THERMAL SPRAYED ZINC COATINGS

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About the Cover Photo

The Forth Road Bridge spans the Firth of North connecting Edinburgh to Fife in east central Scotland. When the bridge opened in 1964, its 2.5km in length, including the approach viaducts, made it the longest single span bridge outside the United States. Thermally sprayed zinc was chosen to protect the steel structure from corrosion. The Forth Road Bridge is still going strong today. This is just one project of many that is testament to the metal spraying process in protecting steel structures from corrosion.

PROTECTING STEEL AGAINST CORROSION

At US$ 2.2 trillion, the annual cost of corrosion worldwide is over 3% of the world's GDP. This figure reflects only the direct cost of corrosion – essentially materials, equipment, and services involved with repair, maintenance, and replacement. It does not include the environmental damage, waste of resources, lost production, or personal injury caused by corrosion. With proper corrosion protection, much of this damage is avoidable. The World Corrosion Organization estimates that a net of 20% to 25% of this annual cost (approx. US$ 400 billion) can be saved by applying currently available corrosion control technologies.

When left unprotected, steel will corrode in almost any environment. More harsh environments will hasten corrosion, ruining the appearance of steel while threatening its structural integrity. No method of corrosion protection is more effective than coating steel with zinc. Zinc coatings protect steel by providing a physical barrier as well as a cathodic protection for the underlying steel. Zinc is so important in this role that the coating market represents nearly 60% of total zinc consumption each year.

HOW ZINC PROTECTS STEEL

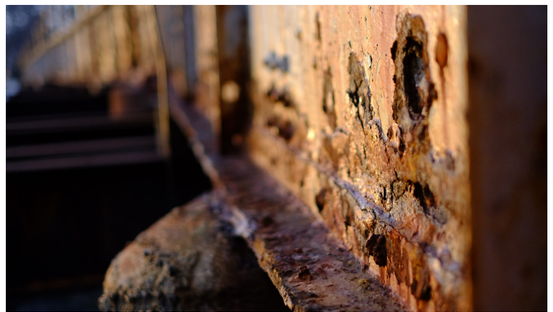
Anti-corrosion coating systems work in essentially one of two ways. Either passively, by placing a barrier coating between steel and the corrosive environment; or actively, through electrochemical processes.

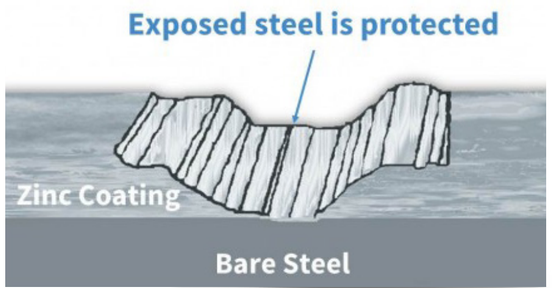
Barrier systems, such as paint, attempt to guard against rust by preventing moisture and oxygen from reaching the steel surface. However, paints are inherently permeable and when the coating is penetrated or mechanically damaged, corrosion occurs at that point and spreads, leading to a layer of rust at the steel interface beneath the coating.

Sacrificial systems, such as zinc coatings, also provide barrier protection but protect in an entirely different way as well. Unlike a purely barrier system, zinc coatings protect galvanically, corroding in preference to steel. Damaged areas are contained, and there is no corrosion of adjacent exposed steel until all the surrounding sacrificial coating has been consumed. The presence of zinc is the key to cathodic protection. All zinc-containing metallic coatings, including zinc-rich paints, share this beneficial characteristic.

A range of methods can be used to apply zinc coatings to steel. These include galvanizing, zinc thermal spray metalization, electroplating and zinc-rich paints, among others.

These coatings can be used individually, or in combination with a paint topcoat for a synergistic effect. Zinc thermal spraying often complements galvanizing. For example, it can be used to coat existing steel structures and to treat steel too large to be hot dipped. It can be used to restore corrosion protection to areas where galvanizing is removed during fabrication, such as along cuts or threaded ends; and to assure coverage of welds and rivets. It can also repair mechanical damage to galvanized surfaces.

