Influence of silicone-based hydrophobic admixture on structural and mechanical properties of concrete mortar

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Abstract - *The influence of organosilicone admixture (alkoxysilanes-siloxane), on concrete hydration, water repellency and compressive strength has been investigated systematically. The concrete mortar hydration process was intensified on the pilot-commercial scale by silicone admixtures, which benefited in bringing down the conventional curing process (water evaporation rate) as well as assisting in good compressive strength. The compressive strength of concrete was increased by 11 % at 0.3 % addition of admixture as compared to reference concrete. Capillary water suction through fine interconnected pores in concrete was reduced significantly and the reduction rate was higher than 80 %. It was observed that used admixtures noticeably extend the initiation period and delay hydration of concrete mortar. These results are further supported by RILEM, Dip and Slump analysis. Additionally, this admixture helps to maintain the workability of fresh concrete and enhance the self-life of concreter mortar with minimum water quantity. These findings are commercially useful, because, high compressive strength, less water consumption, higher workability and sufficient self-life are the essential requirements of the construction industries.*

Key Words: **Silicone admixtures, Alkoxysilanes-siloxane, Concrete applications, compressive strength, water repellency.**

1. INTRODUCTION

The sustainable building strategy places a high value on the better resilience and extended life of building materials and components. Notably for removing the ecological and financial effects of frequent maintenance and repairing work. Hence, continuous development in building material and concrete technology is growing over the past several decades. The substantial use of chemical admixtures and mineral additions is largely responsible for the significant advancement of concrete technology [1]. To produce structural concrete of the highest quality, chemical additives must be used. One of the pinnacles of twentieth-century civil engineering was the development of chemical admixtures for concrete [2]. These admixtures are categorized in accordance with the EN 934-2: 2002 standard based on the results of modifications [3].

Typically, silicates, aluminates, calcium and ferrite-aluminates are the major components of cement and have a specific reactivity toward the water. Its hydration phenomenon causes the setting and hardening of the concrete. Cement hydration is a lengthy process, it can require several years to cure [4]. It depends on the type of cement and blended mineral additives. Once cement and water have been combined, polar water molecules adhere to the surface of the cement grains. The hydrolysis or dissolution of the cement stage occurs before this process and this layer is almost amorphous and forms in a matter of minutes. This layer is mostly made of calcium sulfate and hydrated calcium silicates (C-S-H phases). After saturation is reached, the liquid phase becomes supersaturated with hydrolysis products, which leads to fast nucleation. Consequently, with the crystallization of calcium hydroxide, hydrated calcium silicates develop a solid three-dimensional skeleton. This hydration of cement is an exothermic phenomenon, it might due to the chemical reaction of calcium aluminate, calcium alumino-ferrite, alite and belite. Within the first few hours, this reaction between the cement components and water results in significant amounts of heat release (~ 250-400 kJ kg^{-1}). Because of this heat emission, the hydration process is affected and this can significantly impact the durability of concrete massive structures [3–5].

The hydration of cement can be considerably impacted by admixtures. Products precipitating or solution-derived particles sticking to the surface of cement grains can cause hydration retardation. Numerous papers examine how various admixtures affect how cement hydrates, including water reducers, accelerators, and retardants. However, there is not enough information to determine how waterproofing admixtures like organosilicone affect Portland cement's ability to hydrate. A few researchers have worked to comprehend and explain Portland cement hydration in the presence of polymers [3,6–8]. A polymer coating is created primarily by the adsorbed polymer particles on the surface of the cement grains. It can impede the nucleation of hydration products like C-S-H or the dissolution of mineral phases. By lowering the Ca^{2+} ion concentration in the pore solution, it may delay the precipitation of the hydration product (C-S-H) and therefore lengthen the time needed to achieve the requisite supersaturation. For this, three potential mechanisms for polymer-cement reactions were listed by Ukowski and Kubens [6,9,10]: (1) electrostatic interaction between the polymer and cement grain surfaces, (2) steric hindrance of one polymer adsorbed particle to another adsorbed particle on adjacent cement grains and (3) hydrophilic mechanism in the case of admixtures based on surfactants. The majority of them are started or continue when water is present and filling the pores in the concrete. Concrete should be kept dry or with little water content in order to increase its durability. The usage of hydrophobic admixtures is one approach to achieving this objective.

Typically, organosilicone agents are used as the outside coating. A preferred alternative is to include the hydrophobic additive as one of the elements in the concrete mixture. Therefore, it becomes crucial to understand how these hydrophobic organosilicone chemicals affect the hydration of cement. Organosilicone materials are widely used in the building construction sector. They are used as sealing and protective coating materials, among other things. Organosilicone compounds are frequently utilized in the building sector as moisture protection due to their versatile characteristics. Therefore, the objective of this study is to investigate the effects of organosilicone-based water repellents on concrete mortar hydration and gain a better knowledge of the interacting processes. In order to create the internal hydrophobic substance, the hydrophobic admixtures are intended to be introduced to the water used for mixing. Further, this study presents an in-depth analysis of concrete hydration, mortar workability and water evaporation of concrete blocks prepared from portland cement, crushed sand, coarse aggregate and silicone admixture. This study also explores the water repellency property and compressive strength of the resulting concrete blocks.

2. Material and Method:

2.1. Materials

In experimental studies, crushed mining sand that was accessible locally was used as the coarse aggregate. Table 1 displays certain fractions of crushed mining sand in various sizes. The respective ranges are specified in IS 383. Ordinary Portland cement (ASTM Type I) from Birla Super and crushed sand was used as the main binder. Normal tap water was used for concrete preparation and curing purpose. To prepare integral water repellent concrete, during the mixing process 0.1 %, 0.2 %, 0.3 % and 0.4 % silicone admixture was added to fresh concrete. The silicone admixture was an alkoxysilanes-siloxane emulsion (LK-Aqua Em-290) with 35 % active substances, manufactured by Elkay Chemicals Pvt. Ltd. Pune, Maharashtra India (ELKAY SILICONES). The physical properties of major constituent material are shown in table 2. Particular tests were performed in Cetrs lab, Pune, Maharashtra, India (An NABL accredited laboratory).

