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# Variance of water diffusion coefficients with sorptivity in concrete cubes

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ABSTRACT
The movement of water or other fluids through concrete can carry aggressive agents which create various types of durability problems for concrete construction. Thus the quantities of concrete ingredients are determined in order to produce concrete having

appropriate long-term durability properties. It is needed to be able to accurately predict the sorptivity coefficient, relationship between water diffusion and sorptivity coefficient, water diffusion coefficient and moisture content within the concrete structures. Therefore, there is a need to quantify the sorptivity coefficient in concrete cubes which is of the most prominent factor in the concrete infrastructures. The present research work is made an attempt to interpret the concrete sorptivity coefficient (rate of absorption) in ordered to characterize the different concrete mixtures design for in case of concrete cubes. Thus the objecti ves of this present research are such as: 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 on the water diffusion coefficient, moisture content, and different time duration respectively. As from this research work that, it's possible to establish power type of equation relationship between water sorptivity coefficient and square root of time in designed mixtures type. The water sorptivity coefficient is predominantly increased at an initial stage as when compared to longer time duration for in case of all mixtures type. It's also confirmed from the results that, the water sorptivity coefficient is significantly decreased for in case of higher compressive strength and varied slump. But in the case of lower compressive strength and constant slump, the variation of water sorptivity coefficient with square root of time is slightly higher and goes on decreases with increased compressive strength for in case of designed mixtures type. In fact, from this research work that, it's possible to establish power type of equation relationship between water diffusion coefficient and sorptivity coefficient in designed mixtures type. The water diffusion coefficient is lesser at an initial stage when the rate of absorption (sorptivity) is lesser at an initial stage for in case of all mixtures type. It's also confirmed from the results that, the water diffusion coefficient is co-related with sorptivity coefficient, in turn the average variation of water diffusion coefficient with 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 variation of water diffusion coefficient with sorptivity coefficient is slightly higher in case of lower compressive strength and constant slump and goes on decreases with increased compressive strength for in case of designed mixtures type. From this research work that, it's possible to establish polynomial type of equation between water diffusion coefficient and moisture content with constant higher concrete compressive strength and varied slump value for in case of designed mixtures type. Finally, from this research work that, it's possible to establish power type of equation between water diffusion coefficient and moisture content with varied compressive strength and constant slump value for in case of designed mixtures type. The water diffusion coefficient is increased at an initial stage with lesser moisture content for in case of lower compressive strength and constant slump value and goes on reduced with pre-dominantly increased moisture content. But it's also confirmed from the results that, the water diffusion coefficient is slightly decreased at initial stage with lesser moisture content and goes on reduced with lower moisture content for in case of for in case of higher compressive strength and constant slump value. Whereas in the case of constant higher compressive strength and varied slump value, the variation of water diffusion coefficient with moisture content is slightly increased at an initial stage with lower moisture content and goes on decreases with increased moisture content for in case of constant higher compressive strength and varied slump value for in case of designed mixtures type.

**Keywords:** Concrete, Mixture proportion, Grade of concrete, Water-cement ratio, slump, water diffusion coefficient, sorptivity coefficient, moisture content

## 1. INTRODUCTION

The reinforced concrete is the most widely used construction material around the world. It is the most durable and versatile composite material, and can be used for almost any structural member, ranging from small streets, large bridges, tall buildings, poles, pipes, and retaining walls. In fact the reinforced concrete is a very resilient construction material, the concrete is still susceptible to deterioration and the reinforcing steel to corrosion. The reinforced concrete structures were to be deteriorate faster than its service life time duration. This can be caused by incorrect expectations in the design phase, inadequate specifications/construction and sometimes due to more undesirable conditions than originally assumed. Unfortunately, many concrete structures in the field are experiencing major damage from corrosion [1]. Deterioration of reinforced concrete infrastructures is strongly associated with corrosion of steel caused by the application of dicing salts. In Montreal, the severity and duration of the winter period is a major concern. The chlorides from the dicing salt enter the concrete and destroy the passive oxide layer protecting the reinforcing steel, making the steel vulnerable to corrosion. The factor responsible for the failures in the highway structures are the result of strength degradation caused by environmental stressors. The most common environmental stressors are chemicals, moisture, and cycles of extreme temperatures. These stressors over time reduce the overall strength of the structure. The aggressiveness of the environment, the concrete and steel properties, the amount of concrete cover, and the geometry of each section control the extent of this resistance loss [2]. The location of damage is dependent on the structural member type, location of the element on the structure, and lastly the source or stressor which is causing the damage [2]. The durability of concrete bridge decks, beams, columns, and abutments are significantly affected by the ingress of chloride ions. In fact the common sources for internal chlorides are calcium chloride containing admixtures, contaminated aggregates, and seawater and for external chlorides are seawater exposure, de-icing salts, fire, and chloride contaminated groundwater or soils [3]. Generally, external chloride ion sources are the dominant contributor to corrosion initiation and internal chloride sources are often negligible. Actually the concrete's high pH causes an oxide film to form on the surface of the steel. The corrosion process of the reinforcement can only begin once this passive oxide layer has been destroyed. The concentration of chloride ions needed to destroy the oxide film is referred to as the critical chloride ion concentration. In addition to that the carbonation of the concrete is also destroys the oxide film by lowering the pH of the concrete [4]. There have been numerous researches into the critical chloride concentration and there is a large variability in the values obtained. The factors such as mix type and proportions, pH, $C_3A$ content, w/c, relative humidity, and temperature may induced variations in critical chloride concentration value as noted by researcher [4]. It has been assumed that because of the large variation in concrete properties, the critical chloride concentration is found to be within a range between (0.2-3) percent by weight of cement [4]. The duration (corrosion initiation period) is dependent on the length of time it takes for the substances needed for corrosion, such as water, oxygen, chloride ions and carbon dioxide, to penetrate the concrete clear cover and reach the depth of reinforcing steel in a sufficient amount to begin corrosion of the steel. Therefore, the transport process of these substances into the concrete and various chemical reactions that take place characterizes the corrosion initiation process [5].

The sodium chloride salt is considered as the best dicer because it works fast, cheap and is very easy to use. There are numerous products on the market, but none has matched the cost effectiveness of salt [9]. On the other hand, the de-icing salts is found to be detrimental to reinforcing steel and reinforced concrete structures. Even though the de-icing salts are harmful to reinforcing bars, their benefits to society cannot be overlooked. In fact the deicing salt is used to prevent or destroy the snow/ice bond to the pavement so that traffic action/snow plows can clear the road as pointed out by [6]. The commonly used salts are sodium chloride and calcium chloride which are used to melt snow and ice on pavements in cold countries around the world. Salt exposure in the concrete can lead salt crystals to form in the pores, and at high concentrations can change the chemical composition in the cement paste [7] and chemical reaction causes the cement paste to lose its structure, and the bonds can be destroyed [8]. Studies have confirmed that a 2-4% percent solution of salt causes maximum scaling the in saturated conditions, and that above and below this range less scaling is expected [9]. In addition to that, conversely, for the wetting-drying condition, the amount of damage increases as the concentration of salt increases [10] respectively. In cold region, freezing rain and snow will affect the road traffic especially in winter. So that it is generally used to decrease the traffic problems by seeding the chloride salt snow melting agent on the road to remove snow and ice. It will cause the spalling of concrete, corrosion of reinforcement, and the increasing damage by the freeze thaw to the concrete pavement as confirmed by researcher [11]. In fact that, so many high grade concrete pavements and the urban overpass bridge decks are prematurely destroyed due to insufficient understanding of the damage of spreading snow-melting agent [12-13]. The concrete structures which have been built in cold, harsh climates are frequently subjected to freezing and thawing. Thus the concrete structures needed to exhibit constant adequate functional performance in terms of traffic safety [14] respectively.

