ANALYSIS

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Discovery

Assessment of sorptivity coefficient in concrete cubes

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The quantity of water present in the concrete matrix controls many fresh and hardened properties of concrete such as workability, compressive strengths, permeability and water tightness, durability and weathering, drying shrinkage and potential for cracking. Thus the limiting and controlling the amount of water present in concrete matrix as well as cement paste is important for both constructability and an extension service life of concrete infrastructures. The successful key for making durable concrete is to limit its ability to transport fluids like water. In order to devise realistic testing methods, that determine the ability of concrete to withstand water penetration requires an understanding of water mobility. In order to build durable oriented and practicable concrete structures, it is needed to be able to accurately predict the water absorption, cumulative water absorption, sorptivity coefficient, relationship between cumulative water absorption and sorptivity within the concrete structures. Therefore, there is a need to quantify the sorptivity coefficient in concrete cubes which is of the most important factor in the concrete industries. The present research work is made an attempt to interpret the concrete sorptivity coefficient in ordered to characterize the different concrete mixtures design for in case of concrete cubes. Thus the objectives of this present research are such as: First, this research will examine the influence of concrete ingredients on the results of water sorptivity performed on concrete cubes with different mixtures proportion in which slump, and w/c ratio value is varied with constant compressive strength as in the First case and compressive strength, and w/c ratio value varied with constant slump as in the Second case. Seventy-two concrete cubes (100 mm^3) with Grades of concrete ranges from 25 to 40 N/mm^2 were prepared and evaluate the water sorptivity effect in designed different mixtures type. It's clear from the results that, the water absorption is co-related with square root of time by the tri-polynomial type of equation, in turn an average variation of water absorption is slightly more for in case of higher compressive strength and varied slump. But in the case of lower compressive strength and constant slump, the water absorption is slightly higher and its goes on decreases with increase in compressive strength and constant slump value. It's confirmed from the results that, the water sorptivity coefficient is co-related with square root of time by the power type of equation, in turn the average variation of sorptivity coefficient is more for in case of higher compressive strength and varied slump. But in the case of lower compressive strength and constant slump, the sorptivity coefficient was slightly higher and its goes on decreases with increase in compressive strength and constant slump value. As observed from the present results that, the water cumulative absorption is co-related with square root of time by the tri-polynomial type of equation, in turn an average variation of water cumulative absorption is more/less same for in case of higher compressive strength and varied slump as when compared with varied compressive strength and constant slump value. But in the case of lower compressive strength and constant slump, the water cumulative absorption is predominantly higher and its goes on decreases with an increase in compressive strength and constant slump value. Also its revealed from the results that, the water sorptivity coefficient is co-related with cumulative absorption by the power type of equation, in turn an average variation of sorptivity coefficient is more for in case of lower water cumulative absorption. The water sorptivity coefficient is goes on decreases with increased in water cumulative absorption. This may be due to, the pore structure may reached its saturation state. It's also observed from the results that, the sorptivity coefficient is found to be lesser for in case of higher compressive strength and varied slump value. Whereas the sorptivity coefficient is found to be more for in case of lower compressive strength and constant slump value and its goes on decreases with more increased water cumulative absorption. But the sorptivity coefficient is goes on reduced with increased compressive strength and constant slump value as well as with lesser water cumulative absorption.

INTRODUCTION

The durability of concrete structure is predominately depends up on the ease with which fluids can enter and move through the concrete matrix. The permeability is considered as an indicator of a concrete's ability to transport water or oxygen and carbon dioxide. In fact there are two mechanisms which controls the uptake and transport of water. Permeability, which is a measure of the flow of water under pressure in a saturated porous medium, and sorptivity, characterises the material's ability to absorb and transmit water through it by capillary suction. The feature of the matrix structure of concrete that which relates to the

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transport of water is the pore system of the cement paste, particularly in the vicinity of the aggregate-paste interface. Aggregates can also affect the transport properties but these, in general, contain pores which are discontinuous and do not allow water movement by capillarity, and hence do not contribute to sorptivity. However, despite the higher porosity at the interfacial zone, it is generally found that water movement in concrete is predominantly controlled by the bulk of the hardened OPC paste, which is the only continuous phase in concrete [1]. The sorptivity is predominantly useful in exploring the near surface characteristics of concrete and effect of moisture diffusion is also to be included in order to develop a comprehensive understanding of the long-term moisture transport phenomena. The researcher [2] uses a combination of the exponential equation for sorption and a solution of Fick's Second Law for diffusion to predict water transport in mortars and concrete. Its conclude from the results that, for concrete structure at any saturation index, sorption contributes to approximately 70% of the overall moisture intake and diffusion to approximately 30%, which indicates that it is necessary to consider the effects of both the mechanisms while describing moisture transport. The research is carried out in order to investigate the effectiveness of the water absorption and sorptivity properties of mechanically loaded engineered cementitious composites [3]. It's a newly developed high performance fibre reinforced cementitious composite with substantial benefit in both high ductility and improved durability due to tight crack width. It's confirmed from the result that, the micro cracks induced by mechanical loading increases the sorptivity value of ECC without water repellent admixture. However, the use of water soluble silicone based water repellent admixture in the production of ECC could easily inhibit the sorptivity even for the mechanically loaded ECC specimens. It's also clear from the results that, the risk of water transport by capillary suction in ECC, cracked or un-cracked, is found to be low compared as when compared to normal concrete. An extensive study is carried out by investigator [4] in order to interpret the influence of compaction pores on the sorptivity and the carbonation of concrete. Compressive strength, porosity, sorptivity coefficient, mass change due to carbonation and carbonation were tested in order to estimate the properties of concrete with various compaction pores. The test results showed that change in the compaction pores may significantly affect the carbonation rate and the sorptivity coefficient. It's confirmed from that, the sorptivity is a measure of the capillary forces exerted by the pore structure which causes fluids to be drawn into the body of the material [5].

