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Assessment of water absorption of concrete by Initial surface absorption test

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ABSTRACT

The deterioration of reinforced concrete usually involves movement of aggressive gases or liquids from the surrounding environment into the concrete through the near surface concrete. In turn followed by physical or chemical actions in its internal structure. The near surface concrete is highly heterogeneous in nature, due to the relative movement of cement paste and aggregates during the compaction of fresh concrete and bleeding of mix water during the early stages of hydration of cement. Therefore, there exists a porosity gradient in the near surface concrete. The transport of the various aggressive substances into the concrete depends on the quality of the near surface concrete and on its permeation characteristics. Therefore, there is a need to quantify the permeation characteristics of the near surface concrete, which is of paramount importance. The present research work attempted to assess the Water absorption of concrete by Initial surface absorption test (ISAT) in ordered to interpret different concrete mixtures design, which gives a test method for structural health assessment by a suitable correlation between Initial surface absorption value, and Time. Thus, the objectives of this present research are threefold. First, this research will examine the influence of conditioning such as drying condition on the results of Initial surface absorption test performed on Concrete cubes with different mixtures proportion. In which slump, and w/c ratio value is 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 (100 mm^3) with Grades of concrete ranges from 25 to 40 N/mm^2were prepared and tested using Initial surface absorption test. First, the non-destructive test parameters were related to different mixtures proportion in ordered to characterize mixtures design. Second, this research will examine the influence of the ISAT value on time. Third, this research will also aims to develop non-destructive charts for different concrete mixture proportions. Thus, the Initial surface absorption test due to the developed chart gave a better value. This implied that the developed chart was more suitable for normal strength concrete in turn minimizing inaccuracy in non-destructive tests. In dry conditioned concrete cubes, the ISAT value was increase in all designed mixtures type at an initial time as when compared to longer time duration. 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 and constant slump value. In addition, its confirmed results that, the 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.

Keywords: Concrete, Mix proportion, Grade of concrete, Sample conditioning, Slump, Water-cement ratio, Moisture content, Initial surface absorption

1. 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. In the absence of routine maintenance and appropriate repair work, this will eventually have brought the integrity of the structure to an unsafe level. To establish the integrity of reinforced concrete structures, conventional test, were conduct, which usually involve visual and intrusive inspection techniques. These tests are costly, and labour intensive and may include destructive tests in order to allow concrete samples to be extract from the structure for laboratory chemical analysis. Structural effectiveness of concrete can be affect by the environmental conditions. Such effects on the material can be significant and in under certain conditions the concrete matrix can be destroyed. In the case of chloride attack which can be triggered by the penetration of chloride ions found dissolved in water, chemical compounds formed as a result of chemical reactions create an increase of the volume needed to accommodate the newly formed compound on and around the rebar. This results in cracking or spoiling of this area of the concrete and subsequent leading to the degradation of the structure. This emphasizes the value of effective monitoring of water transport and with that the contaminants, which are waterborne with the material.

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 [1]. 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, had been develop and investigated [2-4]. The permeation measurements from them had been to provide durability indices, which correlate with the results from accelerated exposure testing [5]. 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 [4]. For this reason, meaningful in situ testing of concrete for permeation properties has not been possible. There are two possible approaches to overcoming this problem. The first is to measure the moisture content and compensate for it in the results, and the second is to precondition the sample by removing the moisture. 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 [6].

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 [7].Since in most deterioration mechanisms fluid ingress plays an important role, the surface skin of concrete provides the initial resistance to such factors as de-icer salt penetration, freeze–thaw resistance, and sulphate attack. Surface durability testing must evaluate resistance to the predominant mechanism of initial fluid ingress: capillary absorption or sorptivity. The primary focus of this study was to develop a test device suitable for non-destructive field use to evaluate the durability of covercrete by determining the rate of absorption of concrete, including high-performance concrete. This type of testing device must be simple to use, easily handled in the field, portable, and inexpensive. This particular device allows for ease of operation and accommodates a wide range of surface applications such as vertical, horizontal, or sloped surfaces, and smooth or rough finishes, while providing quick, consistent, and meaningful results. 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 [8].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. The method is quick, simple and practical for in situ applications. 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 [9].