## 2. RESEARCH OBJECTIVES

The concrete infrastructures such as roads and bridge decks, and parking building are some of the most important and most expensive assets in which large amount of money is invested each year for maintaining and repairing these assets. Thus there is a need to protect these concrete infrastructures in order to secure their long service life. But there are so many different parameters that affect the concrete service life. Generally, these parameters can be divided into two categories including mix design parameters such as water-cement ratio, fine aggregate percentage and using air entrainment admixture, and environmental parameters such as water flow and de-icing salt or chemicals respectively. Therefore there is a need to study water transport mechanisms on concrete structures 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 respectively.

## 3. EXPERIMENTAL PROGRAM

In the present research work, six different mixtures type were prepared in total as per BRE, 1988 [15] 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.

**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 |

### 3.1. Relationship between sorptivity coefficient and time duration

The Sorptivity coefficient was decreased when compared to an initial time duration (5-10) min. In fact there was decrease in Sorptivity coefficient (21.89%) at 10 min as when compared to an initial time duration (5 min) for in case of all mixtures type (M1-M6). Similarly, Sorptivity coefficient was goes on decreases gradually at certain point, it reaches parabolic pattern, and afterwards it reaches equilibrium (28 day) in turn Sorptivity coefficient was found to be decreased (95.18%). Whereas at 1 day, the increase in Sorptivity coefficient was found to be

82.07% for in case of all mixtures type (M1-M6). The variation of sorptivity coefficient (S) with square root of time (√ t) for in case of designed mixtures type with their correlation equation as well as $R^2$ values was represented in (Table.3). The sorptivity coefficient for in case of mixtures type (M1-M3) at an initial time duration (10 min) was 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 was always more at an initial time duration because of differential gradient exists between higher to lower concentration gradient section, there was a variation in the rate of abs orption 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.

**Table 3** Variation of Sorptivity coefficient with time

| MIX ID | Co-relation Equation | $R^2$ |
|---|---|---|
| **M1** | $S = 0.0016(\sqrt{t})^{-0.647}$ | 0.9921 |
| **M2** | $S = 0.0019(\sqrt{t})^{-0.641}$ | 0.9911 |
| **M3** | $S = 0.0015(\sqrt{t})^{-0.640}$ | 0.9930 |
| **M4** | $S = 0.0023(\sqrt{t})^{-0.644}$ | 0.9906 |
| **M5** | $S = 0.0016(\sqrt{t})^{-0.636}$ | 0.9917 |
| **M6** | $S = 0.0016(\sqrt{t})^{-0.687}$ | 0.8818 |

### 3.2. Relationship between water diffusion coefficient and sorptivity coefficient

The water diffusion coefficient is depends on factors such as square root of moisture content ratio, material thickness, and time. Whereas Sorptivity coefficient is depends on factors such as cumulative water absorption, and square root of time. It's interpreted from an experimental results that, the diffusion coefficient is very lesser at an initial stages with decreased Sorptivity coefficient, and the diffusion coefficient is increased gradually with an increased rate of Sorptivity coefficient in all mixtures type (M1-M6). The water diffusion coefficient is lesser at an initial stage with decreased Sorptivity coefficient, this may be due to variation in aggregates to cement paste matrix, mixtures proportion, slump value, grade of concrete, and rate of absorption. In fact, the diffusion coefficient is varied between 2-0.5 $mm^2/min$ at short and long time duration. Whereas the Sorptivity coefficient is varied between 0.0005-0.0015$m/min^{0.5}$. There is a relationship exists in the present research between water diffusion coefficient and Sorptivity coefficient for in case of designed mixtures type (M1-M6), which in turn it follows linearly proportional state at some short time duration, afterwards its gradually deviates and takes inverse parabolic shape. The variation of water diffusion coefficient with sorptivity coefficient for in case of designed mixtures type with their correlation equation as well as $R^2$ values is represented in Table 4.

**Table 4** Variation of Water diffusion coefficient with Sorptivity coefficient

| MIX ID | Co-relation Equation | $R^2$ |
|---|---|---|
| **M1** | $Dw = 73.018S^{0.5035}$ | 0.9995 |
| **M2** | $Dw = 83.558S^{0.5221}$ | 0.9993 |
| **M3** | $Dw = 68.385S^{0.4848}$ | 0.9963 |
| **M4** | $Dw = 49.991S^{0.4661}$ | 0.9901 |
| **M5** | $Dw = 66.652S^{0.4893}$ | 0.9979 |
| **M6** | $Dw = 70.452S^{0.5039}$ | 0.9994 |

Actually the diffusion coefficient is lesser at an initial stage as when the rate of absorption is lesser at an initial stage for in case of all mixtures type (M1-M6). The concentration gradient is increases in turn the flow of water was starts moving towards lower concentration. Thus clearly the rate of absorption is goes on increases as time passes and reaches equilibrium and there was no further increase in diffusion coefficient in all designed mixtures type (M1-M6). The variation in diffusion coefficient and Sorptivity coefficient is found to be varied in between ($D_{5\ min}$ = 2.25 $mm^2/min$, and $S_{5\ min}$ = 0.001 $m/min^{0.5}$) as well as ($D_{185.90\ min}$ = 2.25 $mm^2/min$, and $S_{185.90\ min}$ = 0.001 $m/min^{0.5}$).

### 3.3. Relationship between water diffusion coefficient and moisture content

The water diffusion coefficient was increases at an initial time duration in all mixtures type (M1-M6) in which its ranged about 2.25 $mm^2/min$ at 5 min time duration with moisture content (Mc = 1.07%). The diffusion coefficient moisture content curve is deviates nearer point at moisture content (Mc = 1.9-2%) in almost all mixtures type at which the diffusion coefficient was about at least 1.072 $mm^2/min$. After time passes, the water diffusion coefficient was reached equilibrium state with increase in moisture content. The diffusion coefficient was very higher; it's may be due to higher concentration gradient at lesser moisture content availability at an initial stage. Once if moisture content was increased in concrete matrix may be due to mixing water, aggregate quantity, and pore structure may become fully filled water, in turn thus diffusion coefficient was goes on reduced as time passes with an increase in moisture content for in case of all mixtures type (M1-M6). The variation of water diffusion coefficient with moisture content for in case of designed mixtures type with their correlation equation as well as $R^2$ values is represented in Table 5.