The sorptivity test is conducted by researchers [6] not only, after 28 days, but also after longer periods of time (2, 3, 6, 9, 12, 24 months) on samples made of the same concrete. The differences between the initial value of sorptivity and further measured ones were statistically tested and it's proved that the initial value of sorptivity can be regarded as quite an exact approximation of further measured values of this parameter. The concrete sorption was measured by researchers [7] in order to determine its sorptivity coefficient as specified by ASTM C 1585. It's clear from the test results that, the concrete sorptivity is decreased by 42.7% when cement content was increased from 350 kg/m^3 to 450 kg/m^3 for specimens cured in water for 28 days at 20^{0}C. Also, for the same cement content, utilization of 10% SF as a partial replacement of cement resulted in sorptivity is decrease by 64.5% and 68.3% with cement content 350kg/m^3 to 450kg/m^3 respectively, for specimens cured in water for 28 days at 20^{0}C. Even though specimens stored in air, its experienced 11.6% loss in compressive strength, the sorptivity increased by 80.4% while permeability increased by nearly 345.3%. It's also confirmed from results that, the specimens with lower sorptivity possessed lower permeability, and higher compressive strength. The study is carried out by investigators [8] on sorptivity and water absorption properties of Cashew nut shell Ash concrete. An excess of water in concrete structures evaporates; in turn it leaves voids inside the concrete element creating capillaries which are directly related to the concrete porosity and permeability. In fact that, the proper selection of ingredients material, adequate mix proportioning methods and good construction practices may lead to almost impervious concrete structure. Hence there is a need for type of test, which should measure the rate of absorption of water by capillary suction Sorptivity of unsaturated concrete. The measurements of the permeability of concrete were used as an indicator of durability. The more quickly a fluid moves through the material, higher permeability, the lower anticipated durability. It's concluded that permeability [9] is the key to all durability problems. It should also be kept in mind that concretes with identical strength provide the same permeability. Now days, there is an extensive interest in finding better ways of assessing the properties of concretes through determining its durability. Due to problems associated with the absorption and permeability tests, which measure the response of concrete to pressure, hence there is a need for another type of test. Such tests should measure the rate of absorption of water by capillary suction; "sorptivity" of unsaturated concrete [10]. The sorptivity test is considered to be an easy and quick test to measure the material property that characterizes concrete mixture proportioning to absorb and transmit water by capillarity and it's also directly related to permeability. It's clear that, minimizing sorptivity is an important factor in order to reduce the ingress of aggressive agents into concrete structure [11]. The curing condition is found to be a major issue which affects the variation of the sorptivity test results and consequently the reproducibility of the test as confirmed by researchers [12]. It has generally been accepted that curing is more important for concrete with mineral admixtures than for normal concrete, as the pozzolanic reaction between amorphous silica and calcium hydroxide needs water to continue. Also, water curing has more effect on the sorptivity than on the strength of concrete as concluded by [13].

RESEARCH OBJECTIVES

The water transport in a porous network like concrete is a complex criteria. This is due to the fact that, many different kinds of transport mechanisms in combination with various types of pores that typically appears in the same porous system. Therefore there is a need to study water transport mechanisms with different designed mixtures type in order to assess the sorptivity coefficient in concrete structures. The present research work is made an attempt to interpret the concrete water sorptivity coefficient in ordered to characterize the different concrete mixtures design for in case of concrete cubes. Thus the objectives of this present research is to examine the influence of concrete ingredients on the results of concrete water sorptivity coefficient performed on concrete cubes with different mixtures proportion in which slump, and w/c ratio value is varied with constant compressive strength as in the First case and compressive strength, and w/c ratio value is varied with constant slump as in the Second case. Seventy-two concrete cubes (100 mm^3) with Grades of concrete ranges from 25 to 40 N/mm^2 were prepared and evaluate the concrete water sorptivity coefficient in concrete cubes.

EXPERIMENTAL PROGRAM

In the present research work, six different mixtures type were prepared in total as per BRE, 1988 [14] code standards with a concrete cubes of size (100 mm^3). Three of the mixtures type were concrete cubes (100 mm^3) with a compressive strength 40 N/mm^2, slump (0-10, 10-30, and 60-180 mm), and different w/c (0.45, 0.44, and 0.43). These mixtures were designated as M1, M2, and M3. Another Three of the mixtures type were concrete cubes with a compressive strength (25 N/mm^2, 30 N/mm^2, and 40 N/mm^2), slump (10-30 mm), and different w/c (0.5 0.45, and 0.44). These mixtures were designated as M4, M5, and M6. The overall details of the mixture proportions were to be represented in Table.1-2. Twelve concrete cubes of size (100 mm^3) were cast for each mixture and overall Seventy-two concrete cubes were casted for six types of concrete mixture. The coarse aggregate used is crushed stone with maximum nominal size of 10 mm with grade of cement 42.5 N/mm^2 and fine aggregate used was 4.75 mm sieve size down 600 microns for this research work.

Water absorption

The size (100 mm^3) of concrete cubes after casting were immersed in water for about 28 days curing. These specimens were then oven dried at 50 ±2ºC for 3 days until the mass became constant and again weighed. This weight was noted as the dry weight (W1) of the concrete cube. After that, specimens were put in contact with water from one surface with 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 for a specified time interval as per (ASTM C 1585) [15] with their arrangement as shown in Fig.1. Then this weight is noted as the wet weight (W2) of the concrete cube.

Figure 1 Water absorption test on concrete cubes

$$\text{Water absorption } (\%) = \left[\frac{\text{W2} - \text{W1}}{\text{W1}}\right] X100$$

