Effect of hydrophobic agent in cement and concrete: A Review

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Abstract. Hydrophobic agents have been used in cement and concrete to reduce water penetration in concrete since many years. Hydrophobic agents are the materials that are employed in cement for enhancing the contact angle between the water and the concrete surface. Fatty acids and their fractions have been introduced in the cement as either phase change materials or as an admixture to minimize water ingress into concrete. Many alkenes, oils, fats, and greasy substances come under the category of hydrophobic molecule. Due to reduction in water permeability, hydrophobic agent enhances the durability and aesthetic appearance of the concrete. Since the mid-20th century, hydrophobic concrete found much popularity in building and construction. Hydrophobic are non-polar and lipophilic substances exhibit high contact angle thereby minimizes the rate of detrimental reactions. This article presents an overview of the work that has been carried out on the application of hydrophobic agents in cement mortar and concrete.

Keywords: Hydrophobic agents; penetration; durability; permeability

1. Introduction
Penetration of water and water pollutants like chlorides and sulfates are the main concern towards the damage of concrete structure. Therefore, there is an urgent need for minimizing the uptake of water in concrete structures to overcome this damage[1]. From the past studies, it has been noticed that lots of treatment and new technologies have been adopted to protect the concrete surface[2]. Among the numerous techniques used for safeguarding concrete surface, incorporation of hydrophobic agents has been the one which is least harmful for concrete structure. Hydrophobic agents have been used in concrete to suppress the capillary absorption of water. Entering of water born aggressive has been forbidden by these agents helping in drying the interior over time. Most of the detrimental reactions in concrete take place when water reacts with the cement in the concrete. This ingress of water has been forbidden by introducing hydrophobic agent in it. This will finally improve the durability of concrete structure. Proper details of different kind of treatments that have been applied to concrete structures are very less.[1] Some authors incorporated polymeric fibers to the cement paste to minimize water penetration and to make hydrophobic cement for building material[3]. Structure built with hydrophobic cement found to have larger durability, self-cleaning ability, and resistance to paints[4]. When hydrophobic agent used as an admixture, minimizes lengthen capillary water absorption in cement paste by approximately 70%. Hydrophobic admixtures increase the setting time of cement pastes for mixes. hydrophobic agents minimizes the chloride diffusion coefficient to a lesser extent (app. by 11% - 17%)[5]. some author used waste paper sludge ash as a hydrophobic agent and performed various experiments like workability, strength, sorptivity, water absorption, diffusivity, permeability, electrical conductivity etc., it has been reported that hydrophobic Paper sludge ash lessened absorption and sorptivity by 85–99%. Mortar surface having hydrophobic PSA shows excellent water repelling and self-cleaning properties[6]. Recently, many researchers using bacteria in concrete to enhance the durability and minimize the cracks[7]–[9]. Physical and mechanical properties of cement by incorporation of oleic acid, iminodiacetic acid in cement as an admixture has been reported by some authors[10][11]. Incorporation of 0.5 % of vegetable oils by dry cement weight seems to be the most economic hydrophobizing agents [12]. For resisting high alkaline environment, heat, UV radiation and low temperature in concrete, hydrophobic agents are mostly applied to concrete[13][14].

2. Characterization of hydrophobic agents

Hydrophobizing agents are the chemicals that are capable to develop a thin hydrophobic layer within the pores and voids and on concrete surface. Some of the chemicals that has been used as a hydrophobic agents are

- Stearic acid, C17H35COOH Oleic acid, C17H33COOH , Capric, C9H19COOH, acids and Vegetable and animal fats, Butyl stearate (ester), Caprylic, C7H15COOH etc[15][12][16]. These are the chemicals that reacted with the cement properties during its hydration.

- Extremely fine wax emulsions are very effective towards hydrophobicity in cement. Whn alkaline pore water of concrete comes in contact with wax emulsion, it forms a hydrophobic layer after coalescence. Emulsion of synthetic polymers (like latex) have also finds its major effect on various properties of concrete like air entrapment, workability, retardation etc. Latices powder found its
major use in repairing mortars, improving adhesion between old and fresh concrete. Latices found to have a stronger network than waxes.

