ABSTRACT

In many projects, water logging of parking and walkway is the major issue, especially during monsoon, as pavement and floors are normally impermeable. As the usage of pervious concrete is continuously increasing dramatically, a better understanding of linkages between microstructure, transport properties and durability will assist in mix preparation and design. In this study deals with the effect of fine aggregate in strength and durability properties of pervious concrete. A total numbers of 42 specimens were cast cured and tested for compressive strength, flexural strength, and void ratio. This research is total of seven different mixes were used such as with and without fine aggregates, two different coarse aggregates, of size 12mm and 20mm and with fine aggregate as Normal River sand and crusher stone sand. The mix M4 with river sand and 12mm coarse aggregate has shown superior performance in terms of higher void ratio than other mixes. It gives 83% more compressive strength 72% more flexural strength 51% less void ratio than M1 mix.

1. INTRODUCTION

A zero – slump open-grade material consisting of Portland cement, coarse aggregate, little or no fine aggregate, admixtures and water will produce a hardened material with connected pores, ranging in size from 2 to 8 mm that allow water to pass through easily. The void content can range from 18 to 35% with typical compressive strengths of 400 to 4000 psi (2.8 to 28 MPa). The drainage rate of pervious concrete pavement will vary with aggregate size and density of the mixture, but will generally fall into the range of 2 to 18 gal/min/ft² (81 to 730 L/Min/m²). Fig. 1 depicts the pervious concrete cube.
1.1 Objectives of the Study
- To design the concrete mix for pervious concrete with and without fine aggregate.
- To study the strength and durability characteristics of pervious concrete.

1.2 Application of Pervious Concrete
- Parking Lot Pavements.
- Sub base for conventional concrete pavements.
- Light Traffic Streets.
- Road Shoulders.
- Bridge Embankments.
- Edge Drains.
- Driveways, Sidewalks.
- Patios, Tennis Courts.
- Low water crossings.
- Slope stabilization.
- Low-volume traffic.

1.3 Benefits of Pervious Concrete Pavement
Nowadays, pervious concrete pavements are used in different places due to the following benefits
1.3.1 Environmental Benefits
- Reduces storm water & snowmelt runoff
- Recognized by the EPA as a BMP
- Reduces heat island effect
1.3.2 Economic Benefits
- Reduces the need for large detention ponds
- More land can be developed at a lower cost
- Allows the use of smaller capacity storm sewers
1.3.3 Structural benefits
- Surface texture provides enhanced traction.
- Void structure provides increased safety for drivers.
- Pervious concrete is a strong and durable material.

1.4 Necessity of the study
The concern has been growing in recent years towards reducing the pollutants in water conservation and the environment. The continual urbanization has led to the increase in impervious surface area of the cities, further leading to blockage in percolation of precipitation from rainfall. This result is excess surface run off. To counteract this, pervious concrete is the solution. Hence, the pervious concrete having 15% to 35% interconnected pores by volume, allows direct infiltration of water through its structure.

2. METHODOLOGY
The Methodology used in this study is depicted below:
3. MATERIALS AND ANALYSIS

Pervious concrete also known as no fines, permeable, or enhanced porosity concrete, usually consists of normal Portland cement, uniform-sized coarse aggregate, and water. This combination forms an agglomeration of coarse aggregate surrounded by a thin layer of hardened cement paste at their points of contract. This configuration produces interconnected voids between the coarse aggregate, which allow water to permeate at a much higher rate than conventional concrete. Pervious concrete is considered a special type of highly porous concrete. Such porous concrete can be classified into two types one where the porosity is present in the aggregate component of the mixtures (pervious concrete). Light weight aggregate concrete can be constructed by using extremely porous natural or synthetic aggregate. Pervious concrete has little or no fine aggregate. Pervious concrete has little or no fine aggregate in the mixture. Another distinction between these two types of porous concrete is based mainly on the voids structure. Lightweight aggregate concretes contain large percentage of relatively non connected voids. Pervious concrete, however, contain high percentage s of interconnected voids, which allows for the rapid passage of water through the body of concrete.

3.1 Cement

Ordinary Portland cement of 53 Grade (Zuari) is used throughout this work. The properties of cement used are given in Table 1.
3.2 Fine Aggregate

Villupuram river sand is used throughout this work. The properties of river sand used are given in Table 2.

