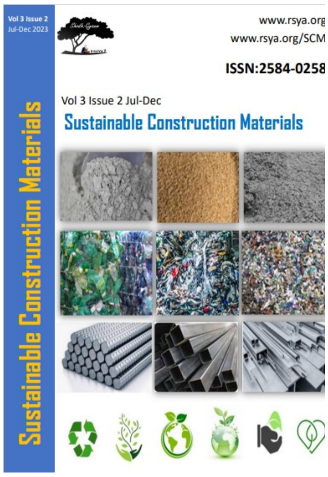

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An Analysis of the Impact of Hydrophobic Agents on Mortar and Concrete

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Abstract:
Hydrophobic additives have long been employed in cement and concrete to mitigate water infiltration. Hydrophobic agents are chemical substances that are incorporated into cement in order to increase the angle at which water comes into contact with the surface of the concrete. Fatty acids and their fractions have been used into cement as admixtures or phase-change agents in order to reduce water infiltration into concrete. Alkenes, oils, fats, and other greasy compounds are commonly classified as hydrophobic molecules. The hydrophobic component enhances the durability and aesthetic appeal of the concrete by reducing its water permeability. Water-repellent concrete has become increasingly common in design and construction since the mid-20th century. The high contact angle of non-polar, lipophilic, hydrophobic compounds reduces the occurrence of unpleasant responses. This article is a concise overview of the research conducted on the application of hydrophobic materials in cement mortar and concrete.

Keywords: Hydrophobic agents; penetration; durability; permeability

Introduction

The primary factors of concern for the deterioration of concrete buildings are water infiltration and the presence of water contaminants such as chlorides and sulphates. Minimise the water absorption of concrete structures to prevent such deterioration[1]. Previous studies[2] have implemented a variety of measures and advanced technology to safeguard the concrete surface. Injecting hydrophobic chemicals has emerged as the most effective method for safeguarding concrete surfaces while minimising damage to the underlying structure. Hydrophobic substances have been employed in the treatment of concrete to reduce water absorption via capillaries. Due to the presence of these compounds, access to any abrasive water is now prohibited, since it has contributed to the gradual desiccation of the interior. The majority of detrimental reactions occur when water comes into contact with the cement in concrete. Hydrophobic chemicals were applied to prevent water infiltration. Ultimately, this will enhance the durability of the concrete structure. Only a small number of descriptions accurately depict the many treatments used for concrete structures. The user's text is a reference to a source or citation. In order to reduce water absorption and create a hydrophobic cement for construction purposes, certain writers included polymeric fibres into the cement paste[3]. Research has demonstrated that the use of hydrophobic cement can enhance the durability, self-cleaning properties, and resistance to paint of a structure[4]. When used as an additive, a hydrophobic component reduces the capillary water absorption of cement paste by approximately 70%. Hydrophobic additives prolong the curing period of cement pastes in mixtures. Hydrophobic compounds saw a rather modest (11–17%) decrease in the chloride diffusion coefficient[5]. Multiple investigations have demonstrated that the utilisation of hydrophobic Paper sludge ash as an agent significantly decreases absorption and sorptivity by 85-99 percent. These studies have examined various factors like as workability, strength, sorptivity, water absorption, diffusivity, permeability, and electrical conductivity. The hydrophobic PSA has remarkable water repellency and self-cleaning properties on mortar surfaces[6]. Recent research has indicated that the presence of bacteria in concrete might mitigate the formation of cracks and enhance its durability[7]-[9]. According to multiple authors[10][11], the use of oleic acid and iminodiacetic acid in cement has been found to improve its mechanical and physical characteristics. Based on the findings of reference [12], it seems that vegetable oils, when used at a concentration of 0.5 percent relative to the weight of dry cement, are the most cost-effective hydrophobizing agent. Hydrophobic compounds are commonly used to concrete to enhance its resistance to severe temperatures, heat, UV radiation, and acidity[13][14].

