THE ART OF CORROSION RISK MANAGEMENT

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SUMMARY: The art of corrosion risk management lies in the workmanship, the key contributor to the success of a coating's long term performance. Despite the evolution of new corrosion resistant metals, steel still retains its unique place among the metals used in the structural applications and is the most widely used metal in bridge structures. However, bare steel is very prone to corrosion and is generally protected using protective coating or coating system prior to being placed in service. Premature coating failures on bridge structures result in costly rework, particularly due to the associated service conditions.

This paper describes corrosion, the associated risks, the preventive measures and some of the factors contributing to the coating failures. It presents some examples of coating failures on bridge structures, identifying the factors that may have caused such failures. The paper discusses examples of protective treatment works on some bridge projects wherein the use of the preventive measures, based on the lessons learned on the previous projects, has resulted in the expected outcome in terms of the coating quality.

The paper emphasises the need to achieve high level of workmanship on coating projects in order to eliminate or minimise rework as part of an effective corrosion risk management and an efficient corrosion prevention strategy.

Keywords: Art, Corrosion, Risk management, Workmanship, Prevention, Strategy.

1. INTRODUCTION

Corrosion and its prevention are the two acts, both of which originate from the nature even though the latter has human intervention. Decay is a natural phenomenon and, when applied in the corrosion sense, can be seen in the different definitions put forward by the organisations or the individuals. For example, the National Association of Corrosion Engineers (NACE) definition of corrosion states that corrosion is deterioration in the material, usually metals, or its properties, due to interaction with the environment. It is, therefore, evident that even though the corrosionist is primarily focussed on metals, the term corrosion, when applied broadly, has the potential to contain virtually everything that exits and that is because there is nothing that is not bound by the natural law of deterioration. Since deterioration is associated with a change of form or energy level, it is simply in accordance with the natural law.

Corrosion prevention has human intervention but the act of prevention is based on the natural defence mechanism. For example, a galvanic or sacrificial protection mechanism for corrosion prevention of steel (or pure iron), using zinc anodes, is based on the fact that both naturally occurring elements have a potential difference, a characteristic that has been used by humans against the act of corrosion or for corrosion prevention. Even in case of application of paint coatings as a measure of corrosion protection, though the paint formulation is a human act, the coatings provide protection only when they cure in a conducive environment that is generally provided by the nature at the site of coating application. On micro scale, even the paint formulation is influenced by the natural affinity of the molecules towards each other in the process of cross linking.

Generally corrosion prevention for structures is aimed at achieving an intended durability design life using a protection system. The structure is protected by shifting the corrosion to the parts of the protection system e.g. coating, sacrificial anode etc. Therefore, the corrosion of the protected structure is halted as long as the protection system is efficiently active.

Corrosion risk management involves identification and mitigation of the corrosion risks. It has been said that 'prevention is better than cure'. This is equally applicable to the corrosion damage. Effective corrosion prevention strategies can reduce the risk of corrosion to an acceptable level. Though the common practice for corrosion prevention in steel bridges is to protect these by the application of a suitable paint coating system, there are several other factors that need to be considered for corrosion prevention. Some of these factors are efficient design and detailing, use of corrosion resistant material, regular inspection and maintenance etc.

Several lattice truss girder bridges were designed and constructed in NSW in the late 19th century [Fig 7]. The truss structure has a plated hollow section, similar to a boxed section with one side removed, at each end of the truss [Fig 1]. As is evident, there is accumulation of debris and dirt in this area. In many cases, it also provides shelter to the local fauna. The bottom chord of the trusses is typically 'U' shaped fabricated (riveted) section and, similar to the plated section, is prone to accumulation of debris [Fig 2]. Needless to say that these areas are very much prone to corrosion. The complex geometry of the truss, with a large number of connection points due to the lattices, makes recoating work a challenge. Since these trusses are heavily fabricated, there are a number of crevices present that could easily lead to crevice corrosion, if not maintained adequately. This type of design detail is not used in the current steel bridges. In fact, the recent trend is to use steel trough or box girder that provide a flat exterior surface, thus facilitating not only easy application of paint coating but also avoiding the likelihood of local corrosion.

Figure 1 Accumulation of debris in plated section at the end of a lattice truss girder

Figure 2 Accumulation of debris in fabricated bottom chord of a lattice truss girder

The risks associated with corrosion of steel structures are multi faceted, varied in nature, range from almost negligible to very high, depend on the service or the condition of use and the nature of ownership. A corroded safety fence on a farmland, residential dwelling, industrial premises and on a bridge over a roadway has a varied level of risk. Corrosion in privately owned assets does not pose as much risk of reputation damage as for publicly owned assets. The financial risk associated with repair work on a highway bridge is significantly more than a pedestrian bridge due to the nature of the service condition.

