EFFECTIVENESS OF CONCRETE INGREDIENTS ON ISAT IN DCC CUBES

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Abstract: *The present research work aim to assess the water absorption of concrete by Initial surface absorption test (ISAT) to interpret concrete mixtures design. This research will examine the influence drying condition on ISAT in concrete cubes and effectiveness of ISAT with time. In DCC concrete cubes, the ISAT value was increase in all designed mixtures type at an initial time as against to longer time. ISAT value was increase at initial time in lower compressive strength and constant slump as well as the ISAT value goes on reduced with higher compressive strength and constant slump value. ISAT value was increase at initial time with higher compressive strength and varied slump value as when compare to later time duration with same higher compressive strength as well as varied slump value. Furthermore, the ISAT value was increase at initial time in lower compressive strength and constant slump as well as the ISAT value goes on reduced with higher compressive strength, constant slump value, and at later time duration. The ISAT was increased in higher compressive strength concrete cubes with higher w/c ratio. ISAT values were decreased in constant higher compressive strength mixtures type (varied slump) as when compared to varied compressive strength with constant slump. ISAT was also found to be more for in case of higher compressive strength in designed concrete mixtures type with increased water diffusion coefficient. ISAT was goes on decreased with decreased water diffusion coefficient. It's confirmed from the results that, ISAT was increased in lower compressive strength with increased water diffusion coefficient and goes on decreased with decrease in water diffusion coefficient, increased concrete compressive strength and constant slump for in case of concrete mixtures design.*

Keywords*: Initial surface absorption, dry conditioned concrete cubes, aggregate volume fraction, water diffusion coefficient, moisture*

1.0 Introduction

The concrete structures are prone to chemical attacks, which may lead to structural deterioration and instability. The moisture is one of the key elements of the degradation mechanism, and along with the contaminants that dissolve in it can lead to the corrosion of the reinforcement bars within the concrete matrix. The measurement of the rate of ingress of water into hardened concrete is a key step in the determination of the potential durability of a structure [Dhir, 1986]. Water is a necessary ingredient for the corrosion of embedded steel and freeze-thaw damage to concrete. Water ingress rates are also good predictors of the likelihood of the ingress of other detrimental fluids and ions into concrete. Several in situ tests, which are intend to measure the permeation characteristics of concrete in structures [Levitt, 1970; Figg, 1973; and Dhir, 1987]. The permeation measurements from them had been to provide durability indices, which correlate with the results from accelerated exposure testing [Dhir, 1988]. However, the major difficulty in applying these tests in situ is that their measurements are substantially affect by the amount of water already present in the concrete, and it has been shown that any uncertainties about the original moisture content lead to poor reproducibility of the results [Dhir, 1987]. For this reason, meaningful in situ testing of concrete for permeation properties has not been possible. The effective water/cement ratio for workability is more difficult to define. It can be assume, provisionally, that initially dry aggregates will have achieved, at the time of the workability test, the same degree of saturation, as they would have in water. These effects of absorption only apply to high-strength mixes. Rich, uneconomical site mixes can be avoid if laboratory trials was based on the effective water/cement ratio as defined in this paper [Newman, 1959]. The result showed that using more amount of water and less amount of cement in the concrete mix lessens its strength and, at the same time, increases its vulnerability to deterioration [Ernesto. T. Anacta, 2013]. The primary focus of this study was to develop a test device suitable for non-destructive field use to evaluate the durability of cover-crete by determining the rate of absorption of concrete, including high performance concrete. The apparatus was work on principles presented in the British Initial Surface Absorption Test BS 1881, Part 5: 1970, since it focuses on water absorption. Tests of this nature, however, are very sensitive to the in situ moisture content of the surface concrete, as it will drastically alter the rate of absorption. In this paper, the field rate of absorption equipment is describe and both calibration and field data are present [De Souza, *et al*, 1998].A new method for testing concrete using the initial surface absorption test (ISAT) has been develop for site use. It has been base on applying a vacuum to an ISAT cap placed on the concrete surface until drying is achieved. The progress of the drying is monitor by placing indicating silica gel desiccant in the ISAT cap and observing the colour change. Results of comparisons with the existing in situ method in BS 1881 show that the new method is simple, quick, and practical for in-situ applications. Results of comparisons with the existing in situ method in BS 1881 show that the new method is potentially more capable of producing reliable and reproducible measurements and therefore will allow better comparison of in situ and laboratory-obtained data [Dhir, *et al*, 1993].