Characterization of hydrophobic agents

A thin hydrophobic layer can be created on the surface of concrete as well as inside of its pores and voids by substances referred to as hydrophobizing agents. The following chemicals have been used as hydrophobic agents: Butyl stearate (ester), Caprylic acid ($C7H15COOH$), Oleic acid ($C17H33COOH$), Capric acid ($C9H19COOH$), Stearic acid ($C17H35COOH$), etc. [15][12][16]. These are the substances that interact with the characteristics of cement when it hydrates. Highly fine wax emulsions are very good in lowering the hydrophobicity of cement. Wax emulsion coalesces and forms a hydrophobic coating when it comes into touch with the alkaline pore water of concrete. Air entrapment, workability, retardation, and other properties of concrete have all been discovered to be greatly impacted by emulsions formed of synthetic polymers, such Latix. Latices powder is primarily used to repair mortars, which improves the adherence of both new and old concrete. It was discovered that latice networks are stronger than wax networks. Silane ($SiH4$) is a chemical that is typically utilised on the surface of concrete structures that have already been erected and is hardly ever used on freshly poured concrete surfaces. It was shown that silane is more expensive than fatty and vegetable acids. Other substances that can be utilized as a hydrophobic agent include siloxane, calcium stearate, aluminum stearate, bitumen in finely divided form, vegetable oils, and esters.

Effect of hydrophobic agents on properties of cement

The integration of a hydrophobic ingredient in cement and concrete has been documented by many authors to have a variety of different effects on the mechanical and chemical properties of cement and concrete, some of which are as follows:

Compressive strength

When the concentration of the hydrophobic agent was 1% and the ratio of cement to sand in the CPB was either 1:6 or 1:10, it was proven that the compressive strength of the cement paste backfilled block was much greater compared to when the hydrophobic agent was not used[17-20]. The figure [17] displays the compressive strength of cement paste-backfilled blocks with different dosages of hydrophobic ingredient. The addition of the hydrophobic agent LYN-1 to cement at concentrations of 1 and 2 percent resulted in a respective increase of 75 and 81 percent in the compressive strength of hydrophobic concrete cubes [21-23]. When unsaturated fatty acids and their acid fractions, such as oleic acid, linoleic acid, and linolenic acid, are employed as a grinding aid in the cement industry, the compressive strength of conventional concrete is dramatically diminished (as shown in fig.1). The compressive strength of regular concrete is positively correlated with the length of the saturated oil chain, such as stearic acid, myristic acid, and lauric acid [24-25].

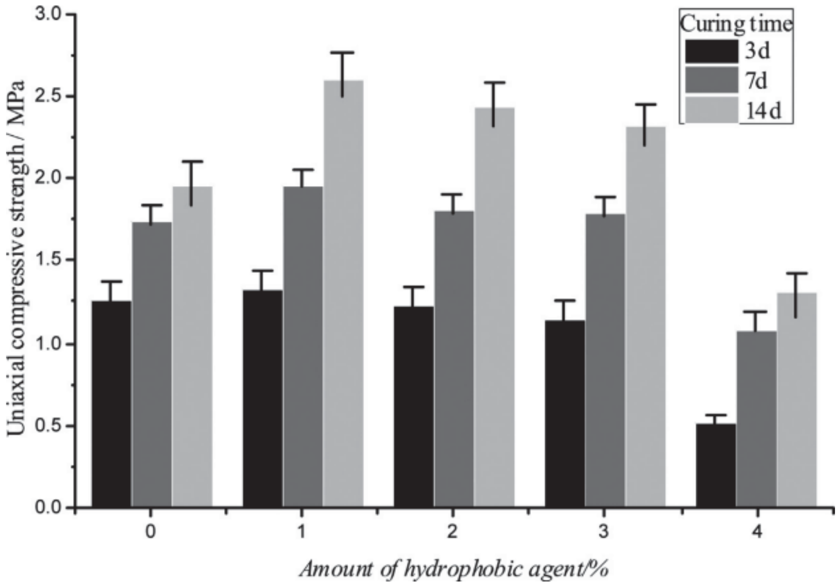

Fig. 1 Effect of hydrophobic agent on compressive strength of concrete[17]

Carbonation Resistance

The study conducted by Vikan and Justnes (2006) indicated that the carbonation depth of oil-incorporated mortar was much higher compared to the control specimen. This study specifically examined the carbonation resistance of a 3-year-old mortar specimen that had been mixed with vegetable oil. The researchers discovered that the oil-incorporated mortar exhibited a much greater resistance to carbonation compared to the control specimen. Figure 2 illustrates the extent of carbonation that takes place in mortar after the addition of different quantities of acid.

