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Roofing

Corrugated Iron – Options for Repair

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About the Speaker

Anne Warr is an architect and currently the Manager of Heritage at Sydney City Council. For several years she was the Manager of Heritage Design Services within the Buildings Branch of the Department of Public Works and Services. She is a member of the Heritage Council's Technical Advisory Group. In 1989 she completed her Master's thesis on *History and Conservation*. The paper presented is given in response to a growing appreciation of the importance of corrugated iron in Australian culture, and a desire amongst practitioners to understand appropriate ways of preserving and conserving the material.

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CORRUGATED IRON: OPTIONS FOR REPAIR OR REPLACEMENT

Corrugated iron is an important element in the Australian landscape. Widespread recognition of this importance has led to concern amongst conservation practitioners regarding adequate protection of corrugated iron structures and correct replacement of the material.

Common questions amongst conservation practitioners are:

- When and how to **repair** corrugated iron?
- When and how to **replace** corrugated iron?

As with all conservation questions, the answer begins with ascertaining the significance of the item. With corrugated iron an understanding of the historic, scientific, aesthetic and/or social significance is necessary before being able to determine an option for repair or replacement.

Historic significance

Within a few years of corrugated iron being invented and patented in Britain in 1829, it was appearing in Australia: firstly as verandahs (to protect the English style cottages from the sun) and then as whole buildings.

During the gold rush of the 1850s, emigrants would arrive in Australia with their dwellings in packing cases in the hold of the ship. Each component would be numbered for easy assembly. Vast numbers of portable houses were sent to Victoria during the gold rush, along with groups of shops, hotels, villas (including one for Caroline Chisholm) a theatre and three portable corrugated iron churches.

Statistics on the importation of iron buildings into Victoria show that in 1853, 6,639 packages of iron worth £111, 380 were imported (remembering that a large building like a church could require up to 60 packages.) In 1854 a peak number of 30,329 packages worth £247,165 were imported, which dropped to £24,118 in 1855.

Despite these large numbers of imported buildings and the fact that iron from the 1850s was of excellent quality, the gauge thick, and the corrugations large, very few intact corrugated iron portable buildings from this period survive in Australia. One of the survivors is a cottage manufactured by John Walker and dating from 1853. Corio Villa is now owned by the National Trust of Australia, Victoria, and is located at 399 Coventry Street South Melbourne.

Corio Villa was manufactured in Scotland and exported to Geelong in 1853 and is the finest example of a prefabricated building still standing in Australia. It is, however, predominantly made of cast iron, with only the rear walls of the house and the roof covering being of corrugated iron sheets. The corrugated iron wall sheets span horizontally between cast iron supports. The relegation of corrugated iron to the rear of a building behind a more imposing façade became a feature of many Australian buildings.

The Legislative Council building in Macquarie Street, Sydney, was originally a portable church, sent to Victoria, then moved to Sydney. The large pitch corrugated iron on the side walls is easily visible from Macquarie Street.

The corrugated iron in these structures is indeed iron, not steel, and is of a large pitch not manufactured after about 1940. Therefore it has historic and scientific rarity. Every effort should be made to preserve and repair such examples. Replacement should not be an option until every effort at preservation has been exhausted.

The roofing iron removed from Elizabeth Farm in 1980 dated from the 1880s, and was probably iron imported from Britain. Attempts were made during conservation works in 1980 to preserve the iron by rust removal and re-galvanising. This proved unsuccessful and the iron was replaced with galvanised steel, painted red initially, then later repainted in “harbour bridge grey.”

In the 20th century structures of historic significance include the Nissen Huts of World War I and World War II; the backyard air-raid shelters of World War II, known as Anderson Shelters; imported portable, industrial buildings; or the large grain silos of Western Australia.

Examples of corrugated iron used in imaginative, utilitarian ways often have historic and aesthetic value. In country Australia, there is a tradition of using corrugated iron for houses, roofs, sheds, barns, stables and water tanks. The isolation of farming properties and the harsh, demanding climate, led to functional buildings, and distinctive forms of appealing simplicity. The versatile ways in which farmers over the past century recycled corrugated iron for utilitarian structures tell a graphic story of thrifty survival and development in the bush, often worthy of conservation.

