ISSN: 2277-3754
ISO 9001:2008 Certified
International Journal of Engineering and Innovative Technology (IJEIT)
Volume 2, Issue 7, January 2013

Evaluation of Sorptivity and Water Absorption of Concrete with Partial Replacement of Cement by Thermal Industry Waste (Fly Ash)

Jayeshkumar Pitroda, Dr F S Umrigar
Assistant Professor & Research Scholar, Civil Engg Department, B.V.M. Engg. College, Vallabh Vidyanagar
Principal, BVM Engineering College, Vallabh Vidyanagar, Anand, Gujarat-India

Abstract- ***When excess water in concrete evaporates, it leaves voids inside the concrete element creating capillaries which are directly related to the concrete porosity and permeability. By proper selection of ingredients and mix proportioning and following the good construction practices almost impervious concrete can be obtained.The flow of water through concrete is similar to flow through any porous body. The pores in cement paste consist of gel pores and capillary pores. The pores in concrete as a result of incomplete compaction are voids of larger size which give a honeycomb structure leading to concrete of low strength.Due to problems associated with the absorption test and permeability tests, measures the response of concrete to pressure, which is rarely the driving force of fluids entering concrete, there is a need for another type of test. This test should measure the rate of absorption of water by capillary suction, "sorptivity" of unsaturated concrete. In this paper, an attempt is made to study the properties of fly ash concrete. The mix design was carried out for M25 and M40 grade concrete as per IS: 10262-2009.***

Keywords-**Capillary Suction, Sorptivity, Water Absorption, Fly Ash Concrete.**

I. INTRODUCTION

Concrete is a porous material which interacts with the surrounding environment. The durability of mortar and concrete depends largely on the movement of water and gas enters and moves through it. The permeability is an indicator of concrete's ability to transport water more precisely with both mechanism that is controlling the up-take and transport of water and gaseous substances into cementitious material. Permeability is a measure of flow of water under pressure in a saturated porous medium whileSorptivity is materials ability to absorb and transmit water through it by capillary suction. Uptake of water by unsaturated, hardened concrete may be characterised by the sorptivity. This is a simple parameter to determine and is increasingly being used as a measure of concrete resistance to exposure in aggressive environments. Sorptivity, or capillary suction, is the transport of liquids in porous solids due to surface tension acting in capillaries and is a function of the viscosity, density and surface tension of the liquid and also the pore structure (radius, tortuosity and continuity of capillaries) of the porous solid. It is measured as the rate of uptake of water. Transport mechanisms act at the level of the capillary pores and depend on the fluid and the solid characteristics. The porous structure of concrete is intimately related with its permeability. A low water/cement ratio results in concrete structures which are less permeable because they are characterized by having small pores which are not interconnected.

Table 1: Acceptance Limits for Durability Indexes

Acceptance Criteria		OPI (log scale)	Sorptivity (mm/h)
Laboratory concrete		>10	< 6
As-built Structures	Full acceptance	> 9,4	< 9
	Conditional acceptance	9,0 to 9,4	9 to 12
	Remedial measures	8,75 to 9,0	12 to 15
	Rejection	< 8,75	>15

II. DESIGN MIX MATERIALS

a) Supplementary cementitious material: Fly Ash

Fly ash is composed of the non-combustible mineral portion of coal. Particles are glassy, spherical 'ball bearings' finer than cement particles. Sizes of particle are 0.1µm-150 µm. it is a pozzolonic material which reacts with free lime in the presence of water, converted into calcium silicate hydrate (C-S-H) which is the strongest and durable portion of the paste in concrete. The fly ash is procured from Maize Products (A division of Sayaji Industries Ltd) Power plant. This plant is located near kathwada in Ahmedabad District in Gujarat State. Fig. 1 shows storage of fly ash in open fields.

b) Cement

The most common cement used is an Ordinary Portland Cement (OPC). The Ordinary Portland Cement of 53 grade (Hathi OPC) conforming toIS:8112-1989 is used. Many tests were conducted on cement; some of them are specific gravity, consistency tests, setting time tests, compressive strengths, etc.

Table 2 Properties of HATHI Cement (OPC 53 grade)

Sr. No.	Physical properties of cement	Result	Requirements as per IS:8112-1989
1	Specific gravity	3.15	3.10-3.15

ISSN: 2277-3754
ISO 9001:2008 Certified
International Journal of Engineering and Innovative Technology (IJEIT)
Volume 2, Issue 7, January 2013

2	Standard consistency (%)	28%	30-35
3	Initial setting time (hours, min)	35 min	30 minimum
4	Final setting time (hours, min)	178 min	600 maximum
5	Compressive strength- 7 days	38.49 N/mm^2	43 N/mm^2
6	Compressive strength- 28 days	52.31 N/mm^2	53 N/mm^2

c) Coarse Aggregate

The fractions from 20 mm to 4.75 mm are used as coarse aggregate. The Coarse Aggregates from crushed Basalt rock, conforming to IS: 383 are to be used. The Flakiness and Elongation Indices were maintained well below 15%.

