

Review of Magnelis® coating performance as corrosion protection – ZM310

Report to:	ArcelorMittal Flat Carbon Europe
Document:	RT1999
Version:	03
Date:	December 2024

SCI (the Steel Construction Institute) has been a trusted, independent source of information and engineering expertise globally for over 30 years, and is one of the leading, independent providers of technical expertise and disseminator of best practice to the steel construction sector.

We support everyone involved in steel construction; from manufacturers, consulting and design engineers, architects, product developers to industry groups.

Version	Issue	Date	Purpose	Author	Reviewer	Approved
01	01	Sep-24	Draft for review	AW	GHC	GHC
02	01	Oct-24	Issue to client	AW	GHC	GHC
03	01	Dec-24	Issue to client - Final	AW	GHC	GHC

Although all care has been taken to ensure that all the information contained herein is accurate, The Steel Construction Institute assumes no responsibility for any errors or misinterpretations or any loss or damage arising therefrom.

EXECUTIVE SUMMARY

This report has been prepared by the SCI at the request of ArcelorMittal Flat Carbon Europe. The purpose of this report is to review the performance of Magnelis® ZM310 as an alternative to Z600.

The most commonly used corrosion protection on strip steel in the UK and Ireland is Z275 zinc galvanising. However, for some locations which are potentially more susceptible to corrosion many warranty providers require Z600 coating e.g. near and below ground level.

The performance of Magnelis® ZM120 as an alternative to Z275 was reviewed by SCI in 2021 and is reported in SCI RT1892.

The Magnelis® coating is a ZM (zinc magnesium) coating in accordance with EN 10346.

This report describes an independent review of the performance of the Magnelis® ZM310 coating for corrosion protection which has been carried out by SCI.

The scope of this report and performance review is limited to the corrosion protection performance of Magnelis®, as defined in documentation supplied to SCI by ArcelorMittal, SCI did not undertake or commission any independent research. Other characteristics such as cost, environmental credentials, aesthetics and fabrication are not included.

Following the performance review and assessment of the research information provided by ArcelorMittal, in the opinion of SCI, the conclusions and recommendations are;

a) In UK environments for typical light steel framing applications and similar warm-frame applications Magnelis® ZM310 can be expected to provide corrosion protection which is not less than the corrosion protection provided by Z600.

b) Conclusion a) applies to surface protection and to protection of cut edges.

Contents

		Page No
EXECUTIVE SUMMARY		iii
1	BACKGROUND	1
2	SCOPE	3
3	INFORMATION PROVIDED	4
4	MAGNELIS® COATING	5
	4.1 Introduction	5
	4.2 Availability	5
	4.3 Storage	6
	4.4 Forming	6
	4.5 Weldability	6
5	REVIEW OF PERFORMANCE DATA	7
	5.1 Accelerated tests	7
	5.2 White rust	9
	5.3 Role of magnesium	9
	5.4 Natural exposure tests	10
6	ADDITIONAL DATA	15
	6.1 National Standards	15
7	CONCLUSIONS	16
8	REFERENCES	17

1 BACKGROUND

This report has been prepared by the SCI at the request of ArcelorMittal Flat Carbon Europe. The purpose of this report is to review the performance of Magnelis® ZM310 as an alternative to Z600.

The most commonly used corrosion protection on strip steel in the UK and Ireland is Z275 zinc galvanising. However, some for some locations which are potentially more susceptible to corrosion many warranty providers require Z600 coating.

The performance of Magnelis® ZM120 as an alternative to Z275 was reviewed by SCI in 2021 and is reported in SCI RT1892[1].

The Magnelis® coating is a ZM (zinc magnesium) coating in accordance with EN 10346[2].

Information on the performance of the Magnelis® coating is available from ArcelorMittal, however, for additional verification and more general acceptance within the UK and Irish markets ArcelorMittal understand the benefits of an independent review of the performance of the Magnelis® coating for corrosion protection.

SCI has a history of carrying out reviews of this type and assessments of the corrosion protection of cold formed steel. SCI publication P262 "*Durability of Light Steel Framing in Residential Building*" (First Edition 2000, Second Edition 2009[3]) focused on the performance of Z275 coating as that was the standard coating in use at the time. Since then SCI has carried out a review of AZ150 (Aluminium Zinc) which resulted in its addition as a suitable coating to NHBC Standards Chapter 6.10 for light steel frame buildings[4].

NHBC is the largest new-build residential building warranty provider operating in the UK. The metallic corrosion protection coatings that are currently recognised as suitable in NHBC Standards Chapter 6.10 are Z275 and AZ150 for standard situations. It states that "*All steel should be pre-galvanised in accordance with BS EN 10346 (minimum 275 g/m^2 zinc coating (Z) or 150 g/m^2 aluminiumzinc alloy coating (AZ))*". For some situations, where a more aggressive environment could be expected, higher levels of corrosion protection may be required such as Z450 or Z600, alternative non-metallic corrosion protection may also be used in these situations. The requirements given in NHBC Chapter 6.10 which reference the use of Z600 are presented in Figure 1.1.

