

Development of surface coating for underwater concrete structures

S. Sharmila ^{1*}, P. Keerthana ²

¹Assistant Professor, Department of Civil Engineering, Kongu Engineering College, Perundurai, Tamil Nadu, India.

²UG Student, Department of Civil Engineering, Kongu Engineering College, Perundurai, Tamil Nadu, India.

*Corresponding author E-mail: kssharmi@gmail.com

Abstract

Surface coating is the most focused research problem in the construction sites to repair the deteriorated concrete. Surface coating is an most necessary process to be performed in concrete to avoid the issues such as aesthetics, sealing, chemical resistance or abrasion resistance. These coatings are termed as special resins with proper compositions of materials which can prevent the transmission of water and contaminants while at the same time keeping the structure safe. This research work focuses on preparation of surface and the protective surface coating to protect the concrete. High performance coal tar with polyurethane coating materials are used to protect concrete from chemical and mechanical attack in interior, exterior and marine environments. Coal tar with polyurethane coating systems consist of two or more components blended and applied as a film, reacted chemically to form a protective film of high integrity, excellent adhesion, toughness and impact resistance. The coating were applied on 4"x4"x4" concrete cubes and kept for one week curing the samples, thickness of the coating were $\sim 70 \pm 5 \mu\text{m}$ measured using hegman gauge. The tests such as Abrasion resistance, pull off test, water absorption test, chloride resistance test and Rapid chloride penetration test were performed and the results exemplifies that coal tar mixed with polyurethane coating can be used for underwater concrete structures.

Keywords: Corrosion, concrete, acrylic resin, epoxy and durability properties.

1. Introduction

Concrete structures generally make up a significant and important part of the national infrastructure. The growing number of deteriorating concrete structures, not only affects the productivity of the society, but has also a great impact on resources, environment and human safety. The operation, maintenance and repair of concrete structures are consuming ever more energy and resources while heavily burdening the environment with the large quantities of waste produced. Thus, the poor durability and premature end of the service life of concrete structures do not only represent the technical and economic problems, but also a poor utilization of natural resources and therefore an environmental and ecological problems occur. The traditional methods used for durability design are usually based on deem-to-satisfy rules, where sufficient durability of a concrete structure is secured with prescriptive requirements. The purpose of this research work is to develop of surface coatings for underwater concrete structures for the durability analysis of concrete surface coatings in marine environment, and to understand how the model parameters influence durability analysis. The goal is to provide engineers with an aid that helps to understand the impact their decisions have on the durability performance. Another goal is the use of performance based criteria in the specification of parameters for the evaluation of surface coating durability.

2. Materials used

The polymer chemistry with some specific aspects of polymers is used in the construction industry. These polymers include epoxies, polyurethanes, acrylics, silicones, polysulphides, alkyds and

polyesters. Coal tar, Epoxies and Polyurethane polymer are discussed covering only those aspects of chemistry which are related to construction industry products. Coal tar can be applied without a primer in thickness of 10.0 mil (0.25 mm) per coat. These coating find application on clean blasted steel and concrete for immersion service or below-grade service. Epoxy resin cures by cross linking with a curing agents or catalyst. Epoxy resin based coatings are always supplied as a two pack system. In these coatings, epoxy resin containing pigments and extenders will be supplied in one pack. The other pack containing curing agents or catalyst. The content of the two packs have to be mixed before application over the substrate. Air drying type of epoxy system uses the various type of curing agents. The properties of curing agents are given in Table 2.1.

Table 2.1: Curing Agents for Epoxies

Curing agents	Properties
Amine and amine-adduct	Best chemical resistance
Polyamide	Best flexibility and water resistance
Ketimine	Longer pot life
Modified aromatic amines	Low temperature cure

Carbon black, lead white, bone black, chrome yellow and titanium white were used as pigments. Volcanic ash and laterite were used as replacement for cement.

3. Experimental investigation

The prolific use of concrete in the construction industry has led to the development of a series of standardized testing procedures for determining concrete material properties. The compressive strength was determined using 100mm concrete cubes. Cubes were cast for the four replacement levels (0%, 10%, 20%, and 30%) of volcanic ash replacements of cement, four laterite

replacement levels (0%, 10%, 20%, and 30%) of sand and six curing durations (3, 7, 28, 56, 90, and 120 days). The control mixture was proportioned for a target concrete strength of 25 N/mm² and had a cementitious material content of 300 kg/m³, fine aggregate content of 530 kg/m³, coarse aggregate content of 1465 kg/m³, and a water cementitious materials ratio of 0.65 giving a free water content of 196 kg/m³. Types of coatings developed are Coal tar+ Epoxy resin and Coal tar+ Polyurethane. The different paint systems have been characterized based on their film thickness, structure and adhesion. Abrasion resistance, pull off test, water absorption test, chloride resistance test and Rapid chloride penetration test were conducted on specimens coated with the coatings mentioned above. The following formula was used to calculate the wear index.

