Primers for Steel: Their Purpose and Performance

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Date: *12th February 2009*
Ref.: *CTG1005*

Key Words
Pre-construction primer, shop primer, coatings, exposure, intumescent coatings, alkyd, mill scale

Introduction

This article addresses some problems that can occur when primers are incorrectly specified, and examines some misconceptions on their expected performance. Costly remedial rework can be incurred if a shop primer is damaged or exposed to exterior weather conditions for longer periods of time, or that are more severe than were expected, prior to being closed in or subsequent finishing coats being applied on site.

These thoughts and observations are based on the author's experience in the coatings industry. A common cause for arbitration on disputes over coating failures is where a short term, single pack primer has been specified and applied over St 2 (Hand Tool Clean) or more frequently St 3 (Power Tool Clean) prepared steel and left exposed for long periods during construction. Premature breakdown of the coating often initiates from undercut mill scale, transit damage, strop, chain and handling damage if it is left exposed to the weather without repair.

Primers – Their Description . . .

A primer is typically the first coat of a coating system designed to provide a level of corrosion protection to mild steel. Primers should have good wetting and adhesion properties for subsequent coatings (Mandeno, 2008). Preconstruction primers are typically designed to protect the surface preparation and surface profile of steel-work that has been prepared by abrasive blast cleaning, during transit and storage for later surface finishing after steel construction is complete. A shop primer by contrast, is a fast drying inhibitive coating for application onto fabricated units. The usual expectation is that the shop primer will be over-coated. In recent years there has been a tendency for a shop primer to take the role of the first and last means of corrosion protection applied to a piece of steel.

A shop primer may be left as a single coat system for short-term protection in a benign or internal environment. This primer coating will typically contain an anti-corrosive pigment to suppress corrosion. For example the single coat alkyd coating system ALK1 (SAA/SNZ, 2004), has a nominal dry film thickness of 40 microns. Most single pack shop primers in current use are alkyds. Alkyd primers are solvent based, surface tolerant, low cost coatings that provide lower levels of corrosion protection over hand (St 2) or power tool cleaned (St 3) steel.

The inhibitive pigment in most current alkyd primers is zinc phosphate, which passivates the steel surface by preventing an anode from forming. This replaced the carcinogenic zinc chromate that in turn replaced lead, one of the best performing inhibitive pigments in primer coatings. Legislation and voluntary action by paint manufacturers has seen the demise of lead based inhibitive primers (such as HD441) and zinc chromate inhibitive pigments (Mandeno, 2008). Industrial opinion, environmental pressure, Safety, Health & Environment legislation over time have all contributed to the reduction in performance of alkyd primers. These are now not as robust and durable as their predecessors. While the coatings industry at a global level is always looking to create products that are effective within the parameters of environmental and social impact, SH&E, product functionality and commercial sustainability, the price will always remain linked to the product's performance. The cost to effectiveness ratio for primers has reduced as a result. Unfortunately the actual product price at time of purchase and application is not often compared in a life cycle continuum of the coating's longevity. The true value of a coating needs to be considered in terms of its time of effectiveness.

Surface Preparation for Primers

It is generally accepted that the most cost effective premises to apply a specified coating is either at the steel fabricator's facility or in an abrasive blasting shop. Most steel fabricators have an area within or attached to the fabrication shop where relatively unsophisticated, usually single pack primers can be applied after approved preparation of the steel surface. As a single pack primer is generally specified for use over steelwork in a benign environment or for a shorter term of exposure (prior to being closed in) then cost savings may be made by the lesser level of St 2, or more likely St 3, surface preparation that is prescribed. However steelwork that has this type of surface preparation and primer coating applied cannot be left exposed in a damp environment. Premature coating breakdown will ensue, as this type of coating is not resistant to moisture. As mentioned earlier, the presence of moisture concentrates the detrimental activity of the contaminants on the surface that leads to rust forming underneath the impervious Alkyd Zinc Phosphate primer.

The level of surface preparation prior to application of the coating system has a significant influence on its effectiveness of its protection against corrosion. Typically systems incorporating St 2 or St 3 wire brush surface preparation will have a significantly shorter durability than those applied over abrasive blasted surfaces Sa 2 or Sa 2.5.