Table1: Classification concrete raw materials

Test	Sieve size	Weight Retained	Passing Weight	Passing %	Aggregate Passing %	Specification IS 383 (1970)
Crushed aggregates fractions	40 mm	0	0	0	100	100
	20 mm	86.2	98	1.96	97.12	95-100
	4.75 mm	0.1	2954	56.08	39.4	30-50
	600 mic	51	4362	87.24	12.52	10-35
	150 mic	25.2	4779	95.58	4.5	0-6

Table 2. Physical properties of concrete raw materials

Test performed	Results	Acceptance limit	References
Specific gravity- 20mm	2.89	2.85-2.90	(IS 2386-III)
Specific gravity- 10mm	2.85	2.85-2.90	(IS 2386-III)
Water absorption - 20mm	0.97	< 2 %	(IS 2386-III)
Water absorption - 10mm	1.14	< 2 %	(IS 2386-III)
Aggregate impact value	9.89	< 30 %	(IS 2386-IV)
Dry loose bulk density CA-20mm	1567 kg/m3	-	-
Dry loose bulk density CA-10mm	1575 kg/m3	-	-
Physical properties of cement			
Initial setting time	27 min	30 min	(IS 4031)
Final setting time	284 min	600 min	(IS 4031)
Fineness of cement	1.90%	< 10 %	(IS 4031)
Soundness of cement	1.20 mm	< 10 mm	(IS 4031)
Strength of cement (28 days)	61.30 N/mm2	-	(IS 4031)
Physical properties of silicone base admixture			
Parameter	Results	Method	
Appearance	Milky White	Visual	
Active content	35%	ASTM D2834-95	
pH	6	pH meter	
Viscosity	52 cps	B5 Cup viscometer	
Solvent	Water	Visual / Centrifuge	

(Where, IS 2386- III: Indian standard, method of test of aggregate in concrete part 3;

IS 2386- IV: Indian standard method of test of aggregate in concrete part 4; IS 4031: Indian slandered method of test of cement in concrete)

2.2. Methods

All concrete mixtures were prepared in the pilot-laboratory. The mixture design procedure was adopted from M-20 grade concrete process and maintained a water to cement ratio (w/c) of 0.55. The detailed mixture proportions of the concrete studied are given in Table 3. The proportion of cement, sand and other material was modified to achieve a compressive strength of more over 33 N/mm^2 after 28 days. The absolute volume of the constituents was used to determine the characteristics of the materials.

Table 3: Concrete mixture proportion.

W/C ratio	Portland cement	Sand	Fine aggregate (10 mm)	Coarse aggregate (20 mm)
0.55	335 Kg/m^3	763 Kg/m^3	480 Kg/m^3	720 Kg/m^3
	1	2.28	1.43	2.15

Five types of concrete mortars were prepared. Including one reference sample and four silicone admixtures based mortar. The admixture includes reactive polysiloxanes applied as a water emulsion. Alkoxysilanes and siloxanes are the active components. Amount of added hydrophobic admixture was 0.1 %, 0.2 %, 0.3 % and 0.4% (weight/weight). The details of mixture proportions are given in Table 4.

Table 4: Silicone admixture and concrete mix proportion.

Mixer	Description	Silicone admixture (%)	Cement (Kg/M^3)	Sand (Kg/M^3)	Fine aggregate (Kg/M^3)	Coarse aggregate (Kg/M^3)	Water (lit/M^3)
M0	Reference sample-M20 grade	0	335	763	480	720	203
M1	M20 + Silicone admixture	0.1	335	763	480	720	203
M2	M20 + Silicone admixture	0.2	335	763	480	720	203
M3	M20 + Silicone admixture	0.3	335	763	480	720	203
M4	M20 + Silicone admixture	0.4	335	763	480	720	203

The manufacture of concrete blocks consists of three basic processes: mixing, moulding, and curing.

1. Mixing: For homogenous mixing of all the concrete raw material, used a rotary mixer. It consists of revolving drum or square box, rotating diagonal axis with deflector and bled to improve the mixing.

2. Moulding: In a specialized cube mould, size: 150 X 150 X 150 mm, that specify the shape and size, the mix material was compacted. The device has mechanical vibrations, which compacting the concrete block. Three layers of filling, each measuring four inches, totaled about one-quarter of the height of the mould. Twenty-five strokes of the rounded end of the tamping rod are required to tamp each layer. The strokes must be dispersed evenly across the mould's cross section, and for the second and subsequent layers, they must pierce the layer below (Fig. 1).

3. Curing: After blocks established in mould machine, the blocks were put in shady place and allow the cubes to dry at a temperature of 24 ºC ± 2 ºC for 24 hours. The newly laid blocks are kept out of the direct sun. The blocks were arranged in a stockpile the next day, and then new water was poured over them to ensure that the chemical reaction between Portland cement and water went smoothly.

Fig. 1. Casting of concrete blocks

To create blocks with the required qualities, the three procedures mentioned above must be subject to systematic quality control. To guarantee that the blocks are properly cured and reach the required strength, the curing process was watered. In addition to quality control, the plain concrete block will keep evolving by architects and manufacturers to create new approaches or methods. Buildings will be constructed more quickly, more robustly, and more affordably with these innovative techniques. After curing, remove the concrete cube from the mould. The specimens were weighed and submerged in water for curing. Regular tap water was utilized and it was not saturated with lime. The curing temperature was maintained to 23.0 ± 2.0 ºC. The variation in percentage of water may affect the compressive strength of concrete and hence concrete blocks were made with different water percentages (Fig. 2).

