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Absorption and Permeability Studies on Concrete with Pulverized Used Foundry Sand as Mineral Admixture

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Abstract

This paper presents the detailed study on the absorption and permeability characteristics of concrete with pulverized used foundry sand as mineral admixture. Mineral admixtures are widely used in the production of concrete for enhancing the strength and durability properties. The mineral admixtures commonly available are fly ash, metakaolin, rice husk ash, silica fume. In this project absorption and permeability characteristics of concrete made using Pulverized Used Foundry Sand (PUFS) is discussed in detail. The absorption and permeability characteristics have great importance on the durability of structures. These characteristics have wider impacts on reinforced concrete structures than plain concrete structures. M 40 concrete was made with PUFS content at 0%, 5%, 10%, 15% and 20% to that of the cement content. Specimens were casted and cured in water for the required duration. Then the tests were conducted as per standard procedure. The concrete made with the addition of PUFS showed better results than the normal concrete without using PUFS. Further an addition of PUFS in the range 10-15% of the cement content gives good concrete with least absorption and least permeability.

Keywords: Chloride Permeability, Pulverized Used Foundry Sand, Sorptivity, Water Absorption, Water Permeability

INTRODUCTION

Mineral admixtures are extensively used in the production of concrete for attaining good strength and durability characteristics. Fly ash, rice husk ash, metakaolin and silica fume are the commonly used mineral admixtures. Apart from strength durability of the concrete is also a main concern now days. Concrete is a porous material. Various chemical substances can penetrate through the pores in the concrete which will induce serious durability problems and ultimately deteriorate the concrete. Water absorption, water permeability and sorptivity tests are the important tests relating to the durability of concrete.

Water absorption is the property of concrete to contain water in the pores. Permeability is the property of concrete in which a fluid can penetrate in to the microstructure of concrete. If the permeability is low then the chances of penetrating chemicals in to the concrete is low and there by the durability becomes high. High permeability led to the introduction of molecules that react and destroy its chemical stability [1].

The sorptivity of concrete is related to the capillary rise of water through the capillaries from one surface only. C Hall and W D Hoff (2012) described that the sorptivity expresses the tendency of a material to absorb and transmit water and other liquids by capillarity [2].

PULVERIZED USED FOUNDRY SAND

Used foundry sand is an industrial waste material from foundry industries. These materials are normally used for land filling of low lying areas. These can also be used as a partial replacement to fine aggregates in concrete. Used foundry sand is pulverized to get the pulverized used foundry sand (PUFS).By pulverizing the used foundry sand we will get an even distribution of the chemical components.

RESEARCH SIGNIFICANCE

Many research papers are available on the absorption and permeability study on concrete with different mineral admixtures. Since PUFS is a newly introduced material no studies were conducted on concrete containing it. So it is of immense important to conduct study on the performance of concrete containing PUFS for the absorption and permeability characteristics.

LITERATURE SURVEY

No literature is available on the absorption and permeability properties of PUFS contained concrete. However related literatures are reviewed.

Kolias and Georgiou (2005) studied the effect of paste volume and of water content on the strength and water absorption of concrete [3]. It is found that capillary absorption is higher when the value of effective water to cement ratio is higher and, with constant effective water to cement ratio, increases approximately linearly as the paste content increases.

Zhang and Zong (2014) conducted tests to evaluate the relationship between water absorption and durability of concrete [4]. Results from the tests showed that only surface water absorption related to the performance of concrete including permeability, sulfate attack, and chloride ion diffusion.

De Schutter and Audenaert (2004) conducted experiments to evaluate water absorption of concrete as a measure for resistance against carbonation and chloride migration [5]. From this study it is observed that the water absorption by immersion is not a reliable parameter for the estimation of the concrete durability. The water absorption by immersion gives an estimation of the total (reachable) pore volume of the concrete, but gives no indication on the concrete permeability, which is more important with regard to durability.

OBJECTIVES OF STUDY

The objective of the present study includes the detailed investigation of the absorption and permeability characteristics of concrete containing Pulverized Used Foundry Sand (PUFS) as a mineral admixture. This will be achieved by making concrete of M 40 grade and casting specimens and curing the specimens in water for the required time and testing the specimens for the required characteristics.

