COATING OF CONCRETE

INTRODUCTION

In recent years a greater attention has focused on the use of surface coatings of various formulations to enhance the aesthetic appearance and durability performance of both new and existing concrete structures by providing additional protection against exposure to the in-service environment [1,2,3,4,5,6].

Although great care is usually taken in the selection of both decorative and protective coatings, not enough attention is paid to the on-site practical aspects associated with coatings. These include surface preparation, method and timing of application, surface moisture condition of concrete, quality control testing and general detailing of concrete coatings, which would greatly affect their overall performance and effectiveness.

The purpose of this technical note is therefore to discuss various aspects of coatings and to highlight a number of required on-site conditions which would compliment the selection of an appropriate coating, to improve both the appearance and performance of concrete structures in typical environments. These on-site requirements generally apply to film forming, membrane and impregnation coatings of both the decorative and protective type.

PROTECTIVE COATINGS

General

Protective coatings play a key role in the overall concrete repair process, and they are characterised by their ability to prevent the ingress into the concrete of such deleterious materials as chlorides, carbon dioxide and other aggressive liquids or vapours. They are widely used to provide additional protection and enhance the aesthetic appearance not only of patch repairs but also the surrounding concrete, in order to prevent further deterioration of areas which have not as yet needed repair. In addition, they can provide extra protection and increase the durability of existing low quality concrete structures and new structures which are not as yet subject to deterioration, particularly the ones exposed to severe and aggressive environments as part of a preventative maintenance strategy [2,4,5,6]. It should be noted that where deterioration has already begun but is not yet visible, the application of a protective coating will prevent further ingress of corrosive agents, but will not halt the deterioration process as this is too late.

In general, pigmented coatings give much better protection and decorative finish and are more durable than unpigmented coatings. Ideally coatings should possess elastic properties, in order to bridge over any cracks which are present in or which might appear subsequently in the concrete or any repair mortar.

Types of Protective Coatings

Materials which are commonly used to formulate proprietary coating systems for the protection of concrete include both organic and inorganic generic types such as polyurethane resins, acrylic resins (i.e. decorative/anticarbonation coatings), epoxy resins, polymer modified cementitious material, bituminous material, chlorinated rubber, silane and silane/siloxanes [1,2,3,4,5,6,7]. Most of the protective coating systems originating from the above materials form a thin film on the concrete surface. However, protective coating systems based on the silane and silane/siloxane materials are pore-lining penetrants which impregnate the concrete and react with the moisture and silicates present in the concrete microstructure, thus modifying the concrete surface including the penetrated layer to form a water repellent but vapour permeable (breathable) barrier.

Pore-Lining Penetrants

Pore-lining penetrants (i.e. small molecule impregnations of pure silane and solid silane/silane cream with at least 95% and 80% active ingredients respectively) prevent contamination by preventing water containing salts and other deleterious substances from entering the concrete. It should be noted that mixtures of silane/siloxanes (with around 20% active ingredients) and siloxanes (larger molecules with around 15% active ingredients) on their own are less effective pore-lining penetrants. However, being vapour permeable, pore-lining penetrants have a low resistance to carbon dioxide and they are not effective against carbonation. A more suitable film forming coating (i.e. polyurethane or acrylic resin anticarbonation coating) would have to be applied to act both as a carbonation barrier and as an effective dual protective coating system together with a silane or siloxane impregnation treatments (Fig. 1). Due to their water vapour transmission properties, silane or silane/siloxane penetrating sealers allow concrete to dry

out and hence cause an increase in the concrete resistivity together with a significant decrease in the measured electro potentials of the steel reinforcement. However, although they are excellent in preventing ingress of water (and hence chlorides) under normal conditions, they do not protect against hydrostatic penetration of water. In regards to marine environment however, they are useful in the splash, spray and mist chloride zone but less effective where there is direct tidal action. These generally impregnate approximately the outer 3 mm (siloxane) to 5 mm (silane) of the concrete surface and effectively seal cracks and other defects up to 0.3 mm wide. These materials are easy to reapply after 20 to 25 years and some form good primers for other types of film forming coatings.

Anticarbonation and other Film Forming Coatings

Generally most proprietary coating systems consist of a separate primer and top coats for the concrete, in order to improve the overall adhesion characteristics and achieve the required coating thickness. Proprietary coating systems available range from thin coatings such as decorative/ anticarbonation coatings (i.e. dry film thickness (DFT) of 150 micron) to high build coats such as epoxy and cementitious coatings (i.e. over 2 mm in DFT for some). The general life expectancy of decorative/anticarbonation coatings and other film forming coatings is in the order of 15 years, although this depends greatly on exposure conditions and compliance with the specified requirements such as those in Section 6863. It should be noted that anti-graffiti coatings and protection are covered by Technical Note No. 16 of this series.

