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Assessment of Sorptivity and Water Absorption of Concrete with Nano Sized Cementitious Materials

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ABSTRACT: Nano technology is the incorporation of nano sized particles. Particle in nano size can enhance the structural property in concrete. Past study reveals that nano particles increase the strength and durability of concrete. Permeability tests in concrete showed that the behaviour of concrete for durability depends mainly on its degree of absorption and porosity of concrete. Materials incorporated at nano size results in improving property of the concrete composites. Experimental investigation has been done to understand the influence of nano materials on the sorptivity and water absorption of concrete. M20 grade, M30 grade, M40 grade and M50 grade of concrete has been used. Cement was replaced with 10%, 20%, 30%, 40% and 50% of nano sized cement, fly ash and silica fume. Materials were converted to nano size by grinding in ball milling machine and its particle size was determined by scanning electron microscope. It was found that cement replaced with 50% of nano cement showed less moisture ingression and less water absorption.

Keywords: Nano technology, nano cement(NC), nano fly ash(NFA), nano silica fume(NSF), scanning electron microscope, sorptivity, carbonation.

I. INTRODUCTION

Nanotechnology is an extension of science and incorporation of nano particles in concrete is a progressive area. Here the behaviour of concrete has been examined by the incorporation of particles at smaller scale. Nano scale technology will modify and enhance the behaviour of concrete. Nano technology plays a very vital role in all foregoing innovations in construction industry. The better understanding of cementitious materials and incorporating nano materials in it can increase the performance of concrete. Nano scale technology has a ability to change the properties of concrete to suit our needs.

Strength and durability of concrete are most important parameter to determine the life and serviceability of the structure. Durability mostly depends on penetrability of water, chloride ion, sulphate ion, alkali and acid ions. Permeability of water depends on the porosity of concrete, size of pore and the interconnection of pores. The penetrability of harmful chemicals causes concrete to crack, spall and also affects the reinforcement to corrode. The rate of fluid penetration depends on the type of cement, impurities in aggregates, curing solution, type of curing, temperature at initial curing, the duration of curing, the exposure climatic condition of concrete, the mineral and the chemical admixtures used in concrete. The transport of moisture in to concrete by capillary action is also considered as one of the durability characteristics of concrete. This property, defined as sorptivity, is very important to determine the serviceability of concrete. Ingress of moisture through capillary suction paves way to the carbonation reaction. Hence an attempt is made to study the effect of sorptivity and water absorption on concrete with cement replaced with nano materials.

II. LITERATURE REVIEW

Nath P and Sarker P (2011) found that fly ash samples showed less drying shrinkage, reduced sorptivity and chloride ion penetration significantly at 28 days. The experimental results at 6 months showed a much improved durability properties of concrete. Prince Arulraj G and Jemimah Carmichael M (2011) experimentally determined that concrete with nano fly ash showed higher compressive strength and had better workability compared with normal cement concrete. Jayeshkumar Pitroda and Umrigar F S (2013) evaluated that the water absorption and sorptivity of concrete with fly ash and hypo sludge shows lower water absorption. The optimum reduction in sorptivity was found at 10% replacement with fly ash and hypo sludge for M25 and M40 grade of concrete. It was concluded that fly ash along with hypo sludge can be used as an innovative supplementary cementitious construction material. Santhosh Kumar T et al (2016) concluded that the partial replacement of cement in concrete with unprocessed sugarcane bagasse ash and 10% silica fume performed better in resisting sorptivity.