**Table 5** Variation of Water diffusion coefficient with moisture content

| MIX ID | Co-relation Equation | $R^2$ |
|---|---|---|
| **M1** | $Dw = 0.2155(Mc)^2-1.5497Mc+3.3328$ | 0.9540 |
| **M2** | $Dw = 0.1704(Mc)^2-1.4602Mc+3.6678$ | 0.9481 |
| **M3** | $Dw = 0.2260(Mc)^2-1.5805Mc+3.3415$ | 0.9350 |
| **M4** | $Dw = 2.9459(Mc)^{-0.791}$ | 0.9390 |
| **M5** | $Dw = 2.0988(Mc)^{-0.819}$ | 0.9297 |
| **M6** | $Dw = 2.0627(Mc)^{-0.939}$ | 0.9994 |

## 4. DISCUSSION ABOUT RESULTS

The concrete infrastructures such as buildings, bridge decks and harbours, parking places, pre-stressed concrete structures, and steel structures may deteriorate due to de-icing agents, water ingress, and so many other aggressive chemicals in the cold countries region. The concrete infrastructures deterioration is considered to be as one of the major factors that could significantly change the long-term performance of concrete structures. It is well-known fact that, the deterioration rate not only depends on material compositions and construction processes, design criteria, maintenance, and protection methods but also relies on the on-going climatic environment effect during the service phase of the concrete infrastructures lifecycle. Thus in the present research work, an attempt is made to investigate the effect of rate of water absorption on time duration, water diffusion coefficient, and how the water diffusion coefficient is varied with moisture content for in case of designed mixtures type. 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 Figs.1-6 respectively. The water sorptivity coefficient is pre-dominantly increased at an initial stage as when compared to longer time duration for in case of all mixtures type. It's also confirmed from the results that, the water sorptivity coefficient is significantly decreased for in case of higher compressive strength and varied slump. But in the case of lower compressive strength and constant slump, the variation of water sorptivity coefficient with square root of time is slightly higher and goes on decreases with increased compressive strength for in case of designed mixtures type. The concrete curing process maintence the moisture and temperature conditions of concrete for hydration reaction in order to develops hardened concrete properties over time. The concrete curing process is required in order to prevent the concrete to dry out prematurely due to solar radiation and wind, maintain the concrete temperature by allowing the hydration process, concrete to harden and bond with internal materials and reinforcement, prevent damage to bond between concrete and reinforcement due to vibration and impact, development of impermeable, crack free and durable concrete. In fact the curing duration of concrete depends on factors such as reason for curing (to prevent plastic sh rinkage, temperature control, strength and durability of concrete), size of concrete member, and type of concrete grade and rate of hardening of concrete, temperature and moisture conditions of surroundings, exposure conditions of the concrete surface during and after curing, and requirement of curing duration as per specification of concrete.

Actually an excess of water in the concrete structure evaporates, it leaves voids inside the concrete element creating capillaries which are directly related to the concrete porosity and permeability. By proper selection of concrete ingredients, and mixture proportioning, and, good construction practices in turn impervious concrete can be obtained. The pores in cement paste consist of gel pores and capillary pores and pores in concrete as a result of incomplete compaction are voids of larger size which give a honeycomb structure leading to concrete of low strength. In order to solve the problems associated with the absorption test and permeability tests, there is need to measure the rate of absorption of water by capillary suction, in turn by sorptivity of unsaturated concrete. Sorptivity is materials ability to absorb and transmit water through it by capillary suction. An uptake of water by unsaturated, hardened concrete may be characterized by the sorptivity. Sorptivity/capillary suction, is the transport of liquids in porous solids due to surface tension acting in capillaries and is a function of the viscosity, density and surface tension of the liquid and also the pore structure (radius, tortuosity and continuity of capillaries) of the porous solid as confirmed by researcher [16]. As pointed that, the ingress of moisture and the transport properties of the concrete materials have become the main source of investigation for many engineering problems such as corrosion of reinforcing steel, and damage due to freeze-thaw cycling/wetting and drying cycles respectively. Thus the sorptivity is based on the rate of absorption, which is proportional to the surface area exposed to moisture and time. Sorptivity testing on concrete was shown to be more sensitive to compaction. Prolonged ramming of specimens which results in an increased bulk density and decreased porosity. With prolonged ramming, their finding brought forward the concept that, reduction of large pores created this non-linearity [17].

