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Review

A review on concrete surface treatment Part I: Types and mechanisms

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ABSTRACT

The application of surface treatments in concrete has been widely investigated over the past decades. Surface treatment technology has become more important in concrete structures especially in preventing deterioration and damage when exposed to extremely aggressive environments, and in further extending service life. This paper presents comprehensive details of four types of concrete treatments, including surface coating, hydrophobic impregnation, pore blocking surface treatment and multifunctional surface treatment. Additionally, the knowledge of their interaction mechanisms with cementitious substrate is presented and discussed. The advantages and drawbacks of each treatment as well as the influencing factors on the protective effects of surface treatments on concrete, such as air permeability, bonding strength and cracking resistance, are also discussed. Despite decades of study, the mechanisms of many newly developed surface treatments remain poorly understood. A deeper understanding of the chemical and physical reaction mechanisms is therefore essential, especially at micro-scale levels.

Contents

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1. Introduction

Durability problems of concrete structures usually begin with the deterioration of materials. Although the deterioration of materials does not cause immediate safety problems at the beginning, it gradually creates a potential danger for the whole structure.

Extensive research has been conducted over the last four decades due to the economic impact caused by the durability problem. Several methods to provide better and durable concrete or reinforced concrete structures have been proposed. The most common strategy adopted is to delay the degradation process of reinforced concrete by decreasing the porosity by reducing the water-to-cement ratio and adding nanoparticles. However, this method has two main drawbacks: firstly, the protection might be sufficient in highly aggressive environments, such as marine, saline and alkaline land, and frigid area; and secondly this method has generally led to overdesigning the whole structure [1–4]. Thus, several approaches which are more economical are applied to provide additional protection for materials against degradation [5–8]. They are (1) metal, epoxy resin and polymer coatings for steel rebar; (2) corrosion inhibitor; (3) electrochemical method which is usually used in concrete re-alkalization; and (4) concrete surface treatment. Among these methods, (1) and (2) cannot be used in old structures, and the effect of coatings for reinforced steel is a controversial issue, because the corrosion rate increases rapidly in broken areas of coatings. So far, the effect of corrosion inhibitors in prolonging the service life of steel bar is still unclear. Meanwhile, (3) can be used in existing structures but is relatively expensive. On the other hand, (4) concrete surface treatment has received wider acceptance due to its effectiveness in preventing the ingress of aggressive substances.

Since 1986, a hydrophobic agent named isobutiltrimetoxisilane (100% pure) has been used on bridges in the United Kingdom to prevent chloride penetration. Agencies in America and the Department of Transportation in Germany use hydrophobic agents on bridges subjected to chloride penetration [9]. A detailed review of the performances of surface treatment was presented by Basheer et al. [10]. However, a lot of progress has been made in understanding the mechanisms of surface treatment agents which have been commercially available for a long time. Moreover, a new generation of surface treatment agents has emerged over the last 20 years.

This review includes two parts. This first part explores the classification, mechanisms and factors influencing the surface treatment performances by summarizing the current state of knowledge of the interaction between surface treatment agents and cementitious substrate. The second part reviews and compares the effects of surface treatments and their durability performance [11]. This paper provides a comprehensive review of the research and development of surface treatments over the past 30 years. In addition, some insights and suggestions for further research are presented.

2. Types and mechanisms of surface treatment

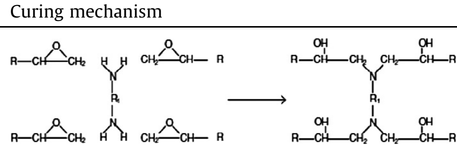
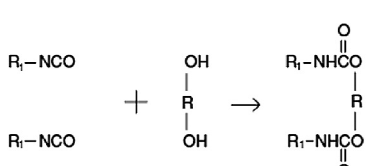
According to the chemical composition of surface treatment agents, they can be classified into two categories: inorganic and organic treatments. Organic surface treatments are the most commonly-used treatments because of their good protective effect. However, there are concerns over their poor fire resistance, ease to crack and detach, limited service life, and difficulty to be removed after losing their protective effects [12,13]. The most common inorganic surface treatment is sodium silicate solution (also known as "waterglass"). To a much smaller extent, potassium silicates, lithium silicate, and fluosilicates have also been reported to be used for inorganic surface treatments [3,14]. Although inorganic surface treatments have better durability performance, less research has focused on this area, especially their penetration depth and interactions with cementitious substrate.

In term of functions, the surface treatments are grouped into three types according to the EN 1504-2:2004 [15–17]: hydrophobic impregnation, impregnation, and coatings. However, this classification does not include some newly developed surface treatments. Thus, all the surface treatments discussed in this paper are divided into four major groups: surface coating, hydrophobic impregnation, pore blocking surface treatment, and multifunctional surface treatment. The following sections describe these four types of treatment in detail.

2.1. Surface coating

Surface coating forms a continuous polymer film which acts as a physical barrier to prevent corrosive substances from penetrating into cementitious substrate [5,16,18]. There are several types of surface coatings, including traditional polymer coatings, polymer/-clay nanocomposite coatings and cementitious coatings. Traditional polymer coating and polymer/clay nanocomposite coatings form a dense polymeric film with a thickness of about 0.1–1 mm on the concrete surface, whereas, cementitious coating acts by

Table 1
Properties of traditional polymer coating used for concrete surface treatment.

	Curing mechanism	Advantages	Disadvantages
Epoxy resins [19–27]		Low shrinkage; Easy to cure; Good chemical resistance; Good adhesive strength;	Low fracture energy; Low impact on strength; Poor hydrophobicity Low thermal stability; Easy to weathering; Poor resistance to the initiation and propagation of cracks
Acrylic [28–33]	Physically drying	High resistance to hydrolysis and ultraviolet radiation; good alkali resistance	Low bond strength; Poor ductility; Generally not applied for constant immersion in water or soil
Polyur-ethane [34–41]		Excellent resistance to weathering; self-healing; no shrinkage	Poor resistance towards mechanical strains and deformation and/or degradation at high temperatures