# AN EXPERIMENTAL ANALYSIS OF USING MELT PROCESSED PLASTIC PELLETS IN POROUS CONCRETE BY PARTIALLY REPLACENG FINE AGGREGATES

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**Abstract**

**In many developed countries, the use of pervious concrete for the construction of pavements, car parks and driveways is becoming popular. In order to develop material specification for pervious concrete, it is necessary to conduct testing to evaluate the performance of this new type of high performance concrete. The pervious concrete is produced by using conventional cementitious materials, aggregates and water. This concrete is tested for its properties, such as density, porosity, compressive strength and water permeability. The most important property of pervious concrete is its water permeability. Currently, there is no standard experimental procedure to determine this property. Pervious concrete having density around 1800kg/m$^3$ shows the following properties: Porosity 30 % to 35%, 14 days compressive strength between 2 MPa to 5 MPa and water permeability in between 4 cm/s and 7 cm/s.**

**Key Words: Pervious concrete, permeability**.

## 1.0 INTRODUCTION

Pervious concrete is a special high porosity concrete used for flatwork applications that allows water from precipitation and other sources to pass through, thereby reducing the runoff from a site and recharging ground water levels. Typically, pervious concrete has no fine aggregate and has just enough cementitious paste to coat the coarse aggregate particles while preserving the interconnectivity of the voids. Pervious concrete is also known as porous concrete and permeable concrete.

Pervious concrete has become significantly popular during recent decades because of its potential contribution in solving environmental issues. Pervious concrete is a type of concrete with significantly high water permeability compared to normal weight concrete. It has been mainly developed for draining water from the ground surface, so that storm water runoff is reduced and the ground water is recharged.

Pervious concrete shows both advantages and disadvantages over conventional concrete. The advantages of pervious concrete are:

1. Decreasing flooding possibilities, especially in urban areas
2. Recharging the ground water level.
3. Improving water quality through percolation
4. Sound absorption
5. Supporting vegetation growth.

The disadvantages of the pervious concrete are

1. Low strength due to high porosity
2. High maintenance requirement
3. Limited use as a load bearing unit due to tis low strength.

## 2.0 OBJECTIVES OF THE INVESTIGATION:

- Grade of coarse aggregates needed.
- Percentage of plastic pellets i.e. 0%, 5%, 10% used as fine aggregate and their effect on compressive strength and permeability are noted.
- Finding the porosity of pervious cube and correlating it with permeability.
- To find the compressive strength of pervious cube for a range of water cement (w/c) ratio for achieving better compressive strength.

## 3.0 SCOPE OF THIS INVESTIGATION:

- A number of pervious concrete mixes were produced with and without plastic pellets. The main properties studied include density, porosity, compressive strength and water permeability. These properties were compared with those for conventional concrete.
- There is a well-established method for preparing pervious concrete. Therefore, by trial and error method, w/c ration and cement content were found.

## 4.0 LIMITATIONS:

- This study is limited to understand the properties of pervious concrete with selected materials of construction and compositions.
- The performance of pervious concrete in the service environment is outside the scope of this study.

## 5.0 MATERIALS AND THEIR PROPERTIES

**5.1 Coarse aggregate**: The properties of coarse aggregates are tabulated in the table 1 below:

**Table1**:**loose and compacted density of coarse aggregates**

| S.no | Aggregate size (mm) | Weight of loose aggregate (kg) | Weight of compacted aggregate (kg) | Loose density (g/cm$^3$) | Compacted density (g/cm$^3$) |
|---|---|---|---|---|---|
| 1 | 4.75-10 | 18.9 | 21.4 | 1.30 | 1.47 |
| 2 | 10-12.5 | 19.8 | 22.1 | 1.36 | 1.52 |
| 3 | 12.5-16 | 20.0 | 21.2 | 1.37 | 1.46 |
| 4 | 16-20 | 20.2 | 21.7 | 1.39 | 1.49 |

**5.2 Fine aggregate:** The specific gravity of the fine aggregate is found to be 2.61. From the sieve analysis of fine aggregate, it is observed that it meets the requirements of zone – II.