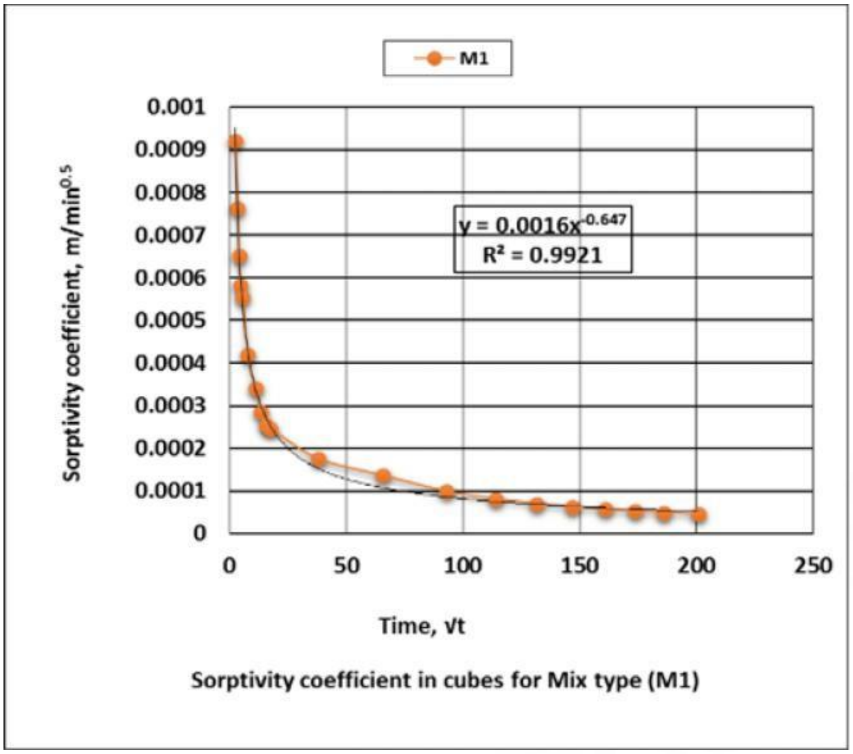


**Figure 1** Sorptivity coefficient in concrete cubes (M1)

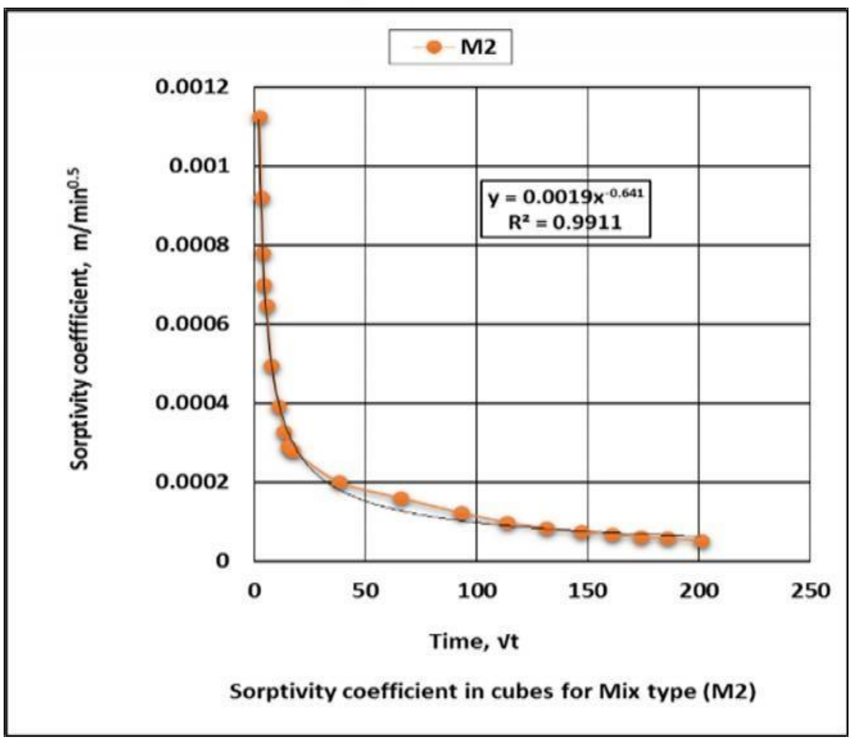


**Figure 2** Sorptivity coefficient in concrete cubes (M2)

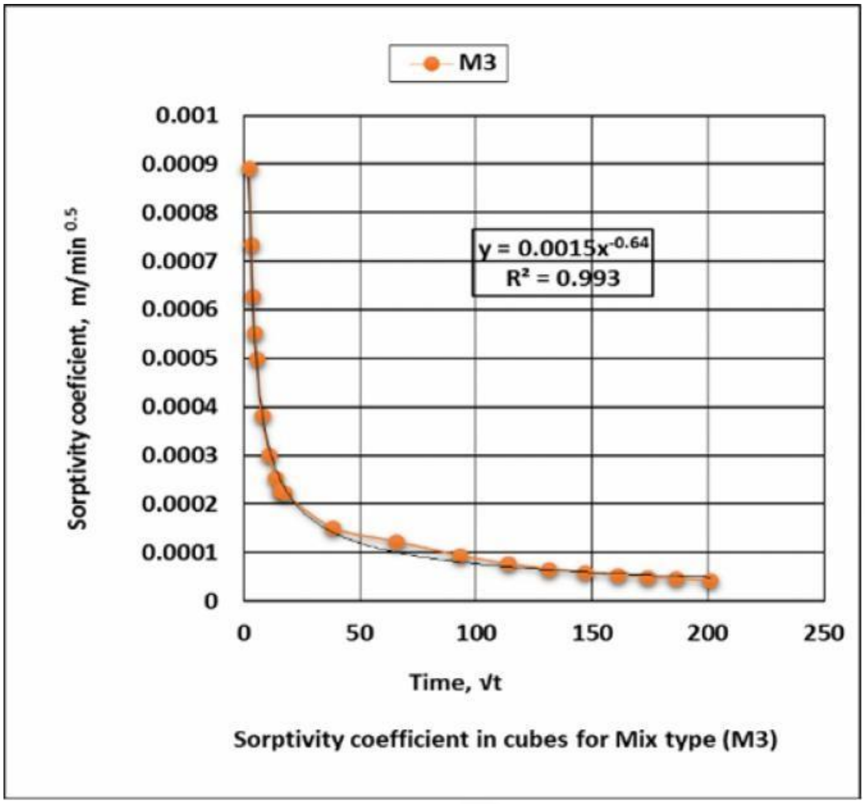


**Figure 3** Sorptivity coefficient in concrete cubes (M3)

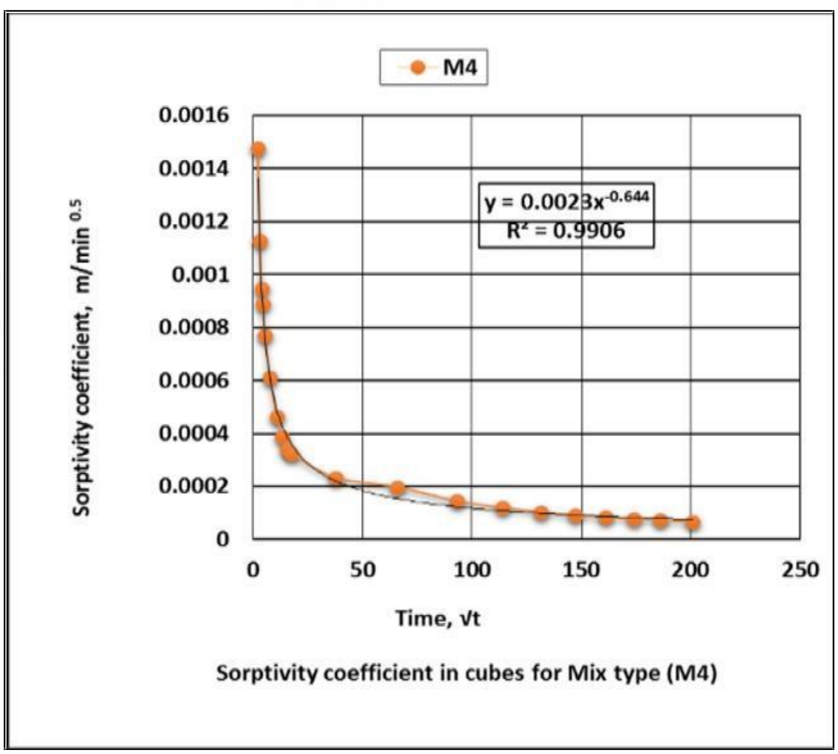


**Figure 4** Sorptivity coefficient in concrete cubes (M4)

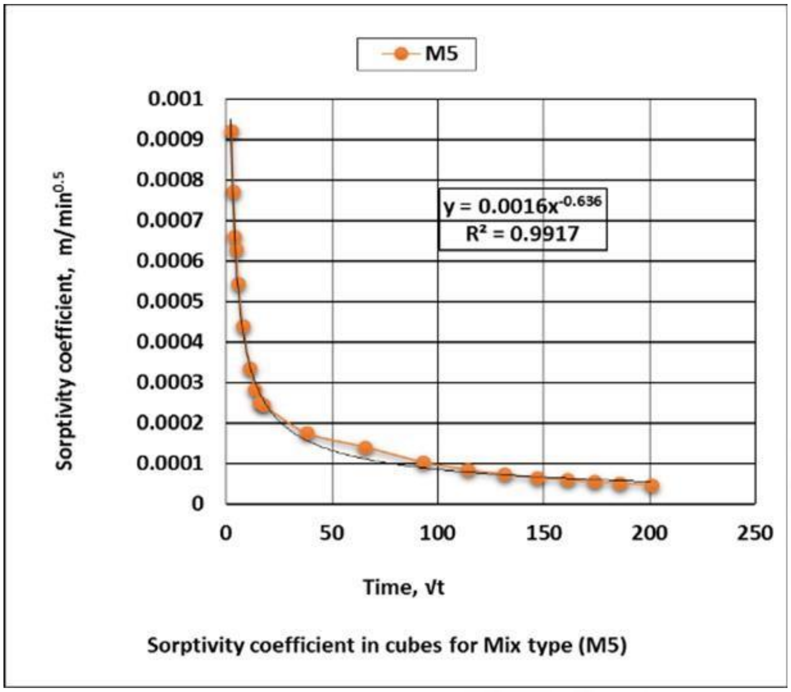


**Figure 5** Sorptivity coefficient in concrete cubes (M5)

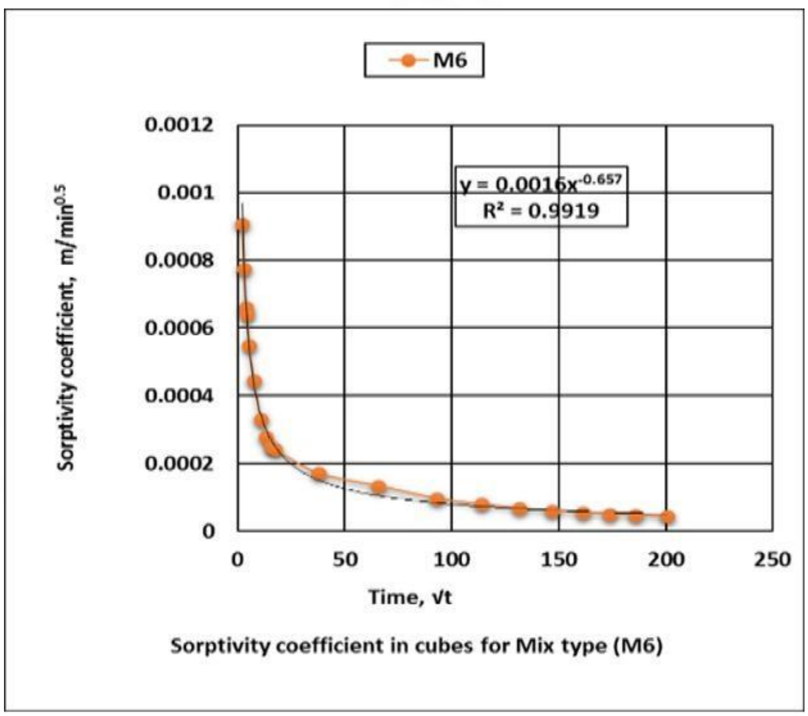


**Figure 6** Sorptivity coefficient in concrete cubes (M5)

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 more sensitive to the quality of the cover skin of concrete members and has been proven to be more effective in revealing poor placing and finishing techniques in the field [18]. Furthermore, an extensive support was given to sorptivity testing as it was discovered that testing was also sensitive to the depth of concrete.

Specimens that were tested at different depths for sorptivity gave different results, which could be indicative of signs of segregation or bleeding due to poor construction practices [19]. It was generally accepted that good quality concrete was represented by low sorptivity values and extensive work had been done on the influence of various factors on water sorptivity. It was shown that the quality of concrete increased with curing time, and that it varied based on the source and type of material used. The use of admixtures and the source of Portland cement also had a large influence on the quality of concrete described by sorptivity testing as confirmed by researchers [20]. The research is carried out by [21], on the addition of pozzolanic materials and curing condition on the mechanical properties as well as the capillary water absorption (sorptivity) lightweight concrete. Its confirmed from the results that, as the concrete compressive strength is increased due to hydration, the sorptivity coefficient is significantly reduced which indicates that, a denser microstructure of the concrete matrix.

The variation of water diffusion coefficient with sorptivity coefficient for in case of designed mixtures type with their correlation equation as well as $R^2$ values is represented in Figs.7-12 respectively.