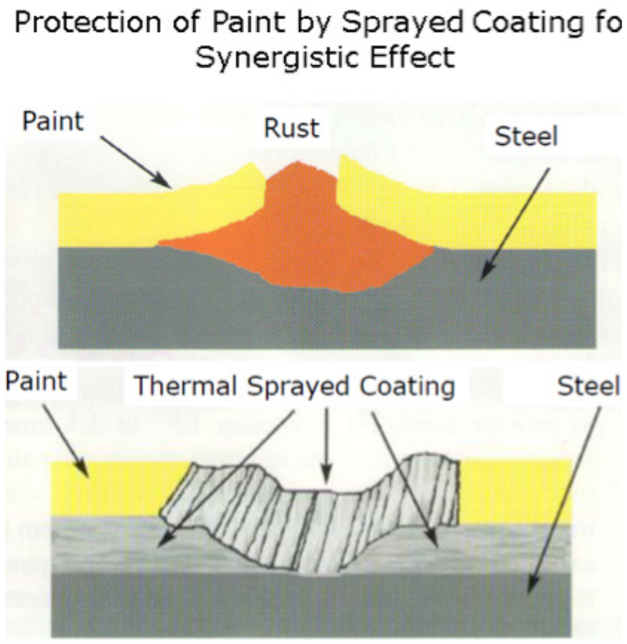




TYPES OF ZINC COATINGS

Similarly, the application of zinc-rich paints over galvanized or thermal sprayed coatings, known as a duplex system, can also extend barrier coating longevity. This subject has been researched for many years and the literature is well supplied with reports on zinc's performance in different climates, with different alloy additions to the coating and at different coating thicknesses.

Each system comes with its own set of advantages so it is important that the correct zinc coating is specified to provide optimal performance under the exposure conditions to which the coating will be subjected. The remainder of this brochure will focus on the specification and performance of thermal sprayed zinc coatings. More information on the other systems is available at www.zinc.org.



THERMAL SPRAYED ZINC: AN ALTERNATIVE COATING SOLUTION

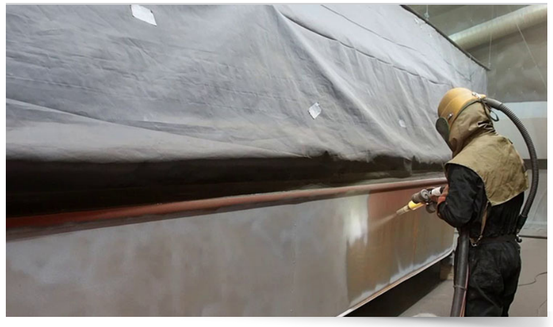
Thermal sprayed zinc coatings are a highly effective, long lasting means of corrosion protection in a variety of applications and environments. The technique is not new and there are many zinc-sprayed structures, throughout the world, some dating to the 1930's which have excellent corrosion resistance and have required only minimum maintenance.

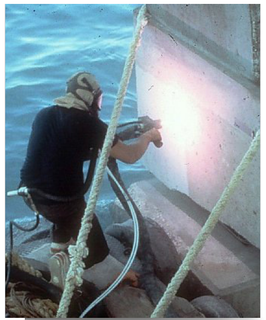
Many important structures throughout the world are protected by sprayed zinc. For example, zinc spraying was chosen to repair parts of the Tower Bridge in London, the Bosporus Bridge connecting Europe and Asia, and the Pierre-Laporte Bridge in Canada.

The hulls and decks as well as parts of the superstructures of boats such as barges, tugboats scows, lifeboats, fishing trawlers, and ferries have been thermal sprayed. When the famous tea clipper Cutty Sark was refitted in 1953, her welded steel yards were protected by thermal sprayed zinc.

In the chemical and petrochemical industry, thermal spraying protects process assemblies, flare stacks, gas cylinders, storage tanks, and all sorts of pressure vessels that could not otherwise be galvanized.

Zinc thermal spraying is also frequently used for corrosion protection of near-shore and offshore wind turbine towers in the rapidly growing renewable energy sector.





THE PROCESS

Zinc thermal spraying is a process where zinc or zinc alloys are melted and then sprayed onto a prepared substrate, creating a layered coating. Thermal spraying is a highly effective and proven method of corrosion prevention, giving galvanic as well as barrier coating protection to iron and steel.

Surface Preparation

As with any coating process, proper surface preparation is essential. Grit blasting prior to coating application produces a properly clean and roughened surface, upon which the molten sprayed zinc anchors with bond strengths in the range of several thousand pounds per square inch.

Zinc Metal Coatings

The main sprayed metal coatings are either pure zinc or an alloy of zinc and 15% aluminum.

Sprayed coatings of pure zinc have been available since the 1920's and are typically applied with a thickness of 100 microns or more. If not further coated, the pure zinc coating will form a stable, passive film of zinc corrosion products with a predictable weathering rate. In many environments, the sprayed zinc alone can provide sufficient service life.

