DURABILITY OF CONCRETE WITH DIFFERENTIAL CONCRETE MIX DESIGN

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Abstract: *Concrete resists aggressive environmental weather condition in order to maintain desired engineering properties. Different concretes require different degrees of durability which depends on the exposure condition. Mechanical properties of concrete are influenced by its density in turn provide higher strength as well as lesser amount of voids and porosity. Smaller the amount of voids in concrete, which leads to less permeable to water and soluble elements. So that better durability is expected from this type of concrete. There is a need to consider durability properties during the design criteria as well as concrete mixture designs are which affects performance of concrete structures. The aim of the present research was to examine the influence of uni-directional exposure of concrete cubes to water absorption to evaluate different mixtures proportion. Slump, and w/c ratio value was vary 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 with different grades of concrete were prepared and evaluate the water absorption characteristics in different concrete mixtures design. In the present research work, water absorption test was conducted on concrete cubes to ascertain sorptivity coefficient characteristics on concrete density in designed concrete mixtures type. It's confirmed from the results that, the sorptivity coefficient is co-related with density of concrete by the power type of equation. In turn the average variation of sorptivity coefficient is more for in case of higher grade of concrete and varied value of slump as when compared to varied concrete compressive strength and constant slump value. But in the case of lower compressive strength and constant slump, the sorptivity coefficient was slightly increases and its goes on mitigates with increase in grade of concrete and same slump value. It's confirmed from the research work that for in case of constant concrete compressive strength and varied slump value, the rate of concrete density was slightly increased in concrete mix design as when compared to concrete mix design with varied concrete compressive strength and constant slump value. The rate of concrete density was decreased in lower concrete compressive strength and constant slump values and goes on increases with increase in grade of concrete for in concrete mix design.*

Keywords: *Sorption, concrete density, durability, moisture, exposure condition, transport mechanism*

1.0 Introduction

The ingress of moisture in to the concrete leads to deterioration at worldwide. Designers, contractors, and owners need to thoroughly understand the differences in the mechanisms to ensure the structures they are building provided adequate problem-free service life of concrete structures. Concrete, as a structural material and as the building exterior skin, has the ability to withstand nature's normal deteriorating mechanisms. Durability of concrete may be defined as the ability of concrete to resist weathering action in turn maintains engineering properties. In the late 1980's, sorptivity was used to describe the transport properties of concrete. In above-ground structures, the sun and wind dry the exposed region of concrete while the core remains at a higher degree of saturation. This differential in saturation creates capillary forces that become the dominant transport mechanism [McCarter 1993]. Sorptivity testing on concrete was shown to be sensitive to compaction, ramming of specimens increased bulk density and decreased porosity. This finding brought forward the concept that elimination or reduction of large pores created this non-linearity [Hall and Raymond Yau 1987]. Application of the sorptivity test to concrete became more important as there was a worldwide concern about the poor durability of concrete structures. Sorptivity has been shown to be sensitive to the quality of the cover skin of concrete members and has proven effective in revealing poor placing and finishing techniques in the field [McCarter 1993]. It is investigated that testing was also sensitive to the depth of concrete. Specimens that were tested at different depths for sorptivity gave different results,could be indicative of signs of segregation or bleeding due to poor construction practices [Khatib and Mangat 1995].An experimental program was conducted by [Suresh Thokchom, 2009] to study the effect of water absorption, apparent porosity and sorptivity on durability of fly ash based geopolymer mortar specimens in sulphuric acid solution. Specimens containing lesser alkali were found to possess higher apparent porosity, water absorption and water sorptivity. The finding showed that the selection of well cured-OPC and 10 days cured-PPC for concrete water tanks could be the cause for deterioration associated with leaching and leakage in concrete water retaining structures. The study contributes to the design of water storage structures [Matiwos Tsegaye and Abebe Dinku, 2018]. Sorptivity is an index of moisture transport into unsaturated specimens, and it has also been recognized as an important index of concrete durability [Dias, 2000] and during this process, the driving force for water ingress into concrete is capillary suction within the pore spaces of concrete, and not a pressure head [Hall, 1989]. Sorptivity testing is more representative of typical field conditions. Some experts have suggested that the method can also be used to measure the total pore volume of capillary and gel pores in the concrete [Mohr, 2004]. Researcher has shown that the sorptivity coefficient is essential to predict the service life of concrete as a structural material and to improve its performance [Martys and Ferraris, 1997].

