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Research Paper

Performance and Effectiveness of Concrete Coatings - A State of Art Review

Engineering

KEYWORDS : Durability, coatings, corrosion, chemical attack, abrasion, strength, permeability.

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ABSTRACT

The durability of concrete depends on its quality. Good quality concrete is inherently durable. The durability can be increased by proper choice of materials, proportioning, placing and curing. Usually concrete with higher strength and lower permeability is more durable. Another way of enhancing the durability of concrete is by applying a coating. Concrete coatings can provide decoration, cleanliness, dust reduction, water proofing, improved surface release properties, enhanced slip resistance, protection against reinforcement corrosion (reduction of carbonation and chloride ingress), as well as resistance to chemical attack. Coatings can also protect concrete from damage caused by frost, abrasion, mechanical stress, salt penetration, water and from solar beat. For good performance of coated concrete, the characteristics of the concrete have to be taken into consideration for selection of the correct surface penetration prior to the application of the right coating for a given environment. This review paper describes extensive studies attempted so far in application of various coatings over concrete surface as well as tests commonly carried out to examine the efficacy of surface coatings.

1. INTRODUCTION

Concrete is a most widely used construction material by virtue of its easy casting to any shape and size. Also it is more durable and sustainable to various aggressive environments including fire resistance. Concrete is used by everyone next to water, to an extent of 2 cubic metre per head per day and 3 cubic kilometre of concrete is produced every day, global wide. Obviously it is known that the concrete is used starting from ordinary platform to many mega structures online and offline i.e. coastal area. But, the durability of concrete is still a subject of importance by considering several examples of failures occurring all over the world. Now-a-days concrete structures are exposed to more aggressive environments such as chemical, fire, moisture, rain, marine, gaseous, etc. A single coat will not be sufficient to satisfy all these aggressive environmental factors. Because all these media can easily penetrate through concrete surface, in turn deteriorate and disintegrate concrete. Hence, eco friendly water based concrete surface coating has to be formulated to counteract the environmental problems.

2.LITERATURE REVIEW

2.1 GLOBAL CURRENT SCENARIO OF SURFACE COATING OF CONCRETE:

Huseyin Saricimen. et. al. (1996) [1] "Evaluation of a surface coating in retarding reinforcement corrosion" investigated the effectiveness of concrete surface cementitious coating which is a mixture of Portland cement, very fine silica and active organic materials upto 2 years after application in high concentration of chloride and sulfate zone. They reported that there was initial increase in corrosion but it decreased with time which in turn indicated the usefulness of surface coating in retarding reinforcement corrosion

Barbucci. et. al. (1997) [2] "Organic coatings for concrete protection: liquid water and water vapour permeability" compared the water and water vapour permeability coefficients of different concrete coatings viz. epoxy, epoxy(water based under coat) and Acrylic-Polyurethane (top coat), epoxy (modified solvented primer) & epoxy (modified solvent free top coat), epoxy (modified, solvent primer) & epoxy polyurethane (top coat) and acrylic (solvented). They concluded that by adopting new methods, the theoretical results were in agreement with that of experimental results.

La Rosa Thompson. J. et. al. (1997) [3] "Characterisation of silicate sealers on concrete" applied aqueous sodium silicates (N & OW) and observed that silicates performed as sealers as the result of combination of mechanisms.

Seneviratne . A.M.G. et. al. (2000) [4] "Performance characteristics of surface coatings applied to concrete for control of reinforcement of corrosion" applied three water based acrylic elastomeric coatings to naturally carbonated concrete components obtained from buildings that were suffering from reinforcement corrosion and they reported that elastomeric coating system could protect carbonated concrete from water ingress, extend the service life of a RC structure by controlling the rate of corrosion where significant chloride contamination did not exist. They also added that the coats developed a modest adhesional bond to the concrete substrate so that it could tolerate stress associated with movements in the concrete without cohesional failure.

J. Z. and Buenfeld. N.R. (2000) [5] "Chloride profiles in surface treated mortar specimens" measured chloride profiles of specimens applied with six different surface treatments such as acrylic sealer, polyurethane sealer, alkylalkoxysilane, acrylic coating, polyurethane coating and polymer modified cementitious coating and immersed in 1 M NaCl solution. They calculated interfacial chloride content (C_i) between surface treatment layer and the substrate and pseudo diffusion coefficient (D_{ps}). They found that all the surface treatments reduced C_i below than that of the untreated specimens.

