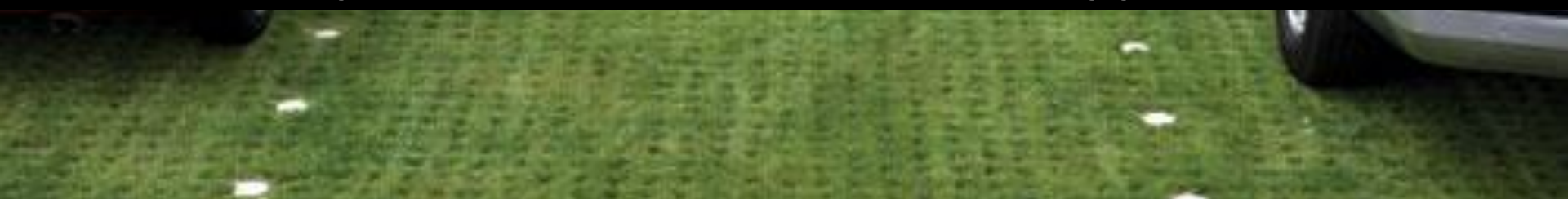
SOIL RETENTION

Plantable concrete systems®

Design Considerations for Vegetated Permeable Pavement

Creating open, multifunctional spaces and providing green benefits



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Learning Objectives

- Define permeable pavement including vegetated permeable pavement types, applicable government regulations, and best management practices for their use.
- Recognize the environmentally friendly attributes of vegetated permeable pavement systems.
- Identify basic design considerations of vegetated permeable pavement.
- Contrast the attributes of the four main types of vegetated permeable pavements.
- Apply sustainable design considerations for vegetated permeable pavements to project types, including their application to LEED® and SITES® credits.

Course Outline

- Section 1: Demonstrating Environmental Leadership
- Section 2: Benefits and Design Considerations of Vegetated Permeable Pavement
- Section 3: Differentiating between Vegetated Permeable Pavements
- Section 4: Green Infrastructure Initiatives and LEED® and SITES®
- Section 5: Conclusion

Course Introduction

- Vegetated permeable pavement will be the focus of this course, exploring some of the current environmental regulations, codes, and guidelines that incorporate their application, design considerations, modular options, and sustainable landscape benefits to help you make an informed decision.
- The main types of vegetated permeable pavements are flexible concrete mats, concrete grid slab, concrete grid paving units, and plastic geocells, each of which can be planted with turf or groundcover, or filled with aggregate or crusher fines.

Section 1 Demonstrating Environmental Leadership

Using permeable pavement, whether vegetated or not, is one of several strategies within a comprehensive site design and green infrastructure approach to creating more functional and sustainable landscapes.

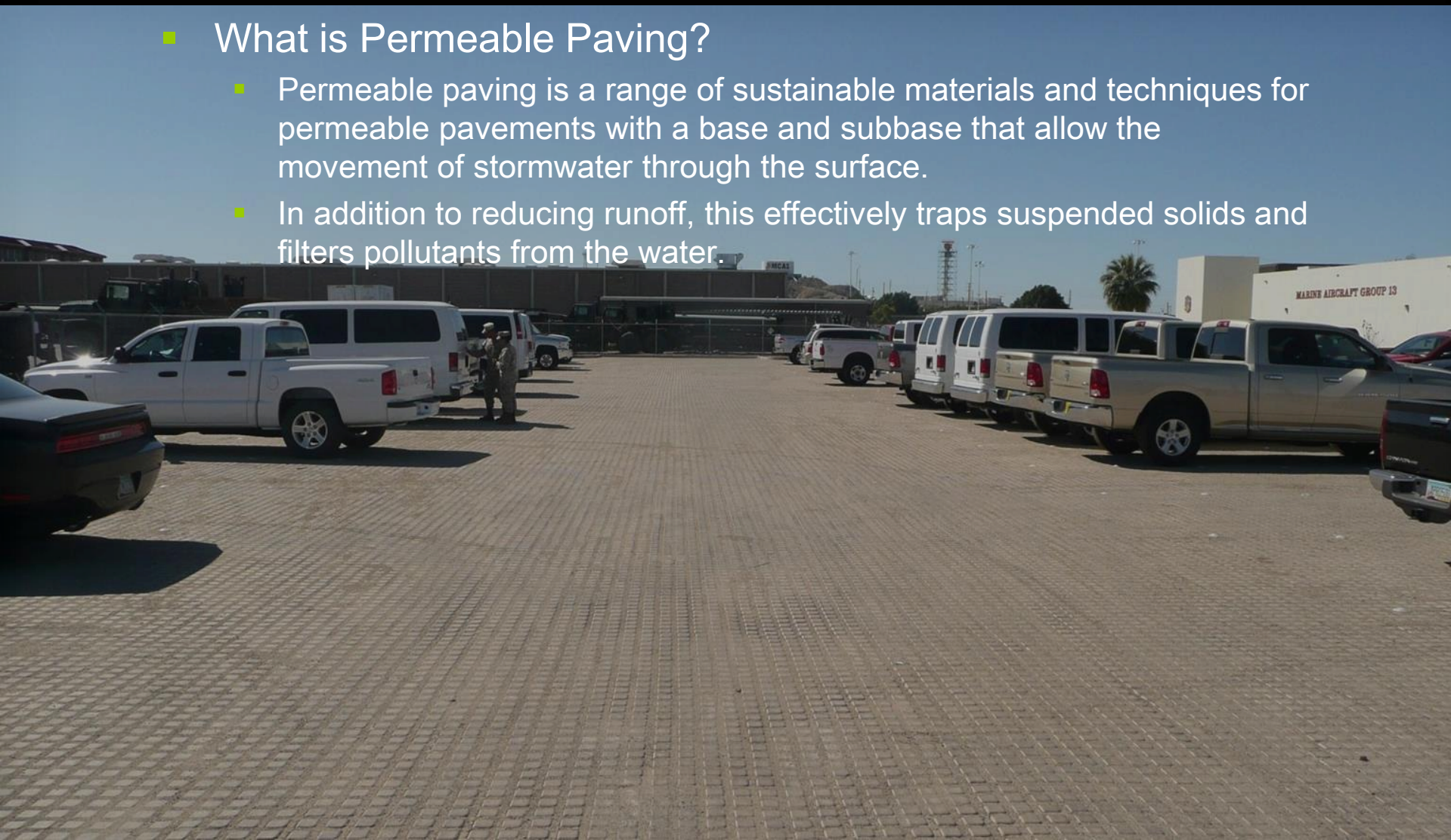
- The Environmental Protection Agency (EPA) considers “stormwater runoff in urban and developing areas to be one of the leading causes of water pollution in the United States”.
- In 2011, the EPA compiled a list of green infrastructure case studies nationwide.
- As part of a national rule-making process to create an EPA program to reduce stormwater runoff, 47.3 percent of the 479 case studies used some type of permeable pavement system, with just over half of the projects being retrofits of existing properties.