Whereas the risks associated with assets need to be assessed based on the specific variables, some of the corrosion risks could be:

i. Compromised aesthetics
ii. Reduced durability design life
iii. Reduced safety
iv. Financial loss
v. Contamination
vi. Loss of efficiency
vii. Service disruption
viii. Damaged reputation

One example of contamination is lead ingestion from corroded lead coil condensers used in the past in making brandy that caused 'dry bellyache' with accompanying paralysis. This caused Massachusetts Legislature to pass a law against the use of lead in alcoholic beverage production [1].

Paint application is a special process wherein it is crucial to control the process in order to ensure the desired coating performance is achieved. The coating industry is enriched with high performing coatings and application technologies. However, failure of coatings has been reported to have occurred in many instances. Evidence of indiscriminate coating failure across the wide range of structures (e.g. bridges, tanks, pipelines, offshore platforms) creates the need for the academicians, researchers, asset owners, coating manufacturers, suppliers, applicators and other associated groups to meet together with a view to share the information.

The reasons for coating failures can be innumerable including the material, method, skill, specification and its compliance. However, it has been acknowledged by the majority in the coating industry that paint formulations seldom have been found to be the cause of coating failures. With the advent of the technology, the method of application also has been recognised as a minor contributor to the coating failures. In most of the situations, it is the compliance aspect that has been found to have been ignored, often deliberately due to rush to complete the work within the time but mostly inadvertently due to not paying appropriate attention to the specification requirements.

Coating failures result in costly repair work, similar to any other failure that requires rework. The cost of the material and the labour may not be very high but the associated costs, e.g. traffic management, environmental and work health and safety requirements may add up to the very high cost. An efficient management targets to control and minimise the rework. This can be achieved by clearly specifying the requirements in the specification and ensuring that the work is carried out in compliance with the requirements.

Needless to say that coating failures have contributed to the development of the modern materials and techniques utilising the knowledge gained from the past failures. The following sections of the paper focus on the coating failure examples, the possible causes, the lessons learnt and its application to projects to achieve success.

2. COATING FAILURE EXAMPLES

Coating failure is a term that, in essence, should be used only for the coatings that breakdown prematurely i.e. during its durability design life. Eventually all coatings break down or wear out as part of the natural process of degradation. However, if the coating has been able to protect the structure during the durability design life, it should not be seen as a coating that has 'failed' [2].

2.1 First Example

Fig 3 and Fig 4 show elements of a bridge with premature failure of the paint coating. The project specification required application of a zinc rich epoxy primer followed by MIO epoxy top coat. The coating developed cracks, flakes and blisters prematurely. The follow up investigation revealed that:

1. In some areas, the zinc primer was initially found to be low. These areas were re-coated to make up for the low film build and, in the process, the resulting primer thickness was significantly more than the specified nominal requirement.
2. Painting of the elements commenced in mid May and the paint coating was applied generally in the late afternoon.
3. The overall thickness of the coating was generally much in excess of the specified thickness.
4. The records indicated that the painting work continued during intermittent shower.
5. There was evidence to the fact that removal of the spent abrasive from the surfaces was not satisfactory.
6. The work was carried out in rush.

Figure 3 Premature coating failure

Figure 4 Premature coating failure

2.2 Second Example

Fig 5 and Fig 6 show paint coating failure on another bridge. In this instance, the coating was found to have been delaminated. The delamination was observed to be at the interface of primer and the intermediate coat. The investigation included dry film thickness measurements that were found to be excessive at some locations. The report noted the possibility of inadequate curing of the primer.

It is worth noting here that in both the above cases, the project specification did not include an upper limit on the dry film thickness. The current version of RMS specification for protective treatment of steel work stipulates an upper limit on the DFT.

Figure 5 Coating delamination

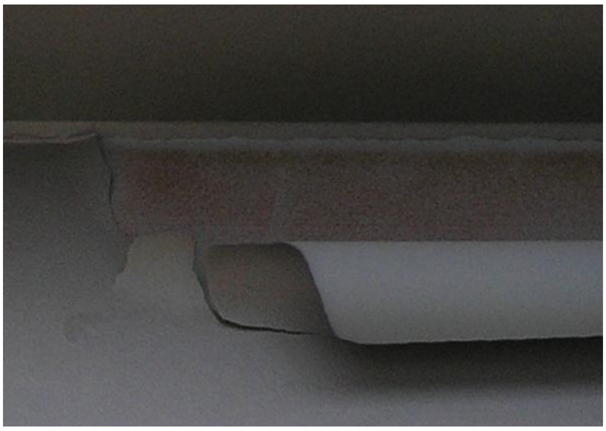

Figure 6 Coating delamination

3. JOURNEY TO SUCCESS

The journey to success begins when failures are revisited in an effort to learn lessons. Wise people in the past emphasised the importance of failures by saying ‘failures are the pillars of success’. Failure analysis paves the way to improvement. One unacknowledged failure results in another. The following examples describe some of the successful painting projects wherein lessons learnt on the past projects helped achieve a better outcome.

