Concrete as a substrate for coating

Introduction

Concrete is a widely used construction material and comes in a variety of shapes and sizes. Typical properties of concrete are easy manufacture and casting, very high resistance to impact and stress. The conctete can obviously not corrode and will often perform well without corrosion protection.

However, concrete is neither impermeable nor inert. Water, oxygen and other substances permeate it over time and concrete gradually deteriorates with exposure to the environment. Additionally the reinforcing steel bars begin to corrode when the pH inside the concrete drops due to reaction with CO_2. Accordingly, concrete may be coated with protective coatings to help ensure long and trouble-free service. Concrete may also be coated for decorative purposes. Preparing a concrete substrate for coatings requires a different and more complex set of considerations than when coating steel.

Safety

Use adequate personal safety equipment and follow sound procedures. Apply only in well-ventilated areas. Observe safety labels on packaging and paint containers and consult Hempel’s Safety Data Sheets for the products to be applied.

Scope

This Hempel Technical Guideline provides a brief overview of the basic constituents of concrete, the deterioration mechanisms of concrete when exposed to an aggressive environment, the specific properties of new as well as aged concrete related to painting are explained, as well as recommended surface preparation and the selection of suitable coatings.

The information is applicable to a number of Hempel's protective coatings, typically epoxies or vinyl esters. Of particular relevance are:

Sealers

- Hempel’s Sealer 05990
- Hempaline Prepare 110
- Hempaline Prepare 120
- Hempaline Prepare 130
- Hempel's WB Primer 28830
- Contex fillers / primers

Epoxies

- Contex series
- Hempaline Defend series

What are the constituents of concrete?

Like dry paints, concrete is a mix of binder, filler and additives. The binder in concrete is cement, the filler stone and gravel, and the water acting as the "solvent and curing agent”. Admixtures are added to adjust the concrete mixture for specific performance criteria.

Cement

Cement reacts and hardens when mixed with water, and binds all of the ingredients together. The main purpose of cement is to form the continuous phase and hold together the stone/gravel. Cement content should not be excessive as it increase cost and affects volume stability (cement increase drying shrinkage and plasticity of concrete).

Water

Water plays the primary role in cement hydration and concrete workability and its content should keep as according to concrete mix design so that it will not decrease strength and increase porosity of the concrete.

Aggregate

Aggregates are a chemically inactive material which is bonded together by the cement. Most of the aggregates used are naturally occurring aggregate such as sand, gravel, and (crushed) stone.
Aggregates are classified into fine aggregate and coarse aggregate according to particle size and bulk density.

Admixtures

Admixtures are material other than cement, aggregate and water that are added to concrete either before or during mixing to alter its properties and performance in fresh (workability, setting time etc.) and hardened state (strength, durability etc.).

Deterioration of Concrete

A well-engineered concrete structure can perform well for a very long time. There are many examples of buildings and structures in good conditions for decades and even centuries.

Nevertheless, there are cases of the concrete having been severely attacked, sometimes with corrosion to the reinforcing iron bars.

Fresh concrete possesses an alkalinity of up to pH 13. This alkalinity, caused by the calcium hydroxide ($Ca(OH)_2$) component of the cured cement, protects the reinforcing steel bars against corrosion. Reinforcing steel in concrete, starts to corrode when the pH of the moisture in the concrete is lower than 9.

Moisture present in the concrete loses its alkalinity due to, for instance, the reactions:

- $Ca(OH)_2 + H_2CO_3 \text{ -> } CaCO_3 + 2H_2O$ (“carbonation”)
- $Ca(OH)_2 + H_2SO_4 \text{ ->} CaSO_4 + 2H_2O$ (“sulphation”)

H_2CO_3 (carbonic acid) and H_2S0_4 (sulphuric acid) are reaction products of respectively CO_2 (carbon dioxide) and SO_2 (sulphur dioxide) in the atmosphere. Carbon dioxide is a natural component of the atmosphere, present in a concentration of approx. 600 mg/m^3. Sulphur dioxide is one of the components of air pollution and is present in an average concentration of approx. 0.02 mg/m^3 in urban atmosphere and may be higher locally.

