Laboratory investigations on properties of Nanosilica Pervious concrete

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Abstract: Porous concrete also called as no fines concrete has become more and acceptable construction and low-traffic road applications. It can be used to prevent flooding in parking lots and pavements, as well as with other materials. The resilience of porous pavement surface is the major issue. Physical properties, cement matrix, particle distribution, binder ratio, admixtures, and water absorption are all important factors. The current research focuses on the compressive, tensile splitting, and flexure strengths of porous concrete with a total aggregate to cement (TA/C) ratio of 3.5:1 and a w/b ratio of 0.34 and 0.30. The test findings reveal that the inclusion of Nano silica has a considerable impact on possessions of porous mix of concrete. The maximum strength in compression achieved was over 40MPa. Tensile strength ranges between 2.02 MPa to 3.99 MPa. The coefficient of permeability also ranges from 3.24 to 5.65 mm/s. The R² value for 28,90 and 180 day age of pervious concrete mix is 0.9176, 0.8651 and 0.838 respectively. For higher compressive strength, water permeability was shown to be compromised.

Keywords: pervious concrete, admixtures, nano silica

1. Introduction

In recent years, no fines concrete has seen a lot of uses in pavement construction as a storm water controlling solution. Rainwater percolation through the earth has diminished as a result of fast population increase and continuous urbanization. Pervious concrete roads have evolved into a method for water saving. Conventional concrete is incapable of arresting rainwater and does not provide adequate support. Furthermore, traditional concrete pavements require more acreage for retention ponds and other storm water control strategies. The existence of pores in porous concrete gives more advantage than regular concrete in that it allows water to infiltrate. However, there is a exploration besides application gap for permeable material as a roadway material. The main reason among all other is a lack of standardized material groundwork of making and testing practices [9],[10]. More than a few investigations on various factors such as aggregate size distribution, aggregate source, cement adhesive content, water-powder ratios, and so on were conducted [9]. These factors have been utilized to investigate strength qualities like as compressive strength, penetrability, and pore content [9], [27], [1],[11],[2],[12],[26],[3]. For testing pervious concrete's characteristics, a few researchers have highlighted partial additional of rice husk ash (RHA) with partial replacement of cement [9] [24], and the strength and abrasion properties have been upgraded by addition of plasticizer, sio2 and polymers [25], [23],[4],[14]. Kerven et al has used fibers to improve the freezing & thawing action [22]. Neoprene rubber has been utilized in porous concrete pavements by a few experts [7]. Pervious concrete has also used reused collections and municipal unwanted solid materials of burnt bottom residue as aggregates.
The least binding material needed for no fines concrete ranges from 350 kg/m$^3$ to 900 L/min/m$^2$ of surface [18],[19]. Most researchers attained compressive strengths ranging from 3.5 to 28 MPa [19]. Mechanical system improvements are also critical.

2. Materials used and Methods

The work was done to determine the mechanical properties and permeation of pervious concrete using local material.

2.1 Cement (OPC)

The binding material as cement used here is 53 grade OPC (Ultra Tech), which met the requisite specific gravity, beginning and final setting durations, and fineness standards as per IS 12269.

2.2 Sand

The study uses river sand as a fine aggregate. The bulk density and water concentration of the sand are all measured as per IS 2386-1963. Coarse aggregate is partially substituted with 5% fine particles in this study.

2.3 Coarse Aggregates

As coarse aggregate, crushed granite with nominal sizes of 10 mm and 20 mm is employed which satisfies the standards of IS 383. In 50:50 ratios, a distinct proportion of (20 mm: 10 mm) was used.

2.4 Water

For mixing and curing, drinkable water as per standards IS 456:2000 was used, that was free of pollutants such as oils, salts, sugar, organic compounds, and so on.

2.5 Admixtures

As admixtures, commercially available Nano silica and superplasticizer Consplast SP 430 are employed. The Nano silica was supplied by Astra chemicals and had a specific gravity of 2.12 with a particle size of 17nm. The superplasticizer Conplast SP 430 was employed in this study. It's blended with 0.7 percent cement by weight before being mixed with water.