MATERIALS

Cement

Cement used was Ordinary Portland Cement (OPC), 53 grade conforming to IS: 12269-1987[6].The specific gravity of cement used was 3.15.The chemical properties of cement is shown in Table 1.

Table 1 Chemical properties of cement

Sl. No.	Property	Results obtained	Requirement as per IS:12269/1987
1	Loss On Ignition (LOI)	1.72%	<4.00%
2	Insoluble Residue (IR)	1.00%	<4.00%
3	Sulphuric Anhydride (SO3)	2.09%	<3.50%
4	Magnesia (MgO)	1.53%	<6.00%
5	Alkalis as Na_2O	0.50%	<0.60%
6	Total Chloride Content (Cl)	0.013%	<0.10%
7	Lime Saturation Factor (LSF)	0.918	0.8-1.02
8	Al_2O_3/Fe_2O_3	1.19	>0.60

Aggregates

Fine aggregate used was manufactured sand from crushed rocks. Coarse aggregate used was crushed rock aggregates. Fine aggregate and coarse aggregate used were conforming to ASTM C-33/C33 M-16e1 [7].

Water

Water used was ordinary tap water of potable quality. The properties of water were conforming to the requirements of IS: 456-2000, for concrete [8].

Super Plasticizer

Super plasticizer used was Fosroc SP 430 A2 conforming to IS 9103-1999[9].

Pulverized Used Foundry Sand

Pulverized used foundry sand is not available from market as it is newly introduced. Used foundry sand was obtained from a foundry in Chavara near Kollam, Kerala, and India. After proper processing this sand was pulverized using specially prepared mechanical sand pulverizer to get PUFS.

MIX DESIGN

The concrete mix design was based on the guidelines of ACI-211.1-1991[10].A concrete mix of M 40 grade was designed. The cement content used was 430kg/m^3.The Pulverized Used Foundry Sand (PUFS) were added to the mix at 5%, 10%, 15% and 20% of the cement content. The concrete mix without the addition of PUFS constitutes the control mix.

The proportions of ingredients of the control concrete mix is shown in

Table 2 Proportions of concrete mix

Sl. No.	Particulars	Proportion by weight to cement
1	Cement	1.000
2	Water	0.419
3	Fine Aggregate	1.721
4	Coarse Aggregate	2.560
5	Super Plasticizer	0.007

Concrete cubes of size 100mmx100mmx100mm 3 numbers were casted for each category with 0%, 5%, 10%, 15% and 20% addition of PUFS to that of the cement content for the water absorption test. Concrete cubes of size 150mmx150mmx150mm 3 numbers were casted for each category with 0%, 5%, 10%, 15% and 20% addition of PUFS to that of the cement content for the water permeability test. Concrete cylinders of size 100mm diameter and 50 mm height 6 numbers were casted for each category with 0%, 5%, 10%, 15% and 20% addition of PUFS to that of the cement content for the sorptivity test and Rapid Chloride Permeability Test(RCPT).

WATER ABSORPTION TEST

The water absorption is an important parameter when we consider the durability of structures. The water absorption test was conducted as per BS 1881: Part 122:1983[11].The cube specimens were placed in the oven. The specimens were dried in the oven in which temperature was controlled at 110°C for 72 hours. Care should be taken to provide at least 25mm gap between each specimens. After removal from the oven the specimens were allowed to cool for 24 hours in an air tight container. The weight of each specimen was noted. Immediately after that the specimens were immersed in water for 30 hours. Then each specimen were removed from the water tank and shake it to remove excess water. Further the specimens were wiped with soft cloth to make it dry. The weight of specimens was further noted. The percentage of weight of water absorbed to the dry weight of the sample is the water absorption. The specimens placed in oven are shown in Figure 1.

Figure 1. Water absorption test specimens placed in oven

The water absorption test results are shown in Table 3.

