Acknowledgments

I would like to thank IAPA, Kevin Burke and Anne Bigane Wilson for this scholarship and the opportunity to further immerse myself into the world of asphalt. I have had many great times as well as trying times during my college career, but you all have had a hand in making my last year of my undergrad, my best year. I am grateful for the opportunity to have visited the Bigane Paving Co. plant. It is opportunities like these that really make learning new information in the construction industry both impactful and memorable in a way that a classroom setting could not. It has laid the foundation for exponential personal and professional growth. Additionally, amid a pandemic, academic financial assistance has been invaluable.

Abstract

Asphalt is used in road construction and maintenance. It can practically be used anywhere a vehicle would normally drive including parking lots and airport runways. In some cases, rapid surface water drainage is required. In these cases, porous asphalt is used to create a permeable surface. Porous asphalt is prepared in such a way that it maintains a large quantity of interconnected void spaces through which water can pass.

Similarly, concrete is used in areas with foot traffic such as sidewalks. There are cases where water in these areas would need to be drained more quickly. Pervious concrete is often implemented to fulfill drainage requirements in these cases. Like porous asphalt, it contains ample void space for water to flow through.

It is important to investigate the trade-off between the enhanced drainage capability of permeable/porous/pervious pavements and the reduction in their strength. The relationship between compressive strength and void ration can be analyzed through research, to determine the best application for these types of pavements. From literature, it is apparent that pervious pavements should not be used to withstand heavy traffic loading. They are primarily used in areas with low traffic volume including driveways, walkways, and parking lots.

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Permeable Pavement Systems

Asphalt is made up of a composite of aggregates, filler and binder. Aggregates typically used in asphalt include slags, sand, gravel, and crushed rock. Recently, recycled construction materials have been incorporated as aggregates, to create a more sustainable asphalt. In order to form a more cohesive mixture, bitumen in generally used. Bitumen is what is known as a binder. Asphalt contains approximately 5% binder. As with aggregates, sustainable alternatives are being developed to minimize the impact of construction materials, on the environment.

There are three different categories of asphalt; hot mix, warm mix and cold mix. The difference is the temperature at which they are produced. Hot mix asphalt is produced at temperatures ranging from 120 to 190 degrees Celsius while cold mix asphalt is not heated at all. There are various mixtures that can used in each category based on surface usage requirements and local conditions.

Concrete is made up of a composite of fine and course aggregates, water and cement. The most common type of cement is Portland cement. Aggregates typically used in concrete include sand, gravel, and rock.

As stated in the Virginia Department of Conservation and Recreation (DCR) (2011) Stormwater Design Specification No. 7 for Permeable Pavement:

"*Permeable pavements are alternative paving surfaces that allow stormwater runoff to filter through voids in the pavement surface into an underlying stone reservoir, where it is temporarily stored and/or infiltrated. A variety of permeable pavement surfaces are available, including pervious concrete, porous asphalt and permeable interlocking concrete pavers. While the specific design may vary, all permeable pavements have a similar structure, consisting of a surface pavement layer, and an underlying stone aggregate/reservoir layer. The thickness of the* *reservoir layer is determined by both a structural and hydrologic design analysis. The reservoir layer serves to retain stormwater and also supports the design traffic loads for the pavement. If infiltration rates in the native soils permit, permeable pavement can be designed without an underdrain, to enable full infiltration of runoff."*

These systems consist of three main layers. The top layer is known as permeable pavement or surface layer. This layer has void spaces ranging from 18%-25% compared to traditional pavement which has void spaces between 2%-3%. The middle layer is made up of open-graded bases and subbases. The bottom later is the uncompacted soil subgrade. These layers impact strength, durability, and overall performance. Permeable pavement systems can be designed with underdrains and/or liners to meet certain stormwater management requirements.

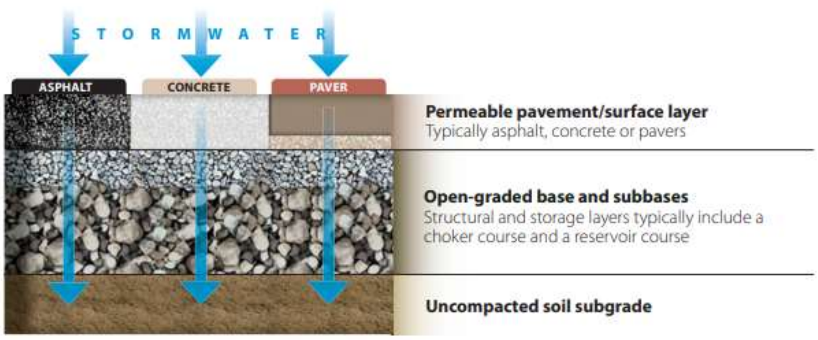

Figure 1 (3)

Types of Permeable Pavement

As mentioned earlier, there are multiple types of permeable pavement including porous asphalt and pervious concrete. In porous asphalt, void space is created by removing the fine aggregates, normally found in traditional asphalt, from the mixture. Alternatively, the void space in pervious concrete is created by the addition of larger aggregates to the traditional concrete mixture. Other types of porous asphalt include permeable interlocking concrete pavement, grid pavement systems, permeable pavers and rubber overlays.