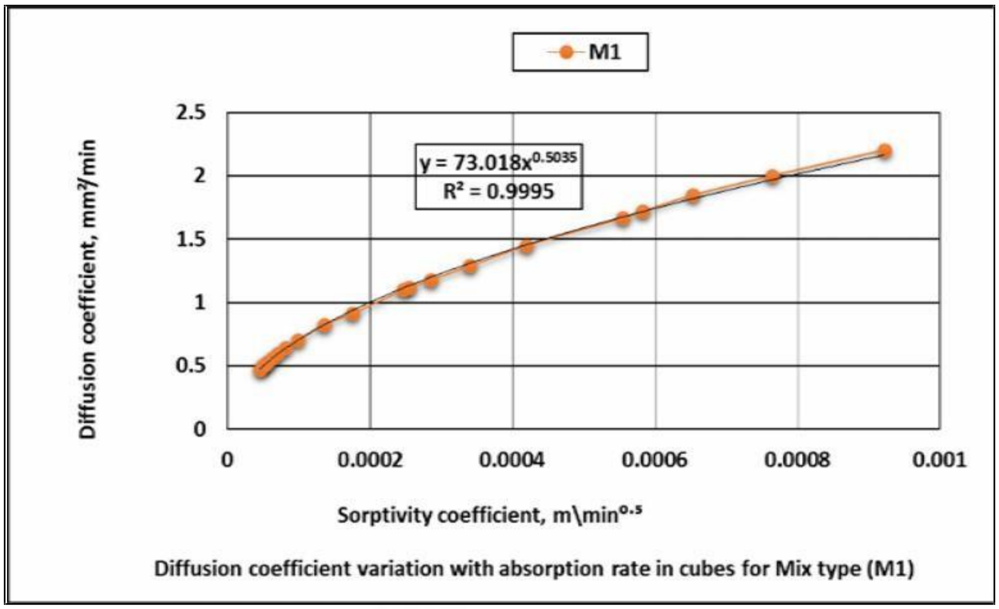


**Figure 7** Sorptivity coefficient in concrete cubes (M1)

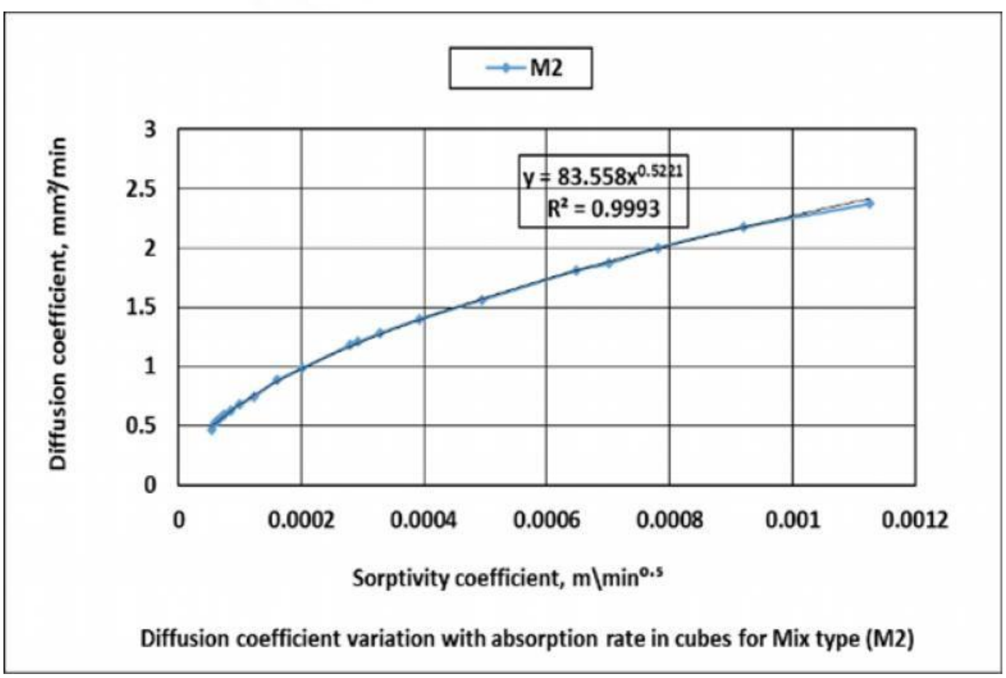


**Figure 8** Water diffusion and sorptivity coefficient (M2)

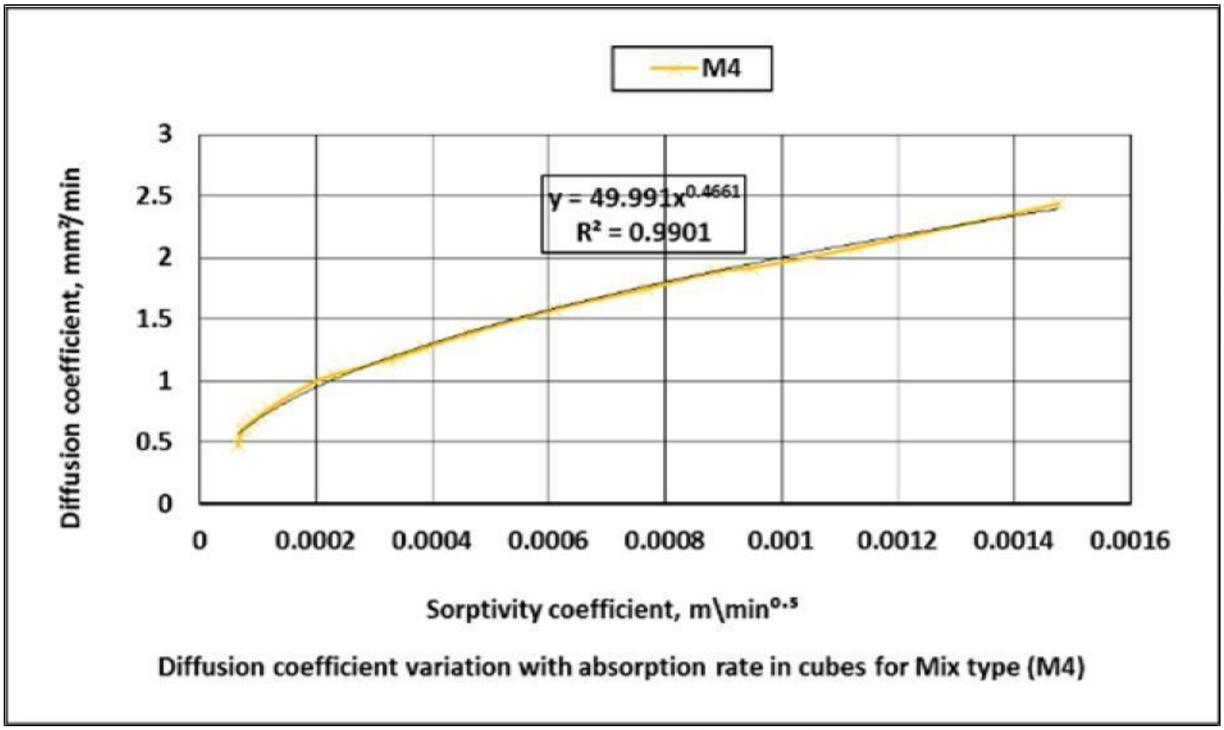


**Figure 9** Water diffusion and sorptivity coefficient (M3)

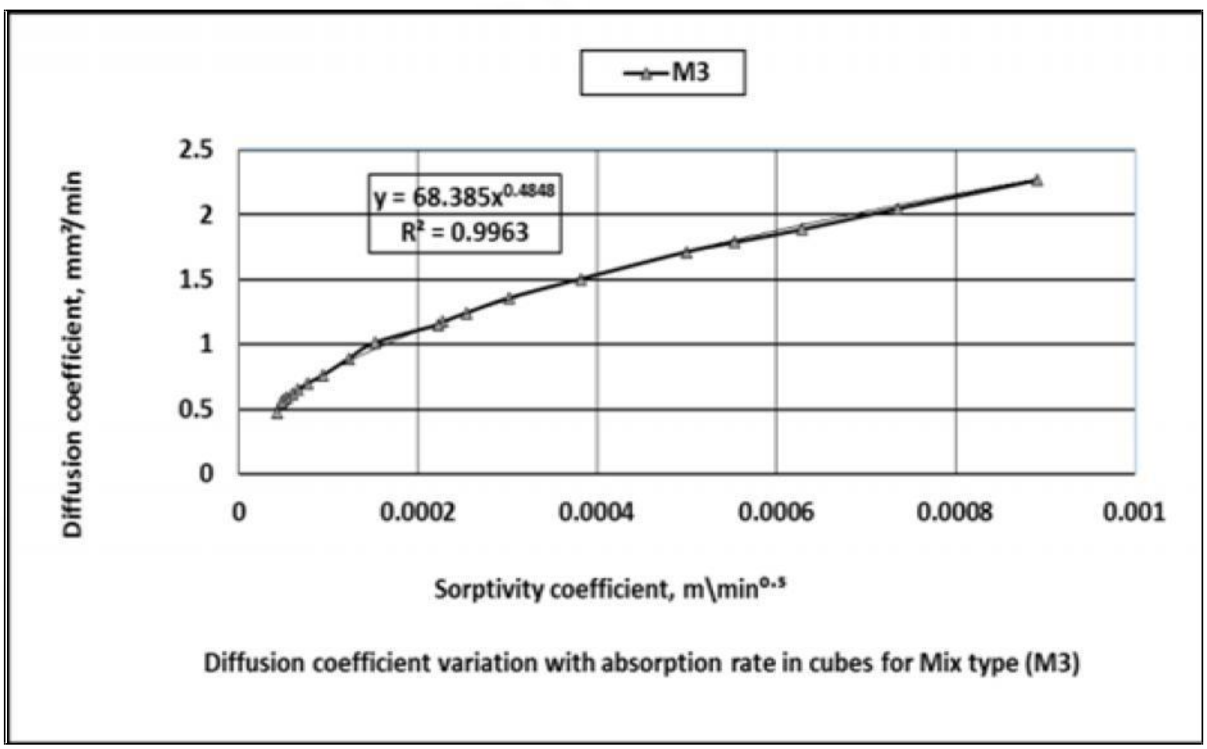


**Figure 10** Water diffusion and sorptivity coefficient (M4)

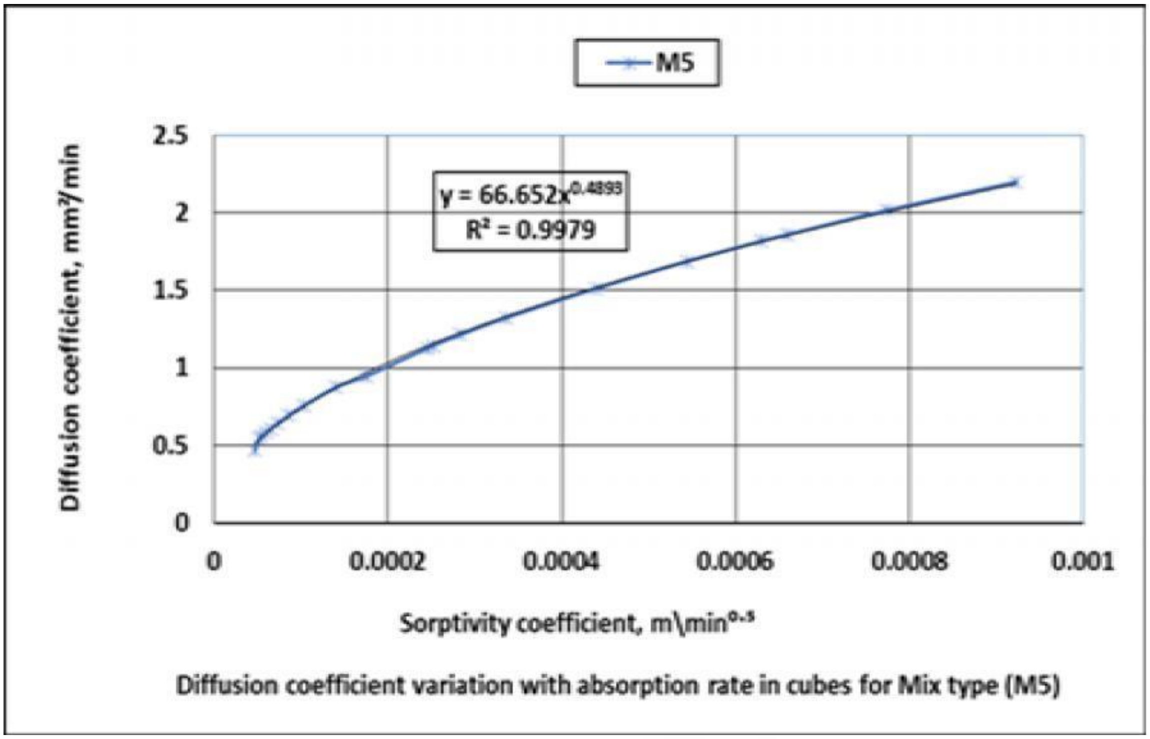


**Figure 11** Water diffusion and sorptivity coefficient (M5)

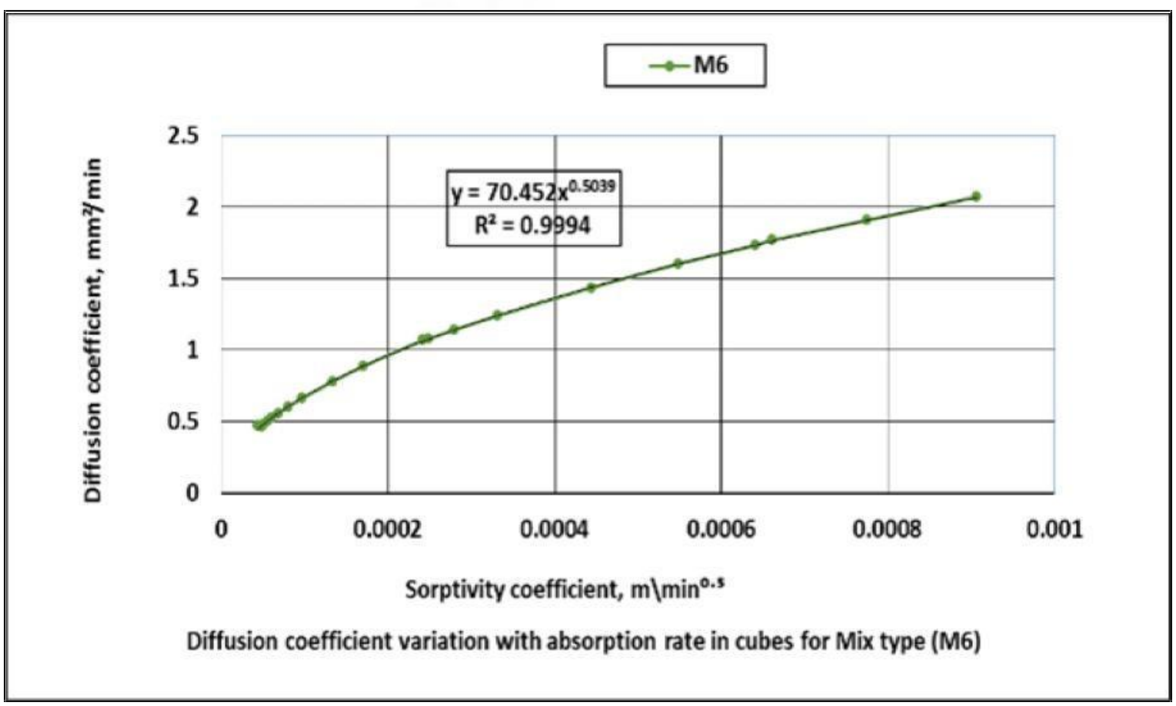


**Figure 12** Water diffusion and sorptivity coefficient (M6)

The water diffusion coefficient is lesser at an initial stage when the rate of absorption (sorptivity) is lesser at an initial stage for in case of all mixtures type. It's also confirmed from the results that, the variation of water diffusion coefficient with sorptivity coefficient is slightly more/less for in case of higher compressive strength and varied slump. But in the case of lower compressive strength and constant slump, the variation of water diffusion coefficient with sorptivity coefficient is slightly higher for in case of lower compressive strength and constant slump and goes on decreases with increased compressive strength and constant slump value for in case of designed mixtures type. The drying test on cement mortar and concrete specimens is carried out in order to evaluate water movement behaviour in cement based material. It's clear from the results that, the temperature dependency of water diffusion coefficient is controlled by power law and the aggregate size doesn't have much impact on water diffusion coefficient as confirmed by researchers [22]. The water movement in concrete structures is one of the most important factor for their concrete durability and service life. Even though, an extensive study of water movement in concrete is carried out, it's still needed for