Where,

W1 = Oven dry weight of concrete cubes in grams

W2 = Wet weight of concrete cubes after specified time in grams

The water absorption test is carried out on 72 concrete cubes with size (100 mm^3) in all six mixtures type (M1-M6). In which ASTM C1585 is commonly used to determine the absorption and rate of absorption of water in unsaturated hydraulic cement concretes. The results confirm that, the water absorption testing is considerably influenced by sample preparation. Samples that were conditioned in the oven at 105^0 C do not appear to follow a similar trend as when compared with specimens conditioned in chambers at lower temperatures for a longer time duration. The absorption is also influenced by the volume of paste in the samples. The experiments show that, a lack of control on moisture content or lack of consideration of the material composition may lead to a misunderstanding of the actual absorption behaviour. The water absorption is increased (49.76%) at time duration 5 min as when compared to initial time duration 0 min in all mixtures type (M1-M6). The water absorption (87.98%) is predominantly increased at longer time duration (28 day). The water absorption (48.91-50.57%) at 0 min as well as (87.82-88.13%) at 28 days is little bit varied as when compared to different mixtures type (M1-M3) and (M4-M6). Similarly, the water absorption is more increased in mixture type (M4) for lower compressive strength with constant slump value. Also the water absorption is goes on decreased with increased compressive strength in case of mixture type (M5), but increased with compressive strength in mixture type (M6) at an initial stage as well as at longer time duration at 28 day. The variation of average water absorption is slightly increased with constant higher compressive strength and varied slump value. It's found to be higher with lower compressive strength and constant slump value and its goes on decreases with increased compressive strength. Its average variation in water absorption (minimum or maximum) as well as standard deviation for in case designed mixtures type is as shown in Table 3. Also the relationship between water absorption and square root of time is co-related with tri-polynomial equation with their variation of R^2values is represented in Table 4.

Cumulative absorption

The cumulative absorption coefficient is found to be decreased at initial time duration (0.00097-0.00107) m for in case of mixtures type (M1-M3) as when compared to (0.00134-0.00097) m mixtures type (M4-M6). The cumulative absorption coefficient is increases (0.00899-0.0087) m at longer time duration for in case of mixtures type (M1-M3) with same grade of concrete, and cumulative absorption coefficient is varied (0.01323-0.00877) m in mixtures type (M4-M6) with different grade of concrete at constant slump value. In turn the rate of absorption is more at longer time duration and this rate of absorption decreases with increased grade of concrete. In fact the cumulative absorption coefficient is increases with increased rate of absorption (sorptivity coefficient) and lower grade of concrete. In general, water acts as the medium for agents to move into concrete, and water penetration by capillary absorption is more common for the real concrete structures since concrete is rarely saturated. As a result, absorption of water is regarded as the dominant factor for the ingress of aggressive substances. The sorptivity is chosen as a parameter to describe the rate of water moving into concrete since it can characterize the tendency of cementitious material to absorb and transmit water by capillary mechanism. The principal mechanism responsible for water transport during the absorption process is hydrostatic pressure due to the capillary suction. Therefore, the microstructures of concrete, that is, the porosity and pore distribution or micro cracks play a crucial role in the velocity of water ingress. The variation of average cumulative absorption, minimum, maximum and standard deviation for different designed mixtures type in concrete cubes is represented as in Table 5. Also the relationship between cumulative absorption and square root of time is co-related with tri-polynomial equation with their variation of R^2 values is represented in Table 6.

$$\text{Cumulative absorption (i)} = \text{S}.\sqrt{\text{t}}$$

i = cumulative absorption at time (t), m/s

S = Sorptivity in mm,

t = elapsed time in min,

The cumulative water absorption is interpreted for about 28 days in concrete cubes for designed six mixtures type (M1-M6). The cumulative absorption is found to be increased at an initial time duration (10 min) as when compared to (5 min) which is varied as 11.53%. Similarly, the cumulative absorption is found to be increased at final time duration (28 day) as when compared to 5 min which is varied as 77%. The cumulative absorption curve reaches first phase of equilibrium level at time duration 65.72 min. Thus the cumulative absorption of the concrete mixtures were decreases with the decrease in water-cementitious

Table 1 (Variable: Slump & W/C value; Constant: Compressive strength)

Mix No	Comp/mean target strength(N/mm^2)	Slump (mm)	w/c	C (Kg)	W (Kg)	FA (Kg)	CA(Kg) 10 mm	Mixture Proportions
M1	40/47.84	0-10	0.45	3.60	1.62	5.86	18.60	1:1.63:5.16
M2	40/47.84	10-30	0.44	4.35	1.92	5.62	16.88	1:1.29:3.87
M3	40/47.84	60-180	0.43	5.43	2.34	6.42	14.30	1:1.18:2.63

Table 2 (Variable: Compressive strength & W/C value; Constant: Slump)

Mix No	Comp/mean target strength(N/mm^2)	Slump (mm)	w/c	C (Kg)	W (Kg)	FA (Kg)	CA(Kg) 10 mm	Mixture Proportions
M4	25/32.84	10-30	0.50	3.84	1.92	5.98	17.04	1:1.55:4.44
M5	30/37.84	10-30	0.45	4.27	1.92	6.09	16.50	1:1.42:3.86
M6	40/47.84	10-30	0.44	4.35	1.92	5.62	16.88	1:1.29:3.87

Table 3 water absorption in concrete cubes for different mixtures type

Mix ID	Average,%	Min,value(%)	Max,value(%)	STD
M1	2.52	1.34	0.44	4.02
M2	3.02	1.64	0.58	4.96
M3	2.43	1.32	0.49	3.91
M4	3.77	2.05	0.63	6.08
M5	2.64	1.43	0.55	4.24
M6	2.53	1.32	0.45	4.00

Table 4 Relationship between water absorption and Square root of time

MIX ID	Co-relation Equation	R^2
M1	$Y = 1E\text{-}06X^3 - 0.0006X^2 + 0.075X + 0.7776$	0.9935
M2	$Y = 1E\text{-}06X^3 - 0.0006X^2 + 0.089X + 0.9303$	0.9942
M3	$Y = 1E\text{-}06X^3 - 0.0005X^2 + 0.067X + 0.7727$	0.9950
M4	$Y = 2E\text{-}06X^3 - 0.0007X^2 + 0.106X + 1.1929$	0.9903
M5	$Y = 1E\text{-}06X^3 - 0.0006X^2 + 0.078X + 0.8096$	0.9947
M6	$Y = 1E\text{-}06X^3 - 0.0006X^2 + 0.076X + 0.8179$	0.9912

Table 5 Cumulative absorption in concrete cubes for different mixtures type

Mix ID	Average	Min,value	Max,value	STD
M1	0.0058	0.0031	0.0093	0.0010
M2	0.0069	0.0038	0.0115	0.0013
M3	0.0054	0.0030	0.0088	0.0011
M4	0.0084	0.0047	0.0137	0.0013
M5	0.0060	0.0033	0.0097	0.0012
M6	0.0057	0.0030	0.0091	0.0010