## 6.0 MEASUREMENT OF PERVIOUS CONCRETE PROPERTIES:

**6.1 Compressive strength:** compressive strength was performed according to IS specifications. For the pervious concrete, three cubes of 150 mm were used. The specimens were cured in water until the testing. The compressive strength reported is the average of three results taken from three identical cubes.

**6.2Porosity:** The porosity of the hardened concrete was calculated from the air-dry and saturated weights, using the equation

$$V_r = 1 - \frac{w_2 - w_1}{\rho w \text{ x } vol} \text{ x } 100$$

Where $V_r$ = porosity (%)
$W_1$ = weight under water (kg)
$W_2$ = air dry weight (kg)
Vol = volume of sample (m$^3$)
$P_w$ = density of water (kg/m$^3$)

**6.3Water permeability:** The test cylinders were casted in plastic pipe itself, to avoid leakage of water. For 170 mm water head, the permeability testing was carried out when a steady state of flow was reached. Time was noted to collect water of 100 mm height and permeability coefficient was calculated.

## 7.0 TRIAL SAMPLES

**7.1Pervious concrete – no fine aggregate:** The binding material used in ordinary portalnd cement (OPC). 4.75 – 10 mm, 10 – 12.5 mm, 12.5 – 10 mm and 16 – 20 mmm crushed gravel, were used as coarse aggregate. The water/cement ratio was determined by a trial test, which consisted of forming a concrete ball with hand. Two ratios of w/c used as high (0.48) and low

(0.40). One trial pervious concrete sample of size 150 mm and 100 mm. cubes were cast for all four ranges of aggregates and properties like density, porosity, permeability and compressive strength for 28 days were found. The low cement content taken is 158 kg/m$^3$ and high cement content is 195 kg/m$^3$.

**Table 2: Mix design of trial samples of no fine aggregate, high cement content**

| S.no. | Aggregate size (mm) | Cement (kg) | Water/cement ratio | Coarse aggregate (kg) |
|---|---|---|---|---|
| 1 | 4.75 - 10 | 1.052 | 0.40 | 10 |
| 2 | 10 – 12.5 | 0.950 | 0.45 | 10 |
| 3 | 12.5 - 16 | 0.879 | 0.48 | 10 |
| 4 | 16 - 20 | 0.948 | 0.45 | 10 |

**Table 3: Porosity and Density of 150 mm cubes trial samples**

| S.no. | Aggregate size (mm) | Cement content | Porosity (%) | Density (kg/m$^3$) |
|---|---|---|---|---|
| 1 | 4.75 - 10 | High | 33 | 1733 |
| | | Low | 34 | 1693 |
| 2 | 10 – 12.5 | High | 32 | 1773 |
| | | Low | 34 | 1737 |
| 3 | 12.5 -16 | High | 39 | 1668 |
| | | Low | 33 | 1722 |
| 4 | 16 - 20 | High | 34 | 1701 |
| | | Low | 31 | 1811 |

**Table 4: Porosity and Density of 100 mm cubes trial samples**

| S.no. | Aggregate size (mm) | Cement content | Porosity (%) | Density (kg/m$^3$) |
|---|---|---|---|---|
| 1 | 4.75 - 10 | High | 35 | 1692 |
| | | Low | 38 | 1609 |
| 2 | 10 – 12.5 | High | 33 | 1762 |
| | | Low | 37 | 1667 |
| 3 | 12.5 -16 | High | 38 | 1613 |
| | | Low | 35 | 1688 |
| 4 | 16 - 20 | High | 37 | 1625 |
| | | Low | 38 | 1604 |

**7.2Mixed aggregate samples – no fine aggregate**

To help reduce the porosity of the trial samples, two ranges of aggregates were mixed and the porosity and density of the mixed aggregate samples were calculated for 150 mm cube high cement content cube. Mix design for this is same as in table 2 above, but a combination of two fractions is tried.