3.1 First Example

The bridge shown in Fig 7, constructed in 1888, was last recoated in the year 2008. A project specification was developed to address the project specific needs. The specification generally required application of the primer on a surface prepared to class AS 1627.4 Sa 2½. This was to be followed by the intermediate and the top coat.

Figure 7 Lattice truss girder bridge recoated in 2008

Prior to tender, a site inspection was carried out to identify the limitations of the work and the site constraints. The bridge consists of lattice Wrought Iron truss girders with a box at each end of the girder [Fig 8]. The box was approximately 400 mm wide and accessing the inside of the box was a difficult task. Similar access difficulty was identified with the top flanges of the cross girders beneath the timber deck [Fig 9]. Due to the complexities inherited from the design, some other areas were also identified as areas that can be accessed with difficulty [Fig 10]. The specification called for the use of surface tolerant epoxy primer in the areas that could not be prepared to class Sa 2½ due to access difficulty.

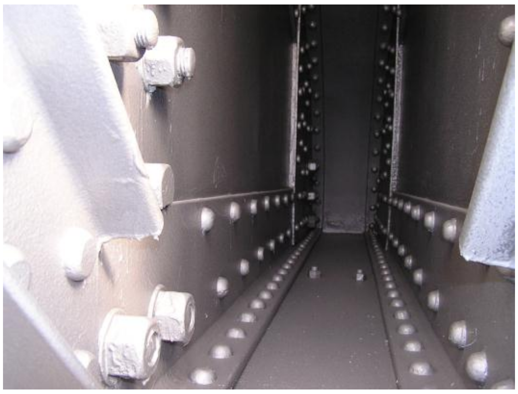

Figure 8 Painted plated section

Figure 9 Typical cross girder under the deck

During the tender meeting, these issues were brought to the attention of the prospective contractors. Once the tender was awarded, the site was again visited by RMS project team and the contractor to arrive at an agreed way to address the project issues. The contractor proposed to use smaller nozzle [Fig 11] to blast the plated section at the end of the trusses. The environmental conditions were closely monitored by the RMS surveillance officer on site during the cold weather in May.

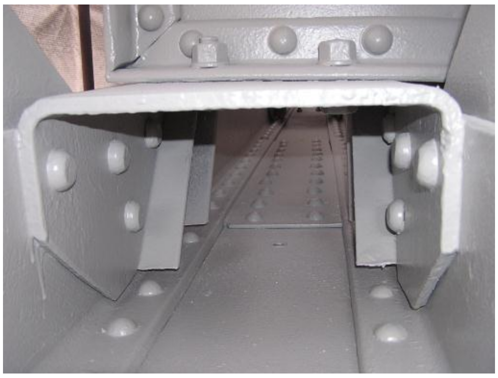

Figure 10 Area identified as ‘difficult to access’

Figure 11 Nozzle used to blast the plated section

3.2 Second Example

The through truss bridge shown in Fig 12 was repainted in the year 2010. A project specification was developed to address the project specific needs. The process adopted was similar to aforementioned. During the tender meeting, the site was visited by the project team and the prospective contractors who attended the meeting. The structure was simpler than the lattice truss girder bridge in the first example. However, it was difficult to access some of the areas. Considering the difficulty in achieving class Sa 2½ finish, provision was made in the specification for the use of surface tolerant epoxy primer in these areas. The specification also nominated a maximum value for the dry film thickness for each coat.

Figure 12 Through truss bridge

4. CONCLUSION

The domain of corrosion has no limits and equally gigantic is the effort made by humans to combat it. The high cost involved in corrosion prevention and corrosion damage repair of metals is well known even though the cost can not be precisely estimated. The common practice to protect steel against corrosion is to apply a paint coating or a coating system.

The quality of a painted product relies on several key contributing factors, including the workmanship. It is not only the skill of the crew involved in the paint application that comes under workmanship but, in broader sense, workmanship is the commitment to achieve the desired quality outcome by implementing the requirements of an appropriately developed project specification. In both the project examples quoted under section 3, an RMS surveillance officer was on site for most of the duration of the project and also there was commitment on the part of the contractor to achieve the desired quality. Audits were conducted on both of the projects in an effort to identify the missing link in the quality system. The following specific conclusions can be drawn from the above project examples:

i. The corrosion risks can be successfully managed by achieving the desired product quality.
ii. The required product quality can be achieved through the use of good workmanship.
iii. Careful planning and execution can avoid costly rework.
iv. Good team work is imperative to the success of a painting project.

5. ACKNOWLEDGMENT

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7. AUTHOR DETAILS

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