A special use of some coatings is the waterproofing of concrete bridge decks before they are surfaced with a wearing course. These coatings must be able to withstand both the laying temperature of bituminous materials and punching from the aggregate when the surfacing is rolled. In addition to the protective coatings and sealers, waterproofing membranes can also be applied either as liquids or as preformed sheets.

Criteria for Selection of Protective Coatings

The following technical properties should be considered when selecting protective coating systems:

- excellent adhesion in dry, damp or permanently wet conditions;
- high compatibility with the repair mortar;
- breathability - by allowing moisture trapped within the concrete to be released without blistering or debonding the coating;
- elastomeric capability in order to bridge cracks subject to movement;
- high resistance to diffusion of carbon dioxide, chlorides, sulphur dioxide and moisture;
- high resistance to chemical exposure and weathering;
- high water impermeability;
- high abrasion resistance;
- high inherent alkalinity;
- good aesthetic qualities including colour and texture;
- high resistance to degradation by ultra-violet light and therefore good durability without loss of coating thickness or breakdown;
- suitability for permanent underwater application;
- long life and therefore long maintenance free period and low maintenance costs.

SURFACE PREPARATION

The surface preparation should be undertaken in accordance with the requirements of Section 686[3] and the material manufacturer's specification, in order to achieve the appropriate adhesion, coating penetration into the concrete and aesthetic requirements. Concrete should be clean and reasonably dry for the coating to adhere properly and be resistant to peeling or blistering.

Previously painted surfaces must be clean and sound. All traces of peeling or loose paint should be removed. Mechanical means such as abrasive blasting (wet or dry, depending on environment), high pressure water blasting and steam cleaning are some of the methods found to be satisfactory for cleaning large areas of old concrete (Fig. 2). For new concrete it is possible to coat without much cleaning provided that the surface is free from the oil or wax used to release the formwork. In addition, wax or chlorinated rubber based curing membranes would prevent the adhesion of coatings and therefore their removal is necessary and this is usually best achieved by mechanical means. Cleaning of new concrete however, by mechanical means, should not be undertaken until the concrete is at least 28 days old and has reached its required strength. Mechanical cleaning of new concrete prior to 28 days old, or prior to reaching its required strength, may adversely affect the ultimate bond between the coating and concrete.

According to well established research, newly placed concrete must be adequately cured, allowed to mature for a reasonable time and sufficiently dry prior to the surface preparation and subsequent application of these coatings, in order to ensure adequate adhesion and overall effectiveness.

ENVIRONMENTAL CHECKS

Environmental checks[3] which must be determined and be acceptable prior to coating application include air temperature (10°C - 35°C), relative humidity (<85%), dew point (3°C above concrete surface temperature), concrete surface moisture condition and moisture content of concrete (less than 10%) (Fig. 2).

SURFACE MOISTURE CONDITION

The surface condition required prior to the application of a coating is governed by the type of coating used and the material manufacturer's requirements. Where materials to be used require a dry surface, the substrate areas to be

treated should be surface dry before application commences. Artificial drying of surfaces should not be carried out, hence, depending on climatic conditions, it may be necessary to protect surfaces to be treated to ensure that they are surface dry before applying a film coating or impregnation. It should be noted that some coatings are available which can be applied under wet conditions for special applications.

MOISTURE CONTENT OF CONCRETE

Manufacturers of some coatings specify that the moisture content of the concrete be limited in order to prevent water back pressure on the coating. In general the moisture content of concrete should be less than about 10%, as required by Section 686 with respect to appropriate timings for application of coatings. Moisture content can be measured by one of several moisture meters (Fig. 2).

APPLICATION

Film coatings or impregnations should be applied as a series of continuous operations, in accordance with the material manufacturer's specified techniques and recommendations. For most coatings, application is generally done by brush, spray (Fig. 3) or roller although some protective coatings can be hand/gloved applied (Fig. 4). The manufacturer's requirements in relation to the method of application, time limitations of materials and intercoating time intervals should be strictly adhered to. The coatings should be applied so as to produce a smooth, even coating free of lumps, ripples, sags, runs, air holes and other defects. Quality assurance methods and inspection and test plans addressing surface preparation, application, bond, thickness and other testing should be prepared in accordance with the requirements of Section 686.