Steel fabrication usually precedes the substrate and surface preparation processes after which the specified coating system will be applied in accordance with the specification document. Shop-primed steelwork is frequently required to be cut and re-welded on site through the erection phase of the project. All care must be taken when cutting and welding steelwork that has already been coated, as fumes produced are toxic and hazardous (SAA/SNZ, 2004).

Environmental Corrosivity Categories

To briefly explain the Corrosivity Categories, these range from A to F where A is Very Low i.e. inside an air-conditioned building with a clean atmosphere to an external, alpine environment again with minimal airborne, atmospheric contamination; to E-Industrial, where the harshness of the environment is more chemically acidic; E-Marine where the harshness of the environment has chloride availability from proximity to seawater; through to F, that is described as Inland Tropical, where corrosivity levels may be low, but the persistent high atmospheric temperature and high humidity fluctuations combine to accelerate the detrimental and degrading effects on organic coatings. The time to first maintenance of Category F is similar to Category C. Much of the metropolitan areas of Auckland and Wellington are in Category C.

It is the combination of constant wetting of steelwork and high atmospheric temperatures that increases the corrosion rate by keeping the electrolyte available. Corrosion, in this context, can be described as the degradation of the steel surface by an electrochemical or chemical reaction with it's environment i.e. moisture, oxygen and degrading contaminant ions, including chlorides, chlorates, nitrates, sulphates, sulphides, urea and phosphates to name some. This phenomenon occurs when moisture from the air, or from anywhere else, reaches an object with iron in it. Oxygen in the moisture combines with atoms of iron to form molecules of a compound called iron oxide, or red rust.

Effects of Mill Scale on Primers

Mill scale is a complex layer of tightly adherent oxides that form on the steel surface during the hot rolling process. (Brockenbrough, Merritt, 1999) It is however brittle and with exposure to atmospheric moisture, will crack. Even though the mill scale is more chemically inert than the underlying steel and could provide an inherent level of protection to the steel, an electrochemical cell will form in the presence of moisture and the underlying steel will corrode in preference to the mill scale. Weathering, shipment, storage and the fabrication process frequently undercut mill scale. (Brockenbrough, Merritt, 1999) If undercut mill scale is simply painted over, trapped air and moisture will continue to corrode the steel, and the porous and comparatively low built coating will behave as if it has 'failed'. However this cannot always be construed as a coating failure but more likely to be as a result of inadequate surface preparation.

Steltech beams are typically manufactured from new steel with intact mill scale. However by the time the steel surface is ready for painting, it may vary between intact, 'blue' mill scale at one extreme, and a brown rusty surface which is mill scale free, at the other. Undercut mill scale is best removed by abrasive blasting to minimum Class Sa 2, (however Class Sa 2.5 is more usual and cost effective on economic grounds) as St 2 or St 3 will not remove this mill scale adequately. St 2 or St 3 can successfully prepare rusty steel that has lost the mill scale. However this type of surface preparation must be taken in its durability context. In Table 6.3 of AS/NZS2312:2002, all coating systems that utilise St 2 surface preparation go to a maximum of 2-5 years time to first maintenance in Category D, except MCU1 which goes to 5-10 years. Moisture Cured Urethane coatings have greater durability because of their inherent combination of strength with flexibility. This means greater resistance to cracking.

Figure 1 Mill scale that has been coated is loosing adhesion and breaking away.

Figure 2 Blue mill scale (on left) and mill scale 'free' rusting surface (on right)

Selection of Primers

In many cases the writer of a steel coatings specification will be a structural or design engineer who has decided that the steelwork will have a certain design service life, subject to budget, practicality and the possibly to include a fire resistance rating. Guidance is given in AS/NZS 2312:2002 Section 3 – Planning and Design for Corrosion Protection.

In order to decide on the correct coatings or system, the designer should give thought to:

1. Whether the Steelwork is Internal, External, Enclosed, Exposed to View, Rain-washed, not Rain-washed?
2. The Atmospheric Corrosivity Category of the completed steelwork,
3. The life to first maintenance, at which patch repairs or recoating could be required.
4. The coated surface's time of exposure and the corrosivity of the environment it is exposed to during the construction and in-service phase i.e. likelihood of the primer coating being left wet, stored incorrectly and for ponding to occur on the steelwork.

