due to insufficient operation and maintenance.
A) Sediment has filled entire basin and is level with the drop inlet
B) Presence of cattails indicate wetland conditions and failure to drain properly
C) Use of non-selective herbicide led to swale erosion

Regulated Municipal Separate Storm Sewer Systems (MS4s) are required to address maintenance as part of their Storm Water Pollution Prevention Program, as described in two of the required minimum control measures:

- *Post-Construction Runoff Control Minimum Control Measure*
  Ensure adequate long-term operation and maintenance of controls
- *Pollution Prevention/Good Housekeeping Minimum Control Measure*
  Develop and implement an operation and maintenance program with the ultimate goal of preventing or reducing pollutant runoff from municipal operations into the storm sewer system

Operation and Maintenance of Green Infrastructure Receiving Runoff from Roads and Parking Lots
Technical Memorandum

Performance

Inadequate operation and maintenance of vegetated GI can affect performance in a number of ways:

- When vegetation dies and is not replaced, bioretention, bioswales, and other practices lose the pollutant uptake and evapotranspiration benefits provided by the plants.
- Mulch layers provide some direct pollutant removal, help retain soil moisture for plants, and protect the soil media from clogging by fine sediment particles. Mulch is an organic material that decomposes over time and therefore requires periodic replacement.
- Clogged soil media prevents infiltration and can lead to a complete failure of a practice, requiring replacement of the media.

Tetra Tech

Lack of vegetation in bioretention area (Beachwood, OH)

It is important to consider that pollutants removed from stormwater are typically retained in the bioretention system; therefore, their ultimate fate remains a concern. Triggers for replacing soil media, as well as thresholds for reuse versus disposal, are discussed in later sections.

While there are several examples of how operation and maintenance can affect performance, the literature currently lacks comprehensive research on how performance relates to operation and maintenance. Blecken et al. (2015) state that future research should focus on how operation and maintenance affects the long-term function of SCMs. While some practices have been operating for at least 20 years, they have not been studied to determine how performance changed over time or how operation and maintenance has affected performance. Lessons learned from this research could be applied to new installations in the future and prevent further loss of function. In general, if a practice is clogged or vegetation lost, performance is expected to deteriorate.

Benefits of Restorative Maintenance

Brown and Hunt (2012) studied clogged bioretention cells that drained an asphalt parking lot and had become clogged by fines from the gravel layer during parking lot construction. Beginning one month after construction, the cells were monitored for hydrology and water quality. After the first year, the monitoring indicated that the cells were both clogged and undersized. To increase surface storage and repair the infiltration function, the side slopes were steepened and the top 75 mm of soil media were removed. The cells were monitored for a year following this repair. Storage, infiltration rate, and nutrient and sediment removal were compared between the pre-repair and post-repair timeframes. Brown and Hunt (2012) found that the repair substantially decreased overflow events and allowed a greater volume of stormwater treatment. Peak outflow rates decreased, and the duration of higher flow rates was reduced by factors of 2 to 3. Also during post-repair, pollutant load reductions improved for most constituents measured except ortho-phosphorus for all cells and total phosphorus for some of the cells. The study results emphasize both the importance of inspection and maintenance as well as correct design and installation.

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Aesthetics

GI is often used to enhance the aesthetics of a public space. The value of GI in the beautification of a site is often discussed as a reason to choose GI over other more conventional approaches. As with any landscaped feature, GI requires maintenance to uphold its intended appearance, and more frequent maintenance is often required than for performance alone. Common aesthetic problems include overgrown or undergrown vegetation, trash accumulation, and nuisance vegetation (e.g., invasive species).

The aesthetics of a site should be maintained with performance goals in mind. Establishing specific goals and objectives for the "look" of a practice can help in planning for the correct frequency of maintenance. The public may prefer a more manicured look at some sites while elsewhere a more natural look may be preferred. The public may also raise safety concerns with overgrown vegetation. Strategies to address these issues include setting measurable targets that trigger maintenance tasks and training operation and maintenance staff on invasive species identification.

Where vegetation is lacking or overgrown, investigation into the causes can sometimes point to more serious performance concerns. Mazer et al. (2001) found that excessive inundation in bioswales was limiting vegetation growth in King County, Washington bioswales. The cause of inundation was not specified; however, design and soils were both suggested as contributing factors to the performance issues. Among several design and operation and maintenance recommendations, the study recommended that bioswale managers minimize inundation during the dry season and ensure appropriate soil drainage and stability. In some cases, maintenance based on aesthetic goals may lead to excessive use of fertilizer, which negates the water quality benefits of the practice. The need for fertilizer can be avoided by selecting native plants or other species that are adapted to a variety of conditions.

The Effect of Land Use

For bioswales and bioretention adjacent to paved areas, understanding the importance of operation and maintenance starts at the source. In many communities, most impervious cover is related to the transportation system. Material and pollutants accumulate on roadways and parking lots during dry weather conditions, forming a highly concentrated first flush of pollutants during rainfall events. Streets and parking lots are often among the land uses with the highest pollutant loads and concentrations.

Bioretention systems are stressful environments for plant growth due to periods of flooding and pollutant loading, followed by long dry periods. Certain plant species are more capable of thriving in these hydraulic and pollutant loading extremes than others and can help to minimize the amount of maintenance needed due to plant die off.

The major categories of pollutants in urban stormwater include metals, organic chemicals, pathogens, nutrients, biochemical oxygen demand, sediment, and salts. Once these pollutants are deposited onto road and parking surfaces, they are available for transport in runoff to receiving waters during storm events. The table on the next page summarizes common contaminants and sources of pollutants in roadway and parking lot runoff.

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In a meta-analysis, Cave et al. (1994) listed highways among the higher polluting land uses for many sediment, nutrient, and heavy metal constituents. Metals loading (copper, lead, zinc, etc.) has been shown to increase with traffic and human activity occurring on streets or parking lots, especially for commercial, industrial, and high density residential land uses (Bannerman et al. 1993, Sanger et al. 1999, Stein et al. 2008).

A nationwide study by the US Federal Highway Administration found that event mean concentrations of pollutants in highway runoff were appreciably higher for sites with average daily traffic greater than 30,000 vehicles per day (Driscoll et al. 1990). Traffic above this threshold produced higher concentrations of total suspended solids, volatile suspended solids, total organic carbon, chemical oxygen demand, nitrate-nitrite, total Kjeldahl nitrogen, phosphate, copper, lead, and zinc (see table).

Pollutant concentration in highway runoff (urban highways with average traffic more than 30,000 vehicles per day) (source: Driscoll et al. 1990)

Pollutant	10% of Sites LESS Than	Median Site	Corrective Measure
	mg/L		
TSS	68	142	295
VSS	20	39	78
TOC	12	25	52
COD	57	114	227
NO_2+NO_3	0.39	0.76	1.48
TKN	1.05	1.83	3.17
PO_4-P	0.15	0.40	1.07
Copper	0.025	0.054	0.119
Lead	0.102	0.400	1.564
Zinc	0.192	0.329	0.564

Common contaminants and sources of pollutants in roadway and parking lot runoff

Sediment	Sources of sediment in urban runoff include construction activities, erosion of unvegetated areas, and winter sand application. Sediment also accumulates on impervious surfaces whether from atmospheric deposition or wind erosion and deposition. Sediment that is routed to bioretention areas can build up at inlets, clog soil media, and smother plants.
Nutrients	Phosphorus and nitrogen are the primary nutrients in stormwater runoff, originating from sources such as lawn fertilizers, leaf litter, grass clippings, unfertilized soils, detergents, atmospheric deposition, and rainfall. Highways and other transportation corridors can increase atmospheric nutrient deposition from the by-products of vehicle exhaust.
Heavy Metals	The primary source of heavy metals in stormwater runoff is wear of motor vehicle parts, such as brake pads and tires. Gasoline, motor oil, brake linings, rubber, and asphalt all contribute heavy metals to roadway surfaces. Roadway stormwater runoff may contain trace metals such as copper, lead, and zinc. Where runoff is allowed to infiltrate, these metals may accumulate in soil and potentially leach into the groundwater once the soil sorption capacity is reached.
Petroleum Hydrocarbons and Organic Chemicals	Many sources of petroleum hydrocarbons exist in urban catchments, including leaky storage tanks, parking lot and roadway runoff, automotive emissions, elicit dumping, spills, and tire particles. Petroleum hydrocarbons in stormwater, particularly oil, grease, and organic compounds (e.g., benzene, toluene), can be traced to transportation activities such as fuel spills and engine oil leaks. Organic chemicals can also be found in runoff—high concentrations of polycyclic aromatic hydrocarbons (PAHs) have been found in runoff from roads and parking lots that use sealcoats.
Salt	In cold climates, salt usage is common to mitigate icy streets, sidewalks, and paved areas during winter months. Salt (e.g., sodium chloride) can build up on paved surfaces between melt events but will eventually be washed off into nearby SCMs and downstream to receiving waters. Salt can also accumulate in soils and can be transferred to the shallow groundwater system over time. High salt concentrations in soils can hinder a plant's access to water and cause declines or loss of vegetation in bioretention cells and bioswales. Early spring is the most critical period for managing salt concentrations when plant leaves are emerging and rains have not yet flushed the soil media of excess salts.