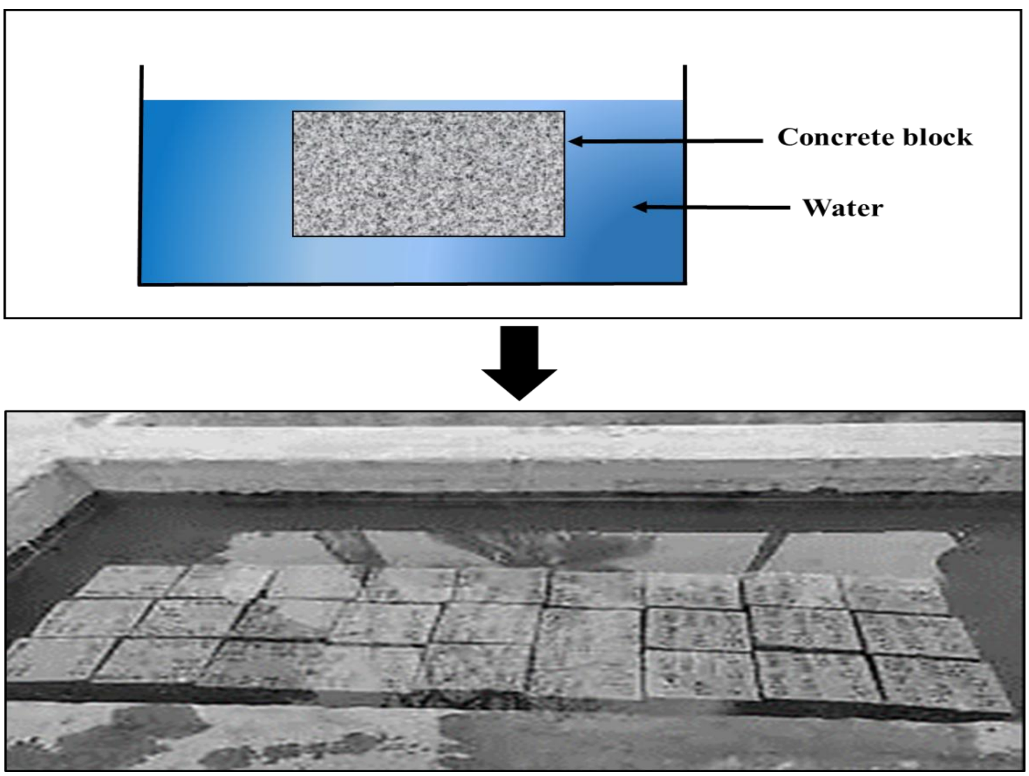

Fig. 2. Curing of concrete blocks

2.3. Experimental methods

2.3.1. *Slump Test:*

The slump test is used to gauge concrete's consistency. The results of a slump test reveal if concrete in various batches is uniform. Concrete slumps' shapes reveal details about the material's quality and usability. Making a few tamping or blows by tapping a rod on the base plate can also be used to assess the qualities of concrete with regard to its inclination to segregate. The approach was used to determine the slump wasASTM-C143. The Slump cone's design demonstrates how easily concrete can be worked. The proportions utilised for a metallic cone-shaped mould are 20 cm at the bottom, 10 cm at the top, and 30 cm at the height. A 600 mm long, 16 mm diameter steel tamping rod with a bullet end. The frustum cone is filled with concrete. After removed the frustum cone, the resultant change in height of concrete is defined as slump value.

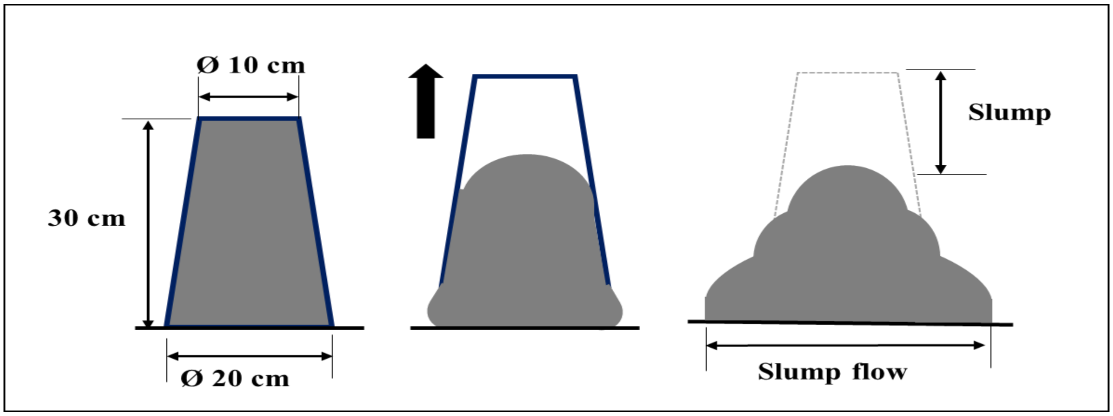

Fig. 3. Fundamental of slump test method

2.3.2. RILEM test for water repellency performance

Water repellency and capillary suction of water performance was assessed using RILEM test. ASTM E 514 outlines the accepted procedure for calculating water infiltration and leakage through brickwork. Here, the flat, circular brim of the pipe was placed between a piece of putty tape and the surface of the concrete blocks to secure the 5 ml tube. Manual pressure was being applied to the cylinder to guarantee adherence. Water was then poured into the pipe's upper open end until the column reached the "0" gradation point. The graduated tube was directly read to determine how much water the substance had absorbed over a predetermined amount of time. The porosity of the material being tested will determine the proper testing intervals; typically, data collected at intervals of 24 hours is the most helpful. By weighing the samples after 24 hours, the amounts of absorbed water were calculated as a function of time.

2.2.3. Dip test method for water repellency performance

Dip test is one of the regular laboratory test method to measure water gain percent. It also indicates the water repellence of concrete blocks with respect to time. This test can be done after the completion of curing of concrete blocks. Initially weigh the dry concrete blocks and dip it in the water tank for an hour. After one hour keep out the concrete block from water tank and dry for two minutes, taken first reading of weight gain. Repeated same procedure and weighed the all concrete blocks in 1hr time interval (i.e. 1 to 8hrs) and calculate the amount of water gain in the all concrete blocks. Make sure keep the same temperature condition for each concrete block.

The percent water gain calculated by following formula;

$$\% \boldsymbol{W} = \frac{\boldsymbol{Iw - Fw}}{\boldsymbol{Fw}} \times \mathbf{100}$$

Where, W = % water repellence in concrete blocks; Iw= Initial weight of concrete blocks; Fw= Final weight of concrete block.

2.2.4. Foot Print: To measure spreading area of water drops on the surface of concrete blocks

The water repellency or water absorbance performance was assessed by measure the footprint area (cm^2) of the water drops on the concrete surface. Herein, taken concrete blocks were having a clean and dry surface. Under room temperature, five to six water drops (have same size and same weight) was put on the surface of concrete blocks. After half an hour measure the foot prints of the every drops of water and calculate the area of the footprint. On the basis of area of drops footprint we conclude the water repellency on concrete blocks.

2.2.5. Water evaporation test

The water evaporation rate of the mortars and effect of silicone admixture on surface cracking of concreate blocks were evaluated and measuring weight loss over time. Record initial weight of concrete blocks and dip in water tank for one day. After 24 hrs, remove all the blocks from the water tank and weigh accurately by maintaining same measurement protocol. To calculate the evaporation rate, measured water loss after every 30 min interval till initial weight of the concrete block.

Percent relative water evaporated calculated by following formula;

$$\% \boldsymbol{R} = \frac{(\boldsymbol{Iw} - \boldsymbol{Fw})}{(\boldsymbol{Iw} - \boldsymbol{Dw})} \times \mathbf{100}$$

Where, Iw= Initial weight of concrete weight; Fw=Final weight of concrete weight; Dw=Dry weight of concrete blocks; R= % relative water evaporated

2.2.6. Compressive strength test

The compressive strength of concrete blocks were examined by compression machine. The technical standard for this method shall be as accordance to the ASTM C-39. Ensure the dimensions and weight of the concrete cube and place it in the compression testing machine. Apply the load till the cube completely crushes or fails and record the same. The compressive strength of the given concrete cube was determined by using the following equation:

$$\mathbf{C} = \frac{\mathbf{l}}{\mathbf{A}}$$

Where, $\mathrm{l} = \text{load}$,$\mathrm{A} = \text{Area}$

3. Results and discussion

Effect of organoilicone admixture on concrete properties

The effect of alkoxysilane-siloxane on the concrete in terms of water repellency and compressive strength properties were evaluated. The silicone-based admixture included in the study, contains a silicone polymer, surfactant and water. This water-based emulsion or dispersions were prepared containing the silicone active of about 35%.