Note: NHBC do not reference proprietary products within their standards.

2024 I Light steel framed walls and floors
Chapter 6.10

6.10.16 Moisture control

The structure shall be adequately protected from the effects of moisture. Details for LSF at low level shall fully consider the durability of materials, protection of the building from moisture ingress and thermal bridging. Issues to be taken into account include:

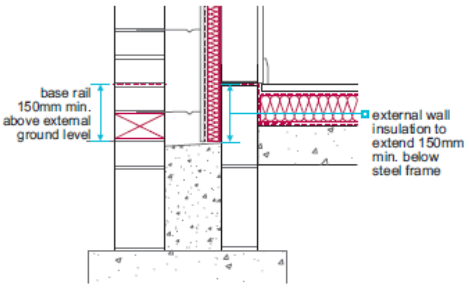
a) cavities in external walls
b) protection of steel at low level
c) DPCs, DPMs and cavity trays.

Protection of steel at low level

The base rail of LSF should be kept a minimum of 150mm above the external ground level (or waterproofing layer of a flat roof, balcony or terrace) and cavity fill. In such cases, the LSF may be protected against corrosion in accordance with Cl. 6.10.7

Locally raised ground levels (up to the internal floor finish) to less than 15% of the external perimeter (of an individual building, eg row of terraced homes, apartment blocks and detached garages, measured on plan) to accommodate level thresholds can be accepted. The cavity should be kept clear and allow drainage. Wall insulation should overlap the base rail by a minimum of 150mm.

Figure 13: Ground level interface



Alternatively, where the base rail or lowest steel is less than 150mm above ground level (or waterproofing layer of a flat roof, balcony or terrace), the design should consider the following:

- factory-applied protection to the steel frame to achieve a design life of 60 years. This may be LSF:
  – Galvanised to 600g/m², or
  – Galvanised to 275g/m² with the addition of two coats of heavy duty bituminous paint, 200µm total thickness
- sheathing, or backing boards to waterproofing, used below 150mm, should be service class 3 in accordance with BS EN 13986
- drainage of the cavity (ground conditions should be considered where the cavity discharges below ground level)
- insulation to limit thermal bridging and interstitial condensation. NHBC may ask for thermal modelling of the junction to demonstrate that these issues have been sufficiently limited.

Figure 1.1 Extract from NHBC Chapter 6.10 with reference to Z600

2 SCOPE

The scope of the SCI's independent review of the performance of the Magnelis® ZM310 coating for corrosion protection involved three main activities:

1. Collation of information and liaison with appropriate parties
2. Review and analysis of performance data
3. Production of (this) SCI report

The first part of the work was for SCI to liaise with ArcelorMittal for collection of their performance data on Magnelis® ZM310. Prior to commencement of the review SCI agreed with ArcelorMittal that they were willing to provide the necessary information. This was necessary to ensure that the required information was available, including background data in addition to the information which is in the public domain through the ArcelorMittal website. See Section 3 for the list of information provided by ArcelorMittal.

For the purposes of SCI's previous report RT1892, SCI liaised with other relevant parties including warranty bodies (e.g. NHBC, LABC Warranty and Premier Guarantee) to find out their position on alternative coatings and any particular concerns they may have. The findings of the SCI review may not directly determine the policy of these organisations regarding the Magnelis® coating however it is expected, and demonstrated from experience, that they will take into account the conclusions and recommendations put forward by SCI, see Section 7.

Following the gathering of the necessary information (mainly from ArcelorMittal) SCI carried out a review and analysis of the data. This involved studying the claimed performance of the Magnelis® coating and ensuring that this could be substantiated with the background data. One of the main aspects was to determine if Magnelis® ZM310 coating could be considered to give an equivalent design life duration to Z600 in the typical environmental conditions to which it is expected to be used. This included ascertaining if the equivalent thickness is constant for different environmental conditions, or if there are specific situations in which different 'equivalency' rules should be applied.

The primary application under consideration is the use of Magnelis® ZM310 on cold formed sections used in light steel framing. Cold formed sections used in light steel framing are typically in a warm-frame environment and with a Z275 coating the predicted design life is 250 years [Ref.3] However, even in this application there are different exposure conditions which need to be considered e.g. near and below ground level, ground floors and roof structures.

The final part of the process was to document the performance review carried out by SCI in this SCI report, which includes conclusions and recommendations.

It is important to note that this report specifically covers the ArcelorMittal Magnelis® coating and is not applicable to generic ZM or ZAM coatings.

The scope of this report and performance review is limited to the corrosion protection performance of Magnelis® ZM310, other characteristics such as cost, environmental credentials, aesthetics and fabrication are not included.

3 INFORMATION PROVIDED

The following documentation has been provided to SCI by ArcelorMittal and has been used during the SCI review process.