Water contact angle

The primary factors that influence the behaviour of pore size distribution in Portland cement are the initial water cement ratio (w/c) and the level of cement hydration. The pore size in standard Portland concrete varies between 0.05 and 1.0 microns in diameter. The capillary rise phenomenon allows water from external sources to penetrate the concrete surface via these openings. The literature review states that the addition of hydrophilizing chemicals to cement resulted in the formation of a layer consisting of molecules or particles on the surfaces of the concrete. The hydrophobic materials of concrete exhibit a high degree of water repellency, as seen by the large contact angles observed in Figure 3. Wetting behaviour can be classified into two types: hydrophobic, which refers to a water contact angle (WCA) more than 90°, and severely hydrophobic, which refers to a WCA greater than 120° [4].

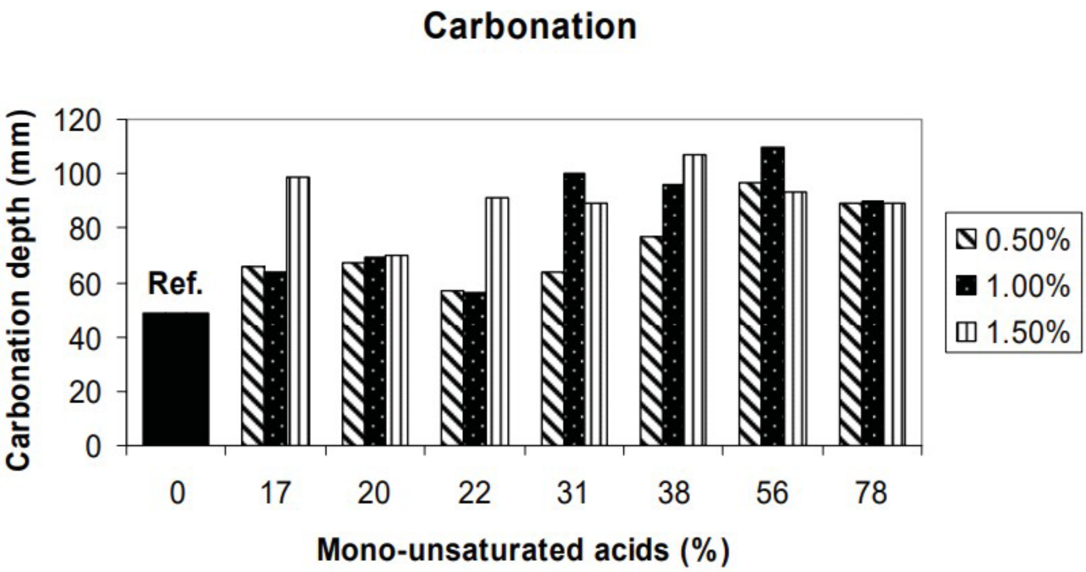

Fig. 2 Carbonation depth of mortar with different amount of acid[12]

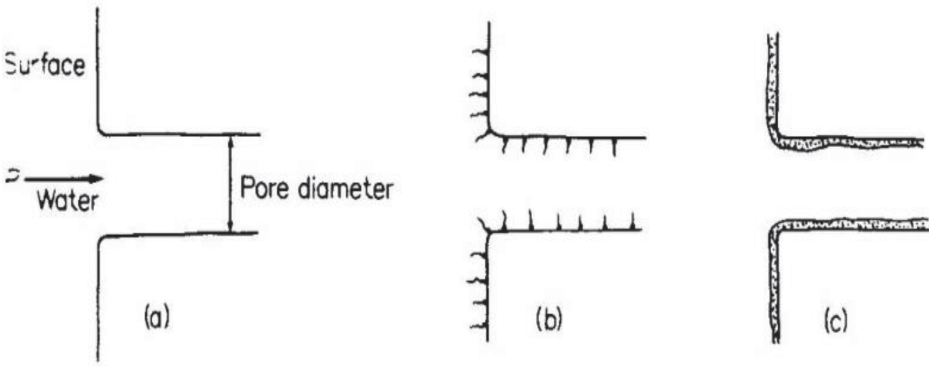

Fig.3 (a) Capillary pore without hydrophobic agent[12]