A stable connection between silicon and carbon, nitrogen, or sulfur is one of the distinguishing characteristics of organosilicone compounds. The majority of them show the same characteristics as organic compounds, including being stable, colorless, and hydrophobic. In the majority of organosilicone compounds is tetravalent. The carbon-silicon bond (186 pm) is longer than the carbon-carbon bond (154 pm). Additionally, it has lower dissociation energy (451 kJ mol1) than the carbon-carbon bond (607 kJ mol1), which facilitates simpler atom separation [11]. The C-Si bond becomes more polarized toward carbon due to carbon's stronger electronegativity. Compared to carbon (2.5), silicon (1.8) is less electronegative. Hence, the silicon-oxygen bond acquires an ionic nature. The fundamental building blocks of organosilicone polymers are Si-O-Si, also known as siloxane bonds, and Si-C-Si, also known as silicon-carbon bonds. Organosilicone compounds have a basic structure made up of the polysiloxane chain (-O-Si-O-Si-O), which is composed of silicon and oxygen atoms. In a siloxane chain, the angle between silicon and oxygen is relatively large (approximately 120^{o}). This makes the chain incredibly flexible [11,12]. A repeating group, [R2Si-O], describes the structure of polysiloxanes. Organosilicone compounds are also referred to as "silicones" in everyday speech. They are artificial organosilicone polymers made of siloxane chains, where silicon atoms are joined to alkyl (most frequently methyl or ethyl) or aryl (most frequently phenyl) groups. Along the polysiloxane chain, only one silicon atom has an organic group linked to it. The range of spatial systems that can be generated from basic chains depends on the structure of the substituents [12]. Poly(dimethylsiloxane) (PDMS) is well-liked organosilicone polymers. A silicon atom is bonded to two methyl groups (-CH3) in the high-molecular polymer known as PDMS (Fig. 4(a). The poly-dimethylsiloxane chains can be organised in a helix with the methyl groups facing outward due to the tiny size of the methyl group. The hydrophobic characteristics are brought about by these organic substituents. Polysiloxanes have an amphiphilic character due to an inorganic chain with strongly polar Si-O bonds (Si-O bonds have an ionic character in 50% of cases) and non-polar organic groups connected to silicon atoms. Due to their amphiphilicity, siloxane chains can easily adopt a shape that corresponds to the surface's minimum-free energy [13,14]. A longer organic group chain results in greater water resistance. Fig. 4(b) illustrates the water resistance phenomenon of silicone admixture with concrete mortar.

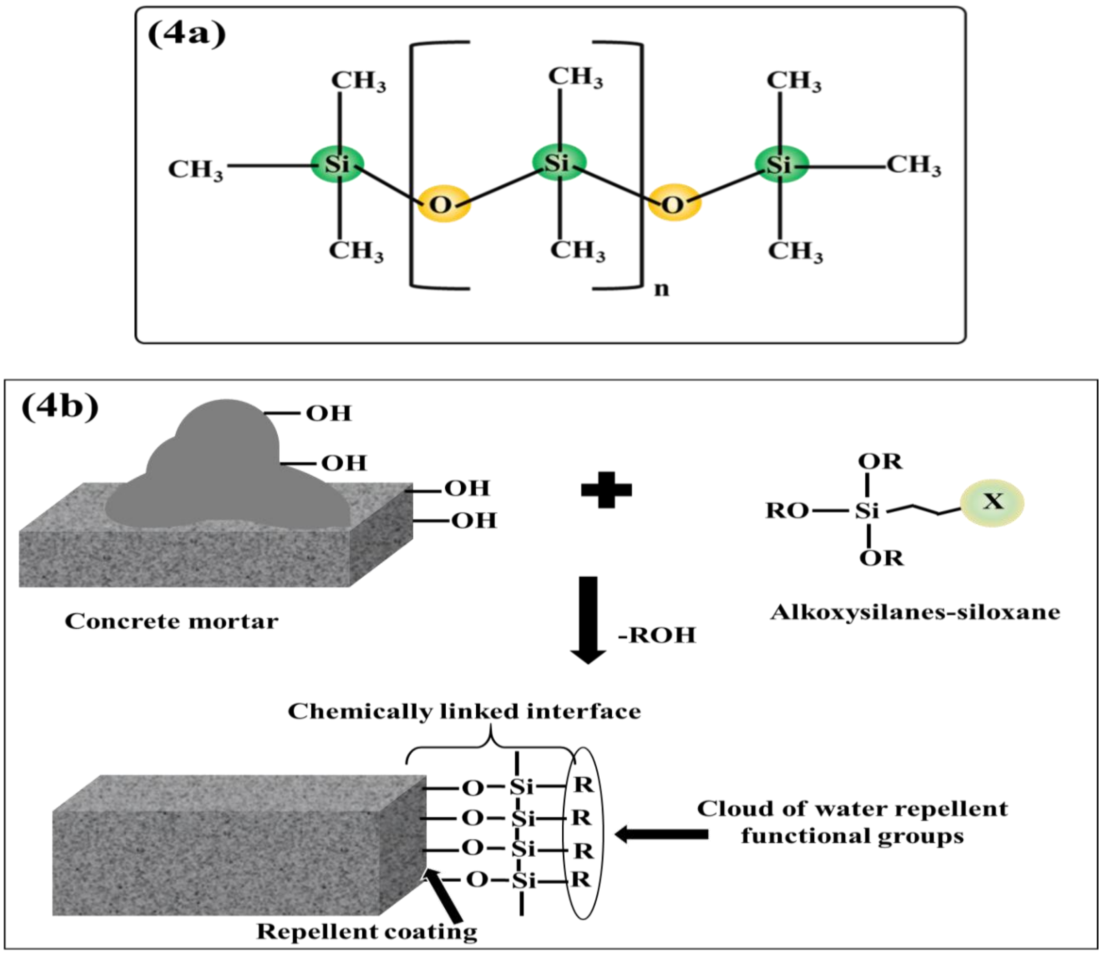

Fig. 4. Organosilicone admixture water resistance phenomenon (a) structure of poly(dimethylsiloxane) (PDMS); (b) water repellent phenomenon of silicone admixture with concrete mortar

4.1. Relation of silicone admixture and slump characteristic of concrete

As described in the methodology, the concrete materials were prepared with and without admixture using a rotary mixer. After 10 minutes of mixing, transfer the homogeneous mass into a pan and analyzed the consistency, workability and fluidity of concrete with the help of a slump test.