**Table 5: Combination of 25% of 4.75 – 10 mm aggregate and 75% of 12 – 16 mm aggregate**

| S.no. | Porosity (%) | Density (kg/m$^3$) | Avg Porosity (%) | Avg Density (kg/m$^3$) |
|---|---|---|---|---|
| 1 | 36 | 1658 | 32 | 1709 |
| 2 | 29 | 1760 | | |

**Table 6: Combination of 25% of 4.75 – 10 mm aggregate and 75% of 12 – 16 mm aggregate**

| s.no. | Porosity (%) | Density (kg/m$^3$) | Avg Porosity (%) | Avg Density (kg/m$^3$) |
|---|---|---|---|---|
| 1 | 32 | 1766 | 31 | 1774 |
| 2 | 31 | 1782 | | |

**7.3 Pervious concrete with inclusion of fine aggregates:**

To help reduce the porosity of trial samples further, sand was added. Three cubes of varying sand by 0, 33, 66% of void remained in trial samples were cast. Mix design is shown in table 7 below and porosity, density were calculated in table 8 below.

**Table 7: Trial mixes with variation in sand**

| s. no. | Aggregate size (mm) | Fine aggregate (%) | Cement (kg) | Water (kg) | Coarse aggregate (kg) | Fine aggregate (kg) |
|---|---|---|---|---|---|---|
| 1 | 4.75 - 10 | 0 | 0.631 | 0.260 | 6.0 | 0.00 |
| | | 33 | 0.723 | 0.310 | 6.0 | 1.18 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | 66 | 0.815 | 0.460 | 6.0 | 2.38 |
| 2 | 10 – 12.5 | 0 | 0.631 | 0.260 | 6.0 | 0.00 |
| | | 33 | 0.683 | 0.299 | 6.0 | 1.15 |
| | | 66 | 0.735 | 0.344 | 6.0 | 2.30 |
| 3 | 12.5 -16 | 0 | 0.631 | 0.260 | 6.0 | 0.00 |
| | | 33 | 0.681 | 0.310 | 6.0 | 1.39 |
| | | 66 | 0.731 | 0.510 | 6.0 | 2.79 |
| 4 | 16 – 20 | 0 | 0.631 | 0.260 | 6.0 | 0.00 |
| | | 33 | 0.639 | 0.310 | 6.0 | 1.22 |
| | | 66 | 0.709 | 0.410 | 6.0 | 2.44 |

**Table 8: Density and porosity of 150 mm cubes trial samples**

| s.no. | Aggregate size (mm) | Fine aggregate (%) | Porosity (%) | Density ($kg/m^3$) |
|---|---|---|---|---|
| 1 | 4.75 - 10 | 0 | 34 | 1733 |
| | | 33 | 26 | 1888 |
| | | 66 | 14 | 2104 |
| 2 | 10 – 12.5 | 0 | 33 | 1773 |
| | | 33 | 35 | 1849 |
| | | 66 | 18 | 1948 |
| 3 | 12.5 -16 | 0 | 39 | 1668 |
| | | 33 | 22 | 1957 |
| | | 66 | 11 | 2136 |
| 4 | 16 - 20 | 0 | 35 | 1701 |
| | | 33 | 27 | 1976 |
| | | 66 | 11 | 2143 |

## 8.0 MAIN SAMPLES:

**8.1 Pervious concrete with fine aggregates:** Three cubes for aggregate size 4.75 – 10 mm of varying sand by 0, 33, 66 % of void remained in trial samples were cast. Mix design is shown in table 7 above.

**8.2 Pervious concrete with plastic pellets:** The 10% of coarse aggregate was replaced by fine aggregate and plastic pellets. Three cubes were cast for the aggregate size of 4.75 – 10 mm. Porosity and density for 14 days and 28 days were calculated. And compressive strength for 7, 14 and 28 days were calculated.