Brands

The two companies which exported the largest quantities of corrugated iron to Australia were “ Gospel Oak” and “ John Lysaght.”

Gospel Oak commenced export of corrugated iron to Australia around 1850 and it continued for many years, until a company called Baldwin acquired the brand in

1920 and used it until as late as 1939. The Gospel Oak brand consisted of an anchor symbol between the letters G and O.

John Lysaght was established at Bristol and commenced the manufacture of corrugated iron in 1857, exporting to many countries including Australia and South America. By 1880 Lysaghts was exporting so much corrugated iron to Australia that it established a central selling agency in Melbourne. In 1897 the first edition of the Lysaght Referee was published, outlining the range of products sold through the company.

The original Lysaght brand of corrugated iron was ORB, followed in 1897 by a cheaper version of REDCLIFFE. Both brands were exported in large quantities to Australia, and limited quantities of GLOBE, a brand produced for American and African markets ended up in Australia.

A limited quantity of galvanised sheet and plate was produced between 1880 and 1912 at the Eskbank steelworks at Lithgow. The brand used was CROWN but there is no evidence that any of the sheet was corrugated for roofing. Any sheet steel bearing the brand CROWN would be extremely rare and valuable.

In 1920 John Lysaght UK was acquired by the steel giant GKN, while John Lysaght (Australia) commenced manufacture of corrugated iron in 1921. The rights to the ORB brand passed to Lysaght Australia; GKN retained the rights to the REDCLIFFE brand and Lysaght Australia called their cheaper version of corrugated iron GUINEA. Lysaght Australia's corrugated iron always included the words LYSAGHT AUSTRALIA. Red Orb was introduced in the 1930s (prior to 1934) using a base of high tensile steel, being intended for heavy duty applications and not being suitable for curving. From 1934 all ORB and RED ORB sheets were dated with the year of manufacture, the last two digits of the year being placed within the Maltese cross at the top of the sphere. By 1950 the brand name ORB had been changed to BLUE ORB . In 1967 CUSTOM ORB was introduced, replacing RED ORB. By this time BLUE ORB was generally restricted to curved applications, including water tanks, but not general roofing.

Scientific Significance

Understanding the history of the manufacture of corrugated iron can assist in determining whether particular examples have scientific significance.

The corrugated iron first produced in 1829 used wrought iron made by the puddling process. The constituents of iron in the mid 19th century, particularly the amount of carbon and impurities present, were difficult to control and hence varied widely. The Bessemer process for making steel, invented in 1856, led to the widespread replacement of iron by steel by the 1880s. However, wrought iron was still being used for corrugated iron into the early 20th century. This was due to the financial limitations on manufacturers replacing their plant, and on the slow acceptance of steel in the marketplace due to its greater susceptibility to corrosion than wrought iron.

While steel is primarily an alloy of iron and carbon, it was soon found that the addition of small amounts of other alloying elements could radically alter the properties of steel. In 1882 it was discovered that by adding 13% manganese to steel containing 1% carbon an intensely hard steel resulted, now known as manganese steel.

In 1913 when Harry Brearley of Sheffield was experimenting with alloy steels he noticed that a steel containing 14% chromium remained bright while other steels rusted. This led to the development of "stainless steels". In 1933 it was found that by adding a small amount of copper to carbon steel the resistance to corrosion and the strength were increased. This steel was called *corten*. Today corrugated steel can be rolled from mild steel, corten steel and stainless steel to a range of thicknesses. If a piece of corrugated iron/steel from each decade over the last 170 years was examined metallurgically, no two pieces would be the same. BHP was constantly updating its steel making processes at Wollongong and Newcastle leading to changes in the constituency of the resultant steel.

Numerous attempts were made in Australia in the 19th century to establish iron works using local iron ore, but the only successful iron works were the Eskbank Ironworks at Lithgow which commenced operations in 1876. Steel was produced for the first time from a small open hearth furnace in 1900. However, steel production on a large scale did not commence until 1915 when the Broken Hill Proprietary Company established its steelworks at Newcastle. In 1921 John Lysaght opened a sheet rolling and galvanising works next to BHP at Newcastle. In 1936 a further plant was opened at Port Kembla, and by 1939 these two plants were meeting 100% of the local demand for galvanised sheeting.