The ease with which concrete flows is determined by its consistency, which is a term used to describe the workability or fluidity of freshly formed concrete. The degree of fluidity in the concrete mix is therefore measured on-site using the concrete slump test, also known as the workability test of concrete. Table 5 shows the slump test results of all the concrete samples.

Table 5. Effect of silicone admixture on concrete workability

Mixer	Dose of admixture(ml)	Slump (mm)	Compaction Factor	Degree of workability
M0	Reference sample-M20 grade	45	0.87	Low
M1	M20 + Silicone admixture	77.5	0.91	Medium
M2	M20 + Silicone admixture	98.75	0.974	High
M3	M20 + Silicone admixture	102.5	0.978	High
M4	M20 + Silicone admixture	107.5	0.98	High

The impact of silicone-based admixture on the workability of concrete is clearly differentiated in Fig. 5(a). The slump value of concrete is increasing with increased percentages of silicone admixtures. There is a sharp increase in slump gain as silicone admixture increased from M0 to M2 and then observed small changes in it from M2 to M4. Although, the water parentage was same in all the concrete mixer and still it showed difference slump behavior. This might be because of a change in structural properties of concrete material due to the silicone chemistry. As silicone emphasized concrete mixtures to boost the addition of C-S-H bridges into the mortar. It constitutes the welding points between the granules and other components and also helps in the setting and hardening of concrete [4]. It resulting higher workability, constancy and sustainability to concrete slaps or blocks.

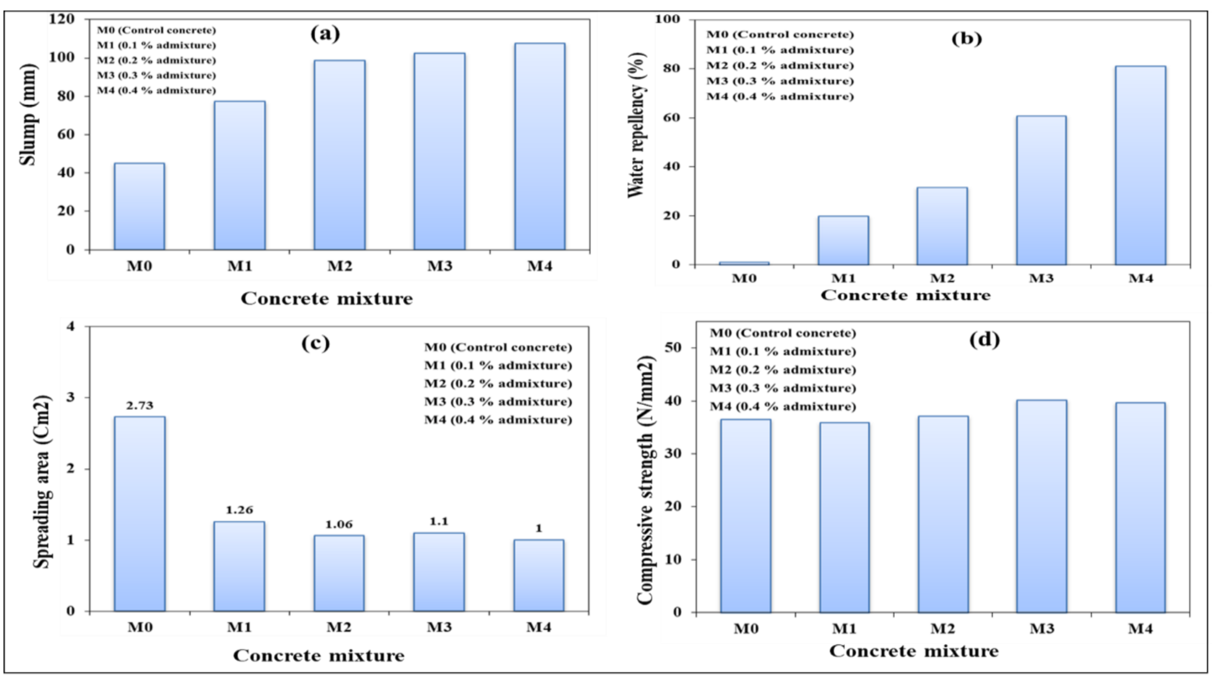

Fig. 5. Effect of silicone admixture on concrete properties (a) Slump test; (b) Relation between silicone admixture and water repellency; (c) Water spreading on the surface of concrete blocks (footprint test); (d) Compressive strength of concrete blocks.

4.2. Relation between silicone admixture and water repellency

The effect of silicone on water repellency was characterized by the RILEM test, dip test and footprint test. These methods provide a simple and effective methodology for measuring the water repellency of concrete blocks within a specified time period. All of the masonry construction materials are porous and water permeable by nature. A network of tiny, linked pores makes up a masonry material's internal structure. A wetting liquid will be absorbed by capillary action into a porous material if it comes into contact with the porous material's surface. This entails capillary conduction (suction), which travels along both vertical and horizontal paths through this pore system. Hence, water penetration (absorption) in concrete with and without the addition of silicone admixture was measured and the results are shown in Fig. 6.