The zinc 15%-aluminum thermal spray coating was introduced in the late 1970's and is about the highest aluminum composition in zinc that can be industrially made into wire. Because the micro-structure of each of the droplets of this sprayed coating consists of both a zinc-rich and aluminum-rich phase, Zn-15%Al offers the optimum corrosion protection to steel in aggressive atmospheric conditions such as marine environments.

Method of Application

Zinc is thermal sprayed using either an electric arc or a combustion flame process. The electric arc process, which allows higher deposition rates with improved economy, uses two consumable zinc wire electrodes. The wires are given opposite electric charges and are fed close together to maintain an electric arc, causing the wires to melt. The molten material is sprayed onto the prepared surface with compressed air. In the combustion process, a single zinc wire, or a source of zinc powder, is fed into an oxy-fuel flame, which melts the zinc which is then atomized by compressed air.

Applications of zinc and zinc alloy thermal sprayed coatings can be easily controlled by the equipment operator to provide a thickness of 50 – 500 microns (.002" to .020"). This is important when considering atmospheric conditions that will dictate the protective thickness required. For example, a very long life or highly corrosive conditions necessitate a thicker coating. Edge coating, a normally difficult task for all coating systems, is easily and efficiently achieved using the zinc thermal spraying process. The use of sealers and/or topcoats over a zinc metalized coating will further protect the surface and usually provide an even longer life of the coating system. Again, environmental conditions will determine the use and type of sealers.

ADVANTAGES OF THERMAL SPRAYED ZINC

The application of sprayed zinc is an uncomplicated, yet versatile procedure, and should be considered because:

Versatile. With thermal spraying, it is possible to apply zinc coatings of almost any thickness, from 0.002 inches to more than 0.02 inches (50 to 500 microns). Since the life of the zinc coating is proportional to the coating weight, spraying allows the thickness of the coating to be controlled according to the degree of protection required. For very long life or highly corrosive conditions, coating thickness is readily increased. Also, coating thickness can be varied on different areas of the same structure, such as flange edges, and parts not intended to be coated can be masked off before spraying.

Can be applied in the field. Spraying can be carried out in a shop or in the field. Application equipment can be moved from one site to another.

No steel restrictions. All grades of steel, including highly alloyed steels, can be spray coated. Spraying does not affect the metallurgical structure of the steel.

No size limitation. Thermal spraying makes it possible to apply zinc coatings to structures and components that are too large for hot-dip galvanizing, such as many bridge sections and structural members.

Single application system. The metal coating is laid down in a single application.

No drying time. Since zinc adheres and sets quickly, no drying time is needed. Designated top coating operations can start immediately.

Abrasion and adhesion. Zinc coatings have excellent adhesion to steel and resist abrasion, enabling the structure to withstand rough usage.

Proven long-term protection. The surface of a sprayed zinc coating is slightly rough and slightly porous, which makes it an excellent base for a sealer or paint top coat. Because the zinc is anodic to steel, the slight porosity allows zinc corrosion products, which form during service, to fill up the pores to give an impervious coating. In many cases, building up a subsidiary protective barrier layer. A sealed, zinc thermal sprayed coating can realistically provide 30 years of corrosion protection in rural environments and 15 to 25 years in urban and coastal areas.

'Ronja Polares', a Norwegian fish carrier, was thermal sprayed with zinc and zinc-aluminum alloy coatings. The external areas metal sprayed included the hull, all external decks, superstructures, the bridge, mast and chimney. Prior to metal spraying, surfaces of the ship's components, both internal and external, were shot blasted to Standard SA 2.5 to clean and prepare the surface.

LIFE EXPECTANCY OF THERMAL SPRAYED ZINC

The corrosion protection of sprayed zinc coatings is well documented. Type of environment, proper surface preparation, thickness of coating, use of sealers and/or topcoat, and the nature of the structure are all important elements when considering a coating system. Each job must be treated individually, as requirements for protection may differ.

There are hundreds of case histories relating to the longevity of zinc thermal sprayed coatings on steel. Bridge structures, interiors of potable water tanks, pipelines, and dam locks show, in many cases, over 30 years of service without major repair.

LIFE CYCLE COSTS

The initial coating application costs are small compared to the maintenance costs over the life of the structure. Continuous maintenance is not required with a properly applied zinc thermal sprayed coating. A single application will give years of lasting corrosion protection, including areas where minor mechanical damage may have exposed the steel.