Rodrigues.M.P.M.C.et.al (2000) [6] "Effectiveness of surface coatings to protect reinforced concrete in marine environment" investigated chloride concentration profiles (Co) and water permeability coefficients by applying acrylic coatings and the results were compared with control ones. They reported that depending upon formulation, Co was reduced more than 80%. The ranking of effectiveness to stop chlorides is the same as water imperviousness but the minimum requirement (0.1Kgm-2h-0.5) did not prove to be enough for effective protection against chloride penetration.

Almusallam. A.A. et. al. (2003) [7] "Effectiveness of surface coatings in improving concrete durability" evaluated the durability of concrete coated with 5 generic type coatings by assessing water absorption, chloride permeability

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and chloride diffusion and chemical resistance was evaluated by immersing uncoated and coated samples in 2.5% sulphuric acid. They pointed that epoxy and polyurethane coatings had a better performance than acrylic, polymer and chlorinated rubber coatings. They noticed that there was a variation in performance of same generic type produced from different manufacturers and the selection warranted trial tests.

Yang.C.Cet.al (2005) [8] "Relation between migration coefficient from accelerated chloride migration test and diffusion coefficient from ponding test" estimated the chlorine diffusion into Plain Cement Concrete, fly ash concrete and slag with various w/b ratios of 0.35,0.45, 0.55 & 0.65 by using ponding tests. Their results proved that for same w/b ratio, migration of chloride diffusion coefficient of concrete with mineral admixtures was less and they suggested that the diffusion coefficient measured by 180-day ponding test was higher than migration coefficient obtained from ACMT.

Han Young Moon. et. al. (2005) [9] "Evaluation of the durability of mortar and concrete applied with inorganic coating material and surface treatment systems" assessed diffusivity of chloride by using mortar specimens and durability performance related to inorganic coating materials by using concrete specimens via carbonation and frost resistance tests. Their results revealed that all the resistances were improved than that of the control ones, especially inorganic Top Coating (0.15-0.25 l/m2) exhibited remarkable performances.

Mustafa Sahmanan.et.al. (2007) [10] "Transport properties of engineered cementitious composition under chloride exposure" investigated chlorine ion transport properties of Engineered Cementitious Composites by using immersion and salt ponding tests. Their results showed that ECC waseffective in slowing down the diffusion of chlorine ion under combined mechanical and environmental loading by its ability of self-controlled tight crack width.

Jose B. Aguiar. et.al. (2008) [11] "Coatings for concrete protection against aggressive environment" studied the effect of two polymers (acrylic and epoxy) applied over concrete specimens by conducting chloride penetration, sulfates, acids and bases attack tests. In chemically aggressive environments ion diffusion and resistance to aggressive solutions tests were also conducted. The results revealed that overall performance of epoxy resin was better than that of other used coatings.

Jose B. Aguiar. et. al. (2008) [12] "Performance of concrete in aggressive environment" conducted tests like ion diffusion and resistance to aggressive solutions of several hydrophobic agents on concrete surface treated with coats like silicone hydrophobic agent, acrylic and epoxy. The results proved that performance of epoxy resin was better than the remaining.

Medeiros.M.H.F. and Helene.P (2008) [13] "Surface treatment of reinforced concrete in marine environment: Influence of chloride diffusion coefficient and capillary water absorption" treated concrete surfaces with hydrophobic agents, acrylic coating, polyurethane coating and double systems and tested for chlorine penetration. The reduction rate of polyurethane coating was high in the rate of 86%, where the remaining were in the rate of 70%.

Poola Scarfato .et.al (2011) [14] "Preparation and Evaluation of Polymer/clay naonocomposite surface treatments for concrete durability enhancement" tested the efficacy of nano composite systems at 2,4,6 wt% of nanoclay by applying it on concrete substrates and compared with that of plain resins (Fluoline CP & Anti-pluviol s) by performing salt attack resistance, porosity, surface water repellency tests and color changing were analyised. The results indicated that nanoclay addition significantly improved protection effectiveness of both used plain resins.

