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A comprehensive

guide to corrosion protection

Specified to **Last**

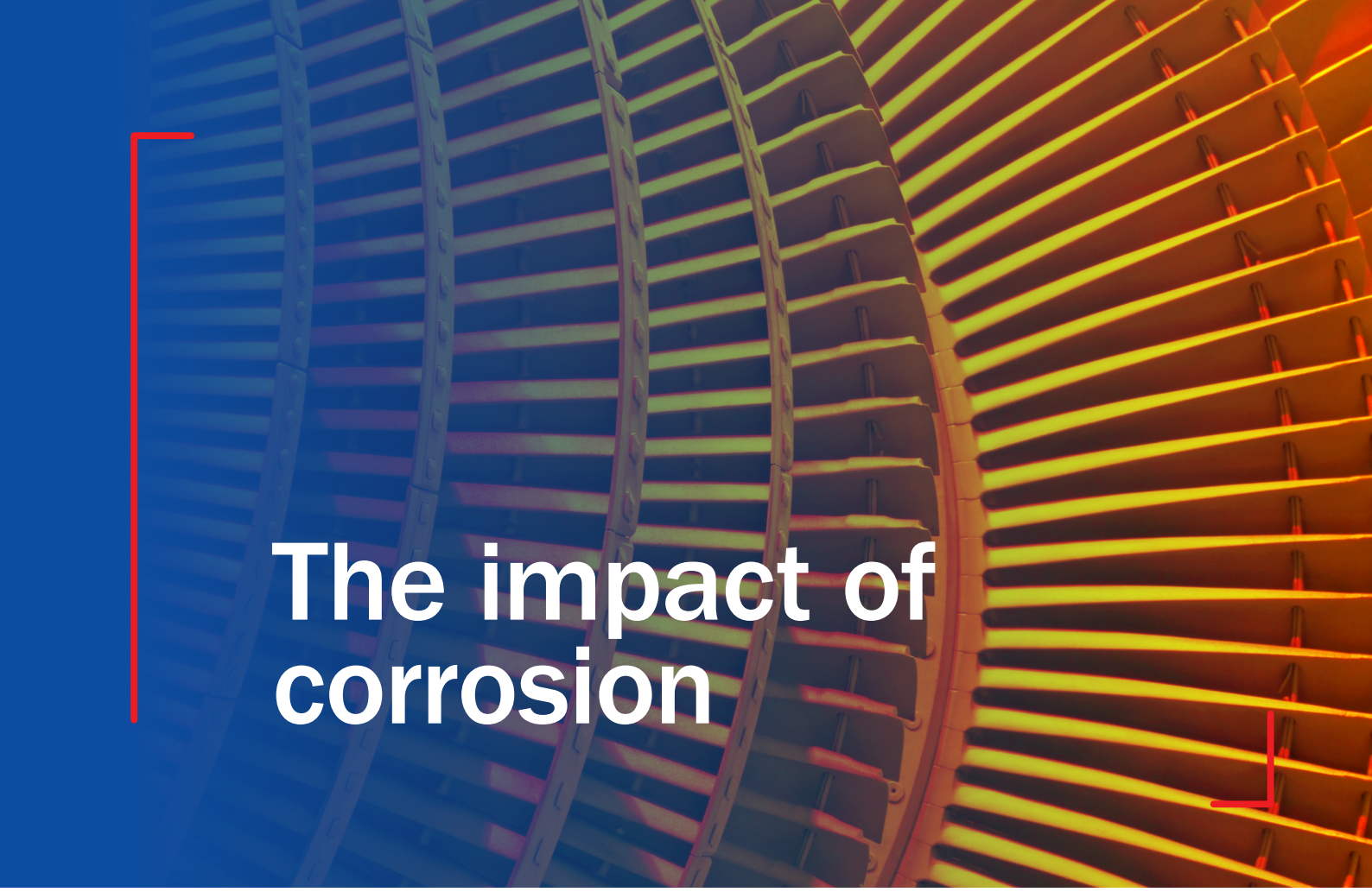
Introduction

Corrosion, the gradual wearing away of steel, is an ever-present challenge for engineers. It starts subtly when steel encounters common electrolytes like salt, oxygen, and water, which lead to the formation of oxides that compromise structural integrity. Therefore, mastering the specification of corrosion protection is substantial for enhancing the sustainability and longevity of construction projects.