2.6 Proportion of mixture

Pervious concrete mix, without Nano sio2, and 3 percent Nano sio2 by weight of cement were added to each of the control mixes. By 5%, coarse particles were partly replaced with fine aggregates. The two sizes coarse aggregates are used as mentioned. Based on the results of the trials, the required plasticizer dose of roughly 0.7 percent by weight of cement was chosen. For all of the mixes, two distinct water-binder (w/b) ratios of 0.34 and 0.30 were used. ACI 522 R-10 was used to create the mixtures. Table 1 lists the specifics of the various blends employed.

Table 1: Designations for pervious concrete mixes, including the proportions of constituents used in the mixes:

| S no | Mix type | Cement kg/m$^3$ | Sand kg/m$^3$ | Coarse aggregate kg/m$^3$ | w/b | Nano silica kg/m$^3$ | sp % |
|------|----------|----------------|--------------|---------------------------|-----|-------------------|-----|
| 1    | CPC1     | 450            | 79           | 1568                      | 0.30| -                 | 0.7 |
| 2    | CPC2     | 450            | 79           | 1568                      | 0.34| -                 | 0.7 |
| 3    | NPC1     | 450            | 79           | 1568                      | 0.30| 13.5              | 0.7 |
| 4    | NPC2     | 450            | 79           | 1568                      | 0.34| 13.5              | 0.7 |

2.7 Method of mixing Pervious concrete

The ingredients are first inspected and weighed correctly according to the mix design. Initially, the constituents are mixed dry in pan mixture and then half the quantity of water calculated added for 1 minute. The remaining water with superplasticizer is then added to the mix and mixed for 2 minutes before being compressed with a tamping rod. The regular curing is completed, and the specimen is taken from the mould and cured for a predetermined age the next day.
Testing of specimens

3.1 Compressive strength
For each mix, customary cubes of 150 mm x 150 mm x 150 mm were cast and cured. According to the Indian standard IS:516-1959 [3] compressive strength was measured at 28, 90 and 180 days of curing.

3.2 Split tensile strength
For each combination, regular cylinders of 150 mm dia and 300 mm height were cast and cured. According to the Indian standard IS:5816-1999 [9], split tensile strength was evaluated at 28, 90 and 180 days of normal water curing.

3.3 Flexural strength
As per Indian standard IS:516-1959, Flexural strength of samples was calculated by point load test on beam specimens of size 100 × 100 × 500, after 28, 90 and 180 days of standard curing.

3.4 Permeability
A novel experimental apparatus falling head penetrability as basis method has been constructed to know the permeability of porous concrete cylinder specimens with dimensions of 150 X 300 mm were casted and tested for permeability [9] (figure 2). Neithalath, Weiss, and Olek [16] were the ones that started it.

3.5 Porosity
The terms porosity and permeability are used to describe pervious concrete. The porosity of cylinder specimens was determined using ASTM C1754 criteria. The following is the formula for calculating it:

\[ P = \left(1 - \frac{W_2 - W_1}{p_w V}\right) \times 100 \% \]  \hspace{1cm} (1)

Figure 1. (a) casting procedure of pervious concrete

Figure 2. (a) Porosity setup \hspace{1cm} (b) Permeability setup
4. Discussions and Findings

4.1 Effect on Compressive strength

Figure 3 depicts the compressive strength of porous mixes with various w/b ratios and the inclusion of Nano silica. The use of Nano silica and fine particles as partial replacements for coarse aggregates boosted the strengths of pervious concrete. For a w/b ratio of 0.34, compressive strength ranged from 25.98 to 32.14 MPa, while for a w/b ratio of 0.30, it ranged from 32.51 to 41.12 MPa with respect to age of the concrete. The addition of nano silica to pervious concrete has had a significant impact on its strength with 21.83 % increase for w/b of 0.30 at 180 days compared to control mix. With a 5% substitution of coarse aggregate with sand, the strength of pervious concrete with admixture was peak. The mix with 3 percent nano silica substitution of cement for a w/b ratio of 0.3 had the maximum strength of 41.12 MPa after 180 days of curing. The outcomes obtained meet Indian standards, making them appropriate for usage as a sub-base material in pavements. When compared to normal pervious concrete mix, nano silica has demonstrated superior performance. As a result, NS is highly suggested as a pavement sub foundation.