2. RESEARCH OBJECTIVES

The objectives of this research are threefold. First, this research will examine the influence of conditioning such as drying condition on the results of ISAT performed on Concrete cubes with different mixture proportions. In which, W/C ratio, Slump, Grade of concrete, Fine aggregate, Coarse aggregate, Cement content, and Water content under two different conditions such as Slump, and W/C ratio value was 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. Second, this research will examine the influence of the Initial surface absorption values on Time, W/C ratio, Grade of concrete. Third, this research will also aim to develop non-destructive charts for different concrete mixture proportions. Thus, the Initial surface absorption test due to the developed chart gave a better value, suitable for normal strength concrete and in turn can be utilised in minimising inaccuracy in non-destructive tests.

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

3. EXPERIMENTAL PROGRAM

In the present research work, six different mixtures were prepared in total as per BRE, 1988 [10] code standards with a concrete cubes of size (100 mm^3). Three of the mixtures 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 designate as M1, M2, and M3. Another Three of the mixtures 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 designate as M4, M5, and M6. The overall details of the mixture proportions were to be representing in Table.1-2. Twelve concrete cubes of size (100 mm^3) were casted for each mixture and overall 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 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

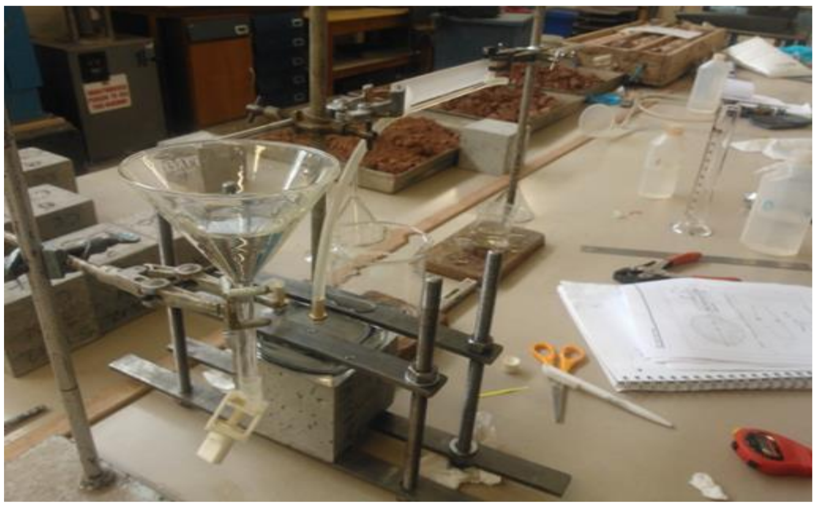

Figure 1 Schematic diagram of ISAT

4. 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 use as an indicator of its durability. Transport processes, which describe the movement of aggressive substances through concrete, which could be absorption, permeability or diffusion. However, due to the difficulty in achieving a unidirectional penetration of water and problems of determining the water penetration depth without actually splitting the concrete sample, the absorption characteristics of concrete are usually measure indirectly. The initial surface absorption 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 in 1931 [11]. This was further developed into a commercial test by Levitt [2], and incorporated into the British Standards in 1970 [12]. 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 [13]. “A low value of initial surface absorption may be due to the inherent low absorption characteristics of the concrete tested or else to the fact that the pores in poor-quality concrete are already full of water.” Another disadvantage is that the 200mm head of water is consider quite low, and although the results may be relate to surface weather exposure, they are of little relevance to behaviour under high water pressures. The Initial surface absorption test (ISAT) were conducted in the present research work as per BS 1881: Part 208:1996 [14] 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. A cap (acrylic) was attached to the concrete surface and making it watertight by clamping it, (the cap carries a rubber O-ring for this purpose). This cap was connecting to a reservoir with a water pressure head of 200 mm as shown in Fig.1. The cap was also connecting to a horizontal capillary tube. Water was allowed to penetrate the concrete surface from the reservoir into the cap. At the end of 10, 30, and 60 min, the reservoir flow was close and the water was allowed to penetrate the concrete surface from the capillary tube. The test gives the water flow (ml/m^2/sec) into the surface of the dry concrete cube by calibration capillary tube.