Md. Safiuddin and Soudki. K.A. (2011) [15] "Sealer and coating systems for the protection of concrete bridge structures" highlighted selection criteria for different types of sealers and coatings, surface preparation & application methods, evaluation methods.

Barbara Pigino.et.al. (2011) [16] "Ethyl silicate for surface treatment of concrete-PartII: Characteristics and performance" analysed water sorptivity, chloride diffusion and carbonation depth of two concrete specimens with different w/c ratios as 0.45 and 0.65 by applying tetra ethyl ortho silicate. They concluded that there was a considerable decrease in capillary suction, chloride diffusion and carbonation depth. Also microstructural investigations showed evidence of formation of calcium silica gel which was deposited in the small pores. The brightness and colour change was limited and was decreased over a period of time.

Franco Sandrolini et.al. (2011) [17] "Ethyl silicate for surface treatment of concrete-PartI: Pozzolanic effect of ethyl silicate" investigated the pozzolanic behavior of ethyl silicate in combination with slaked lime. They revealed that ethyl silicate had the ability to penetrate in porous building materials as a liquid solution and after curing only it gave a pozzolanic materials which acted as a protection for reinforced concrete.

Liang Shi.et.al. (2012) [18] "Effect of polymer coating on the properties of surface layer concrete" explored the feasibility of using modified styrene acrylic emulsion as surface coating on concrete. They inferred that the thicker the coating, the more reduction in mortar shrinkage and enhanced strength at early ages. Also the carbonation resistance and mortar infiltration resistance and chloride diffusion resistance were improved and capillary absorption ratio was reduced by 87% and 78% in dry and standard curing conditions.

Zeinab A. Etman (2012) [19] "Reinforced concrete corrosion and protection" cast RCC beams of size 10x15x100cm using SCC and tested the mechanical properties like compressive, split tensile and flexural strengths. They emphasized that the steel mass loss increased as the duration of exposure to corrosive environment is more and epoxy resin protected concrete from corrosion more than cement based resin by 15%.

Christian Christodoulou.et.al.(2012) [20] "Assessing the long-term durability of silanes on reinforced concrete structures" extracted cored from 12 structures treated with silane, 10 years ago and their permeability were measured by capillary absorption and water penetration and compared with untrated ones constructed during the same year. Their findings showed that silane treatment even after 20 years could offer a residual protective effect.

Medeiros.M.H.F.et.al. (2012) [21] "Reducing water and chlorine penetration through silicate treatments for concrete as a men to control corrosion kinetics" analyzed the contribution of three surface concrete protection systems such as coatings, linings and pore blockers (sodium silicate).

They recommended that sodium silicate reduced chlorine diffusion coefficient, water absorption and increased the service life of structure. But polyurethane coating was more effective.

Zuhua Zhang.et.al. (2012) [22] "Potential application of geopolymers as protection coatings for marine concrete III – Field experiment" experimented in the field the in-situ application of geopolymer coating in coastal area. They observed that the geopolymer coat with a thickness of 5mm was ideal and set within 4 hours, had a strong bond with concrete and able to resist the wave shock in the first tide rise. In spite of addition of Mgo based expansion agent and polypropylene fibres, large shrinkage was observed and they suggested that to counteract this problem, appropriate shrinkage reducing agents could be used.

Chu-Chia Yang.et.al. (2012) [23] "The relationship between migration time in ACMT and ponding time in ponding test for cementitious materials" carried out diffusion test and migration test with ponding test AASHTO T259 and accelerated chlorine migration test ACMT respectively with different times (60,90,120&180 days) for fly ash, slag and fly ash plus slag samples with w/b rations of 0.35,0.45,0.55&0.65. They suggested that the relationship between the ponding time and migration time would not be affected by different mixes of different w/b ratio and 90-day salt ponding test was a long-term test for measuring penetration of chloride into specimen.

Panjit.K.Nath.et.al. (2012) [24] "Photocatalysis – A novel approach for solving various environmental and disinfection problem: A brief review" reviewed photocatalytic process in different sectors since it was a versatile and effective process for disinfection in both air and water medium, the power requirement would be less, while some reactions required only light.

