Experimental Investigation of Top Mix Permeable Concrete on Pedestrian Pathway

M.P. Indhu[1,a*], S. Krishnamoorthi[2,b], S. Manivel[1,c]

[1]PG Student, Department of Civil Engineering, Kongu Engineering College, Perundurai, Erode, Tamil Nadu, India

[2]Professor, Department of Civil Engineering, Kongu Engineering College, Perundurai, Erode, Tamil Nadu, India

[*a]indhuperiasamy98@gmail.com, [b]skmoor@kongu.ac.in, [c]manivel2702@gmail.com

Keywords: Hot Island, Permeable, Air Proof Concrete, Pavement, Porosity, Skid Resistance

Abstract. Our towns are increasingly protected by buildings and water paved pavements. Moreover, the city's climate is far from normal. Rainwater is not filtered underground due to the absence of the permeability of the common concrete pavement to water and air permeability. In addition, the exchange of heat and humidity with air is difficult for the soil, and it's not possible to change the temperature and relative humidity of the Earth's surface in urban areas. At the same time, the safety from both car and foot passenger traffic is limited by a plash on the road on a rainy day. Since the 1980s, work on permeable asphalt pavements has started in developed countries like the US and Japan. For roadway applications, permeable concrete is also widely used as a surface course in Europe and Japan Improving skid resistance and reducing noise from traffic. Only about 20 – 30 MPa can the material reach's compressive intensity. Due to their low strength, such materials cannot be used as pavement. Only frames, walking routes, parking garages, and park trails can be used with permeable concrete. Utilizing specified analyses, small materials, admixtures, organic intensifiers and changing the ratio, strength and abrasion resistance of the concrete mix, the porous concrete may be greatly enhanced.

Introduction

Concrete mixture, often referred to as cement mortar and rigid pavements, is a special type of concrete with a highly porous that allows precipitation water to pass through it directly, thereby minimizing the leakage from the properties and allowing water to infiltrate [1]. Using broad aggregates with next to no concrete mixes, permeable concrete is created. Then the pavement layer covers the analyses and helps the concrete slab to move water around [2]. In parking areas, places with rural roads, pedestrian walkways permeable concrete is used. It is important for conventional design and one of the techniques of low impact construction. Porous reinforced concrete is a specific and successful way of addressing key environmental problems and fostering efficient, economic development [3]. Concrete mixture is efficient in water harvesting, decreasing groundwater and storing and allowing storm water to evaporate into the soil [4]. One of it's management techniques (BMPs) recommended by the Environmental Protection Agency is currently the need for a pervious concrete (EPA). By removing the need for detention ponds, and other storm water management devices a productive land usage is created [5]. In being, on a first-cost basis, permeable concrete has the potential to reduce total project costs. Properly regulated amounts of water/cement materials are used to produce a paste that forms a dense coating around fine aggregates. Using enough paste to coat and bind the aggregate particles

together requires a great conductivity, porous medium framework that drains easily [6]. Usually, the compressive strength reaches between 15 percent and 25 percent voids, and flow of water rates through concrete mixture are typically about 480 in/hrs. Compared to traditional cementitious materials, both the small mortar content and mechanical strength also decrease intensity, but enough strength is readily obtained for many uses [7].
Although a disturbing amount of uses can be used for concrete mix, its major use is in asphalt. This motivated on the material asphalt mixes, which have also been related to as concrete mixtures, concrete pavers, concrete without fines, concrete with gap grades, and concrete with improved permeability.

Flexible pavement vs permeable pavement

Flexible pavement

- ✓ Subgrade deformation is moved to top layer.
- ✓ The design concept is based on the load distribution features of entire thickness.
- ✓ Flexural strength is low.
- ✓ Repair cost is high.
- ✓ High maintenance cost.
- ✓ Substructure cannot be mounted on the pavement directly, but a sub-base is necessary.
- ✓ As the asphalt has the capacity to contract and expand freely, no thermal stress is caused. This is why extension joints are required.
- ✓ The intensity of the path depends heavily on the intensity of the subsurface.

Permeable pavement

- ✓ Design is based on flexural strength or slab action.
- ✓ Flexural strength is high.
- ✓ Low repair cost.
- ✓ Low maintenance cost.