The methods of rolling slabs of iron or steel into flat sheets have undergone many changes over the last 170 years. Improvements in the design of rolling mills have enabled sheets to be rolled to thinner gauges. The standard thicknesses available today range from 0.42mm to 0.8mm, while in the mid-nineteenth century thicknesses of 1.2 – 1.6mm were common.

The shape and size of the corrugations formed from the flat sheet have also changed in the 19th century, a range of pitch from 1'' to 9 ½ '' was available, with 3" and 5" being common. By the 1940s, 3" pitch was standard although sizes from 2" to 9 ½" were still available. Sinusoidal sheets are now only available from BHP in 3" pitch (17mm rib height) with mini-orb available in 6mm rib height. Thus to replicate a corrugated sheet of 5" pitch would require BHP to install new roll-forming machinery. Unfortunately, BHP have not preserved any of its early corrugating machinery.

In the last 170 years corrugated sheets have been given a variety of protective coatings. The process of dipping iron sheets into molten zinc to prevent corrosion was patented in France in 1837. The first galvanising works were set up in Sydney in 1863 by Simon Zollner. Early galvanising that was hand-dipped provided a thick coating of zinc, while later mechanical methods produced thinner coats.

Galvanising was undertaken by a cumbersome hand-dipping process until Lysaghts Bristol developed the first commercially successful four-roll galvanising machine in 1888. The machine continued to evolve, of course, but essentially the “sheet pot” remained the method for galvanising until continuous galvanising lines were introduced. BHP replaced their sheet pots with continuous lines at Port Kembla in 1955 and at Newcastle in 1961. According to BHP’s literature, they were the “ most productive galvanising lines in the world.”

The continuous galvanising lines are totally mechanised and designed to coat the sheet steel evenly with a minimum thickness of zinc. Continuous coating weight gauges measure the coating mass and automatically position air jets to correct coating mass along the sheet – removing zinc or zinculume if applied too thickly. The resulting sheet has a very even and precise thickness of coating.

The sheet pots, however, were not totally mechanised, and did not provide even coatings of zinc. The rollers at the bottom of the pot sometimes became eccentrically aligned, allowing more zinc to be placed to one side of the sheet. The exit rolls were grooved with 2mm deep grooves, and as the sheet came out of the galvanising pot, the grooves took more zinc off the underside of the sheets, and also drew more zinc to the end of the sheet. Galvanisers understood the failings of their machinery and allowed for overall thicker coats of zinc to compensate. The new continuous lines were more economical in the use of zinc.

In 1972 the Bethlehem Steel Corporation of the United States developed a new product under the name *galvalume. Galvalume* is steel that is hot-dip coated with an alloy consisting of 55% aluminium, 43% zinc and 2% silicon. This zinc/aluminium alloy resists atmospheric corrosion from 2-4 times effectively as conventional hot-dip zinc coatings of equal thickness. British Steel produced a similar coating under license from Bethlehem steel, known as *zalutite*, while Lysaghts Australia marketed their similar product as *zincalume.* In the mid 1990s BHP took over Lysaghts Australia, and also bought the Bethlehem steel company’s patent for *zalutite.* BHP are now the sole producers world wide of *zincalume.* Since the 1960s plastic coatings have been applied to sheet steel as an additional protective device and as a means of achieving a durable colour finish.

Aesthetic Significance

For a while I've been curious about certain rusting patterns such as the rusty " wave" marks on sheets, and the pattern of alternate rusting sheets. These patterns didn't seem to make sense as they weren't related to fixings, sheet laps, or obvious weather problems.

Knowing the way that sheets used to be galvanised in the "sheet pots", and the problem of the eccentrically aligned rollers, explains the wavy pattern of rust – the line of the rollers on the sheets is almost discernable. The pattern of alternately heavy and lightly rusting sheets is caused when the underside of a sheet is placed upwards, and the unrusted line at the end of the sheet is due to the thicker coating of zinc that was deposited at the end of the sheet.