By actively selecting the right protective measures, you can significantly reduce maintenance costs and contribute to the creation of durable and sustainable constructions.

The aim of this paper is to clarify the fundamental principles of corrosion protection and assist engineers in specifying structures that will withstand the test of time and the elements. While this document offers valuable insights and guidance, its primary purpose is to serve as a source of inspiration. We always recommend to consult directly with a coating specialist for tailored solutions that fit the specific needs and circumstances of your project.

We hope you will enjoy the read.



The impact of corrosion

The impact of corrosion extends far beyond just costs; **it's a significant environmental concern as well.**

Not only does corrosion incur substantial expenses globally each year – currently estimated at 3 to 4% of the global GDP – but the frequent need for maintenance and replacement of steel structures also imposes a heavy environmental toll.

CORROSION RELATED COSTS

3-4%

OF THE GLOBAL GDP

Iannuzzi M. and Frankel G.S.[1] roughly estimated that between 25% and 33% of the annual steel production is destroyed once in service by corrosion. Projections suggest that by 2030, based on current EU and U.S. targets for reducing greenhouse gases (GHG), the environmental impact of corrosion could contribute to 4.1% to 9.1% of total CO_2 emissions. This underscores the critical need to adopt protective measures early in a project's life to mitigate such impacts.

Yet, we often experience insecurities and questions when engineers are specifying these protective measures. Hesitation often stems from weighing the potential outcomes of one option against another.

Furthermore, the choice of protective coatings is often left to contractors, even though the complexity and structural advantages of choosing the right coating really call for an engineer's guidance and expertise to ensure that every construction benefits from the most effective protection available.

1. Iannuzzi, M., Frankel, G.S. (2022) The carbon footprint of steel corrosion. npj Mater Degrad 6, 101 (2022). https://doi.org/10.1038/s41529-022-00318-1

Understanding corrosion protection

In short, corrosion protection is the process of safeguarding metal surfaces from the damaging effects of corrosion, which can lead to a loss of structural integrity, aesthetic appeal, and an increased need for maintenance or even steel replacement.

In this paper, we focus mainly on protective coatings, which we deem to be the most effective solution and sustainable for corrosion prevention. However, it is worth knowing that corrosion protection can also be obtained through various other methods, each with its own set of advantages and disadvantages.

Corrosion protection with coatings

When you want to secure optimal corrosion protection for steel structures, protective coatings are also a popular choice. However, to specify the correct protection level requires a comprehensive understanding of three key principles:

1. The barrier effect
Imagine the coating as an umbrella for steel. We apply special coatings that act like a shield, blocking harmful substances like water and oxygen from touching the steel.

2. The galvanic effect
We coat the steel with a metal like zinc, which prefers to corrode instead of the steel. This zinc coating takes the hit, keeping the steel safe, especially in harsh environments.

3. The inhibitor effect
We add certain chemicals to the coating that slows down or stops the corrosion process. These chemicals either create a protective layer on the steel or interrupt the chemical reactions that cause corrosion. This is especially useful when extra protection is needed.

Understanding the extent to which these corrosion protection principles must be applied ensures not just precision and minimal waste in your specifications, but also prolongs the lifespan of your structure, preserving its structural integrity and aesthetic appeal.

ISO 12944 as a vital tool

For ensuring correct coating specification, you should rely on the corrosivity classification outlined in the international standard for corrosion protection of steel structures by protective paint systems, ISO 12944.

This classification helps engineers understand the environmental challenges a structure might face and, consequently, select the appropriate protective coatings.

