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INFLUENCE OF SURFACE TREATMENT MATERIALS ON PROPERTIES OF CONCRETE SUBJECTED TO PHYSICAL SULPHATE ATTACK

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Abstract

Most common group of engineering materials like concrete is for construction activities. Due to changes in the environmental condition exposed concrete will varies in characteristics, its durability and hydraulic engineering properties. Variation in ionic mobility's and ion valences, sulphate ions infiltrate into concrete mould compare to other ions. For this maximum saturation, sulphate ions may interact with aluminum sulphate of cement paste to forms salt. According to guidelines of IS 10262 -2009, w/c ratios of 0.60 and 0.45 with cured and non cured are the two groups were kept in sulphate solution. Curing was made as per ASTM C511 code. The specimens were treated with commercially available silane (water repellent), epoxy (membrane coating), bitumen (water proof membrane) and water based solid acrylic resin. The intrusion of mercury falls down from 0.069 m/Lg to 0.038 m/Lg, for w/c ratios are 0.60 and 0.45 respectively. About 50% reduction was observed in pore size for concrete appeared with w/c 0.45 when compare with w/c = 0.60. This variations was additional prominent in non-cured specimen. Utilizing a semi solid acrylic polymer resin will not have sufficient safety to concrete under physical sulphate attack. The aim of work is appraising the property of covering the surface of concrete with various types of surface treatment materials on its surface exposed to sulfate attack. The product of the research work could gives guidance to control number of rules pertaining to sulfate attack damage of surface concrete.

Keywords: Surface treatment, Crystallization, Surface treatment materials

1.1 Introduction

Most common group of engineering materials like concrete is for construction activities. Due to changes in the environmental condition exposed concrete will varies in characteristics, its durability and hydraulic engineering properties (Hossack and Thirnas, 2015).

The majority of the research work interprets in field study that sulphate deteriorates and creates more serious problems in concrete structures especially in oceanic environment (Lee, *et al.,* 2008).

Variation in ionic mobility's and ion valences, sulphate ions infiltrate into cement mould compare to other ions. For this maximum saturation, sulphate ions may interact with aluminum sulphate of cement paste to forms salt this may leads in the reduction of products of cement also gypsum (Chiker, *et al.,* 2011). Only limited research work enlighten on surface treatment materials with sulfate attack. Certainly, the chemical structure of sulfate attack was the chief significance of past work (Aye and Oguchi, 2016 and Haynes, et al., 2008). Most of the previous study reveals concrete changes its physical property due to sulfate attack and also chemical attack on surface (Mehta and Monteriro, 2006). Concrete surface generally contains pores like macro and small cracks provide routs for the entrance of damaging materials into the concrete, then it leads to process like deterioration (Swamy, *et al.,* 1998). Currently, environmental and economic causes, there has been identifiable usage in the use of concretes with limestone as additives, but the degradation process of these cements are very complex due to pressure of sulphate solution. Minerals mixed with the cement reduce the dilution effect in the cement (Irassar, 2009).

Protecting the surface of concrete can be necessary for civilizing its durability under certain environmental circumstances (Aguiar et al., 2008). However, various types of surface treatment substances are commercially accessible, which creates its various properties which are not easy to notify the proper type, particularly in the case of concrete exposed to physical sulfate attack (Suleiman, *et al.,* 2014). Hence, in the present work highlights on appraising the property of covering the surface of concrete with various types of commercially available surface treatment substances on fighting to physical sulfate attack. The product of the research work could gives guidance to control number of rules pertaining to sulfate attack damage of surface concrete.

1.2 Experimental Program

According to guidelines IS 10262 - 2009, with a W/C ratio of 0.6 and 0.45 the cylinder shaped samples, with 100 x 200 mm in size were casted as two separate groups to accelerate the degradation process (Brubetaus, *et al.,* 2012). One group was maintained before coating at ambient laboratory temperature (20°C - 23°C) for 72 hours (Non cured), while the second group was soaked for 28 days (Cured) before exposure to the sulphate solution. The curing made out based on ASTM C511. Table 1 prescribes the concrete mixture composition. Physical and chemical composition of the used surface treatment materials is given in Table 2. The coarse aggregate used in the study is river gravel, with 20 mm maximum size of the particle.

For concrete specimens after the coatings has completely dried, specimens were partially immersed in an 8% sodium sulphate solution and maintained a temperature of 20^0C and RH=82% for one week followed by T=40^0C and RH=31%. The cycles will continue for 180 days. Two different types of specimens were treated with commercially available silane, epoxy, bitumen and water based solid acrylic resin.