Regional Considerations

There are several considerations that must be taken with considering using porous pavement. Two of the most important factors include climate and material availability, locally. Certain temperatures and precipitation behavior can require design modifications. This can affect cost and performance. You must also take into consideration the soil types in a particular region. This will affect infiltration rates and requirements.

Several additional considerations must be taken when attempting to use permeable pavement in areas that experience prolonged freezing temperatures including frost durability of the saturated system. There are potential freeze-thaw issues in these types of areas. However, these types of pavements generally do well in cold climates.

Design

Permeable pavements act not only as stormwater management systems but also as load bearing surfaces. Both must be taken into consideration when designing such a system. Each layer must be appropriately sized in order to achieve both structural stability and appropriate drainage and storage. Factors to consider include type of use, traffic load, subgrade characteristics, contributing area runoff, infiltration rate, and overflow rate. Design methods published by AASHTO (1993) *Guide for Design of Pavement Structures* can be used to aid in the structural design of these pavement systems.

Maintenance

Research indicates that permeable pavement will maintain appropriate infiltration rates if the surface is vacuumed regularly. This is typically done twice per year. However, if the surface does become clogged, it can typically be unclogged with the use of regenerative vacuums. If the surface is not maintained, it will need to be fully replaced.

Cost

The cost for permeable pavement systems can very. Cost depends on pavement surface type, system design, local material availability, plant to site distance. A retrofit design is typically less expensive than new construction however, the material cost for permeable pavement systems is generally more expensive than that of traditional pavement. Most of the increased cost of porous pavement systems stem from the aggregate stormwater bed. It is usually thicker than that of conventional pavement. Management cost reductions can be found in the stormwater storage and infiltration capacity if it is beyond the requirements of the property. This can eliminate construction costs of other stormwater infrastructure meant to perform a similar task. It is important to note that pervious concrete is more expensive than porous asphalt.

Applications

Porous asphalt is typically used in low traffic areas such as driveways and parking lots. It can also be used on low speed, low volume roads. While there have been some higher volume applications, porous asphalt is not generally used in these types of applications due to the intricacies of the construction process.

Benefits and Setbacks

Porous pavement reaches a surface permeability between 430-1250 cm/hr. Due to its permeability, it reduces pavement runoff. It also aids in water pollutant removal. In northern climates, it's use can minimize salting requirements and is less likely to form black ice. UNHSC found that a porous asphalt parking lot reduced the need for winter maintenance salt by approximately 50% to 75% (Roseen and Ballestero 2008; UNHSC 2009). It is less susceptible to damage resulting from freeze and thaw cycles than traditional pavements as well. Porous pavement also offers noise reduction, which given the areas in which it is used, would be highly beneficial.

While porous pavement behaves well in certain conditions, it can only be used in a small range of applications due to it's reduced strength and durability. In general, the cost for these surfaces are approximately 20%-50% higher than conventional asphalt. This does not include the storm water facilities that are required.

Strength and Permeability

Strength and permeability are inversely related when it comes to permeable pavements. A pervious concrete of a given void ratio, can obtain an increase in strength by supplementing stronger aggregate with more fractured faces. This can lead to better locking. Additionally, the aggregate gradation and/or the cement can be improved. ASTM test methods are being developed for characterizing flexural or compressive strengths of pervious concrete as well as other properties. These tests are needed to model fatigue of rigid pavement under loads. Fatigue equations published by the American Concrete Pavement Association (Rodden et al. 2010a) assume such inputs to be comparable in nature to those used for conventional rigid concrete pavements.

Permeable pavements are not structurally adequate for truck traffic or heavy loads due to the lack of fine aggregates as well as the different mix properties of porous pavement. Additionally, areas with heavy traffic are cot conducive to use with permeable pavements. An increase in traffic load bearing capacity can be accomplished by increasing the base/subbase aggregates depth with proper compaction and installation. That said, they still do not perform as well as conventional pavements.

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