Table 3. Water absorption test results

Sl. No.	% PUFS	Mix Designation	Water Absorption (%)
1	0	C	4.64
2	5	F1	4.53
3	10	F2	4.32
4	15	F3	4.22
5	20	F4	4.42

The graphical representation of the water absorption variation with respect to percentage addition of PUFS is shown in Figure 2.

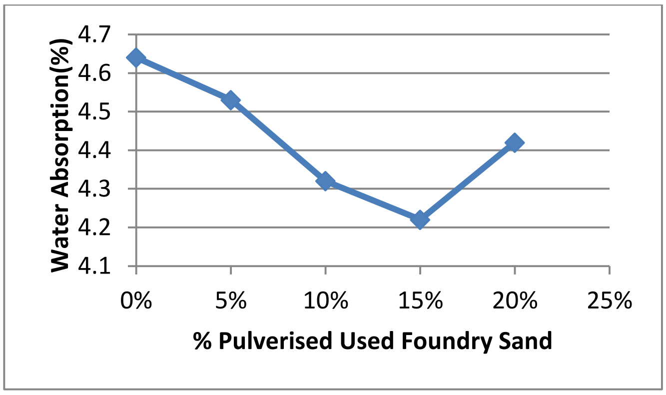

Figure 2. Water absorption vs. %PUFS

WATER PERMEABILITY TEST

The water permeability is measured by conducting permeability test as per DIN: 1048(part 5)-1991[12].The cube specimen of size 150x150x150 mm is subjected to a water pressure of 5kg/cm2 for three days. Then the specimen is taken out and split in to two pieces using compression testing machine. Water penetration is measured using a Vernier scale. For RCC works a penetration of up to 25mm is permissible. Water permeability test results are shown in Table 4.

Table 4. Water permeability test results

Sl. No.	% PUFS	Mix Designation	Water Permeability(mm)
1	0	C	13.00
2	5	F1	11.33
3	10	F2	9.67
4	15	F3	8.67
5	20	F4	10.33

The graphical representation of the water permeability variation with respect to percentage addition of PUFS is shown in Figure 3.

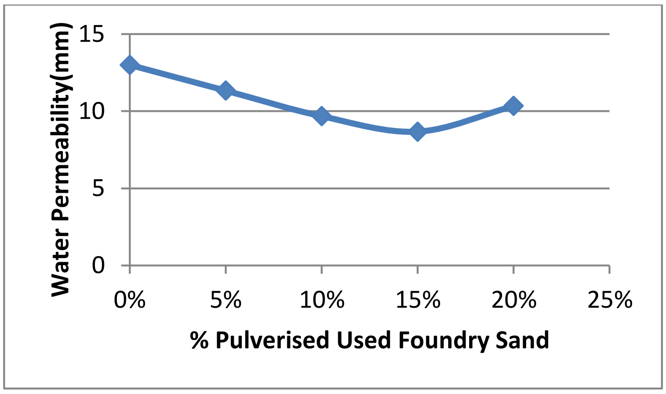

Figure 3. Water permeability vs. %PUFS

SORPTIVITY TEST

Sorptivity test is a simple test for measuring the capillary rise of water in the concrete. The test is conducted as per ASTM C 1585-2004[13]. The samples are oven dried at 100ºC for 72 hours. After that the samples are kept at room temperature for 24 hours. Then the sides of the specimens were applied with an epoxy coating. The weight of the specimens is noted. The specimens are then placed in a tray with 5mm water filled in it. The water should only have an access from the bottom side of the specimen. Again the weight of the specimen is noted after wiping the excess water from the wet surface. The readings were taken at 2 minutes interval up to 30 minutes. The Sorptivity is calculated by the following equation.

$$S = I/\sqrt{t}$$

Where S=Sorptivity in mm/min$^{0.5}$

t=Elapsed time in minutes

I=Δw/Ad

Δw=Weight of capillary water=W2-W1

W1= Initial weight of the specimen in grams

W2= Final weight of the specimen in grams

A= Water penetrating surface area of the specimen in cm^2

d= Density of water in g/cm^3

Sorptivity test set up is shown in Figure 4.

Figure 4. Sorptivity test set up

Sorptivity test results are shown in Table 5.