As I drive around Sydney, I'm building a mental map of places which have distinctive rusting roof patterns. Now I know that these roofs must be pre-1961, and that such roofs will never be produced again. I would argue a case that some examples of historically rusted and patterned sheets of corrugated steel have historic and aesthetic significance. They are certainly developing a rarity factor.

Thus, although corrugated iron has only been in production for 170 years, it has undergone numerous changes to its constituency, shape, size and finish. To replace a piece of 19th century corrugated iron with its currently available equivalent means replacing iron with steel of a different thickness, finish and possibly pitch. The profiled steel of today is not the corrugated iron of the nineteenth century. Nineteenth century corrugated iron is irreplaceable, and modern equivalents can only be a rough substitute.

Once it has been determined that the corrugated steel has significance, for historic, scientific or aesthetic reasons, then the case for retaining and preserving the steel is established.

Similarly, if the corrugated steel is not significant, the case for replacement may be clear.

Options for "how to repair" and "how to replace". Is it possible to preserve corrugated iron?

Preservation of corrugated iron involves understanding the principles of the material: how it was made, how it corrodes.

Principles of corrosion

Iron in its natural state is an unstable metal that tends to react with oxygen to form iron oxide or "rust". Iron products, likewise, when placed in the atmosphere will tend to revert to their oxide form and rust.

Rust, or corrosion, is an electrochemical reaction requiring the presence of an anode (or negatively charged area) and cathode (or positively charged area) and an electrolyte or conducting medium, such as water. The anode and the cathode may be two different metals, in which case the flow of electrons will be from the " less noble" to the "more noble" metal.

For iron to corrode it must have a simultaneous presence of oxygen and water. In the absence of either, corrosion does not occur. Prevention of corrosion by the removal of all oxygen and water is possible only in a totally controlled environment. In normal circumstances, corrosion prevention involves the application of a coating to separate the iron from the water and/or oxygen in the air – thus suppressing the basic electrochemical process.

The need to isolate iron from the air was realized from early times: oil, wax, tar and paint being common isolators. Iron oxide paints were commonly used in the 19th century giving iron roofs their characteristic red colour.

It is important that a continuous layer of separation is maintained between the metal and the atmosphere. When corrosion starts attacking the coated metal at a defective point in the coating, it tends to propagate under the coating itself, because the areas which have less access to oxygen are differently charged from the exposed ones. The corrosion will therefore spread under the coating.

Coatings are applied in several layers to reduce the chance that pin-holes and thin areas in the coating will coincide in all layers. The aim is to make the isolation of the metal from its environment as complete as possible.

Preservation of iron therefore involves understanding the principles of corrosion. Isolation of iron from the atmosphere involves application of an isolating film/paint layer, and maintenance of that layer. Breaking of the layer will allow rust to propagate under the paint surface. Paint cannot be re-applied to a surface until all the rust is thoroughly removed.

Once an iron sheet has rusted through and conservation of the material has failed, the following options are available before replacement becomes inevitable: Place a second sheet over the top of the rusted sheet; patch with hessian and bitumen.

What alternatives are available?

What are the range of options?
1. Mild steel, hot-dip galvanised and corrugated to 3" profile.
2. Mild steel, coated with zincalume, and corrugated to a 3" profile.
3. Mild steel, coated with zincalume and colour bonded in a grey finish to resemble unpainted galvanising, and corrugated to a 3" profile.

4. Mild steel, coated with zincalume and colour bonded in a red finish to resemble the red oxide paint finish of earlier roofs, and corrugated to a 3” profile.

Zincalume, being an alloy of zinc, aluminium and silicon, will resist atmospheric corrosion 2 – 4 times as effectively as conventional hot-dip zinc coatings of equal thickness. A zincalume roof should therefore last longer than a galvanised roof, save the building owner maintenance costs, and perhaps save the fabric of the building in the long-term.