design and maintenance of concrete structure for its longterm service periods. Experimental study of water movement is firstly developed by [23]. He used BoltzmannMatano method for obtaining the relation of water content and water diffusion coefficient. In fact there is a difficulty in obtaining water movement phenomenon in concrete, because it takes too much time to obtain equilibrium than those of other porous materials. Therefore, compared to other methods, Boltzmann-Matano method has a benefit regarding cement based material research. The dependency of water diffusion coefficient on the water content is indicated by numerical approach of [24]. It is consequently suggested that moisture diffusion from the interior of concrete is closely related to the moisture content of the concrete. More precisely, in the range of high moisture content, the diffusion coefficient falls sharply with decrease in moisture content, but with moisture content below 70 to 80%, it may be considered to be more or less constant. Furthermore, an extensive is done researchers on water movement [25-27]. They used different approaches to obtain the relationship between water content and water diffusion coefficient, and obtained consistent results to those by Sakata. In addition to these results, they found the temperature dependency of water diffusion coefficient, water diffusion coefficient in very low water content region, and water diffusion coefficient of desorption and adsorption processes. Thus in the present research work that, at higher moisture content the water diffusion coefficient is decreased for in case of constant higher concrete compressive strength and varied slump value as observed from the Fig.13. It's also true that for in case of varied concrete compressive strength and constant slump value, the water diffusion coefficient is decreased with increased moisture content as observed from the Fig.14 respectively.

