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Corrosion protection for bridge expansion joints and structural bearings

mageba

Importance and key requirements

* **Sources:**

- *www.corrosion.org*
- *www.nace.org/Publications/Cost-of-Corrosion-Study*
- *www.g2mtlabs.com/corrosion/cost-of-corrosion*
- *www.tradingeconomics.com/united-states/gdp*
- *www.galvanizeit.org*
- *www.feuerverzinken.com*

The importance of reliable, long-lasting corrosion protection

The annual direct costs of corrosion have been estimated to amount to approximately 3 % of GDP, both in the context of the United States and on a global scale. Including also indirect costs, the figure is estimated to increase to approximately 6 % of GDP – or trillion of dollars per year*.

In the case of critical bridge components such as bearings and expansion joints, the impacts of corrosion are especially strongly felt, because the performance, serviceability and even safety of a bridge depends on the proper functioning of these key components.

Repair works on bearings and expansion joints can be very expensive and have a significant impact on traffic, and the impacts are likely to be much greater when a component needs to be fully replaced, as it may arise when corrosion damage has become very serious.

Key requirements of factory-applied corrosion protection systems include:

- Long life to first major maintenance
- Ease of repair of minor damage
- Resistance to further deterioration once damage occurs
- Hardness
- Abrasion resistance
- Good appearance

The life to first major maintenance depends strongly on the environment in which the structure is located, and particularly on the corrosivity of that environment.

For example:

- temperate zones
- atmospheric environment with high pollution (SO_2:30 µg/m^3 to 90 µg/m^3) or substantial effect of chlorides, e.g. polluted urban areas, industrial areas, coastal areas without spray of salt water, exposure to strong effect of de-icing salts
- subtropical zones with atmosphere with medium pollution, are far more corrosive to steel and to corrosion protection systems than inland, rural environments

Therefore, it is critically important that the environment is considered in selecting and designing any corrosion protection solution.

When a bridge bearing requires to be replaced, the costs (including for lifting of the bridge deck) can be substantial

Corrosion of expansion joints, and at their moving / sliding interfaces in particular, can cause severe deterioration, often necessitating complete replacement of the joint which causes severe cost impact on traffic

Painted systems

Introduction

Painted corrosion protection systems have a long and successful history in all sectors of the construction industry, with the result that there is widespread experience of their use, and widespread general confidence in their performance and reliability.

Performance with respect to key requirements

Long life to first major maintenance

The relevant ISO standard, ISO 12944, considers three different durability ranges (low, medium and high), defining these in terms of the expected life of a protective paint system to the first major maintenance painting:

- Low = 2 to 5 years
- Medium = 5 to 15 years
- High = over 15 years

A much longer life can generally not be expected.

Ease of repair of minor damage

By brush, following cleaning of corrosion and defective corrosion protection.

Resistance to further deterioration once damage occurs

Water can spread underneath painted coatings, causing paint to flake off quickly.

Hardness

Low – damage can occur quite easily.

Abrasion resistance

Not high – quite susceptible to abrasion, e.g. on trafficked surfaces.

Appearance

Initially good, but can deteriorate quickly as damage or deterioration occurs.

Particular limitations

- Several steps/coats required, with appropriate drying times in between: Labour-intensive | Working space needed throughout the application and drying process | Quality control effort/difficulty in achieving uniform thickness
- Highly susceptible to environmental conditions (temperature and humidity) during application and drying processes

Particular advantages

Wide choice of colours generally possible.

mageba's standard painted corrosion protection systems for bearings and expansion joints, in accordance with ISO 12944:

	Corrosivity category C3	Corrosivity category C4 Alternative 1	Corrosivity category C4 Alternative 2	Corrosivity category C5
Sandblasting	Sa 2 ½	Sa 2 ½	Sa 3	Sa 2 ½
Zinc dust EP primer, 2-pack	80 µm	80 µm	-	80 µm
Zinc metal spray galvanising	-	-	80 µm	-
EP, 2-pack	-	80 µm	80 µm	160 µm
PUR, 2-pack	80 µm	80 µm	80 µm	80 µm

Hot dip galvanizing (HDG)

Introduction

Hot dip galvanizing (HDG) consists of the application of a protective zinc / zinc alloy coating to a steel element, by dipping it into a bath of molten zinc, where a chemical reaction > 450 °C (842 °F) occurs between the steel and the zinc. As a result of a diffusion reaction, the galvanized coating "grows" perpendicularly to all surfaces at a uniform rate – not as a "separate" coating, but as part of the structure.

Therefore, the coating will be as thick at corners and edges as on flat surfaces, providing uniform protection against corrosion – an important characteristic, since a corrosion protection system might be considered to have failed completely as soon as it has failed to a significant extent, regardless of the precise location on the structure.