2.0 Research Objectives

The present research will investigate the influence of drying condition on the results of ISAT in concrete cubes with different designed concrete mixture proportions. An investigation was carried out in two different conditions such as slump, and w/c ratio value was varied 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. This research will also aim to interpret the effectiveness of different concrete ingredients on ISAT values in dry conditioned concrete cubes.

3.0 Experimental program

For the present research work, six different mixtures were prepared in total as per BRE [Teychenné, *et al*, 1988] standards with concrete cubes of size (100 mm^3). Three of the mixtures type (M1, M2, M3) were with a constant compressive strength, different slump value, and w/c ratio. Another three of the mixtures type (M4, M5, and M6) were with a different compressive strength, same slump value, and different w/c ratio. The overall details of the mixture proportions were to be representing in Table.1-2. Overall seventy-two concrete cubes were casted for six types of concrete mixtures type. The coarse aggregate used was crush stone (10 mm), grade of cement 42.5 N/mm^2, and fine aggregate used was 4.75 mm sieve size down 600 microns for this experimental 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 Initial surface absorption test

The most important parameter that leads to premature deterioration of reinforced concrete is the ingress of moisture by absorption or permeation, which can therefore to be used as an indicator of its durability. The ISAT is defined as the rate of flow of water into the concrete surface per unit area at a stated interval from the start of the test at a constant applied head and temperature. The first version of a test to measure this property was proposed by [Glanville, 1931]. This was further developing into a commercial test by [Levitt, 1970], and incorporated into the [BSI, 1970].The main advantage of the ISAT is a quick and simple non-destructive in situ test method that can be used to measure water penetration into a concrete surface. The difficulty of ensuring a watertight seal is probably one of the greatest limitations of this test because of the problems achieving this in practice. Another limitation is that, the measured property is affect by the moisture condition of the concrete. This, however, applies to nearly all near-surface absorption and air permeability tests and is best summarize by [Neville, 1995]. ISAT were conducted in the present research work as per [BS 1881: Part 208:1996] on all 72 concrete cubes of size (100 mm^3) after oven dried (3 days) at a constant temperature of 105±5 °C and exposure to natural air for about 7 days until it reaches constant weight change. The arrangement of ISAT (cap carries a rubber O-ring) and reservoir with a water pressure head of 200 mm as shown in Fig.1.

Fig.1 Arrangement of ISAT

The average values of ISAT with different mixtures type (M1-M6) in DCC concrete cubes was represent in Table.3. Average values of ISAT at various compressive strength values with different mixtures type (M1-M6) in DCC concrete cubes was represent in Table.4.

Table.3 ISAT on DCC cubes for Mixtures type (M1-M6)

Mix ID	Comp/mean target stg, N/mm^2	Slump (mm)	Mix proportion	ISAT,avr ml/m^2/s 10 min	30 min	60 min
M1	40/47.84	0-10	1:1.63:5.16	2.26	1.49	1.17

M2	40/47.84	10-30	1:1.29:.3.87	2.52	1.53	1.19
M3	40/47.84	60-180	1:1.18:2.63	2.67 2.1	2.14	1.71
M4	25/32.84	10-30	1:1.55:4.44	2.90 2.27	2.27	1.90
M5	30/37.84	10-30	1:1.42:3.86	2.83 2.13	2.13	1.76
M6	40/47.84	10-30	1:1.29:3.87	2.70 2.5	2.08	2.08

Table.4 Variation of ISAT, ml/m^2/s with compressive strength in DCC cubes

Mix ID/Time Com stg, N/mm^2	M1 31.34	M2 32.43	M3 34.48	M4 25.48	M5 31.91	M6 32.13
10 min	2.26	2.52	2.67	2.90	2.83	2.70
30 min	1.49	1.53	2.14	2.27	2.13	2.50
60 min	1.17	1.19	1.71	1.90	1.76	2.08

