DEVELOPMENT OF PERVIOUS CONCRETE HAVING STRENGTH ENHANCEMENT ADMIXTURE FOR MANAGING STORMWATER RUNOFF

Yaqoob Shah1*, Fawad Ahmad2, Dr. Muhammad Zeeshan Ahad3, Muhammad Saleem4

1, 4 MS Student Department of Civil Engineering, Iqra National University Peshawar, Pakistan
2 Lecturer (Supervisor), Department of Civil Engineering, Iqra National University, Pakistan
3 Assistant Professor, Chairman Department of Civil Engineering, Iqra National University, Pakistan

Email: yaqub.shah111@gmail.com1, fawad.cengr@gmail.com2, muhammadahad@gmail.com3, salimdakorak@gmail.com4

*Corresponding author: Yaqoob Shah1

Abstract

Pervious concrete technology is a special and reliable way of fulfilling increasing specifications for the climate. Pervious concrete is important in restoring groundwater, minimize erosion and converging flood water by absorbing rainwater and allowing it to seep through the land. Pervious concrete is comprised of coarse aggregate, Portland cement and chemical admixtures and is a building substance. It is somewhat different from standard concrete since there are little to no fine aggregates. The main objective of this project work is to study the densification and splitting tensile strength with the infiltration rate of pervious concrete. Also to do water quality test of rainwater after passing from 3 inches of the charcoal layer. The results concluded Compressive and splitting stability of Pervious concrete shows an extensive increment in strength when 2% of Ta titanium Dioxide is replaced by cement at the curing age of 7, 14 and 28 days. At 28 Days mean compressive and splitting tensile strength (Having Strength Enhancement Admixture) comes up to be 2104.5 psi and 531.4 psi respectively which is considerable for Pervious concrete. From the infiltration rate test it can be concluded that as the percentage of gravel increases in the concrete mix, the permeability or infiltration rate increases. Infiltration rate ranges from 838.5 in/hr to 927.8 in/hr for the two concrete mixes M1 (1:0:2.5) and M2 (1:0:3) respectively. From the water quality test it can be concluded that when rainwater is passed from a 3 inches layer of charcoal the PH value increase from 4.47 to 5.77 which can be used for cleaning and bathing in our houses. Hence it is recommended that 100% reduction of sand from concrete give significant mechanical strength and an increase of infiltration rate can be proposed for the

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roadway of parking and walking track. Also after passing rainwater from 3 inches layer it can be recommended for cleaning and Bathing Purposes.

**Keywords:** Pervious concrete, strength enhancement admixture, Full sand Reduction, Mechanical Properties, Infiltration Rate test, Rainwater, water quality test using charcoal.

I. **Introduction**

Every day, the socio-economic atmosphere around the world changes. In addition to taking into account the economics of the project, architects must also recognize the effects that developments would have on the human and natural world more than ever before [I]. For several years, permeable concrete had existence in one way or another, but only lately have environmental restrictions and the expense of stormwater control permitted its true consideration in engineering designs. Iowa State University (ISU) widespread concrete study started in 2004, coinciding with a rise in concern prompted by the U.S. Environmental Protection Agency (EPA) introducing the Phase II National Pollutant Discharge Elimination Method (NPDES) standards for stormwater upgrades for smaller towns and building sites (U.S. Gov. 2004) [II]. As a result, the test results for pervious concrete cold weather were timely as many developers, both public and private, started investigating the altering world of infrastructure sketch measured via an environmental lens. In the most severe conditions, confirmation of the freeze-thaw toughness of widespread concrete provided an incentive to investigate many other elements of previous concrete and to enhance resilience through a systematic study project through enhanced mixture analysis and innovative building techniques [III]. A completely fitted carport was designed at ISU to measure the advantages of the Pervious concrete structure (Jones 2006) based on the laboratory findings. Pervious concrete paving is a noteworthy and productive way of fulfilling increasing demands for the environment. Previous concrete is instrumental in recharging land, minimizing flood water leakage and achieving the U.S. by collecting rainwater and allowing it to flow to the land. Rainwater laws from the Environmental Protection Agency (EPA) [IV]. "Pervious concrete is defined by the American Concrete Institute (ACI) 522R as" a zero slump, an open graded substance composed of Portland cement, coarse aggregate, small or no fine aggregates, chemical admixtures, and water [V]. The drainage rate of the previous concrete pavement varies with the mixture's aggregate size and density, but will usually lie within the range of 81 to 730 L / min / m2 (2 to 18 gal/min / ft²) [VI]. Pervious concrete, made of coarse aggregate, Portland cement and water, is a composite substance. In that it comprises few or no fine aggregates, it is slightly different from standard concrete. Typically, the coarse aggregate consists of a single dimension and is held together by a paste formed by cement and water at its touchpoints. The outcome is concrete with a high percentage of linked voids that enable the fast percolation of water along with the concrete while working properly [VII].
II. Literature Review