d) Fine aggregate

Those fractions from 4.75 mm to 150 micron are termed as fine aggregate. The river sand is be used in combination as fine aggregate conforming to the requirements of IS 383- 1970. The river sand is washed and screened, to eliminate deleterious materials and over size particles. Table-3 gives the properties of aggregates. Specific gravity, water absorption and gradation of sand (FM) test were carried out as per IS 2386 (part I and Part III) - 1963. Physical test for specific gravity, water absorption, bulk density were carried out for coarse aggregate as per IS -2386 (I, II & IV) 1963.

Table 3 Properties of Aggregates

Property	Fine Aggregate	Coarse Aggregate	
		20 mm down	10 mm down (Grit)
Fineness modulus	3.35	7.54	3.19
Specific Gravity	2.38	2.76	2.69
Water absorption (%)	1.20	1.83	1.35
Bulk Density (gm/cc)	1753	1741	1711

e) Water

Water is an important ingredient of concrete as it actually participates in the chemical reaction with cement. Since it helps to from the strength giving cement gel, the quantity and quality of water is required to be looked into very carefully. Water cement ratio used is 0.40 for M25 and 0.30 for M40 concretes.

III. DESIGN MIX METHODOLOGY

a) Design Mix

A mix M25 and M40 grade was designed as per IS 10262:2009 and the same was used to prepare the test samples. The design mix proportion is shown in Table 4

Table 4 Concrete Design Mix Proportions

Sr. No.	Concrete type	Concrete Design Mix Proportion (By Weight)				Cement Replacement by Fly ash
		W/C ratio	C	F.A.	C.A.	
1	A1-M25	0.40	1.00	1.01	2.50	-
2	B1-M25	0.40	0.90	1.01	2.50	0.10
3	B2-M25	0.40	0.80	1.01	2.50	0.20
4	B3-M25	0.40	0.70	1.01	2.50	0.30
5	B4-M25	0.40	0.60	1.01	2.50	0.40
6	A2-M40	0.30	1.00	0.44	2.17	-
7	B5-M40	0.30	0.90	0.44	2.17	0.10
8	B6-M40	0.30	0.80	0.44	2.17	0.20
9	B7-M40	0.30	0.70	0.44	2.17	0.30
10	B8-M40	0.30	0.60	0.44	2.17	0.40

W= Water, C= Cement, F. A. = Fine Aggregate, C.A. = Coarse Aggregate

b) Water absorption test

The 100mm dia x 50 mm height cylinder after casting were immersed in water for 90 days curing.These specimens were then oven dried for 24 hours at the temperature110°C until the mass became constant and again weighed. This weightwas noted as the dry weight (W1) of the cylinder.After that the specimen was kept in hot water at 85°c for 3.5 hours. Then this weight was noted as the wet weight (W2) of the cylinder.

% water absorption = [(W2– W1) / W1] x 100

Where,

W1 = Oven dry weight of cylinder in grams

W2 = After 3.5 hours wetweightof cylinder in grams.

Fig 1: Setup of Oven

Fig 2: Setup of Hot Water Curing

ISSN: 2277-3754
ISO 9001:2008 Certified
International Journal of Engineering and Innovative Technology (IJEIT)
Volume 2, Issue 7, January 2013

c) Sorptivity test

The sorptivity can be determined by the measurement of the capillary rise absorption rate on reasonably homogeneous material. Water was used of the test fluid. The cylinders after casting were immersed in water for 90 days curing. The specimen size 100mm dia x 50 mm heightafter drying in oven at temperature of 100 + 10 °C were drowned as shown in figure 4with water level not more than 5 mm above the base of specimen and the flow from the peripheral surface is prevented by sealing it properly with non-absorbent coating. The quantity of water absorbed in time period of 30 minutes was measured by weighting the specimen on a top pan balance weighting upto 0.1 mg. surface water on the specimen was wiped off with a dampened tissue and each weighting operation was completed within 30 seconds. Sorptivity (S) is a material property which characterizes the tendency of a porous material to absorb and transmit water by capillarity. The cumulative water absorption (per unit area of the inflow surface) increases as the square root of elapsed time (t)

$I=S.t^{½}$ therefore $S=I/\,t^{½}$

Where;

S= sorptivity in mm,

t= elapsed time in mint.

$I=\Delta w/Ad$

Δw= change in weight = W2-W1

W1 = Oven dry weight of cylinder in grams

W2 = Weight of cylinder after30 minutes capillary suction of water in grams.