Table 2 Properties of Fine Aggregate

<table>
<thead>
<tr>
<th>Name of the Test</th>
<th>Experimental Results</th>
<th>Std values as per 383 - 1970 (RA 2007)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sp. Gravity of Cement</td>
<td>2.5</td>
<td>-</td>
</tr>
<tr>
<td>Water Absorption</td>
<td>3%</td>
<td>-</td>
</tr>
</tbody>
</table>

3.3 Coarse Aggregate

Normal Coarse Aggregates of Angular shape is used. Coarse Aggregates is kept to a narrow Gradation. Graded aggregates of 10 mm and 20 mm are used. Coarse aggregate of Angular shape is used throughout this work. The properties of coarse aggregate used are given in table 3.

Table 3 Properties of Coarse Aggregate

<table>
<thead>
<tr>
<th>Test Conducted</th>
<th>Result Aggregate Size</th>
<th>Std values as per IS 383-1970 (RA 2007)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>20mm</td>
<td>12mm</td>
</tr>
<tr>
<td>Sp. Gravity</td>
<td>2.7</td>
<td>2.65</td>
</tr>
<tr>
<td>Water Absorption</td>
<td>0.74%</td>
<td>2.50%</td>
</tr>
<tr>
<td>Crushing Value</td>
<td>17</td>
<td>19</td>
</tr>
<tr>
<td>Flakiness Index</td>
<td>21</td>
<td>24</td>
</tr>
</tbody>
</table>

3.4 Water

Water sample collected SRM College Campus (Kattankulathur, Chennai) is used throughout this work. The properties of water used is given in Table 4.

### Table 4 Properties of Water

<table>
<thead>
<tr>
<th>Name of the Test</th>
<th>Experimental Result</th>
<th>Std values as per 456 - 2000 (RA 2005)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chloride</td>
<td>255 mg/l</td>
<td>RCC max. 500 mg/l</td>
</tr>
<tr>
<td>Sulphate</td>
<td>166 mg/l</td>
<td>PCC max. 2000 mg/l</td>
</tr>
<tr>
<td>Organic Solids</td>
<td>66 mg/l</td>
<td>Max. 400 mg/l</td>
</tr>
<tr>
<td>Inorganic Solids</td>
<td>794 mg/l</td>
<td>Max. 3000 mg/l</td>
</tr>
<tr>
<td>Suspended Matter</td>
<td>24 mg/l</td>
<td>Max. 2000 mg/l</td>
</tr>
<tr>
<td>pH Value</td>
<td>7.8 mg/l</td>
<td>Shall not be less than 6</td>
</tr>
</tbody>
</table>

#### 4. MIX DESIGN

As per the ACI design procedure followed and given below.

4.1 Determination of Coarse Aggregate (Wa)

Stone with no fine aggregate ACI table 6.1 recommends bbo of 0.99, with dry-robbed density given as 1450 Kg $m^3$

\[ W_a = \text{Dry rotted density} \times (b/b_o) \]
\[ W_a = 1450 \, \text{Kg/m}^3 \times 0.99 \]
\[ = 1436 \, \text{Kg} \] (Dry weight)

4.2 Adjust to ssd Weight ($w_{ssd}$)

\[ W_{ssd} = W_a \times \text{water absorption on Aggregate.} \]
\[ W_{ssd} = 1436 \, \text{Kg} \times 1.0074 \]
\[ = 1477 \, \text{Kg} \] (ssd)

4.3 Determination Paste Volume ($V_p$)

ACI table 6.3 and read along the required percentage voids (40% for this example) to the well compacted curve. Then read down to find the paste percentage at 30% of a cubical yard is 8.10ft³. Thus,

\[ V_p = 8.10 \, \text{ft}^3 \]

4.4 Determination of Cement Content (C)

\[ C = \left( \frac{V_p}{(0.315 + \text{water cement ratio})} \right) \times 1000 \]
\[ C = \left( \frac{8.10/35.314}{(0.31 +0.38)} \right) \times 1000 \]
\[ = 330 \, \text{Kg} \]