- Silane (SiH4) is a chemical compound, that often used as a hydrophobizing agents that has been mostly implemented to the surface of existing concrete structures, and rarely used for fresh concrete surface. Silane found to be more expensive than fatty acids and vegetable oils.
- Siloxane, Calcium stearate, Aluminium stearate, Bitumen in finely divide form and vegetable oils, esters can also be used as a hydrophobic agent.

3. Effect of hydrophobic agents on properties of cement

Different authors reported distinct effect on mechanical and chemical properties of cement and concrete by incorporation of hydrophobic agent in cement and concrete as given as follows:

3.1 Compressive strength

When the dosage of hydrophobic agent reached to 1% having cement sand ratio of CPB was 1:6 or 1:10, the compressive strength of the Cement paste backfilled block has been found to be much better than without agent[17]. Compressive strength of cement pastes backfilled blocks having different dosage of hydrophobic agent has been shown in fig. [17]Concrete treated with a concentration of 1% of when 1% and 2% of hydrophobic agent LYN-1 incorporated in cement, enhancement of 75% 81% respectively in compressive strength were achieved in hydrophobic concrete cubes[18]. When unsaturated fatty oils and their acid fractions like oleic acid, linoleic and linolenic acids used as a grinding aid in cement industry, compressive strength of the normal concrete significantly decreases (as shown in fig.1). Compressive strength of normal concrete increases with the increase in chain length of saturated oil (stearic acid, myristic, acid, lauric acid)[19]
3.2 Carbonation Resistance

Vikan and Justnes (2006) reported the carbonation resistance of 3-year-old mortar specimen incorporated with vegetable oil and found that carbonation depth for oil incorporated mortar has significantly greater than that of control specimen[12]. Fig. 2 shows the carbonation depth of mortar incorporated with different dosage of acids.
3.3 Water contact angle

Initial water cement ratio (w/c) and the degree of cement hydration are the two important parameters on which pore size distribution of Portland cement depends. Normal Portland concrete has pore size in the range of 0.05-1.0 μm (diameter). Water from external sources enters the concrete surface through these pores by the action of capillary rise phenomenon. From the literature survey, it has been noticed that incorporation of hydrophobizing agents in cement, the concrete surfaces got a layer of molecules or coalesced or different particles. Hydrophobic agents in concrete have high contact angels to water (as shown in Fig. 3). Wetting behavior can be hydrophobic (WCA > 90°) or over hydrophobic (WCA > 120°)[4]

![Fig.3 (a) Capillary pore without hydrophobic agent][12]
(b) Lined with molecular agent
(c) Lined with an emulsion layer

3.4 Water absorption

When silica-based organic and inorganic hybrid composites like Poly-methyl hydrosiloxane / nanosilica, (PMHS/NS) applied for surface treatment on hardened cement, capillary water absorption of the mortar specimen significantly reduced to 5.4% of the value as that of ordinary mortar specimen. The capillary water absorption of mortar samples after six months age treated by different hydophobic agents has been shown in fig2. Capillary water absorption rate of mortar specimens has been significantly reduced by incorporating hybrid agents. Water absorption rate has been reduced to 66.25 and 71.3% for NS and PMS-treated samples whereas 89.69, 80, 85, and 87.5% for H1.2, H0.95, H0.7, and H0.6 samples after 390 minutes of soaking. Addition of oil in cement also reduces the water absorption of cement mortar and concrete specimen sample (as shown in fig. 4). This reduction in water uptake depends on the concentration of oil or hydrophobic agent used in cement[20]
Fig. 4 Water absorption rate of mortar having different types of hydrophobic agent[20]

4. Conclusion

Based on our finding in the present work, the following conclusion can be made as given as:

Addition of hydrophobic agents in cement and concrete suppressed the capillary water absorption of mortar and chloride diffusion coefficient to a certain extent depending on the dosage of hydrophobic agent. hydrophobic agent in cement and concrete creates resistance towards low temperature, UV, alkalis and acids. these improves water proofing performance and impermeability under normal conditions. hydrophobic agents in concrete develops resistance towards chloride ion penetration and carbonation. Compressive strength of concrete having hydrophobic agent increases with the curing age and depends on the dosage of agent. Density and shrinkage of concrete has been little effected by incorporation of hydrophobic agent. sorptivity of concrete has been greatly reduced by the addition of hydrophobic agent due to large water contact angle to water. Consequently, it can be summarized that incorporation of hydrophobic agent in cement and concrete improves the durability of the concrete.

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