Case Study

Non-Galvanized Steel Expiring? Collie Street Car Park

Figure 1: The Collie Street Car Park during construction in 2003.

Background

Collie Street is located in the lively coastal region of Fremantle, Western Australia. The area boasts a myriad of local shops and restaurants which are all well within walking distance to the beach. Gaymark Investments had a clear vision to develop a car park on Collie Street, with a plan to incorporate street level retail shops and a 9 deck car park able to accommodate 448 cars.

The local council's streetscape plan for the area consisted of masonry and glass, which was incorporated stylishly into the car park through the brickwork façade and glass awnings over shops to protect shoppers. The aesthetic was desired to be bright and friendly with clean open lines inside and out, with the angled beams at the top of the car park, which can be seen in Figures 1 and 2, giving the feeling of a larger open space.

Steel was chosen as the primary building material for the car park, with the CEO of Gaymark Ross Finacchiaro saying "we looked at several car parks and all the ones we liked were in steel." The benefits of using steel for the project included faster erection times, lower cost and a simpler design, following guidance given by OneSteel's helpful publication *Economical Carparks – A Design Guide*.

Wood and Grieve Engineers were the structural engineers for the project, electing to use OneSteel 300Plus 610UB125 structural beams for the horizontal sections that spanned the 17 metres of the steel grid. Vertical columns were OneSteel 800WBs, with a 0.75 mm BMT profiled steel deck beneath the 140 mm thick concrete slab.

The car park was completed in 2003 and had been open around 13 years at the time of this case study.

Initial Corrosion Protection

Corrosion of the steel was foreseen to be an issue, with parts of the car park less than 300 metres from the unsheltered ocean. Using the current standard for the atmospheric corrosivity zones in Australia (AS 4312), the car park is in a high corrosivity environment (C4), being between a few hundred metres and a kilometre from the unsheltered sea. The car park employed regions of paint, hot dip galvanizing and duplex systems (paint over

Figure 2: The structural frame of the car park during construction.

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Figure 3: The Collie Street Car Park, June 2016

hot dip galvanizing) in different areas to provide the corrosion protection for steel. Following advice in the OneSteel Guide, all perimeter and vertical columns were galvanized. Paint was used for corrosion protection for all internal structural members. Additional protection to the galvanized members was provided by the use of a duplex system.

The corrosion mitigation strategy chosen for the long spanning horizontal members and 45° members was a protective paint system. The beams were blast cleaned to class Sa 2½ and coated with 75 µm of inorganic zinc rich primer, 150 µm of a high build epoxy intermediate, and 60 µm of a high gloss acrylic top coat. The system used in the car park had a total DFT similar to ACC5 (AS/NZS 2312:2002) which has an expected life to first maintenance of 10-15 years in a C4 environment.

Paint applied over hot dip galvanizing (HDG) was used on the vertical structural members and crash barriers, creating a duplex system expected to have increased protection against corrosion than paint or galvanizing alone. The paint system used and surface preparation method for the galvanizing are thought to have been HDG600P6 from AS/NZS 2312:2002, consisting of an initial sweep abrasive blast, followed by a 75 µm epoxy primer, 125 µm high build epoxy intermediate, and a 60 µm top coat of high gloss acrylic. The structural nuts, bolts and washers were also hot dip galvanized to maintain a uniform level of corrosion protection throughout the structure. The 0.75 mm BMT profiled steel deck used as the permanent exposed formwork was specified to AS1397 Z450 providing a minimum zinc coating thickness of 25 µm on the exposed surface. This lower coating thickness material would expect to have a life to first maintenance of 6-12 years in the exposed areas.

Revisiting the Car Park

The car park (Figure 3) was inspected in June 2016 to examine the effects of corrosion after around 13 years in the C4 environment. The car park was quite busy, with no evidence of any structural failure or fatiguing of the steel.

Localised failure of the paint was seen on some sections, with delamination and red rust visible especially on flange edges of structural beams, as seen in Figure 4. This indicates the edges may not have been stripe coated, with paint pulling back from

Figure 4: Localised rusting of the structural beam flange under the paint film.

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the corners while wet resulting in a thinner coating of these critical areas. There was no recommendation for stripe coating in the OneSteel Guide.