Initially with the inlet tap opened, water flows to fill the cap and then through the outlet it climbs into the calibrated horizontal capillary tube. After 10 min, the tap is close and the rate of water suction by the concrete is monitor by following the retraction of the meniscus in the capillary tube. This provides the initial surface absorption at 10 minutes. The absorption values are determined in this manner at 30, and 60 min from the start of the test. The inlet tap is open after taking each measurement and water in the reservoir topped up in order to allow the head of water to be maintain at 200mm.For smooth concrete surfaces, a conventional cap with a rubber gasket is preferred, whilst a knife-edge cap with the edges sealed with modelling clay is recommend for rough surfaces. If the concrete surface is not quite smooth, high sealing forces are required to keep the cap watertight and under unfavourable circumstances, this is not simply achievable. The method takes more than 2 hours to be completed and can be perform by a single operator. In fact, a circular cap with a surface area of at least 5000 mm^2 is clamp tightly onto the concrete surface and filled with water from a reservoir. To ensure that all the air is removing from the cap during this operation, the flexible tube (connected to the capillary) should not be connect to the outlet. Another requirement to ensure that no air is trap and cap is manufacture from transparent material to allow the detection of air bubbles. After the cap has been filling, the flexible tube is connecting to the outlet. The other end of the tube is connecting to a horizontal calibrated glass capillary tube. To commence a test the reservoir is filling with water to a level that is 200 mm above the concrete surface (the same height as the horizontal capillary tube). Once this has been achieved and there are no leaks or air bubbles in the system, the inlet tap from the reservoir is closed. The movement of the water in the capillary tube is then monitor. From the movement of the water in the calibrated capillary tube, the initial surface absorption value can be calculated in units of ml/m^2/s. The reason for measuring absorption at specified intervals after the start of the test is that water absorption of a dry surface is initially high but decreases as the water-filled length of the capillaries increases. The average values of initial surface absorption with different mixtures type (M1-M6) in dry conditioned concrete cubes was represent in Table.3-4.Similarly, the average values of initial surface absorption at various compressive strength values with different mixtures type (M1-M6) in dry conditioned concrete cubes was represent in Table.5.

Table 3 ISAT on DCC cubes for Mixtures type (M1-M3)

Mix No	Comp/mean target strength(N/mm^2)	Slump (mm)	Mix Proportion	Average values of ISAT, 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	2.14	1.71

Table 4 ISAT on DCC cubes for Mixtures type (M4-M6)

Mix No	Comp/mean target strength(N/mm^2)	Slump (mm)	Mix Proportion	Average values of ISAT, ml/m^2/s		
				10 min	30 min	60 min
M4	25/32.84	10-30	1:1.55:4.44	2.90	2.27	1.90
M5	30/37.84	10-30	1:1.42:3.86	2.83	2.13	1.76
M6	40/47.84	10-30	1:1.29:3.87	2.70	2.50	2.08

Table 5 Variation of ISAT with compressive strength in DCC cubes

ISAT, ml/m²/s, aver on DCC cubes in different mixtures type						
Mix ID/Time, min	M1	M2	M3	M4	M5	M6
Com Stg, N/mm²	31.34	32.43	34.48	25.48	31.91	32.13
10	2.26	2.52	2.67	2.9	2.83	2.7
30	1.49	1.53	2.14	2.27	2.13	2.5
60	1.17	1.19	1.71	1.9	1.76	2.08