The research was carried out to study the effectiveness of water absorption on the durability of concrete. Surface sorptivity and internal sorptivity have no clear relationship with compressive strength and surface water absorption related to the performance of concrete. There is no apparent relationship was found between internal water absorption and durability [Zhang and Zong , 2014]. The results showed that, moist sand curing method produced concrete specimens with the highest 28-day compressive strength followed by the burlap curing method. Air curing method showed reduction in strength after 21-days thereby resulting in the lowest 28-day compressive strength. [Akeem Ayinde Raheem, 2013]. There are many factors affect the development of strength of concrete and durability which includes quality-quantity of cement, grading of aggregates, maximum nominal size, shape and surface texture of aggregate [Arum and Alhassan, 2005], water/cement ratios, degree of compaction [Aluko, 2005] and the presence of clayey particles and organic matter in the mix [Arum and Udoh, 2005]. Results indicated that the concrete sorptivity decreased when cement content was increased 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 decrease by 64.5% and 68.3% with cement content (350kg/m ^{3}- 450kg/m^3) respectively, for specimens cured in water for 28 days at 20^0 C. Specimens with lower sorptivity possessed lower permeability, and higher compressive strength [Esam Elawady, 2014]. Concrete must ensure satisfactory compressive strength and durability. The mechanical properties of concrete are highly influenced by its density. The comparisons on test results are presented with respect to time. It was observed from the experiment that, strength and density increases with maturity of concrete, void and absorption capacity decreases with time. Improved results were obtained from stone aggregate concrete than brick aggregate concrete in cases of all of the tests [Shohana Iffat, 2015].

2.0 Research Objectives

The present research work is aim to interpolate the rate of water absorption to characterize the different concrete mixtures design. This research will investigate the influence of uni-directional exposure of concrete cubes surface to water absorption to evaluate designed mixtures proportion and for which w/c ratio was vary with same grade of concrete as in the first case and grade of concrete, and w/c ratio varied with same slump as in the second case. Seventy-two concrete cubes with different grades of concrete were prepared and evaluate the rate of absorption characteristics in concrete mixtures design.

3.0 Experimental program

For this research work, six different mixtures type were prepared in total as per [BRE, 1988] code standards with concrete cubes of size (100 mm^3). Three of the mixtures types (M1, M2, and M3) were with a same compressive strength, differential slump, and w/c. Another Three of the mixtures type (M4, M5, and M6) were with a differential compressive strength, same value of slump, and different w/c. The overall details of the mixture proportions were represent in Table.1-2. Totally seventy-two concrete cubes were casted for six types of concrete mixture. The coarse aggregate used was crush 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.

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

Mix ID	Comp/mean target stg,N/mm^2	Slump (mm)	w/c	C (Kg)	W (Kg)	FA (Kg)	CA (Kg) 10 mm	Mix 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 ID	Comp/mean target stg,N/mm^2	Slump (mm)	w/c	C (Kg)	W (Kg)	FA (Kg)	CA (Kg) 10mm	Mix 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

3.1 Sorptivity test

It's defined as a measure of medium capacity to absorb/desorb liquid by capillarity. It's widely used in characterizing soils and porous construction materials (brick, stone, and concrete) respectively. Sorptivity coefficient 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 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 kept in contact with water. The sorptivity test is performed in accordance with the [ASTM C 1585]. The cubes (100 mm^3) were immersed in water for about 28 days curing and prior to the test specimens were placed in a desiccator's oven at temperature (50 ±2ºC) for 3 days. 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 [Balakrishna, *et al*, 2018]. The sorptivity test is carried out on 72 concrete cubes in six mixtures type (M1-M6) and noted the rate of water absorption at consecutive time interval like (5 min, 10 min, 15 min, 20 min and up to