Carmen Couto Ribeiro.et.al. (2013) [25] "Microstructural and topographic characterization of concrete protected by acrylic paint" assessed utilizing profilometric and microstructural characterization, the efficiency of acrylic paint as a protective coating in concrete in aggressive environment. They proved that acrylic painting as a protective coating minimizes surface degradation and the durability was increased.

Theodosia Zafeiropoulou.et.al. (2013) [26]"Carbonation resistance and anticorrosive properties of organic coatings for concrete structures" experimentally investigated the anticorrosion properties of 9 coating systems namely 3 different categories i.e. conventional coatings (acrylic paint, elastomeric & acrylic resin dispersion and silicone-acrylic paint), high performance coatings (epoxy, polyurethane and chlorinated rubber) and nanotechnology paint system (silicone coating, pure acrylic paint and an elastomeric-nano acrylic coating). They concluded that the polyurethane coating exhibited good results against chloride induced corrosion and high performance coatings were harmful to environment due to the organic solvents that present. Also, nano coating I showed improvement regarding chloride-ion corrosion but worst regarding carbonation.

Elisa Franzoni.et.al (2013) [27] "Ethyl silicate for surface protection of concrete: Performance in comparison with other inorganic surface treatments" experimentally investigated the efficacy of ethyl silicate as surface treatment for reinforced concrete and compared with some inorganic products based on sodium silicate and nanosilica by observing water absorption rate, water contact angle, chloride carbonation and abrasion resistances. They highlighted that the performance of ethyl silicate was most effective.

Brenna. A..et.al (2013) [28] "Long-term chloride induced corrosion monitoring of reinforced concrete coated with commercial polymer-modified mortar and polymeric coatings" tested the performance of 4 commercial concrete coatings i.e. one polymer modified cementitious mortar and three elastomeric coatings by means of steel corrosion long term monitoring and by chloride penetration profiles in concrete. The results revealed that there was a delay in chloride penetration and for lower polymer content, a higher thickness was warranted.

Rosa Vera.et.al. (2013) [29] "Effect of surface coatings in the corrosion of reinforced concrete in acid environments" exposed uncoated, acrylic and epoxy coated concrete cylinders to an artificial acidic solution for 589 days and evaluated corrosion of steel reinforcement by means of corrosion potential and polarization resistance. They concluded that reinforcing steel was in a passive state in the epoxy coated concrete and was in an active state in the uncoated and acrylic coated concrete when measured for concentration profiles of chlorides, acidity and sulfate.

Diamanti.M.V.et.al. (2013) [30] "Effect of polymer modified cementitious coatings on water and chloride permeability in concrete" evaluated the efficiency of 2 cementitious coatings modified with acrylic polymers in preventing chloride induced corrosion. They concluded that coatings highly reduced water-content of concrete, slowed down the chloride penetration. The increase in polymer-to-cement ratio from 0.35 to 0.55, the more the protective effect.

Yudong Dang.et.al. (2014) [31] "Accelerated laboratory evaluation of surface treatments for protecting concrete bridge decks from salt scaling" investigated the effect of 3 concrete sealers, 2 crack sealants and 2 water repellents against salt scaling by subjecting concrete cylinders to wet/dry cycles in exposure of diluted deicer simulated by 3 wt.% NaCl solution. They further investigated water absorption rates, gas permeability and water content angle. They confirmed that all the coatings were outstanding among which epoxy based sealer T48CS and water repellent ATS-42 exhibited best performance against salt scaling.

Liliana Baltazar.et.al. (2014) [32] "Surface skin protection of concrete with silicate based impregnations: Influence of the substrate roughness and moisture" experimentally investigated the efficacy of silicate based impregnation to protect concrete elements with 0.40 & 0.70 w/c ratios. Different procedures like 3 surface roughness (no surface penetration, 160 bar water jet and needle sealers). Three different moisture contents (3%, 4.5% & 6%) were followed and assessed product penetration depths, water absorption by immersion, abrasion resistance, impact resistance and bond strength. The results indicated that silicate based impregnation was effective except resistance to impact. The surface roughness and moisture content proved that performance of impregnation was improved.