5. DISCUSSION ABOUT RESULTS

Thus in the present research work, the effectiveness of 72 preconditioned concrete cubes of size (100) mm such as dry condition was evaluated for in case of six designed mixtures type (M1-M6). In which first mixtures type (M1-M3) was design as constant compressive strength (40 N/mm^2) with varied slump value (0-10, 10-30, and 60-180) mm and whereas second mixtures type (M4-M6) was design as constant slump value (10-30) mm with different compressive strength. The initial surface absorption was increased (2.26-2.67 ml/m^2/s) in mixtures type (M1-M3) at initial time duration (10 min) as when compared to longer time duration (60 min) which was ranged between (1.17-1.71 ml/m^2/s) for in case of 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 duration (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 duration for constant 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 Fig.2.

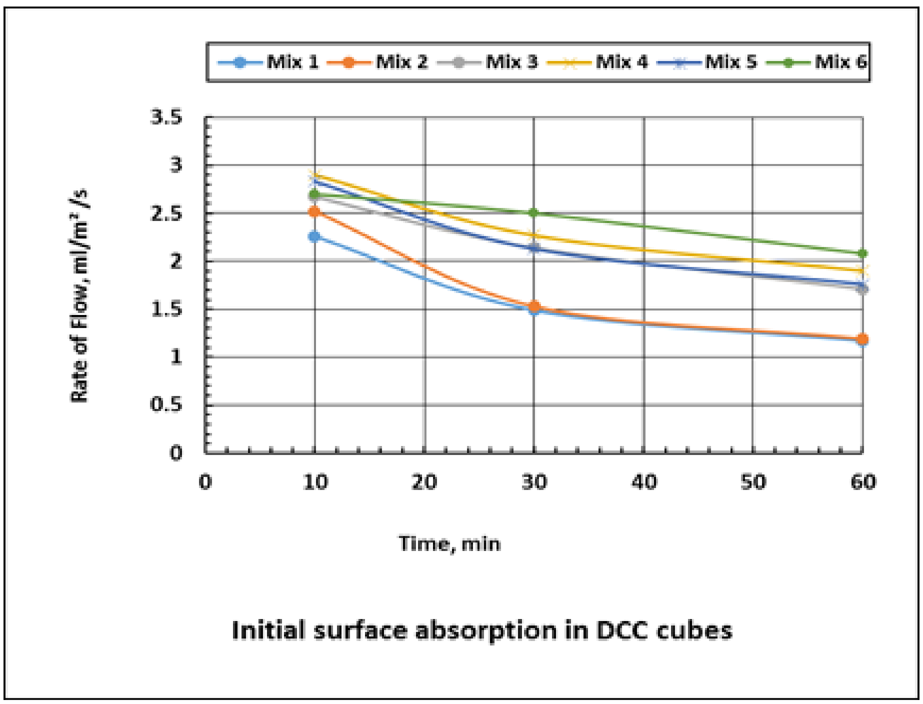

Figure 2 ISAT test on DCC cubes

The ISAT value was reduce with constant higher compressive strength and varied slump at initial time duration (10 min) in all mixtures type (M1-M3).In addition, it is confirm from present results that, the ISAT values decreases for different time intervals (10-60) min. However, ISAT value was increases at longer time duration even though the compressive strength is higher in turn it may be due to different slump as well as w/c ratio. Whereas, ISAT values was increase in mixtures type (M4-M6) at initial stage (10 min) with different compressive strength and constant slump as compared to mixtures type (M1-M3). In fact, it is observe from the results that, the ISAT values was clearly decrease for longer time duration at 30 min and 60 min with higher compressive strength. Furthermore, the ISAT values was vary in dry conditioned 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 (Fig.2), 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.