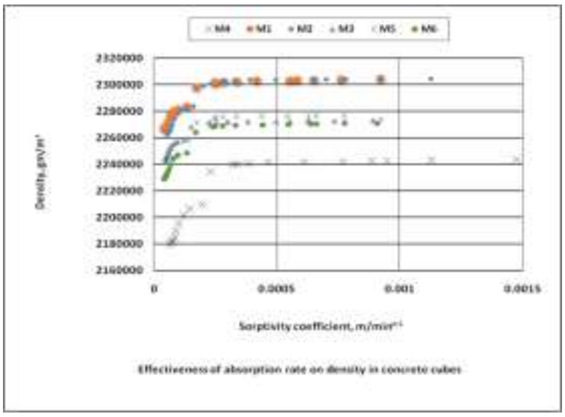
28 days). Water absorption testing is considerably influenced by sample preparation. Samples that were conditioned in the oven do not follow a similar trend as against with specimens conditioned in chambers at lower temperatures for longer time duration. The absorption is also influenced by the volume of paste in the samples. The experiments show that, a lack of control on moisture content or material composition may lead to a misunderstanding of the actual absorption behaviour.

3.2 Density of concrete cubes

The grade of concrete mixes was enhancing with age of concrete and w/c ratio. Increased w/c ratio leads to enhance in grade of concrete, however increase in w/c ratio leads to decrease in aggregate content followed by decreases in density of concrete mix [Mohammed Abas salem, *et al*, 2015]. Density of hardened concrete after 28 days of curing and noted their weight [BS 12390-7]. The 72 designed concrete cubes with six mixtures type (M1-M6) were immersed in water with one surface exposed to water as well as noted weights of concrete cubes at consecutive time interval (5 min-10 min-15 min-20 min and up to 28 days).

4.0 Discussion about Results

The deterioration of concrete is caused by the transport of aggressive agencies from the environment into the concrete. 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. Permeability is not directly related to absorption and been related to w/c ratio of concrete. The lower the sorptivity value, the higher the resistance of concrete to water absorption and it's depends on the pore distribution and micro structural properties of concrete [Abdul Razak, *et al*, 2004]. 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. 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 [Alamri, 1988]. There is need to investigate the sorptivity coefficient with concrete dry density in the concrete cubes to characterize different designed mixtures type in the present research work. Thus the variation of sorptivity coefficient-density of concrete cubes for in designed concrete mixtures type is as shown in Figs.1-7 respectively. It's possible to correlate a relation between the density-sorptivity coefficients in concrete cubes with power type of equation. It's observed from the results that, the average rate of water absorption (sorptivity coefficient) is varied in the different concrete mixtures design (M1-0.00029, M2-0.00034, M3-0.00027, M4-0.00042, M5-0.00030, and M6-0.00029) m/min$^{0.5}$ respectively. Whereas the minimum as well as maximum values (sorptivity coefficient) were varied in the range (M1:4.48E-05-0.00092, M2:5.37E-05-0.0011, M3:4.34E-05-0.0008, M4:6.59E-05-0.0014, M5:4.72E-05-0.0009, M6:4.37E-05-0.00091) m/min$^{0.5}$. Also the standard deviation were varied in the designed concrete mixtures type (sorptivity coefficient) as in the following range (M1-0.00029, M2-0.00032, M3-0.00025, M4-0.00041, M5-0.00027, and M6-0.00027) respectively. It's confirmed from the research work that for in case of constant concrete compressive strength and varied slump value, the rate of water absorption (sorptivity coefficient) was slightly increased in concrete mix design (M1-M3) as when compared to the concrete mix design (M4-M6) with varied grade of concrete and constant slump. The rate of water absorption was increased in lower concrete compressive strength and constant slump values and goes on decreases with increase in concrete compressive strength for in concrete mix design (M4-M6).



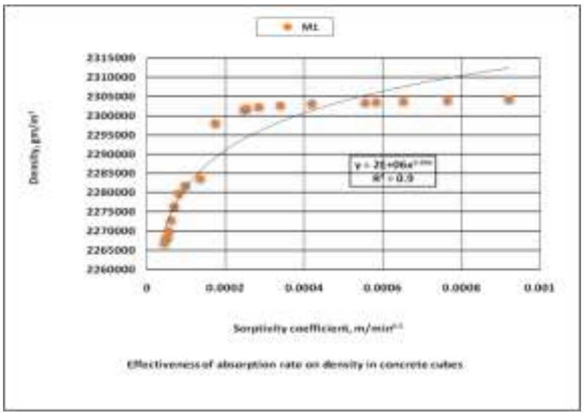


Fig.1 Sorptivity coefficient in Mix type Fig.2 Sorptivity coefficient in Mix type 1