Suleiman.et.al. (2014) [33] "Effect of surface treatment on durability of concrete exposed to physical sulfate attack" applied 2 layers of 4 different types of surface treatment materials like saline, epoxy, bitumen modified polyurethane and water based solid acrylic polymer resin and tested resistance to physical sulphate attack. The results obtained showed that low w/c ratio improved resistance of concrete to physical sulfate attack, epoxy and saline surface treatments protected concrete against physical sulfate attack where bitumen treatment was adequate when properly cured and water based solid acrylic resin did not provide adequate protection of concrete.

Mathieu Eymard .et.al. (2014) [34] "Interfacial strength study between a concrete substrate and an innovative sprayed coating" investigated the strength of interface with its concrete substrate by applying thermal insulating coat (ISO) as inner coat and Monorex GF (MGF) as top coat ad conducting slant-shear test. They inferred that the stress concentration influenced the friction parameters for ISO configuration.

Guo Li.et.al. (2015) [35] "Time dependence and service life prediction of chloride resistance of concrete coatings" determined chloride resistance of concrete specimens applied with typical coatings viz. EP, PO, CE & SI coatings and aged under outdoor natural climate conditions and indoor artificial accelerated experiments using ultra violet light radiation and wetting/drying cycles. The results showed that chloride resistance was remarkably improved, organic film coatings deteriorate faster than infiltrating coatings and service lives of concrete coatings were closely related with solar irradiance.

Lihong Jiang.et.al. (2015) [36] "The investigation of factors affecting the water impermeability of inorganic sodium silicate-based concrete sealers" explored factors affecting water impermeability of inorganic sodium silicate-based concrete sealers. They reported that low surface tension and approximate density, viscosity and gelation times improved water proofing properties.

Guanglin Yuan and Qingtao Li (2015) [37] "The use of surface coating in enhancing the mechanical properties and durability of concrete exposed to elevated temperature" evaluated compressive strength, modulus of elasticity and carbonation resistance of air-cooled concrete with silicate surface coating. Their results revealed that with SCC, compressive stress exposed to 200 – 700 degree C could recover, modulus of elasticity exposed to 200-700 degree C was enhanced and carbonation resistance exposed to 200-600 degree C was increased.

Seyeddhamed Sadata.et.al (2015) [38] "Long term performance of concrete surface coatings in soil exposure of marine environments" monitored carbonation depth and chloride ion penetration into concrete after application of 5 tupes of surface coatings i.e. aliphatic acrylic, bitumen and rubber emulsion, modified cementitious type D & type E and polyurethane to samples after 88 months of natural exposure to coastal soil of the Persian Gulf. Surface chloride built-up was monitored and to corrosion initiation ws calculated to rank the performance of coatings. They inferred that aliphatic acrylic and polyurethane coatings reduced chloride ion diffusivity.

Faraldos.et.al. (2015) [39] "Photocatalytic hydrophobic concrete coatings to combat air pollution" explored the possibility of using hydrophobic coating based on photolys & nanoparticles suspended in a siloxane sealant. This showed similar conversion at low NO concentrations but required greater loading of TiO2. They suggested that a threshold of 1% TiO2 in hydrophilic coating and 5% in case of hydrophobic was needed to obtain a quantity NO conversion.

2.2 LOCAL CURRENT SCENARIO OF SURFACE COATING OF CONCRETE:

Rajesh.K.Varma and Ajay Chourasis (2015) [40] "Protection of bio-deteriorated reinforced concrete using concrete sealers"reviewed bio-deterioration of concrete and various types of concrete sealer for protection of reinforced concrete structures.

3.CONCLUSION:

We have thoroughly discussed various studies carried out regarding various surface coatings of concrete for improving durability and trsting methods for finding the efficiency of coatings. Still there are niches in the literature to explore. It has not been focused on formulation and development of various coatings based on silicates, polyvinyl alcohol, water based polyurethane, silicone and other binders suitable to various environments which are durable and increase the life of concrete structure to manifold and testing the efficiency of coating using various tests like Coating adhesion test, abrasion test, crack bridging ability test, linear polarization test, electro chemical impedence test, gloss resistance test, U-V degration test, fire endurance limit, salt ponding test, fungal attachment test, pendulum impact resistance test, etc. in addition to routine testing methods.

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