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. At different time duration such as at 10 min as (2.26, 2.52, and 2.67) ml/m^2/s, at 30 min (1.49, 1.53, and 2.14) ml/m^2/s as well as at 60 min (1.17, 1.19, and 1.71) ml/m^2/s. In mixtures type (M4-M6), the ISAT was found to be more at 10 min time duration with their values as (2.9, 2.83, and 2.7) ml/m^2/s, (2.27, 2.13, and 2.5) ml/m^2/s, and (1.9, 1.76, and 2.08) ml/m^2/s respectively. 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. The effectiveness of constant compressive strength on ISAT for mixtures type (M1-M3) in DCC concrete cubes at different time duration as shown in Fig.3. 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.

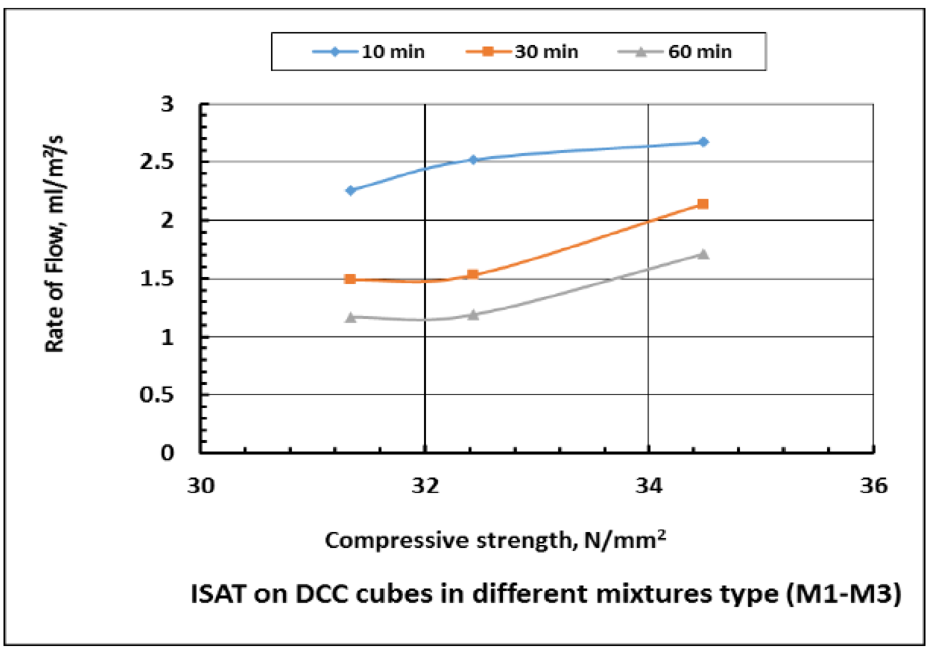

Figure 3 ISAT versus compressive strength

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. At different time duration such as 10 min as (2.9, 2.83, and 2.7) ml/m^2/s, at 30 min (2.27, 2.13, and 2.5) ml/m^2/s as well as at 60 min (1.9, 1.76, and 2.08) ml/m^2/s. In mixtures type (M4-M6), the ISAT was found to be 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 duration 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 duration at 60 min with higher compressive strength and constant slump. The effectiveness of different compressive strength (25, 30, and 40 N/mm^2) on ISAT for mixtures type (M4-M6) in DCC concrete cubes at different time duration as shown in Fig.4.