Pervious concrete has been reintroduced in years for the growth of the earth in the struggle to fulfill the requirements surrounding environmental problems [VIII]. This includes the use of a low slump, a high-consistency concrete blend that has been progressively accepted as a solution to the issues resulting from the heavy drainage of floodwater over the ground surface. Four distinct samples of pervious concrete for its laboratory work to attain the highest compressive strength and different variables interrelations [IX]. The samples had separate aggregate and compaction energies for cement ratio and water cement ratio. He finds out that ubiquitous concrete is only equal to conventional concrete if we take into account its wear depth and shrinkage characteristics [X]. It is also suggested that if the right mix size fraction and maximal compaction energy is utilized, compressive pressure up to 3000 psi is possible, which was contradictory to the results of the other researchers. Finally, the findings he obtained from his tests on pervious concrete to determine the relevant thickness for various soils of subgrade and rupture modulus [XI]. A long-term analysis was initiated on the quantity of stormwater and the presentation of last pavement schemes, offering the ability to evaluate the long-term efficacy of the previous pavement. In the loss of watershed quality in urbanized environments, ubiquitous surfaces have long been involved [XII]. Many of these regions act as a means of migrating pollutants into habitats and waterways [XIII]. A study performed in Reston, Virginia, noticed the activity of the previous pavement over a period of six years. In that analysis, four pairs of numerous previous pavements were installed [XIV]. Until choosing the site, soil properties were analyzed. The sidewalks were 9.8 ft. wide and 19.7 ft. tall [XV]. To capture all subsurface and surface runoff, a mechanism was mounted. Water samples were obtained and examined after precipitation events. The pervasive pavements analyzed had different outcomes, but for the most permeable strains that met the lowest criteria, the general pattern of minimizing stormwater contaminants was observed. The efficiency of the runoff was very good; nearly all precipitation penetrated all the pavements [XVI]. The experiments were carried out in a laboratory of different mixtures and cylinders of concrete [XVII]. The consequence of the experiment confirmed the fact that the compressive strength of pervious concrete is weaker than that of standard concrete. On mixtures with the following fly ash content, compressive tests were performed: 0 percent, 2 percent, 9 percent, 30 percent and 32 percent of total cement material by weight. A falling head permeability test was provided for mixtures of 2 percent and 32 percent fly ash [XVIII]. The utilization of fly ash was intended to greatly improve the strength and longevity of the Pervious concrete that was Pervious and whose quality satisfies the requirements of the pavement design. The research concluded that the reached compressive power was 2300 psi with a permeability rate of 184.25 in / hr and 15 percent voids for the blend of 2 percent fly ash. The previous concrete mix configuration of 32 percent fly ash, on the other hand, had a compressive power of 2000 psi and a permeability rating of 297.64 in / h at 15.8 percent void material [XIX]. A stronger intensity of cement bonding was demonstrated by further study of the mix with 2 percent fly ash. The failure of the 32 percent fly ash specimen revealed that admixtures resulted in poorer cement bonding [XX]. In general, the resistance increased as the packing density of the aggregate increased, while the permeability decreased. In addition, test outcomes

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claim that the advantageous consequences of small particles on the perennial concrete’s strength growth [XXI].