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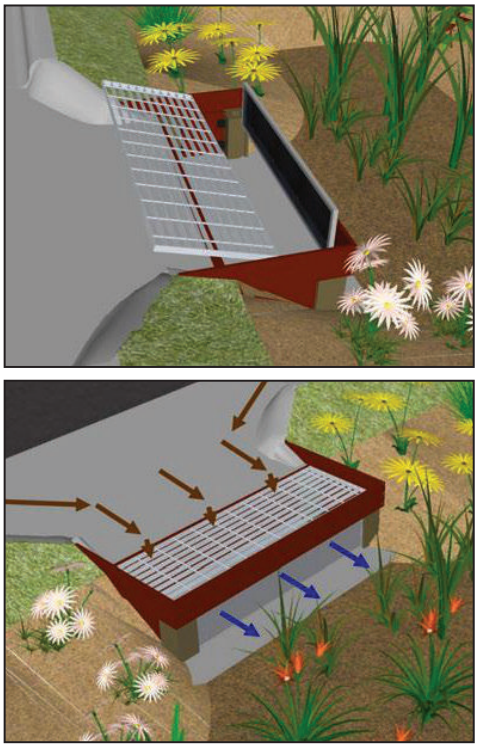
Start with Design

During the design phase of a project, two key elements that will enhance a successful maintenance program include (1) access to the practice and (2) design and construction that includes pretreatment.

Access is critical to both inspect and conduct maintenance activities in the bioretention area. During the design and permitting phase of a project, mechanisms can be put in place (e.g., easements, agreements) to ensure access to the practices for the purposes of inspection and maintenance. The design should ensure that adequate space is provided for maintenance equipment. GI that is placed near roads or in parking lots likely will not have physical access issues, but working with private landowners to ensure safe access is important. In addition, communicating maintenance activities to local landowners can provide education and outreach opportunities.

Dedicated pretreatment can simplify maintenance activities and help to focus inspections. For example, a grass filter strip can be used to catch sediment and other particulates that may enter a bioretention area. These grass filter strips can tend to build up with sediment and cause runoff to bypass the GI practice. Regular inspection of filter strips is critical to ensure the bioretention areas function as needed. Rock inlets are also commonly used. These inlets capture sediment well but require labor-intensive maintenance to remove sediment build-up. Structural pretreatment practices are becoming more common and can be used to capture sediment and particulates at the inlet. There are several designs that have been used such as the Rain Guardian, available from the Anoka Conservation District (http://www.rainguardian.biz/index.php). These inlets were designed by practitioners who recognized the challenges of maintenance activities with the goal of minimizing the labor and intensity of maintenance activities typically needed for filter strips or rock inlets. Trench or channel drains can also be used to capture sediment at bioretention inlets. Other types of structural pretreatment practices include grit chambers, sumps, and sediment forebays.



The Rain Guardian, images courtesy of Anoka Conservation District and rainguardian.biz.

Materials selected for use in bioretention and bioswales can also reduce maintenance needs. Non-floating mulch helps maintain functionality and reduce the need for premature replacement of mulch. The selection of low-maintenance plants (correct hardiness zone, tolerate wet and dry conditions, etc.) can also reduce maintenance needs.

Inspection and Assessment

Maintenance typically begins with a regular inspection or assessment program. Inspections by qualified staff can identify and prioritize maintenance needs. These inspections should occur at least once per year. While inspection frequencies can vary, local governments tend to rely on visual inspections to determine whether higher levels of assessment are needed. For example, if visual inspection observes that standing water is present 48 hours after a rainfall event, then the practice may not be infiltrating at the desired rate, triggering further evaluation of the infiltration rate. Schedules may need to be adjusted over time as issues arise. Frequencies of inspection and maintenance also

depend on drainage area, land use, activities in the watershed, and rainfall magnitude and intensity. Determining when more infrequent, restorative maintenance is needed can be less straightforward.

Visual inspections often include observations of vegetation growth and health, ponded water, clogged inlet and outlet structures, sediment accumulation, and other conditions. Several tests, such as infiltration rates, soil texture, and inflow/outflow monitoring, can be conducted as part of a site visit or visual inspection that can help inform maintenance needs. As part of the University of Minnesota On-Line Assessment and Maintenance Manual (Erickson et al. 2010), a series of inspection checklists describes the observations necessary for an effective visual inspection (see Attachment A). Simpler approaches to inspection are also common, such as the guidance provided below.

Bioretention Basin Maintenance Guide

Ramsey-Washington Metro Watershed District

Inspection Checklist	Y/N		If yes, perform the following maintenance.
Are weeds or invasive plants present?	Yes ☐	No ☐	Pull weeds and invasive plants out by the roots to prevent them from returning. Spot treat perennial weeds with appropriate herbicide if necessary.
Is there sediment accumulation?	Yes ☐	No ☐	Remove sediment that has accumulated in the inlets, outlets, and bottom of the basin with a shovel or other appropriate tool.
Are trash, excessive leaves, grass clippings, or other debris present?	Yes ☐	No ☐	Remove any debris present.
Is anything blocking or clogging inlets or outlets?	Yes ☐	No ☐	Remove any debris or sediment that may be preventing the water from flowing into or out of the bioretention basin.
Are there areas of bare soil or erosion?	Yes ☐	No ☐	Add mulch where it has been depleted and add additional plants where necessary. Use appropriate erosion control methods for more serious cases of erosion.
Is there standing water 48 or more hours after a rainfall?	Yes ☐	No ☐	This is an indication that your bioretention basin is not functioning as designed, likely due to a larger problem that will require further study and action.
If underdrain is present, is there standing water 48 or more hours after a rainfall?	Yes ☐	No ☐	Remove any trapped sediment present. If sediment does not appear to be blocking flow, this may be an indication that your underdrain is not functioning as designed and will require further study and action.

Infiltration Rates

Bioretention and bioswales are often designed to meet a specific infiltration rate following installation. Some states and municipalities require or recommend minimum infiltration rates that can be used as benchmarks to determine when restorative maintenance is needed. Tracking infiltration rates over time can help to identify declined performance and trigger maintenance activities. Studies have indicated that bioretention infiltration rates appear to drop immediately following installation and then level off (Jenkins et al. 2010; MPCA 2016a). Plant roots help maintain the infiltration rate by forming macropores, and planted bioretention areas have shown slight increased infiltration rate after the initial decrease (MPCA 2016a).

Infiltration rate monitoring can be accomplished in several ways:

- A staff gage or other type of level measurement can be used to monitor decline in water levels over time. Ideally these measurements are taken hourly or several times a day, but daily observations may also be sufficient to determine an infiltration rate.

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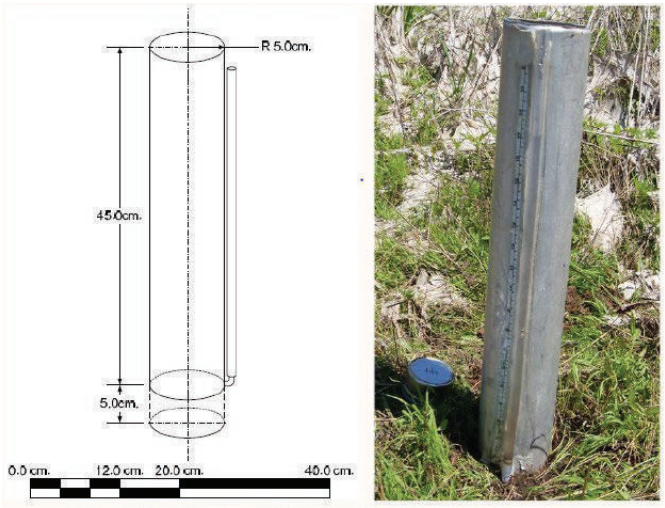
- Point measurements of infiltration rate at the bottom of the practice can be made and compared against other point measurements over time using an infiltrometer or permeameter. Multiple point measurements are needed to characterize the infiltration rate.

If the monitored infiltration rate falls below the design rate, the practice should be investigated to determine the cause of the reduced rate. Quick, approximate soil texture tests can also be easily incorporated into a visual inspection to help determine whether the soil media might be clogged. If the soil media texture has become more silty or clayey, further investigation is warranted into potential replacement of the soil media. Additional assessment of the contributing drainage area should be conducted to determine if there are existing activities that could be contributing to the lower rate (e.g., construction activities releasing sediment).



