Construction and Building Materials 133 (2017) 81–90

Contents lists available at ScienceDirect

Construction and Building Materials

journal homepage: www.elsevier.com/locate/conbuildmat

Review

A review on surface treatment for concrete – Part 2: Performance

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ARTICLE INFO

Article history:
Received 24 March 2016
Received in revised form 21 November 2016
Accepted 26 November 2016

Keywords:
Concrete
Surface treatment
Compressive
Permeability
Durability

ABSTRACT

There are variety of surface treatments used for concrete structures protection. This paper presents a review of the effect of surface treatments on mechanical properties and durability concrete, and the durability of treatment materials themselves. Several common surface treatment are reviewed, including acrylic coating, polyurethane coating, epoxy coating, silanes, siloxanes sodium silicate, and nano-SiO_2. These surface treatments showed different impacts on physical and mechanical properties, water permeability, chloride migration, carbonation resistance, sulphate attack, and freeze-thaw cycle. It is important to consider their strengths and weakness when choosing a surface treatment. In addition, there are limited prediction model for the service-life of treated concretes, though many tests were conducted to measure the barriers properties of these surface treatments. Many of the surface treatments, especially organic treatments, are generally subjected to aging and weathering, and thus the long-term protection cannot be promised. Hence, both the protective effect and long-term durability of the surface treatment should be taken into account in service-life modelling.

Contents

1. Introduction

In many cases, the reliability of concrete structures is, determined by durability problems, e.g. carbonation, corrosion of steel bars and sulphate attacks [1,2]. The surface layer of concrete which usually refers to a 30 mm thick layer below the surface affords both physical and chemical protections against ingress of aggressive substances [3–5]. Since many aggressive substances transport through water or air, the permeation characteristics of the surface concrete is an important factor for the durability of whole concrete element [5–8]. Surface treatment is an economical and effective

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http://dx.doi.org/10.1016/j.conbuildmat.2016.11.128
0950-0618/

method to improve the quality of surface layer and protect the concrete structure compared with other methods, such as decrease water to cement ratio and add admixtures etc.

There are a variety of surface treatments that can be used for protection of concrete. According to the chemical compositions of the surface treatment agents, the surface treatments can be classified into two groups: inorganic and organic [9–11]. The organic surface treatments have good barrier properties, but their limiting service life has got wide concerns. The inorganic surface treatments are more stable and have better resistance to aging, but limited studies about their application have been published. Surface treatments were grouped into four categories according to functions. (a) Surface coating can form a continuous polymer film and create a physical barrier to suppress the ingress of the aggressive substances [12–14]. Many surface coatings have been using in foundations and quays, e.g. acrylic, butadiene copolymer, chlorinated rubber, epoxy resin, oleoresinous, polyester resin, polyethylene copolymer, polyurethane, vinyl, coal tar and polymer modified mortar [15]. (b) Hydrophobic impregnation is usually performed through silane or siloxane-based water repellent products [13,16]. They create a water-repellent pore surface in the surface-near zone and leaves the pores open [15,17]. (c) Pore-blocking treatment agents are able to partially or completely fill the capillary pores and thus reduce the porosity of surface layer. Silicate-based pore blockers are the most common products in this group. There are some new generation pore-blocking agents which drew lots of concerns, such as nano-SiO_2 and $CaCO_3$ precipitation. Recently there has been an increasing acceptance of pore-blocking treatment materials for protecting buildings and highway bridges [17–19]. (d) Multifunctional surface treatments have at least two functions, such as ethyl silicate and modified clay nanocomposites which cannot only block the capillary pores but also form hydrophobic layer [11,16,20].

This review includes two parts. The first part reviews the classification, mechanism and influencing factors for surface treatments [21]. This second part provide summary and comparison of the effects of surface treatments on concrete properties, and durability of surface treatments. The purpose of this review is to facilitate the successful applications of surface treatment, and some suggestions for further research.