Every hourly, visual along with mass observation of the specimens was executed, after all main variables. A visual examination, to appraise the deprivation of the surface of mortar, was executed. The visual observation of the specimens was recorded on an hourly and the clarifications are made as per Malhotra *et al.,* (1987).

Table 1 Proportions of tested concrete mixtures

Concrete Mixtures	Specimen 1	Specimen 2
Cement	240	258
Fly-ash	80	86
Aggregates (Coarse)	1149	1254
Aggregates (Fine)	749	720
Plasticizer	_	_
Water/Cement	0.6	0.45

Table 2 Physical and chemical properties of surface treatment materials

Properties	Epoxy	Bitumen	Silane	Acrylic
Colour	Gray	Black	Clear	Milky white
Adhesion (MPa)	2.5	-	-	-
Moisture (kg/m^3)	-	-	-	0.53
Flash Point (^{0}C)	-	-	62.8	-
Water content (%)	-	-	91	-
Reduction in Chloride content (%)	-	-	97	-
Tensile Strength (MPa)	20.8	1.0	-	-
Compressive Strength (MPa)	58.7	600	-	-
Flexural Strength (MPa)	29.8	-	-	-

1.3 Results and Discussion

Visual ratings was measured as per Malhotra, *et al.,* (1987) defined rating of visual. Each concrete cylinder was exposed to sulphate solution for physical contact. After one month of exposure, both the specimen shows scaling on the surface of the dried specimens. In bitumen coated specimens, bitumen layer was segregated from the cylinder in non-cured specimen but no weakening process was occurred in epoxy and silane coated specimens. Hence in the present study reveals that lower water cement ratio (0.45) made reduction in deterioration process for non cured specimens and coated with acrylic. In continuation for same water cement ratio in non cured concrete specimens, bituminous layer was not separated from the specimens.

In the other hand for w/c = 0.60, damage was found below the solution level in cured and non cured specimens. Severe damage was identified when it is coated with aryclic. Further, no changes found in epoxy and silane coated specimens, but damage was identified with bitumen coated specimen which are casted with w/c =0.60. The observed trends were of visual

Table 3 Visual ratings as per Malhotra, *et al.*, (1987) exposed to sulphate attac period of six months

Materials coated	w/c = 0.60		w/c = 0.45	
	Cured	Non cured	Cured	Non cured
Non coated	5.3	5	1.9	1
Epoxy coated	0	0	0	0
Bitumen coated	0.9	0	0	0
Silane coated	0	0	0	0
Acrylic coated	4.7	4.3	1.1	0.6

ratings of specimens for w/c =0.60 and 0.45 are given in Table 3.

The mass of the concrete was also measured for partially immersed specimens in an 8% sulphate solution for period of six months using w/c ratio 0.60 and 0.45. Cured and non-cured specimen results were given in Figure 3, 4, 5 and Figure 6 accordingly.