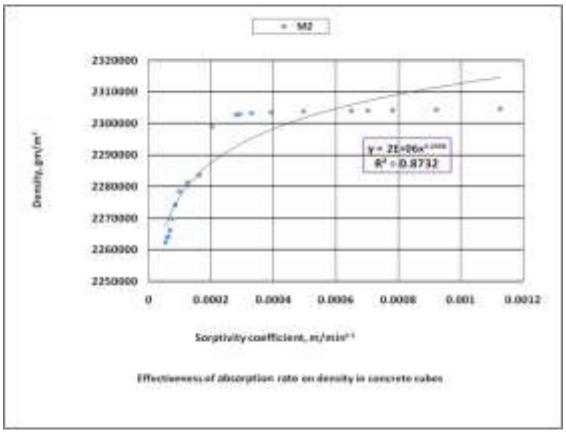


Fig.3 Sorptivity coefficient in Mix type 2

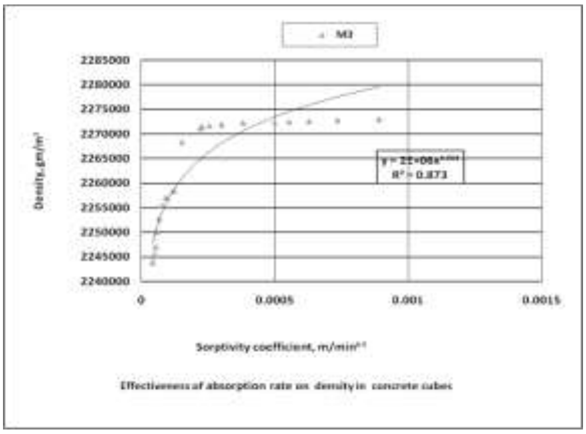


Fig.4 Sorptivity coefficient in Mix type 3

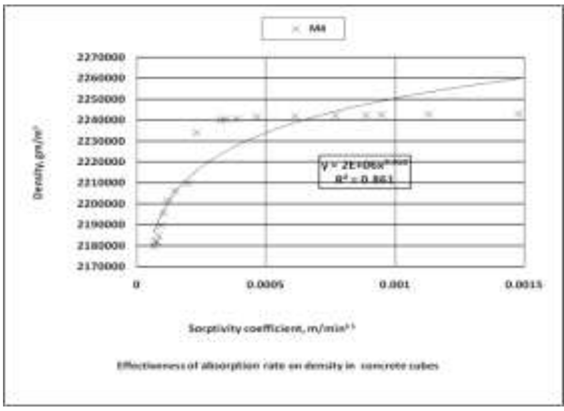


Fig.5 Sorptivity coefficient in Mix type 4

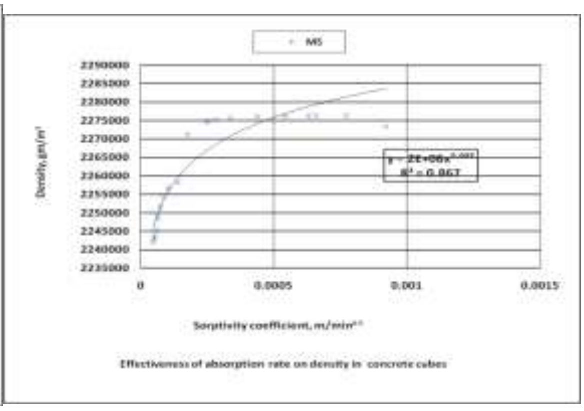


Fig.6 Sorptivity coefficient in Mix type 5

It's observed from the results that, the average rate of concrete density is varied in the different concrete mixtures design (M1-22,89991, M2-22,88994, M3-22,62230, M4-22,19153, M5-22,63437, and M6-22,54984) gm/m³ respectively. Whereas the minimum as well as maximum values (concrete density) were varied in the range (M1:2267086-2304390, M2:2262277-2304555, M3:2243825-05-2272971, M4:2179531-2243183, M5:2241910-2276356, M6:2229011-2270940) gm/m³. Also the standard deviation were varied in the designed concrete mixtures type (concrete density) as in the following range (M1-15097.92, M2-17069.71, M3-11470.90, M4-26027.68, M5-13851.85, and M6-16943.69) respectively. It's confirmed from the research work that for in case of constant concrete compressive strength and varied slump value, the rate of concrete density was slightly increased in concrete mix design (M1-M3) as when compared to the concrete mix design (M4-M6) with varied concrete compressive strength and constant slump value. The rate of concrete density was decreased in lower concrete compressive strength and constant slump values and goes on enhance with increase in concrete compressive strength for in concrete mix design (M4-M6). Furthermore, it's possible to interpret the variations in the water absorption rate as well as density of concrete at different time intervals in the concrete mix design (M1-M6) as representing in the Figs.8-9.