2. Effect of surface treatment on mechanical and physical properties of concrete

The effects of surface treatments on the strength of concrete have not attracted much attention. It is widely accepted that most other surface treatments cannot directly improve the strength of concrete because they cannot improve the quality and porosity of the whole concrete element. However, surface treatments are able to prevent the degradation of strength when the concrete is subjected to a fire. According to research of Li [22], the compressive strength of concrete with silicate-based coating enhanced by 3.8%, 3.7%, 11.0%, 17.3% and 6.1% compared to uncoated concrete, after being exposed to 150, 300, 450, 600 and 750 °C. Recently, Yuan et al. [23] also reported that silicate surface treatment could effectively enhance the residual compressive strength and elastic modulus of concrete exposed to temperature from 200 to 700 °C.

The abrasion resistance is a good indicator for evaluation of the longevity of surface-treated concrete under repetitive traffic loadings. Many of surface treatments can improve the abrasive resistance of concrete surface [24–26]. Dang et al. [27] found that most organic surface coatings could improve the abrasion resistance of concrete. Among the organic coatings they investigated, epoxy performed best while methacrylate with high molecular weight showed no protection. A slight enhancement of abrasion resistance was observed for the concrete treated with silanes, because the friction coefficient of concrete surface could be reduced by silanes [16,27]. Franzoni et al. [11] investigated the effects of some inorganic surface treatments on abrasion resistance. According to their results, the abrasion resistance of surface-treated concrete has the following order: sodium silicate > ethyl silicate > nano-silica. Sodium silicate showed best effect because it could form a protective layer with remarkable thickness. Since above researches used different matrixes and testing methods, it is hard to compare the effects of surface treatments in different groups. Thus, some researches need to conduct to further identify the most anti-abrasion surface treatment.

In addition, concrete surface treatments can affect the shrinkage due to changes in the moisture transportation and evaporation rate. However, relatively few researches focused on this area. Shi et al. [28] showed that polymer coating could obviously reduce the mortar drying shrinkage. The thicker the polymer coating was and the earlier the coating was applied, the greater shrinkage reducing ratio was observed, as shown in Fig 1. A thicker polymer coating could form highly compact film on the surface of mortar to seal open capillaries and avoid the moisture dissipation. Thus, it could block more capillary and coarse pores to suppress moisture evaporation, finally reducing more drying shrinkage. When the polymer was coated at a later time, the almost fully developed capillary structure and the low residual moisture in capillary pores caused small remaining shrinkage. Thus, the coating showed less effectiveness. There are not investigation about the effect of hydrophobic and pore-blocking treatment.

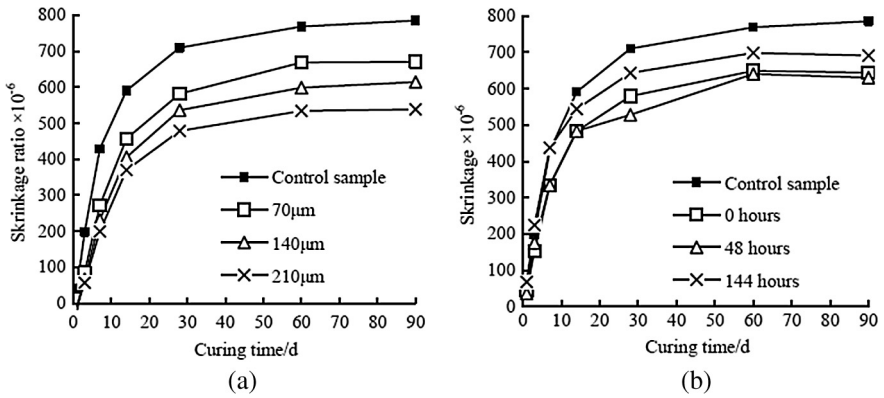

Fig. 1. Shrinkage ratio of mortar coated with polymer with different thicknesses (a) and various coating time (b).