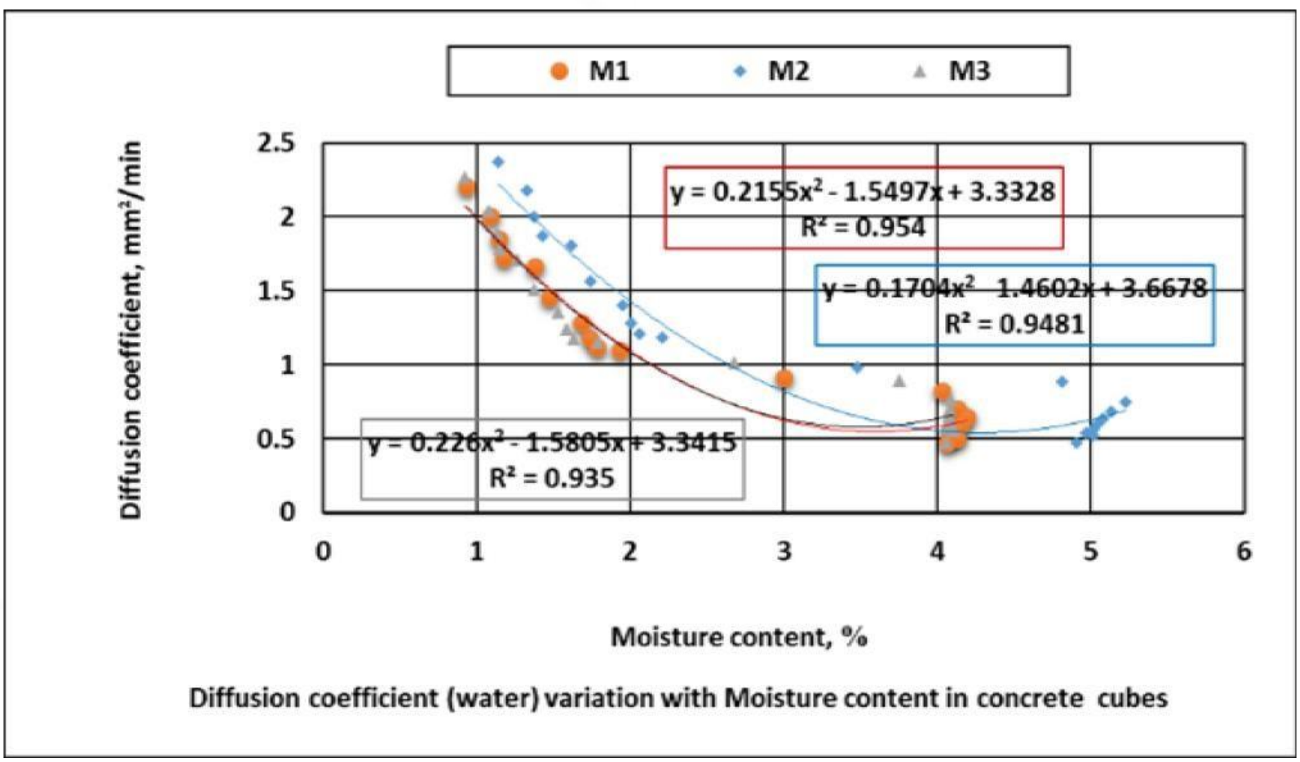


**Figure 13** Water diffusion coefficient and moisture content

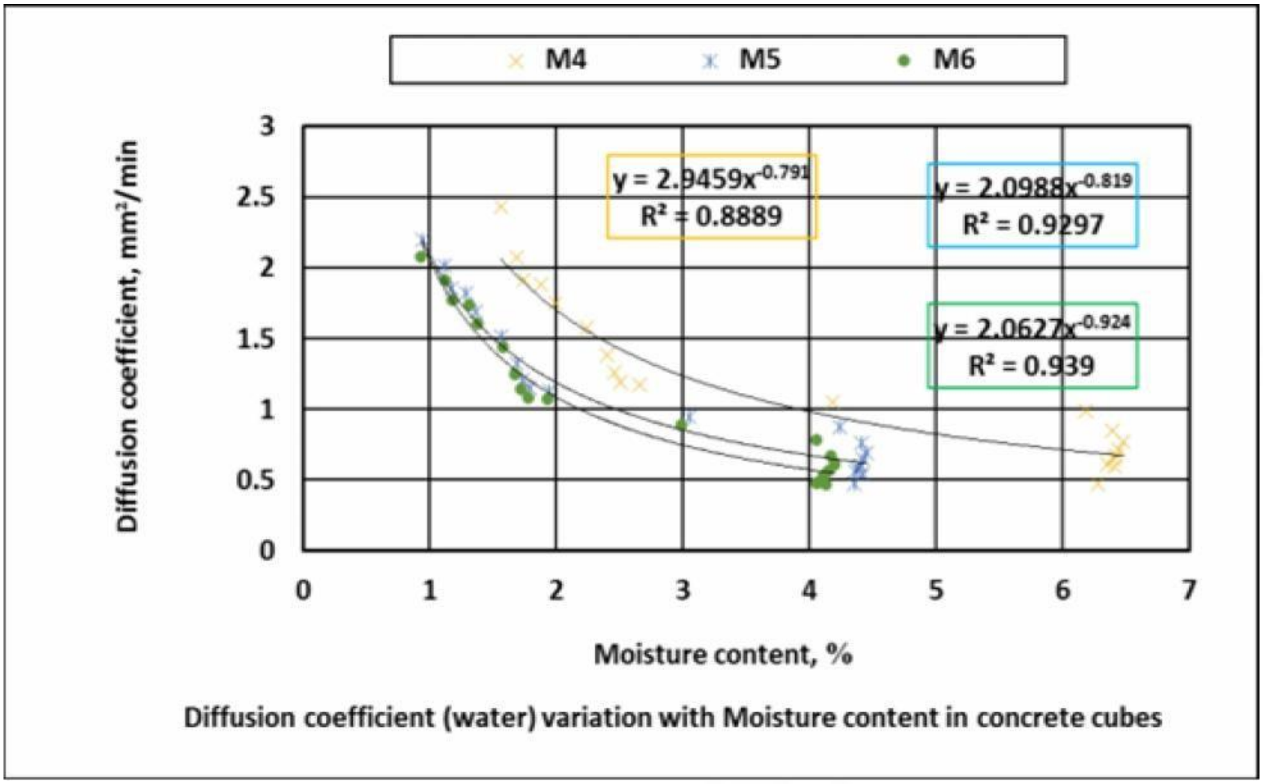


**Figure 14** Water diffusion coefficient and moisture content

## 5. CONCLUSIONS

As from this research work that, it's possible to establish power type of equation relationship between water sorptivity coefficient and square root of time in designed mixtures type. The water sorptivity coefficient is pre-dominantly increased at an initial stage as when compared to longer time duration for in case of all mixtures type. It's also confirmed from the results that, the water sorptivity coefficient is significantly decreased for in case of higher compressive strength and varied slump. But in the case of lower compressive strength and constant slump, the variation of water sorptivity coefficient with square root of time is slightly higher and goes on decreases with increased compressive strength for in case of designed mixtures type.

In fact, from this research work that, it's possible to establish power type of equation relationship between water diffusion coefficient and sorptivity coefficient in designed mixtures type. The water diffusion coefficient is lesser at an initial stage when the rate of absorption (sorptivity) is lesser at an initial stage for in case of all mixtures type. It's also confirmed from the results that, the water diffusion coefficient is co-related with sorptivity coefficient, in turn the average variation of water diffusion coefficient with 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 variation of water diffusion coefficient with sorptivity coefficient is slightly higher in case of lower compressive strength and constant slump and goes on decreases with increased compressive strength for in case of designed mixtures type.

From this research work that, it's possible to establish polynomial type of equation between water diffusion coefficient and moisture content with constant higher concrete compressive strength and varied slump value for in case of designed mixtures type. Finally, from this research work that, it's possible to establish power type of equation between water diffusion coefficient and moisture content with varied compressive strength and constant slump value for in case of designed mixtures type. The water diffusion coefficient is increased at an initial stage with lesser moisture content for in case of lower compressive strength and constant slump value and goes on reduced with pre-dominantly increased moisture content. But it's also confirmed from the results that, the water diffusion coefficient is slightly decreased at initial stage with lesser moisture content and goes on reduced with lower moisture content for in case of for in case of higher compressive strength and constant slump value. Whereas in the case of constant higher compressive strength and varied slump value, the variation of water diffusion coefficient with moisture content is slightly increased at an initial stage with lower moisture content and goes on decreases with increased moisture content for in case of constant higher compressive strength and varied slump value for in case of designed mixtures type.

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