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Dear Takafumi,

RE: Suitability of ZAM alloy coated steel sheet to achieve a 50 year service life in New Zealand atmospheric exposure

Background:

ZAM is a corrosion resistant alloy coated steel sheet developed by Nisshin Steel. The steel sheet can be formed into standard steel sections and the protective coating provides an alternative to traditional hot dip galvanizing.

The ZAM protective coating is a metal alloy consisting of the following elements: Zinc (91%), Aluminium (6%) and Magnesium (3%). AS 1397 recognizes this alloy coating at Type ZM and provides the following comment “shows superior to high corrosion resistance in many aggressive environments with good galvanic protection and scratch resistance”

New Zealand Standards:

The requirements for the protection of steel sections in New Zealand can be found in the following publications:

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

NZS 3404.1: Steel structures standard – Materials, Fabrication and Construction

NZS 3404.1 defines five atmospheric corrosivity categories ranging from A (very low) to E (very high). Category E is further sub-divided to E-M and E-I denoting a Marine and Volcanic Influence environments. The corrosivity categories are based on the corrosion rate of mild steel in microns per year.

Figures 20 and 21 have been used in conjunction with Table 14 of NZS 3404.1 to provide a general guide to corrosivity of some cities and coastal areas which are summarized in the table below:

Island / Location		Distance from sea (km)	Corrosivity Zone	Comments
North	Wanganui	0.6	D	Sea Spray
North	Wairoa	0.5	C	Zone 1
North	Masterton	50	B	Zone 2
North	Taihape	95	B	Zone 3
North	Taupo	95	E-I	Zone 4 (Taupo Volcanic Zone)
North	Rotorua	35	B	Zone 4 (Taupo Volcanic Zone)
South	Hokitika	0.2	E-M	Sea Spray
South	Haast	0.5	E-M	Sea Spray
South	Invercargill	1.5	C	Zone 1
South	Mount Cook Village	45	B	Zone 2
South	Queenstown	85	B	Zone 3
South	Hanmer Springs	55	B	Zone 3

The standards also consider the effect of the micro environment of the steel being used. The micro environment factors are site specific factors such as exposure and pollution which could affect the rate of corrosion.

It is considered that the Terracade steel rails will be permanently fixed behind the Terracade façade. This should provide additional protection to the steel rails from the atmosphere thereby reducing the corrosivity rate.

It should be noted that the above table does not take into account the site proximity to industrial areas which may increase the corrosion rate. Also, sites located within Zone 4 should be carefully considered as the site proximity to the Taupo Volcano significantly affects the atmospheric corrosivity rate.

Corrosion Resistance of ZAM:

The ZAM Product Brochure published by Nisshin Steel states that the ZAM products show a higher resistance to corrosion than other traditional galvanic protection however does not state a definite corrosion rate for the product.

Within the product brochure several test results have been published depicting the products performance against other steel protection coatings. Test have generally been carried out in a controlled laboratory environment; these tests include a salt spray test, bend test, scratch resistance test and an acid/alkali test among others. It should be noted that the ZAM product showed close to 20 times better performance in the salt spray test compared to traditional zinc galvanized protection.

Nisshin Steel has also conducted outdoor exposure tests in both coastal and rural environments in order to obtain a real world understanding of the products performance. Test results of the outdoor exposure test have been published with an exposure period of close to 8 years (the Japanese product brochure shows updated test results with an exposure period up to 10.4 years).

