PERVIOUS CONCRETE IN SUSTAINABLE PAVEMENT DESIGN

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Summary: *Climate change means that incidences of 'extreme weather' are becoming commonplace. Increasingly frequent bouts of heavy rainfall should be anticipated as the norm rather than the exception, and in conjunction with our increased rate of urban development, this means that risk of flooding is rapidly increasing. Pervious concrete allows the water to percolate through the concrete into the sub-base and recharge the underground water level. Voids within the pervious concrete should be interconnected so as to create channels through which water can freely flow. The advantages of pervious concrete can be classified into 3 basic categories: environmental, safety and economics. Pervious concrete pavement is a unique and effective means to meet growing environmental demands. By capturing rainwater and allowing it to seep into the ground, pervious concrete is instrumental in recharging groundwater, reducing stormwater runoff. Although not a new technology (it was first used in 1852), pervious concrete is receiving renewed interest.*

Keywords: *pervious concrete, water, pavement, sustainable*

1. INTRODUCTION

Reducing the strain on our environment is essential to the overall health and wellbeing of our society. While a variety of new designs and technologies have transpired from this green movement, one of the more profound impacts has been in the area of stormwater management (SWM).Named one of the best management practices for SWM quality,

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pervious concrete has the ability to capture the runoff of rainwater and remove trace pollutants. **Pervious concrete,** figure 1., can be defined as an open graded or "no-fines" concrete that allows rain water to percolate through to the underlying sub-base (ACI Committee 522 2006). Pervious concrete can replace traditional impervious pavement for most pedestrian and vehicular applications except high-volume/high-speed roadways. Pervious concrete can be designed to handle heavy loads, but surface abrasion from constant traffic will cause the pavement to deteriorate more quickly than conventional concrete. Pervious concrete has performed successfully in pedestrian walkways, sidewalks, driveways, parking lots, and low-volume roadways. The environmental benefits from pervious concrete allow it to be incorporated into municipal green infrastructure and low impact development programs. In addition to providing stormwater volume and quality management, the light color of concrete is cooler than conventional asphalt and helps to reduce urban temperatures and improve air quality. Unlike the smoothed surface of conventional concrete, the surface texture of pervious concrete is slightly rougher, providing more traction to vehicles and pedestrians [1,2].

2. TYPICAL COMPOSITION OF PERVIOUS CONRETE

Pervious concrete, sometimes referred to as "no-fines concrete" is a mixture of hydraulic cement, coarse aggregate of smaller size, admixtures and water. Typically, pervious concrete does not contain any sand and its air void content varies between 15 and 30%. A small amount of sand can be used for compressive strength improvement but air void content will be reduced and permeability lowered. It is important to maintain the proper volume of paste/mortar in the mix design so that the aggregate is equally coated but the excess of paste/mortar does not fill the void space within coarse aggregate. Voids within the pervious concrete should be interconnected so they create channels through which water can freely flow, Figure 1. 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.When properly constructed, pervious concrete is durable, low maintenance, and has a low life cycle cost. [3,4].

Figure 1. Pervious Concrete

Figure 2 show typical cross sections of pervious concrete pavements. On level sub-grades, stormwater storage is provided in the pervious concrete surface layer (15% to 25% voids), the sub-base (20% to 40% voids), and above the surface to the height of the curb (100% voids). (source ACI 522) [3].

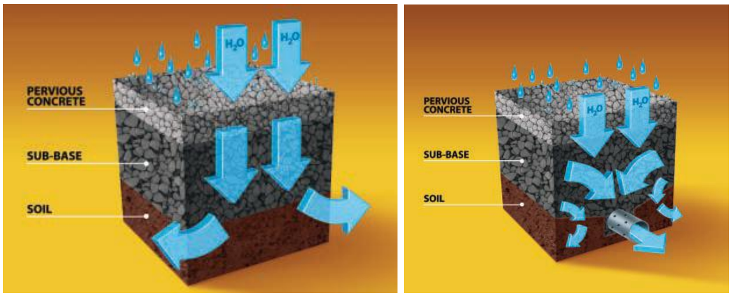

Figure 2. Typical cross sections of pervious concrete pavements

3. TYPES OF PERVIOUS PAVEMENTS

There are several types of pervious pavements that are used in practice. The three common types as shown in Figure 3a,b,c are pervious concrete, pervious interlocking concrete pavers, and concrete grid pavers[5].