Table 5. Sorptivity test results

Sl. No.	% PUFS	Mix Designation	Sorptivity ($mm/min^{0.5}x10^{-5}$)
1	0	C	3.26
2	5	F1	3.02
3	10	F2	2.79
4	15	F3	2.56
5	20	F4	2.71

The graph of the variation of sorptivity with different percentage addition of PUFS is shown in Figure 5.

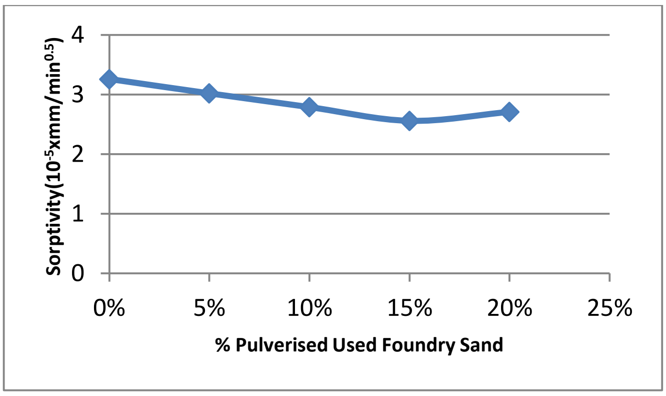

Figure 5. Sorptivity vs. %PUFS

RAPID CHLORIDE PERMEABILITY TEST

The Rapid chloride permeability test is a test to measure the durability of concrete .Durability of concrete is of great importance for structures with steel reinforcements. RCPT test is conducted as per AASHTO T277-1989[14] and ASTM C1202-1997[15].The cylindrical specimen is having the size of 100mm diameter and 50 mm height.

RCPT Apparatus

The RCPT apparatus consists of two reservoirs of approximate 250 ml. capacity on each end of the specimen. At each end of the specimen is provided with copper mesh to act as electrodes to pass the electric current. Washers are also provided for leak proofing. One reservoir is filled with 3.0%NaCl solution and the other is filled with 0.3M NaOH solution. The electrode at NaCl is connected to the –ve terminal of a 60 V regulated DC power supply. The electrode at NaOH is connected to the +ve terminal of the power supply through an ammeter showing milliamperes .The reservoirs are also provided with probes for collecting temperature data.

RCPT Procedure

The cylindrical surface of the test specimen was applied with a coat of epoxy. After the epoxy was tack free the specimen was placed in a vacuum desiccator and the vacuum was maintained for 3 hours by using the vacuum pump. After that de aerated water was filled up to the top of the specimen while the vacuum pump was still operating. The vacuum was again maintained for one hour. After that released the vacuum and allowed the specimen to be immersed in de aerated water for 18 hours. After the elapse of 18 hours the specimen was fitted in the apparatus.60V DC is applied to the electrodes. The current reading is noted at 30 minutes interval for 6 hours.

The total current passed through the specimen in coulombs

$$Q = 900x\,[I_0 + 2I_{30} + 2I_{60} + 2\,I_{90} + 2I_{120} + 2I_{150} + 2I_{180} + 2\,I_{210} + 2I_{240} + 2I_{270} + 2I_{300} + 2I_{330} + I_{360}]$$

Where I_0=Initial current reading

I_{30}= Current reading at 30 minutes

I_{60}= Current reading at 60 minutes

I_{90}= Current reading at 90 minutes

I_{120}= Current reading at 120 minutes

I_{150}= Current reading at 150 minutes

I_{180}= Current reading at 180 minutes

I_{210}= Current reading at 210 minutes

I_{240}= Current reading at 240 minutes

I_{270}= Current reading at 270 minutes

I_{300}= Current reading at 300 minutes

I_{330}= Current reading at 330 minutes

I_{360}= Current reading at 360 minutes

As per ASTM C 1202-97, the chloride permeability based on charge passed is classified as negligible to high. The details are shown in Table 6.

Table 6. Chloride permeability classification

Sl. No.	Charge passed (Coulombs)	Chloride Permeability
1	>4000	High
2	4000-2000	Moderate
3	2000-1000	Low
4	1000-100	Very Low
5	<100	Negligible

The chloride permeability results are shown in Table 7.