The degree of carbonation and sulphation depends on the porosity of the concrete. The porosity itself is a function of the cement species used (e.g., Portland cement, blast furnace slag cement, etc.) and the water content (the so-called water-cement ratio) of the concrete mixture.

Due to the previously mentioned reactions, the alkalinity in the concrete will steadily decrease. Many investigations have shown that the depth of carbonation penetration depends on the square root of the exposure time. For a good quality concrete, the relation is roughly:

$$Depth\ (mm) = \sqrt{Exposure\ time\ (years)}$$

Thus the acidification caused by carbonation will be around 1 mm the first year. As the specified thickness of the concrete over the reinforcement is normally 20-50 mm, reinforcement will be protected for many years. However, when the concrete is applied in thinner layers premature corrosion may take place.

When the reinforcement begins to corrode it causes a significant increase in volume. As a result, the outer concrete is damaged.

Another form of damage is caused by chlorides from, for example, seawater or de-icing salts. The chlorides penetrate the concrete and can cause corrosion of the reinforcement bars even at high pH, where steel would otherwise be passivated.

Freeze off phenomena also occur (freeze-thaw cycles), when concrete saturated with water is exposed to frost - The expansion of the water, can cause cracking.

Needless to say that prevention of these faults is much cheaper than renovation, and this can be achieved by providing the undamaged concrete with a protective barrier coating.

New Concrete

Laitance:

Laitance is a thin layer of surplus cement and water, which rises to the surface during setting of concrete. Unless removed, it will severely reduce adhesion and even cause the failure of anything bonded to its surface.

Curing compounds

Curing of concrete requires humidity. Curing compounds are liquids forming a vapour-impermeable film, which are sprayed on to the green (= fresh) concrete to allow adequate curing replacing other methods to maintain humidity. Such methods may be water hosing or covering the fresh concrete with a PVC coated tarpaulin.

Some of these curing compounds are based on wax or paraffin which cause adhesion problems during the subsequent paint treatment. Usually, these curing compounds are fairly quickly decomposed by the strong alkalinity in green concrete, but it would be wise to make reservations on the performance of the coating system when the concrete has been treated with curing compounds.

A test for residual curing compound can be done by sprinkling water drops on the concrete. If the drops are not absorbed this may indicate the presence of curing compounds or other water-repellent contaminants.

Blow holes

Blow holes and other minor surface defects may be present. They should be filled with a cement-based mortar which must be allowed to cure fully prior to painting. Plasters should only be used to repair interior concrete areas receiving decorative finishes. If used on exterior surfaces they may absorb moisture, expand and cause total failure.

Lack of cure

Fresh concrete should be allowed to fully cure prior to coating application. Traditionally 28 days curing period is considered practicable.

Humidity

The moisture must be below 4 % by weight in the surface layer at the time of painting. This can be checked by various moisture indicators developed to detect moisture in concrete.
Comparatively cheap and simple instruments are the electromagnetic types which are placed directly on the concrete surface. These instruments do not always give a definitive value of moisture, but more often are instruments indicating whether the concrete is moist or not.
Another method is to drive two metal pins 2-3 cm into the concrete and measure the humidity as electric resistance between the pins.
Another way to check the moisture content in the concrete is to tape a sheet of an impermeable polymer film, onto the concrete surface. After 24 hours it is checked if condensation has formed on the underside of the film. The moisture is seen as a darkening of the concrete surface. (ASTM D 4263). This method can be combined with electric moisture indicators. The described method is very realistic as it shows how much moisture can concentrate under a coat of paint.

Efflorescence:

Noticed on walls more often than floors, efflorescence is seen as a salty stain. It is caused by moisture moving towards the surface of concrete (or bricks, etc.). These salts must be removed before any painting takes place.