A= surface area of the specimen through which water penetrated.

d= density of water

Fig 3: Setup of Weight

Fig 4: Setup of Captivity

IV. EXPERIMENTAL RESULTS

Table-5 and 6gives the water absorption and Sorptivity test results of % replacement of fly ash in concrete for 90 days curing. The % replacement vs % water absorption and Sorptivity results are graphically shown in figure 5 and 6.

Table 5 Average % water absorption at 90 days for M25 and M40

Concrete grade	Concrete Type	dry wt in grams (W1)	Wet wt in grams(W2)	% water absorption
M25	A1-M25	929.67	934.67	0.54
	B1-M25	942.67	957.67	1.59
	B2-M25	910.67	925.33	1.61
	B3-M25	887.67	904.00	1.84
	B4-M25	902.67	920.33	1.97
M 40	A2-M40	968.67	972.67	0.41
	B5-M40	931.67	938.00	0.67
	B6-M40	900.67	910.00	1.04
	B7-M40	900.67	920.67	2.22
	B8-M40	889.33	912.33	2.59

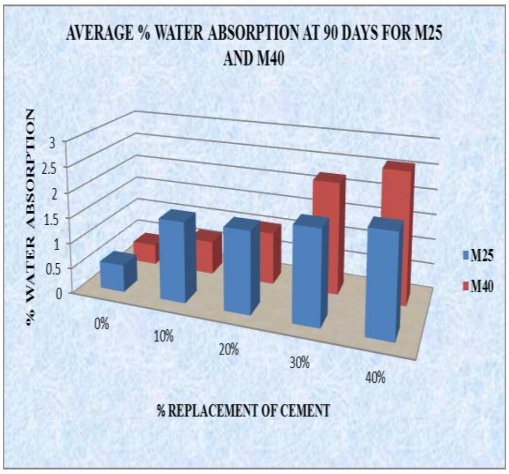

Fig. 5: % Replacement of Cement versus % Water Absorption

Table 6 Sorptivity at 90 days for M25 & M40

Concrete grade	Concrete Type	Dry wt in grams (W1)	Wetwt in grams (W2)	Sorptivity value in 10^{-5} $mm/min^{0.5}$
M25	A1-M25	979	980	2.32
	B1-M25	948.5	950	3.48
	B2-M25	908.5	910.25	4.07
	B3-M25	885.5	887.5	4.65
	B4-M25	918	920.25	5.23
M 40	A2-M40	979	979.5	1.16
	B5-M40	965.5	966.25	1.74
	B6-M40	877	878.25	2.90
	B7-M40	906	907.5	3.48
	B8-M40	896	897.75	4.07

ISSN: 2277-3754
ISO 9001:2008 Certified
International Journal of Engineering and Innovative Technology (IJEIT)
Volume 2, Issue 7, January 2013

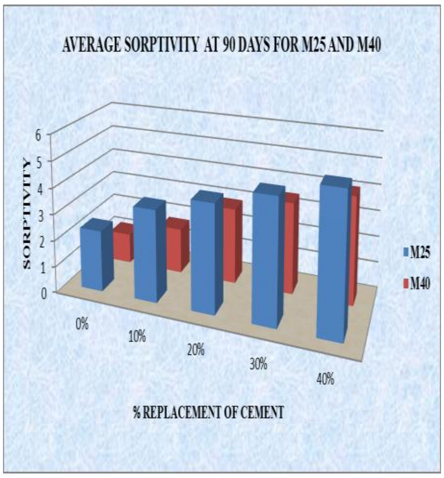

Fig. 5: % Replacement of Cement versus Sorptivity

V. CONCLUSION

Based on limited experimental investigation concerning the water absorption and sorptivity of concrete, the following observations are made regarding the resistance of partially replaced fly ash for M25 and M40 grade concrete:

(a) The water absorption and sorptivity of fly ashconcrete shows lower water absorption and sorptivity at 10% replacement with fly ashfor M25 and M40 grade concrete. There after the water absorption and sorptivity shows a increasing trend.

(b) For 90 days strength, where percentage decrease in water absorption is found to be 1.59% for M25 and 0.67 for M40 and sorptivity is found to be 2.32 mm/min0.5 for M25 and 1.74 mm/min0.5 for M40 with respect to reference mix.

(c) The water absorption and sorptivity of fly ash concrete shows lower water absorption and sorptivity at a replacement level of 10% with fly ash for M25 and M40 grade concrete.

(d) The water absorption and sorptivity of fly ash concrete shows higher water absorption and sorptivity than traditional concrete.

(e) The water absorption and sorptivity of M25 fly ash concrete is lower water absorption and sorptivity than M40 grade concrete.

(f) The fly ash can be innovative supplementary cementitious Construction Material but judicious decisions are to be taken by engineers.