III. Research Approach

In the laboratory of the Department of Structural Engineering, the Iqra National University of Peshawar, permeable concrete mixing, sampling and testing were carried out. Consequently, concrete cubes and cylindrical specimens with no sand were packed. 1:0:2.5 and 1:0:3 concrete mix ratios were planned and designated as M1 and M2, respectively. Moreover, with a 2 percent substitution of cement by titanium dioxide, the same blends were prepared for strength enhancement. Two companion specimens with and without power enhancing admixture (Titanium dioxide) were prepared for each blend. After 7, 14 and 28 days of completion, the respective sample was examined for mechanical strength. The following methodologies were used, based on the literature review.

Fresh State of concrete

Slump Test (ASTM C-143-M03)

The slump test was conducted on two mixtures according to ASTM C 143, as seen in the table below. There has been a recorded slump in inches. The whole process was carried out without delay and completed within 1.5 minutes from the initiation of the filling to the withdrawal of the mold. The concrete mix was prepared without sand. The concrete mix was prepared and designated as M1 and M2, respectively, providing a ratio of 1:0:2.5 and 1:0:3. To verify the workability of concrete, slump tests were conducted on both concrete mixes in a fresh condition.

Hardened State of Concrete

B.1 Compression Test on Cube specimen (IS: 516-1959)

As mentioned above in the table, the compression strength test was conducted on two mixes in compliance with Standard IS: 516-1959. The below is a tabulation of the comprehensive number of concrete cubes and cylindrical specimens:

Table 1: Number of concrete cubes

| Mix Designation | Without Titanium di-oxide | With 2% Titanium di-oxide replaced by Cement |
|-----------------|---------------------------|--------------------------------------------|
|                 | 1 week 2 weeks 4 weeks | 1 week 2 weeks 4 weeks                     |
| M1 (1:0:2.5)    | 2 2 2                   | 2 2                                         |
| M2 (1:0:3)      | 2 2 2                   | 2 2                                         |
| Total           |                          | 24 Concrete Cubes Specimen                  |

B.2 Splitting Tensile Strength of Cylindrical Concrete Sample (ASTM C 496/C 496M – 04)

As mentioned above in the table, the splitting tensile strength test was conducted in compliance with ASTM C 496 / C 496-04 on two mixes. The detailed number of cylindrical concrete samples for tensile strength test are tabulated below:

Table 2: Number of concrete Cylindrical Specimen

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Mix Designation | Without Titanium di-oxide | With 2% Titanium di-oxide replaced by Cement
--- | --- | ---
M1 (1:0:2.5) | 2 | 2 | 2 | 2 | 2 | 2
M2 (1:0:3) | 2 | 2 | 2 | 2 | 2 | 2
Total | 24 Concrete Cylindrical Specimen

### B.3 Infiltration Rate Test (ASTM C 1701)

According to ASTM C 1701, the infiltration rate test was conducted. Pervious concrete pavement slabs were cast on-site for M1 (1:0:2.5) and M2 (1:0:3) respectively for this test. Inside the campus INU, the location for the previous concrete pavement infiltration test was chosen. Two previous concrete slabs were installed and they were tested for infiltration. An infield permeability measure of pervious concrete is the penetration scale. On the top of concrete pavement, an infiltration ring is partially sealed. A provided mass of water (40 lb) is injected into the ring after pre-wetting the test position and the time for the water to penetrate the pavement is registered, which provides the rate of infiltration. The formula that is used to assess infiltration is as follows:

\[
I = \frac{KM}{D^2 t}
\]

Where; 
- \( K = 126,780 \text{ in (inch-pound) units} \)
- \( M = \text{Mass of Infiltrated Water (lb)} = 40 \text{ lb} \)
- \( D = \text{Inside Diameter of Infiltration Ring (in)} = 12 \text{ inches} \)
- \( t = \text{Time Required for Measured Amount of Water to Infiltrate through Concrete (sec)} \)

### A. Water Quality Test (PH value Determination)

Because of its composition, water, being a liquid and a solution (i.e., when it is not 100 percent pure H2O), has certain chemical properties. Both solutions are acidic, base or neutral, based on the pH (hydrogen power) scale, with values varying from 0 to 14. This is simply a calculation of the presence of both hydrogen ions or the presence of hydroxide ions. In the drums, rainwater is stored and later moved from the charcoal. Checking is done before and after moving water from charcoal PH value.

