Thermally sprayed metal coatings

No. 8.04

Scope

This Guidance Note describes the process of applying metal coatings by the thermal spray process and explains the properties of the coating system.

Introduction

Thermally sprayed coatings of zinc and aluminium, and more recently zinc-aluminium alloys, have been applied for many years to provide long-term corrosion protection to steel structures exposed to aggressive environments. They are an important component of the coating systems that are currently specified for steel bridges. However, note that the Highway Agency is considering removal of aluminium spray Type II from the Specification for Highway Works 1900 Series at the next revision (February 2010). Metal spray is also commonly used on steel bridge decks prior to surfacing with mastic asphalt systems.

For bridge components, the sprayed metal used for the coating is either aluminium or zinc. Aluminium is usually preferred, except for rail bridges likely to be subjected to collision damage, where zinc is recommended due to its sacrificial nature.

In atmospheric conditions of exposure, aluminium acts as a barrier coating whilst zinc provides protection by a sacrificial process. The thermally sprayed metal coating may be over-coated with paints to form a 'duplex' coating system. The combination of metal and paint in a duplex protective treatment has greater durability in comparison with that of the individual components, and also offers an opportunity to provide an aesthetically attractive finish to the structure by offering a choice of colour.

The total thickness of the selected coating system is usually determined by the required life to first maintenance.

A typical specification for thermally sprayed aluminium and zinc coating thicknesses as part of a multi-coat protection system would be a minimum of 100 μm.

Coating application

Before the application of the metal coating, it is essential that the surface of the component to be coated is thoroughly cleaned to ensure that all traces of rust and mill scale are removed and to impart a suitable profile and amplitude to provide the necessary mechanical 'key' for adhesion of the coating.

Surface preparation is normally achieved by blasting with a suitable angular abrasive.

It is well established that the performance of any corrosion protection coating system is significantly influenced by the quality of the initial surface preparation. (See GN 8.01).

The metal to be sprayed can be either in powder or wire form. It is first passed through a heat source that melts the material. The hot molten particles are then projected by compressed air towards the surface to be coated. The particles impact on to the surface, flatten and solidify as overlapping platelets. The equipment used for the melting and spraying process is a hand-held gun that uses either a gas flame system or an electric arc process to provide the necessary heat.

Gas flame spraying

Metal spraying using the gas flame process is a long established practice that uses powder or wire. However, particular care must be taken to ensure that the surfaces to be treated are properly prepared, especially in areas that have been locally hardened due to flame cutting etc. The process is less tolerant to inadequate preparation than electric arc spraying.

Electric arc spraying

The electric arc process uses twin wire electrodes that are melted when positioned to form an arc produced by an applied electric current. This process affords many advantages including high speeds of application and improved adhesion to steel substrates, particularly with sprayed aluminium, compared with the gas flame process. Generally, electric arc is not considered as flexible as the gas flame process where intricate articles have to be treated or where access for the equipment is constrained.

Electric arc spraying gives good results on large flat areas, but tends to be relatively rough around web/flange intersections and the corners created by typical stiffener arrangements. This condition is normal and is not detrimental to the performance of the coating.

Sealer coat

After the application of the metal coating, it is usual to apply a thin 'sealer' coat.

The function of a sealer coat is to impregnate the natural pores in the sprayed metal coating and thus prevent any moisture and oxygen reaching the steel surface. Sealants are therefore usually low-viscosity materials that easily penetrate the coating. They do not add significantly to the coating thickness even where several coats of sealer are applied. There are now many different types of sealers available, including those based on vinyl, phenolic and polyurethane formulations. They are readily obtainable in a wide range of colours.

'Over-thick' application is to be avoided. In the Specification for Highways Works, sealer application is specified in terms of an application rate (between 12 and 20 m^2/litre).

It may be noted that sealer manufacturers state that an application rate of 20 m^2/litre results in a thickness of 25 μm, but that value relates to thickness on a non-absorbent surface. It is difficult to measure the thickness of sealer after it is applied to metal spray.

Over-application of the epoxy sealer can lead to a smooth glass-like surface and adhesion problems for the first paint coat can result.

As soon as practical, and before the onset of surface deterioration, all thermally sprayed metal surfaces (excluding faying surfaces and abutting surfaces) should be coated with the sealer. Failure to do this may in certain circumstances (i.e. storage in damp or wet conditions) lead to the appearance of dark staining, which is indicative of corrosion of the substrate. In such situations, there is little recourse other than to lightly sweep blast the surface before sealing but this is not an ideal solution.

Life expectancy

Aluminium

The life expectancy of sealed, un-painted, sprayed aluminium will extend over several decades, but it is not easy to predict actual life with accuracy. The protection afforded by aluminium is due to the formation of insoluble salts produced on its surface in corrosive conditions. The inert film accounts for the low corrosion rate of the coating in most environmental conditions.

Zinc

By contrast, the durability of zinc coatings are generally predictable under known local environmental conditions, This is mainly because the coating reacts with the corroding media at a steady rate through the solubility of the zinc corrosion salts that are formed. For this reason, the life of the zinc coating is generally proportional to its thickness. Wetness and contaminants increase the corrosion rate of zinc. At discontinuities in the coating, which may arise due to mechanical damage etc. the zinc provides a measure of protection for the substrate by galvanic action; the zinc behaves in a sacrificial manner.

Treatment of faying surfaces at slip-resistant bolted joints

Research has shown that reliable slip factors can be achieved with metal sprayed surfaces. However, sealers should not be applied to the faying surface, except for a small margin (10 – 15 mm) around the edges, as they will significantly reduce slip factors.