Section 1 Demonstrating Environmental Leadership

- “The primary motivation for using permeable pavement, is that it doesn't eat up the land (like surface retention basins, bioswales, and filtration basins do). This is especially important in urban areas where sites are smaller and must meet stormwater regulations.”

Neil Weinstein, executive director of the non-profit Low Impact Development (LID) Center in Washington, D.C.

Section 1 Demonstrating Environmental Leadership



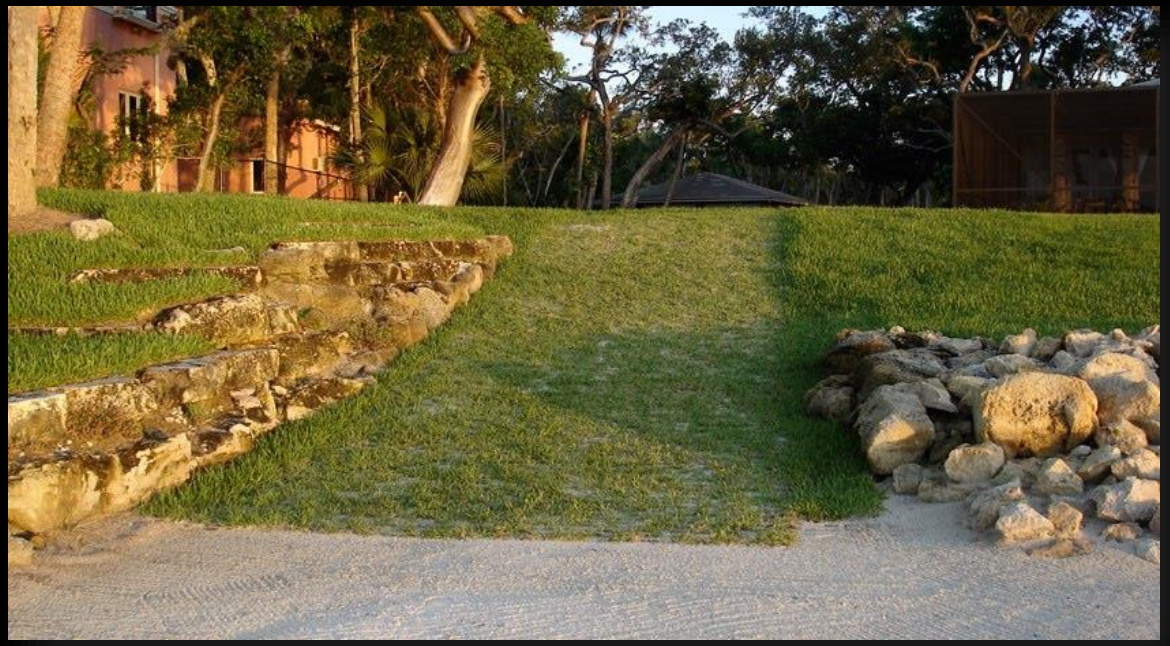
- What is Permeable Paving?
  - Permeable paving is a range of sustainable materials and techniques for permeable pavements with a base and subbase that allow the movement of stormwater through the surface.
  - In addition to reducing runoff, this effectively traps suspended solids and filters pollutants from the water.

Section 1 Demonstrating Environmental Leadership

- Reducing Flooding and Erosion While Cleaning Our Water
  - All permeable pavements have shown their ability to clean polluted urban runoff water before it reaches local streams and rivers by filtering out heavy metal contaminants such as lead, zinc, cadmium, and copper as well as acid rain and phosphorus.
  - Individual projects, whether public or private, can potentially use them to meet local and federal flood control and stormwater pollution regulations under the Clean Water Act's National Pollution Discharge Elimination System (NPDES).

