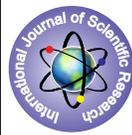


## Strengthening of Pervious Concrete for High Load Road Application; a Review



### Engineering

**KEYWORDS :** Pervious concrete, Mechanical properties, Permeability, Highways

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### ABSTRACT

*Pervious concrete has been increasingly used all over the world to reduce the amount of runoff water and improve the water quality near light volume pavements and parking lots, but its use in India is question of concern. However, due to the significantly reduced strength associated with the high porosity, pervious concrete mixtures currently cannot be used in highway pavement structures. This paper provides the review of improving the mechanical properties of pervious concrete through different factors i.e. using additives, using different type and size of aggregates, different w/c ratios; without considerable effect on permeability. This review paper aims at looking for a vision to introduce pervious concrete with optimum Mechanical properties for using in Highways as an alternative for storm water mitigation and increasing the ground water level.*

### INTRODUCTION

Pervious concrete is a mixture of Portland cement, coarse aggregate or gravel, and water (Figure 1). Unlike conventional concrete, pervious concrete contains a void content of 15 to 35 percent (average of 20 percent) that is achieved by eliminating the finer particles such as sand from the concrete mixture. This empty space allows water to infiltrate the underlying soil instead of either pooling on the surface or being discharged as runoff. Sidewalks and parking lots are ideal applications for pervious concrete(1). Pervious concrete is being used as pavement as one of solutions to decrease the storm water run-off.

Although not a new technology (it was first used in 1852), pervious concrete is receiving renewed interest in the USA, partly because of Federal Clean Water Legislation. Pervious concrete is recognized as a structural infiltration Best Management Practice by Environmental Protection Agency for providing first flush pollution control and storm water management (2).

Massive urbanization in Indian cities is causing the ground water to go deeper and is causing water shortage. For example; Cherrapunji suffers drought while the monsoons bring flooding, Chandigarh city taps ground water from deep confined aquifers which do not get naturally recharged. Further the rain water falls on the concrete and asphalt surfaces tends to carry a high level pollution and this pollution ends up in waterways ultimately (2). So, sustainable technologies like pervious concrete are likely to become more popular in India.

Pervious concrete has reduced strength compared to the conventional concrete but studies show that it can be increased by using smaller sized aggregates (3), flexural strength can be increased by using latex, polymers etc as admixtures (4), freeze-thaw and abrasion resistance could be increased by using cellulose fiber (5), Compressive strength can be increased by addition of sand up-to 7% (6), method of compaction also effects the mechanical and hydraulic properties of pervious concrete (6).

This paper provides the review of improving the mechanical properties of pervious concrete through different factors i.e. using additives, using different type and size of aggregates, different w/c ratios; without considerable effect on permeability. This review paper aims at looking for a vision to introduce pervious concrete with optimum Mechanical properties for using in Highways as an alternative for storm water miti-

gation and increasing the ground water level.



**Figure 1: Pervious Concrete**

**Sources:** <http://www.tececo.com.au/images/photographs/permeconcrete/PerviousPavement.JPG>

LITERATURE REVIEW (Material Properties and Mechanical Properties)

### Aggregates

The standard type aggregate for use in pervious concrete is typically crushed stone or river gravel. Typical sizes are from 3/8 in. to 1 in. (7). It has been shown that using smaller aggregates increases the compressive strength of pervious concrete by providing a tighter bond between coarse aggregate and cement. Using fine aggregates in the mix design of pervious concrete will also decrease the void space (7). Increasing the percent amount of larger aggregates will increase the void ratio in pervious concrete, but will decrease the compressive strength (8). The size of the aggregate also has an important role in pervious concrete. While a 3/4 in. aggregate size allows for greater void space, a 3/8 in. aggregate improves the workability (9).

Using recycled aggregates has also been researched. Four mix designs were studied using 15%, 30%, 50%, and 100% recycled aggregates and compared to the virgin pervious concrete samples. It was found that samples containing 15% or less recycled aggregates exhibited almost identical characteristic to the virgin sample (10).

The angularity no. of aggregates increases with the increase in size of aggregates. As the angularity no. of aggregate increases in the Pervious Concrete Mix the compressive strength decreases and the permeability of the mix increases (11)

#### Fine Particles

While pervious concrete is considered a “no fines” concrete, a small percentage of fine particles can be added to increase the compressive strength of the pervious concrete mix. The inclusion of fine particles has a direct correlation to the paste/mortar strength. Providing a thicker paste layer around the coarse aggregates results in improved compressive strength (6). When the sand to gravel ratio is increased to 8 %, the mortar bulks up and increases the strength. When the sand to gravel ratio increases beyond the 8 % mark, the 7 day compressive strength begins to fall (6). A slight decrease in permeability correlates to the increase in fine particles.

#### Cementitious Material and W/C Ratio

Cement is used as the cementitious material in porous concrete it can be PPC OR OPC. Additional materials that can be used in the cementitious mix are silica fume, fly ash, and slag cement (7). While any potable water can be used for mixing, the amount of water is critical for the formation of the voids in pervious concrete. Water-to-cement ratios can range from 0.27 to 0.30 with ratios as high as 0.40. Careful control of water is critical. A mix design with little water can create a very weak binder. This will create a very dry mix that is susceptible to spalling and crumbling. A mix design with too much water can collapse the void space, making an almost impenetrable concrete surface (12). As seen in Figure 2, the specimen in Figure 2 a. has too little water, the specimen in Figure 2 b. has the correct amount of water, and the specimen in Figure 2 c. has too much water.



a.



b.



c.