Table 6 Relationship between cumulative absorption and square root of time

MIX ID	Co-relation Equation	R^2
M1	$Y = 3E\text{-}09X^3 - 1E\text{-}06X^2 + 0.0002X + 0.0017$	0.9940
M2	$Y = 3E\text{-}09X^3 - 1E\text{-}06X^2 + 0.0002X + 0.0020$	0.9943
M3	$Y = 2E\text{-}09X^3 - 1E\text{-}06X^2 + 0.0002X + 0.0017$	0.9952
M4	$Y = 3E\text{-}09X^3 - 2E\text{-}06X^2 + 0.0002X + 0.0025$	0.9907
M5	$Y = 3E\text{-}09X^3 - 1E\text{-}06X^2 + 0.0002X + 0.0018$	0.9948
M6	$Y = 3E\text{-}09X^3 - 1E\text{-}06X^2 + 0.0002X + 0.0018$	0.9918

material ratio for in case of all designed mixtures type (M1-M6) and as result of that, less amount of water availability in the mixture which results in dense concrete.

Sorptivity

It's defined as a measure of the capacity of the medium to absorb/desorb liquid by capillarity. The Sorptivity is widely used in chacterizing soils and porous construction materials such as brick, stone, and concrete respectively.

$$\text{Sorptivity coefficient (S)} = \frac{i}{\sqrt{t}}$$

$\boldsymbol{S}$ = Sorptivity in mm,

$\boldsymbol{i}$ = cumulative absorption at time (t), m/s

$\sqrt{\boldsymbol{t}}$ = square root of elapsed time in min,

The Sorptivity coefficient (rate of water absorption) is found to be increased at initial time duration (0.0009-0.0011 m/min$^{0.5}$) as when compared to longer time duration (4.2E-05-5.4E-05 m/min$^{0.5}$). The Sorptivity coefficient is increases at initial time duration, this may be due to unsaturated pore structure, and in turn the rate of absorption is more at that time. As time increases, the rate of absorption goes on decreases with increased time duration in turn indicates that, pore structure may be reached fully saturated condition. Sorptivity test is a very simple technique that measures the capillary suction of concrete when it comes in contact with water. The Sorptivity test is performed in accordance with the ASTM C 1585. This test is used to determine the rate of absorption (Sorptivity) of water by measuring the increase in the mass of a specimen resulting from absorption of water as a function of time when only one surface of the specimen is exposed to water ingress of unsaturated concrete by capillary suction during an initial contact with water. The rate of sorption is the slope of the best-fit line to the plot of absorption against square root of time. The cubes (100 mm^3) after casting were immersed in water for about 28 days curing. Prior to the test, specimens were placed in a desiccator oven at temperature (50 ±2ºC) for 3 days. After that, specimens were put in contact with water from one surface with 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 variation of sorptivity coefficient is directly proportional to the cumulative water absorption and in-directly proportional to the square of time with their variation of average, minimum, maximum, and standard deviation in concrete cubes is depicted in concrete cubes as shown in Table.7.

The quantity of water absorbed in specified time interval is measured by weighting the specimen on a top pan balance weighting up to 0.1 mg. The surface water on the specimen is wiped off with a dampened tissue and each weighting operation is 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).

$$i = S\sqrt{t}$$
$$\mathrm{S} = \frac{\mathrm{i}}{\sqrt{\mathrm{t}}}$$

Where
S= sorptivity in mm,
t= elapsed time in mint. I= Δ w/Ad
Δ w= change in weight = W2-W1
W1 = Oven dry weight of cube in grams
W2 = Weight of cube after specified time minute capillary suction of water in grams
A= surface area of the specimen through which water penetrated
d= density of water

As observed from the results that, the sorptivity coefficient is increased at initial time duration with decreased cumulative water absorption in all mixtures type as when compared to longer time duration. The Sorptivity coefficient at initial time duration is found to be in the range (0.0009-0.0014 m/min$^{0.5}$) and (4.5E-05-5.5E-05 m/min$^{0.5}$) at final time duration. Cumulative absorption varied at an initial stage between (0.002-0.003 m) at an early time duration and (0.008-0.013 m) at longer time duration. Finally, the sorptivity coefficient is decreases with decreased rate of cumulative absorption at longer time duration in turn it indicates that, the pore structure reaches fully saturated condition in all mixtures type. The sorptivity coefficient is decreased as when compared to initial time duration (5-10) min. In fact there is decrease in sorptivity coefficient (21.89%) at 10 min as when compared to initial time duration (5 min) for in case of all mixtures type (M1-M6). Similarly, Sorptivity coefficient is goes on decreases gradually at certain point, it reaches parabolic pattern, and afterwards it reaches equilibrium (28 day) in turn sorptivity coefficient is found to be decreased (95.18%). Whereas at 1 day, the increase in sorptivity coefficient is found to be 82.07% for in case of all mixtures type (M1-M6). The variation of sorptivity coefficient with square root of time for in case of designed mixtures type with their correlation equation as well as R^2 values is represented in (Table.8). The sorptivity coefficient for in case of mixtures type (M1-M3) at an initial time duration (10 min) is found to be increased (21.32%) as when compared to time duration (5 min). Similarly, at 10 min, there is an increase in sorptivity coefficient (22.46%) as when compared to time duration (5 min) for in case all mixtures type (M4-M6). The rate of absorption is always more at an initial time duration because of differential gradient is exists between higher to lower concentration gradient section, where there is a variation in the rate of absorption up to certain time duration after that, it reaches parabolic pattern which is very smooth flow of rate of absorption. Once it reaches that, pore structure, cement paste, and concrete matrix reaches fully saturated condition in turn finally the sorptivity coefficient reaches equilibrium state.