## 9.0 RESULTS AND DISCUSSIONS

**9.1 Pervious concrete properties - Density and porosity:** The densities and porosities at the age of 14 and 28 days of the pervious concrete with and without sand replaced plastic pellets are shown in table 9,10,11,12 respectively. The density, porosity for each specimen and the mean value of porosity is reported.

**Table 9: Porosity and density of main samples with sand at 14 days**

| Fine aggregate (%) | Trial No. | Porosity (%) | Avg. Porosity (%) | Density ($kg/m^3$) |
|---|---|---|---|---|
| 0 | 1 | 29 | 31 | 1834 |
| | 2 | 31 | | 1768 |
| | 3 | 32 | | 1737 |
| 33 | 4 | 25 | 26 | 1902 |
| | 5 | 26 | | 1866 |
| | 6 | 27 | | 1852 |
| 66 | 7 | 13 | 13 | 2127 |
| | 8 | 13 | | 2139 |
| | 9 | 14 | | 2114 |

**Table 10: Porosity and density of main samples with sand at 28 days**

| Fine aggregate (%) | Trial No. | Porosity (%) | Avg. Porosity (%) | Density ($kg/m^3$) |
|---|---|---|---|---|
| 0 | 1 | 31 | 30 | 1777 |
| | 2 | 29 | | 1789 |
| | 3 | 31 | | 1791 |
| 33 | 4 | 21 | 24 | 1874 |
| | 5 | 26 | | 1881 |
| | 6 | 25 | | 1905 |
| 66 | 7 | 14 | 16 | 2111 |
| | 8 | 16 | | 2052 |
| | 9 | 18 | | 2015 |

**Table 11: Porosity and density of main samples with pellets at 14 days**

| Replacement | Trial No. | Porosity (%) | Avg. Porosity (%) | Density (kg/m³) | Avg. Density (kg/m³) |
|---|---|---|---|---|---|
| No fine | 0 | 34 | 34 | 1733 | 1733 |
| 10% fine | 1 | 29 | 29 | 1835 | 1827 |
| | 2 | 31 | | 1791 | |
| | 3 | 28 | | 1854 | |
| 5% fine + 5% pellets | 4 | 27 | 28 | 1845 | 1815 |
| | 5 | 28 | | 1809 | |
| | 6 | 29 | | 1792 | |
| 10% plastic pellets | 7 | 35 | 35 | 1711 | 1729 |
| | 8 | 35 | | 1757 | |
| | 9 | 35 | | 1720 | |

**Table 12: Porosity and density of main samples with pellets at 28 days**

| Replacement | Trial No. | Porosity (%) | Avg. Porosity (%) | Density (kg/m³) | Avg. Density (kg/m³) |
|---|---|---|---|---|---|
| No fine | 0 | 34 | 34 | 1733 | 1733 |
| 10% fine | 1 | 26 | 28 | 1832 | 1839 |
| | 2 | 28 | | 1857 | |
| | 3 | 29 | | 1828 | |
| 5% fine + 5% pellets | 4 | 28 | 29 | 1807 | 1804 |
| | 5 | 28 | | 1835 | |
| | 6 | 30 | | 1770 | |
| 10% plastic pellets | 7 | 22 | 27 | 1794 | 1768 |
| | 8 | 30 | | 1733 | |
| | 9 | 29 | | 1776 | |

## 9.2 Compressive strength:

Table 13, 14, 15, 16, 17 summarize the compressive strengths of each specimen and the mean value. The specimens of coarse aggregate range 4.75 – 10 mm were tested at the age of 7 days and 14 days for water cured pervious concrete with and without plastic pellets replacement.