**Figure 2: Pervious Concrete With a. Too little Water, b. Appropriate Amount of Water, c. Too much Water**

Sources: <http://www.perviouspavement.org/images/materialsfig5.jpg>

#### Admixtures

The use of admixtures in conventional concrete is essential and vital to performance and workability. High strength pervious concrete can be achieved through addition of supplementary cementitious material using silica fumes and polymer modification using polymer SJ-601 (13). It is noted that Polymer Modified Pervious Concrete demonstrated much higher fracture toughness and far longer life than Supplementary Cementitious Pervious Concrete (13). High-range water-reducing (HRWR) admixtures are applied to concrete mixes to affect the set time of concrete (12). They require less water and increase the slump of concrete. Caution must be used when applying HRWR to pervious concrete. Large dosage can cause the cement to segregate from the aggregate and settle at the bottom of the concrete, forming an impervious layer of cement (9).

Latex, a styrene butadiene rubber material which has been used to improve the cement-aggregate bond (14), was used to replace a certain amount of Portland cement to determine its potential application in pervious concrete pavements (15). The addition of Latex increases the flexural strength of Pervious Concrete (16). Approximately 10% of Portland cement was replaced with Latex and it was found that pervious concrete specimens with Latex had, on average, a lower compressive strength. Although the use of Latex lowered the compressive strength, the specimens showed an increase in tensile strength, indicating an improved resistance to cracking.

Crumbed rubber, tire chips, fine crumbed rubber when used by the partial replacement of 10%, 20% of volume of single sized coarse aggregates, the best results for abrasion and freeze-thaw resistance of Pervious Concrete are achieved using fine crumbed rubber at partial replacement of 10% volume of coarse aggregates where as compressive and flexural strength of the mix reduces (17).

The uses of hydration controlling admixtures (HCA) were beneficial by slowing down the rate of hydration. This extended the time before the fresh concrete started to set, thereby allowing more time to form and finish the concrete surface. Using of the HCA allowed 60 to 90 minutes of added working time (18). Delayed set modifiers helps in gaining the compressive strength at early age of 7-14 days (5)

Viscosity Modifying Admixtures (VMA) may also play a pivotal role on the performance of pervious concrete. While little has been researched about the use of viscosity modifiers, the small

amount of research has shown that VMAs can increase flow of concrete as well as provide ease of compaction and placement. While different VMAs can have differing effects on the overall result of pervious concrete, special attention is needed to determine and verify the correct type and amount prior to installation (18).

Cellular fiber results for the flexural strength, abrasion and freeze-thaw resistance of Pervious Concrete are better than Pervious Concrete with delayed set modifier and viscosity modifier respectively (5).

#### LITERATURE REVIEW (Porosity, Permeability and Advantages)

If the density of Pervious Concrete increases the porosity and permeability decreases (3). Porosity has little effect in rate of strength development and it was further noticed that Flexural strength is more sensitive to porosity than compressive strength (13). Minimum 19% porosity is required in a Pervious Concrete mix to produce the permeability of 1 mm/sec (19). With increase in angularity no. of aggregates in Pervious Concrete the permeability increases (11). The compressive strength and permeability test results of Pervious Concrete do not show clear dependence on the size of specimen (20).

Pervious concrete also has the ability to reduce the noise due to vehicles (21). Through the open voids in the concrete, the amount of air pumping between the tire and road is minimized. By providing a reduction in traffic noise, this can potentially eliminate the need for costly noise barriers (22; 23).

Pervious concrete has a texture that is different from conventional concrete; it has an open voided surface that some have compared to "rice crispy treats". The open porous nature of pervious concrete has allowed sound to dissipate into the underlying sub-base.

Pervious concrete also has the ability to purify the storm water as it percolates through to the sub-base (24). This so called "eco-concrete" has the ability to not only control and mitigate the amount of runoff from storm water, but also reduce the environmental load on the surrounding ecosystem and purify the storm water as it seeps through to the sub-base. By submerging the freshly cured pervious concrete in water to allow microorganisms to grow, nitrogen and phosphorous can be removed from the Storm water (24).

Pervious concrete can be beneficial to building site designs by aiding in qualifying for LEED credits under the US Green Building Council (25).

#### RESEARCH GAP NOTICED

Although extensive work has been done in world on Pervious Concrete, but still Pervious Concrete Mix for high load road application has not been achieved yet with a specific permeability required and also limited work has been done in the field of fracture and fatigue behavior of Pervious Concrete, which are especially important for concrete pavement subjected to heavy traffic and to severe seasonal temperature change. Being a brittle material, the mechanical behavior of pervious concrete is critically influenced by its crack propagation, or fracture behavior. Subjecting repeated traffic and environmental loads, concrete pavements often fail under fatigue cracking. A better understanding of fracture and fatigue behavior of pervious concrete can help to improve pavement design procedures.

Also it has been noticed that not a significant amount of work on Pervious Concrete has been done in India.

#### OBJECTIVES FOR FUTURE WORK

The objectives of future study would be aimed at filling the above-mentioned research gap, and it is to investigate the various responses (such as the compressive and flexural strength, fracture toughness, fatigue and permeability properties) of the high-strength pervious concrete through use of selective supplementary cementitious materials (SCMs) or polymer modification.

#### CONCLUSION

Currently, porous concrete pavement is becoming a popular choice over the world as an effective stormwater runoff management device. There are a lot of previous studies that have been conducted by other researchers in order to improve the conventional porous concrete pavement. The main problem of porous concrete pavement is its strength. Due to high voids content in the concrete, it is hard to produce concrete with high strength. One of the important parts in porous concrete is cement paste binder. To strengthen the cement paste binder, various types of additives have been studied by previous researchers. Even though various fundamental information has been studied, the optimum condition to produce good porous concrete has still not been established. The objective of this paper was to explain the effects of various component of Pervious Concrete on its properties and introduce a research gap for future study.

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