Example of infiltrometer (Erickson et al. 2010)

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Tetra Tech

Examples of bioswales in downtown Indianapolis, IN. Left bioswale is in need of maintenance and revegetation; right bioswale is well vegetated and appears to be working properly.

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Soil Chemistry Testing

Soil testing can be used to assess whether a bioretention area requires restorative maintenance, specifically media replacement, by determining if pollutant concentrations in the soil affect performance. Soil testing is most effective in combination with inflow/outflow monitoring so that the soil conditions can be linked to a measured decline in performance. Soils and media can become saturated with a particular pollutant and soil testing will vary by pollutant. While soil conditions are a concern for all constituents, soil phosphorus content more often affects removal efficiencies of bioretention and should be given particular attention. Salts are also a common issues in cold weather states.

Some communities set requirements for phosphorus concentrations in soil media; in these cases, the soil media must be tested prior to installation. A Phosphorus-Index (P-Index) between 10 and 30 mg/kg is commonly used as a requirement or guideline for bioretention soil media, especially in watersheds with high phosphorus loads (NCDEQ 2009, MPCA 2016b, and ODNR 2006). Phosphorus net export is likely to occur when soil media is above this range.

Salt accumulation in roadside bioretention and bioswales can affect vegetation health and survival. If visual inspections indicate that vegetation has declined, soils should be tested for salt concentrations. Plants are most vulnerable to high salt concentrations in early spring when leaves emerge and before rains flush salt from the soil media. Several states recommend maximum salinity levels, which can be used as a benchmark for when more management is needed. Some states require or recommend that soluble salts (soil/water 1:2) should not exceed 500 parts per million (MPCA 2016b, ODNR 2006).

In addition to vegetation effects, preliminary research suggests that high sodium concentrations in soil media may decrease bioretention infiltration rates and increase mobilization of dissolved organic carbon if the soil media contains swelling clays (Barak 2012). These findings suggest that communities should use caution with de-icing applications that drain to bioretention and bioswales, conduct further studies, and explore management techniques that decrease potential sodium concentrations in soil.

Management to reduce soil salinity and its effects include planting salt tolerant vegetation, using alternatives to sodium chloride (e.g., calcium chloride, sand, or cinders), and avoiding late season applications near the devices (Perry 2016). The Transportation Association of Canada (TAC 2013) has published extensive guidance on designing and managing roadside areas to protect vegetation from salt damage: http://tac-atc.ca/sites/tac-atc.ca/files/site/doc/resources/roadsalt-6.pdf.

Inflow/Outflow Monitoring

Comparing the inflow and outflow pollutant concentrations and loads directly measures the pollutant reduction performance of the practice. For most communities, this type of monitoring would not be practical for every bioretention area or bioswale, but managers could select a subset of practices for more detailed study, which would help provide triggers for maintenance.

Example Assessment Program

Erickson et al. (2010) describe how an assessment program can be developed based on a community's specific information needs, budgetary constraints, time frames, and legal requirements. The first step in developing an assessment program is defining the goals. Relating to bioretention and bioswales, examples of assessment objectives include:

- System-wide visual examination of stormwater treatment practices to determine if they are malfunctioning
- Identification of maintenance needs and scheduling

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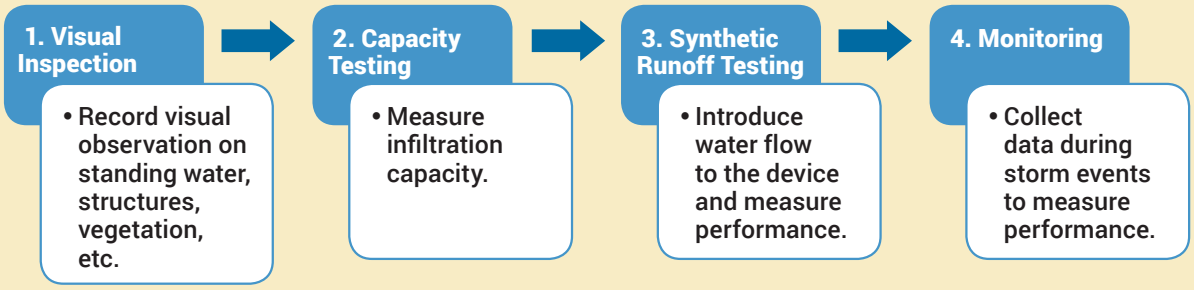
- Determination of effects in reducing runoff volumes, phosphorus, and sediment loading rates
- Optimization of life expectancy by scheduling appropriate and timely maintenance procedures

Once the objectives have been established, information is compiled on the location and design specifications, receiving waters, past maintenance schedules (if any), seasonal treatment needs, and limitations on schedule, budget, and personnel. This information is evaluated with the goals to determine whether and how often the assessment should or can be performed. Four assessment levels are provided, in order of increasing effort. The four assessment levels help establish a process for visual inspection, can help point out the need for higher levels of assessment, and can help determine maintenance needs. In the table below adapted from Erickson et al. (2010), each level is compared in terms of objectives, effort, frequency (elapsed time), advantages, and disadvantages.

The Four Maintenance Assessment Levels (Erickson et al. 2010), defined for bioretention and bioswales



Comparison of four levels of assessment (adapted from Erickson et al. 2010)

	Visual Inspection	Capacity Testing	Synthetic Runoff Testing	Monitoring
Objectives	Determine if stormwater BMP is malfunctioning	Determine infiltration or sedimentation capacity and rates	Determine infiltration rates, capacity, and pollutant removal performance	Determine infiltration rates, capacity, and pollutant removal performance
Typical Elapsed Time	1 day	1 week	1 week to 1 month	14+ months
Advantages	Quick, inexpensive	Less expensive, no equipment left in field	Controlled experiments, more accurate with fewer tests required for statistical significance compared to monitoring, no equipment left in field	Most comprehensive, assesses stormwater BMP within watershed without modeling
Disadvantages	Limited knowledge gained	Limited to infiltration and sedimentation capacity/rates, uncertainties can be substantial	Cannot be used without sufficient water supply, limited scope	Uncertainty in results due to lack of control, equipment left in field

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Operation and Maintenance Activities and Schedule

A maintenance program is critical to the long-term effectiveness of GI practices, particularly those that rely on vegetation, such as bioretention and bioswales. Maintenance can be conducted by a public agency or by a private landowner; mechanisms should be put in place to ensure maintenance is being conducted on all practices. Maintenance needs can be aesthetic in nature (e.g., overgrowth of plants, weeds, trash) or can require partial or full restoration.

Aesthetic maintenance of bioretention areas often consists of weeding, trash removal, clipping and pruning vegetation, and mulch replacement. This type of maintenance typically can be accomplished by landowners, residents, and non-technical staff.

Partial restoration may require sediment removal from the inlet or bottom of practice or replacement of plants. This type of maintenance is typically performed by public works staff or similar.

Full restoration is needed when an inspection identifies that performance does not meet the original project goals. For example, the presence of ponded water or wetland vegetation may indicate that the bioretention area no longer infiltrates. Adjustments might also be needed for inlets and outlets. Prior to any significant restoration activities, a survey of the watershed is recommended to identify activities that may be contributing to the practice failure (e.g., inadequate erosion control).

Operation may include protecting GI from construction runoff, enforcing rules for surrounding activities, and preventing inappropriate use of the practice. To avoid vegetation damage, salt buildup, and other issues, GI should be avoided for snow storage areas if possible.

Proper operation and maintenance involves performing multiple tasks at recommended time intervals (first year, semi-annually, annually, etc.) as well as regular inspection to determine further maintenance needs. Operation and maintenance tasks serve to uphold an expected level of performance, prevent more expensive operation and maintenance needs, and extend the life of the GI.

When to Weed?

- When sunlight no longer reaches the surface of the soil
- When invasive species are present
- When desirable views are obstructed
- As needed to achieve performance and aesthetic goals

Measurable targets for operation and maintenance often serve to maintain both performance and regular maintenance. Some maintenance tasks are regularly scheduled to sustain performance and prevent damage. Other maintenance tasks occur as needed and may be triggered by an extreme weather event. In the latter case, properly timed inspections help identify maintenance needs beyond the regularly scheduled tasks. While the importance of maintenance is clear from a pollutant source perspective, the timing of maintenance needs can vary and is often specific to geography, climate, and site conditions. Feehan (2013) emphasizes that a number of factors should be considered in maintenance schedules, including practice type, runoff volume, traffic loading, sediment loading, litter/debris loading, seasonal variations, adjacent construction, and irregular weather events.