3) a. Pervious Concrete; b. Pervious Interlocking Concrete Pavers; c. Concrete Grid Pavers

4. ENVIROMENTAL BENEFITS - LEED CREDIT

Pervious concrete is recognized by United States Green Building Council (USGBC), which sets the green building rating system known as the LEED program (The Leadership in Energy and Environmental Design). The LEED program is the nationally accepted benchmark for the design, construction, and operation of high performance "green" buildings. Under the LEED rating system, pervious concrete can contribute to the following credits: **Stormwater Design Credit:** Using pervious concrete can contribute immensely to managing stormwater runoff as well as providing on-site infiltration and reducing contaminant loading before entering the groundwater. **Heat Island Effect – Non-roof credit:** With lighter color than paved asphalt, pervious

concrete has the ability to reflect solar radiation. The relatively open pore structure also stores less heat than paved asphalt.
Water Efficient Landscaping Credit: Trees and other landscaping have a hard time growing and thriving in covered areas due to the difficulty of getting water and air through the impervious pavements. Using pervious concrete reduces the need for potable water for irrigation. **Recycled Content Credit:** As mentioned previously, the aggregate usage in the pervious concrete mix can contain a percentage of recycled aggregate and not compromise the integrity of the structural performance or durability of pervious concrete. **Regional Materials Credit:** Similar to conventional concrete, pervious concrete can utilize much of the natural stone and other such aggregates that are local to the building site; thereby reducing the pollution needed to transport materials [6,7].

5. DURABILITY

Permeability. Typical flow rates for water through pervious concrete are 11,5 to 30,2 liters per square foot per minute, but can be double that amount if desired.
Compressive Strength. Pervious concretes can develop compressive strengths in the range of 3,5 do 35 PMa – suitable for a wide range of applications.
Shrinkage. Drying shrinkage of pervious concrete is faster but much less than that experienced with conventional concrete. Many pervious concretes are made without control joints and are allowed to crack randomly.
Abrasion resistance. Because of the rougher surface texture and open structure of pervious concrete, abrasion and raveling of aggregate particles can be a problem, particularly where snowplows are used to clear pavements. Surface raveling in new pervious concrete can occur when rocks loosely bound to the surface pop out under traffic loads.
Experience has shown that pervious concrete pavements in **cold weather climates** tend to have an inherent ability to withstand freeze-thaw cycles. **Freeze-thaw resistance of pervious concrete** appears to depend on the saturation level of the voids in the concrete at the time of freezing. Field observations have shown that the rapid draining characteristics of pervious concrete prevent saturation from occurring. It is important to understand that the porosity of pervious concrete from the large voids is distinctly different from the microscopic air voids that provide protection to the paste in conventional concrete in a freeze-thaw environment. When the large voids are saturated, complete freezing can cause severe damage to the pervious concrete pavement. Thus, it is critical to protect and maintain the void structure of pervious concrete in order to ensure cold weather durability. Anecdotal evidence also suggests that snow covered pervious concrete clears quicker, possibly because its voids allow the snow to melt more quickly than it would on conventional pavements. Mechanical removal of ice and snow can be accomplished using snow blowers or snow plows. Because of its rigid nature, pervious concrete pavement is actually less susceptible than other flexible paving materials to damage from snow plowing [8].