Section 1 Demonstrating Environmental Leadership

- Reducing Flooding and Erosion While Cleaning Our Water
  - The value of permeable pavement systems to mitigate the flow of this type of pollution has increased its role in green infrastructure design, helping cities and private landowners alike to comply with these regulations.
  - These pavements are strong enough to carry the loads from vehicles yet allow for rainfall infiltration through the pavement surface. This infiltration quality lessens the potential for flooding and erosion as well as cleaning stormwater.



Section 1 Demonstrating Environmental Leadership

- Reducing Flooding and Erosion While Cleaning Our Water
  - Following on EPA's leadership in green infrastructure, many of the most recent and developed handbooks for best management practices (BMPs) and stormwater regulations are at the municipal level, in locations near bodies of water—streams, rivers, lakes, and coastal areas. This is where permeable pavement has seen its greatest public benefit—the cleaning of urban runoff into fisheries and water supplies.
  - Research on the use of permeable pavement for stormwater and erosion control is extensive and compelling.
  - Non-profit organizations such as LID Center and American Rivers tout permeable pavement and green infrastructure investment as important to the rebuilding of our aging national infrastructure.

Section 1 Demonstrating Environmental Leadership

- Reducing Flooding and Erosion While Cleaning Our Water
  - The City of Santa Monica, California, recently adopted a municipal code to reduce stormwater volume and improve water quality from existing properties and new development into Santa Monica Bay.
  - Developers must now reduce by 20 percent any projected runoff through an Urban Runoff Mitigation Plan, achieved by increasing permeable areas such as parking lots and driveways, while also increasing the percentage of green space. This is a perfect application for vegetated permeable pavement.

Section 2 Benefits and Design Considerations

- Benefits of Vegetated Permeable Pavement

- When permeable pavement is vegetated with turfgrass or groundcover, the overall effect can be stunning, and serves to integrate a project into its environment.
- Vegetation over pavement has the ability to absorb carbon dioxide, emit oxygen, and biodegrade pollutants.
- As a living plant material, its evapotranspiration naturally makes it cooler than inert surfaces such as concrete, reducing albedo and the Urban Heat Island (UHI) effect.
- The turfgrass surface reduces glare and absorbs noise, while adding to green open space on a developed site.

Section 2 Benefits and Design Considerations

- Benefits of Vegetated Permeable Pavement

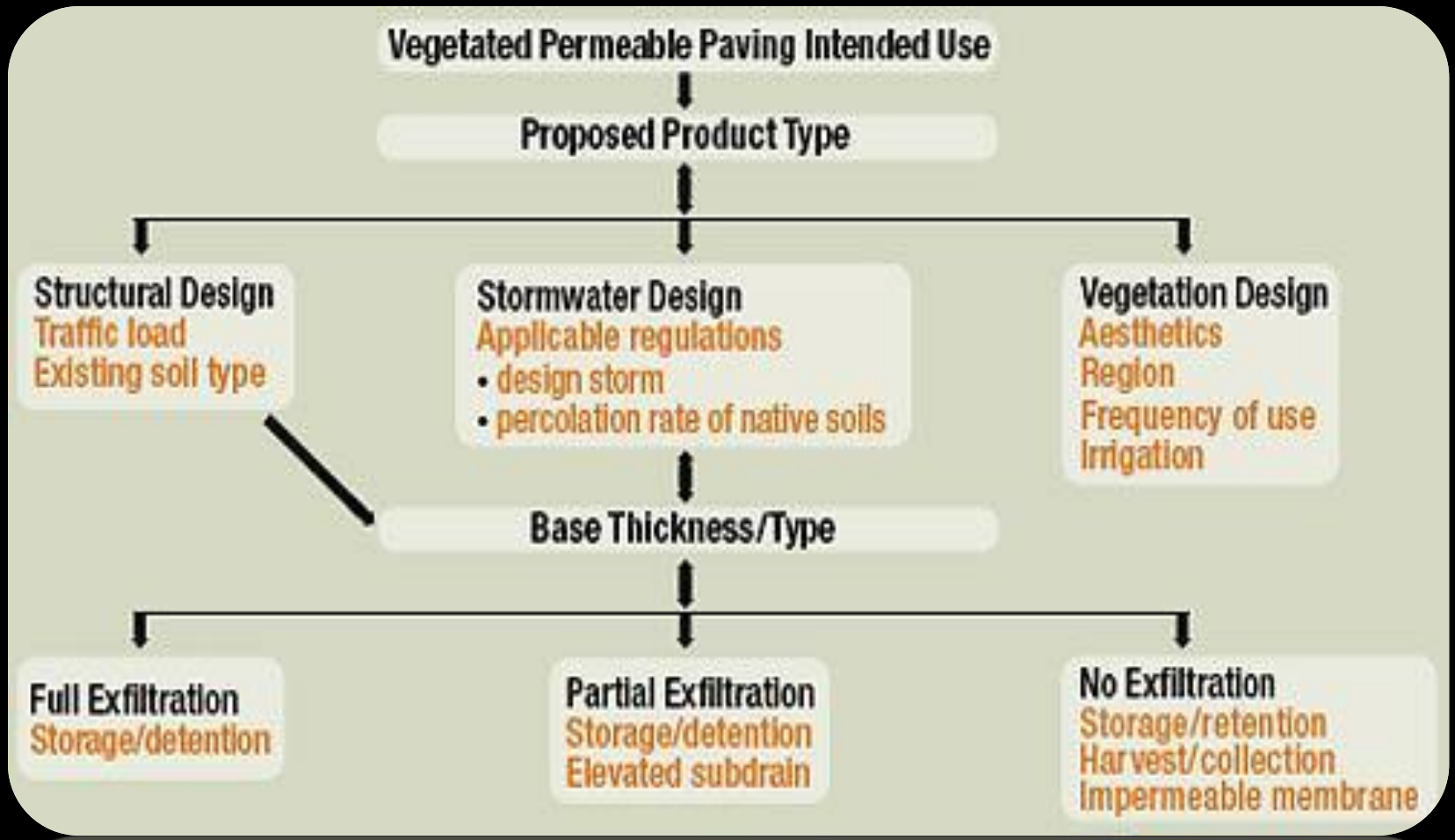
- Suitable for a variety of scales, vegetated permeable pavement is typically not used for major streets, except perhaps for parallel parking spaces.
- These pavements' ability to add vegetation into the voids, and even to cover the paved area, creates site area that becomes more a part of the landscape.
- Many applications are perfect for site areas infrequently used, such as fire lanes, utility easements, and drainage ways.
- Critical when site area is limited, vegetated permeable pavement can add green space, giving additional landscape and usable area back to the project