Existing stormwater management literature provides guidance on how to develop appropriate maintenance programs and schedules. The text box below provides an example operation and maintenance schedule. Some stormwater manuals recommend that vegetation density be limited so that sunlight can reach the soil and promote bacteria removal, which also prevents overgrowth from an aesthetic perspective. Other triggers for controlling vegetation

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include the presence of invasive species or obstruction of desirable views. Structural components, such as outlets, can be damaged over time if woody vegetation is allowed to grow in cracks. Proper operation and maintenance, as described in Mazer et al. (2001), also involves ensuring that the design provides a balanced inundation frequency over the life cycle of a practice. Too much flow could cause excessive erosion, leading to malfunction and costly repairs.

Even when maintenance schedules are followed adequately, variables such as climate patterns, weather variability, public use of the devices, etc. can lead to unforeseen maintenance needs. Inspection and adaptive management are critical components to any maintenance program.

Recommended Maintenance Activities for Bioretention Areas

From the Minnesota Stormwater Manual Wiki, accessed May 2016
http://stormwater.pca.state.mn.us/index.php/Operation_and_maintenance_of_bioretention

First year after planting

- Adequate water is crucial to plant survival, and temporary irrigation will be needed unless rainfall is adequate until plants mature

As needed

- Prune and weed to maintain appearance
- Stabilize or replace mulch when erosion is evident
- Remove trash and debris
- Mow filter strip
- Renew mulch to replace that which has broken down into organic matter
- Replace vegetation whenever percent cover of acceptable vegetation falls below 90 percent or project specific performance requirements are not met; if vegetation suffers for no apparent reason, consult with horticulturist and/or test soil as needed

Semi-annually

- Inspect inflow points for clogging (off-line systems) and remove any sediment
- Inspect filter strip/grass channel for erosion or gullying and sod as necessary
- Inspect herbaceous vegetation, trees, and shrubs to evaluate their health and replant as appropriate to meet project goals
- Remove any dead or severely diseased vegetation

Annually in fall

- Inspect and remove any sediment and debris build-up in pretreatment areas
- Inspect inflow points and bioretention surface for build-up of road sand associated with spring melt period; remove as necessary and replant areas that have been impacted by sand/salt build up
- Cut back and remove previous year's plant material and remove accumulated leaves if needed (or controlled burn where appropriate)

For proper nutrient control, bioretention cells must not be fertilized unless a soil test from a certified lab indicates nutrient deficiency. The one exception is a one-time fertilizer application during planting of the cell, which will help with plant establishment. Irrigation is also typically needed during establishment.

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Recommended Maintenance Activities for Bioretention Areas (continued)

Pretreatment devices need to be maintained for long-term functionality. Accumulated sediment in the forebay will need to be cleaned out at a minimum when it is half-full, which should be approximately every 10 to 20 years. In an especially dirty watershed, the frequency may be increased to every 2 to 3 years. Sediment should also be cleaned out of rip rap and sumps. A vacuum truck is typically used for sediment removal. If a grassed filter strip or swale is used as pretreatment, it should be mowed as frequently as a typical lawn. Depending on the contributing watershed, grassed BMPs may also need to be swept before mowing. All grassed BMPs should also be swept annually with a stiff bristle broom or equal to remove thatch and winter sand. The University of Minnesota's Sustainable Urban Landscape Series website provides guidance for turf maintenance, including mowing heights.

Maintenance of vegetation after establishment is similar to adjacent gardens (except for application of fertilizer). Weeding is especially important during the plant establishment period, when vegetation cover is not 100 percent yet, but some weeding will likely always be needed. It is also important to budget for some plant replacement (at least 5 to 10 percent of the original plantings) during the first few years after planting, in case some of the plants that were originally planted die. Rubbish and trash removal will likely be needed more frequently than in the adjacent landscape, since the hydraulic loading ratio is high. Trash removal is important for prevention of mosquitoes. Mulch renewal will be needed two or three times after establishment (first five years). After that, the plants are typically dense enough to make it difficult to mulch, and the breakdown of plant material will provide enough organic matter to the infiltration/filtration device. It is recommended that bioretention performance evaluations follow the four level assessment system in *Stormwater Treatment: Assessment and Maintenance* (Gulliver et al. 2010). More detailed information about maintenance procedures, a maintenance schedule, and estimated maintenance costs are also available in Gulliver et al. (2010).

The following are minimum requirements for plant coverage.

- At least 50 percent of specified vegetation cover at end of the first growing season
- At least 90 percent of specified vegetation cover at end of the third growing season
- Supplement plantings to meet project specifications if cover requirements are not met
- Tailoring percent coverage requirements to project goals and vegetation; for example, percent cover required for turf after one growing season would likely be 100 percent, whereas it would likely be lower for other vegetation types

Owner's Representatives may wish to consider deducts and liquidated damages for bad construction practices. Regulating authorities may wish to consider fines for bad construction practices.

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The following photos compare the same bioretention site just after installation, after several years of vegetation growth, and following routine maintenance. The aesthetics of the site changed dramatically across these three stages. An open, natural aesthetic was achieved at this site while controlling overgrowth and ensuring access to the outlet structure for other maintenance tasks.

All photos: Tetra Tech

Comparison of three stages of vegetation maintenance at one bioretention practice: A) Shortly after installation; B) After several years of vegetation growth; C) After routine maintenance

When Restoration and Disposal Are Needed

While the majority of routine bioretention maintenance is focused on maintaining aesthetic features, removal of sediment or bioretention media may be needed periodically. Li and Davis (2008) found that sediment and heavy metals concentrate in the top 5- to 10 cm of bioretention media, so that removal and replacement of surface layers may revitalize water quality performance. As bioretention and bioswales are used more frequently and accumulate sediment over greater time periods, restoration is likely to become a more important consideration.

Limited research is available on the management and maintenance of bioretention in order to enhance performance and reduce lifecycle costs. Brown and Hunt (2012) repaired two sets of bioretention cells by excavating the top 75 mm of fill media to remove accumulated fine sediments. This increased the surface storage volume by nearly 90 percent and the infiltration rate by up to a factor of 10. Overflow volume also decreased. For most constituents, the effluent pollutant loads exiting the post-repair cells were lower than their pre-repair conditions. This outcome showed that clogging was limited to the surficial media layer, and maintenance was critical to performance (Liu et al. 2014).

Maintenance Costs

Houle et al. (2013) evaluated different types of stormwater control and found that more distributed measures required higher percentages of "predictive or proactive" maintenance activities but tended to have lower maintenance costs per load removed overall compared to devices that required less frequent but more expensive repairs or rehabilitation (see table below).

Operation and Maintenance Costs per Load Removed (Houle et al. 2013)

Operational Costs	Vegetated Swale	Wet Pond	Dry Pond	Sand Filter	Gravel Wetland	Bio-retention	Porous Asphalt
Total Suspended Solids ($/kg/year)	6	17	11	21	8	8	4
Total Phosphorus Performance ($/g/year)	NT	NT	NT	7	3	6	2
Dissolved Inorganic Nitrogen ($/g/year)	NT	0.89	0.93	NT	0.28	0.64	NT

NT = No treatment; values are incalculable as lack of SCM pollutant treatment results in infinite costs.

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Process and Best Practices

Stormwater collection and conveyance systems collect and concentrate pollutants to prevent them from reaching surface waters and impacting water quality, aquatic life, or human health. Maintaining these systems often includes regular clean out and disposal of contaminated sediment and soil. Sampling is typically required prior to disposal to determine proper management. Sediment disposal from bioretention cells and bioswales presents a similar need to determine whether disposal or re-use of media is appropriate.

Sediment that accumulates in stormwater collection systems varies greatly with regard to contaminant concentrations and chemistry, and may differ among samples from the same system. Collection systems also vary in size and shape, as well as design. For example, some may have multiple inlets and outlets, and the types of media may differ. Land uses in the drainage areas can also influence contaminant concentrations in sediments.

The Minnesota Pollution Control Agency (MPCA 2015) outlines important procedures and steps when planning for sediment removal:

- Inventory and maintenance needs
- Evaluating and testing sediment
- Engineering and contracting
- Excavating sediment
- Site restoration
- Records and documentation to keep on file
  - Volume of sediment removed in cubic yards
  - Evaluation, testing, and/or laboratory results
  - Place of disposition/disposal
  - Employee training records and certifications

Feasibility of sediment removal can be improved by intentionally designing bioswales and bioretention for equipment access.

Handling Considerations

Maintenance staff should use caution when handling soil media that is potentially hazardous. When taking soil samples, staff should wear protective gloves and avoid any bodily contact with the soil. Soil samples should be collected in a consistent manner, and the sampling device should be decontaminated between samples. Samples should be submitted to an accredited laboratory for analysis. Typical laboratory accreditations include the National Environmental Laboratory Accreditation Program certification and state-based certification programs.