Other considerations:

1. Be realistic about the number and complexity of coating systems specified. Savings in coating costs can soon be eroded by extra masking, double handling of steel, and the effect of application variances of some products on the coatings contractor. These can include waterborne vs solvent borne product, drying time prior to overcoating, tolerances to application in optimum climatic conditions, overspray and application settings on equipment. Single pack Alkyd primers and some Zinc Phosphate Epoxy

primers can be quick drying, however steel work that could be exposed for a prolonged period, should be abrasive blasted to Class Sa 2.5 and have applied an Epoxy Zinc Phosphate primer. The epoxy content provides more of a barrier to moisture.

2. Decide on the erection timeframe for this phase of the construction? If the building is large and/or the steelwork is complex to erect, there will an elongated period of exposure before the steelwork is 'closed in'. Single pack Alkyd primers over Power Tool Cleaned steel are not durable on prolonged exposure to inclement weather. They should not be exposed for more than 4 weeks during construction in a B category.
3 Understand access equipment is expensive. How easy will the coating system be to access for either remedial or maintenance painting? When the components of the structure become difficult to access after being erected, access and time constraints (costs) will need to be considered as part of the performance of the entire system.
4. Think about the effects that delays in planning for Building Code compliance and site development, changes in steel design and delays by other subcontractors may have on this coating system? Again if exposed to prolonged inclement weather?

Primers Under Intumescent Fire Protection Coatings

It is recommended that intumescent coatings are only applied over a high quality anticorrosive primer, over Sa 2.5 abrasive blast cleaned surfaces. Intumescent coatings start working from around 150 ^{o}C. But before 150 ^{o}C a single pack alkyd primer over a power tool cleaned surface may have already come away from the steel, taking with it the intumescent coating. The result is fire rated steel that has lost its intumescent coating, an unacceptable scenario.

Primer Application Methods

Be very clear about how coatings should be applied, including intumescent coatings for passive fire protection. For practical purposes specialist applicators may apply different coatings to steel because of a requirement for the use of expensive specialist equipment and application knowledge. For example, some by spray only, some by brush and roller, some by either technique deemed commercially applicable from a practical perspective. Refer AS/NZS 2312:2002 Section 8 – Painting and Paint Application Methods. Some in a fabrication shop, some on site (say after steelwork has been erected). Product compatibility is paramount, including sequence of coatings to ensure both a compliant, durable and robust system remains for the building owner. At tender stage all documentation pertaining to coatings should go to all tenderers/applicators to assist this process. That way the specification document will be read in its entirety.

Quality Control of Primer Application

While there is a greater requirement for an applicator to run a recognised Quality Control system registering climatic conditions at application time including sign off of acceptable level of surface preparation and compliant dry film thickness, this will not always indemnify the applicator if the system proposed was inadequate or ill conceived in the first instance. Coating manufacturers supply product data sheets that outline application parameters to advise applicator of product idiosyncrasies, however most generic products behave in a similar manner, which an experienced applicator will be aware of.

The cost of remedial work on an existing coating system that has broken down prematurely can be directly disproportional to the savings that could have been made by specifying a budgetary coating system from the outset. The efficacy of the coating system that includes correct coating type (fitness for purpose), surface preparation, coating application, wear and tear and durability has to be evaluated in a competitive market. The ultimate cost of extra work to the coating system to ensure compliance with the specification can become contentious however this cost will need to be recovered possibly at the expense of either the client, building owner, building management company, developer, specifier, steel fabricator or coatings applicator.

Conclusion

For any project where the steelwork is anticipated to be exposed for a prolonged period, there is a range of easy to use, relatively fast drying two pack coatings offering better anti anticorrosive and barrier protection to steel work. These include high performance primers such as inorganic zinc silicate (solvent borne and water borne), zinc phosphate epoxy, general purpose epoxy (tintable), epoxy MIO (Micaceous Iron Oxide) and surface tolerant epoxy MIO coatings. These primers all have differing application and performance parameters, will combine with other generic coatings i.e. mid coat epoxies and proprietary (tintable) urethane topcoats to provide a cost effective anti corrosive and barrier system for the steelwork. There may also be a requirement that these primers are applied over Class Sa 2.5 Abrasive Blasted steelwork to ensure mill scale and residual rust are removed and also to provide an 'anchor profile' to assist coating adhesion.

The author would like to acknowledge the assistance of corrosion and materials engineer, Geoff White, and Holmes Fire & Safety, in putting this article together. For further information or any other queries about coatings performance and specification, please contact the author at Dulux NZ Protective Coatings: michael.d.williams@orica.com

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