Section 2 Benefits and Design Considerations

- **Design Considerations for Vegetated Permeable Pavement**
  - Structural and stormwater design
  - Flood mitigation/stormwater retention or detention?
  - Water quality improvement, whether filtration or retention?
  - Water conservation for collection and reuse?
  - And ability to carry the intended site traffic.
  - In the chart below, a design decision flowchart clearly illustrates the process for designing a vegetated permeable pavement.

Section 2 Benefits and Design Considerations

- Design Considerations for Vegetated Permeable Pavement



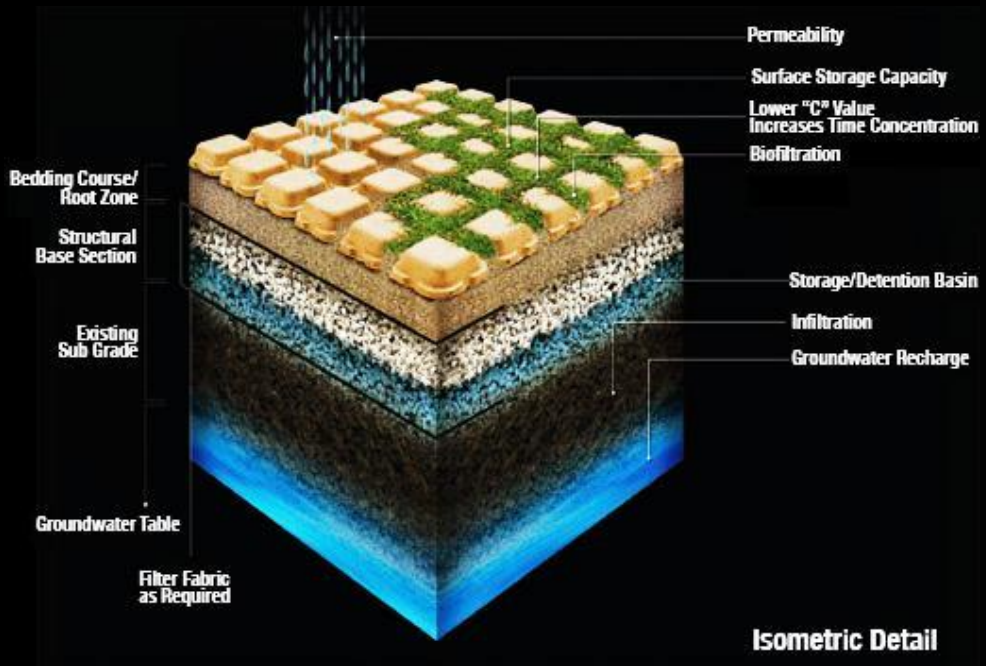
Section 2 Benefits and Design Considerations

- **Design Considerations for Vegetated Permeable Pavement**
  - A key design consideration is the composition of the subgrade (native soils below the paving section) and their infiltration rates.
  - Depending on the composition of the subbase (structural base material), in some cases enough rainfall can be collected to offset and store a percentage of the increased runoff from site development.

Section 2 Benefits and Design Considerations

- **Design Considerations for Vegetated Permeable Pavement**
  - For some projects, this may eliminate an expensive and separate “hard” drainage system. For other projects, with native soils with low infiltration, excess water could be detained and stored. Use of this excess stored water may have to be considered.
  - For example, this excess water could be harvested for reuse, or alternatively, piped away with an elevated underdrain.

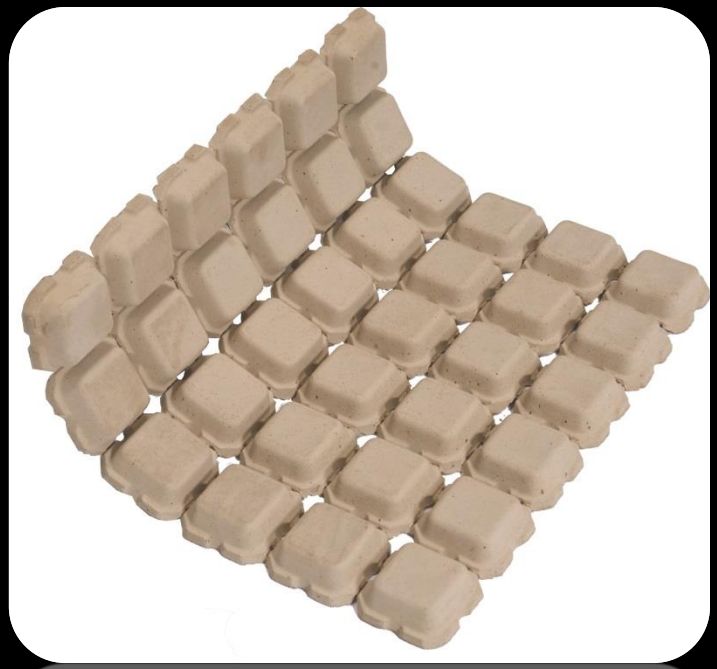
Section 2 Benefits and Design Considerations