German guidelines

In Germany, guidelines published by the country's Federal Environmental Agency (see Figure 1) show that the corrosion rate in most of the country is between 0.5 and 0.8 microns per year (approx. 0.02 to 0.032 mils). At that rate, across most of Germany, a zinc coating of thickness 85 µm can be expected to provide protection for a period of between 106 and 170 years. In comparison with the international standard DIN EN ISO 14713-1 regarding of life span shows that, if applied to Germany, the above mentioned guidelines are on the safe side.

American guidelines

In the United States, the American Galvanizers Association, using decades of corrosion rate data from all over the world, provides guidance for how service life (defined as the time to 5 % rusting of the steel surface) can be related to environment – see Figure 2.

International guidelines

The international standard EN ISO 14713-1 defines the expected life of a hot dip galvanized corrosion protection system as presented in Figure 3.

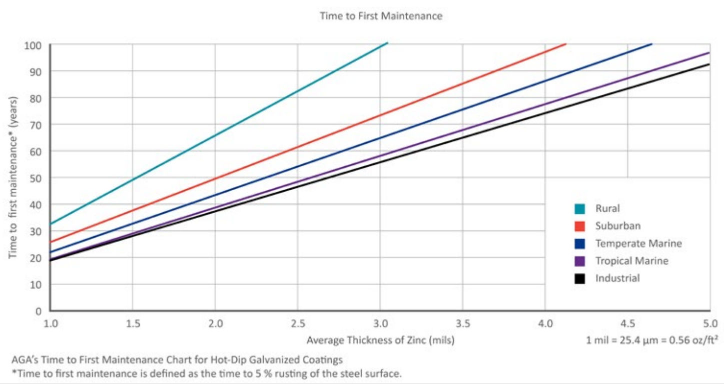
1 German Federal Environmental Agency "Zinc Corrosion Rate Map"

2 American Galvanizers Association – "Time to first maintenance"

3 EN ISO 14713-1, Table 2 – Life to first maintenance for a selection of zinc coating systems in a range of corrosivity categories

1

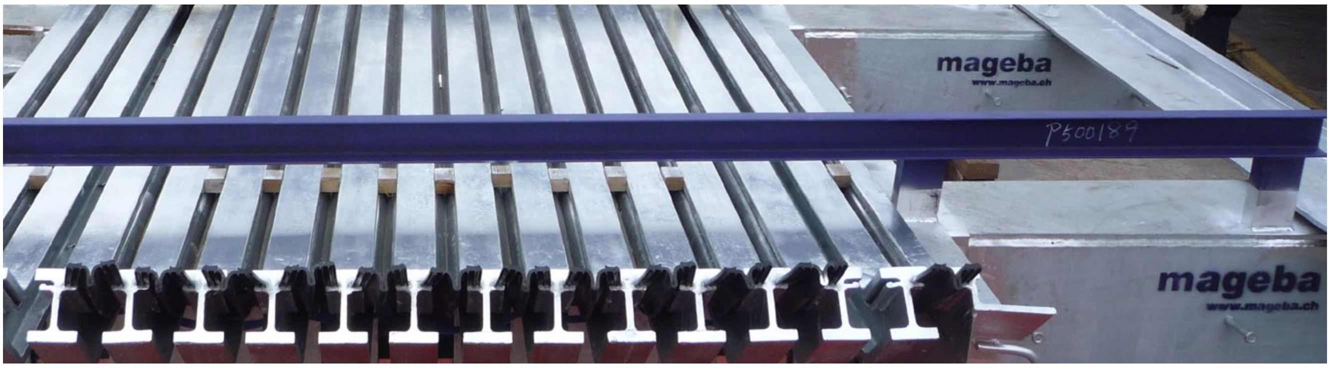
2



3

System	Reference Standard	Minimum thickness	Selected corrosivity category (ISO 9223) life min./max. (years) and durability class (VL, L, M, H, VH)							
		µm	C3		C4		C5		CX	
Hot dip galvanizing	ISO 1461	85	40/>100	VH	20/40	VH	10/20	H	3/10	M
		140	67/>100	VH	33/67	V H	17/33	VH	6/17	H
		200	95/>100	VH	48/95	VH	24/48	VH	8/24	H

mageba HDG systems and benefits



As a conservative approach – ensuring that the durability of corrosion protection is not over-estimated – mageba's HDG corrosion protection solutions are based on EN ISO 14713-1.

mageba's standard HDG systems

C4 – Hot dip galvanized

Corrosion protection according to EN ISO 14713-1. Corrosivity category C4, expected durability VH (very high). Steel components (with specific exceptions, depending on the product) are hot dip galvanized (per EN ISO 1461) with a minimum zinc coating of 85 µm.

