In the previous discussion, various common traps for steel designers that can compromise corrosion protection were examined. This theme is continued here, including a discussion on sheltering, in the author’s practical experience, one of the most prevalent corrosion issues in coastal infrastructure and dwellings.

**Sheltering**

The concept of “sheltering” and how it causes accelerated corrosion can be a difficult concept for designers to understand. The term “sheltering” with respect to corrosion protection can be counter-intuitive at first glance since sheltering will normally evoke thoughts of extra protection.

Steel that is sheltered is not exposed fully to the elements, but the external atmosphere still has access to it. A common example of a sheltered building component is an eave. The material under the eave is exposed to the environment, but it does not normally have rain falling on it or direct sunshine. This means that it is not subject to either the washing effect of the rain or the drying effect of the sun. If the component is located in a coastal area, then it is likely that there will still be the deposition of salt spray on any steelwork under the eave. This salt spray is then allowed to sit on the surface of the steelwork without being promptly dried by the sun or washed off by the rain. This means that the corrosion process can be accelerated compared to if it were fully exposed.

A further complication is that when the salt spray eventually dries, the chloride solids are left behind because they are not washed away by the natural process of rain. At times of high humidity or condensation, the chlorides will again be dissolved, but this time, the moisture will have a much greater concentration of salt than would normally be the case. This is because a larger amount of chloride solids are dissolved in less water than would be the case for the original seawater. This increases the conductivity of the solution making it a more efficient electrolyte. The greater conductivity causes accelerated corrosion of the so-called “sheltered” steelwork.

It is important in corrosive environments that sheltered steel is designed out where possible and, if this is not possible, then greater corrosion protection is required. Corrosion protection systems that rely on the drying-wetting cycle to develop a protective patina to perform at their optimum level are particularly susceptible to sheltering. This includes galvanized steel and electroplated steel. For example, in galvanized steel, the interruption of the drying-wetting cycle will retard or totally prevent the development of the protective zinc carbonate patina (refer Corrosion and Materials April 2012 p 41). The lack of a patina greatly reduces the protective capacity of the galvanized steel.

An example of designing out the problem of sheltering in a coastal environment is the Geelong Carousel Pavilion in South Western Victoria. The structure is located directly on the foreshore of Port Phillip Bay. The Pavilion houses the oldest and most valuable carousel in Australia, hand carved in the United States in 1892.

All of the structural steel in the Pavilion is hot dip galvanized and most of it is exposed to the sea. The design of the overhanging roof on the Pavilion means that sheltering would be an issue as it faces directly onto the sea with the prevailing winds regularly blowing salt spray onto the structure. The design of the structure paid due consideration to corrosion through the use of bolting, the minimization of “corrosion hotspots” due to proper detailing and the expanded metal roofing that reduced the wind loading and allowed the beneficial washing effects of rain on the external steelwork.

**Appropriate Material and Corrosion Protection Systems for Specific Environments**

The best design will not mask the problems of inappropriate material selection. Materials that perform well in one environment can perform poorly in another. Microclimates can cause a significant difference in corrosion performance even on the same structure. Also, the location and orientation of the structure (notwithstanding the corrosivity of the environment) can have an impact on
the selection or otherwise of what is the most economical and durable method of corrosion protection. It is always important to remember that corrosion protection is definitely not a “one size fits all” process, rather a number of issues need to be considered and then a selection made from the available alternatives. Rarely is there a single solution to a corrosion problem.

Galvanized steel, as can be seen from the discussion above on sheltering, is much more suited to environments where it is exposed to the washing effect of the rain and the drying effect of the sun. Placing galvanized steel (without extra protection) in sheltered or continuously damp and shaded areas will usually result in more rapid deterioration of the steelwork due to the inability of the galvanizing to develop its protective patina. Examples of this include swimming pools, under jetties, in manufacturing processes with high humidity or condensation and so on. In these sorts of areas, then extra protection is required or galvanizing may be dispensed with altogether in favour of another protection system, for example a multi-coat paint system or even another material might be considered instead of mild steel.

Materials also perform differently on exposure to various atmospheres or contaminants in the environment. Using the example of galvanized steel again, it behaves amphoterically, like aluminium and lead. Amphoteric metals will tend to corrode at both a low pH and a high pH. In the case of galvanized steel, it actually performs a little better at a higher pH than a lower one, but for the sake of this example, it is sufficient to say that the performance at either end is worse than if it were in a neutral environment of pH around seven. There is nothing a designer can do except to account for the fact that galvanized steel has an increased rate of corrosion and therefore reduced durability if the environment is acidic or highly caustic. The designer may find that the required compromises require the use of an alternative material or corrosion protection system.

