Bridge deck Waterproofing on Steel

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Conclusion

Bridges are critical structures of our infrastructure. Particularly steel bridges, due to their determination and geographical position are overexposed to corrosive attack.

ISO 12944, 1-8, is the worldwide recognised standard for corrosion protection of structural steel and is also valid for bridge structures. The 8 parts of this standard cover different items, however parts 2 & 5 are most important for preservation, but it’s difficult to find standards for the protection and refurbishment of bridge decks.

Bitumen based state of the art systems cannot fulfil the increasing requirements for modern bridges, when it comes to extended service life and resistance to severe stresses, so developing new resin based systems which can provide a longer service life, shorter down times in case of maintenance works and reduced repair costs are the main target for system manufacturers. The introduction of 2 new systems, with excellent physical properties, is shown in this paper.

Keywords: Steel Bridges, Deck Waterproofing, Corrosion protection, Bond to Overlay, Shear Resistance, ISO 12944

1. Introduction

Bridges and overpasses are an essential part of modern infrastructure and commonly use brick, concrete, wood and steel as construction materials. Steel provides a lightweight, fast, low cost solution with the highest strength-to-weight ratio of any construction materials, hence these advantages have been in use for more than 100 years, particularly for longer spans.

Due to their location and scope, bridge decks are often subject to the most severe climatic conditions, having to withstand attack from water, sulphates, chlorides, frost and heat together with high loads and movement from traffic and earthquakes, which can lead to deterioration and potential issues with structural integrity, so installation of an effective bridge deck waterproofing system should be an essential part of any new build project or refurbishment programme.

Currently, modern bridges have a design life of approximately 120 years however the performance of the protective systems for the structure and bridge deck have an expected life of 10-20 years, therefore whilst regular repainting adds to the life time cost of the structure, failure of the protective system if not regularly maintained, is one of the major causes of premature deterioration of the steel.

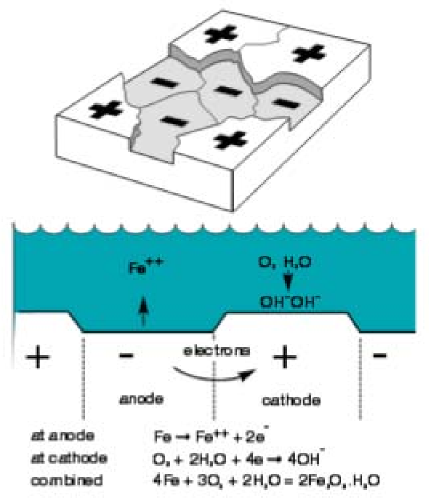
2. Corrosion of Steel

The corrosion of steel can be seen as an electrochemical process. Ferrous ions react in the presence of water and oxygen to hydrated ferric oxide.

This process goes in steps with the final reaction shown as follows:

4Fe	+	$3O_2$	+	$2H_2O$	=	$2(Fe_20_3H_20)$
Steel	+	Oxygen	+	Water	=	Rust

This process requires the presence of both oxygen and water.



[1] Fig. 1: Mechanism of corrosion

The main factors determining the rate of corrosion are:

"Time of wetness": meaning the time during which the surface is wet due to rain, condensation, etc.

"Atmospheric pollution": meaning the pollution in the air and the presence of salts, chlorides, sulphates, etc. Sulphates are the result of burning fossil fuels and chlorides are caused by salt water spray & de-icing salts.

3. EN ISO 12944

The international standard ISO 12944 is divided in 8 parts.

Part 1: General introduction, scope, health, safety and environment
Part 2: Classification of environments
Part 3: Best practice in structural steel design (design consideration)
Part 4: Types of surface and surface preparation
Part 5: Protective paint systems and durability
Part 6: Laboratory performance and test methods
Part 7: Application on site, inspection, reference areas
Part 8: Preparation of specifications and ancillary issues

Parts 2 and Part 5 are the important parts for determining the best suited coating systems.

Part 2 gives advice on how to determine the corrosion rate depending on the climate and microclimate surrounding the bridge to be protected, whilst Part 5 gives advice on which coating system build-up and thickness to use, depending on the expected life time of the coating. This is not the given warranty time, but the expected life duration of the protective systems.
Unfortunately ISO 12944 only takes into consideration the structural steel work, not the deck itself.