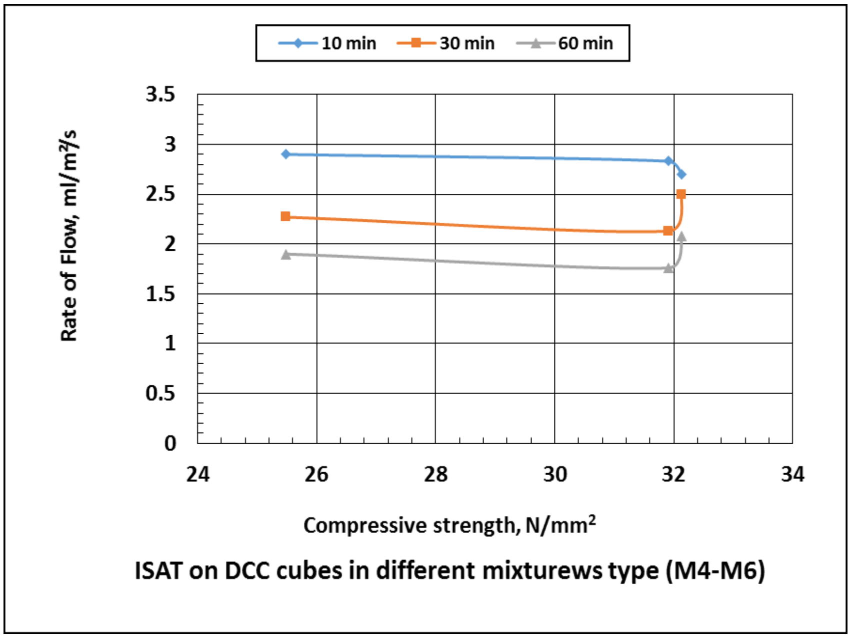

Figure 4 ISAT versus compressive strength

6. CONCLUSION

In dry conditioned concrete cubes, the ISAT value was increased in all six mixtures type at initial time (10 min) as when compared to (30 min-60 min). Furthermore, the ISAT value was increase at 10 min in lower compressive strength and constant slump as well as the ISAT value goes on reduced with higher compressive strength and constant slump value. The ISAT value was increased at initial time (10 min) with higher compressive strength and varied slump value as when compared to later time duration (30 min-60 min) with same higher compressive strength as well as varied slump value. Furthermore, the ISAT value was increase at 10 min 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 (30 min-60 min).

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REFERENCE

1. Dhir. R.K. et al. Near surface characteristics and durability of concrete: an initial appraisal. Mag.Concr.Res., 1986, 38, pp.54-56.
2. Levitt. M. The ISAT-Anon-destructive test for the durability of concrete. Br.J.Non-destructiveTest., 1970, 13, pp.106-112.
3. Figg. J. W. Methods of measuring the air and water permeability of concrete. Mag.Concr.Res., 1973, 25, pp.213-219
4. Dhir. R.K. et al. Near surface characteristics of concrete: assessment and development of in-situ test methods. Mag.Concr. Res., 1987, 39, pp.183-195.
5. Dhir. R.K .et al. Near surface characteristics of concrete: prediction of carbonation resistance. Mag.Concr.Res., 1988, 41,pp.137-143.
6. Newman. K, The effect of water absorption by aggregates on the water/cement ratio of concrete, Magazine of Concrete Research, V.11, Issue 33, 01 November 1959, pp.135–142.
7. Ernesto. T. Anacta,, The Effect of Quantity of Cement and Mixing Water on Strength and Durability of Concrete, International Journal of Science and Engineering Investigations V.2, issue 21, pp.110-113 October 2013.
8. S.J. DeSouza, R.D. Hooton, and J.A. Bickley, A field test for evaluating high performance concrete cover Crete quality, Can. J. Civ. Eng. 25: 551–556 (1998).
9. R. K. Dhir, I. G.Shaaban, P. A.Claisse and E. A.Byars, preconditioning in situ concrete for permeation testing Part 1: Initial surface absorption, Magazine of Concrete Research, 1993, 45, No.163, 113-118.

10. D C Teychenné, R E Franklin and H C Erntroy. Design of normal concrete mixes, Second edition, BRE, 1988.
11. Glanville, W.H., The permeability of Portland cement concrete, Building Research Establishment, Tech. Paper, No 3, 62 pp, 1931.
12. British Standards Institution, Methods of testing hardened concrete for other than strength, BSI London, BS 1881: Part 5, 1970.
13. Neville, A.M., Properties of Concrete, 4th ed., Longman, London, 1995.
14. British Standard Institution. BS 1881-208 Testing concrete. (1996). Recommendations for the determination of the initial surface absorption of concrete. BSI. London.