Relationship between sorptivity coefficient and cumulative absorption

The Sorptivity coefficient is found to be higher/lower for in case of all mixtures type (M1-M6) at an initial time duration. But it goes on gradually decreased and reached equilibrium state as when pore structure is reached fully saturated condition. Logically at an initial time duration, the sorptivity coefficient is more but the cumulative absorption is lesser. Because the cumulative or net absorption is not achieved once for all, this may in turn depends on cement paste matrix, concrete matrix, aggregate volume fraction, w-c ratio, compressive strength, and slump. At an inetermedaite time duration, the sorptivity coefficient is gradually decreased with an increased cumulative absorption for in case of all mixtures type (M1-M6). But once equilibrium reached, the sorptivity coefficient is still goes on reduced slightly in turn net cumulative absorption is found to be increased up to cetain time duration, after that both sorptivity coefficient and cumulative absorption is reversed in nature in turn both tries to decreases which indicates that pore structure is reached fully saturated state and finally there is no more increased rate of absorption for in case of longer time duration.The variation of sorptivity coefficient with cumulative absorption for in case of designed mixtures type with their correlation equation as well as R^2 values is represented in Table.9.

It has been possible to explain the process of water transport satisfactorily for early ages indry samples and without additions. It's clear from the results that, if a mortar or concrete surface is exposed to wetting by water, then the cumulative water absorption (normalized to the exposed surface area) is proportional during an initial absorption period, to the square root of elapsed wetting time as confirmed by investigator [16]. After a period of sorption, an initial rate of ingress observed to be decreases as the water has accessed all the major capillary pores. The decrease in gradient of the straight line portion of the water uptake versus square root of time indicates that sorptivity is now occurring via the finer pores and its indicates that, an increasing importance of small pores with time [17]. In addition to that, some materials with extremely coarse pore structure, experiences little

Table 7 Sorptivity coefficients in concrete cubes for different mixtures type

Mix ID	Average	Min,value	Max,value	STD
M1	0.00029	0.00027	0.00092	0.00004
M2	0.00035	0.00033	0.00113	0.00005
M3	0.00027	0.00026	0.00089	0.00004
M4	0.00043	0.00041	0.00148	0.00007
M5	0.00030	0.00027	0.00092	0.00005
M6	0.00029	0.00027	0.00091	0.00004

Table 8 Relationship between Sorptivity coefficient and Square root of time

MIX ID	Co-relation Equation	R^2
M1	$Y = 0.0016x^{-0.647}$	0.9921
M2	$Y = 0.0019x^{-0.64}$	0.9911
M3	$Y = 0.0015x^{-0.64}$	0.9930
M4	$Y = 0.0023x^{-0.644}$	0.9906
M5	$Y = 0.0016x^{-0.636}$	0.9917
M6	$Y = 0.0016x^{-0.657}$	0.9919

Table 9 Relationship between Sorptivity coefficient and cumulative absorption

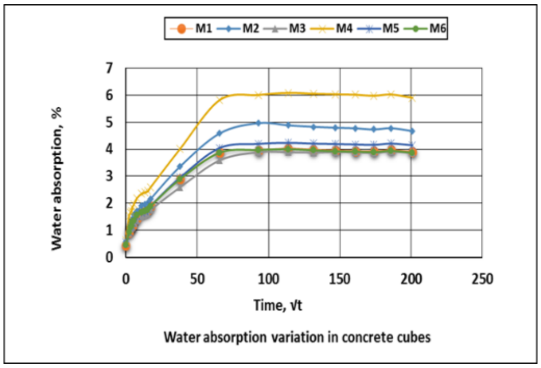
MIX ID	Co-relation Equation	R^2
M1	$Y = 2E\text{-}08x^{-1.757}$	0.9383
M2	$Y = 4E\text{-}08x^{-1.708}$	0.9328
M3	$Y = 2E\text{-}08x^{-1.716}$	0.9474
M4	$Y = 6E\text{-}08x^{-1.725}$	0.9328
M5	$Y = 3E\text{-}08x^{-1.681}$	0.9328
M6	$Y = 1E\text{-}08x^{-1.831}$	0.9335

capillary suction and may show significant deviation from linearity after prolonged wetting. It is widely known fact that, in dry/partially dry mortars or concretes, the predominant mechanism in the water absorption is the capillary suction and when the time lapses, and the material begins to be saturated, the predominant mechanism is the discussion in turn through the finer and gel pores [17]. It's a known fact that, the materials with extremely coarse pore structure experience little capillary suction and may show significant deviation from linearity after prolonged wetting. Sorption does not take place in saturated materials/totally dry materials. It's due to substantial absorption of water by the gel which will distort the results. The sorptivity will depend on the initial water content and its uniformity throughout the specimen under test. It is, therefore, essential that materials under test be consistent and homogeneous, point of origin, and frequently the very early readings, are omitted when determining the slope of the graph. This is because, there is an increase in the mass of the specimen caused by the filling of the open surface pores on the inflow face and the sides of the specimen when it is submerged. In order to reduce these effects to a minimum, it is essential that, the specimen be submerged in water to no more than 2-5 mm as confirmed by researcher [18].

DISCUSSION ABOUT RESULTS

The deterioration of concrete is caused by the movement of aggressive gases/ liquids from the surrounding environment into the concrete which is followed by physical/chemical reaction within its internal structure, and that leads to an extensive damage to the concrete structures. The one of the most important properties of a good quality concrete is low permeability. A concrete with low permeability resists ingress of water and is not as susceptible to freezing and thawing. Water enters pores in the cement paste and even in the aggregate. Permeability relates to the size of the pores, their distribution and most importantly their continuity. As a result, permeability is not necessarily directly related to absorption. It has been related to water cement ratio of concrete. The lower the sorptivity value, the higher the resistance of concrete towards water absorption. It's mainly depends on the pore distribution and micro structural properties of concrete as noted by the researchers [19]. The cumulative water absorption of the concrete mixtures decreases with the decrease in w/cm ratio for all the concrete due to less amount of water in the mix, resulting into dense concrete. Concretes with lower w/cm ratio have lower water absorption for all the mixtures. The sorptivity values are least due to lower amount of water in the mix, resulting in lower porosity. The higher the porosity of the specimens causes the reduction of pervious concrete density, which in turn that affects the compressive strength. The higher level of porosity can be resulted from the higher level of water absorption that exceeds the required limit of water infiltration. Moreover, the mechanical properties of concrete are highly influenced by its density. A denser concrete generally provides higher strength and fewer amount of voids and porosity. Smaller the voids in concrete, it becomes less permeable to water and soluble elements. The water absorption will also be lesser and better durability is expected from this type of concrete mixture proportion. Thus the minimum water-cement ratio is desirable to maintain appropriate compressive strength and durability of the concrete. The water is usually provided externally by curing/internally by using water saturated porous aggregates. By proper curing, reduces the rate of moisture loss and provides a continuous source of moisture required for the hydration that reduces the porosity and provides a fine pore size distribution in concrete as pointed out by [20].