CURING AND DRYING

Curing and drying should be carried out in accordance with the material manufacturer's recommendations.

PARAPET DETAIL

Where coatings are applied on walls or other vertical concrete components which have exposed top horizontal surfaces, coatings should be taken over the top of the "parapet" and also down to the back of the wall. This is required to stop water and moisture from getting in behind the coating system, thus causing it to slowly blister and subsequently peel off.

RETAINING WALLS

Where coatings are applied on retaining walls or other soil retaining structures, it is recommended that adequate waterproofing membranes and drainage systems be installed behind the wall. This is to prevent moisture egress which slowly comes to the surface of the concrete causing the coating to blister and peel off.

APPROPRIATE TIMINGS FOR APPLICATION

The following are suggested as acceptable timings for the application of coatings on concrete surfaces.

NEWLY CONSTRUCTED CAST IN-SITU CONCRETE/PASSIVELY CURED PRECAST CONCRETE

On newly constructed concrete, decorative or protective coatings should be applied not earlier than 28 days after the concrete has been placed and provided the concrete is in a surface-dry condition. Passive curing includes use of water, wet hessian, polyethylene plastic, formwork in place and a combination of these.

Steam or Radiant Heat Cured Concrete

For steam cured components, the application of coatings should be carried out not earlier than 14 days after concrete has been placed.

Repaired Concrete

For existing concrete structures where concrete repairs have been completed with proprietary materials, the application of coatings should be carried out not earlier than 14 days after completion of repair. However, where normal concrete is used for repair, the requirement of not earlier than 28 days should be observed.

QUALITY CONTROL TESTING

The following quality control testing should be undertaken.

Testing Prior to Application of Materials

- Surface moisture condition of the concrete substrate - to satisfy manufacturer's recommendations.

  This could be evaluated by the pickup of moisture as one's finger is dragged along the substrate surface. An alternative method is to press an absorbent paper very tightly against the concrete. If the paper darkens, it indicates the pickup of moisture which is inappropriate for the successful application.

- Moisture content of the concrete - to demonstrate that it is free of water back pressure, to satisfy manufacturer's recommendations.

  This could be evaluated by moisture meters (Fig. 4). It can also be tested by taping a square piece of polyethylene plastic (i.e. 1 m x 1 m) to the concrete surface overnight and observe any evidence of condensation on the plastic the following morning.

Testing After Application of Materials

- Bond strength - to demonstrate conformance with the minimum adhesion strength as specified by Section 686 (Fig. 5).
- Wet and dry film thickness or the amount of penetration of the coatings into the concrete as specified by Section 686 (Fig. 5).

The location and frequency of testing of the protective/decorative coating system or the pore-lining penetrant (i.e. silane or silane/siloxane) (Fig. 3) should be undertaken on completion of the application of the final coat in accordance with prescribed requirements such as those of Section 686.

Useful standards for some of the above tests (i.e. adhesion, pull off strength, wet and dry film thickness etc.) can be found in AS1580.408, ASTM D4541 and AS1580.107.3 and AS1580.108.2. However, as these are applicable to steel substrates some minor modifications may be required for application to concrete substrates. Test Method RC 252.02[8] for the determination of the bond strength of concrete repairs can also be used for bond testing of film-forming coatings.

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Fig. 1 Decorative/anticarbonation coating (L), Dual protection with silane/anticarbonation coating (R)

Fig. 2 Preparation of the concrete surface for coating application (L), Measurement of relative humidity, dew point and temperatures (R)

Fig. 3 Spray application of anticarbonation coating (L), Application of silane with fugitive dye on 3 year old bridge as part of preventative maintenance (R)

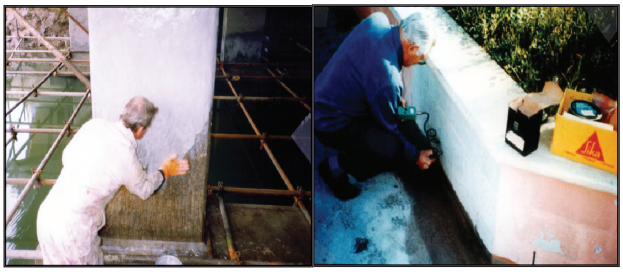

Fig. 4 Application of epoxy coating by hand (L), Moisture meter in use (R)

Fig. 5 Wet Film Thickness Gauge (L), Dollies attached onto coating surface and pull-off test in progress (R)