4.0 Discussion about Results

The ISAT was increased (2.26-2.67 ml/m^2/s) in mixtures type (M1-M3) at initial time (10 min) as when compared to longer time (60 min) which was ranged between (1.17-1.71 ml/m^2/s) for in same mixtures type. Whereas the ISAT was more increased (2.9-2.7 ml/m^2/s) in mixtures type (M4-M6), at an initial time (10 min) as when compared to longer time duration (1.9-2.08 ml/m^2/s) at 60 min. In which, rate of ISAT was found to be lesser in concrete cubes for mixtures type (M1-M3) at initial time for same grade of concrete and varied slump value as when compared to mixtures type (M4-M6), with different grade of concrete and constant slump value as observed from Figs.2-3. ISAT values were clearly decrease for longer time duration at 30 min and 60 min with higher compressive strength. Furthermore, the ISAT values was vary in DCC concrete cubes even though the mixtures proportion was designed with constant slump and compressive strength as well as varied compressive strength and slump. As observed from results that (Figs.2-3), ISAT was increased in all mixtures type (M1-M6) at 10 min. Actually ISAT was increase at early stage (10 min) as compared to 30 min and 60 min, which was varied about 24.51% as well as 38.70% respectively. Similarly, the ISAT was observe to increase at early time duration (10 min) as compared to longer time duration at 30 min and 60 min in which it is varied as 31.06% as well as 45.65% for in mixtures type (M1-M3). Whereas in case of mixtures type (M4-M6), the ISAT was slightly decreased at early stage (10 min) as when compared to longer time duration at 30 min and 60 min which was varied about 17.95% as well as 31.75% respectively.

