PERVIOUS CONCRETE – A SUSTAINABLE CHOICE IN CIVIL ENGINEERING AND CONSTRUCTION

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Abstract

Pervious concrete (no-fines concrete) is a concrete containing little or no fine aggregate; it consists of coarse aggregate and cement paste. It seems pervious concrete would be a natural choice for use in structural applications in this age of 'green building'. It consumes less raw material than normal concrete (no sand), it provides superior insulation values when used in walls, and through the direct drainage of rainwater, it helps recharge groundwater in pavement applications.

The first pervious concrete has been used in Europe and the United Kingdom since 1930s for the building of single story and multistory houses, but had found little acceptance in rest of the world. In recent years, however, due to increased awareness of the need for conservation of nonrenewable mineral resources, increased consideration is being given to the use of pervious concrete in most countries. Even though, it is not yet widely used in Sri Lanka, pervious concrete is generally used for light-duty pavement applications, such as residential streets, parking lots, driveways, sidewalks, channel lining, retaining walls and sound walls.

This paper discuss the art of pervious concrete; materials and possible mix proportions, properties such as compressive strength, flexural strength, shrinkage, permeability with initial tests done at Innovation & Application Center of Holcim (Lanka) Limited, and the principal advantages, major disadvantages and principal applications in Sri Lankan construction industry.

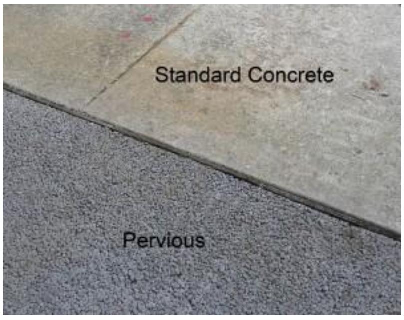
Key Words: Pervious concrete, no-fines concrete, Porous concrete, permeable concrete, green concrete, sustainable concrete

1. INTRODUCTION

Pervious concrete is one of the leading materials used by the concrete industry as GREEN industry practices for providing pollution control, storm water management and sustainable design. The increased interest in pervious concrete is due to those benefits in storm water management sustainable development. This paper will provide technical information on application, mixture design and construction methods of pervious concrete. It will also discuss the suitability of pervious concrete in tropical countries like Sri Lanka while analysis environmental and economical benefits.

2. What is pervious Concrete?

Pervious concrete is a zero-slump, open-graded material consisting of hydraulic cement, coarse aggregate, admixtures and water. In the absent of fine aggregates, pervious concrete has connected pores size range from 2 to 8 mm, and the void content usually ranges from 15% to 25% with compressive strength of 2.8MPa to 28MPa (however strength of 2.8 to 10 MPa are common). The draining rate of pervious concrete pavement will vary with aggregate size and density of the mixture, but will generally fall within the range of 81 to 730 L/Min/m2.



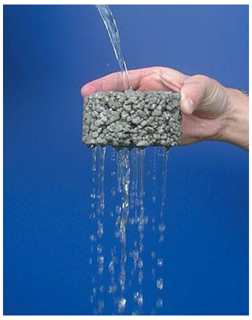
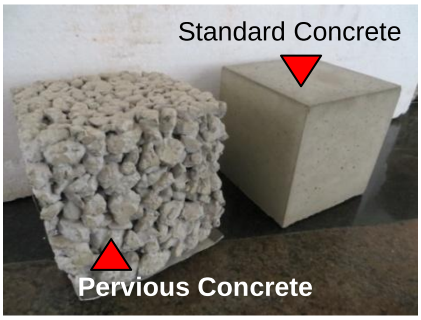



Figure1, 2 & 3: Samples of Standard Concrete & Pervious Concrete

Figure 4: Different types of concrete tested at Holcim Lanka Innovation & Application Center (Pervious, light weight, Low strength, high strength, coloured etc…)

3. Pervious Concrete mix design

Pervious concrete uses same materials as conventional concrete, except that there are usually No or little fine aggregates. The size of the coarse aggregate used is kept fairly uniform in size (most common is 3/8 inch) to minimize surface roughness and for a better aesthetic, however sizes can vary from ¼ inch to ½ inch. Water to cement ratio should be within 0.27 to 0.34. Ordinary Portland cement and blended cements can be used in pervious concrete. Water reducing admixtures and retarders can be used in pervious concrete.