Applications of permeable concrete

- ➢ Low-volume pavements
- ➢ Residential roads and driveway
- ➢ Sidewalks
- ➢ Slope stabilization
- ➢ Well linings
- ➢ Pavement edge drains
- ➢ Parking areas

Permeable layer

The strong amount of water through a conductive pavement surface facilitates the absorption and percolation of rainfall into the land, decreasing the leakage of groundwater, recharging groundwater, encouraging sustainable development, providing an environmentally conscious building solution, and ensuring developers align with Environmental protection agency rainwater requirements [8].

By regulating rainwater on-site and resolving storm water runoff problems, this specific capacity of permeable concrete provides environmental benefits, public authorities, and property managers. In large cities, or where land is very costly, it can be of particular concern. A porous reinforced concrete and its subsurface will provide adequate groundwater storage to remove the need for culverts, seawalls, and other pollution precipitation management techniques, depending on the specific requirements and the ecosystem [9]. It has some other important uses due to high permeability: it is heat shielding (in building walls, for example) and has excellent thermal conductivity (for sound barrier walls). While asphalt are the dominant U.S. usage for concrete mixture, it has been used in the Europe for several years as a structural material [10]. Applications involve two-story walls, high-rise load-bearing walls (up to 10 stories), and tall building infill plates, sea groin area, paths, and parking lots [11]. Many of these methods take advantage of the strengths of the properties of permeable concrete. However, it is important to prepare a combination of design and construction specifics to achieve these results.

Results and discussion

Compressive strength test

The cube specimen is 150mm x 150mm x 150mm in dimension. If the aggregate's largest nominal size does not exceed 20mm.

By using the relationship, compressive strength was measured.

Compressive strength = (P/A) MPa

Where,

P - Ultimate load in Newton

A - Area of cube in mm^2

Compressive strength of permeable concrete without silica fume

Table 1. *Result of permeable concrete without silica fume*

Specimen	Days of curing	Load in (KN)	Load in (N/mm^2)
Specimen – 1	3	160	7.12
Specimen – 2	7	290	12.89
Specimen – 3	14	410	18.22

Compressive strength of permeable concrete with silica fume (10%)

Table 2. *Result of permeable concrete with silica fume (10%)*

Specimen	Days of curing	Load in (KN)	Load in (N/mm^2)
Specimen – 1	3	180	8
Specimen – 2	7	320	14.23
Specimen – 3	14	440	19.51

Compressive strength of permeable concrete with silica fume (15%)

Table 3. *Result of permeable concrete with silica fume (15%)*

Specimen	Days of curing	Load in (KN)	Load in (N/mm^2)
Specimen – 1	3	195	8.6
Specimen – 2	7	335	14.88
Specimen – 3	14	450	20

Compressive strength of permeable concrete with silica fume (20%)

Table 4. *Result of permeable concrete with silica fume (20%)*

Specimen	Days of curing	Load in (KN)	Load in (N/mm^2)
Specimen – 1	3	185	8.2
Specimen – 2	7	330	14.66
Specimen – 3	14	420	18.67

Infiltration test

$$I = {}^{KM}/_{D^2(T)}$$

Where,

M= Water Mass
D= Ring Diameter
T= Time to Infiltrate
K= 126,870 in (constant)

Table 5. *Tabulation for infiltration test*

Description	Trial – 1	Trial – 2
Water mass in (lit)	1.5	3.0
Diameter of ring in (cm)	30	30
Time of infiltration in (sec)	19.65	42.55

Calculation
Trail -1

$$I = \frac{126870*1.5}{30^2 * 19.65}$$
$$= 10.761 \text{ mm/sec}$$

Trail -2

$$I = \frac{126870*3}{30^2 * 42.55}$$
$$= 9.940 \text{ mm/sec}$$

Permeability test

The cylinder sample is 150 mm long and 95 mm in diameter. If the largest aggregate nominal size does not exceed 12.5 mm.

$$K = \frac{2.303 \text{ aL}}{\text{A t}} \text{ x log } \frac{h1}{h2}$$

Where,

A = the sample cross section area (cm)
a = the cross section of the standpipe of diameter (cm)
L = the height of the permeable concrete sample (cm)
t = time interval (sec)
h1= upper water level (cm)
h2= Lower water level (cm)

Materials Research Proceedings **19** (2021) 60-65 https://doi.org/10.21741/9781644901618-8