If the soil in the practice is potentially hazardous, the soil should not be disturbed until test results are received. In the event that soil is disturbed prior to testing, this soil should be contained using drums, tarps, or other appropriate containment device that prevents leaching, airborne dust particles, or other release until testing can be completed. If soil media is determined to be non-hazardous, then specialized staff would not be required for soil handling.

If soil testing determines that soil media is hazardous, then trained professionals should be used for the removal and disposal of the media. The removal may require air monitoring, dust suppression, and other specialized procedures.

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State regulatory agencies post lists of approved contractors for hazardous materials handling. Prior to disposal in a landfill, it is likely that samples will need to be collected for waste characterization analysis. Waste characterization allows landfills to ensure that they properly handle and dispose of hazardous materials and aids in determining the type of landfill that can accept the hazardous material.

Ultimate Disposal

If inspections and monitoring lead to findings that soil media contains too much phosphorus or other pollutants of concern, the next step is to determine whether that soil media can be re-used or if disposal is needed. Disposal of sediment removed from GI generally falls within two categories: regulated and unregulated. Unregulated sediment is characterized as sediment that does not have contamination exceeding residential soil reference values or residential soil screening levels. Unregulated sediment may be managed locally and without disposal restrictions. However, disposal of contaminated sediment is more challenging and more expensive. Excavated sediment that is considered regulated fill is generally sent to a solid waste landfill. Depending on the types and concentrations of contaminants, sediment may need to be disposed of at a landfill that has an industrial solid waste management plan. Coordination with state agencies that regulate contaminated sediment is recommended.

Research conducted on stormwater pond sediments in the Minneapolis–St. Paul, Minnesota metropolitan area showed that polycyclic aromatic hydrocarbons (PAHs) are the primary contaminants of concern affecting disposal decisions (Polta et al. 2006).

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EPA United States Environmental Protection Agency

Operation and Maintenance of Green Infrastructure Receiving Runoff from Roads and Parking Lots Technical Memorandum

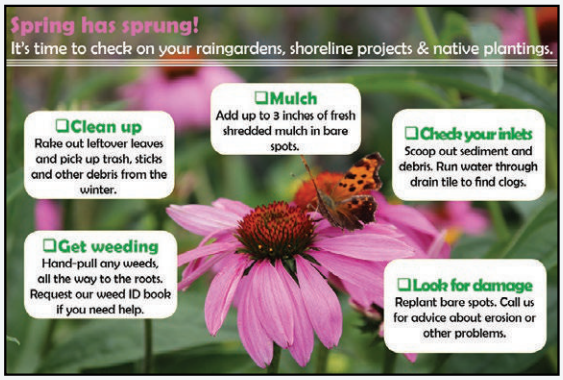
Case Study

Middle St. Croix Watershed Management Organization Inspection and Maintenance Program

Case Study Contact: Mike Isensee, Administrator of the Middle St. Croix Watershed Management Organization

The Middle St. Croix Watershed Management Organization (MSCWMO) is a watershed group tasked with cooperatively managing water resources in a 19.8 square mile watershed located along the pristine St. Croix River in Minnesota. There are ten member communities that have signed a joint powers agreement and have contracted staff from the Washington Conservation District to conduct watershed planning and implementation. The MSCWMO is overseen by a board made up of locally elected or appointed representatives from each member community.

Tetra Tech



MSCWMO

The MSCWMO conducts a comprehensive inspection and maintenance program for the many best management practices (BMPs) in the watershed. As of 2015, there were over 200 BMPs installed in the watershed, most of the BMPs are bioretention areas that receive runoff from streets via curb cuts and range in size from 200-300 square feet. These BMPs include four types of projects with varying maintenance strategies:

Residential Raingardens and Native Shoreline Restoration Projects

90 small scale residential raingardens and shoreline restoration projects located on private property.

Maintenance Strategy: Send annual maintenance post card reminder with MSCWMO contact information to provide assistance if requested.

Retrofit Projects Installed and Maintained by MSCWMO and/or Member Communities

Since 2007 the watershed and cities have installed 88 BMPs, primarily bioretention basins, on public property or within right-of-ways.

Maintenance Strategy: Annual inspections and maintenance. Maintenance has been provided by the Minnesota Conservation Corps through an annual grant program since 2012. The MSCWMO directs the crews and the member communities provide funding for materials such as mulch and plant replacement.

Retrofit Projects Installed by MSCWMO and Maintained by Landowners

Beginning in 2012, the MSCWMO required landowner maintenance agreements prior to the installation of voluntary projects. The MSCWMO provides maintenance for the first two years, then in the third year provides onsite maintenance consultation to landowners. The watershed then conducts annual inspections of these 23 projects.

Middle St. Croix Watershed Management Organization Inspection and Maintenance Program

Inspection letters are sent to landowners and they are encouraged to contact the MSCWMO for further on site consultation if they have any questions.

Maintenance Strategy: For new voluntary projects, the MSCWMO provides maintenance for the first two years, after which the private landowner is responsible for maintenance.

New and Redevelopment Stormwater Projects

During the review process project applicants are required to submit a legal agreement with the City identifying maintenance items and responsibilities. Currently, there are 16 permitted permanent stormwater volume control facilities in the MSCWMO.

Maintenance Strategy: These BMPs are not part of the annual inspections program at this time.

MSCWMO inspections identify three types of potential maintenance activities needed:

1. Aesthetics (weeding, inlet clean-out, invasive plant management)
2. Restore partially functioning BMP (replacing plants, mulching, minor grading)
3. Restore non-functioning BMP (full restoration)

For those practices requiring aesthetic maintenance, the MSCWMO currently contracts with the Minnesota Conservation Corps. Aesthetic maintenance typically includes inlet clean-out and weeding. Other maintenance needs include mulching every three years or plant replacement are conducted on an as needed basis. Projects requiring repairs such as excavation or larger scale fixes are prioritized and addressed sequentially as part of the annual capital improvements projects.

Most practices identified as partially or non-functioning are due to sod or rock inlets that have filled with sediment and cause stormwater to bypass the bioretention basin. Because of this issue, the watershed requires the use of pretreatment devices that have capacity to remove at least 50 percent of the annual sediment load (Figure 1). This has increased function and decreased maintenance of practices installed since 2014. The other primary cause of failure in this watershed is due to the presence of marginal soils. The MSCWMO now requires at least one soil boring at the location of each proposal BMP. Underdrains suspended in engineered soil media with a gate valve are required for all BMPs constructed in soils that are not hydrologic soil group A (i.e., sandy or sandy loam).

Tetra Tech

Figure 1. Two types of street raingarden inlets: Left – Rock inlet; Right – Pretreatment inlet. The pretreatment inlet is now required for all new street raingardens to aid in collection of gross solids (sediment, leaves, trash, etc.) and maintenance. Rock inlets are no longer allowed due to difficulty maintaining the effectiveness of the inlet for pretreatment.

The MSCWMO also provides technical review for new and redevelopment projects in the watershed and in particular reviews proposed stormwater management for adherence with MSCWMO-specific watershed standards and other regulations. Per state statute and a joint powers agreement, the member communities must implement the MSCWMO

Middle St. Croix Watershed Management Organization Inspection and Maintenance Program

standards. As part of the review process, the MSCWMO now requires pretreatment on all infiltration BMPs and a signed legal maintenance agreement with the community.

The MSCWMO funds the majority of inspection and maintenance through member fees provided by cities and townships within the watershed. Member fees are typically allocated from general funds. Member communities also pay directly for any needed materials (e.g., plants, mulch, etc.). A grant from Minnesota's Clean Water Fund was obtained by the MSCWMO to fund in part of the maintenance work conducted by the Minnesota Conservation Corps.

The MSCWMO estimates that typical maintenance costs which reflect two visits per year are between $200–$300 per BMP, resulting in an annual cost of $16,000–$24,000 per year for the practices they are currently maintaining. These costs do not take into consideration repairs needed for partially or non-functioning BMPs.

In 2014, the MSCWMO partnered with the Washington Conservation District and other nearby watershed organizations to develop an interactive Conservation Project Map to track the pollutant load reduction, location, condition, and maintenance needs for the growing number of practices within the watershed. The Map is updated annually with new BMP information. The geospatial maps and inspection forms are accessible on mobile devices and streamline the inspection process and annual maintenance and repair prioritization projects.