C5 – Hot dip galvanized

Corrosion protection according to EN ISO 14713-1. Corrosivity category C5, expected durability VH (very high). Steel components (with specific exceptions, depending on the product) are hot dip galvanized (per EN ISO 1461) with a minimum zinc coating of 140 µm.

Performance with respect to key requirements

Long life to first major maintenance

100 years or more can be reached in very many cases, even for a relatively modest thickness of 85 microns – and performance can be yet further improved by using high-temperature hot dip galvanizing.

Ease of repair of minor damage

By brush, e.g. using a suitable zinc primer, following cleaning as necessary. To some extent, zinc coatings are self-repairing, with thin cracks effectively sealing themselves.

Resistance to further deterioration once damage occurs

Water cannot spread underneath the zinc coating, causing flaking (unlike for a painted coating), since this is integral with the underlying steel.

Hardness

Very high

Abrasion resistance

Very high

Appearance

Where choice of colour is not important, hot dip galvanized surfaces have a very good appearance – particularly after many years of service due to their excellent durability and long-term ability to prevent corrosion.

Particular limitations

- Size of parts which can be galvanized is limited by the size of the galvanizing bath
- Care must be taken to ensure that steel parts will not deform unacceptably due to the high heat during galvanizing
- Can generally only be done by a specialist HDG supplier
- Depends on availability of a suitable HDG supplier – geographically and time-wise
- Requires transport to and from the HDG supplier

Particular advantages

- Corrosion protection work is done by corrosion protection specialists, ensuring quality
- Not particularly susceptible to environmental conditions during application process

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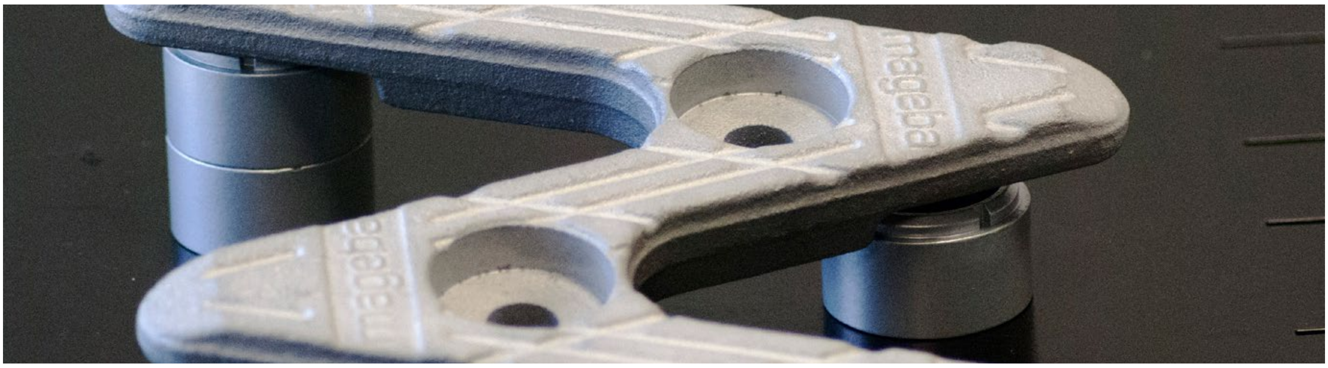
High-temperature galvanizing



Introduction

Normal-temperature galvanizing, with molten zinc at a temperature of approx. 450 °C (840 °F), produces a zinc coating which varies in characteristics and performance from the inside (steel substrate) to the outside (exposed surface). The so-called η-, ζ- and δ-phases (see Figure 4) have hardness values, on the Vickers scale, ranging between approx. 40 HV and 150 HV (with the lowest hardness at the exposed surface).

High-temperature galvanizing is a more advanced hot dip metal coating process, in which steel components are coated in a ceramic-lined, induction-heated pot at temperatures of 560 °C to 630 °C (1040 °F to 1166 °F).

This process produces only a δ-phase (see Figure 5), with a hardness value throughout the coating of approx. 150 HV – greatly increasing abrasion resistance and stone-impact resistance, and clearly far superior to normal-temperature galvanizing.

Sinus plates

For these reasons, mageba uses high-temperature galvanizing to provide corrosion protection for the noise-reducing surface plates of modular and single-gap expansion joints, which are subjected to continual abrasion from vehicle wheels. At the driving surface of a steel expansion joint, mechanical damage is generally the main cause of corrosion protection failure, so the higher the abrasion resistance, the better the durability. For this application, high-temperature galvanizing also improves slip resistance in wet conditions, and the more uniform thickness achieved maximizes the durability of the pre-stressed bolted connections even further.