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Han Yan Leung et al (2016) showed that the presence of fly ash and silica fume can greatly reduce the surface water absorption of self compacting concrete. Esam Elawady et al (2014) investigated the compressive strength, permeability and sorptivity of concrete with silica fume. It was found that the sorptivity decreased up to 42.7% without silica fume and with 10% silica fume sorptivity decreases by 64.5% and 68.3% with 350kg/m^3 and 450kg/m^3 cement content at 28 days. The specimens having lower sorptivity showed less permeability and higher compressive strength. Gopalan M K (1996) compared the durability of fly ash concrete against the cement concrete. Experiments were conducted to measure the sorptivity of cement and fly ash concrete under two different curing conditions. It was concluded that the influence of curing on cement concrete was found to be of much less importance. Wojciech Kubissa and Roman Jaskulski (2013) measured sorptivity at 28 days, 2 months, 3 months, 6 months, 9 months, 12 months and 24 months. It was found that the sorptivity at 28 days was higher compared to sorptivity at olden days. It was also proved that the sorptivity value at 28 days gives an exact approximation for sorptivity of different days.

Jorge I. Tobón et al (2015) studied the durability of portland cement mortars blended with silica nano particles. In this paper the effects of nano silica (NS) on porosity, capillary suction, compressive strength, and sulphate resistance were evaluated for Portland cement mortars and partially replaced with a commercial nano silica suspension. Nano silica showed that it has an important role in pore refining, decreasing the total volume of pores and their diameter.

George Quercia and H. J. H. Brouwers (2010) aimed to present the nano silica application of concrete. It includes the nano silica production process, their addition effects and their application in concrete. The use of nano silica makes concrete financially more attractive and reduces CO_2 footprint of the produced concrete products. The nano silica will also increase the product properties of the concrete: the workability and the properties in hardened state, enabling the development of high performance concretes for extreme constructions. That means a concrete with a better performance, lower costs and an improved ecological footprint can be designed. Elke Gruyaert et al (2012) found out the effect of cement replacement level and curing on carbonation on the pore structure. It is revealed that although blast furnace slag (BFS) concrete has a lower carbonation resistance than ordinary portland cement concrete, the depth of carbonation at the end of concrete life (50 years) can still be accepted in normal environment.

III. MATERIALS USED AND EXPERIMENTAL PROGRAMME

Ordinary Portland cement of 53 grade conforming to IS12269-2013 and procured from a single source is used for this investigation. The locally available natural river bed sand free from debris is used for fine aggregate and good quality hard broken stones are used for coarse aggregate. The aggregates comply with IS383-1970 requirements. The potable water drawn from siruvani water resources was used. Fly ash used in this investigation is procured from mettur thermal power station conforming to IS 3812: 1981 and silica fume was procured from single source. The particle size of cement fly ash and silica fume was generally ranges between10µm to 300µm. These materials were ground in high energy ball grinding milling machine to produce nano particles. High impact collisions are used to reduce microcrystalline materials down to nano crystalline structure without chemical change. The Scanning Electron Microscope (SEM) image gives the size of particles. NC, NFA and NSF were the nano particles used in this experimental investigation. In this experimental investigation nano concrete was made by replacing 10%, 20%, 30%, 40% and 50% of cement with nano particles for M20, M30, M40 and M50 grades of concrete. The mix ratio for M20, M30, M40 and M50 were found to be 1:1.55:3.67:0.55, 1:1.12:2.93:0.44, 1:0.55:2.75:0.37 and1:0.44: 2.35:0.31 respectively.

The sorptivity was conducted with the concrete cylinders of size 100mm diameter and 50mm height. The specimen was oven dried and the weight of the specimen was taken. The measurement of the capillary rise of the saturated calcium hydroxide solution on the concrete cylinder was found. The specimen is sealed by epoxy coating on the sides and immersed in solution with height of 5mm from bottom immersed in water. Two non conducting sticks are kept at bottom of tray to hold the specimen. Care was taken to ensure the penetration of water is only by capillary rise. The quantity of solution absorbed by the specimen for every 30 minutes was measured by weighing it accurately to 0.1mg and the weighing procedure was completed within 30seconds. Sorptivity is the property by which water has been absorbed and transmitted by capillary action. Sorptivity (S) is calculated by

$S=(W_c-W_d)/(A x \delta x t^{0.5})$

W_d = dry weight of the cylinder in grams

W_c = weight of the cylinder after capillary suction in grams

A = surface area of the cylinder exposed to water penetration by capillary action in mm^2

δ = density of water

t = time in minutes

After conducting sorptivity test the specimens were completely immersed in saturated calcium hydroxide solution for 24 hours. Then the specimens are broken and the carbonation test was conducted on the broken surface of the specimen.