6. NRMCA RECOMMENDATIONS

The National Ready Mixed Concrete Association (NRMCA 2004) has developed guidelines for using pervious concrete in areas prone to freeze-thaw conditions.
Dry Freeze and **Hard Dry Freeze** Dry freeze are areas of the country that undergo a number of freeze-thaw cycles (15+) annually but there is little precipitation during the winter. If the ground stays frozen as a result of a long continuous period of average daily temperatures below freezing, then the area is referred to as hard dry freeze area. Since pervious concrete is unlikely to be fully saturated in this environment, no special precaution is necessary for successful performance of pervious concrete. However, a 10 cm to 20 cm. thick layer of clean aggregate base below the pervious concrete is recommended as an additional storage for the water. **Wet Freeze** This includes areas of the country that undergo a number of freeze-thaw cycles annually (15+) and there is precipitation during the winter. Since the ground does not stay frozen for long periods it is unlikely that the pervious concrete will be fully saturated. No special precaution is necessary for successful performance of pervious concrete but a 10 to 20 cm. Thick layer of clean aggregate base below the pervious concrete is recommended. Many parts of the middle part of the Eastern United States come under this category.
Hard Wet Freeze Certain wet freeze areas where the ground stays frozen as a result of a long continuous period of average daily temperatures below freezing are referred to as hard wet freeze areas. These areas may have situations where the pervious concrete becomes fully saturated. The following precautions are recommended to enhance the freeze-thaw resistance of pervious concrete: 1. Use an 8- to 24-in. thick layer of clean aggregate base below the pervious concrete; 2. Attempt to protect the paste by incorporating air-entraining admixture in the pervious mixture; 3. Place a perforated PVC pipe in the aggregate base to capture all the water and let it drain. Not every situation warrants all the 3 safeguards. The safeguards are organized in the order of preference. For example, a pervious concrete sidewalk at Pennsylvania State University in State College, PA, which is a hard wet freeze area, has shown good performance over five winters while it has only an 8–in. thick layer of aggregate base underneath the pervious concrete. High Ground Water Table Pervious concrete is not recommended in freeze-thaw environments where the ground water table rises to a level less than three-feet from the top of the surface or where substantial moisture can flow from higher ground [8,9].

7. CONCLUSIONS

Pervious concrete is a mixture of cement, water, and coarse aggregate, and little to no sand. It also frequently contains chemical admixtures. Pervious concrete creates a very porous medium that allows water to drain to the underlying soils.
Pervious concrete can improve water quality by capturing the “first flush” of surface runoff, reduce temperature rise in receiving waters, increase base flow, and reduce flooding potential. The pavement creates a short-term storage detention of rainfall. In order to fully utilize these benefits, the hydrological behavior of the pervious concrete system must be assessed. The hydrological performance is usually a key parameter in

decisions to use this material as a best management practice (BMP) for storm water management [10,11].

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ПОРОЗНИ БЕТОН ПРИ ПРОЈЕКТОВАЊУ ТРОТОАРА У СВЕТЛУ ОДРЖИВОГ РАЗВОЈА

Резиме: *Климатске промене подразумевају да се екстремне временске непогоде дешавају све чешће. Појава краткотрајних киша изузетно јаког интензитета постаје свакодневна, што у комбинацији са постепеном урбанизацијом повећава опасност од појаве урбаних поплава. Порозни бетон омогућава води да се филтрира кроз бетон и неометано доспе до подземља. Шупљине унутар порозног бетона морају бити међусобно повезане да би формирале мрежу каналчића кроз коју вода може слободно протећи. Предности порозног бетона се могу сврстати у три основне категорије: заштита животне средине, безбедност и економичност. Тротоари направљени од овог материјала представљају јединствен начин задовољавања еколошких услова. Наиме, задржавањем падавина и омогућавањем да оне доспеју и подземље, омогућава се прихрањивање подземне воде и смањује се количина отицаја са урбаних сливова. Мада се не ради о новој технологији (први пут је уведена 1852), порозни бетон је поново доспео у центар пажње стручне јавности.*

Кључне речи: *порозни бетон, вода, тротоар, одрживи развој*