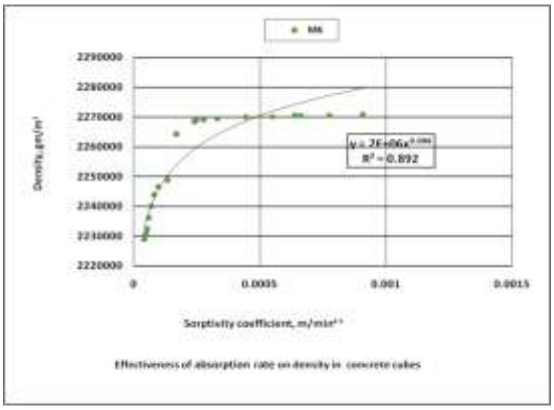


Fig.7 Sorptivity coefficient in Mix type 6

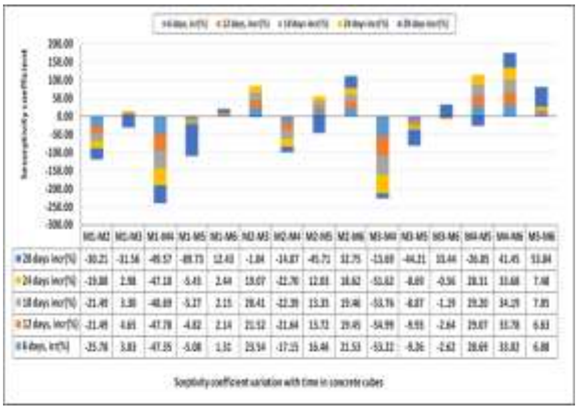


Fig.8 Comparison of sorptivity coefficient in Mixes type

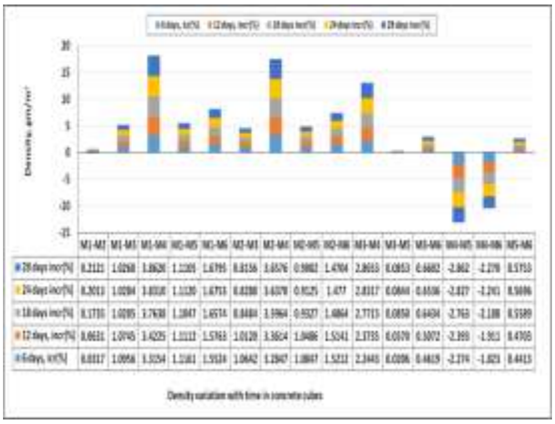


Fig.9 Comparison of density in Mixes type

5.0 Conclusions

- In the present research work, water absorption test was conducted on concrete cubes to ascertain the water absorption (sorptivity coefficient) characteristics on concrete density in designed concrete mixtures type.

- It's confirmed from the results that, the sorptivity coefficient is co-related with density of concrete by the power type of equation. In turn the average variation of sorptivity coefficient is more for in case of higher grade of concrete and differential slump as when compared to differential grade of concrete and same slump value. But in the case of lower compressive strength and constant slump, the sorptivity coefficient was slightly increases and its goes on decreases with increase in grade of concrete and same slump.

- It's confirmed from the research work that for in case of constant concrete compressive strength and varied slump value, the rate of concrete density was slightly enhanced in concrete mix type as when compared to the concrete mix design with varied concrete compressive strength and constant slump value. The rate of concrete density was decreased in lower concrete compressive strength and constant slump values and goes on enhanced with increase in grade of concrete for in concrete mix type.

6.0 References

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