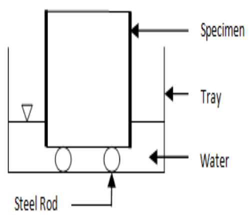

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Figure 1. Sorptivity test, carbonation and pH test

The process by which calcium hydroxide reacts with carbon dioxide and form calcium carbonates in the presence of moisture is termed as the carbonation of concrete. In this process, carbon dioxide present in air gets converted to dilute carbonic acid which intrudes till the reinforcement and affects the reinforcement. The grade of concrete, the permeability characteristics, porosity and the continuous of pores plays a vital role in carbonation process. Carbonation process reduces the alkalinity of concrete. This test was conducted with the spraying of phenolphthalein indicator on the broken fresh surface of concrete. The pink colour indicated that the alkalinity will be more than 9. The alkalinity of the concrete is found using pH meter.

IV. RESULTS AND DISCUSSION

The sorptivity of the concrete with cement replaced with NC, NFA and NSF was found and given in Table 1.In the table GC represents grade of concrete and RCNP represents cement replaced with nano particles in percentage.

Table 1 Sorptivity of concrete with nano particles

GC	RC NP	NC			NFA			NSF		
		dry weight	wet weight	Sorptivity $x10^{-5}$	dry weight	wet weight	Sorptivity $x10^{-5}$	dry weight	wet weight	Sorptivity $x10^{-5}$
		gms	gms	$mm/min^{0.5}$	gms	gms	$mm/min^{0.5}$	gms	Gms	$mm/min^{0.5}$
20	0	892.4	897.5	2.65231	892.4	897.5	2.652310	892.4	897.5	2.652310
	10	910.5	914.9	2.25707	898.0	902.6	2.392280	897.7	902.3	2.381880
	20	918.0	922.2	2.184260	906.8	911.2	2.288270	907.8	912.2	2.277870
	30	928.6	932.5	2.028240	914.5	918.6	2.132250	916.0	920.0	2.080250
	40	932.9	936.6	1.924230	921.3	925.3	2.059440	924.1	927.9	2.002240
	50	940.7	944.3	1.872220	930.0	934.0	2.075050	931.3	935.2	2.054240
30	0	910.6	915.4	2.49630	910.6	915.4	2.49630	910.6	915.4	2.49630
	10	924.5	928.7	2.173860	916.8	921.2	2.298670	916.8	921.2	2.288270
	20	932.7	936.6	2.002240	923.5	927.4	2.038640	922.6	926.5	2.028240
	30	940.2	944.0	1.976230	931.7	935.6	2.007440	929.8	933.6	1.997040
	40	952.4	956.1	1.908630	938.9	942.6	1.924230	935.5	939.2	1.898220
	50	959.9	963.4	1.820220	944.7	948.5	1.955430	941.0	944.7	1.929430
40	0	920.9	925.3	2.288270	920.9	925.3	2.288270	920.9	925.3	2.288270
	10	929.7	933.5	1.976230	929.4	933.5	2.132250	926.6	930.5	2.028240
	20	938.3	941.9	1.872220	933.9	937.6	1.924230	933.2	936.8	1.887820
	30	944.3	947.7	1.768210	941.9	945.4	1.820220	940.0	943.4	1.815010
	40	954.4	957.7	1.71620	945.8	949.2	1.768210	944.2	947.6	1.742210
	50	961.1	964.3	1.66420	949.3	952.8	1.820220	950.3	953.8	1.830620
50	0	930.4	934.6	2.184260	930.4	934.6	2.184260	930.4	934.6	2.184260
	10	936.5	940.2	1.924230	934.0	937.8	1.976230	935.5	939.2	1.945030
	20	945.8	949.3	1.820220	939.6	943.2	1.872220	942.2	945.7	1.799410
	30	952.7	955.9	1.66420	945.0	948.5	1.820220	948.9	952.3	1.768210
	40	960.2	963.3	1.612190	950.2	953.4	1.66420	951.4	954.6	1.69020
	50	970.8	971.1	1.560180	954.4	957.8	1.768210	956.1	959.4	1.71620

