Corrosion of Building Assets – Problems and Prevention

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Summary
Corrosion of building services is sometimes attributed to cost-cutting by the building owner, the constructor, or the building services designer. Poorer maintenance is another contributing factor to building corrosion problems. Inadequate weather tightness of the cladding on a building that results in the ingress of water into a building envelope can also contribute to corrosion of building assets. Some owners are prepared to ignore the risk that a corrosion tax would apply to their building assets if corrosion occurs. Failure to consider the potential for corrosion during the design of building services will eventually increase costs, introduce safety hazards and may also have an environmental impact. It is surprising to note the low priority given by some building owners, architects, designers, contractors and maintenance engineers to corrosion prevention on assets such as HVAC plant, water piping systems and building claddings. The situation can sometimes be accounted for by lack of awareness of the damaging effects that corrosion can have on critical building plant and the serious consequences of an asset failure.

The corrosion of building services and other equipment within a building envelope can have far reaching consequences [1]. Corrosion damage to building services impinges upon the following areas of the building structure:

- The structural soundness of the building and building service equipment may be severely affected.
- If a metal component is embedded in another building material, corrosion products can expand and cause distortion or cracking of the other material with serious consequences.
- Failure of the material due to corrosion may lead to entry of water into the building envelope causing hidden corrosion of structural elements.
- Unsightly corroded surfaces may be produced with visible weeping of red rust, which downgrades the building aesthetics.
- Manufacturing defects or design deficiencies may produce localised corrosion such as crevice corrosion, which may lead to corrosion-induced cracking of structural building elements.

The pre-eminent global organisation for building services design is the American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE), founded in the USA in 1894. This organisation publishes the ASHRAE Handbook [2], an internationally recognised resource for HVAC and refrigeration engineering. ASHRAE is a global leader in the production of Codes and Standards for building services design. The standards are often referenced in building codes used by architects and engineers in many regions, including New Zealand. However, it is unfortunate that increased maintenance costs as the building services have to work harder. Factors such as these can also result in problems for building occupants such as lower comfort levels which affect productivity at work.

In order to avoid building services corrosion problems the ASHRAE handbook generally specifies the use of appropriate materials and standard engineering materials and using water treatment with corrosion inhibitors in building water systems. However, this approach leaves open the possibility that a water treatment program is poorly managed or neglected then corrosion is often inevitable. A corrosion problem may be inadvertently designed into the building system and avoidance relies totally upon proper maintenance to ensure good corrosion control is operational. There are many building water piping designs that include the connection of dissimilar metals which introduces galvanic corrosion issues. Astute building specification of building assets of the potential for galvanic corrosion and they recognise the threats that inadequate corrosion control may impose on the building services. Nevertheless, circumstances still arise that contribute to unexpected building asset corrosion problems.

Many publications outline corrosion problems that are encountered in buildings and which inflict damage on building services [3-9]. Some case studies have been chosen to illustrate building services corrosion problems. A number of the corrosion failures outlined are due to poor design - these are often corrosion blunders. Some corrosion systems are due to poor plant maintenance and others are associated with the ingress of water into a building envelope.

2. Case studies on Corrosion of Building Assets

2.1 Hot Water Heating Plant Corrosion

A hospital for the elderly had installed an underground heating system to provide low pressure hot water to heat wall radiator panels in the residents’ rooms. After several years in service, corrosion occurred in the radiators that resulted in leaks developing in the wall-mounted radiator panels (Figure 1). A disassembled aluminium alloy radiator showed an extensive build-up of corrosion products inside the panel heater (Figure 2). The hot water system comprised an interconnected underground network of copper tubing, steel fittings, copper alloy fittings, and polyethylene plastic pipework (PEX). The water supply was chemically treated with a corrosion inhibitor but the hospital water treatment had unfortunately been neglected after commissioning.

The presence of copper tubing and copper alloy fittings in the hot water heating system gave rise to mobile copper (cans) in the hot water pipes that initiated galvanic corrosion on bare aluminium alloy and carbon steel studs inside the radiator panels. The panel heater design that involved contact between aluminium alloy bodies and steel frames on the hot water had exacerbated the galvanic corrosion process. The underground heating system was vulnerable to internal corrosion because the water supply corrosion inhibitor treatment program had been neglected. After chemical clean of the tubing was carried out an appropriate water treatment regime was reinstated to prevent further internal corrosion of the hot water system and the radiators. Wherever practicable, it is best to avoid incompatible bimetallic couples in heating plant employing the heat transfer medium [4,9]. If this basic corrosion control requirement cannot be achieved and dissimilar metals are incorporated into a heating water system in an institutional building then water treatment programs must be employed and the treatment program must be routinely monitored for efficiency.

Figure 1. Hot water panel heater leaked due to a design comprising aluminium panels joined internally with steel studs.

Figure 2. Corrosion product inside aluminium heater panel. Corrosion is due to galvanic corrosion.