![Compressive strength vs age of pervious concrete](image1)

![Percentage increase in compressive strength](image2)

**Figure 3.** Graph representing compressive strengths and percentage increase of pervious concrete mix with different w/b

4.2 Effect on split-tensile strength

Figure 4 graphically represents the effect of adding Nano silica and 5% sand to porous concrete on tensile strength. It’s worth noticing that tensile split strength follows this very same tendency as compressive strength as shown by this graph. At 180 days, pervious specimens containing NS as a cement additional and 5% sand as a coarse replacement had the greatest strength of 3.99 MPa. At 180 days from 28 days of age for a w/b of 0.3, the inclusion of Nano silica and 5% fines resulted in a noteworthy rise of 29.32 percent when compared to the control mix. Also from curing age of 90 days to 180 days there is an increase of 12.03 % with addition of nano silica. The nano silica addition has significantly increased split tensile strength in the range of 23 to 25 % throughout the curing period of pervious concrete.
4.3 Effect on flexural strength

Figure 5 illustrates the flexural strength with varying percentages of nano substitution. The flexural strength was observed to be within 2.98 Mpa to 4.13 Mpa. The maximum strength for 28, 90, and 180 days is 3.41 MPa, 3.63 MPa, and 4.13 MPa correspondingly, for specimens with 3% nano supplementation for w/b 0.3. For 28, 90 & 180 days, the flexural strength of 3% nano replacement specimens increased 4.06 percent, 5.21 percent and 8.47 percent, correspondingly, as compared to control specimens for w/b of 0.30. As seen in the diagram, the strength continues to improve as the NS replacement percentage change from 0% to 3%. The strength with 5 percent fine aggregate and 3 percent nano replacement has increased 17.43 % as age of concrete from 28 to 180 days of curing whereas for control mix it is 15.87%. NS has microscopic size and can blend in between cement grains, strengthening the density of the concrete mixture, according to Wang et al. [14]. The incorporation of NS develops the relationship amongst the cement matrix and the aggregate, leading to a greater flexural strength.

4.4 Effect on Penetrability and Porosity

The impact of NS along through diverse proportions of fines on perviousness are clearly symbolized in figure 6. The inclusion of admixtures reduces penetrability in an experimental setting. The peak penetrability of 5.65 mm/s is attained without admixture and fines in pervious concrete. Between all
the mixes, the lowermost value acquired is 3.24 mm/s for Nano silica PC with 5 percent sand. Nonetheless, as reported by researches [17],[20], the results obtained are in range of 0.1 to 2 cm/s.

![Figure 6](image-url)  
**Figure 6.** Graph representing permeability Vs porosity of pervious concrete

The pore percentage without admixtures and altered percentages of fines are in the range of 24.21 to 21.15%. The R² value for 28, 90 and 180 day age is 0.9176, 0.8651 and 0.838 respectively. The R² value for 180-day age is low due to occurrences that as the age of concrete increases the correlation coefficient decreases due to the enhanced hydration which decreases the inter particle voids in the mix.

5. Conclusions

The combined effect of NS and fluctuating limiting percentages of fines on pervious concrete is investigated in this study. The compressive strength data attained with different w/b ratios and combinations of fine aggregate proportions and Nano silica suggest that admixture pervious concrete be used as a sub base material in roadway projects. The use of Nano silica to replace 3% of cement has greatly boosted the compressive strength of porous concrete as it ages. The results for split-tensile and flexural strength follow the same pattern as the compressive strength results. The obtained voids content is also within the acceptable range. Finally, it may be stated that adding Nano with a lower w/b to pervious concrete at later ages improves its performance. This is due to the filling effect generated by micro silica particles’ increased surface area. The inclusion of superplasticizer increased the mix’s fluidity while maintaining a consistent consistency. It maintains appropriate binding amongst all powder content and aggregates rather than making any specific changes in terms of strength.

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