![Figure 1: Reference PH Values for rainwater quality test](image)

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IV. Results/Discussion

Slump Test (ASTM C143 M03)

From the above data, it can be concluded that if there is no sand in concrete slump value will be approximately equal to zero. Almost Zero slumps are obtained for both M1 and M2 concrete. By increasing the gravel ratio the slump value decreases more. This concrete will be very tough and its workability will be not good. So it must require a superplasticizer to elevate the viability of Pervious concrete.

Compressive strength (ASTM C-39/39M)

Compressive strength test results are shown in the figures below:
Discussion: The result of 4 weeks’ compressive strength of Pervious concrete shows a linear behavior. From the above results, it can be concluded that adding titanium dioxide in concrete by 2% replacement of cement gives good results at 7, 14 and 28 days of curing age. At 4th week average compressive strength (Having Strength Enhancement Admixture) comes up to be 2104.5psi which is considerable for pervious concrete. This mix of concrete can be used where less strength is required.

Splitting Tensile Strength of Cylindrical Concrete Samples (ASTM C 496/C 496M – 04)
The Splitting Tensile strength result of cylinders of two mixes M1 and M2 with and without titanium dioxide for curing age of 7, 14 and 28 days are shown in Bar Graphs Below:
**Figure 6**: Average Splitting Tensile Strength of cylinders (With 2 % Titanium di-oxide Replaced by Cement) - Psi

**Discussion**: Splitting tensile strength follows the same trend as compressive strength. It can be concluded that adding titanium dioxide in concrete by 2% replacement of cement gives good outcomes at 7, 14 and 28 days of curing age. At 28 Days average Splitting strength (Having Strength Enhancement Admixture-Titanium di-oxide) comes up to be 531.4 psi which is considerable for Pervious concrete. This mix of concrete can be used where less strength is required.

**Infiltration Rate Test (ASTM C 1701)**

**Figure 7**: Infiltration Rate Test Results

**Discussion**: The infiltration rate ranges from 838.5 in/hr to 927.8 in/hr for the two concrete mixes M1 (1:0:2.5) and M2 (1:0:3). It can be inferred from the above findings that as the percentage of gravel rises in the concrete mix, the permeability or infiltration rate increases. The percentage of voids is increased by raising the gravel amount in the mix, thus improving the permeability (infiltration rate) of the concrete mix and vice versa.

**Water Quality Test (PH value Determination)**

Before and after passing rainwater from 3 inch layer of charcoal the PH values were recorded. The results of the water quality test are shown in the bar graph below:

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Figure 8: Water Quality Test of Rain Water

Discussion: Water quality test results show that rainwater average PH value is 4.47 which can be used for cleaning and bathing purposes. While after passing this rainwater from 3 inch layer of the charcoal average PH Value comes to 5.77 which can be recommended to be used for cleaning and bathing in our houses.

V. Conclusion

Compressive and splitting strength of Pervious concrete shows an extensive increment in strength when 2% of Ta titanium Dioxide is replaced by cement at curing age of 1, 2 and 4 weeks. At 4th week mean compressive and splitting tensile strength (Having Strength Enhancement Admixture) comes up to be 2104.5psi and 531.4 psi respectively which is considerable for Pervious concrete. It can be inferred from the infiltration rate test that the permeability or infiltration rate rises as the amount of gravel rise in the concrete mix. Infiltration rate ranges from 838.5 in/hr to 927.8 in/hr for the two concrete mixes M1 (1:0:2.5) and M2 (1:0:3) respectively. From the water quality test, it can be concluded that when rainwater is passed from a 3 inches layer of charcoal the PH value increase from 4.47 to 5.77 which can be used for cleaning and bathing in our houses.

VI. Recommendations

The 100% decrease of concrete sand offers a substantial compressive strength of 2104.5 psi and a penetration rate of 927.41 inches/hour, which can be suggested for parking and walking area pavements. It is also recommended that after passing rainwater from 3 inches layer it can be used for cleaning and Bathing Purposes.

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Conflict of Interest:

No conflict of interest regarding this article

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