**Table 13: compressive strength of trial samples at 28 days**

| s.no. | Aggregate size (mm) | Cement content | Load (kN) | Compressive strength (MPa) |
|---|---|---|---|---|
| 1 | 4.75 - 10 | High | 65 | 2.88 |
| | | Low | 45 | 2.00 |
| 2 | 10 – 12.5 | High | 70 | 3.11 |
| | | Low | 47.5 | 2.11 |
| 3 | 12.5 – 16 | High | 80 | 3.55 |
| | | Low | 50 | 2.22 |
| 4 | 16 - 20 | High | 80 | 3.55 |
| | | Low | 52.5 | 2.33 |

**Table 14: compressive strength of main samples with fine aggregate at 28 days**

| Addition of fine aggregates (%) | Trial no. | Load (kN) | Compressive strength (MPa) | Avg. Compressive strength (MPa) |
|---|---|---|---|---|
| 0 | 1 | 55 | 2.44 | 2.22 |
| | 2 | 50 | 2.22 | |
| | 3 | 45 | 2.00 | |
| 33 | 4 | 60 | 2.66 | 2.89 |
| | 5 | 65 | 2.89 | |
| | 6 | 70 | 3.11 | |
| 66 | 7 | 90 | 4.00 | 4.00 |
| | 8 | 90 | 4.00 | |
| | 9 | 90 | 4.00 | |

**Table 15: compressive strength of main samples with plastic pellets at 7 days**

| Replacement | Trial No. | Load (kN) | Compressive strength (MPa) | Avg. Compressive strength (MPa) |
|---|---|---|---|---|
| 0 | 1 | 35 | 1.55 | 1.55 |
| | 2 | 35 | 1.55 | |
| | 3 | 35 | 1.55 | |
| 10% fine | 1 | 75 | 3.33 | 3.14 |
| | 2 | 67.5 | 3.00 | |
| | 3 | 70 | 3.11 | |
| 5% fine + 5% pellets | 1 | 62.5 | 2.78 | 2.48 |
| | 2 | 60 | 2.67 | |
| | 3 | 45 | 2.00 | |
| 10% plastic pellets | 1 | 55 | 2.44 | 2.22 |
| | 2 | 50 | 2.22 | |
| | 3 | 45 | 2.00 | |

**Table 16: compressive strength of main samples with plastic pellets at 14 days**

| Replacement | Trial No. | Load (kN) | Compressive strength (MPa) | Avg. Compressive strength (MPa) |
|---|---|---|---|---|
| 0 | 1 | 55 | 2.44 | 2.22 |
| | 2 | 50 | 2.22 | |
| | 3 | 45 | 2.00 | |
| 10% fine | 1 | 75 | 3.33 | 3.33 |
| | 2 | 70 | 3.11 | |
| | 3 | 80 | 3.55 | |
| 5% fine + 5% pellets | 1 | 60 | 2.66 | 2.51 |
| | 2 | 55 | 2.44 | |
| | 3 | 55 | 2.44 | |
| 10% plastic pellets | 1 | 50 | 2.22 | 2.30 |
| | 2 | 50 | 2.22 | |
| | 3 | 55 | 2.44 | |

### 9.3 Water permeability:

Table 17 summarizes the range of water permeability coefficient for pervious concrete with 10% sand, 5% plastic pellets + 5% sand and 10% plastic pellets.

**Table 17: water permeability of pervious concrete**

| Replacement | Trial no. | Permeability K (cm/sec) | Avg Permeability, K (cm/sec) |
|---|---|---|---|
| 10% fine | 1 | 4.65 | 4.65 |
| | 2 | 4.65 | |
| 5% fine + 5% pellets | 1 | 5.56 | 5.10 |
| | 2 | 4.65 | |
| 10% plastic pellets | 1 | 7.09 | 6.73 |
| | 2 | 6.37 | |

### 10 Conclusions:

1. The densities of the porous concretes are continuously decreasing with the increase in the percentage of recycled plastic pellets.
2. Only a slight difference was observed in the porosity and density of pervious concrete for using different ranges of coarse aggregate.
3. The results of porosity values are observed to remain same with little variation for both the porous concrete containing plastic pellets and sand as by water displacement method.
4. Compressive strength of the porous concrete containing pellets as FA decreases with increase in percentage of finer aggregate. While the compressive strength increases with increases in percentage of sand as FA.
5. The scope of waste handling and utilization is exploited in this investigation.
6. Direct relationship was found between density and porosity of pervious concrete.

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