- Turfgrass Considerations
  - Vegetation, specifically turf, is commonly used as a surface for applications with light pedestrian traffic, such as parks or ballfields.
  - For it to be a viable cover under vehicle traffic, the pavement design fundamentally needs to prevent soil compaction so that the living root zone for these plants is both porous and permeable to both air and water.
  - Vegetated permeable pavement has void spaces between a load-bearing pavement material, which distributes the imposed load to the underlying base and/or bedding materials.

Section 2 **Benefits and Design Considerations**

- **Turfgrass Considerations**
  - Another aspect of turf establishment and maintenance is to realize that the width of the load-bearing portion of any vegetated permeable pavement system is important to retaining turfgrass as well as carrying the traffic load.
  - The greater area of contact between the pavement and the vehicle tire, the better the pressure is distributed and the root zone is protected.



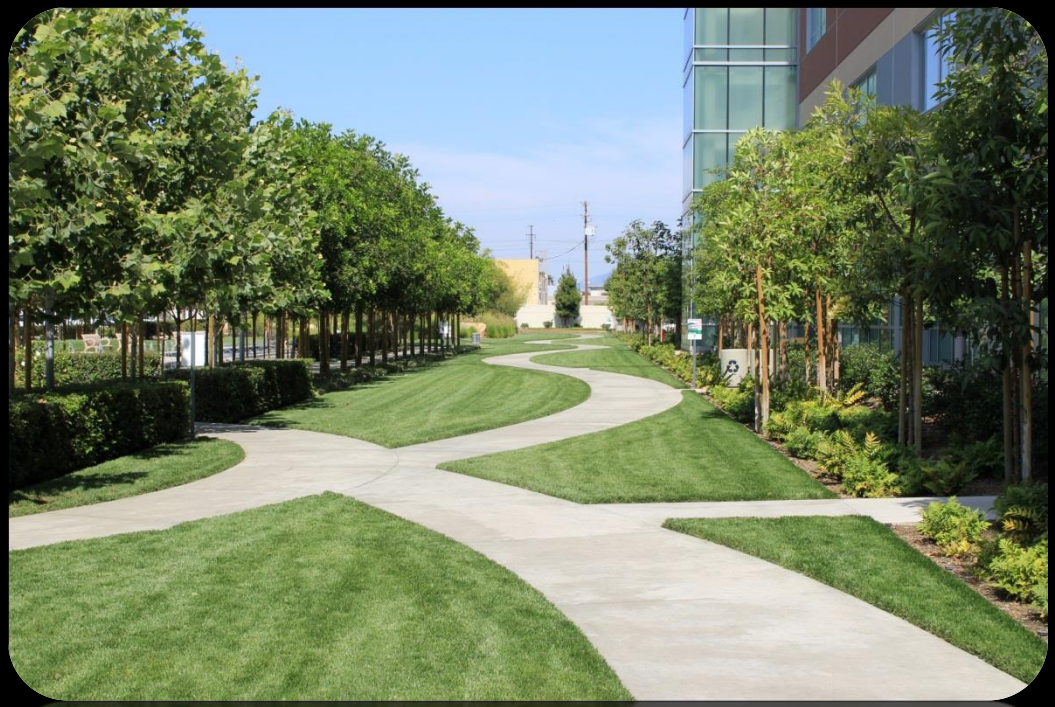
Section 2 Benefits and Design Considerations

- Turfgrass Considerations
  - A relevant ingredient for healthy turfgrass is a bedding course, defined as the underlying sandy material between the pavement and its often heavily compacted base, which allows for a continuous symbiotic root zone and moisture for the plants.
  - The depth of pavement can also have an impact on the ability for roots and moisture to spread along with similar-sized materials for infill and bedding course. Root zones are complex systems, with physical, chemical, and biological components.

Section 2 Benefits and Design Considerations

- **Turfgrass Considerations**
  - Specifying the type of grass species or groundcover, and whether to seed or sod turfgrass over the pavement surface depends greatly on the location and intended use.
  - Many geographic locations receive sufficient moisture to support turf without irrigation.
  - Choosing the appropriate vegetation for the site conditions, and anticipating cold climate factors such as freeze/thaw cycle are also important design considerations.
  - A pavement system can be designed to capture rainwater and collect the runoff for reuse as irrigation.
  - If the vegetated permeable pavement also serves to enhance stormwater regulation, this may be considered an appropriate application of water in an arid environment.

Section 2 Benefits and Design Considerations



- **Turfgrass Considerations**
  - Selection of a turf species must take into consideration microclimates like shade, slope, temperature variations, and seasonal conditions.
  - Parking can create a microclimate that casts shade for a portion of the day over the turfgrass.