An essential part of the tool is the corrosivity categories that classify different environmental conditions based on their corrosivity – from low (C1) to very high (C5 and CX) levels of corrosivity.

If you want to know more about the corrosivity categories, you can read our extended guide here: **How and what to specify for corrosion protection**

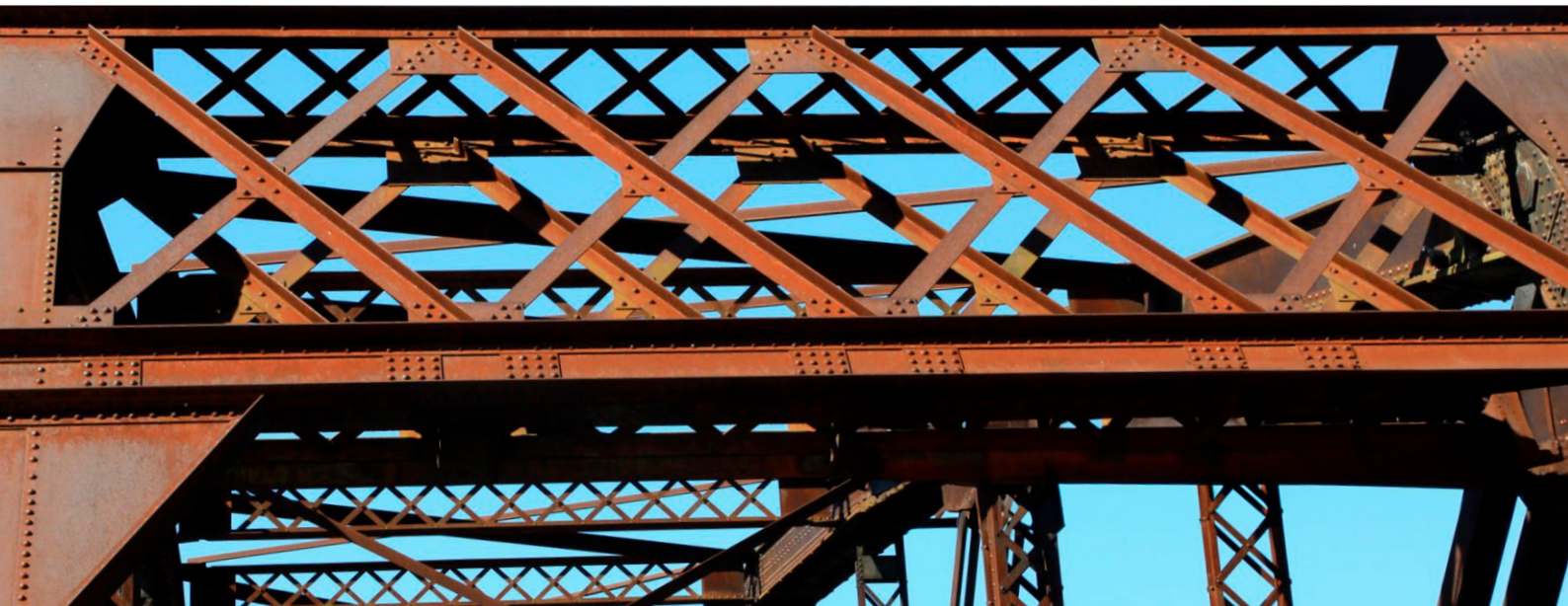
Another part of the ISO 12944 is its durability categories, addressing the paint system's lifetime, measured by the time until significant maintenance is needed.