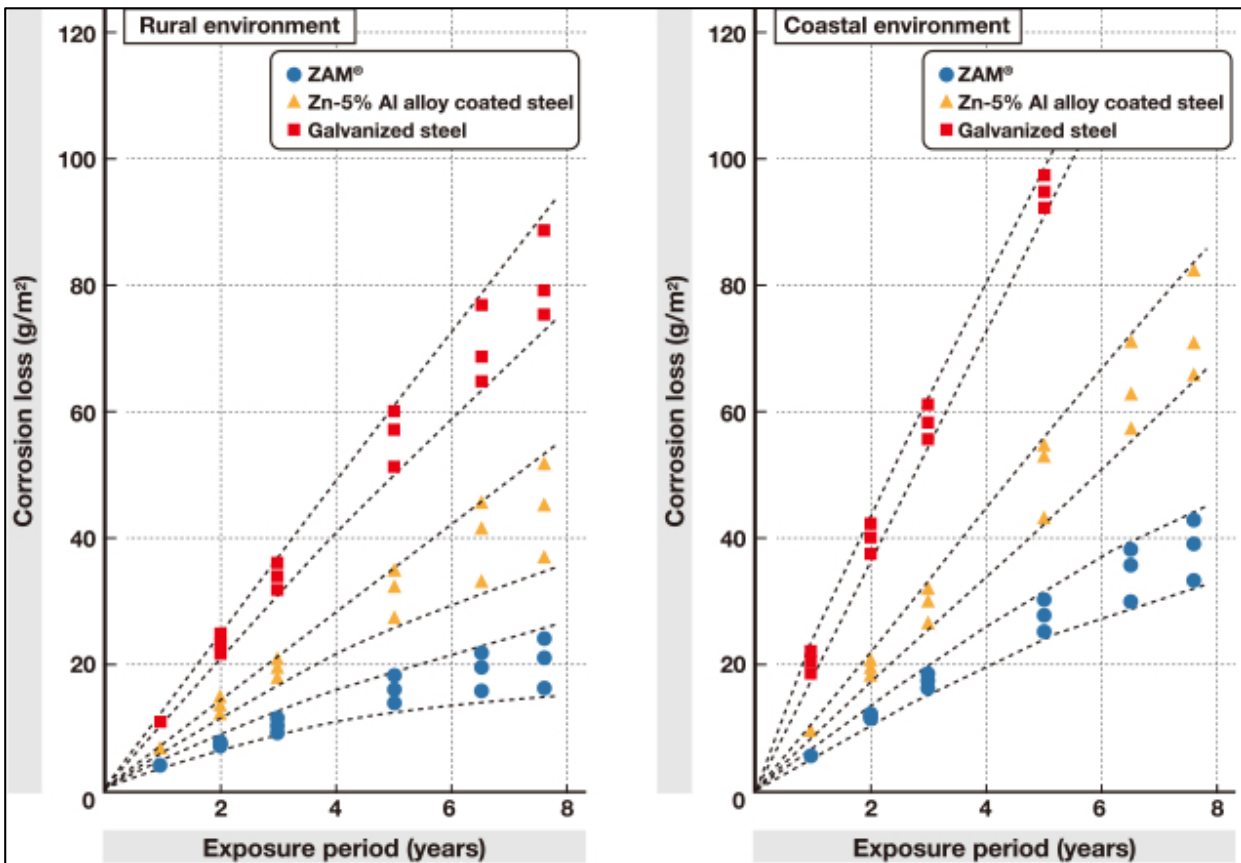


Figure 1 - Outdoor Exposure Test Corrosion Loss of Coating Layers (English Brochure)