On occasions, the economic viability of a corrosion protection system will not be totally dependent on its corrosion protection characteristics. The selection of the appropriate corrosion protection for steel might be more dependent on initial economic savings coupled with substantial economies in service. These economies can be the result of the reduction or elimination of maintenance and its associated labour costs and lost service time and also in the deferral of the replacement of structures and equipment. For example, the remote location of many infrastructure installations places great demands on the transportation and erection of steelwork that will minimise damage to corrosion protection coatings and also reduce the cost of travel for maintenance. The robustness of a corrosion protection material may then take precedence over lower cost corrosion resistance. Alternatively, systems that can be easily set up on site, such as cathodic protection or wrapping tapes may make them more suited to applications where large amounts of steel need to be transported over large distances.

The above comments need to be taken in context. For example, in an architectural application, the robustness of a coating may still not be suitable since precautions will need to be taken to prevent scratching and scuffing of the final finish. The steelwork may be fit for purpose from a corrosion resistance aspect, but its aesthetic functionality may not be so. In an instance such as this, alternative corrosion protection systems could be considered economically superior when weighed up against the fact that the coated steel will require extra care and materials in packing and transport.
and this will add to the relative cost. This also includes issues such as on-site maintenance and repair. Structural engineers, architects, steel fabricators and various contractors need to work together to determine the best economic and durability outcome of their specific corrosion protection systems.

Welding

Fasteners were discussed with respect to dissimilar metals in the previous article, however, welding of structural steel also presents issues for corrosion protection and there are number of potential problems that can occur.

A poor weld can introduce pinholes and cavities that will be difficult to protect with most coatings and will also trap contaminants that can accelerate corrosion. It is important that welds are produced with the least amount of “imperfections” possible. Pinholes and cavities are not only unsightly, but they pose a real risk to the integrity of the corrosion protection system at the weld. Also, depending on the procedure used, welding can produce “splatter” of the weld material onto other areas of the steel. Splatter is not only unsightly, it can diminish the durability of the steelwork. If splatter is not removed during the preparation for coating, it can result in the protective coating over the splatter material not achieving an adequate thickness and therefore increasing the likelihood of corrosion. This is exacerbated by the fact that the small metallic particles will corrode more quickly. Although this sort of initial corrosion is not usually a problem in terms of structurally compromising the steel, it can leave unsightly rust streaks.

A similar problem can occur on galvanized steel that is welded after galvanizing. The splatter lands on the surface of the surrounding galvanized steel and if it is not promptly removed, it corrodes and then marks the surrounding area with a distinctive “lusty” colour. This is very difficult to remove without damaging the galvanizing.

Another problem introduced with the welding of galvanized steel is that it requires that the galvanized coating be removed in the area of the weld due to OH&S reasons (fumes) and also to ensure the integrity of the weld. This means that the weld area then needs to be repaired, ideally to a level matching or exceeding the corrosion protection level of the galvanizing. This is usually achieved through the use of zinc rich paints of which there are a number of different types and systems depending on the corrosivity of the area in which the steelwork is to be placed in service. This is generally successful in inland and benign environments, but the welding and repair of steel in coastal areas is difficult to achieve successfully and normally is not recommended. It is not only a matter of selecting the correct zinc rich paint, but the application must then be followed exactly as per the manufacturer’s instructions. This is not impossible, but can often be difficult to achieve in coastal areas with their high humidity and constant salt spray. It would be preferable to use an alternative system such as bolting which insures that all of the steelwork is protected by the same system. It is worth noting, that due to their lower zinc thickness, galvanized bolts will require greater inspection and maintenance.

Stainless steel also requires careful attention after welding. This is not only due to the routine issues of splatter and other contaminants. The temperature required during some welding processes can result in surface defects and contamination that can reduce the life of the steel. The heating can result in discolouration of the steel around the weld known as “heat tint”. This discolouration indicates the formation of chromium oxide scale on the surface of the stainless steel. These oxides reduce the corrosion resistance of the steel and need to be removed together with the chromium depleted layer beneath during post-welding treatment. Refer to the ASSDA website for further specialised information.

Conclusion

Designing for the corrosion protection of steelwork involves much more than just selecting a protective coating or system. The design of the steelwork will greatly affect the efficacy of any system selected and this should be taken into consideration at the initial design stage, not just as an afterthought at the conclusion of the design and specification stage. Economic considerations also play a significant role in the selection of corrosion protection systems and should not be ignored in the interests of just considering the first suitable system. A general knowledge of both effective steel design and different protective systems will give professionals involved in the specification and design of infrastructure a well-stocked “toolbox” with which to work.

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Acknowledgements and further reading

AS/NZS 2312 – Guide to the protection of structural steel against atmospheric corrosion by the use of protective coatings

Australian Stainless Steel Development Association (ASSDA): www.assda.asn.au


(p) Poor weld finish affecting surface coating

(AS/NZS 2312).

Satisfactory weld preparation

(AS/NZS 2312).