ISO 12944: Definition of durability

Low	up to 7 years
Medium	7 to 15 years
High	15 to 25 years
Very high	over 25 years

The atmospheric corrosivity categories

C1	Very Low	Inside heated buildings like offices, shops, or schools. Here, the air is clean, and corrosion is minimal.
C2	Low	In rural areas or unheated buildings like storage rooms, there's a bit more air contamination or condensation. These places are less likely to see corrosion.
C3	Medium	Urban or industrial areas with some air pollution, or near the coast with low salt. Places like food factories or laundries face medium corrosion.
C4	High	Heavier industrial areas or coastal spots with more salt in the air. Power plants, chemical plants and shipyards see high corrosion.
C5	Very High	The toughest environments, like industrial zones with lots of humidity and pollution, or coastal areas with lots of salt. These areas face very high corrosion.
CX	Extreme	Special cases like offshore structures in the sea or places with extreme humidity and pollution. These face the most severe corrosion.



Common challenges in coating specifications

As a provider of protective coatings, we regularly collaborate with engineers and applicators to ensure optimal outcomes in both specification and application. We've outlined some of the most frequently faced challenges in the specification process.

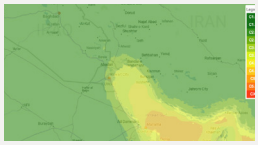
1. **One of the most significant hurdles faced in this process is the accurate identification of the corrosivity category (C1-CX).**

Wrong identification can lead to either over-specification or under-specification, impacting both project costs upfront and long-term effectiveness and maintenance cost.

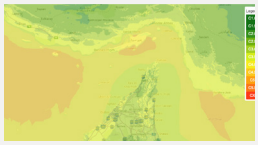
Example

A case in point is the Duqm Refinery project, where a CX category protection was initially sought for both corrosion and fire, despite the structural steel being in a C4 environment. This discrepancy highlights the critical need for precise categorization.

Examples on general corrosivity categories

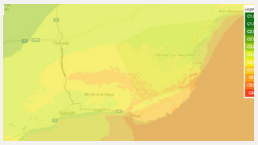


Riyadh, Saudi Arabia, is a category C2 location



Dubai, UAE is a C3 to C4 category location, depending on proximity to the Persian Gulf

Holyhead, Wales is a C5 location



Mirbat, Oman is a C4.5 location (just outside Salalah, which is a C5 area)

You can explore an interactive world map of environmental corrosivity categories here: **www.engineeringdirector.com/iso9223-c1-x**

2. **Additionally, we've observed that engineers sometimes default to previous specifications that may not align with the unique requirements of their current project.**

Such a practice not only runs the risk of implementing inappropriate protective measures but also fails to take advantage of the latest developments in coating technologies. For example, there are cases where engineers continue to refer to obsolete specifications, like BS 5493, which do not incorporate recent industry standards and breakthroughs.

3. **It can be challenging to specify the correct protective coating for a project, especially when dealing with complex environments. One common mistake is not fully considering how environmental factors can affect the durability and performance of coating.**

Example

Coating a parking basement highlighted this challenge. The steel structure inside led the specifiers to believe that a basic protective coating would be adequate. However, the critical factor overlooked was the exposure of the steel to outdoor elements due to the garage's open design.

During windy conditions, rain infiltrated the structure, creating a more corrosive environment than anticipated. Therefore, when specifying protective coatings, it's critical to also consider humidity, temperature fluctuations, chemical exposures, and even the likelihood of weather ingress.

4. **Decision-making in product selection is crucial and should not be left entirely in the hands of contractors, as it can potentially compromise structural integrity and lead to increased maintenance costs.**

The expertise of contractors is important for sourcing materials, securing resources, and carry out the construction work. However, estimating the integrity and endurance of a structure is an engineer's field of expertise, also to ensure that the project meets safety regulations and performance standards.

5. **A fundamental challenge is the underappreciation of different corrosion methods like barrier, galvanic, and inhibitor effects.**

Each method plays a critical role in the long-term efficacy of corrosion protection. Engineers must understand these mechanisms to choose the most suitable coating scheme that provides comprehensive protection against diverse corrosion processes.

6. **Lastly, the long-term cost and environmental impact of corrosion are often underestimated.**

The global GDP's direct cost due to corrosion is estimated at 3 to 4%, yet the environmental impact, particularly CO_2 emissions associated with replacing corroded steel, is significant.