From Table 1, it can be seen that as the percentage replacement of cement with NC, NFA and NSF increases, the sorptivity decreases for all grades of concrete. The sorptivity of cement with NC was found to be decreasing with the percentage replacement but with the replacement of NFA and NSF 40% replacement was found to be optimum.

The sorptivity graph for different grades of concrete for different nano materials replacement was shown in Figure 2.

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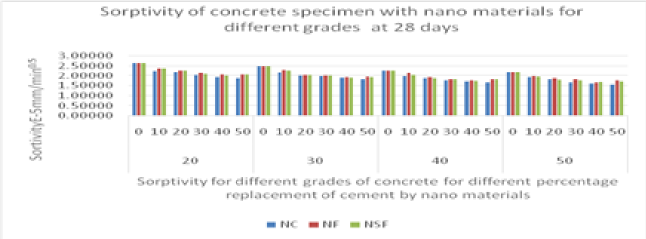

Figure 2. Sorptivity of concrete specimen with nano materials for different grades.

The water absorption of concrete with NC, NFA and NSF was found and given in Table 2. In the table GC represents grade of concrete and RCNP represents cement replaced with nano particles in percentage.

Table 2 Water absorption of concrete with nano particles

NC	NFA	NSF	GC	RCNP	GC	NC	NFA	NSF
Water absorption in %						Water absorption in %		
0.57	0.57	0.57	20	0	40	0.48	0.48	0.48
0.48	0.51	0.51		10		0.41	0.44	0.42
0.46	0.49	0.48		20		0.38	0.4	0.39
0.42	0.45	0.44		30		0.36	0.37	0.36
0.4	0.43	0.41		40		0.35	0.36	0.36
0.38	0.43	0.42		50		0.33	0.37	0.37
0.53	0.53	0.53	30	0	50	0.45	0.45	0.45
0.45	0.48	0.48		10		0.4	0.41	0.4
0.42	0.42	0.42		20		0.37	0.38	0.37
0.4	0.42	0.41		30		0.34	0.37	0.36
0.39	0.39	0.4		40		0.32	0.34	0.34
0.36	0.4	0.39		50		0.31	0.36	0.35

From Table 2, it can be seen that as the percentage replacement of cement with n NC, NFA and NSF increases, the water absorption decreases for all grades of concrete. The sorptivity of cement with NC was found to be decreasing with the percentage replacement but with the replacement of NFA and NSF 40% replacement was found to be optimum. The water absorption graph for different grades of concrete for different nano materials replacement was shown in Figure 3.

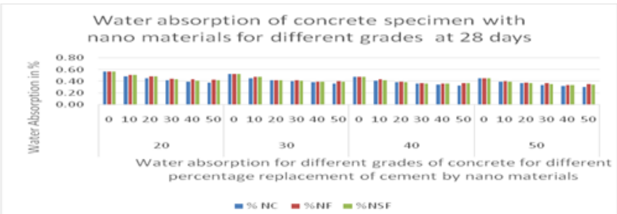

Figure 2. Water absorption of concrete specimen with nano materials for different grades.

The coefficient of correlative values between the sorptivity and water absorption of concrete with cement replaced with nano cement were found to be -0.9990, 0.9980, 0.9996 and 0.9997 for M20, M30, M40 and M50 concrete respectively. Similarly the coefficient of concrete with nano fly ash was found to be 0.9982, 0.9993. 0.9996 and 0.9997 and that of nano silica fume it was found to be 0.997, 0.9976, 0.9934 and 0.9964 respectively.