ACKNOWLEDGEMENT

The Authors thankfully acknowledge to Dr.C.L.Patel, Chairman, Charutar Vidya Mandal, Er.V.M.Patel, Hon.Jt. Secretary, Charutar Vidya Mandal, Mr. Yatinbhai Desai, Jay Maharaj construction, Vallabh Vidyanagar, Gujarat, India for their motivational and infrastructural support to carry out this research.

REFERENCES

[1] Atis, C. D. (2003). “Accelerated carbonation and testing of concrete made with fly ash.” Construction and Building Materials, Vol. 17, No. 3, pp. 147-152.

[2] Bai j., Wild S, Sabir BB (2002) “Sorptivity and strength of air-cured and water cured PC-PFA-MK concrete and the influence of binder composition and carbonation depth”. Cement and concrete research 32:1813-1821.

[3] Bentz, D., Ehlen, M., Ferraris, C., and Garboczi, E. "Sorptivity-Based Service Life Predictions for Concrete Pavements." 181–193.

[4] Caliskan, S. (2006). "Influence of curing conditions on the sorptivity and weight change characteristics of self-compacting concrete." The Arabian Journal for Science and Engineering, 31(1), 169-178.

[5] Claisse, P. A. (1997). "Absorption and Sorptivity of Cover Concrete."Journal of Materials in Civil Engineering, 9(3), 105-110.

[6] Dias, W. P. S. (2000). "Reduction of concrete sorptivity with age through carbonation."Cement and Concrete Research, 30(8), 1255-1261.

[7] Deepa A Sinha, Dr.A.K.Verma, Dr.K.B.Prakash (2012) “Sorptivity and waste absorption of steel fibers reinforced ternary blended concrete”. International journal: global research analysis (GRA),volume:1,issue:5,oct2012,issn no:2277-8160.

[8] Gonen, T. and Yazicioglu, S. (2007). “The influence of compactionpores on sorptivity and carbonation of concrete.” Construction andBuilding Materials, Vol. 21, No. 5, pp. 1040-1045.

[9] Güneyisi, E. and Gesog˘lu, M., (2008). “A study on durability properties ofhigh-performance concretes incorporating high replacement levelsof slag.” Materials and Structures, Vol. 41, No. 3, pp. 479-493.

[10] Hall, C. (1977). "Water movement in porous building materials--I.Unsaturated flow theory and its applications."Building and Environment, 12(2), 117-125.

[11] Hall, Christopher; Hoff, William D (2012). Water transport in brick, stone and concrete, 2nd edn. London and New York: Taylor and Francis. http://www.routledge.com/books/details/9780415564670/.

[12] Philip, John R (1957). "The theory of infiltration: 4. Sorptivity and algebraic infiltration equations". Soil Science 84: 257-264.

[13] Sulapha, P., Wong, S. F., and Wee, T. H., and Swaddiwudhipong, S.(2003). “Carbonation of concrete containing mineral admixtures.”Journal of Materials in Civil Engineering, Vol. 15, No. 2, pp. 134-143.

[14] Song X.J, Marosszeky M, Brungs M, Munn R. 2005. Durability of fly ash based Geopolymer concrete against sulphuric acid attack 10 DBMC International Conference on Durability of Building Materials and Components, Lyon, France, 17- 20 April.

ISSN: 2277-3754
ISO 9001:2008 Certified
International Journal of Engineering and Innovative Technology (IJEIT)
Volume 2, Issue 7, January 2013

AUTHOR BIOGRAPHY

Prof. Jayeshkumar R. Pitroda was born in 1977 in Vadodara City. He received his Bachelor of Engineering degree in Civil Engineering from the Birla Vishvakarma Mahavidyalaya, Sardar Patel University in 2000. In 2009 he received his Master's Degree in Construction Engineering and Management from Birla Vishvakarma Mahavidyalaya, Sardar Patel University. He joined Birla Vishvakarma Mahavidyalaya Engineering College as a faculty where he is Assistant Professor of Civil Engineering Department with a total experience of 12 years in field of Research, Designing and education. He has papers published in National Conferences and International Journals.

Dr. Farokh Sorabji Umrigar completed his B.E. (Civil) Engineering from SVNIT in 1976, M.Tech. (civil) Transportation System Engineering from IIT, Kanpur in 1982 and Ph.D with specialization in Transportation Engineering from University of Roorkee, Roorkee in 1990. Dr. Umrigar joined Birla Vishvakarma Mahavidyalaya Engineering College (BVM) in 1978 as Assistant Lecturer and reached to the position of Principal of BVM in April, 2002 with a total experience of 34 years in field of Research, Designing, education and administration. Dr. Umrigar is also Dean, Faculty of Engineering & Technology, Sardar Patel University since April, 2002. Dr. Umrigar has published many papers at National and International level. He is an author of two books of civil engineering. He has guided many students at master's and Ph.D level in the field of civil and transportation planning.