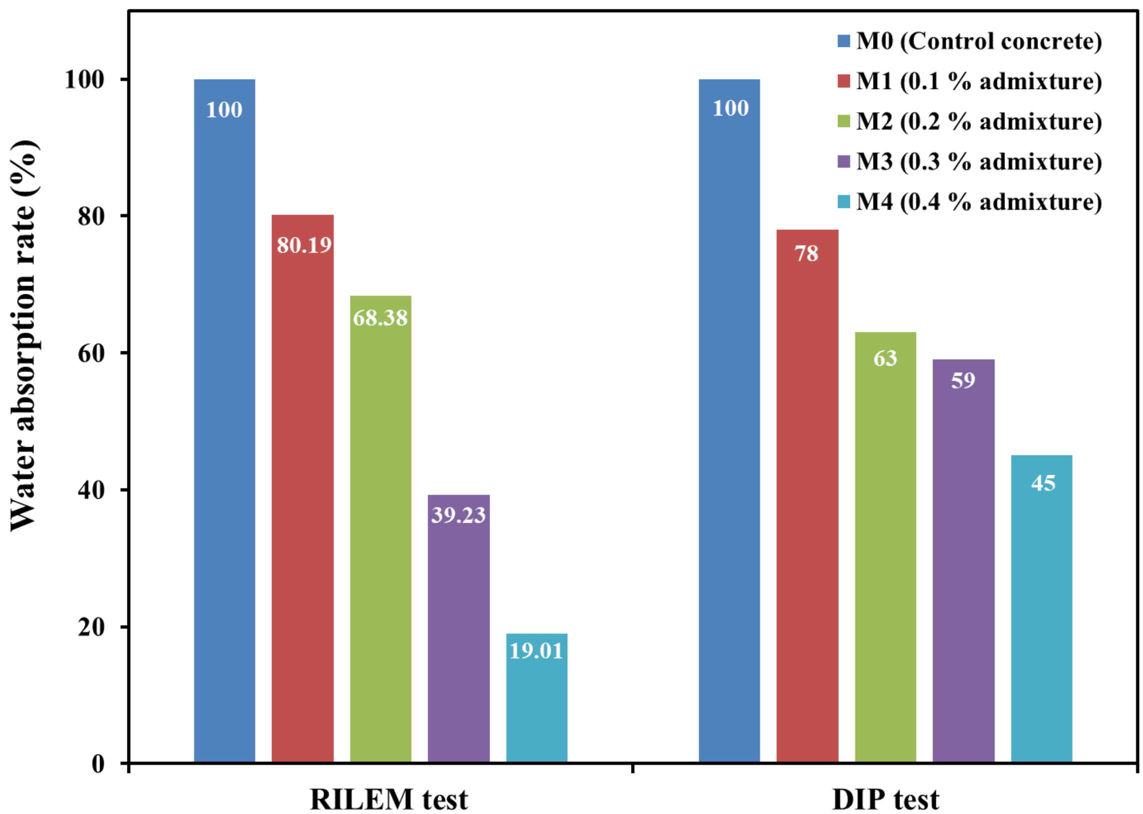

Fig. 6. Relation between water absorption rate and silicone admixture

The reference sample M0 (without silicone admixture) absorbs 100 % water within 24 hrs. On the other hand, silicone admixture with 0.1 % (M1), 0.2 % (M2), 0.3 % (M3) and 0.4 % (M4) showed water gain by 80.19 %, 68.38 %, 39.23 % and 19.01 % respectively. A similar trend of water absorption was found in the dip test. The control (M0) concrete block absorb 100% water within 24 hr and M1, M2, M3 and M4 showed 78 %, 63 %, 59 % and 45 % respectively. It means that there is an inverse correlation between water absorption and water repellency. With increased silicone admixture in concrete blocks, the water repellency percentage was increased (see Fig. 5(b). It might due to the hydrophobic property of silicone admixture. The majority of siloxanes and silanes are made up of tiny molecules that penetrate deeply into the internal pores of the concrete [15]. To give endurance, they interact with the substrate and with one another. After curing, they let water vapor flow but prevent liquid water that might have dissolved acids or chloride ions from penetrating the substrate. Hence, a linear function can be used to explain the amount of water absorbed as a function of the duration of time in contact with the water, as shown in Fig. 7 (a).

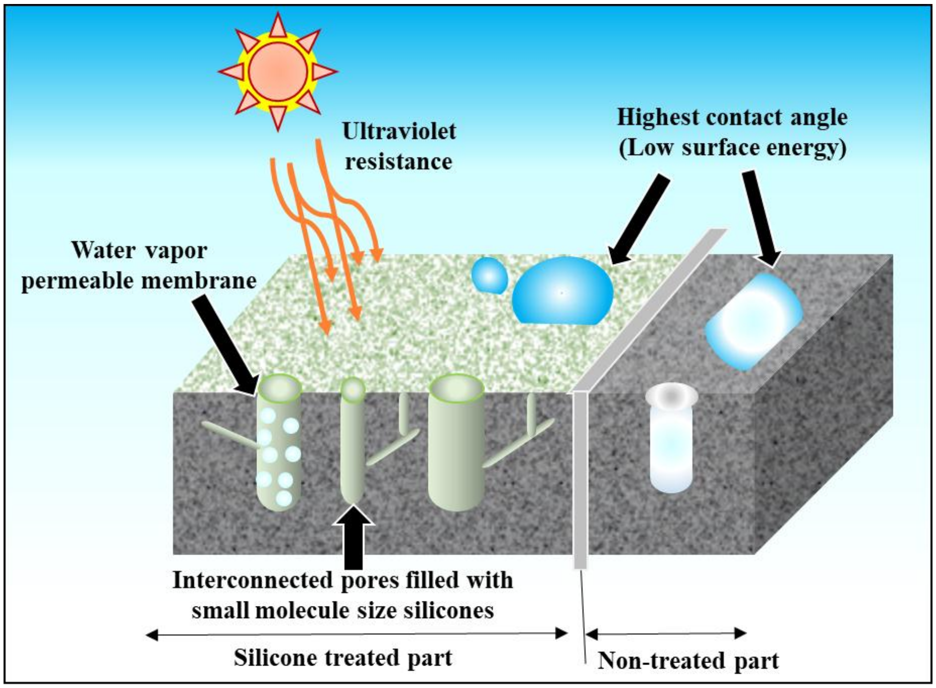

Fig. 7 (a) Water repellency phenomenon of silicone admixture treated concrete.

Fig. 7 (b) Concrete block treated with silicone admixture

Water repellency of concrete blocks was also checked with the footprint area of water drops on the surface of concrete blocks. Fig. 7(b) represent water repellency of silicone treated concrete block. Thus, footprint testing method were applied to quantify the water spreadability and results showed in Fig. 5(c). In which the control blocks (M0) show a larger water spreading area were 2.73 cm^2. On the other hand, concrete blocks content with silicones admixture showed the less water spreading footprint area for M1, M2, M3 and M4 for 1.26 cm^2, 1.06 cm^2, 1.1 cm^2, 1 cm^2 respectively. It means that silicone admixture concrete blocks showed good water repellency and super-hydrophobic surfaces. It might be due to the hydrophobic and low wetting properties of silicone admixture. The interfacial tension between the solid and liquid is low because the interaction between the concrete and water is not that strong. Because, it has high contact angle and low surface energy, which prevents water from spreading out over their surface [13,16]. The wetting angle of water droplets on silicone specimen surfaces can be used to assess these very desirable properties.

4.3. Relation of silicone admixture and water evaporation

Plastic shrinkage, which happens in the first few hours after casting when the concrete is still in a plastic stage, is the volumetric contraction of cement-based materials. Since the material cannot deform freely in constrained overlays, the contraction will produce tensile stresses that could cause surface cracking [17,18].The evaporation of mixing water and capillary pressure inside the cement pores is what causes the majority of plastic shrinkage cracking. Most of the surface evaporation or moisture absorption at the contact with the underlying substrate materials is the cause of the loss of mixing water from the fresh material. Specific environmental factors, such as low relative humidity, high temperatures, and exposure to strong winds, can worsen plastic shrinkage cracking severity by increasing the rate of water evaporation. It is crucial to prevent the emergence of this kind of cracking since it can cause severe surface cracks to form on the material as a result of large plastic shrinkage deformations, which will harm the material's long-term durability.