Table 6. *Tabulation for permeability test*

Height (cm)	Time (sec)	Co – efficient of permeability K (cm/sec)
30	0	-
25	10.90	0.251
20	23.70	0.257
15	39.80	0.261
10	59.60	0.276
5	1.45	0.309

Calculation

$A = a = \frac{\pi}{4}\ x\ 9.5^2 = 70.88\ cm^2$
$L = 15\ cm$

$K_1 = \frac{2.303\ x\ 70.88\ x\ 15}{70.88x\ 10.9}\ \log\frac{30}{25}$
$= 0.251\ cm\ /sec$
$K_2 = 0.257\ cm\ /sec$
$K_3 = 0.261\ cm\ /sec$
$K_4 = 0.276\ cm\ /sec$
$K_5 = 0.309\ cm\ /sec$

$K = \frac{(K1+K2+K3+K4+K5)}{5}$
$= 0.271\ cm/sec$

Results

1. Permeable concrete made from coarse aggregate size 12.5mm has compressive strength of without silica fume is 18.22 N/mm^2 & with silica fume 15% of 20 $N/\ mm^2$.
2. The aggregate/cement ratio of 2.78:1 produced permeable concrete of higher co-efficient of permeability of 0.271 cm/sec for aggregate size 12.5mm respectively.

Conclusions

1. The smaller the scale of the coarse aggregate, the greater the strength properties and the higher the degree of conductivity.
2. The mixtures with aggregate/cement ratio 2.78:1 as M_{20} grade of nominal mix is considered to be useful for laying pavement which requires high permeability.
3. Finally, sufficient research should be done on permeable concrete pavements made with these material compositions to address increased deformation and bending stress caused by high vehicular loads and heavy traffic.
4. Future, studies have to be done for increasing strength using PP fibers.

Reference

[1] Agar-Ozbek A S, Weerheijm J, Schlangen E and Van Breugel K 2013 Investigating porous concrete with improved strength: Testing at different scales *Construction and Building Materials* **41** 480-90. https://doi.org/10.1016/j.conbuildmat.2012.12.040

[2] Binitha K, Priyadharshini M and Ragul M 2017 Experimental Investigation of Pervious Concrete for Rigid Pavement *IJETER.* **5** 16-9

[3] Chandrappa A K and Biligiri K P 2016 Pervious concrete as a sustainable pavement material–Research findings and future prospects: A state-of-the-art review *Construction and building materials* **111** 262-74. https://doi.org/10.1016/j.conbuildmat.2016.02.054

[4] Chen Y, Wang K, Wang X and Zhou W 2013 Strength, fracture and fatigue of pervious concrete *Construction and Building Materials* **42** 97-104. https://doi.org/10.1016/j.conbuildmat.2013.01.006

[5] Chindaprasirt P, Hatanaka S, Mishima N, Yuasa Y and Chareerat T 2009 Effects of binder strength and aggregate size on the compressive strength and void ratio of porous concrete *International journal of minerals, metallurgy and materials* **16** 714-9

[6] Ćosić K, Korat L, Ducman V and Netinger I 2015 Influence of aggregate type and size on properties of pervious concrete *Construction and Building Materials* **78** 69-76. https://doi.org/10.1016/j.conbuildmat.2014.12.073

[7] Kholshevnikov V, Shields T, Boyce K and Samoshin D 2008 Recent developments in pedestrian flow theory and research in Russia *Fire Safety Journal* **43** 108-18. https://doi.org/10.1016/j.firesaf.2007.05.005

[8] Kia A, Wong H S and Cheeseman C R 2017 Clogging in permeable concrete: A review *Journal of Environmental Management* **193** 221-33. https://doi.org/10.1016/j.jenvman.2017.02.018

[9] Lian C and Zhuge Y 2010 Optimum mix design of enhanced permeable concrete–an experimental investigation *Construction and Building Materials* **24** 2664-71. https://doi.org/10.1016/j.conbuildmat.2010.04.057

[10] Lian C, Zhuge Y and Beecham S 2011 The relationship between porosity and strength for porous concrete *Construction and Building Materials* **25** 4294-8. https://doi.org/10.1016/j.conbuildmat.2011.05.005

[11] Moretti L, Di Mascio P and Fusco C 2019 Porous concrete for pedestrian pavements *Water* **11** 2105. https://doi.org/10.3390/w11102105