Section 2 Benefits and Design Considerations

- Turfgrass Considerations
  - This may affect the density and growth of some turfgrasses; therefore, specifying the correct species can be an important long-term maintenance decision.
  - Whether to use a warm-season grass or cool-season grass, bunchgrass or spreading grass type, one that is salt tolerant to de-icing or is shade tolerant, are all design considerations that are site and project specific.

Section 2 Benefits and Design Considerations

- Maintenance Concerns
  - As with any new construction, concern is always expressed for long-term maintenance and durability of the product.

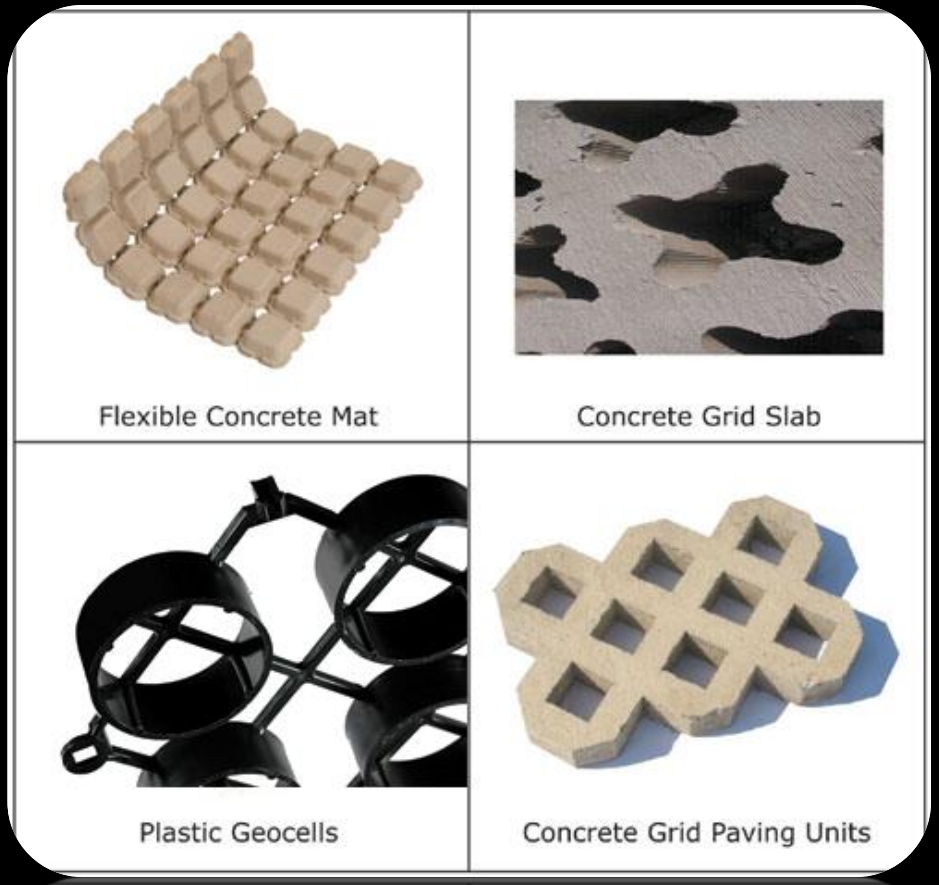
Section 2 Benefits and Design Considerations

- Maintenance Concerns
  - The non-profit organization LID Center has found that as with all the pavement systems—permeable concrete, permeable asphalt, permeable interlocking concrete pavers, and vegetated permeable pavements—“maintenance is low and has been shown to be quite resilient over time, as long as the openings remain permeable”.
  - The pollution-trapping benefit of vegetated permeable pavements is apparent, but there may be some concern about this diminishing over time. With maintenance, these systems can reasonably last up to 20 years, according to several sources.

Section 2 Benefits and Design Considerations

- Maintenance Concerns
  - Tips on keeping these systems functioning:
    1. make sure drainage from other areas with sediment loads does not flow over the pavement, clogging the voids
    2. perform periodic inspections following storms greater than ½ inch in depth to observe any standing water
    3. consider choosing salt-tolerant grasses where de-icing is common, and adding Teflon runners to snow plow blades to prevent damage
    4. monitor the turfgrass for diseases, fungi, and insect infestations, using biological controls such as ladybugs and organic controls
    5. consider implementing “resting periods” that vary access points and parking stall use to reduce wear on turf and giving it time to recover from heavy use
    6. consider the benefits of overseeding and top dressing to promote healthy living turf. The City of Chicago, for instance, recommends special care during snow removal and might even require mowing turf at times.

Section 3 Differentiating between Vegetated Permeable Pavements



- Each type of vegetated permeable pavement system is designed to promote infiltration of rain and snowmelt.
- Each system contains openings to be filled with sand, soil, or a sand/soil mixture that in combination with the bedding layer becomes a rooting zone for vegetation such as turf or groundcover.
- Note that comparison of the four types of vegetated permeable pavements is very difficult based on their diversity and different properties.

Section 3 Differentiating between Vegetated Permeable Pavements

- As Ferguson states:
  - “Many manufacturers supply guidelines for installation of their products. However, the reinforced plastic/geocell-producing industry does not have the benefit of an industrial association to set uniform standards of comparison or to educate potential users about appropriate applications.”
  - Manufacturers' reports of strength and other characteristics are too often based on tests that are inconsistent between one manufacturer and another, and between geocells and other types of paving materials. In the absence of uniform measures of performance, potential users are left to rely on experience with specific models in specific types of settings.”