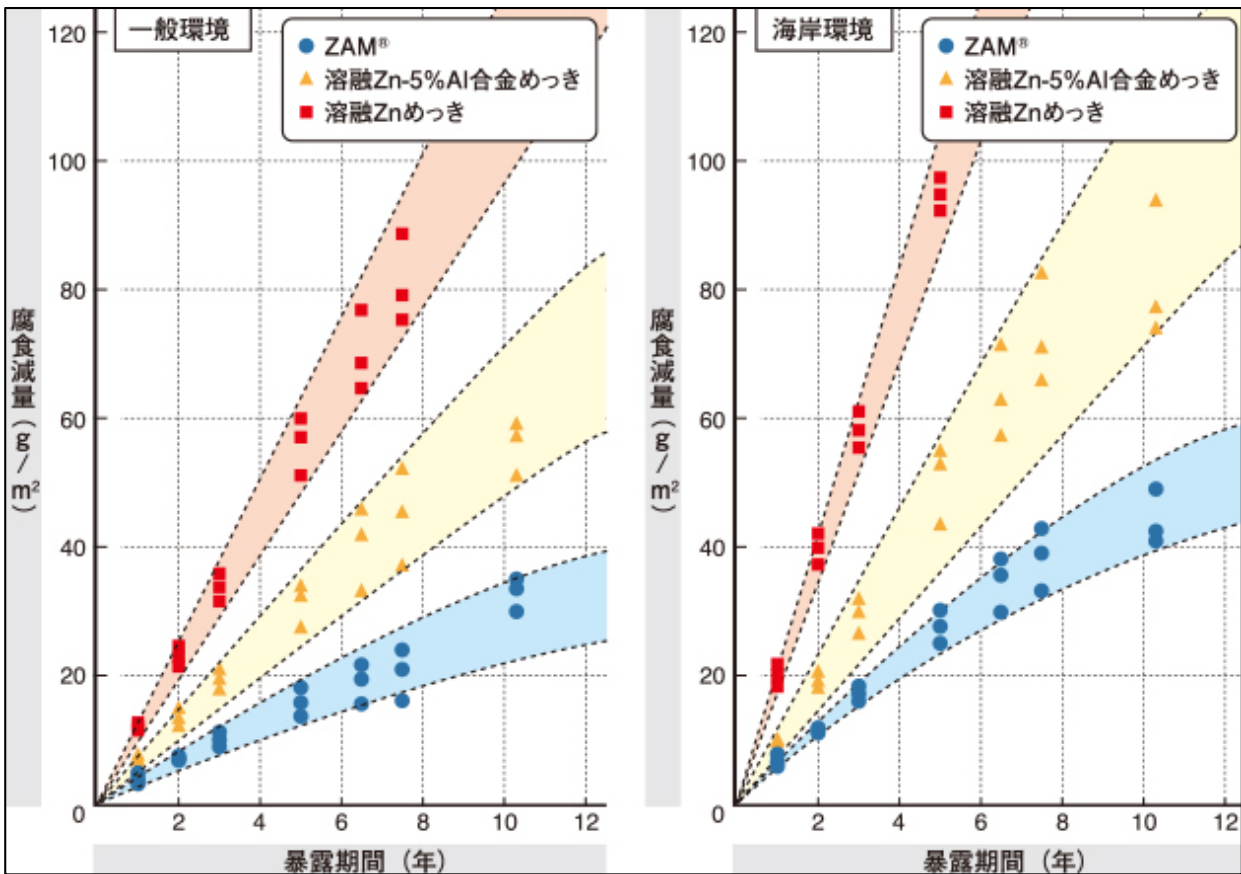


Figure 2 - Outdoor Exposure Test Corrosion Loss of Coating Layers (Japanese Brochure)

Analysis of the test results indicate a non-linear relationship between the exposure period and the coating loss of the ZAM product which trends towards horizontal. Traditional hot dipped zinc coated steel shows a purely linear relationship between the exposure period and coating loss. This indicates that the ZAM products performance becomes more effective over time.

The ZAM product brochure states that according to the outdoor exposure tests “ZAM shows approximately four times higher corrosion resistance than hot dipped zinc coated steel” however this is based only on 8 years of exposure.

When contacted Nisshin steel advised that the maximum performance ZAM can provide, is six times higher corrosion resistance compared to zinc coated steel.

Application:

The maximum coating thickness of the ZAM product is 225g/m², denoted by the coating designation ZM450. Due to this limitation, the application of ZAM products for the Terracade steel rails to achieve a service life of 50 years in New Zealand is deemed acceptable for A to D corrosivity zones only. Additional paint protection will be required to the Terracade steel rails for an E corrosivity zone.

Again, it is emphasised that due to the micro environment of the steel rails (being protected behind the Terracade façade) a full zinc corrosion rate of 8.4µm/yr in Zone E may never be realised. However, as there is no real world test data of the effective protection of the façade, a reduction in the atmospheric corrosion rate cannot be justified.

The following table outlines the minimum required coating thickness for the different atmospheric corrosivity to achieve the required 50 years' service life.

Atmospheric Corrosivity Category	100% Zinc Coating		ZAM Coating	
	Corrosion Rate (µm/yr)	Minimum Coating Thickness (g/m ²)	Corrosion Rate (µm/yr)	Minimum Coating Thickness (g/m ²)
A	<0.1	35.7	<0.02	6
B	0.1 – 0.7	250	0.02 – 0.12	42
C	0.7 – 2.1	750	0.12 – 0.35	125
D	2.1 – 4.2	1500	0.35 – 0.70	250
E	4.2 – 8.4	3000	0.70 – 1.4	500 – N/A

It is noted that the ZAM product has a maximum coating thickness less than the minimum coating thickness required for corrosivity Zone D. The ZAM products with a coating thickness of 225g/m² are deemed acceptable for corrosivity Zone D as the minimum coating thickness is based on the upper bound corrosion rate of 0.7µm/yr which is statistically onerous. Furthermore, the upper bound limit is likely not going to be realised in the real world due to the micro environment of the Terracade rails behind the Terracade facade.

In carrying out the above assessment we exercised the degree of skill, care and diligence normally exercised by Consulting Engineers.

This letter does not relieve other parties of their responsibilities for the works.

Yours faithfully,

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