The exposed painted sections showed a uniform rust percentage of over 5% in most beams, but the majority of the painted elements well inside the car park exhibited less than 1% rust.

The thickness of the original paint system on level 4 was measured on a selection of horizontal structural members by the magnetic method using an Elcometer 456. Ten readings were taken and the average coating thickness was found to be 436 µm, much thicker than the minimum design value of 285 µm. On lower floors the paint had been touched up in places with a cream coloured paint that didn't match the white finish of the original top coat, as seen in Figure 5. The touch-ups were observed to be in similar areas to where rust was seen on other floors. Duplex touch-up had also taken place on these lower floors, but appeared to be to repair adhesion issues rather than corrosion.

The duplex coating was generally intact on the structural members, however loss of

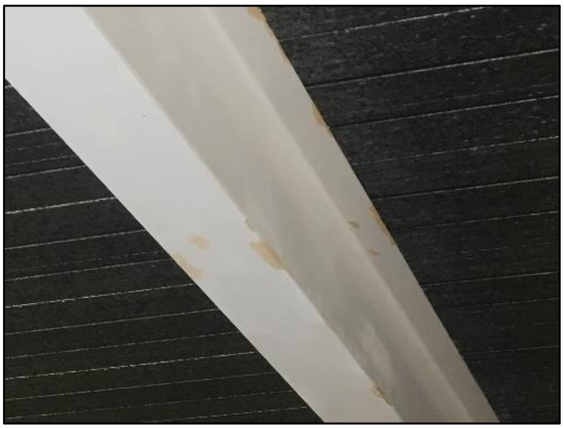

Figure 6: Touched up areas were consistent with locations of visible rust on different floors.

Figure 5: Paint adhesion of the duplex system failing but showing no signs of steel corrosion.

adhesion of the paint system was noticeable on most of the fence panels, seen in Figure 6 – perhaps reflecting different surface conditions or preparation for these minor articles.

The average thickness of the galvanized coating on the structural members where paint had lost adhesion was measured on level 5 with an average of 202 µm, which is over double the minimum thickness required to meet the Australian Standard. This thickness value allows a reasonable expectation of remaining service life above 50 years, even in the corrosive C4 environment. Since the galvanizing is trusted to provide adequate protection, the peeling of the paint is aesthetic only, with maintenance of the duplex system required only due to adhesion failure of the paint and not the corrosion protection. The lack of galvanizing of the exposed horizontal spans was surprising, and may have been due to 17m lengths being too large for galvanizing at the time of construction.

Many of the exposed joints of the car park allowed a direct comparison of steel protection systems, with joints consisting of structural steel protected by duplex systems, painted only members and unpainted HDG fasteners in several critical areas. Figure 7 gives examples of where this occurred, with the duplex coating having paint adhesion issues but no corrosion, the HDG fasteners showing minimal signs of zinc corrosion and the paint only system showing signs of the base steel rusting.

Figure 7: Exposed joints gave a direct comparison between using paint only, duplex systems and HDG to protect the steel when exposed to the same environment. The duplex system protected the base steel although the paint had lost adhesion in some areas. The HDG fasteners had white rust in places, formed by the natural corrosion of the zinc coating but no signs of corrosion of the base steel. The paint only sections showed areas of heavy corrosion of the base steel in some areas, with red rust clearly visible and filiform corrosion likely.

The Influence of the Ocean

The proximity of the car park to the ocean increases the exposure to airborne salts, which deposit onto the steel surface and contribute to an electrolyte that leads to more severe corrosion. The corrosion of exposed fabricated elements and fasteners seemed worst on the south eastern side of the car park, which was closest to the unprotected coast.

Sheltered areas up to a few metres inside the car park were particularly affected, where the salt deposits were shielded from natural cleaning by rainwater. The moisture needed for corrosion to occur is still present in these areas from atmospheric humidity variations and could lead to a micro-environment with a very high corrosivity category (C5).