Though cement hydration produces many solid hydration products, the major hydration product responsible for compressive strength of concrete is a rigid C-S-H gel. The complete hydration of cement in concrete is very important which in turn ensures the development of maximum compressive strength, longevity and service performance of concrete structures. The curing of concrete is used for promoting the hydration process of cement and its controls temperature and moisture movement from and into the concrete. When hydration of cement ceases before hydration is complete, strength reductions and reduction of durability indexes results. As noted by researcher [21] that, the cement hydration ceases below 80% relative humidity. In addition to that, the moisture loss to the environment in concrete also plays an important role in cement hydration. The degree of moisture loss is also related to the thickness of the concrete member and the relative humidity of the



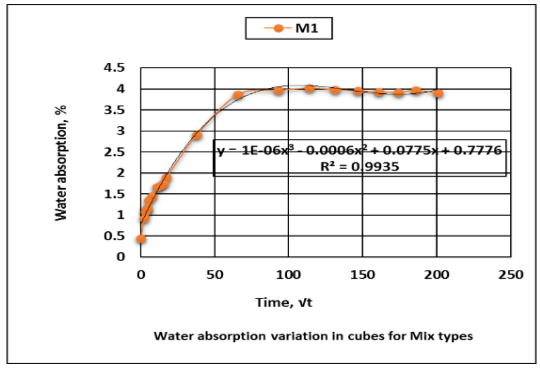
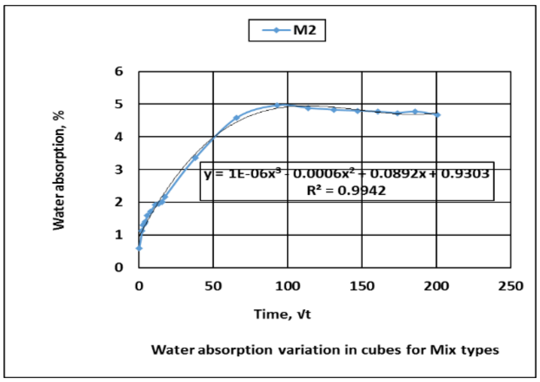


Figure 2 Water absorption in concrete cubes

Figure 3 Water absorption in concrete cubes (M1)



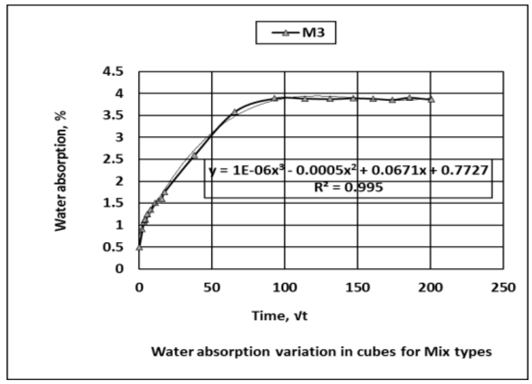
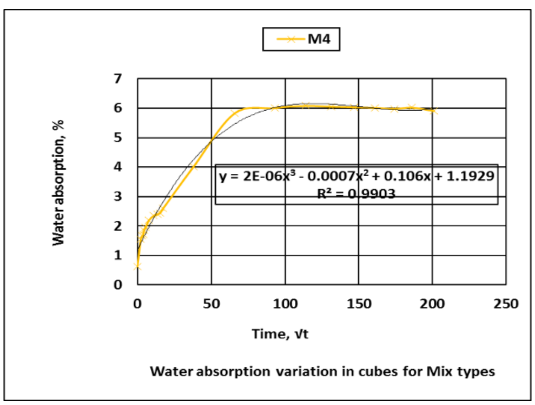


Figure 4 Water absorption in concrete cubes (M2)

Figure 5 Water absorption in concrete cubes (M3)



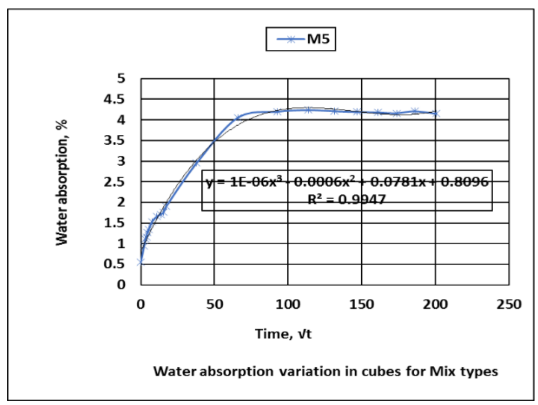
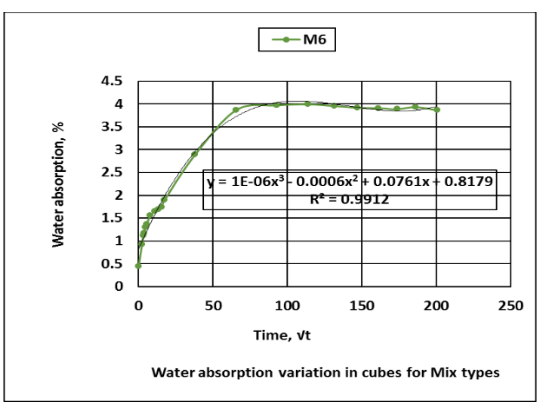


Figure 6 Water absorption in concrete cubes (M4)

Figure 7 Water absorption in concrete cubes (M5)



