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CORROSION AND CORROSION PREVENTION IN EXTERIOR METAL CLADDINGS

J.R. Duncan

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BUILDING RESEARCH ASSOCIATION OF NEW ZEALAND

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Building Research Association of New Zealand

ABSTRACT

The exterior metal claddings usually chosen for food industry buildings are based on stainless steel, aluminium, and galvanised steel. These metals are affected differently by aggressive chemicals in the atmosphere, and the first part of the paper discusses these differences.

Methods of combatting corrosion of claddings are then examined, beginning with design factors such as pitch of roof and allowance for thermal movement, and including special mention of factory-painted claddings. General maintenance (including painting) of claddings is also dealt with. Finally, there is a brief discussion of cladding fasteners and their durability.

KEYWORDS

Aluminium; Atmosphere; Claddings; Corrosion; Corrosion protection; Design; Fixing devices; Painting; Stainless steel; Thermal expansion; Zinc.

INTRODUCTION

An exterior cladding must be viewed as a failed investment if before the end of its planned life it lets the weather in or has to be removed and renewed. The possible economic damage caused by close-down of operations or deterioration of stored goods while repairs or replacement are carried out may far outweigh the cost of having used a more durable cladding initially or having maintained it more effectively.

Metallic claddings are very useful for industrial buildings. They are light, strong and -if appropriately specified, installed and maintained - can be very durable. They are easily altered if operational changes require modifications to the building. They also range in price thus increasing the importance of understanding the factors which affect each type of one in service, so that the most appropriate metal can be specified. If aesthetic considerations are important, they may also effect cost considerations at the design stage; for instance, a factory-coated system may have a longer time-to-first-maintenance than a site-painted one (Cordner and Whitney 1984) but will cost more initially. This paper discusses the properties of metals used for claddings, especially with respect to their resistance to corrosion which can be enhanced by appropriate design, and by painting; brief mention of aspects of these is made. Finally, because the cost of their failure can be high, there is a brief note on cladding fasteners.

PROPERTIES OF METALLIC CLADDING MATERIALS

The materials most commonly used for building claddings by the New Zealand food industry may be simplified as stainless steel; aluminium; and galvanised steel, in that order of decreasing initial cost per square metre. These three materials have the physical properties shown in Table 1.

Table 1. Physical properties of cladding sheet metals.

	Galvanised steel	Aluminium	Stainless Steel	
			Austenitic (eg 302)	Ferritic (eg 430)
Density ($g.cm^{-3}$)	7.8	2.7	8.0	7.7
Tensile strength * ($N.mm^{-2}$)	550	250	600	540
Coefficient of thermal expansion ($\times 10^{-6}$ per ^{o}C)	12	24	17	11

*Can be significantly altered by heat treatment at high temperatures and mechanical working

Each of these three broad categories disguises a range of actual products. The term stainless steel is not specific as a material description, except to indicate that the alloy contains at least 12% Cr and has controlled concentration of other elements in the steel (Building Research Association of New Zealand (BRANZ) 1982). Austenitic stainless steels are the type most usually used for building claddings in New Zealand, though there are reports from Australia of successful use of ferritic stainless steels. Similarly, a range of grades of aluminium alloys are available for building claddings. These differ principally in their trace alloy additives (BRANZ 1979b). Galvanised steel claddings are available with a range of different base metal strength properties, and can have a range of zinc coating thicknesses. Metal coatings on steel which differ from conventional galvanising layers are available overseas; such products as Zincalume (known as Galvalume in USA) have a firm market position in Australia, where this 55%Al/43%Zn/2%Si coating has been claimed to have a corrosion rate a fraction that of conventional galvanised steel (Harvey 1981). Aluminised steel is also available overseas and used frequently.

Galvanised steel, aluminium, and stainless steel all behave differently in corrosive environments (BRANZ 1979a, 1979b, 1982).

The behaviours of aluminium and stainless steel are controlled by very thin non-reactive films at their surfaces, which, on claddings, are usually formed by reaction with air. If these films are disrupted and cannot easily reform, the metal can corrode quickly. Both are fairly tolerant of acidic conditions, such as arise if sulphur-containing gases are present in the air. Flue gases often cause high local concentrations of sulphur-containing gases. Both stainless steel and aluminium can suffer severe corrosion if chloride-containing material (whether from wind-borne seasalt or salt from industrial processes) is allowed to sit for long periods on the metal surface. A common site of corrosion produced in this way is under sheltered eaves or load-out canopies, especially on buildings close to the coast. These metals are also prone to corrosion in crevices or under air-excluding deposits.