If all the steel surfaces of a component are metal sprayed, including the faying surfaces, then masking off for subsequent paint coatings is an easy matter. The steel is in a protected state and the identification and masking of faying surfaces may be done without delay to the finishing process, without undue haste and with no detriment to the eventual protection.

Subsequent paint coats should be kept completely clear of the faying surfaces. This latter margin will be properly coated when final painting takes place, in the knowledge that the substrate is well protected. The arrangement of coating and masking for the flange of a bolted splice is shown diagrammatically in Figure 1.

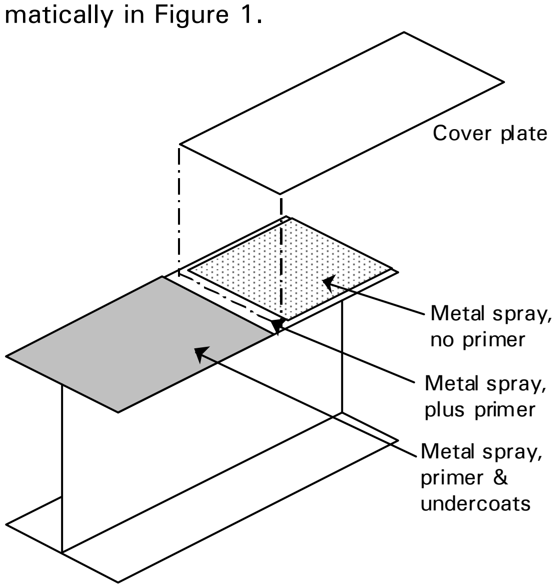

Figure 1 *Coating and masking at a bolted splice*

Repair of damaged areas and treatment at site welds

Where the coating has become damaged, it is generally acceptable to repair the damage by locally blast cleaning followed by the application of a zinc rich epoxy paint to either zinc or aluminium thermally sprayed coatings. Similar treatment can be applied at site welded joints. For structures that are to be exposed to high service temperatures, an inorganic zinc silicate repair coating is preferred.

Properties of thermally sprayed coatings

Thermally sprayed metal coatings have several significant properties that make them suitable for application to steel structures;

- Sprayed metal coatings solidify immediately on application and, unlike paints, no drying time is involved.
- They do not sag or run and can be applied to a range of thicknesses in one operation.
- They have good handling, erection and mechanical damage resistance.
- They do not interact or harden before use in hot weather or during prolonged storage.

As a result, metal-coated components can be handled, lifted and transported as soon as required. (This contrasts with painted components, where a curing period is required.) Coating thickness can be measured as the work proceeds and thin areas rectified at once

When it is not possible to fully coat a beam that has been blast cleaned, the partially coated section can be protected whilst the remainder is re-blasted and coated, with a feathered edge on the end of the previously applied coating.

The metal coatings also offer protection to areas around slip-resistant bolted connections during the construction period, until final site paint over-coating is completed.

Additionally, the coating materials do not require the addition of hardeners, accelerators or thinners and therefore present no mixing problems. Nor do they contain inflammable solvents. However, the formation of zinc fumes does necessitate the use of personal protective equipment.

Thermally sprayed coatings are compatible with a wide range of sealers and paints. They do not suffer from degradation or embrittlement due to ultra-violet or thermal effects. Consequently, they can be over-coated with paints, etc. even after long-term exposure. (The only preparation needed is the removal of loosely adherent corrosion products by light wire brushing.)

However, there are a number of aspects that also need careful consideration.

- Thermally sprayed metal coatings in typical multi-coat protective systems are relatively expensive. They require more time and skill to apply, and need a clean surface ideally to Sa3 standard, although Sa2½ is satisfactory for zinc.
- Thermally sprayed coatings need the substrate to have an angular surface profile with a greater amplitude (in the range 75 μm to 100 μm) than other coatings.

- Thermally sprayed coatings are difficult to remove with blast cleaning. (But if the paint coating in a typical duplex system is properly maintained, then removal of the metal coating will not be necessary.)
- Thermally sprayed coatings are best suited to shop application, as the equipment required is bulky and cumbersome. Nevertheless, the process is used on site for 'touch-up' areas on new construction and for large areas on maintenance contracts.

Measurement of thickness

The use of modern digital thickness gauges, on well applied and uniformly sprayed metal coatings, tends to give significantly varying readings within small test areas due to a combination of the inherent surface profile of the sprayed metal and the relatively rough grit blasted substrate.

To overcome the variation problem, a method of measurement is set out in EN ISO 2063 (Ref 2), based on averaging a set of individual readings within a test area. However, this method does not take into account the profile of the substrate when determining the coating thickness. One way of achieving a more realistic measurement of coating thickness is to take a set of initial 'profile' readings prior to spraying. The averaged value may then be discounted from the final thickness measured using the EN ISO 2063 method. Whichever method is used, it is important to appreciate that thickness can only be assessed, rather than directly measured.

Reference documents

1. Manual of Contract Documents for Highway Works. Specification for Highway Works, Series 1900: Protection of Steelwork against Corrosion, 2005.
2.. EN ISO 2063:2005 Thermal spraying. Metallic and other inorganic coatings. Zinc, aluminium and their alloys

Other relevant Standards and further reading

BS 4479-7:1990. Design of Articles that are to be coated. Recommendations for thermally sprayed coatings.

EN ISO 14713:1999. Protection against corrosion of iron and steel structures-zinc and aluminium coatings-Guidelines.

Corrosion Tests of Flame-Sprayed Coated Steel 19 Year Report American Welding Society Inc., Miami, Florida 33125.

Sealing and Painting of Sprayed Aluminium and Zinc Coatings. Information Sheet No. 2, Thermal Spraying and Surface Engineering Association, Warwickshire.

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