Table 7. Chloride permeability results

Sl. No.	% PUFS	Mix Designation	Charge passed (Coulombs)
1	0	C	1120
2	5	F1	1113
3	10	F2	815
4	15	F3	625
5	20	F4	1098

From the results it is clear that the concrete containing PUFS with 0%,5% and 20% is having low chloride permeability. The concrete with 10% and 15% PUFS is having very low chloride permeability.

The variation of chloride permeability with respect to the percentage addition of PUFS is shown in Figure 6.

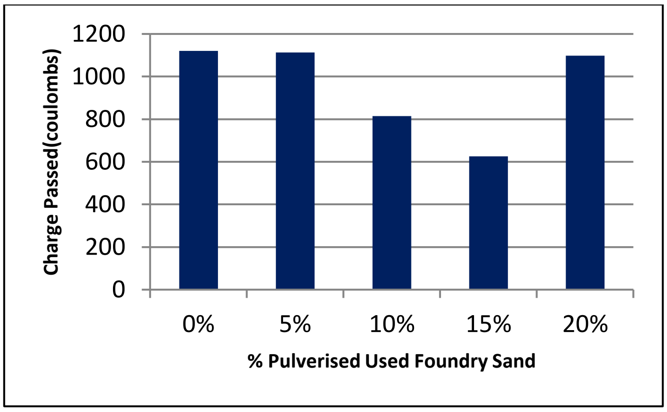

Figure 6. Charge passed vs. %PUFS

DISCUSSION

Water Absorption

The water absorption of concrete with PUFS is decreasing with percentage increase in used foundry sand up to 15% and increasing afterwards.

The water absorption decreased at 2.37%, 6.90%, 9.05% and 4.53% of the controlled concrete for 5%, 10%, 15% and 20% addition of PUFS respectively. The variation of water absorption with respect to the control concrete is shown in Figure 7

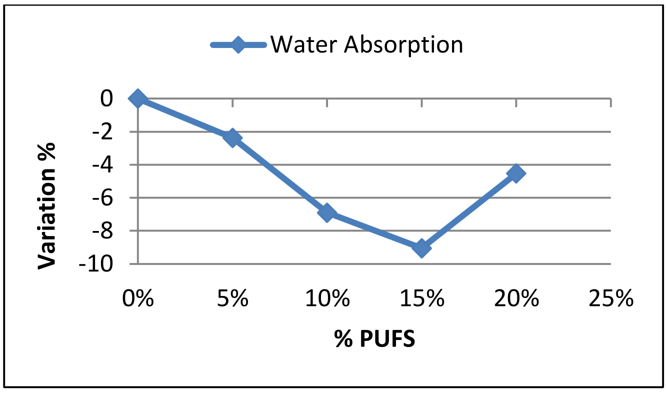

Figure 7. Water absorption variation graph

Water Permeability

The water permeability of concrete with PUFS is decreasing with percentage increase in used foundry sand up to 15% and increasing afterwards.

The water permeability decreased at 12.84%, 25.61%, 33.33% and 20.54% of the controlled concrete for 5%, 10%, 15% and 20% addition of PUFS respectively. The variation of water permeability with respect to the control concrete is shown in Figure 8.

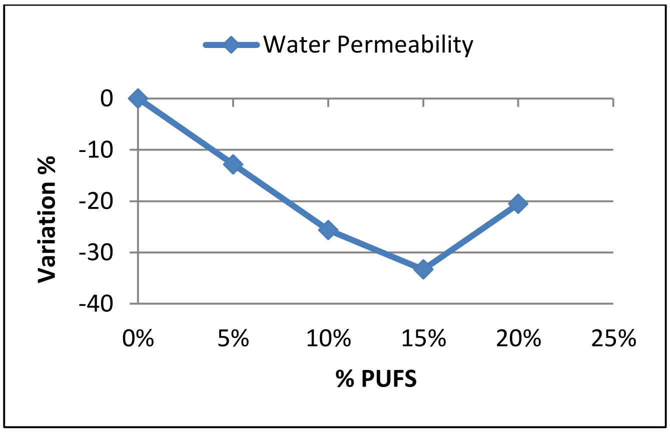

Figure 8. Water permeability variation graph

Sorptivity

The Sorptivity of concrete with PUFS is decreasing with percentage increase in pulverized used foundry sand up to 15% and increasing afterwards.