V. CONCLUSIONS

The effect of replacement of NC, NFA and NSF on the water absorption and sorptivity of concrete was studied. Nano materials were produced using a ball grinding mill. it can be seen that as the percentage replacement of cement with NC, NFA and NSF increases, the sorptivity decreases for all grades of concrete. It is found that replacement of cement with nano materials decreased the sorptivity and water absorption. The coefficient of correlation between the percentage replacement and the strength is very close to 1.0 which shows a very strong positive correlation.

REFERENCE

1. Elke Gruyaert, Philip Van den Heede, Nele De Belie (2013), “Carbonation of slag concrete: Effect of the cement replacement level and curing on the carbonation coefficient- Effect of carbonation on the pore structure”,Cement and Concrete composites, Volume 35, Issue 1, pp39- 48.
2. Esam Elawady, Amr A.El Hefnawy, Rania A.F.Ibrahim (2014), “Comparative study on strength, permeability and sorptivity of concrete and their relation with concrete durability”, International Journal of Engineering and Innovative Technology, Volume 4, pp132-139.

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3. George Quercia Bianchi and Brouwers H J H (2010) “Application of nano silica (NS) in concrete mixtures”, 8th fib symposium in civil Engineering, Lyngby, Denmark, pp1- 6.
4. Gopalan M K (1996), “Sorptivity of fly ash concretes”, Cement and Concrete Research, Volume 26, Issue 8, pp 1189-1197.
5. Han Yan Leung, Kim J, Nadeem A, Jayaprakash Jaganathan and Anwar M P (2016), “Sorptivity of self-compacting concrete containing fly ash and silica fume”, Construction and Building Materials, Volume 113, pp 369-375.
6. IS: 383-1970 “Specification for coarse and fine aggregates from natural sources for concrete”, Bureau of Indian Standards, New Delhi.
7. IS: 10262-2009, “Guidelines for concrete mix design proportioning”, Bureau of Indian Standards, New Delhi.
8. IS: 12269 - 2013. “Ordinary Portland cement, 53 grade- specification”, Bureau of Indian Standards, New Delhi.
9. Jayashkumar Pitroda and Umrigar F S (2013), “Evaluation of sorptivity and water absorption of concrete with partial replacement of cement by thermal industry waste (Fly ash)”, IJEIT, Vol. I, Issue II, pp 33-42.
10. Jemimah Carmichael M and Prince Arulraj.G. (2017), “Strength and permeability studies on concrete with nano-cement”, IJCET, ISSN 0976-6308, Vol. 8, Issue 1, pp 132-139.
11. Jemimah Carmichael M, Prince Arulraj. G., Sam Blessan. J and Elgiva John.M (2018), “Effect of nano materials on the effect of concrete to chloride ion penetration ”, IJCET, ISSN 0976-6308, Vol.9, Issue-2, pp 675-686.
12. Jorge I. Tobon , Jordi Paya, Oscar J.Restrepo (2015), “Study of durability of portland cement mortars blended with silica nanoparticles”, Construction and Building Materials, Volume 80, pp 92-97.
13. Nath P and Sarker P (2011), “Effect of fly ash on the durability properties of high strength concrete”, Procedia Engineering, Volume 14, pp 1149-1156.
14. Prince Arulraj G and Jemimah Carmichael M(2011), “Effect of nano-fly ash on strength of concrete”, IJCSE, Volume 2, No. 2, pp 475- 482.
15. Santhosh Kumar T, Balaji K V G D and Rajasekhar K (2016), “Assessment of sorptivity and water absorption of concrete with partial replacement of cement by sugarcane bagasse ash (SCBA) and silica fume”, International Journal of Applied Engineering Research, Volume 11, pp 5747-5752.
16. Wojciech Kubissa and Roman Jaskulski (2013), “Measuring and Time Variability of the Sorptivity of Concrete”, Warsaw University of Technology, Procedia Engineering, Volume 57, pp 634-641.

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