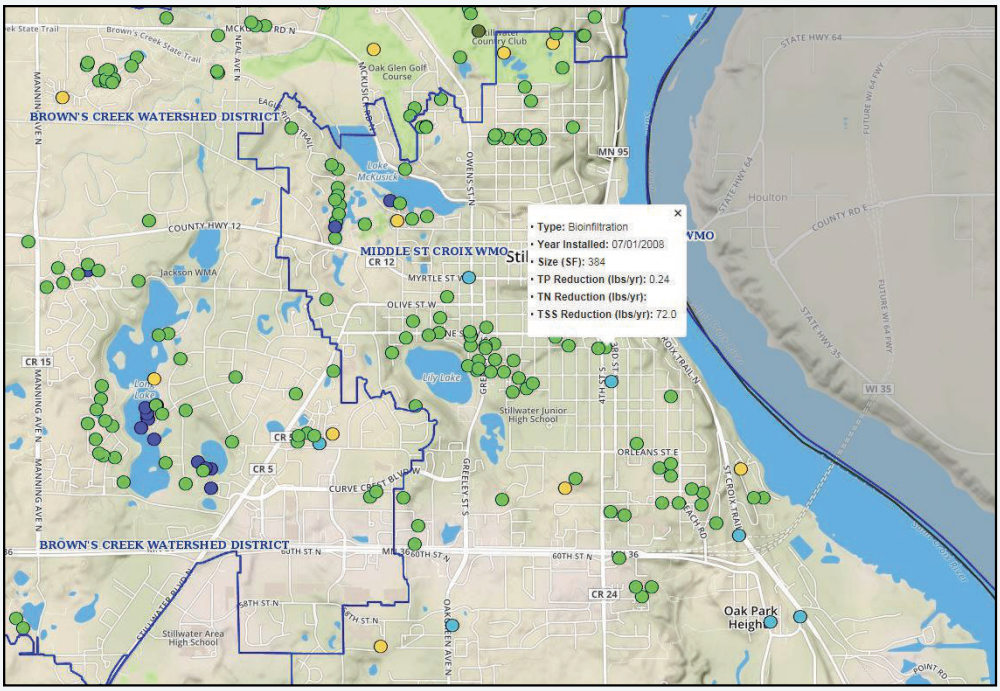


Figure 2.Screen shot from Conservation Practice Map webpage

The inspection and maintenance program has adapted as the number of BMPs has increased in the watershed. Initially, inspection and maintenance activities were conducted by MSCWMO staff; as the number of BMPs increased the MSCWMO contracted with the Minnesota Conservation Corps for aesthetic maintenance. Now, as the number of BMPs has reached a critical number, the MSCWMO is partnering with other government entities to either hire dedicated seasonal staff or use a contractor to carry out maintenance activities.

"Maintenance Begins with Design"

Operation and Maintenance of Green Infrastructure Receiving Runoff from Roads and Parking Lots
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Case Study

Middle St. Croix Watershed Management Organization Inspection and Maintenance Program

2013 Landowner Agreement Template

MIDDLE ST. CROIX WATERSHED MANAGEMENT ORGANIZATION
455 Hayward Avenue N. Oakdale, MN 55128
Phone 651.330.8220 x22 fax 651.330.7747 www.mscwmo.org

RAINGARDEN INSTALLATION AND MAINTENANCE AGREEMENT BETWEEN LANDOWNER AND THE MIDDLE ST. CROIX WATERSHED MANAGEMENT ORGANIZATION

The following agreement has been prepared for the proposed raingarden project in the catchment discharging urban stormwater directly to Lily Lake.

The raingarden located at this property will infiltrate or filtrate urban stormwater that is currently discharging into Lily Lake. The owner agrees to the following guidelines/statements in regards to the raingarden/stormwater treatment facility to be installed in the right-of-way adjacent to their property.

1. The landowner has agreed to have a raingarden installed in the City right-of-way adjacent to their property.
2. The landowner agrees to keep the raingarden in place for period of (10) years for the date of installation.
3. The landowner understands that some land area may be disturbed outside of the City right-of-way as part of this project and that the contractor installing the raingardens will restore these areas.
4. After the two-year maintenance period provided by the Middle St. Croix Watershed Management Organizations, the landowner agrees to maintain the raingarden in the City right-of-way adjacent to their property. Raingarden maintenance activities for the homeowner to perform include:
    a. Remove litter, debris, and accumulated sediment from the raingarden area, including the entrance to the raingarden off of the roadway.
    b. Watering of perennial vegetation when needed.
    c. Maintain the integrity and viability of the raingarden, including all planted perennial vegetation in the raingarden in a manner that does not compromise the effectiveness of the design. All established vegetation should be checked for survival and replaced as quickly as possible.
5. The Middle St. Croix Watershed Management Organization (MSCWMO) will provide periodic inspection to ensure the raingarden is being properly maintained. If an issue is observed, the MSCWMO will assist the landowner in addressing the problem.

By signing this agreement the landowner agrees to the statements above.

Landowner Address Date

MSCWMO Representative Date

Middle St. Croix Watershed Management Organization Member Communities
Afton, Bayport, Baytown, Lakeland, Lakeland Shores, Lake St. Croix Beach, Oak Park Heights, St. Mary's Point, Stillwater, & West Lakeland

Great Lakes RESTORATION

Funding for this project was provided by the Great Lakes Restoration Initiative administered by the United States Environmental Protection Agency—Great Lakes National Program Office.

This report was developed under EPA Contract No. EP-BPA-13-R5-0001 by Tetra Tech, Inc.

17 PERVIOUS CONCRETE MAINTENANCE PLAN

Pervious Concrete Pavement Maintenance and Operations Guide

NRMCA Pervious Concrete Pavement Maintenance and Operations Guide

Pervious concrete pavement is a Portland cement-based, rigid permeable pavement that serves not only as the surface layer of a stormwater management system, but also as a vital part of a water filtration system. Beneath the pervious concrete is the second layer of the stormwater system, the base rock, which is an open-graded, stone layer that is used for temporary stormwater detention. When rain falls, the pervious concrete allows on-site infiltration of stormwater. It also filters sediments and pollution from stormwater deposited on the pavement surface.

Because this permeable surface is a filter, like any filter it must be cleaned periodically. Cleaning is performed by vacuuming to remove sediments that have accumulated. The frequency of the vacuuming is directly related to the amount of sediment that the surface receives over time.

The following chart can serve as a *minimal recommendation* for scheduled maintenance:

ACTIVITY	SCHEDULE
Avoid sealing or repaving with impervious materials. In particular, never use asphalt or other tar-type sealers on pervious concrete.	N/A
Visually inspect pervious pavement area to ensure that it: • is clean of debris • de-waters between storms • is clean of sediments	Monthly
• Maintain upland and adjacent grassy areas. • Seed upland and adjacent bare areas. • Keep the pervious pavement surface free of sediment by blowing, sweeping or vacuuming. • Excessive water flow carrying debris toward the pavement should be diverted.	As needed
Inspect the pervious pavement surface for deterioration or spalling.	Annually

Pervious Concrete Maintenance: Plan and Practice

Maintenance of the pervious concrete pavement is the responsibility of the property owner/manager. The Maintenance Plan should be developed to assure proper maintenance procedures are followed. After the first year of operation, the plan should be reviewed and, if necessary, revised to reflect the actual results of that first period of service. When ownership of the property is transferred, the maintenance plan must be transferred as well.

In general, maintenance of pervious concrete pavement consists of monitoring the surface for sediment buildup, and removing that buildup as needed, to maintain the pavement's permeability. Owners/property managers should follow good housekeeping practices to prevent accumulation of trash, sediment or other debris on the pervious surface. Drainage of all unpaved areas should be directed away from the pervious concrete pavement. If areas are allowed to drain onto the pavement, suspended materials may wash into the void structure of the pervious pavement and reduce the porosity and compromise its service life. Adjacent areas that do drain to the pavement should be kept seeded and maintained to minimize sediment deposition which may increase the frequency of cleaning of the pervious surface. Landscape contractors should be advised of the special precautions required to avoid debris buildup on the pavement surface. Additionally, it is recommended that informational signage be posted to identify the pervious pavement as being part of a stormwater management system and that particular care should be taken to maintain its peak performance.

The first step in creating a maintenance plan is to develop a baseline infiltration rate for your pervious concrete system. ASTM C1701: Standard Test Method for Infiltration Rate of In-Place Pervious Concrete, is the procedure used to determine the infiltration rate of pervious concrete. Performing an initial ASTM C1701 test for a baseline is best done the day that the plastic curing is removed. The pavement has not been in service yet, so this initial baseline measurement will document the optimal performance of the pavement, as constructed, for stormwater management. ASTM C1701 requires three test procedures to be performed for every 25,000 square feet and an average taken of the three tests. This will be the baseline for comparison of all future tests. The original testing locations should be marked or noted in the maintenance log so that future tests can be run at the same locations. A change in the infiltration rate with service will determine the appropriate frequency of maintenance.