General Issues encountered compared to standards concrete are;

1. Long mixing time in the batching plants (about 20 min)
2. Poor workability, very dry mix, difficult for placing
3. Amount of water used in mix is important as same as standards concrete
4. If too much water used, segregate is expected, usually higher than standards concrete
5. If too little water is used, not easy to mix, balling of mix in the mixer

Table 1: Typical mix design of Pervious Concrete as suggested by ACI 522R-10

Materials	**Proportions (Kg/m3)**
Cement (OPC or blended)	270 to 415
Aggregate	1190 to 1480
Water: cement ratio (by mass)	0.27 to 0.34
Fine: coarse aggregate ratio (by mass)	0 to 1:1
Chemical admixtures (retarders) are commonly used Addition of fine aggregates will decrease the void content and increase strength	

*Table 2: Optimised mix design of Pervious Concrete (**with 20mm aggregates, No Sand**), tested at Holcim Lanka Laboratory with local raw materials*

Materials	**Proportions (Kg/m3)**
Cement (OPC or blended)	580*
Aggregate (20mm)	1026
Water: cement ratio (by mass)	0.3
Fine: coarse aggregate ratio (by mass)	0
high-range, water-reducing admixture (Rheobuild 1000) is used – 760mL per 100Kg of Cement	

Achieved Compressive Strength

28 day cube strength = 20.2 MPa

* More cement is to be used because of NO sand & larger aggregates (20mm)

*Table 3: Typical mix design of Pervious Concrete (**with 10mm aggregates, No Sand**), used in Holcim Singapore in a real project*

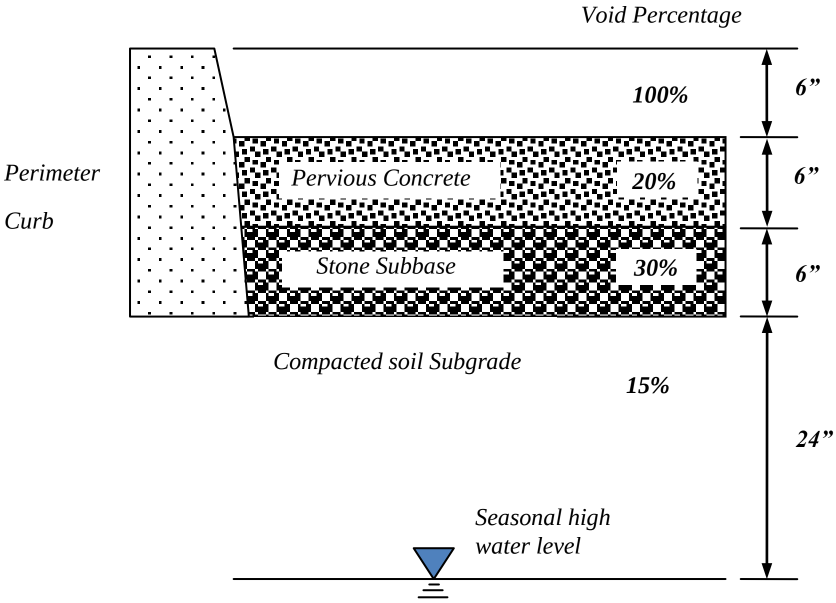
Materials	**Proportions (Kg/m3)**
Cement (OPC or blended)	300-400
Aggregate (10mm)	1026
Water: cement ratio (by mass)	0.3-0.4
Fine: coarse aggregate ratio (by mass)	0
Admixtures: retarder 300 ml per 100 kg cement super plasticizer 800 ml per 100 kg cement Slump less than 75mm	

Achieved Compressive Strength

28 day cube strength = 20 MPa

4. Design Pervious Concrete to control storm water

Typical cross section of pervious concrete designed for storm water is given in figure 5



Curb area: provide to retain flood water, usually 6” layer (100% voids)

Pervious concrete: usually 6” layer (20% voids)

Base or subbase: Compacted metal (stone), usually 6” layer (30% voids)

Subgrade: Compacted existing soil, usually 24” (15% void)

Figure 5: Typical cross section of pervious concrete designed for storm water

4.1 Calculate Storm water Storage Capacity

When used, a curb provides essentially 100% porosity, so the height of the curb adds directly to the storage capacity of the pavement system *(see figure 1)* in a flat area. Total storage capacity of the pavement including curbs will be 8.8 in. (244 mm):

Storm water Storage Capacity ***(without storage volume of subbase soil)***

Voids in Curb + Voids in Pervious Concrete + voids in stone layer = **Total**

(100% X 6 inch) + (20% X 6 inch + (40% X 6 inch) = **9.6 inch (244mm)**

If consider the storage volume of sub base as well

Voids in Curb + Voids in Pervious Concrete + voids in stone layer + Voids in subbase = **Total**

(100% X 6 inch) + (20% X 6 inch + (40% X 6 inch) + (15% X 24 inch) = **13.2 inch (335mm)**

Table 3: Typical rainfalls in Cololmbo Sri Lanka are shown below

Rainfall (mm)	Duration	Rainfall (L/m2/min)	Remarks
354.3	1 month	8.20	Maximum monthly rainfall in 2011
64.9	1 day	45.07	Maximum daily rainfall in 2012 according to times online
75	1 hour	1,250.00	GBCSL Green rating SL; max. rainfall intenity for strm water design 75mm/hour

It proves that above design is suitable to control runoff of maximum possible rainfall in Colombo or the design guidelines given by BGCSL for storm water design.