A small roofed section on the top floor of the car park demonstrated the sheltering effect, seen in Figure 8, with an in-line

Figure 8: The in-line galvanizing that was sheltered and closest to the coast showed worse signs of corrosion, with an adjacent member slightly further from exposure having no visible red rust.

galvanized and perforated channel only showing red rusting of the member closest to the coast. The lower coating thickness of the channel from the continuous galvanizing process leads to a reduced life to first maintenance, especially in the more corrosive micro-environment. A similar phenomenon was seen with the HDG fasteners, where assemblies sheltered and closer to the ocean showed signs of white rust from zinc corrosion but no corrosion of the underlying steel. The fasteners initially would have had at least twice the coating thickness of the in-line galvanized members, giving them increased durability.

Design & Construction Induced Corrosion

Some areas of the car park showed signs of corrosion due to poor design or construction procedures. Base plates used for some of the signage on the exposed top floor were made from painted steel and welded to in-line galvanized SHS, with the bolts anchoring the posts painted and visibly corroding, seen in Figure 9. The flatness of the base plate would also allow for pooling of water and has most likely contributed to its corrosion. Figure 10

Figure 9: The weld line along the fabricated SHS was corroding earlier than the surrounding galvanizing, indicating an inadequate automatically applied initial repair.

shows the weld repair area of the SHS had corroded earlier than the rest of the tube, indicating the repair applied automatically during the section fabrication is likely to have been inadequate.

The pipe used to carry water to fire hoses seemed to consist of galvanized straight sections, with only paint protection on the corner sections. Rust staining can be seen on the ground underneath the bend in Figure 11 and on the small straight galvanized piece between the bends. The clamps used to connect the pipes also seemed to be corroding and contributing to

Figure 10: A painted base plate welded to galvanized SHS has corroded, with ponding of water potentially increasing the corrosion rate.

Figure 11: Curved pipe sections to supply water to fire hoses seemed painted only, with rust staining on the ground underneath from corrosion.

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the rust staining, but the galvanized sections showed no signs of corrosion.

Some corrosion in the middle of the horizontal spans seemed to be caused by paint removal from the roof racks of cars, with red rust visible on the bare spots. Where duplex systems had been subject to impact, such as in Figure 12, the HDG was protecting the base steel with no signs of rust, showcasing the improved abrasion resistance and superior adhesion of HDG to the base steel.

At one point underneath the top floor of the car park, the formwork seemed to be corroding and the adhesion of the top coat on the supporting structural member failing and separating from the intermediate coat, as seen in Figure 13. This seemed consistent with water penetrating through the concrete most likely due to a design or construction issue and leaking onto members, causing the corrosion of the steel and failure of paint adhesion.

Figure 13: The topcoat of paint seemed to be peeling off the intermediate and the formwork rusting, consistent with water leaking through the concrete.

On the ramp near the top floor of the car park, galvanized bolts were embedded in concrete during erection, seen in Figure 14, with ponding and capillary action drawing moisture into the interface causing accelerated corrosion. This has resulted in corrosion of the galvanized coating and made it difficult to replace the bolt, although with the concrete holding the steel in place the joint integrity may not be of concern.

Figure 12: The impact from a vehicle has removed areas of paint, however the galvanizing is still intact and protecting the base steel.

Figure 14: Fasteners have been embedded in concrete on the top floor, leading to ponding of water, crevice corrosion and difficulty when repair is required.

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Conclusions

The Collie Street Car Park was inspected around 13 years after its construction and was generally found to be performing well despite the highly corrosive C4 environment. The duplex system of hot dip galvanized structural steel covered by paint was found to be performing soundly, with the remaining zinc coating thickness under the paint likely to give at least 50 years of future corrosion protection. Some of the in-line galvanized coatings were showing signs of corrosion, which was expected given their lower original coating thickness and shorter lives to first maintenance. Structural steel that was only painted had uniform rust estimated as 5% on exposed beams, and localised corrosion could be seen on many internal beams. Minor touch-ups had been completed on the lowest two floors, but items such as duplex fence panels on all floors were in need of repainting. Special care should be taken when preparing the galvanized surface for painting, with excellent adherence between the paint and galvanizing providing a synergistic effect that greatly extends the life until first maintenance.

Acknowledgements

Original Case Study: OneSteel, 2005
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Steel Detailer: Universal Drafting
Hot Dip Galvanizer: Hartway Galvanizers

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