There are three levels of pervious concrete pavement maintenance:

1. **Routine Maintenance:** Should include visual inspection of the pervious pavement to ensure that it is clean of debris and sediments, and that it will dewater between storms. Routine maintenance cleaning procedures would include blowing (with leaf blower or similar equipment), truck-sweeping and/or dry vacuuming. Routine maintenance may help prevent more stubborn clogging by keeping sediment from becoming ground deep into the pavement's void structure. This routine maintenance should be performed as needed (at least monthly) to keep the entire pervious concrete area clean. Visually inspect the pavement periodically during or immediately following a rain event. Ponding or puddles are signs that it is time to clean the pavement. In some areas, moss growth can be an issue. Moss can be controlled by sprinkling baking soda on the surface, followed by a dry vacuuming within a few weeks. Additionally, moss growth can be retarded/eliminated with lime water applications. Since this pavement is designed to infiltrate water, any surface treatment must be evaluated for environmental impacts to ground water.
2. **Periodic Maintenance:** In areas that see freezing temperatures, it is a good practice to perform periodic maintenance just before winter to insure that the pervious concrete voids are clean and free of non-compressible materials that may inhibit draining and, therefore, could contribute to freeze-thaw damage. Additionally, periodic maintenance may be required following winter to remove any anti-skid materials that may have been used. Proper cleaning procedures would include pressure washing and/or vacuuming the area with either a dry vacuum or a regenerative vacuum sweeper. Care should be taken to avoid extremely high pressures with a pressure washer, as this can degrade the bonding cement paste and increase raveling. Cleaning equipment should allow for the debris to be bagged and removed from the unit so it can be weighed.

A maintenance log should be completed that records the following:

- Date of service
- Name of individual/company performing service
- Type of maintenance performed
- Amount (lbs.) and type(s) of sediment/debris/other material removed as result of cleaning
- General observations and record of pavement condition
- Name/signature of individual completing the inspection
- Additionally, if ASTM C1701 is performed, the test results and locations should be included in the report. (A sample Maintenance Log is included on page 7 of this guide).

Additionally, if ASTM C1701 was performed, the test results and locations should be included in the report. (A sample Maintenance Log is included on page 7 of this guide).

Routine and periodic maintenance is essential with the goal of avoiding renovation/rehabilitation.

3. **Deep Cleaning/Unclogging:** Over time, deep cleaning/unclogging of pervious concrete pavement may become necessary, particularly if routine and periodic maintenance is not performed. If a pervious concrete pavement system is not periodically cleaned, the void structure system will become clogged with debris over time. Typically, an average infiltration rate decrease of 25% from the initial value, or an infiltration rate less than 100 inches per hour, triggers the need for deep cleaning/unclogging. Neglected projects that had never been cleaned and are completely clogged should be restored to a drainage rate of 100-200 inches per hour, per ASTM C1701, by using specialized cleaning equipment.

ASTM C1701: Standard Test Method for Infiltration Rate of In-Place Pervious Concrete

Cleaning pervious concrete can maintain and/or restore its original permeability

Deep cleaning/unclogging is best accomplished by simultaneous pressure washing and vacuuming. Several equipment manufacturers have developed pressure washing/vacuum systems that have proven to rehabilitate the pore structure of pervious pavement. For best results, follow the equipment manufacturer's recommendations. As with the periodic maintenance procedures, when cleaning/unclogging is performed, a maintenance log should be completed and filed with the owner/property manager.

Use of Chemicals to clean pervious concrete should be done with extreme caution to prevent damage to the aquifer, the biological organisms within the pervious system, or the pervious concrete pavement itself.

Winter Maintenance

This is a critical aspect of owning a Pervious Concrete Pavement. Improper winter maintenance has been responsible for many failures of Pervious Concrete Pavement Surfaces.

Freeze-thaw resistance of pervious concrete depends on its saturation level at the time of freezing. When the large voids are saturated, complete freezing can cause severe damage to the pervious concrete pavement. Field observations have shown that, due to its rapid draining characteristics, a properly maintained pervious concrete pavement will rarely be fully saturated.

Winter maintenance issues affect pervious concrete the same as standard concrete. Deicing chemicals should not be used on any type of concrete in the first year. Concrete that is not properly cured is more susceptible to damage from deicing chemicals. Because concrete takes longer to cure in lower temperatures, when it is placed late in the year, such as late fall or early winter, it may be more susceptible to damage due to the use of deicing chemicals. As with conventional concrete, applying a penetrating sealer to the pervious concrete can improve its performance in freezing weather. Use a penetrating sealer manufactured specifically for concrete. **Concrete penetrating sealer should not be confused with impermeable sealers such as asphalt seal coats.**

The following recommendations should be followed:

- Anti-icing pre-treatments should never be used on pervious concrete pavements. If these products are used on adjacent pavements, care should be taken to prevent the adjacent runoff from infiltrating the pervious concrete.
- Deicers containing magnesium chloride, calcium magnesium acetate or potassium acetate should ***never*** be used on pervious concrete pavement.
- Deicing agents that contain fertilizer ingredients such as Ammonium Sulfate and Ammonium Nitrate cause chemical deterioration to any Portland cement-based concrete pavement and should ***never*** be used.
- Calcium Chloride impregnated sand can be used for deicing pavements ***after*** the first year.
- Coarse sand (minimum 1/8"), or small crushed aggregate (1/4 – 10, or similar gradation) can be used as an anti-skid material with the understanding that vacuum cleaning will be performed after the winter season. **Fine sands such as masonry sand or play sand should NOT be used on pervious concrete pavements!**
- Snow plowing can be performed with trucks mounted with plows, but the plow should be fitted with a polyurethane cutting edge. Use of snow blowers may be a better alternative to plowing, if available. Snow removal should not be performed using front end loaders or skid loaders by either scooping or back dragging. Note that snow plowing may result in striations on the concrete surface. These striations are merely aesthetic and will often disappear over time.

The number one concern of property facilities managers is liability. Facilities managers instruct their maintenance personnel to salt and plow when snow begins to lay on the surface. In many cases, that minimal amount of snow will melt when the sun comes out or when temperatures even slightly rise. Once the snow melts, it infiltrates into the pervious concrete and does not refreeze on the surface, as it would on an impervious surface. Additionally, studies show that the ground beneath the pervious concrete system is less susceptible to freezing due to the insulating properties of the air space in the aggregate base. This is very beneficial to the facilities managers who are concerned about safety factors and liability.

Pervious concrete should ***never*** be used as a storage area to pile snow from other areas unless it has been specifically designed as a snowshelf, with special consideration for resistance to deicing chemicals, water quality issues and additional maintenance as requisite. The snow that has been plowed from other surfaces may be full of debris that will clog the pervious concrete voids. Additionally, the plowed snow will most likely have a very high salt or anti-skid content.

An Ounce of Prevention…
The best maintenance practice is prevention. Keeping the pavement clean, and within design specifications, is the owner's responsibility. When proper maintenance techniques are followed, pervious concrete will provide a durable pavement and long-term stormwater management.

For more information, go to www.perviouspavement.org

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Pervious Concrete Maintenance Log

Site Name and Location: _____

Initial ASTM C1701 Test Results: _____ **Inches / Hour**

Date of Inspection	Observations/ Pavement Condition	ASTM C1701 Performed?	ASTM C1701 Results	Type of Maintenance Performed	Type and Amount of Debris/Sediment Removed	Maintenance Performed By:	Name/Signature of Inspector
		Yes ☐ No ☐	Before Maintenance ☐ IN/HR After Maintenance ☐ IN/HR				
		Yes ☐ No ☐	Before Maintenance ☐ IN/HR After Maintenance ☐ IN/HR				
		Yes ☐ No ☐	Before Maintenance ☐ IN/HR After Maintenance ☐ IN/HR				
		Yes ☐ No ☐	Before Maintenance ☐ IN/HR After Maintenance ☐ IN/HR				

Percolation Test Guide

The percolation test is designed to determine the suitability of a site for a subsurface private sewage disposal system (i.e. septic system). More specifically, a percolation test measures the ability of the soil to absorb liquid. Septic system designers use the results of percolation tests to properly construct septic systems.

The percolation tests are designed to simulate conditions in a septic system. The percolation test consists of a hole 6-12 inches in diameter dug in the area of the proposed septic system. The depth of this hole varies depending on the soils encountered but it is generally not greater than 24 inches. The hole is initially filled with water (presoak) in an attempt to saturate the soil, allowed to drain away and than refilled with approximately 12 inches of water. The rate at which the water drops in the hole is measured at intervals over a period of time ranging from 30-60 minutes. The uniform slowest rate of drop of the water level over a measured time interval is converted to minutes per inch and used as a basis of design in determining the septic system size. For example, if the water dropped uniformly 1\4 inch every five minutes the rate would be 20 minutes per inch. The Health Code provides a simple table that determines the size of the system based on the measured perk rate and the number of bedrooms in the home. The greater the number of bedrooms and the slower the percolation rate, the larger the system required. Commercial systems are sized using the perk rate and projected estimates of water usage in gallons per day.