4.2 Quality of subgrade in storm water control

If compacted subgarde soil has not enough permeability to withstand for the design flood, it is good to introduce underground drainage pipes as sown below. The size of the pipes can be calculated as design requirements.

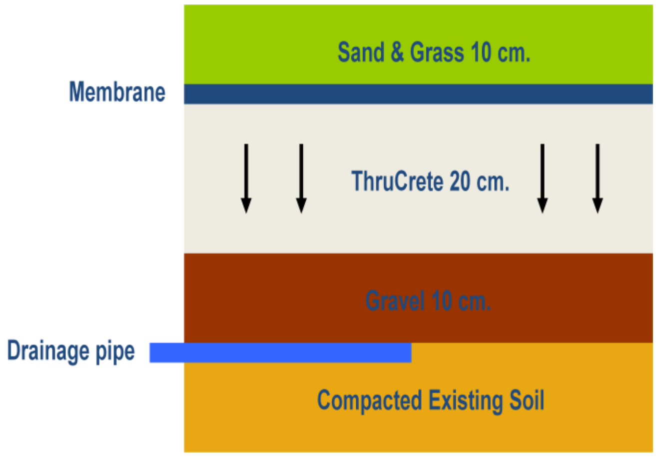


Figure 6: Typical cross section of pervious concrete with drainage pipes which can be used for grounds

Figure 7: Pervious concrete car park, plated grasse on top of concrete.

The correct procedure of placing pervious concrete are Layout and Subbase preparation, Placing pervious concrete, Jointing, Compacting, Curing and surface protection, Testing Compressive Strength & Water permeability, Sand fill & Grow grass.

5. Environmental and Economic benefits of pervious concrete

There are many environmental benefits of pervious concrete such as retain storm water, recharge ground water, keep pavement surfaces dry even in wet situation, reduce or no storm water drainage is required, allow water and air to get to the roots of trees in the area, remove oil and other pollutions from the that washes off the surface, reduce heat island effect, allow to claim LEED points or SLGBC points to green certificates in US or in Sri Lanka.

Economic benefits of pervious concrete are lower installation costs due to elimination of costly storm drains, lower lifecycle cost due to fever repairs and recyclability at the end of life. A typical example cost comparison of pervious concrete (Insee Thrucrete) Vs conventional concrete, us for a car park in Holcim Thailand. The total savings is Rs. 135/m2 (32 THB/m2)