Form oils (slip agent)

Slip agents are used in casting forms to allow easy removal after the casting of the concrete. It has properties similar to Oil and Grease.

Aged Concrete

Hardeners:

Hardeners are solutions frequently applied to existing concrete floor slabs to reduce dusting. Unless these surfaces are prepared properly, coating adhesion is greatly impaired.

Rising moisture

Where concrete is in direct contact with water, e.g., foundations, the moisture absorbed in the capillary system of the concrete may damage the concrete by making it porous or cause breakdown due to freeze-thaw action.

Soundness, hardness:

The cohesion of the concrete must be minimum 1.5 MPa measured by a pull-off test instrument such as the 'Elcometer Adhesion Tester'. The testing is made by gluing a steel dolly direct on to the concrete surface and pulling it off by the instrument.

Peaks and other roughness must be removed.

Humidity

See new concrete.

Pores, crevices, etc.

Pores with a diameter above 5 mm should as well as cracks and crevices are filled with cement mortar or injection epoxy and holes are filled either with epoxy putty or with epoxy mortar depending on availability (and size of the holes). Repair may also be carried out with new concrete which, however, must be allowed to cure fully before being overcoated.

Other

Contaminants such as soaps, detergents, oils, fats, grease, etc. can penetrate deep into a concrete surface.

Surface Preparation

A concrete surface is very different from a steel surface.

Depending on the condition of the concrete, one or more methods of surface preparation may be required.

The surface must be dry, sound and clean of contaminants, laitance efflorescence etc. The surface may be cleaned mechanically (abrasive blasting or power tooling) combined with detergent cleaning if for example oil or grease are among the contaminants.

Water jetting is an alternative to blasting, but be aware that as opposed to steel surfaces, water jetting may create a rather rough surface profile on concrete. A profile which may not be levelled out by an ordinary coating system!

Directions for etching

An alternative to blasting on horizontal surfaces is acid etching. This is preferably carried out with a solution of hydrochloric acid in water. Use one part of 30% hydrochloric acid with 2-3 parts of fresh water. Stronger solutions or repeated treatment may be required to produce the necessary slightly granular surface required for satisfactory adhesion of the paint to the concrete. The concrete surface should be saturated with fresh water, prior to application of the acid solution.
The acid solution should be allowed to remain on the floor until it stops bubbling (approx. 20 minutes) before it is flushed thoroughly with ample quantities of fresh water.
If the surface does not dry uniformly within a few hours, it must be flushed again with fresh water until all acid has been removed.
The pH of the concrete surface should now be within the 6.8-8.0 range for safe coatings application.
Painting may take place after the concrete surface has dried thoroughly, minimum 2 days.

NOTE: Hydrochloric acid is a strong acid. Adequate working and handling precautions must be taken. Operators should wear protective equipment such as boots, goggles and rubber gloves, complying with local regulations.

Coatings for Concrete

In principle many of the same coating systems which are used for steel may also be used for concrete, however with 3 main differences:

1. As especially new concrete is an alkaline material, we do not recommend the use of products which may saponify - so alkyds should not be used!

2. Concrete is a porous substrate. Therefore, sealing the porous substrate is as essential to enhance adhesion to the concrete surface as well as an anchor pattern is essential for adhesion to the coating.
   For high performance coating systems, it is recommendable to use a concrete sealer as first coat. In some cases, heavy thinning of first coat can substitute a sealer coat; this is especially when very high performance is not required.

3. In some cases, there may be a water vapour transport through the concrete – for example through the walls of concrete buildings. If the concrete is only coated on the dry side and not on the wet side, the water vapour pressure (back pressure) may become so high under the coating that it is pushed off the substrate, and the result is peelings. In such cases it is important to use coatings which allow a certain amount of water vapour to pass the film: The paints should allow the concrete to “breathe”. An example of such a coating is Hempel’s Contex Smooth 46600.

For details of concrete paint specifications consult with Hempel.