How to Run a Percolation Test

The following steps outline the procedure for performing a Percolation Test.

1. Dig at least six test holes. The holes should be:
    - Evenly spaced, approximately 30-40 feet apart, but not less than 30 feet, in the area of the proposed septic field.
    - At least six inches in diameter. Larger holes are acceptable, but will require more water.
    - Dig to a depth of 24 inches.
    - No closer than 3 feet to the 48-inch test hole.
    - No closer than 75 feet to the nearest water well or proposed water well.
    - No closer than 5 feet to any lot line or easement.
    - No closer than 20 feet to any building.
    - Not located in any easement or flood plain area.
    - Not located in any area that has previously failed a percolation test.
2. Dig a 48-inch test hole in the lowest part of the test area.
3. The bottom and sides of each 2-foot test hole may be roughened with a saw blade, knife, or other sharp instrument. It is advisable to roughen those surfaces, which may become smeared with mud during the digging process. Smearing of those surfaces will tend to reduce the seepage rate. Remove all loose soil from the bottom of the holes.

4. Fill each of the 2-foot test holes with water and refill as necessary to maintain a minimum depth of 12 inches for a period of at least four hours. This is the presoak. It must be conducted between 12 noon and 4 o'clock p.m. the day before the test. Health Department technicians may spot check the presoak to make sure it is being done properly. Note: DO NOT put any water in the 48-inch test hole.
5. Prepare in advance of the test one wooden stake for each 2-foot test hole. Three nails should be pounded into each stake. The first nail should be three inches from the bottom of the stake, the second nail must be exactly six inches above the first nail, and the third nail must be exactly 20 inches above the second nail.
6. On the morning of the percolation test (the day following the presoak), the test holes should be cleaned out. Any loose soil or silt that accumulated at the bottom of the holes during the presoak should be removed. One of the stakes prepared per the instructions in #4 above should be driven into each hole so that the first nail rests on the bottom and the stake stands by itself.
7. At a time previously arranged between the perc tester and the Health Department technician, each test hole is filled with water to the level of the second nail on the perc test stake (which should be exactly six inches). NOTE: Do not wait for the technician to arrive to start the test. After one hour, the perc tester shall measure how far the water has dropped in each test hole. The holes are then refilled with water to the level of the second nail. This process is repeated for at least three more hours. The Health Department technician will take the measurements for the second and all readings after that.
8. In very porous soils, the water in the test holes may seep away in less than an hour. When this happens, the Health Department technician may go to half-hour or even ten-minute readings. A test may also be extended to five or more hours if the last three readings are inconsistent.

The following is a summary of when and how a perc test may be failed during the presoak.

1. No 48-inch test hole dug.
2. Evidence of seasonal high water table within 24 inches of the surface. (The test may be continued, but only at the request of the tester.)
3. Improper presoaking - less than 12 inches of water in any test hole at any time.
4. Filled lots when the Health Department has not been previously notified.
5. Isolation distances or other location problems with the test area.
6. There is evidence of impropriety.

The following is a summary of how and when a perc test may be failed during the test itself.

1. At least half of the test holes fail to drop one inch or more in any of the hourly readings.
2. There is evidence of impropriety.

When the perc test is completed, most testers are anxious to know the results. The Health Department technician who witnessed the test may be able to say if a test fails, but never if it passes. Perc test results usually take a few days to process. Testers should advise the Health Department technician during the perc test about how he or she would like the results of the perc test reported.

Perc test results are calculated using one of the following methods. The method, which results in the slowest perc rate, is used.

Soil Test

A soil test is the analysis of a soil sample to determine nutrient content, composition and other characteristics. Tests are usually performed with a soil test kit to measure fertility and indicate deficiencies that need to be remedied. Soil testing is often performed by commercial labs that offer an extensive array of specific tests. Less comprehensive do-it-yourself kits are also available, usually with tests for three important plant nutrients - nitrogen (N), phosphorus (P), and potassium (K) - and for soil acidity (pH). Lab tests are more accurate, though both types are useful. The quality of the original soil sample plays a key role in determining the practical value of test results. Soil characteristics can vary significantly from one spot to another, even in a small garden or field. Sample depth is also an important factor. And the presence of various nutrients and other soil components varies during the year, so sample timing may also be important. Mixing soil from several locations to create an "average" sample is a common procedure. All of these considerations affect the interpretation of test results.

Soil Test Components

Soils vary widely in composition and structure from place to place. The best way to determine soil components is to use a soil test kit or hire a professional percolation test service. Soils are formed through the weathering of rock and the breakdown of organic matter. Weathering is the action of wind, rain, ice, sunlight and biological processes on rocks, which breaks them down into small particles. The proportions of minerals and organic matter determine the structure and other characteristics of a particular soil. Soils can be divided into two general layers (strata): topsoil, the topmost layer, where most plant roots, microorganisms, and other animal life are located, and subsoil, which is deeper and often more dense and contains less organic matter. Water and air are also components of soils. Mineral and organic solids comprise about half of the soil by volume. Water occupies the spaces between soil particles and is held by surface tension on particle surfaces. Air occupies the remaining void space. Both water and air components of soils are important to plant growth and other life in the soil profile of a particular ecosystem. The rock and mineral content of soils is categorized according to particle size, from sand (coarsest), to silt and clay (finest). The ratio of these particles to a great degree determines the soil classification and characteristics.


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18 LANDSCAPE MAINTENANCE PLAN - SAMPLE FORM

Wynwood District

Landscape Maintenance Plan

for:

Property Address(es):_____

Development Name:_____

1. Tree pruning
    a. All pruning to be conducted in accordance with City of Miami and ANSI standards/Best Management Practices
    b. No more than 25% of the canopy of any tree can be trimmed within any 12-month period
    c. Trees must in general retain natural form. Trimming may not reduce the height or spread of the trees to increase visibility of signs, buildings, etc. or to achieve a specialized form, except as specifically noted in item “d” below.
    d. Special pruning: [list specific locations where specialized pruning is needed to accommodate security lights, clearance for vehicles, or other infrastructure components, or for special aesthetic forms. Include pruning dimensions (i.e. trim to maintain minimum 14’ clearance above roadway, maintain 5’ clearance from stop sign, etc.]
2. Shrub pruning
    a. All shrubs shall be pruned in a rounded shape, with the width on the top more narrow than the width on the bottom
    b. All shrubs to be pruned to a height of 36 inches, except as noted in item “c” below.
    c. Special shrub pruning locations and heights: [list specific locations, species, and shrub target heights. Example: green island ficus shrubs within parking lot landscape islands will be trimmed to a target height of two feet]
    d. Shrubs must be pruned prior to reaching one foot above target height or the property is considered in violation of the approved landscape plan.
3. Ground cover
    a. All ground cover must be maintained to have complete (90% or greater) cover of the designated bed.
4. Plant replacement
    a. Dead, effectively destroyed, and poor quality plants must be replaced, regardless of reason of death/deterioration of quality. Replacements needs must be verified and replacements conducted a minimum of twice per year, i.e.no dead/poor quality plant will persist for more than 6 months.
    b. All new (replacement) plants must meet minimum city standards per the approved landscape plan for the site. Note – the City tree permitting ordinance may require additional or larger size trees as replacements for trees that have been removed.

5. Irrigation
   Irrigation must remain operational in accordance with the approved landscape plan.

   Responsible party for irrigation: _____
6. Mulch
   All shrub beds and areas within three feet of each tree must be maintained with a three-inch deep cover of mulch. Mulch beds must be inspected and replaced as needed annually.
7. Fertilization
   All landscape beds shall be evaluated for need for fertilizer annually. Fertilizer nutritional components and application methods and intervals shall be as follows:

   _____

   _____
8. Pest Management
   All plants shall be inspected for pests and diseases at minimum annually. Pests/diseases shall be identified and treated per industry standards. If plant quality deteriorates to poor condition or pests/diseases are not brought under control by the following year, plants shall be replaced. Pest Management practices currently anticipated for the site based on species/known pests:

   _____

   _____
9. Trash and debris
   All landscape beds shall be maintained free of trash and debris
10. Annual Inspection and Reporting
    By March 31 of each calendar year, the property owner/maintenance contractor must conduct an audit of the landscaping on the property and confirm compliance with the landscape plan. Any discrepancies must be corrected or reported to the city with a request to approve the variation. Note – major variations will require a modification of the approved landscape plan for the site.

    This landscape plan is submitted by _____, legal representative for the property. By signing below I acknowledge that failure to maintain landscaping on the property in accordance with this landscape maintenance plan may result in a code compliance violation.

    Signed:_____

    Date:_____

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