The corrosion rate of zinc (hence galvanised steel) is, in contrast, controlled by the reactivity of a thicker oxide or oxyhydroxide surface layer. This layer reacts markedly with acidic deposits, and so galvanised steel claddings are often observed to corrode quickly around flues and exhaust vents from industrial processes. Like stainless steel and aluminium, zinc also reacts with chloride-containing deposits, and so is frequently found to corrode on sheltered surfaces. Even on fully exposed surfaces, dust deposits can be deleterious. For example, a roof on which milk powder was being deposited from an exhaust fan was reducing the cladding life to only a few years until a continuous trickle-wash system was installed which carried the corrosive dust away (Sharman and Duncan 1980). The continuous presence of water on the surface was less corrosive than the dust build-up. On galvanised steel claddings, once a significant area of the steel beneath the zinc layer is exposed, the steel will corrode and the rate of this may be up to a hundred times faster than the zinc corrosion rate (the mechanism of steel corrosion is different yet again from those of zinc and aluminium).

DESIGNING FOR DURABILITY

The two major natural corrosion hazards in NZ are the high airborne levels of chloride (which originates as seasalt over the oceans and reaches quite large distances inland from the coast), and long periods of high humidity (Duncan 1984). Localised hazards also arise due to the geothermal emissions in some areas of the North Island. Thus, even with total control of emissions from industrial processes on site, a building may need to be designed to counteract natural atmospheric corrosion hazards. Such design steps will involve eliminating as many places where pools of water can collect as possible, and also those places where wind-borne salt and dusts can be deposited but from which rainwashing cannot carry them away. Freely rainwashed surfaces suffer much less corrosion than sheltered ones.

A very common site where deposits can collect is under the ridge flashing on a low-pitched deep-pan profile roof. There are no very effective details for flashings in this area that do not also create a site for build-up of dust or debris, and maintenance inspections of such areas should be regular. A desirable precaution is to apply a full paint system to the area to be covered in by the flashing at the time of installation, even if it is not intended to paint the whole roof.

Another problem often seen on roofs is sagging between purlins, leading to water collecting in pools. Zinc surfaces, whether painted or not, can corrode extremely quickly in such areas and the trapped water may be very undesirable from a hygiene viewpoint as well. Three factors contribute to this pool formation:

> Inadequate provision for thermal expansion in the fixing details, so that expansion becomes accommodated by permanent cladding distortion. This is a particular problem on aluminium roofs if they are installed using the normal techniques for galvanised steel, since, as shown in Table 1, aluminium expands twice as much for a given rise in temperature. As a general rule, sheet length should be limited to 7.5m for aluminium unless special measures are taken to accommodate thermal movement.

Installation of the cladding at too low a pitch. In the past some manufacturers have marketed sheet metal claddings as suitable for use at 2.5 degrees and less, but it is now recognised as unwise to use pitches below 5 degrees, and even at this pitch there can be problems. If a low-pitched roof must be used, consideration should be given to a reduced purlin spacing towards the eaves line or even full sarking.

Foot traffic across the roof. If regular access across the cladding is needed (e.g. for maintenance), a walkway should be installed with duck-boards etc to lessen the risk of deforming point loads being put on the cladding.

Because of the danger of galvanic corrosion cells being established by deposition of dissolved metals, it is unwise to have overflow pipes discharge on to aluminium or galvanised steel claddings.

A handbook on design of roofs clad with profiled metal sheet is available (Profiled metal roofing design and installation handbook 1981). This gives data on such factors as durability, design loads, fastening methods, and installation procedures, but is primarily concerned with aluminium or galvanised steel claddings which are brought to site unpainted. Additional information on design and installation of coil-coated (i.e. factory-painted) claddings is available (BRANZ 1983a, 1983b). Because these claddings already have a full finish applied there needs to be some additional consideration in deciding when to specify them.