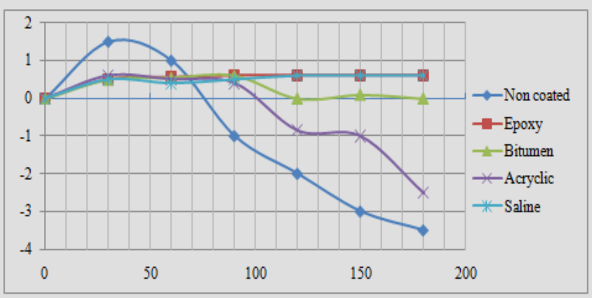

Figure 3: Variation in mass value of the non-cured specimen with w/c = 0.60

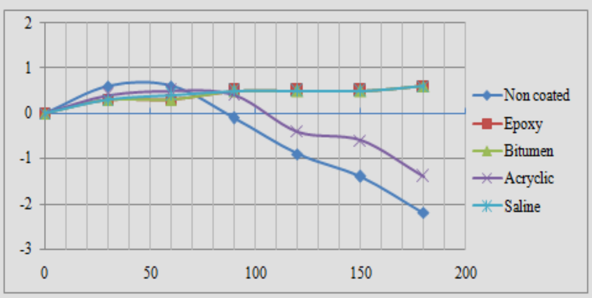

Figure 4: Variation in mass value of the cured specimen with w/c = 0.60

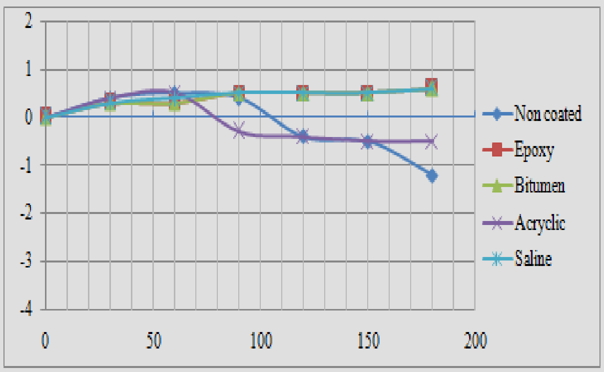

Figure 5: Variation in mass value of the non-cured specimen with w/c = 0.45

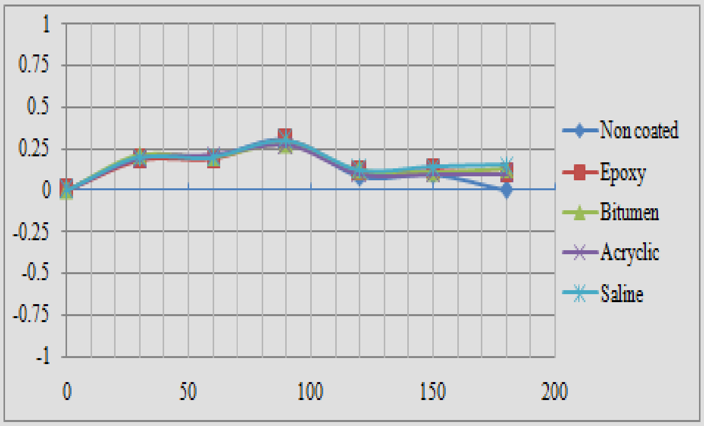

Figure 6: Variation in mass value of the cured specimen with w.c = 0.45

During the entire study period, in the first month study reveals that the specimens shown maximum porosity due to high water absorption capacity in non-coated specimens. In the next concurrent months, study continuous shown reduction in mass in the specimens. The maximum mass reduction in non coated non cured specimen followed by cured specimen by using w/c is 0.60 also reduces the mass in specimen coated with epoxy and silane. Consequently in non-coated and coated with acrylic and bitumen non cured using w/c is 0.45 shown reduction in mass further apart from coated with acrylic

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show less reduction in mass which are made with w/c = 0.45.

Figure 7 indicates, maximum content of pores size 1µm-0.1µm and interference of mercury for specimen with w/c = 0.60 rather than w/c = 0.45. The interference of mercury falls down from 0.071 to 0.041 m/Lg for w/c 0.60 to 0.45 respectively. About 50% reduction was observed in pore size for concrete with w/c 0.45 when compare with w/c 0.60. This variations was more prominent in non-cured specimen. Hence present work shows increasing in w/c ratio enhance the pores and its connectivity, also maximum capillary and salt formation on the outside of the concrete finally enhancing in the mechanism of the degradation.

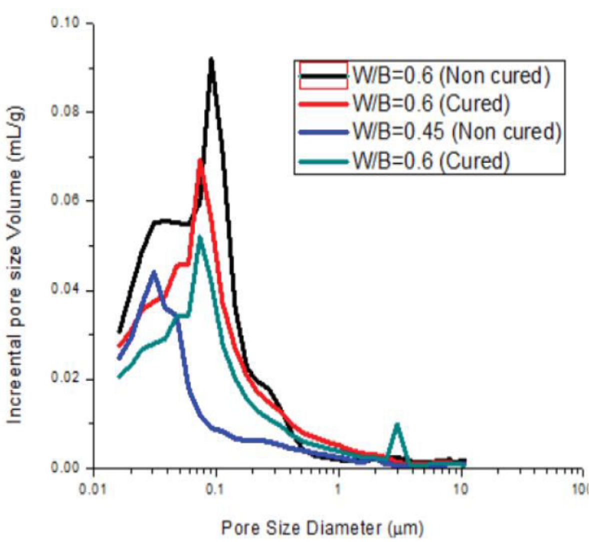

Figure 7: MIP values of specimen exposure to sulphate solution before coating

Conclusions

The durability of surface treated concrete against physical sulphate attack was studied in this paper. The effect of w/b ratio and curing condition was evaluated with various types of surface treatment materials. The following conclusions can be outlined based on the values in the present work.

- Reduction in w/c ratio enhances the characteristics of physically contacted cement with sulpahte solution.
- Best surface treatment and commercially available materials are epoxy and silane to protect from physical sulphate attack for both cured and non-cured concrete.
- Bitumen is the best surface treatment material when adequate curing is required before coating against physical sulphate attack.
- Solid acrylic is not a good surface treatment material for sufficient protection of concrete which is attacked by physical sulphate attack.
- Designing of concrete is depending upon the w/c ratio and curing conditions for their durability in specific environmental condition.

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