2.2 Accelerated Corrosion of Copper Piping in a High Rise Building

Accelerated corrosion of 100mm copper plumbing piping carrying waste water to underground sumps was an ongoing problem in the basement area of a high-rise building. The sumps were constructed of concrete for containment of the wastewater and stormwater. The copper piping carried waste fluids containing waste water, sewage, cleaning chemical residues and stormwater. Leaks due to localised corrosion had developed in the copper piping which required the copper pipes to be frequently repaired by a plumber. However, the copper pipe corrosion continued unabated even after plumbing repairs had been carried out.

The design and construction of the building services piping system for draining waste water into the sumps had contributed to erosion-corrosion damage inside the copper piping. Additional problems included copper pipe encapsulated into concrete, dissimilar metal contact between copper pipe and steel valves (Figures 3,4), bifurcated joints showing erosion-corrosion due to turbulent flow, and poorly brazed copper elbows. The repair of leaking copper pipes by brazing had produced a harmful microstructure in localised areas of the copper piping which contributed to localised internal corrosion on the copper piping.

The failures of the copper drainage pipework could not be avoided because the aggressive fluid inside the copper drainage pipes was not able to be changed. Total
replacement of the copper piping was necessary using a corrosion-resistant polymer (ABS). It was important that the corrosive nature of the waste fluids in the drainage lines be taken into account during the design stage of the waste water piping system, but this design aspect had been overlooked.

2.3 Microbiologically Influenced Corrosion (MIC) in Water Supply Piping

Commercial buildings contain different water supply systems that include potable water, hot water, fire water and cooling water. Water systems utilise pipework and other ancillary equipment made of various materials. Often the control of corrosion in water supply piping does not receive the detailed attention that it requires by plumbing designers to ensure that the water supply system will give uninterrupted service for long periods of time.

The water piping network for a large air conditioning (AC) plant for airport buildings providing cooled air into the busy complex was constructed from black steel with no internal corrosion protection. The water source for the buildings was a bore supply delivered through steel pipework and was not subject to MIC attack under certain circumstances [11].

The extensive corrosion damage was predominantly caused by the ingress of marine aerosol through the open dome cladding. Deposits of corrosive sea salt and bird guano had contributed to premature corrosion occurring on a variety of plant surfaces. Water escaping from AC chiller units had also caused corrosion on the galvanised steel chiller cladding. Corrosion protection for the various structures was provided by poor paint coatings which in many cases had failed after only ten years in service. Galvanised steel components performed better, but some galvanised steel fixings had undergone severe surface corrosion. Copper pipingfair well. However, due to dissimilar metals contact at steel flanges, galvanic corrosion had occurred on the steel (Figure 7). Dissimilar metal corrosion also occurred on steel pipes where stainless steel fixings had been welded to the carbon steel pipework. Little maintenance had been carried out to mitigate the corrosive effects of the marine aerosol on the plant materials located inside the building plant room.

The probable cause of the corrosion on the copper condenser coils was thermogalvanic corrosion. It is not possible to design AC condenser coils with completely isothermal surfaces. Condensers can have temperature differentials along the same surface in the presence of an electrolyte. Localised corrosion occurs in the hotter zone. Depending upon the environment localised corrosion on metals may accelerate or decelerate. The driving force for thermogalvanic corrosion is small and if the resistance of an electrolyte is low the corrosion is confined to small areas causing pitting corrosion at the edge of the hotter zone. Thermogalvanic corrosion is usually a dormant condition that can accelerate localised corrosion on a passive metal such as copper if the environment alters.

2.4 HVAC Equipment Exposed to Marine Environments

Commercial buildings are exposed to the atmosphere and the rate of corrosion of any exposed metals depends on the alloy type, exposure to rain, ambient temperature, degree of atmospheric pollution (e.g. marine aerosol) and the extent of exposure to a prevailing wind. Some undesirable details in building construction permit rain water ingress into a building envelope and the rain water can initiate corrosion of inadequately protected HVAC plant exposed to the environment.

Figures 6-8 show the result of corrosion damage that occurred in the plant room of a prestige high-rise apartment building located near the sea. The plant room was located on the top level of the 40 storey building under an aluminium-slat dome structure through which rain water, marine aerosol and birds gained easy access. The exposed plant area which included HVAC equipment was not well maintained and the design of some of the plant and pipework ensured that galvanic and general corrosion on some metallic components occurred.

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2.6 Corrosion in Heat Pumps and Air Conditioning Units

Over the past decade, the installation of heat pumps and small air conditioning units in residential and commercial buildings has increased rapidly around the world. A modern inverter heat pump provides air conditioning in summer and heating in winter. A heat pump works by extracting heat from the outside air and increasing the temperature thereby with the addition of an external pump. However, if the water does not drain freely and moisture condenses on the bottom of the heat pump cabinet, hidden internal corrosion of the casing can ensue and failure of the heat pump may result (Figure 10).