According to the corrosivity classes given in ISO 12944-2, bridge decks can be considered to be classified as C 4 (high corrosive atmosphere in industrial or coastal areas).

4. Bridge Deck

Having a closer look at the deck itself, two major types of traffic can be identified; pedestrians & bicycles or cars & heavy vehicles which influence the type of the chosen wearing layer.
In general steel bridges and steel decks have a certain thermal elongation when exposed to heat and the orthotropic deck starts bending under dynamic loads between the girders. This is exaggerated depending on the type of traffic, therefore the protective system needs to be flexible enough to take these movements but without cracking or delaminating from the substrate.

4.1 Asphalt wearing surfaces

With increasing traffic loads and weight of vehicles, the adhesion of the asphalt overlay to the waterproofing and corrosion protection system underneath it, must be sufficiently high to prevent delamination of the asphalt overlay, particularly from the high shear forces generated by heavy vehicles accelerating and braking.
The bridge deck waterproofing system also needs to be able to withstand temperatures of up to +250°C during installation of mastic asphalt as a wearing surface.

4.2 Wearing surface without asphalt

Sometimes to reduce weight, the waterproofing system also doubles as the wearing layer, in which case a highly abrasion resistant surface with chemical resistance to hydrocarbons and de-icing salts, together with resistance to UV-ratio due to the missing overlay is necessary.

5. Waterproofing of steel decks

Research has found that there are not many standards in place that refer to the waterproofing of steel bridge decks, unlike concrete bridges where different standards can be found.

In the segment of steel bridges, only the German Standard ZTV-ING, Part 7, Section 4 gives clear test procedures and minimum performance values that should be achieved by the waterproofing system, in combination with asphalt overlay. Although there are some recommendations found in the UK, some states of the US and an initiative in China to create a new standard.

Most often bitumen based waterproof coatings or torch applied bituminous membranes are used as waterproofing underneath asphalt overlays, but these have been proven to fail prematurely due to high shear stresses on the bond line, and poor bond from low asphalt strength particularly if the asphalt is in thin layers and exposed to higher temperatures.

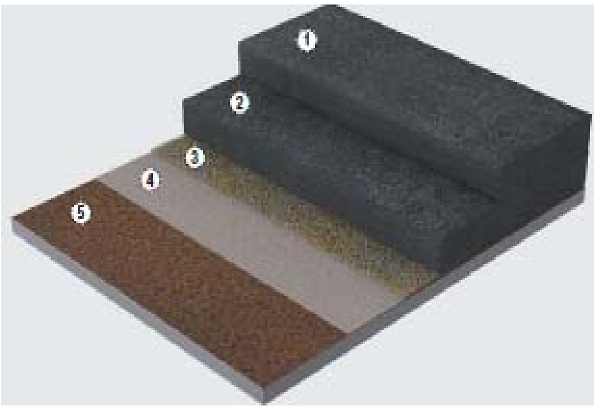
Decks without asphalt overlays are subject to traffic directly on the steel surface, or are treated with a coating normally broadcast with aggregate to increase friction of the tyres.

5.1 Waterproofing underneath asphalt overlay

To overcome the physical issues related to bonding of the asphalt, the idea was to adapt an already existing BDWS (Bridge Deck Waterproofing System) for concrete bridges to the application on steel decks. The key technology is based on expanding hot melt pellets which are uniformly spread into a well adhering tack coat. The heat of the asphalt makes the pellets expand & form a glue, which significantly improves the tensile bond and shear strengths between the asphalt overlay and the waterproofing membrane.
This technology has already been certified in accordance to BBA/ HAPAS (British Standard for waterproofing concrete bridges) and the overall European standard ETAG 033, also related to concrete decks.