Section 3 Differentiating between Vegetated Permeable Pavements

- It is noteworthy to understand that compressive strength is often used to compare plastic and concrete products.
- Concrete products have a required compressive strength for load bearing and unit dimensions and resistance to wear ultimately determine their performance.

Section 3 Differentiating between Vegetated Permeable Pavements

- Compressive strength for plastic products, on the other hand, can be derived from sand-infilled vertical plate lab tests.
- A substantial portion of the load is taken by the sand infill which increases the compaction of the material in the void space.

Section 3 Differentiating between Vegetated Permeable Pavements

- Flexible Concrete Mat
  - A precast mat unit with a network of concrete pads cast around a polymer grid that flex and conform to irregular ground surface contours.
- Concrete Grid Slab
  - Concrete grid slabs are a cast-in-place, monolithic pavement with voids from forms, with steel reinforcement.
- Concrete Grid Paving Units
  - Most people know these as the waffle-like, commonly available individual concrete block pavers with voids.
- Plastic Geocells
  - Reinforced plastic cells are made of a recycled plastic—high-density polyethylene (HDPE)—the #2 category for recycling.

Section 3 Differentiating between Vegetated Permeable Pavements

- Flexible Concrete Mat
  - Basic Product Composition: **Wet cast concrete mat with an engineered grid cast inside. Individual pads are intended to crack at the joints and grid is designed to allow for long-term settlements. Individual mats are butted up similar to conventional pavers. The concrete can use recycled material such as fly ash or slag.**
  - Flexible or Rigid: **Flexible**
  - Typical Infill and Bedding Course: **Specifies 80% sand and 20% organic infill and bedding course. Bedding course is typically 2 inches thick.**
  - Typical Void Width: **1.5 inches**
  - Typical Unit Load-Bearing Surface Area: **40%**
  - Typical Dimensions: **24 inches x 24 inches x 1.5 inches**
  - Measure of Performance: **ASTM. No specific ASTM for this type of product.**
  - Testing: **Manufacturer's reports: Permanent Deflection and Performance Study Sept. 2005 – Feb. 2006; Runoff 911 Test Section Performance**
  - Limitations: **Steel track vehicle areas. No certified installation program.**

Section 3 Differentiating between Vegetated Permeable Pavements

- Concrete Grid Slab
  - Basic Product Composition: **Cast-in-place, monolithic, pervious concrete pavement that is continuously reinforced with steel. The concrete can use recycled material such as fly ash or slag.**
  - Flexible or Rigid: **Rigid**
  - Typical Infill and Bedding Course: **Infill not specified; typically set on 1 inch of bedding sand**
  - Typical Void Width: **4 inches**
  - Typical Unit Load-Bearing Surface Area: **Not available**
  - Typical Dimensions: **continuous slab, 5.5 inches thick**
  - Measure of Performance: **ASTM, ACI. No specific ASTM for this type of product.**
  - Testing: **Common concrete strength testing and reinforcement per ASTM. Manufacturer's report: One-day test 1986 structural load test with Grumman ladder truck 23,000 lb per axle. RAM testing 1994—lateral load testing of the protruding concrete surface posts.[9] One-day test 1980 City of El Segundo Fire Department.**
  - Limitations: **Contoured installations. Accessibility to utilities below installation. Long-term oxidation of rebar. Lack of continuous bedding course for root zone.**

Section 3 Differentiating between Vegetated Permeable Pavements

- Concrete Grid Paving Units
  - Basic Production Composition: Dry cast modular concrete blocks. Some products include steel reinforcement to allow for heavier vehicles (typical spec for any modular block is the length / thickness <= 4). The concrete can use recycled material such as fly ash or slag.
  - Flexible or Rigid: Individual units are rigid.
  - Typical Infill and Bedding Course: Top soil infill or sand, if non-vegetated; ½ inch to 1 inch of bedding sand
  - Typical Void Width: 3 inches
  - Typical Unit Load Bearing Surface Area: 61%
  - Typical Dimensions: 24 inches x 24 inches (L x W) or less. Minimum thickness of 3.125 inches
  - Measure of Performance: ASTM, ICPI, NCMA
  - Testing: Common concrete strength testing. Several light-duty case studies through academic research available. No published field studies with heavy vehicles found.
  - Limitations: Steel track vehicle areas. Heavy loads on larger units without reinforcement (based on ASTM 936) resulting in cracking at surface from base or subgrade settlement. Elaborate contoured installations. Lack of continuous bedding course for root zone.

Section 3 Differentiating between Vegetated Permeable Pavements

- Plastic Geocells
  - Basic Product Composition: **Plastic. Most commonly HDPE plastic in modular tray units or standard roll sizes covering 108 to 538 square feet. Rings connected by tensile members or a network of square or hexagonal cells.**
  - Flexible or Rigid: **Flexible and rigid**
  - Typical Infill and Bedding Course: **Infill varies between top soil and sand. No bedding course is typically specified. Rolled units require staking into the base or subbase material.**
  - Typical Void Width: **2 to 3 inches**
  - Typical Unit Load-Bearing Surface Area: **5 to 13%.**
    Typical Dimensions: **1 to 1.5 inches thick. Varying dimensions for trays and roll sizes.**
  - Measure of Performance: **None at this time.**
  - Testing: **Different laboratory tests per manufacturer for sand filled and unfilled compression tests. A.G. Wassenaar Geotechnical compression resistance/load-bearing capacity test 1991. No published heavy vehicle field tests.**
  - Limitations: **Steel track vehicle areas. Memory in the material once disturbed. Movement of plastic under stress (plastic is susceptible to thermal expansion /contraction). Strength of narrow sidewalls in a saturated environment. Lack of continuous bedding course for root zone. No common measure of performance or certified installation program.**

Section 4 Green Infrastructure Initiatives

- Other decisions that should be part of the initial design process are whether the project is pursuing LEED® and SITES®, other pavement design factors that might be important for your project type, potential first and life-cycle costs will be, and the level of commitment that the client plans for maintenance.