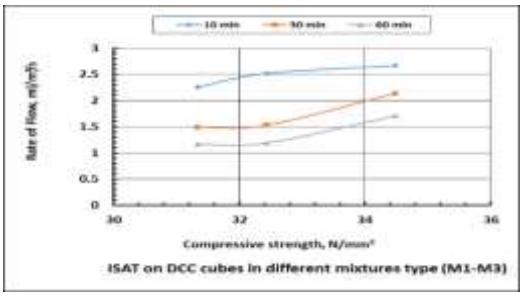

Fig.2 ISAT-w/c ratio in DCC cubes

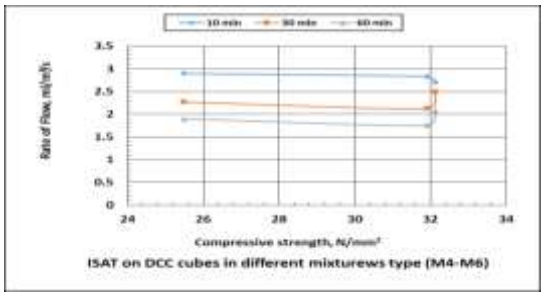

Fig.3 ISAT-compressive strength

The ISAT was lesser at 30 min and 60 min as when compare to initial time duration at 10 min. ISAT values was vary in mixtures type (M1-M3) for constant higher compressive strength with varied slump. In mixtures type (M4-M6), the ISAT was found to be more at 10 min time. Thus, it has confirmed that, the ISAT was be more in lower compressive strength as when compared to higher compressive strength value with constant slump. Similarly, the ISAT values in mixtures type (M1-M3) at time duration 60 min in which, the ISAT was increased in mixture type M2 and whereas in mixture type M3, its slightly higher compared to time duration at 10 min and 30 min with higher compressive strength (30-40 N/mm^2) and constant slump. This may be due to the fact that, if cement content was more, it creates cracks in concrete cubes in turn there exists a differential membrane between cement paste and concrete matrix. Because of that, segregation was occur due that, cement content starts settled at top layer and concrete matrix settled at bottom with variations in ingredient such as aggregate volume fraction and w-c ratio. Similarly, the ISAT was increase at 10 min and 30 min for lower compressive strength as when compare to longer time duration at 60 min. ISAT values was vary in mixtures type (M4-M6) for different compressive strength with constant slump. In mixtures type (M4-M6), the ISAT was more at 10 min time duration with their values as (2.9, 2.27, and 1.9) ml/m^2/s, as when compared to time at 30 min (2.83, 2.13, and 1.76) ml/m^2/s, and at 60 min (2.7, 2.5, and 2.08) ml/m^2/s respectively. Thus, it has confirmed that, the ISAT was more in lower compressive strength as when compared to higher compressive strength value with constant slump. Similarly, the ISAT values in mixtures type (M4-M6) at time duration 60 min, in which the ISAT was slightly decreased in mixture type M6 and whereas in mixtures type M4 and M5, its slightly higher compared to time at 60 min with higher compressive strength and constant slump (Fig.3). Rate of ISAT was increased in (M1-M3) both higher compressive strength (40 N/mm^2) and (M4-M6) lower compressive strength (25-30-40 N/mm^2) DCC cubes with higher w/c ratio. ISAT values were decreased in mixtures type (M1-M3) as when compared to (M4-M6) varied compressive strength (25-30-40 N/mm^2) with constant slump (10-30 mm). The variation of ISAT-w/c ratio with higher (varied slump) and lower compressive strength (constant slump) in DCC cubes was

representing as shown in Fig.4. ISAT was more for in case of higher/lower compressive strength in all designed concrete mixtures type (M1-M6) with increased water diffusion coefficient. ISAT was goes on decreased with decreased water diffusion coefficient. It's confirmed from the results that, ISAT was increased in lower compressive strength with increased water diffusion coefficient and goes on decreased with decrease in water diffusion coefficient, increased concrete compressive strength and constant slump for in case of concrete mixtures design (M4-M6) respectively (Fig.5).

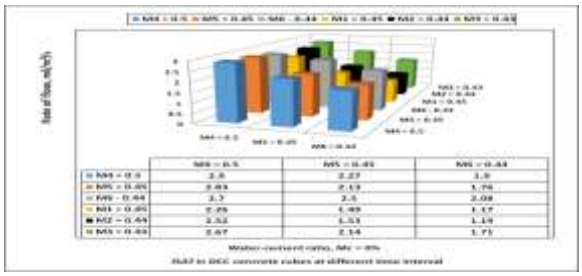

Fig.4 ISAT-w/c ratio

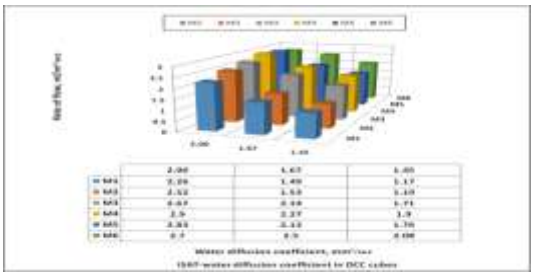

Fig.5 ISAT-water diffusion coefficient

The moisture content was significantly decreased for higher compressive strength (40 N/mm^2) and it goes on increases as against reduced concrete compressive strength (30-25 N/mm^2) at time duration 0 min. Similarly the moisture content was goes on increases at time intervals (5-10-15-20, and 30 min) as against to initial time (0 min).The variation of compressive strength-moisture content at different time interval was representing as shown in Fig.6. The moisture content was significantly decreased for higher aggregate volume fraction (fine-coarse aggregate ratio) and it goes on increases as against reduced aggregate volume fraction at time duration 0 min. Similarly the moisture content was goes on increases at time intervals as against to initial time duration (0 min).The variation of aggregate volume fraction-moisture content at different time interval was representing as shown in Fig.7.