Addition of any kind of admixture in mortar may affect the water evaporations phenomenon. Hence, effect of silicone admixture on water evaporation rate were evaluated and are illustrated in Fig. 8. The weight loss of unrestrained mortar specimens prepared with different silicone admixture concentration. The figure shows that, when compared to the reference specimen without silicone admixture, the addition of silicone admixture (M4, M5) obviously creates a considerable difference in water evaporation (M0). The evaporation rate was a little bit slower for specimens M2 and M3. The concentration effect with a smaller percentage silicone admixture was presumably to blame for this. Hence there is a direct correlation between water evaporation tendency of silicone admixture and water repellency test. It was therefore concluded that alkoxysilanes-siloxane is highly suitable as mortar admixture for concrete, because it enhanced the concrete water repellency and significantly water evaporation rate.

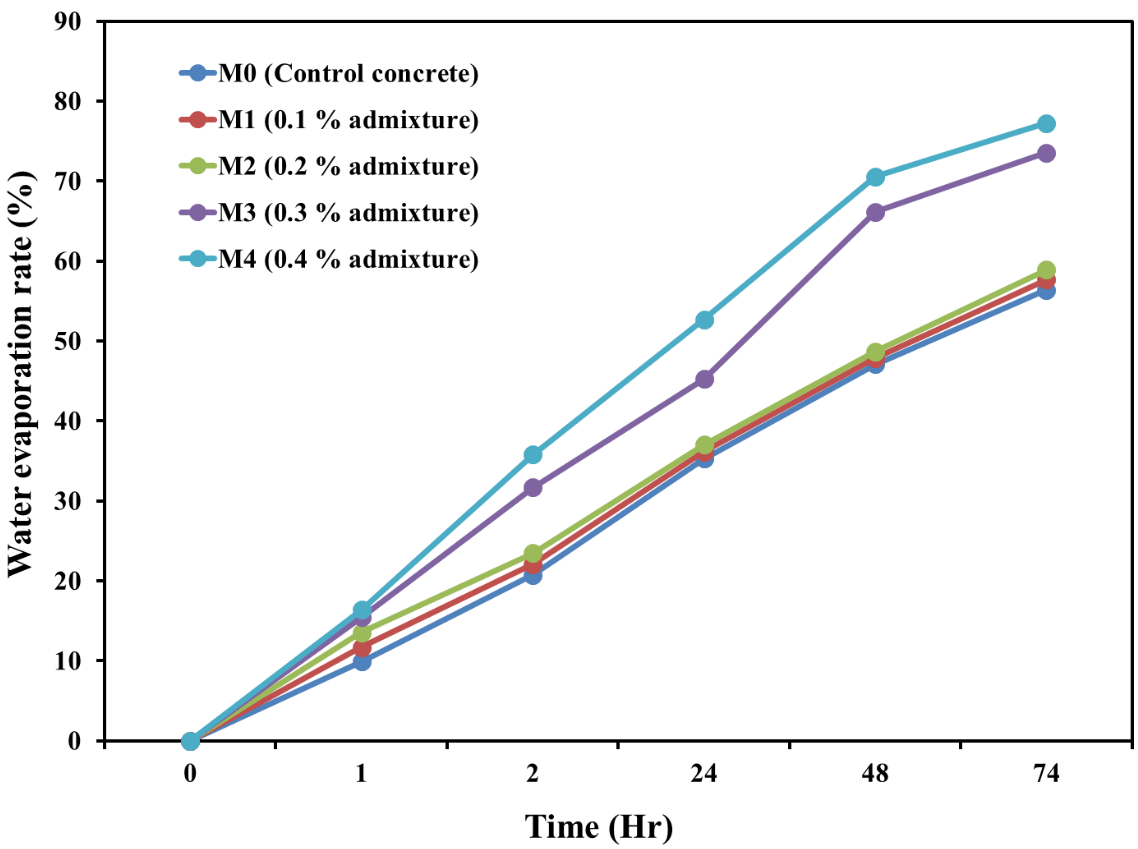

Fig. 8. Water evaporation rate of mortar specimens prepared with different silicone admixture %.

Higher water evaporation rate generate tensile stresses that may result in surface cracking. Hence, effect of silicone admixture on surface cracking were evaluated and are illustrated in Fig. 9. It can clearly see in figure, the concrete blocks surface are intact and does not have any surface cracks. It means that, use of silicone admixture in mortar, which doesn't influence the surface morphology during curing and water evaporation.

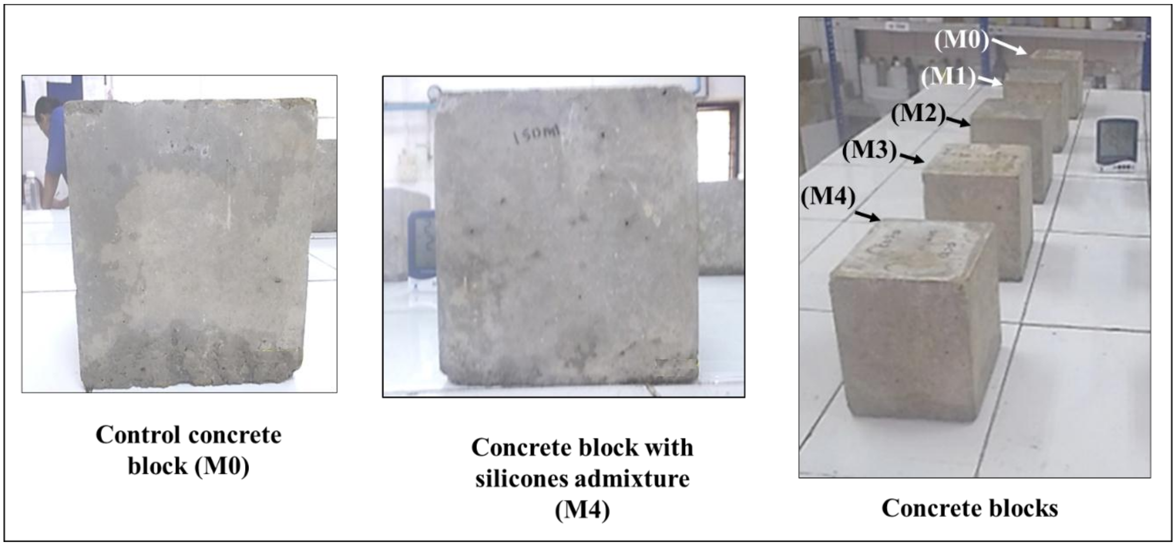

Fig. 9. Effect of silicone admixture on surface cracking of concrete blocks.