4.5 Determination of Water Content (W)

\[ W = \text{Cement} \times \text{water cement ratio.} \]
\[ W = 330 \, \text{Kg} \times 0.31 \]
\[ = 102.3 \, \text{Kg} \]
4.6 Determination Solid Volume ($V_s$)
Aggregate volume ($V_a$) = $\frac{W_{ssd}}{(\text{Specific gravity of coarse aggregate} \times 1000)}$
= $\frac{1477}{(2.75 \times 1000)}$
= 0.102 m$^3$
Cement volume ($V_c$) = $\frac{c}{(\text{Specific gravity of Cement}) \times 1000}$
= $\frac{330}{3.15} \times 1000$
= 0.104 m$^3$
Water volume ($V_w$) = $\frac{W}{1000}$
= 0.102 m$^3$
Total solid volume ($V_s$) = $V_a + V_c + V_w$
= 0.537 + 0.104 + 0.102
= 0.743

4.6 Determination of Percentage of Voids ($P_v$)
Percentage of voids ($P_v$) = $\frac{V_{wt} - V_s}{V_{wt}} \times 100$
= $\frac{(1 - 0.743)}{1} \times 100$
= 25.7 %

4.7 Iterative Trail Batching and Testing
The trail batch weight per cubic meter as follows;
Cement = 330 Kg
Water = 102 kg
Coarse Aggregate = 1447 kg (ssd)
Total weight = 1879 Kg.

4.8 Compressive Strength
Table 5 gives the detail of the number of specimens cast for different mixes. A total number of 21 cubes specimens were casted and tested. The concrete mixes of different proportion M1, M2, M3, M4, M5, M6, and M7. Were tested to compression strength as per Indian standards figure 6 shows the compressive strength while conducting test in compression testing machine.
Compressive strength = $\frac{P}{A}$
$P$ = Applied load in N
$A$ = Area of the cube in mm$^2$

4.9 Flexural Strength
Table 3.5 gives the details of the specimens cast for different mixes. A total number of specimen 21 beams casted and tested. The concrete mixes of different proportion M1, M2, M3, M4, M5, M6 and M7.
$f_{b} = \frac{P}{Bl^2}$
$f_{b}$ = modulus of rapture
$b$ = Measured width in cm of the specimen,
$d$ = Measured depth in cm of the specimen at the point of failure,
$l$ = Length in cm of the span on which the Specimen was supported, and
$p$ = Maximum load in kg applied to the specimen.
4.10 Void Ratio

Void ratio is the ratio between total volumes minus solid volume divided by total volume of concrete. The formula for calculating the percentage of voids is given below,

\[
\text{Percentage of Voids} = \frac{(V_{\text{total}} - V_{\text{solid}})}{V_{\text{total}}} \times 100
\]

Table 5 Details of no. of Specimen and Size

<table>
<thead>
<tr>
<th>Name of the Experiment</th>
<th>Size of the Specimen</th>
<th>Nos. (7 mixes*3 = 21)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compressive Strength</td>
<td>150 X 150 mm cubes</td>
<td>21</td>
</tr>
<tr>
<td>Flexural Strength</td>
<td>100 X 100 X 500 mm beams</td>
<td>21</td>
</tr>
<tr>
<td>Total no. of Specimen</td>
<td></td>
<td>42</td>
</tr>
</tbody>
</table>

5. CASTING AND TESTING OF SPECIMENS

Mixing of concrete, casting of specimens, placing of specimen, curing of specimens and testing of specimens are shown in figure 2, 3, 4, 5 and 6.

Fig. 4 Placing of Specimen

Fig. 5 Specimen after 28 days Curing

Fig. 6 Compressive Strength Testing
6. RESULTS

Different type of mixes with and without fine aggregates and with 12 mm, 20 mm coarse aggregates separately and together are shown below in Table 6.

<table>
<thead>
<tr>
<th>Mix</th>
<th>Cement in Kg</th>
<th>Fine Aggregate in Kg</th>
<th>Fine Aggregate in Kg</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>River Sand</td>
<td>Crusher stone sand</td>
</tr>
<tr>
<td>M1</td>
<td>330</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>M2</td>
<td>330</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>M3</td>
<td>330</td>
<td>145</td>
<td>-</td>
</tr>
<tr>
<td>M4</td>
<td>330</td>
<td>145</td>
<td>-</td>
</tr>
<tr>
<td>M5</td>
<td>330</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>M6</td>
<td>330</td>
<td>-</td>
<td>145</td>
</tr>
<tr>
<td>M7</td>
<td>330</td>
<td>-</td>
<td>145</td>
</tr>
</tbody>
</table>

6.1 Compressive Strength

The results of compressive strengths obtained in this study are compared with all compressive strength for all mixes M1, M2, M3, M4, M5, M6 and M7 are shown in figure 7.