Wear Index, $I = (W_1 - W_2) * 1000 / n$
 W_1 and W_2 are weight of the test specimen before & after abrasion respectively.
 n is the number of cycles recorded in Abrasion test

Figure 3.1 shows the acid resistance test conducted on coated specimens

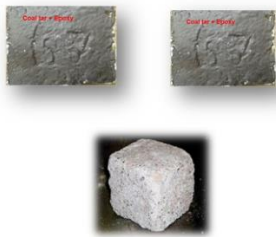


Fig. 3.1: Acid resistance test

4. Test results and discussion

Various tests were conducted on coated specimen and the test results are presented below. Coal tar + polyurethane coatings were tested since they were moisture insensitive. The two coatings had good resistance to abrasion. Out of two polymeric resins, the better one is polyurethane coatings. The test results of Abrasion test are represented in Table 4.1.

Table 4.1: Abrasion Resistance of the Polymeric Coatings

Coating	W1(g)	W2 (g)	n (Rpm)	I
Coal tar + Epoxy	32.43	32.25	1000	0.18
Coal tar + Polyurethane	86.9	86.8	1000	0.10

Figure 4.1 shown below, the coal tar mixed with polyurethane has maximum pull-out resistance capacity. It shows the absorption on concrete surface is very high for coal tar mixed with the polyurethane double coated system.

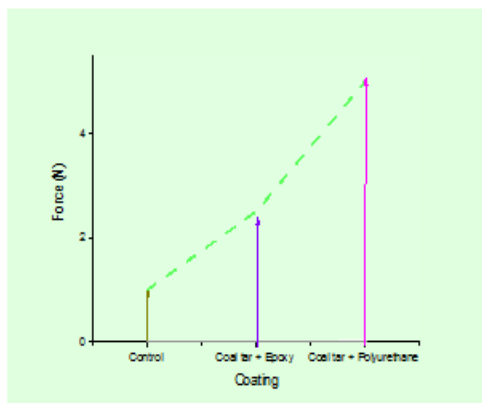


Fig. 4.1: Pull out resistance

The water-absorption test results for the concrete surface coating are shown in Table 4.2. A wide range of water-absorption values were obtained for and within the different generic types. The results are reported in percent of the control after 2 days soaking in water. The solid content of the one coal tar+ epoxy and coal tar

+ Polyurethane that performed poorly was significantly lower than the others.

Table 4.2: Water Absorption of the Polymeric Coatings

Hours	Coaltar+ Poly Urethane	Coaltar + Epoxy
0	0.267	0.315
24	0.267	0.315
48	0.267	0.315
72	0.268	0.315
96	0.268	0.316
120	0.268	0.316
144	0.269	0.316
168	0.269	0.317
192	0.269	0.317

The RCPT test was performed for each mix to ensure that they had similar permeability values. The polyurethane mixed with coal tar shows the higher resistance power compared to coal tar mixed with the epoxy polymeric resin composition.

5. Conclusion

From the experimental works carried out, the following conclusions were drawn.

1. Wear rate decreased with the addition of modifiers (Coal tar + Epoxy and Coal tar + Polyurethane) in the case of curing at 30°C. However, at higher curing temperatures the wear rate increased with the addition of modifiers especially by adding metal powders.
2. Out of the two coatings, Coal tar+ Polyurethane coating was performed better in abrasion resistance test.
3. Pull out resistance on concrete surface was very high for coal tar mixed with the polyurethane double coated system.
4. Coal tar + epoxy coated specimen performed poorly and had total water absorption as higher than 2 percent.
5. It is concluded that coal tar mixed with polyurethane coating can be used for underwater concrete structures.

References

- [1] Bundies FJ, "Component coatings on concrete: Some physical and chemical aspects of adhesion", *RILEM: Second International Symposium on Adhesion between polymers and concrete*, (2012), pp.181-192.
- [2] Kim B, Doh JH, Yi CK & Lee JY, "Effects of structural fibers on bonding mechanism changes in interface between GFRP bar and concrete", *Composites Part B: Engineering*, Vol.45, No.1, (2013), pp.768-779.
- [3] Toutanji HA, Choi H, Wong D, Gilbert JA & Alldredge DJ, "Applying a polyurea coating to high-performance organic cementitious materials", *Construction and Building Materials*, Vol.38, (2013), pp.1170-1179.
- [4] Ghafari N, "Corrosion control in underground concrete structures using double waterproofing shield system (DWS)", *International Journal of Mining Science and Technology*, Vol.23, No.4, (2013), pp.603-611.
- [5] Ohama Y, Demur K, Nagao H & Ogi T, "Adhesion of polymer-modified mortars to ordinary cement mortars by different test methods", *RILEM: International Symposium on Adhesion between polymers and concrete*, (2013), pp.719-729.