(b) Lined with molecular agent

(c) Lined with a emulsion layer

Water absorption

The capillary water absorption of the mortar specimen was greatly diminished to 5.4 percent of the value observed in ordinary mortar specimens when surface treatment with silica-based organic and inorganic hybrid composites, such as Poly-methyl hydrosiloxane / nanosilica (PMHS/NS), was employed on hardened cement. Figure 2 depicts the process of capillary water absorption in mortar samples that have been treated with different hydrophobic agents for a duration of six months. The inclusion of hybrid agents has significantly reduced the capillary water absorption rate of mortar specimens. Following a soaking period of 390 minutes, the water absorption rate for the samples treated with NS and PMS decreased to 66.25% and 71.3% respectively. In contrast, the water absorption rates for the H1.2, H0.95, H0.7, and H0.6 samples were 89.69%, 80%, 85%, and 87.5% respectively. An further advantage of incorporating oil into cement is the diminished water absorption of cement mortar and concrete specimens, as illustrated in figure 4. The quantity of oil or hydrophobic component employed in cement directly influences the extent of water absorption reduction [20].

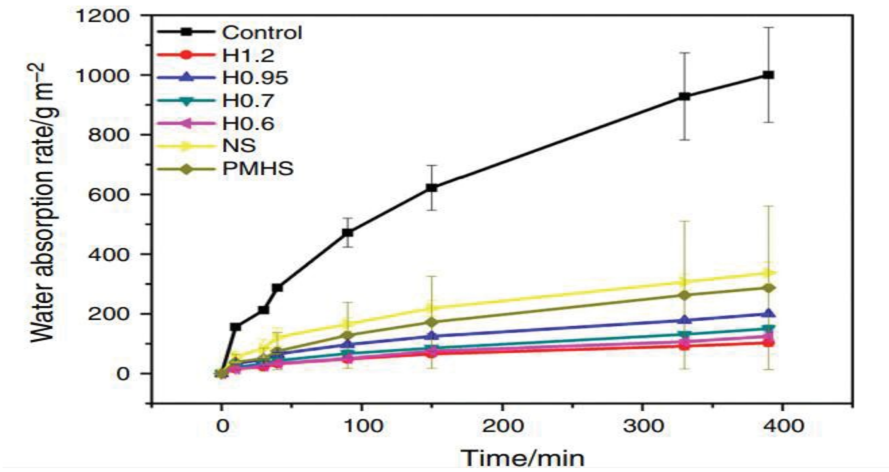

Fig. 4 Water absorption rate of mortar having different types of hydrophobic agent[20]

Conclusion

The addition of hydrophobic compounds to cement and concrete resulted in a reduction in both the capillary water absorption of mortar and the chloride diffusion coefficient, depending on the quantity of hydrophobic agent used. Nevertheless, this decrease was only partial. A hydrophobic component in cement and concrete creates a surface that is impervious to low temperatures, UV light, alkalies, and acids. Under normal circumstances, they enhance the water-resistance and impermeability. Hydrophobic compounds in concrete form a barrier that effectively prevents the infiltration of chloride ions and carbonation. The quantity of hydrophobic agent required to attain the appropriate level of compressive strength in concrete is closely correlated with the duration of the concrete's curing process. The addition of a hydrophobic chemical had minimal impact on both the density and shrinkage of the concrete. The use of a hydrophobic chemical has greatly reduced the sorptivity of the concrete due to the increased contact angle between water and concrete. Hence, it may be inferred that the incorporation of a hydrophobic component into cement and concrete enhances the longevity of the concrete.

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