The Sorptivity decreased at 7.36%, 14.42%, 21.47% and 16.87% of the controlled concrete for 5%, 10%, 15% and 20% addition of PUFS respectively. The variation of sorptivity with respect to the control concrete is shown in Figure 9

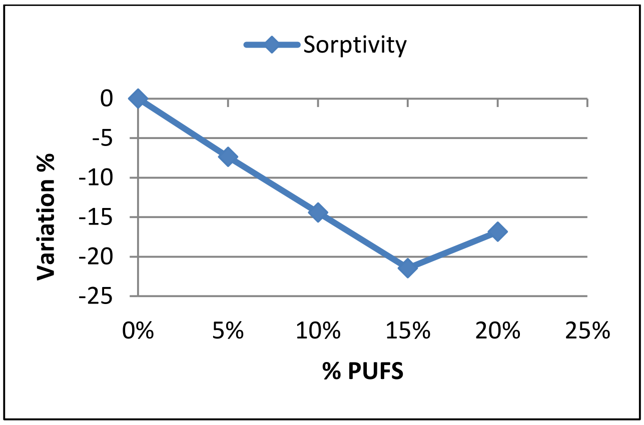

Figure 9. Sorptivity variation graph

Rapid Chloride Permeability

The chloride permeability of concrete with PUFS is decreasing with percentage increase in pulverized used foundry sand up to 15% and increasing afterwards.

The charge passed decreased at 0.63%, 27.23%, 44.20% and 1.96% of the controlled concrete for 5%, 10%, 15% and 20% addition of PUFS respectively. The variation of chloride permeability with respect to the control concrete is shown in Figure 10.

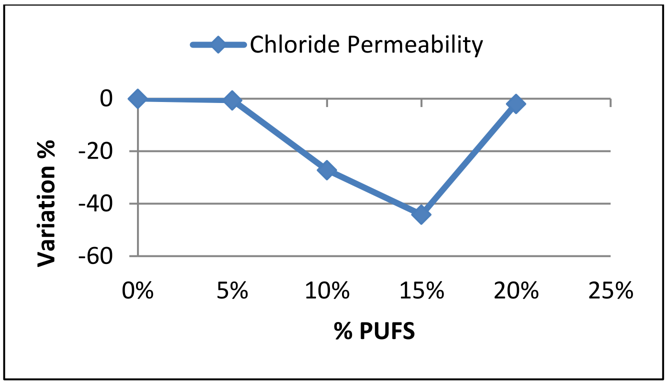

Figure 10. Chloride permeability variation graph

CONCLUSION

- The concrete containing pulverized used foundry sand is more resistant to water absorption, water permeability, sorptivity and chloride permeability than normal concrete without PUFS
- The water absorption of concrete containing PUFS is decreasing with increase in percentage addition of PUFS up to 15% and shows an increase in value further. However up to 20% addition of PUFS the water absorption percentage is less than that of normal concrete without PUFS.
- The water permeability of concrete containing PUFS is decreasing with increase in percentage addition of PUFS up to 15% and shows an increase in value further. However up to 20% addition of PUFS the water permeability is less than that of normal concrete without PUFS.
- The sorptivity of concrete containing PUFS is decreasing with increase in percentage addition of PUFS up to 15% and shows a slight increase in value further. However up to 20% addition of PUFS the sorptivity is less than that of normal concrete without PUFS.
- The chloride permeability of concrete containing PUFS is decreasing with increase in percentage addition of PUFS up to 15% and shows a slight increase in value further. However up to 20% addition of PUFS the chloride permeability is less than that of normal concrete without PUFS.
- The concrete containing PUFS is more durable than normal concrete without PUFS.
- Pulverized used foundry sand can be effectively utilized as a mineral admixture in cement concrete

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