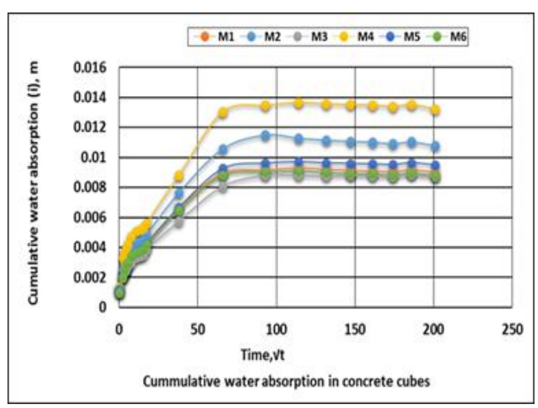


Figure 8 Water absorption in concrete cubes (M6)

Figure 9 Cumulative absorption in concrete cubes

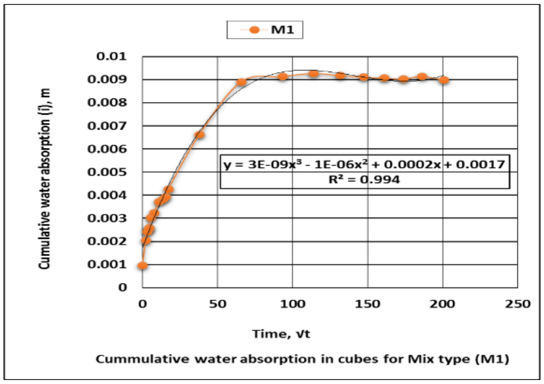


Figure 10 Cumulative absorption in concrete cubes (M1)

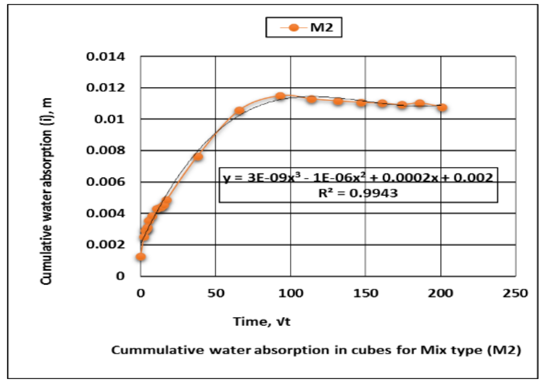


Figure 11 Cumulative absorption in concrete cubes (M2)

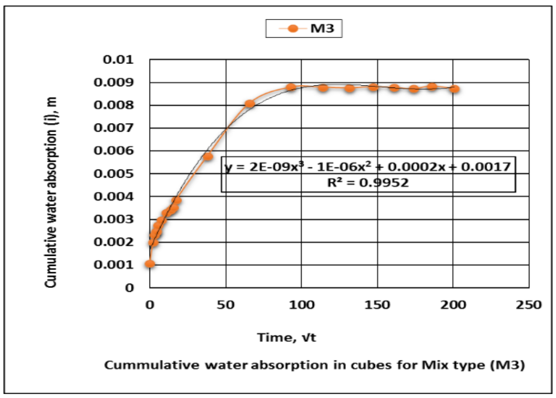


Figure 12 Cumulative absorption in concrete cubes (M3)

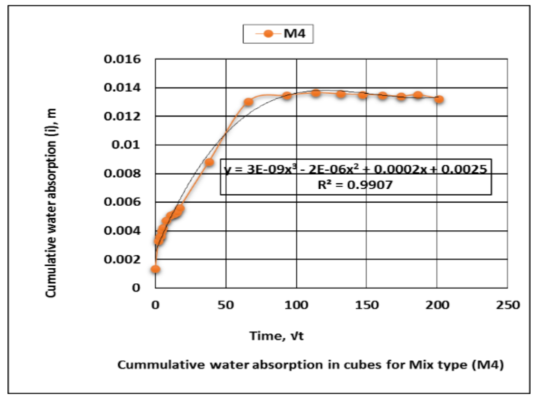


Figure 13 Cumulative absorption in concrete cubes (M4)

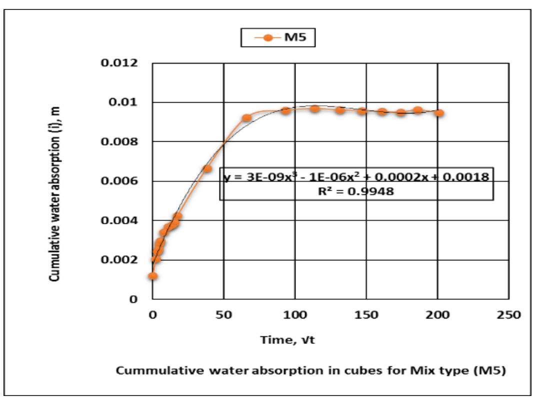


Figure 14 Cumulative absorption in concrete cubes (M5)

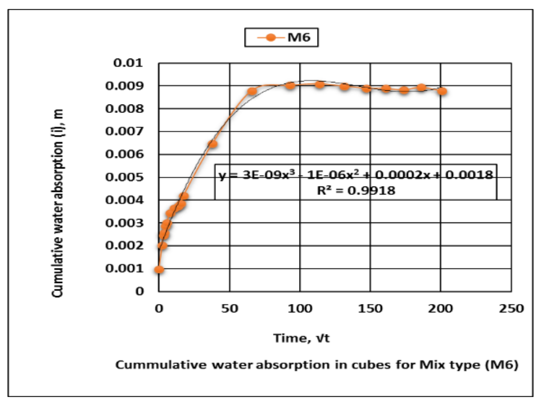


Figure 15 Cumulative absorption in concrete cubes (M6)