A long track record with a low modulus, epoxy resin based corrosion protective coating and a flexible epoxy resin based waterproofing layer followed by a bitumen tack coat, gave the idea to combine these technologies.
Preliminary tests have been done using the anti-corrosion coating as a primer, and the flexible epoxy broadcast with the expanding hot melt pellets whilst still wet as the primary waterproofing layer. After asphalt paving, bond and shear test were conducted with excellent results. Comparing to the German standard, the achieved values are 8 times higher for shear strength and 4 times for bond strength.
Further tests were started, including permanent bending and freeze-thaw-cycling etc. with the BDWS passing all tests so the approval could be achieved.

In parallel, almost identical test procedures were carried out in China by SMEDI (Shanghai Municipal Engineering & Design Institute) where they achieved similar excellent test results.



1 Wearing course: Mastic asphalt (+240° C) / Asphalt concrete (+140–180° C)
2 Base course: Mastic asphalt (+240° C)/ Asphalt concrete (+140–180° C)
3 Solvent-free, flexible epoxy + expanding hot melt pellets evenly broadcast
4 Primer: 2-comp-epoxy, low modulus, solvent free
5 Steel deck 12 mm

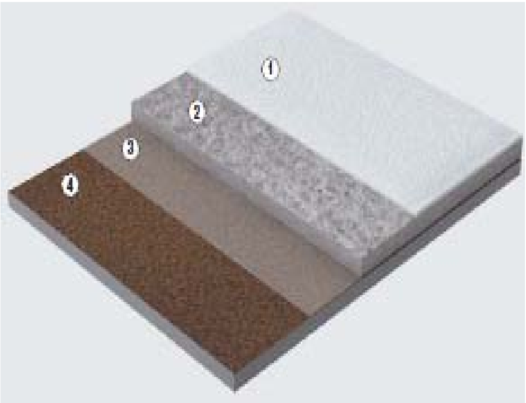
5.2 Waterproofing exposed to traffic

Steel structures built more than 50 years ago, often can´t take the high loads of vehicles today, so road authorities have an option to upgrade these critical bridges by removing the asphalt overlay and replacing with a light-weight, waterproofing solution that can be trafficked directly, observing the short closure times that are often imposed. This solution has a huge impact on weight & installed cost and is mainly used on bridges with lighter vehicular traffic volumes, pedestrians &

bicycles but must be tested for freeze-thaw cycling, permanent bending and abrasion resistance getting approval to supply such a system.

In accordance to the German standard ZT-ING, Part7, Section 5, these waterproofing/wearing layers have to consist of a corrosion protection primer, a membrane and a broadcast bearing layer, finished with a UV and abrasion resistant top coat. To apply these four layers, together with substrate preparation and curing time means the bridge must be closed for at least 2 weeks, normally leading to problems with the local traffic.
To reduce back-in-service time, a fast curing system was developed and tested comprising of a flexible, high-build, solvent-free, accelerated curing epoxy as a corrosion protection primer, followed by a fast setting, spray applied polyurea membrane, applied first as a waterproofing layer, then with aggregate injected at the same time as spraying to give a broadcast wearing course and finished with a fast curing, UV-stable, abrasion resistant Polyaspartic top coat.

The system gave excellent results under independent testing according to the German requirements, followed by a trial bridge done under permanent investigation, with no problems observed after two years.



1 Top coat: Solvent free Polyaspartic coating
2 Spray applied membrane and bearing layer:
Polyurea spray applied membrane, with Korrodur Durop 2–3 mm aggregate injected during application.
3 Primer: solvent free, fast curing epoxy
4 Steel deck > 12 mm

6. Conclusion

An increasing number of vehicles globally require high quality infrastructure and bridges are a sensitive part of this infrastructure, exposed to vulnerable attack by different ambient conditions.

The protection of the structural steel and the bridge deck itself is getting more and more important with bridge deck deterioration being one of the most extensive bridge maintenance problems affecting the service life of bridges.

Refurbishment & traffic diversions are a notable factor regarding the whole life cycle costs of the structure, therefore using more durable systems with quicker back-into-service time is one strategy to extend the life of the structure.

With a slightly higher initial installation cost but much lower life cycle costs compared to bitumen based solutions, modern protective systems based on organic reactive resins can meet these demands for the future.

6.1 References

[1] CORUS CONSTRUCTION & INDUSTRIAL., “Corrosion of structural steel”, 11/2006, pp. 1-5.