Section 4 Green Infrastructure Initiatives

- The goals of reducing stormwater runoff and improving stream health are inherent in both green building/green infrastructure rating systems such as LEED® and SITES®.

- In New York's *Green Infrastructure Plan (2011): A Sustainable Strategy for Clean Waterways* the goal is to reduce by 10 percent its combined sewer overflow through the use of retention and infiltration by 2020.

- Within nearly each land-use type in this large metropolitan area, from streets and sidewalks to parks and parking lots, there are opportunities to use permeable pavement to achieve that 10 percent goal.

Section 4 Green Infrastructure Initiatives

- The City of Chicago, through its *Green Alley Handbook*, and extensive green infrastructure design efforts, lists “Permeable Paving” as one of its preferred materials, being “most effective in areas closer to Lake Michigan that are underlain with sandy, permeable soil.

- Permeable pavement may have aesthetic and marketing advantages over conventional pavement, depending on the materials selected.

- Vegetated pavers, in particular, could substantially improve the aesthetic appeal of paved areas and effective in reducing the 'urban heat island' effect.”

Section 4 Green Infrastructure Initiatives

- To this city, permeable pavement is particularly appropriate for overflow and special event parking, driveways, utility and access roads, emergency access lanes, fire lanes, and alleys.

Section 4 Green Infrastructure Initiatives

- The City of Seattle Public Utilities (SPU) Department and Office of Sustainability recommends use of permeable pavement for their Stormwater Facility Credit (SPU) program.
- The SPU program grants discounts on drainage bills for private stormwater systems that reduce stormwater flow and/or provide water quality treatment.
- Permeable pavement is among the stormwater structures that qualify for up to a 50 percent credit.

Section 4 Green Infrastructure Initiatives

- **LEED® and SITES®**
  - To set a green building leadership example, the U.S. General Services Administration (GSA) increased its stipulation for LEED certification for its facilities in 2010.
  - The GSA now requires all new federal buildings and major renovation projects to achieve at least a LEED Gold certification, up from the previous Silver rating.
  - “Sustainable, better-performing federal buildings can significantly contribute to reducing the government's environmental footprint,” former GSA Commissioner of Public Buildings Robert A. Peck has said.

Section 4 Green Infrastructure Initiatives

- LEED® and SITES®
  - Vegetated permeable pavement options can help projects achieve LEED® and SITES® credits.
  - Points for LEED® Credit 1 Water Efficient Landscape, when planted with drought turf and tolerant groundcover
  - Credit 4 Recycled Content for HDPE, fly ash or slag
  - Credit 5.0, 5.1 & 5.2 Site Development for use in parking stalls and pathways, and use of regional materials, where applicable
  - Credit 6.1 & 6.2 Stormwater Design for water quality and quantity control
  - Credit 7.1 & 7.2 Non-roof (parking) and Roof (pathways).

Section 4 Green Infrastructure Initiatives

- LEED® and SITES®
  - Within the proposed point system for SITES® (the Sustainable Sites Initiative), potential credits may be reached for Site Design/Water
  - 3.3 protect and restore riparian areas
  - 3.4 rehabilitate streams
  - 3.5 manage stormwater
  - 3.6 protect and enhance on-site water resources and water quality
  - Site Design/Soil and Vegetation (4.6 restore biomass

Section 4 Green Infrastructure Initiatives

- LEED® and SITES®
  - 4.7 use native plants, 4.9 restore vegetation native to the ecoregion, and 4.12 reduce urban heat island effects)
  - Site Design/Materials Selection (5.3 deconstruction design, 5.5 recycled content, 5.7 regional materials)
  - Site Design/Human Health and Well Being (6.5 site accessibility, 6.6 opportunities for physical activity
  - 6.8 provide outdoor spaces); Construction (7.2 restore soils disturbed during construction), and Monitoring and Innovation.

Section 5 Conclusion

- Conclusion
  - The use of a vegetated permeable pavement system is becoming very popular with urbanized areas near coastal and riparian environments, and those adjacent to lakes and rivers, essentially where the bulk of all our cities are located.
  - The use of these green infrastructure techniques can have huge significance to efforts to be more sustainable and to lessen our impact on the environment.
  - Infiltration of water through vegetated permeable pavement, with its ability to slow and clean runoff full of pollutants like motor oil, salts, and urban detritus, is but one reason to use vegetated permeable pavements.

Section 5 Conclusion

- **Conclusion, Con't.**
  - The applications for vegetated permeable pavements will continue to grow, as noted in the green infrastructure plans for Chicago, New York, and other major metropolitan areas.
  - All elements of site design can benefit from permeable pavement. Whether a large-scale or small-scale project, the use of vegetated permeable pavement gains valuable space for the site designer and developer in companion with its stormwater benefits.
  - Site landscapes can become more multifunctional, creating more usable open space and a sustainable landscape.

Thank You

This concludes the AIA Continuing Education System Program

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