A zincalume roof affects the appearance of a building in the following ways:

1. in contrast to galvanising, it has a different surface texture;

2. the presence of aluminium in the roofing coating makes it difficult for joints to be soldered. Therefore joints must be sealed using pop-rivets and silicon sealants. BHP have undertaken research to find a soldering flux which will enable zincalume to be soldered. A flux was developed but it was found to be highly poisonous, and no further research is underway;

3. the risk of electrochemical corrosion caused by the use of dissimilar metals means that zincalume products should not be used with lead flashings, lead-head nails or galvanised products. Aluminium is a less noble metal than zinc, and the zincalume roof will become the more reactive, anodic, corroded material. The re-use of salvaged rainwater goods is not advisable. Corrosion of the zinc/aluminium coating may take place when iron, lead or copper based materials are allowed to remain in contact with zincalume steel surfaces subjected to moisture or condensation conditions;

4. BHP’s current technical bulletin (TB-8) on *Flashing materials for zincalume steel sheet* suggests that zincalume can be used as a roof renewal material with lead flashings, provided precautions are taken, such as painting the underside and top of the lead, placing a polyethylene damp-course between the lead and the zincalume. The technical bulletin admits that it is difficult to paint the underside of the lead. Painting the top of the lead is essential to prevent contaminated water run-off. All of these measures require diligent maintenance to ensure the separation layers do not break down and expose any of the lead surface.

Coatings available:

1. Zinc: galvanised
2. Zinc and aluminium: zincalume
3. Colour bonded external plastic coating: colourbond. This can be supplied to either a galvanised base or a zincalume base
4. XSE External severe environment. Finished with high quality fluoro -carbon

paint

5. Aqua plate: zincalume with poly-film on the inside face, to protect the metal from corrosion from direct contact with water.

SUMMARY

Underlying this talk is the premise that building materials can be repositories of memory and information necessary for a society to achieve a sense of richness and continuity. That the very materials themselves can speak to us.

A few years ago I explored this idea in Asia, where, with the assistance of an Asia Fellowship, I looked at the " Marketability of Corrugated Steel from Australia

Many of the traditional roofs in Indonesia and Malaysia, originally clad in thatch or bamboo, are now being re-clad in corrugated steel. Was this a good idea? Was the use of a new replacement material detracting from the cultural significance of the dwellings? Should villagers in Indonesia and Malaysia be encouraged to keep using traditional materials and not replacement materials such as corrugated steel? Was it necessary that traditional materials be maintained in traditional villages in order to achieve a continuity of culture?

What I concluded from my observations was that corrugated steel was being used in vigorous ways that did not seem to detract from the essential culture of the village.

Corrugated steel as a lightweight, flexible, curvable material is ideally suited to the easy re-cladding of traditional roofs in Indonesia and Malaysia. Corrugated steel is light enough to be fixed to existing roof framing systems. It can be worked into the existing shapes easily, comes in manageable sizes, and is easy to transport to remote sites. It comes pre-finished whereas thatch requires much preparation.

Traditional roofs in Indonesia and Malaysia embody important messages regarding social patterns and village life. Over the centuries the roof form has adapted to many influences including religious and technological.

As I studied examples where corrugated steel had replaced traditional materials on traditional buildings, the conclusion I came to was that while the use of corrugated steel may be changing the appearance of the structure, it is evident from the vigorous ways in which the material is used and detailed that it is not detracting from the essential character of the building or the integrity of its place in the life of the village.

What seemed to be important was not the use of a particular material, but the way in which it was being used, and whether this use reinforced or detracted from the cultural base to which it belonged. Corrugated steel is part of the ongoing cycle of adaptation and change.

What I learnt from my study was that, in Asia, it is not the building materials themselves that are important, but the social and cultural network that supports the buildings and places. The cultural fabric is more important than the building fabric.

It could be argued that the essence of the material lies with its qualities such as lightness and strength, being easily transportable, fixable and re-usable. It is a lightweight material that is eminently suitable for short-term uses, and was never envisaged as a long-lasting material. To replace corrugated iron when it has reached the end of its life is consistent with the nature of the material. The qualities of the material such as lightness and strength can be conserved in a new piece of corrugated iron or steel. Or can they?