By 2030, these emissions could account for 4.1–9.1% of the total GHG emissions, based on current EU and U.S. targets for GHG reductions. Adopting corrosion management best practices can significantly reduce GHG emissions related to replacing corroded steel, highlighting the need for coordinated international efforts to mitigate these impacts.

Six recommendations for accurate coating specifications

We recognise that for many engineers, specifying protective coatings isn't a routine task, and staying current with the newest advancements can be daunting. That's why we've assembled six recommendations to guide you through your next specification project:

1. **We recommend that you keep yourself updated with current standards and advancements in coating technologies.**

   This ensures that specifications are not only compliant but also optimal for your specific project.

2. **Be aware that the corrosivity category is fundamental to specifying the appropriate protective coating.**

   This classification depends on the environmental conditions to which the structure will be exposed, such as atmospheric conditions, chemical exposure, and temperature variations. Understanding these factors allows for the selection of coating systems that are tailored to withstand specific corrosive environments. Depending on corrosivity category, you should revisit the optimal a) selection of coating system, according to the substrate and environment, b) total dry film thickness (DFT) of the coating system, c) surface preparation required and d) minimum and maximum recoating intervals.

3. **In terms of durability, the requirements vary based on the project's scope and environmental exposure.**

   Determining the desired lifespan of the coating and considering factors like maintenance schedules and potential for exposure to harsh conditions is crucial. This step helps in selecting a coating system that not only provides immediate protection but also remains effective over the intended duration.

4. **Compliance with local and international regulations is non-negotiable.**

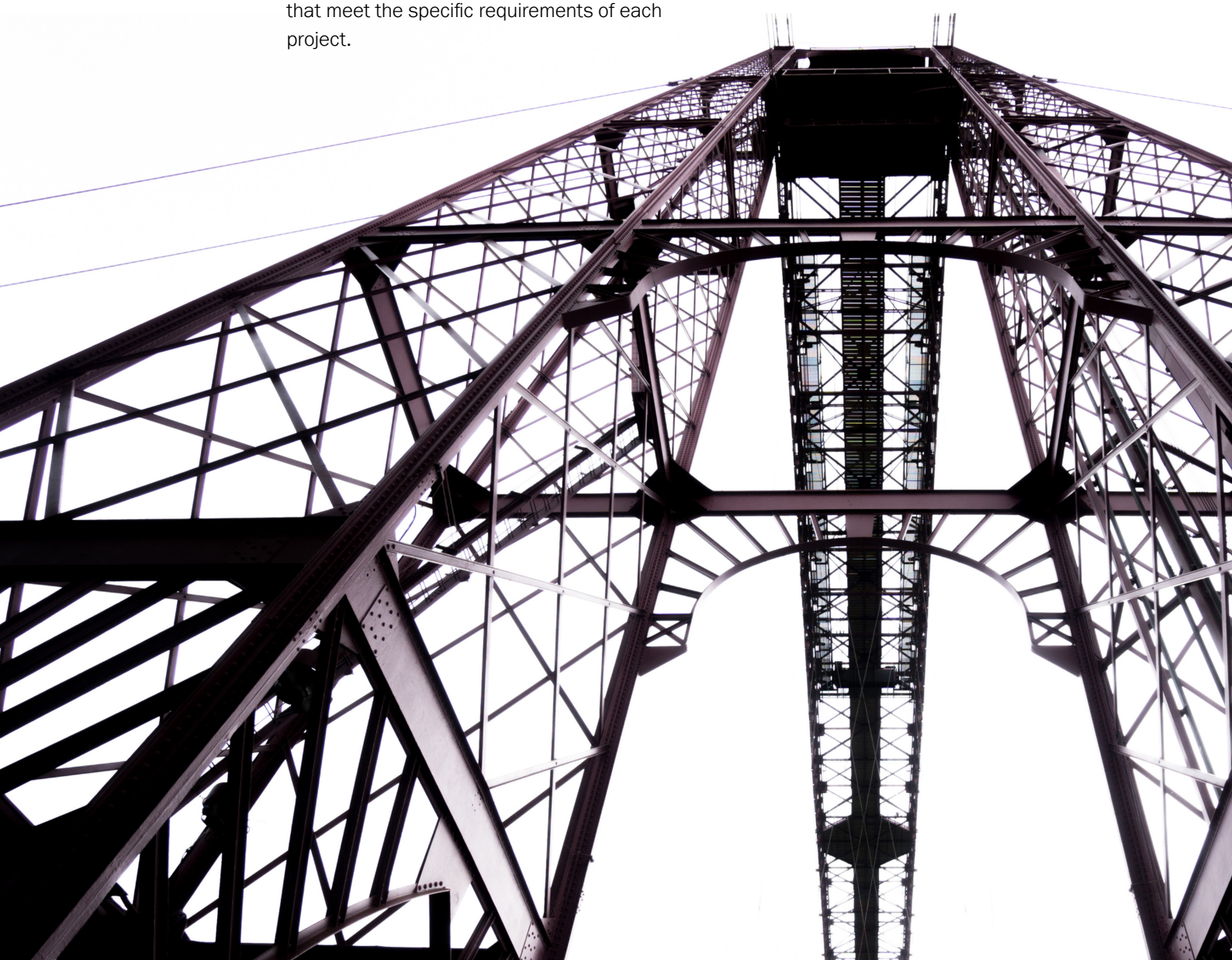
Engineers must ensure that the chosen coating systems meet all standards and regulations, including environmental, health, and safety guidelines. This not only ensures legal compliance but also contributes to the project's overall sustainability and safety.