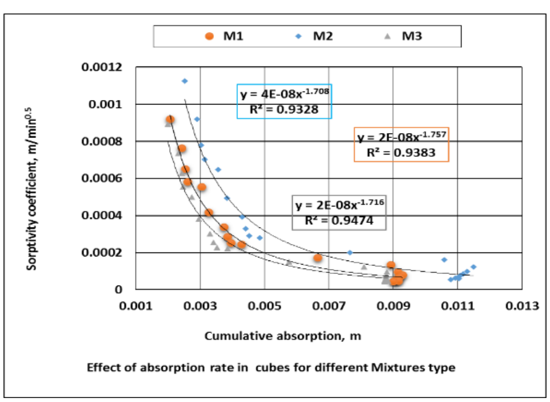


Figure 16 Sorptivity coefficient V/s cumulative absorption

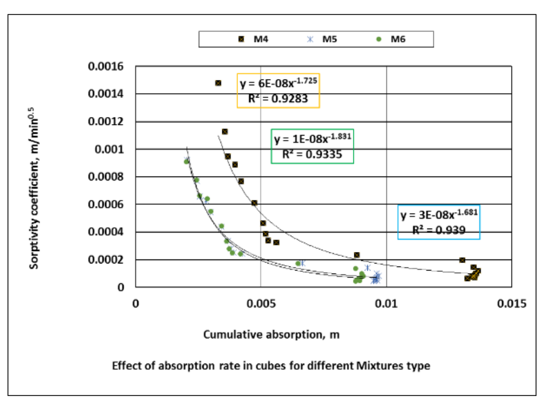


Figure 17 Sorptivity coefficient V/s cumulative absorption

environment. In fact that, the thin concrete members were tends to lose moisture faster than thick members and a surface of concrete that is not properly cured also suffers from inadequate hydration as pointed by researcher [22]. In addition to that, the study carried out by researchers [23] that, on moisture loss from the concrete in a moderately severe field exposure condition confirmed that, the drying in concrete at a depth of 25 mm was not sufficient to stop hydration of cement at 28 days. This indicates that surface or near surface concrete layer that is not properly cured could deteriorate faster than inner layers. Actually the curing process is enables the control of temperature and moisture movement from and into concrete for a definite period of time as noted by researcher [24]. Cement hydration takes place only in water filled capillaries, it is important to keep concrete saturated/nearly saturated as possible, until the water filled pores in the fresh cement paste are filled to the desired extent by hydrating CSH gels and other solid hydration products [25]. The hydration of cement can be defined as the combination of chemical and physical processes that take place after contact of the anhydrous solid with water [26]. However, the site concrete, being the exceptional, which is hardly cured sufficiently for longer time duration. It's confirmed from the results that, the water cured specimens had better compact microstructure than uncured specimens. Also the lower w/c ratio mixes had a more compact microstructure than higher w/c ratio mixes. The growth of more solid hydration products as a result of water curing attributed to this. Furthermore, higher the w/c ratio mixes are known to have more and bigger micro pores resulting from water which is not used in hydration as confirmed from researchers [27]. Thus there is need to investigate in the sorptivity coefficient in the concrete cubes in order to characterize different designed mixtures type in the present research work. Thus the combined variation of water absorption with square root of time for in case of different designed mixtures type is as shown in Figs.2-8 respectively. It's possible to establish a relation between the water absorption and square root of time in concrete cubes with tri-polynomial type of equation. An average variation of water absorption is slightly more for in case of higher compressive strength and varied slump. But in the case of lower compressive strength and constant slump, the water absorption is slightly higher and its goes on decreases with increase in compressive strength and constant slump value.

The combined variation of cumulative water absorption with square root of time for in case of different designed mixtures type is as shown in Figs.9-15 respectively. It's possible to establish a relation between the cumulative water absorption and square root of time in concrete cubes with tri-polynomial type of equation. An average variation of cumulative water absorption is slightly more for in case of higher compressive strength and varied slump. But in the case of lower compressive strength and constant slump, the cumulative water absorption is slightly higher and its goes on decreases with increase in compressive strength and constant slump value.

Also its revealed from the results that, the water sorptivity coefficient is co-related with cumulative absorption by the power type of equation, in turn an average variation of sorptivity coefficient is more for in case of lower water cumulative absorption. The water sorptivity coefficient is goes on decreases with increased in water cumulative absorption. This may be due to the fact, the pore structure may reached its saturation state. It's also observed from the results that, the sorptivity coefficient is found to be lesser for in case of higher compressive strength and varied slump value. Whereas the sorptivity coefficient is found to be more for in case of lower compressive strength and constant slump value and its goes on decreases with more increased water cumulative absorption. But the sorptivity coefficient is goes on reduced with increased compressive strength and constant slump value as well as with lesser water cumulative absorption. The combined variation of cumulative water absorption with square root of time for in case of different designed mixtures type is as shown in Figs.16-17 respectively.

CONCLUSIONS

The Sorptivity test was carried out on 72 concrete cubes with one bottom face exposed to water in order to evaluate the designed six mixtures type. In which first three set of mixtures type were designed as constant higher compressive strength and varied slump. Second three set of mixtures type were designed as varied compressive strength and constant slump. It's possible to interpret the fundamental parameters such as water absorption, cumulative absorption, and sorptivity coefficient.

- It's clear from the results that, the water absorption is co-related with square root of time by the tri-polynomial type of equation, in turn an average variation of water absorption is slightly more for in case of higher compressive strength and varied slump. But in the case of lower compressive strength and constant slump, the water absorption is slightly higher and its goes on decreases with increase in compressive strength and constant slump value.
- It's confirmed from the results that, the water sorptivity coefficient is co-related with square root of time by the power type of equation, in turn the average variation of sorptivity coefficient is more for in case of higher compressive strength and varied slump. But in the case of lower compressive strength and constant slump, the sorptivity coefficient was slightly higher and its goes on decreases with increase in compressive strength and constant slump value.
- As observed from the present results that, the water cumulative absorption is co-related with square root of time by the tri-polynomial type of equation, in turn an average variation of water cumulative absorption is more/less same for in case of higher compressive strength and varied slump as when compared with varied compressive strength and constant slump value. But in the case of lower compressive strength and constant slump, the water cumulative absorption is predominantly higher and its goes on decreases with an increase in compressive strength and constant slump value.
- Also its revealed from the results that, the water sorptivity coefficient is co-related with cumulative absorption by the power type of equation, in turn an average variation of sorptivity coefficient is more for in case of lower water cumulative absorption. The water sorptivity coefficient is goes on decreases with increased in water cumulative absorption. This may be due to the fact, the pore structure may reached its saturation state. It's also observed from the results that, the sorptivity coefficient is found to be lesser for in case of higher compressive strength and varied slump value. Whereas the sorptivity coefficient is found to be more for in case of lower compressive strength and constant slump value and its goes on decreases with more increased water cumulative absorption. But the sorptivity coefficient is goes on reduced with increased compressive strength and constant slump value as well as with lesser water cumulative absorption.

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