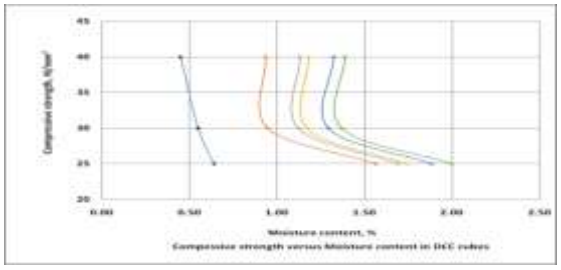

Fig.6 Compressive strength-Moisture content

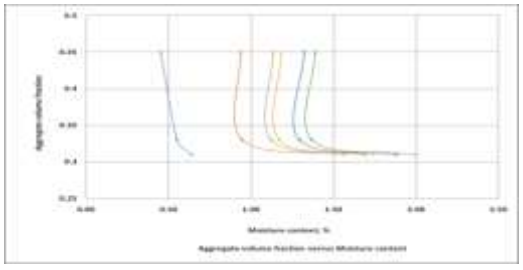

Fig.7 Aggregate volume fraction-Moisture content

5.0 Conclusions

- In DCC concrete cubes, the ISAT value was increased in designed mixtures type at initial time (10 min) as against to (30 min-60 min) and its increase at 10 min in lower compressive strength and constant slump. ISAT value goes on reduced with higher compressive strength and constant slump value.

- ISAT value was increased at initial time (10 min) with higher compressive strength and varied slump value as against to later time (30 min-60 min) with same higher compressive strength as well as varied slump value. ISAT value was increase at 10 min in lower compressive strength and constant slump. Its value goes on reduced with higher compressive strength, constant slump value, and at later time (30 min-60 min).

- The ISAT was increased in higher compressive strength concrete cubes with higher w/c ratio. ISAT values were decreased in constant higher grade of concrete mixtures type (varied slump) as when compared to differential grade of concrete with same slump.

- ISAT value was more for in case of higher grade of concrete in designed concrete mixtures type with increased water diffusion coefficient. ISAT was goes on decreased with decreased water diffusion coefficient. It's confirmed from the results that, ISAT was increased in lower compressive strength with increased water diffusion coefficient and goes on decreased with decrease in water diffusion coefficient, increased concrete compressive strength and constant slump for in case of concrete mixtures design.

6.0 References

1. British Standards Institution. (1970). Methods of testing hardened concrete for other than strength, BSI
2. London, BS 1881: Part 5.
3. British Standard Institution. BS 1881-208 Testing concrete. (1996), Recommendations for the determination of the initial surface absorption of concrete. BSI. London.

4. Dhir. R.K,et al.(1986). Near surface characteristics and durability of concrete: an initial appraisal. Mag.Concr.Res. 38:54-56.
5. Dhir.R.K, etal. (1987). Near surface characteristics of concrete: assessment and development to in situ test methods. Mag.Concr. Res. 39:183—195.
6. Dhir.R.K,et a/. (1988). Near surface characteristics of concrete: prediction of carbonation resistance. Mag.Concr.Res. 41:137—143.
7. DeSouza. S. J, Hooton. R. D, and Bickley. J. A (1998). A field test for evaluating high performance concrete cover Crete quality, Can. J. Civ. Eng. 25: 551–556.
8. Dhir. R. K, Shaaban. I. G, Claisse. P.A, and Byars. E (1993). A preconditioning in situ concrete for permeation testing Part 1: Initial surface absorption, Magazine of Concrete Research, 45(163):113-118.
9. Ernesto. T. Anacta. (2013). The Effect of Quantity of Cement and Mixing Water on Strength and Durability of Concrete, International Journal of Science and Engineering Investigations, issue 21, 2:110-113 October.
10. Figg. J. W. (1973). Methods of measuring the air and water permeability of concrete. Mag.Concr.Res. 25: 213-219.
11. Glanville, W.H. (1931). The permeability of Portland cement concrete, Building Research Establishment,
12. Tech. Paper, No 3, pp.62.
13. Levitt. M.(1970). The ISAT- A non-destructive test for the durability of concrete. Br. J. Non-destructive Test.
14. 13:106—112.
15. Newman.K. (1959). The effect of water absorption by aggregates on the water/cement ratio of concrete,
16. Magazine of Concrete Research, Issue 33, 01 November, 11:135–142.
17. Neville, A.M. (1995). Properties of Concrete, 4th ed., Longman, London.
18. Teychenné. D. C, Franklin. R. E, and Erntroy. H. C. (1988). Design of normal concrete mixes,
19. Second edition, BRE.