5. **If you're not frequently involved in coating specification, seeking advice from industry experts like Hempel can give you assurance and insights into selecting the most optimal coating solution.**

Hempel's coating experts can guide you through the complexities of coating specifications, providing tailored solutions that meet the specific requirements of each project.

6. **The recommendation involves the actual design of the coating system.**

This process should integrate all the previous recommendations, considering the environmental conditions, durability requirements, regulatory compliance, and expert advice. The coating system should be designed to provide optimal protection, considering factors like primer selection, number of coats, and application methods.



Conclusion

In conclusion, effective corrosion protection is a vital aspect of maintaining the integrity and longevity of steel structures across various industries.

The common challenges in coating specification, particularly the need for a thorough environmental assessment, emphasize the importance of detailed planning and expertise in selecting the right protective measures. The example of the parking basement project serves as a reminder of the complexities involved in ensuring adequate protection against corrosion.

Ultimately, the goal is to extend the lifespan of structures while minimising maintenance needs and costs. Adherence to standards like ISO 12944, understanding the corrosivity and durability categories, and consulting with specialists are key steps in achieving this goal.

As we continue to advance in technology and knowledge, the ability to protect our infrastructure from the detrimental effects of corrosion will only improve, leading to more sustainable and cost-effective solutions in the long run.

Tools and relevant resources

1. **The Specified to Last hub**
   Find specification from similar projects, guides and the latest news on corrosion and passive fire protection for civil structures
   www.hempel.com/specifiedtolast

2. **How to specify for corrosion protection**
   Get an overview of the different corrosivity categories and examples on projects within each category
   How to specify for corrosion protection

3. **Corrosivity categories map**
   Explore an interactive world map of environmental corrosivity categories here:
   www.engineeringdirector.com

As a world-leading supplier of trusted coating solutions, Hempel is a global company with strong values, working with customers in the protective, marine, decorative, container and yacht industries. Hempel factories, R&D centres and stock points are established in every region.

Across the globe, Hempel's coatings protect surfaces, structures and equipment. They extend asset lifetimes, reduce maintenance costs and make homes and workplaces safer and more colourful. Hempel was founded in Copenhagen, Denmark in 1915. It is proudly owned by the Hempel Foundation, which ensures a solid economic base for the Hempel Group and supports cultural, social, humanitarian and scientific purposes around the world.

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