Internal corrosion of heat pumps and air conditioners can occur when a building fitted with the appliance is located near the coast or in geothermal area, for example Rotorua in New Zealand. The corrosive environment created by water ponding on the cabinet bottom is worse if pollutants such as sea salt or geothermal hydrogen sulphide (H₂S) are carried inside the heat pump by the air intake. Failures of heat pumps due to corrosion have been recorded in these locations after only five years in service. The heat pump manufacturers often will not accept liability for the appliance failures resulting from internal corrosion.

Manufacturers, installers and owners need to be more aware that heat pump are usually contained in steel cabinets with a basic coating (paint or powder coating) for corrosion protection. The internal steel surface of a cabinet is often susceptible to surface corrosion. The corrosion problem can occur inside small units installed externally on walls and roofs of buildings located in corrosive environments. Heat pumps used to heat swimming pools employing salt water chlorinators may also be susceptible to internal corrosion damage.

2.7 Claddings, Water Ingress and Building Corrosion

The purpose of a building cladding is to ensure that a building looks attractive and to ensure that the building envelope is watertight. It is possible that poor construction detail and the use of some materials for claddings may permit rain water to enter the building envelope. If the cladding is not watertight it is likely that hidden metal fixings within wall cavities will corrode and possibly even fail. Water can be retained in crevices on metal surfaces or between a metal and some other material, resulting in unseen corrosion damage. Water may also drip onto a metallic surface carrying dissolved contaminants such as alkalies or salts which are corrosive to metallic fixings in the building walls. Thus, the integrity of a building cladding is critical to the durability of the materials used in construction of the building.

Figure 12 shows the condition of a proprietary coated steel cladding material on a building after only 15 years in service. The external corrosion is due to poor cladding design resulting in crevice corrosion and ingress of rain water. The steel cladding panels had undergone crevice corrosion in areas where rain water containing aggressive marine salts had been trapped in joint locations causing severe degradation of the cladding. The corrosion damage observed was superficial in some areas but extensive in others, including locations where cladding perforations had occurred. The entire building had to be reclad after 15 years. Similar cladding failures have been reported involving corrosion of proprietary aluminium composite panel claddings on high-rise residential blocks and communal buildings. In most cases the cause of water ingress into the internal wall cavities was poor cladding detail and poor installation of the cladding material on the building façade.

3. Discussion

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3.1 Corrosion in HVAC Systems

The purpose of a heating, ventilation and air conditioning (HVAC) system is to provide a comfortable environment inside a building. HVAC systems include heat pumps, ventilation fans, air filters, dehumidifiers and heat exchangers. HVAC systems are critical for the operation of a building and their failure can cause significant damage to the building and its occupants.

Figure 10. Thermographic corrosion on copper tubes at end plate of condenser unit. Galvanic corrosion on galvanised steel.

Figure 11. Corrosion inside poorly protected steel cabinet of a heat pump. Condensate water inside cabinet supports corrosion.

Figure 12. Failure of proprietary cladding showing corrosion distress at seams resulting in water leakage.

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4. Conclusions

4.1 Many aspects of corrosion control in the design of building services and plumbing systems are well documented and available to architects, designers, and engineers through Codes and Standards. However, some aspects of corrosion protection in the codes are outdated and depend entirely upon application of coatings, and the water treatment for piping being well managed - this does not always happen.

4.2 Failures of plumbing system pipework and HVAC equipment in buildings still occurs. A considerable number of failures reported are due to galvanic corrosion resulting from specification of dissimilar metals connections in water piping systems.

4.3 An increase in failures of water systems due to microbial corrosion may be attributed to the use of poorer quality water in buildings and to inadequate piping system commissioning practices.

4.4 Ingress of a corrosive marine aerosol into HVAC plant areas has increased and this problem is often due to poorly protected building services being openly exposed to corrosive atmospheres.

4.5 Corrosion in heat pumps and air conditioning units for small buildings is an ongoing problem. The corrosion issues encountered are mostly due to inadequate corrosion protection of appliance materials during manufacture. Owners are usually unaware that routine maintenance is necessary to provide a trouble-free life for air handling units installed at locations near the coast and in geothermal areas.

4.6 Stainless steel usage in plumbing systems, HVAC plant and ducting has increased because designers are becoming more aware of corrosion problems occurring in building services. However, stainless steel equipment used in building services must be well fabricated from the correct grade of stainless steel in order to provide a long service life with low maintenance.

4.7 Leakage of rain water into buildings due to external cladding failures has resulted in a number of corrosion issues on hidden metal fixings in wall cavities. Locations with high rainfall are more prone to this corrosion problem in building envelopes.

4.8 Awareness of potential for corrosion issues in the building service industry is slowly improving. However, building service engineers should update their understanding of corrosion control techniques to ensure that corrosion is avoided by good design and proper maintenance.

5. References