4.4. Relation between silicone admixture and compressive strength

The test for concrete block compression strength reveals whether or not concreting has been done correctly. After 28 days of curing, these specimens are evaluated using a compression testing equipment. To fracture the specimens, a load should be given progressively at a rate of 150 kg/cm^2 per minute. Concrete's compressive strength is calculated by dividing the load at failure by the specimen's surface area. The minimum compressive strength for M-20 grade of solid concrete blocks are 20MPa. Numerous variables, including the water-cement ratio, the type and quantity of concrete used, and the manufacturing process, affect compressive strength. Also, compressive strength of concrete is very much depending upon the hydration reaction. The major component of Portland cement is calcium silicate, which contributes to the strength of concrete. The majority of concrete's initial strength is due to tricalcium silicate. Hardening is the process of strength growth and may continue for week or months after the concrete has been mixed and placed. Hardening is done largely to the formation of C-S-H bonding as to cement continues to hydrate. The rate at which water molecules permeate through the calcium silicate hydrate layer now determines how quickly the process proceeds. Hence, Fig. 5(d) represents the results of the compressive strength of M-20 grade of concrete blocks. In which all the blocks pass the compressive strength test. As control block (M0) has compressive strength is 36.5 N/mm^2 and concrete blocks with silicone admixture of M1, M2, M3 and M4 have 35.9 N/mm2, 37.1 N/mm2, 40.19 and 39.7 N/mm2 respectively. Over all admixture used in the concrete enhances the compressive strength of concrete.

Overall, an interesting relationship can be observed in all the structural changes of concrete blocks such as % water absorption, % water repellency and compressive strength. Their interrelation can be seen in Fig 10. It has been seen that drop-in water absorption of concrete, resulted in an increase in water repellency and compressive strength due to the hydration phenomenon as discussed earlier.

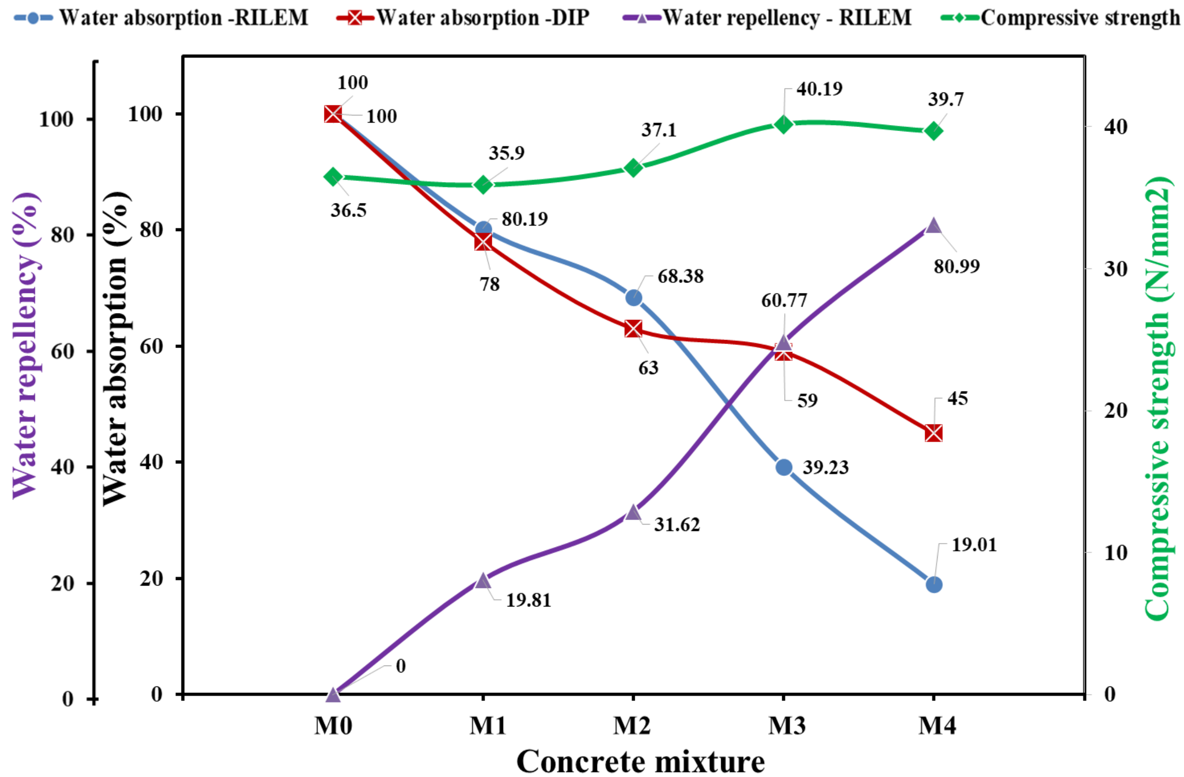

Fig. 10. Correlations between % water absorption, % water repellency and compressive strength at different silicone admixture %.

Fig. 10, shows the steep drop in the % water absorption with increased of silicone admixture %. This impacted the increase in % water absorption in a similar manner. This significant differences in the structural changes were observed in compressive strength [19]. Silicone admixture impacts the hydration phenomenon of the concreate during curing. The concrete materials has porous interior structure with fine interconnected voids. Silicones are penetrating in this voids and forming a protective repellent layer within the substrate. It enhanced water vapor transmission rate through pores and capillaries. It significantly improves tensile stresses of concrete and resulting higher compressive strength.

5. Conclusions:

New developments in construction industries with silicone admixture technology provide expanded options for creating stable sustainable building materials. Silicone admixture offer versatility for building materials as well as concrete materials, presenting new opportunities for cost-effective and highly innovative construction material. The use of alkoxysilanes-siloxane in concentrations higher than 0.3 %, showed an important influence on the water absorption and other properties of the concrete material, increasing the compressive strength by the water repellency phenomenon. The following conclusions can be taken from the collected results and the debate that was previously presented:

– Alkoxysilanes-siloxane is added to concrete to boost its compressive strength. When admixture is added at a rate of 0.3%, the increase above control concrete is around 11%.

– Alkoxy silanes-siloxane can be added to the fresh mix in sufficient amounts to greatly lower the capillary water suction of concrete. Over 80% of the reduction has already occurred. Even after 2–7 mm of its surface abraded removed, integrated water repellent concrete still exhibits significant hydrophobic properties.

– The surface of concrete blocks are remain intact and does not have any surface cracks. It means that, use of silicone admixture in mortar, which doesn't influence the surface morphology during curing and water evaporation. This could potentially increase the service life of reinforced concrete structures and reduce frequent maintenance and repair of conserving resources.

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