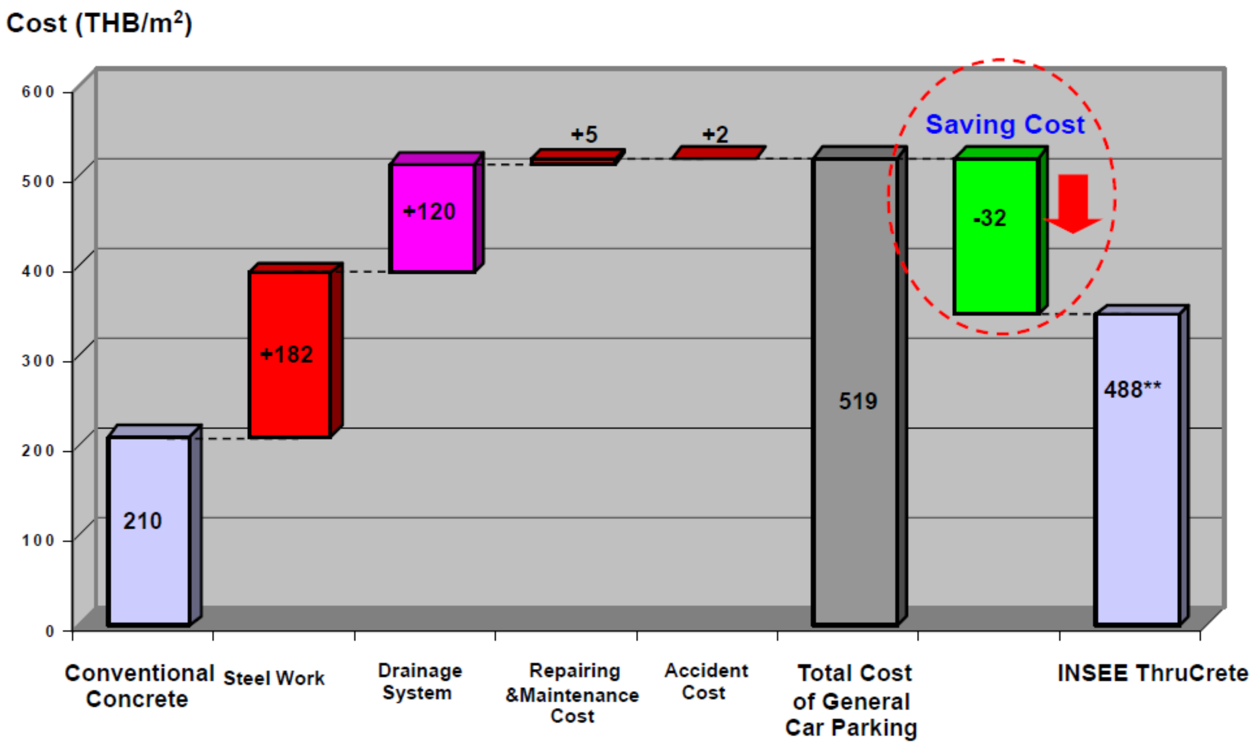


Figure 8: Cost comparison of Pervious concrete Vs conventional concrete (Holcim Thailand experience)

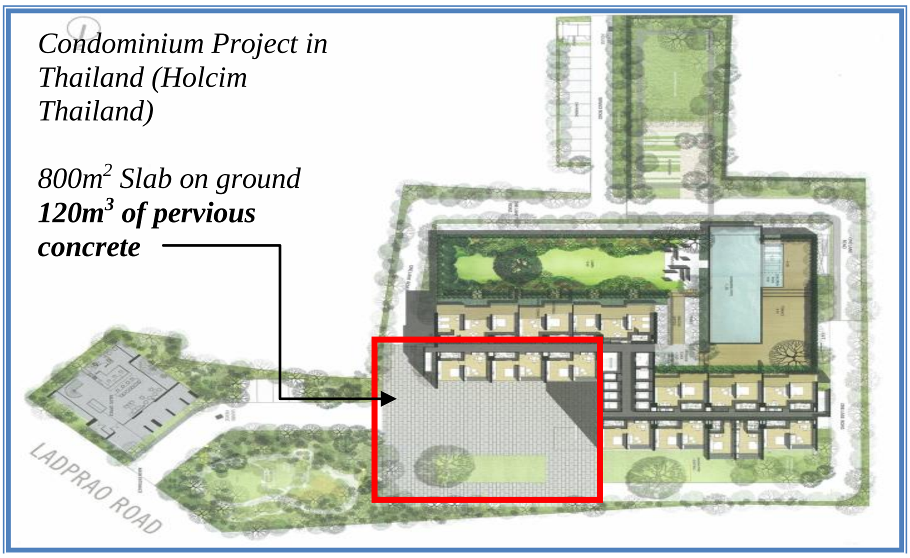


Figure 9: Pervious concrete for a condominium projects in Thailand (Holcim Thailand)

6. Trials with local raw materials

Initial trials are carried out with local raw materials at Holcim Innovation and Application center for compressive strength & flexural strength. The compressive strength of pervious concrete is strongly affected by the mixture proportion and compaction effort during placement. Even though we were able to get high compressive of 20.2 MPa as given in table 2 with 20mm aggregates, lot more trials to be carried out for different aggregate sizes, different w/c ratios etc to localized the mix proportions used by many other projects all over the world. When we are satisfied with lab test trials, commercials to be carried out in our in house projects at two plants and then encourage construction industry to use pervious concrete with confidence.

7. Conclusion

Pervious concrete pavements are a very cost-effective and environmentally friendly solution to support sustainable construction. Its ability to capture storm water and recharge ground water while reducing storm water runoff enables pervious concrete to play a significant role. Pervious concrete is a smart sustainable option with very high potential. Pervious concrete is an ideal solution to control storm water, re-charging of ground water, flood control at downstream and sustainable land management. Knowledge on pervious concrete is very well received by the Specifies / Architects / Engineers.

8. Recommendation for specifies, engineers and architects

Pervious concrete pavements more than 30 years old are still in service in other countries like Europe and USA. As pervious concrete have its own principal advantages and major disadvantages, these concrete to be well designed & applied in the right manner to get desired outcome. Our lab trials show that pervious concrete can be applied in Sri Lankan construction industry, however trials with commercial projects to be done before that. With the experience that we got as Holcim group in other countries, we know exactly that this pervious concrete application will be well accepted by the industry professional in Sri Lanka in next few years time.

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