INITIAL COSTS

Labor costs, interest rates, and general inflation are just some of the many variables that influence the installed cost of a coating system. Zinc thermal sprayed coatings compare favorably in cost to modern three-layer paint systems, especially when considering factors like weather conditions, no VOC regulations, ease of touch up, robust coating that can be applied offsite then installed, etc. And because thermal sprayed coatings provide longer cycles before first maintenance or inspection, they assure additional cost savings during the service life of the structure.

In severe environments, applying paint systems over thermal sprayed coatings - while adding to the initial cost - has been shown to create a synergistic effect, extending the life of both coatings beyond their expected lifetimes.

MAINTENANCE COSTS

Labor rates along with the cost of removing the structure from service for maintenance becomes more and more costly every year. For example, in the mid 1980's, the Ministry of Transport in Canada decided to thermal spray the Pierre LaPorte Bridge over the St. Lawrence River in Quebec after analyzing the various coating methods available. Thermal spraying with zinc has saved millions of dollars in paint, labor maintenance, and scaffolding costs alone.

CASE STUDIES

PROTECTING STEEL BRIDGES

The Norwegian Public Roads Administration (NPRA) has been using zinc thermal spray with a paint topcoat (duplex coating) for corrosion protection of steel bridges since the 1960s. They consider this coating strategy to be a major success and have examples of bridges exposed for 40 years without any maintenance. According to NPRA, "the optimum time for maintenance of duplex coatings is when the topcoat is degraded, before the zinc coating starts to corrode. This will give the lowest life cycle costs." This first maintenance operation is typically performed after about 30 years, which is much longer than the lifetime of a 3 layer paint system due to the synergistic factor of a duplex coating which increases the lifetime of the duplex coating significantly.

Another convincing argument in favor of thermal spraying bridges comes from the U.S. Federal Highway Administration (FHWA). In the FHWA evaluation, 47 coatings, including metalized coatings of sealed and un-sealed aluminum, zinc, and zinc and 15% aluminum were compared with liquid paint coatings, and various combinations of epoxies and urethanes. The study concluded: "Metalized systems consistently provided the best corrosion protection performance. All metalized coatings tested showed no corrosion failure in the aggressive, salt-rich environments over the 5 - 6.5 year exposure periods." [1]

1. Federal Highway Administration's Report FHWA-RD-96-058 "Environmentally Acceptable Materials for the Corrosion Protection of Steel Bridges" January 1997.

CATHODIC PROTECTION OF REINFORCED CONCRETE

The Oregon Department of Transportation (ODOT), in a bid to reduce the high costs of bridge reconstruction, has applied a system of thermal sprayed zinc anodes and impressed current cathodic protection. This process has been used to protect its Cape Creek Bridge from corrosion and subsequent reconstruction. The bridge is exposed to a coastal environment and is subject to attack by chloride from the salty air. Prior to the cathodic protection project on the bridge, it had suffered substantial concrete spalling on its columns and under-deck as a result of rebar corrosion. By selecting to protect the bridge in this way ODOT saved over US$13 million by not having to reconstruct the bridge.

CASE STUDIES ...CONT.

The world´s first offshore wind farm Vindeby, near Lolland in Denmark, will be decommissioned after a service time of more than 25 years. The duplex coatings on the poles of these windmills have given it a proven effective and excellent corrosion protection over its full economic lifetime.

Two of the oldest Danish wind farms, 15 and 22 years old respectively, were recently given a thorough inspection by paint supplier Hempel. The Horns Rev 1 wind farm was installed in 2002, its towers are protected by 60 microns of thermal sprayed zinc followed by a 4-part Hempel paint system. The Thunoe Knob wind farm was installed in 1995 using 80 microns of zinc followed by a 4-part paint system. The exterior and interior surfaces were judged to be in prime condition. The zinc coating prevented the spread of corrosion away from areas of mechanical damage. The Thunoe Knob system is predicted to provide at least 25 years of complete protection with a residual durability of 5-10 years. The Horns Rev 1 system is also predicted to provide 25 years of complete protection with a residual durability of 15 years.

UK-based classic Volkswagen specialist repairers Vanshack Ltd. is using thermal sprayed zinc in a novel way to restore and protect original body panels and floor pans. Traditional methods to repair a corroded panel involved cutting out and replacing the damage but now, using metal spraying, zinc is sprayed over the exposed perforations, replacing what has been lost. Metal spraying is also an excellent alternative to galvanizing for corrosion protection on these restorations, as it provides a good base for the final paint coating to be applied. There are no heat distortion issues sometimes encountered when galvanizing thin panels, and the coating can be applied in localized areas or across the entire panel.

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