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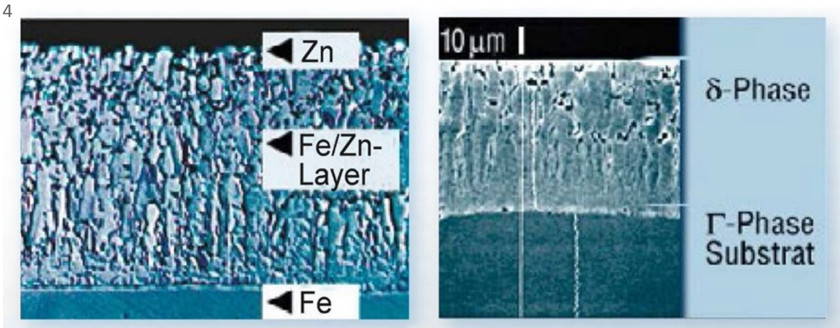

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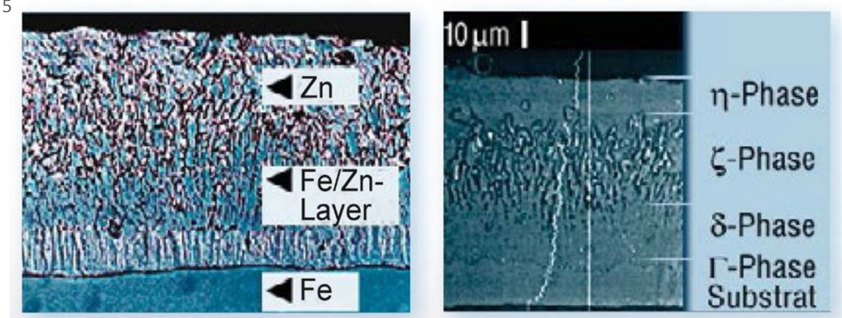

4 Hardness of high-temperature HDG
δ-Phase (only): approx. 150 HV

5 Hardness of normal-temperature HDG
η-Phase: approx. 40–60 HV
ζ-Phase: approx. 60–120 HV
δ-Phase: approx. 150 HV

Conclusions

	Painted system	Hot dip glavanizing
Long life to first major maintenance	Typically **10 to 20 years**	**100 years or more** can often be expected – **minimising life-cycle costs**
Ease of repair of minor damage	Painted coats are **not self-repairing**, **manual painting** for repair **always required**	**Self-repairing**, to some extent, saving the need for manual application of e.g. a zinc primer by brush
Rate of increasing deterioration once damage occurs	**Water can spread** quickly **underneath painted coatings, causing** paint to **flake off**	**Water cannot spread underneath zinc coating** since this is integral with the steel base
Hardness	**Not high** – damage can occur quite easily	Roughly **20 times harder** than a typical painted system
Abrasion resistance	**Not high** – damage can occur quite easily	Roughly **10 times more abrasion-resistant** than a typical painted system
Appearance	Initially **very good,** especially due to possible **choice of colours**, but can deteriorate quickly as damage or deterioration occurs	**No choice of colours** but good, even after many years of service due to their excellent durability and long-term ability to prevent corrosion
Particular limitations	**Several steps required**, with drying time etc. labour-intensive, and working space needed throughout process **Quality control effort**/difficulty in achieving uniform thickness	**Requires transport to/from HDG supplier** **Care** must be taken **to ensure that steel parts will not deform** unacceptably **due to the high heat** during galvanizing
Particular advantages	**Wide choice of colours possible**	**Improved quality control** due to well-defined process and **lower susceptibility to environmental conditions** during application

Note: *Where previously galvanized parts of a structure are to be assembled together, connection by bolting is generally preferable to connection by welding. This is because welding interfaces/areas must be free of galvanizing (or any other corrosion protection), and hot dip galvanizing of the welded area is not possible unless the entire assembly is hot dip galvanized again (if even possible). Then, a mixed system is required, with paint typically applied to the welded areas.*

6 Standard corrosion protection acc. to ZTV-ING, A3 near Passau approx. 15 Jahre, considerable corrosion

7 A3 near Passau approx. 15 Jahre, approx. 10 mm remaining zinc layer, no corrosion

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Worldwide references

Naab Bridge | Germany

Waikato River Bridge | New Zealand

Aizhai Bridge | China

Port Mann Bridge | Canada

Golden Ears Bridge | Canada

Mackays to Peka Peka Expressway | New Zealand

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