![Fig. 7 Comparison of compressive strength for different mixes](image)

6.2 Flexural Strength

The results of Flexural strength obtained in this study are compared with all flexural strength for all mixes M1, M2, M3, M4, M5, M6 & M7 are shown in Figure 8.
6.3 Void Ratio

The results of Void Ratio obtained in this study are presented in Table 7 and the comparison of Void Ratio for all mixes M1, M2, M3, M4, M5, M6 & M7 are shown in Figure 9.

From the Table 7, it has been observed that the Void ratio for all the mixes are increased compared to the mix M4. For the mixes M1, M2, M3, M5, M6 and M7, it is increased by 36.36%, 31.0%, 17.26%, 5.34%, 33.68%, and 1.6%, when compared to the mix M4. For the mix M4, the increase in compressive strength is 51.78% than the mix M4.

<table>
<thead>
<tr>
<th>Mix</th>
<th>Void Ratio in %</th>
</tr>
</thead>
<tbody>
<tr>
<td>M1</td>
<td>22.5</td>
</tr>
<tr>
<td>M2</td>
<td>24.5</td>
</tr>
<tr>
<td>M3</td>
<td>19.7</td>
</tr>
<tr>
<td>M4</td>
<td>18.7</td>
</tr>
<tr>
<td>M5</td>
<td>25.0</td>
</tr>
<tr>
<td>M6</td>
<td>19.9</td>
</tr>
<tr>
<td>M7</td>
<td>19.0</td>
</tr>
</tbody>
</table>

Fig. 9 Comparison of void ratio for different mixes of pervious concrete
6.4 Comparison of Strength and Durability Properties of Pervious Concrete

The result of compressive strength, flexural strength & voids ratio are given below in Table 8.

<table>
<thead>
<tr>
<th>Mixes</th>
<th>CS*</th>
<th>FS **</th>
<th>VR ***</th>
</tr>
</thead>
<tbody>
<tr>
<td>M1</td>
<td>7.16</td>
<td>1.42</td>
<td>25.5</td>
</tr>
<tr>
<td>M2</td>
<td>8.89</td>
<td>2.04</td>
<td>22.6</td>
</tr>
<tr>
<td>M3</td>
<td>10.5</td>
<td>1.72</td>
<td>19.7</td>
</tr>
<tr>
<td>M4</td>
<td>13.1</td>
<td>2.45</td>
<td>16.8</td>
</tr>
<tr>
<td>M5</td>
<td>9.51</td>
<td>1.99</td>
<td>24.1</td>
</tr>
<tr>
<td>M6</td>
<td>10.1</td>
<td>1.82</td>
<td>20.0</td>
</tr>
<tr>
<td>M7</td>
<td>12.5</td>
<td>2.06</td>
<td>17.0</td>
</tr>
</tbody>
</table>

* Compressive Strength (N/mm²)
** Flexural Strength (N/mm²)
*** Void Ratio in %

Compression Strength = Load / Area
= 161000 / 22500
= 7.16 N / mm²

Flexural strength
= pl / bd²
= 3380x420/100x100²
= 1.42N /mm²

Void Ratio = \( \{1000 - [(c/S_c) + (W_a/S_{ca}) + (W_w/S_w)]/1000\} \times 100 \)
= \((330 / 3.15) + (1447/2.7) + (1.24/0.92) + (102/1)\)
= 25.5%

7. CONCLUSIONS

The following are the conclusions and recommendations made by this study. According to the experimental results, it has been observed that,

- If the voids ratio increases, compressive strength & flexural strength values are reduced.
- The compressive strength of pervious concrete with 12mm size aggregates are more compared to 20mm size aggregates.
- Compared to conventional mix, large quantity of admixtures (HRWR & VMA) are required for pervious concrete.
- The mix M4 gives 83.24% more Compressive Strength, 72.53 % more Flexural strength & 34.11% less Void ratio compared to the Mix M1.
- The mix M1 gives 51.78% more voids ratio (Maximum), 45.42% less Compressive Strength and 42.42% less Flexural strength compared to the mix M4.
- Therefore the Mix M4 can be used as M10 grade of pervious concrete from both strength and void ratio properties in pavements.
REFERENCES

2. American Concrete Institute ACI 522R-10.