COIL-COATED CLADDINGS

Coil-coated claddings used in food industry buildings in New Zealand (in greatest volume on sandwich panels) are usually based on galvanised steel, though coil-coated aluminium is also available. The coatings are applied under highly controlled conditions to the flat metal strip before it is profiled. The paint coatings used are highly durable and provide a base for later maintenance coats of paint which is likely to be much better than could be achieved with site applications to a bare metal cladding. A particular deficiency, seen in corrosive locations, of some of these factory-finished claddings is the presence of microcracks in the paint along formed edges of the profile. These cracks may be only marginally discernible to the naked eye, but represent channels through which corrosive species can obtain direct access to the metal underneath. They form during the profiling process when stretching and deforming forces applied to the metal are directly transferred to the very adherent paint coating. The problem is accentuated on galvanised steel claddings because the zinc coating is a thin layer of zinc crystals, and much of the deformation occurs specifically at crystal boundaries. These cracks can penetrate right through the zinc layer. Whether the pre-painted cladding is being used for its enhanced corrosion resistance compared to its unpainted counterpart or for aesthetic reasons, corrosion along these microcracked edges is deleterious. Experience has shown that although the aesthetics may not be apparently degraded provided the surface is fully rainwashed, corrosion is occurring at these areas and in very corrosive environments the appearance can be degraded quickly even on fully rainwashed surfaces (Sketchley 1984). On sheltered surfaces white lines (of corrosion products) appear initially along the formed edges, and these may later contain reddish-brown spots as corrosion of the steel beneath the zinc occurs. Some of these claddings (tending to be the most expensive ones) have a plastic film laminated on to the metal surface before profiling, which can be extremely durable because of the intrinsic non-reactivity of the film and the absence of cracks through it.

PAINTING ON SITE

Painting on site has some advantages: it allows only those areas specifically identified as needing protection to be dealt with, and may be a means of employing staff in off-seasons. But unpainted cladding ought not be left for long periods after erection, since this would entail the risk of degradation and would make surface preparation more difficult. As a general rule, if the whole of a cladding plane is to be painted it would be more economical, when time-to-first-maintenance is taken into account, to use an appropriately coil-coated cladding. If painting is intended, stainless steel is very unlikely to be an economically sensible choice of cladding material.

If the decision is made to paint on site, care should be taken to specify the paint system correctly. The two chief points to remember are:

> The success of the operation will be significantly affected by the quality of the surface preparation. Any salts trapped under the paint film will attract moisture through the paint coating to form concentrated salt solutions beneath the paint coating.
>
> The use of an appropriate primer is extremely important. Not only does it improve the ability of the paint system to protect the metal, but it gives a better basis for subsequent painting.

A metal surface on which the paint film is flaking off, or otherwise degraded, may be more prone to corrosion than an unpainted one because of the differential access of chemicals to different parts of the surface, and the greater chances of dusts and salts being trapped. Once a surface has been painted, it should be properly maintained to protect the initial investment. Some of the factors which should be taken into account in deciding on the type of coating to be used are the relative investment costs, the labour cost, and the expected interval until maintenance repainting (Jansen 1984).

FASTENERS FOR CLADDINGS

The materials used for fasteners must be as durable as the cladding material. No matter how perfect the condition of the cladding, if the fasteners fail it may also fail under storm conditions and possibly expose goods and equipment. Care should be taken that a galvanic cell is not set up between the fastener and the cladding: for example, a mild steel fastener may corrode quickly in contact with a stainless steel surface. Table 2, adapted from the Profiled metal roofing handbook, shows some of the problems which may arise. Where metals must be mixed, it is better to have the less easily corroded one as the fastener; thus, stainless steel fasteners are often recommended for use with aluminium cladding.

It should be remembered in deciding between use of plated and hot-dipped fasteners that the protective metal coating on the plated fasteners is likely to be only a fraction of the thickness of a hot-dipped coating, and accordingly will be corroded faster. As a general rule, plated fasteners do not have sufficient durability to last outdoors in New Zealand without additional protection.

Trough-profile claddings are usually fixed to the purlins with sliding fixings to accommodate thermal movement of the cladding. Care must be taken that these fixings are correctly aligned: examples have been seen of leaks produced in aluminium claddings because an incorrectly installed clip scraped through the cladding.

CONCLUSION AND SUMMARY

Exterior metal claddings will fulfil their function of weather protection, but must be appropriately designed and specified if they are to give trouble-free service. Factors which must be considered are: the corrosiveness of the environment, the degree of slope on the cladding, which will determine how well the surface is washed by rain, the aesthetic requirements, and the method of fastening the cladding to the structure.

Table 2. Additional corrosion effects due to contact of metals under damp conditions.

	Sheet Material			
	Galvanised steel		Aluminium	
Contact metal	Rural	Marine	Rural	Marine
Zinc or galv steel	0	0	0	1
Cadmium	0	0	0	1
Aluminium	0	1	0	0
Mild steel	1	2	1	3
Soft solder	0	0	2	3
Stainless steel	0	1	1	2
Nickel	1	2	2	3
Copper, brass	2	3	3	3
Monel	1	2	3	3
Lead	0	1*	0	3

Key
- 0 No additional corrosion of sheet material
- 1 Slightly or moderately increased sheet metal corrosion
- 2 Severe additional corrosion of sheet metal
- 3 Contact should be avoided
- * 3 in severe marine environments

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