1) Magnelis ZM310 VS Z600 - Presentation to SCI [5]
   Slides summarising relevant research data
2) CMO Service Report 65116 01 [6]
   ArcelorMittal report on corrosion test comparing HDG and Magnelis
3) CMO Service Report 65048 01 [7]
   ArcelorMittal report on corrosion tests on different metallic coatings for samples with press nuts installed
4) Long-term atmospheric corrosion rates of hot dip galvanised steel and zinc aluminium magnesium coated steel [8]
   Technical paper of worldwide exposure tests
5) 2021 CMO - Research Report 125612 Brest Outdoor exposure [9]
   ArcelorMittal presentation slides of Magnelis® versus HDG in outdoor exposure - Outdoor exposure Brest - 5 years evaluation, including cut edges

4 MAGNELIS® COATING

4.1 Introduction

Magnelis® coating is produced on a classic hot dip galvanising line, but the molten bath has a unique chemical composition including 93.5% zinc, 3.5% aluminium, and 3% magnesium.

Magnelis® has a naturally dark grey appearance. It is available with an environmentally friendly chemical passivation coating (E-Passivation® CrVI-free) or it can be supplied with an oiled coating on request. The layers of Magnelis® coated steel are shown in Figure 4.1.

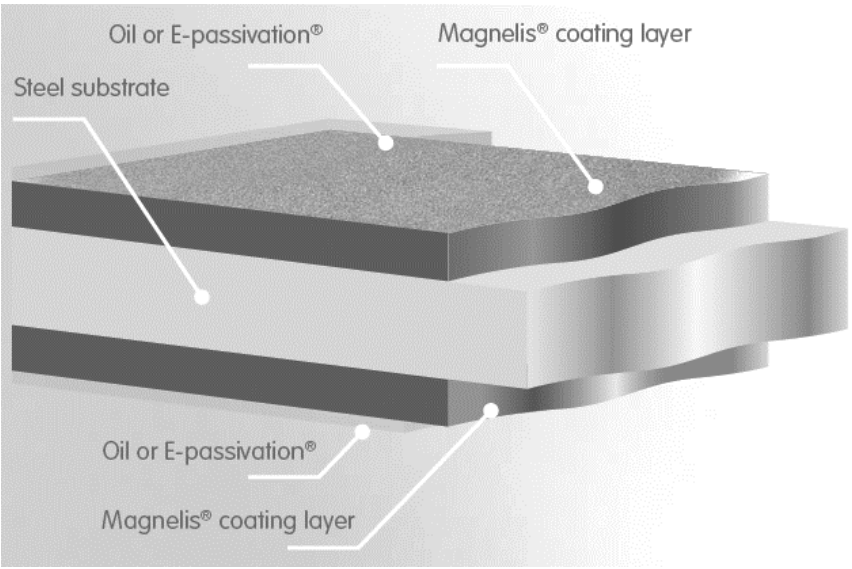


Figure 4.1 Magnelis® coating layers

4.2 Availability

Magnelis® can be applied to a very wide range of steel grades. These include steels for cold forming and deep drawing applications, as well as structural and high strength, low alloy steels.

Steel thickness can range from 0.45 to 6.0 mm, while the coating can be from 5 to 65 µm/per side (ZM800). For example; S450GD+ZM120 (Magnelis®), according to EN 10346. The availability of Magnelis® coatings and corresponding coating mass and thickness are shown in Figure 4.2.

Coating designation		ZM70	ZM90	ZM120	ZM175	ZM200	ZM250	ZM310	ZM430	ZM620	ZM800
Coating mass (total both sides)	g/m²	70	90	120	175	200	250	310	430	620	800
	oz/ft²	0.23	0.30	0.40	0.60	0.65	0.80	1.00	1.40	2.00	2.60
Coating thickness	µm	5	7	10	14	16	20	25	35	50	65

Figure 4.2 Magnelis® coating availability

The density of the Magnelis® coating is 6.2 g/cm^3, due to its chemical composition.

For comparison the equivalent data for zinc galvanising is provided in Table 4.1.

Table 4.1 Zinc coating weights and thicknesses

Coating Designation	Z100	Z140	Z200	Z225	Z275	Z350	Z450	Z600
Coating mass (total both sides) (g/m²)	100	140	200	225	275	350	450	600
Coating thickness (µm per side)	7	10	14	16	20	25	32	42

The density of the zinc galvanising is 7.1 g/cm^3.

4.3 Storage

Magnelis® is supplied passivated and/or oiled to temporarily limit any risk of white rust formation. During transportation and storage, all necessary precautions must be taken to avoid prolonged exposure to moisture.

4.4 Forming

The forming techniques currently used for galvanised steel are also suitable for steel coated in Magnelis®. The coating thickness must be compatible with both the desired degree of corrosion protection and the requirements of the forming processes. A minimum bending radius of twice the steel sheet thickness is recommended by ArcelorMittal.

4.5 Weldability

ArcelorMittal information states that Magnelis® can be arc welded, laser welded, brazed or high frequency induction welded, taking the same precautions as with galvanised steel. The coating thickness must be compatible with both the desired degree of corrosion protection and the requirements of the welding processes. For use in outdoor applications a reprotection of the weld seams from arc welding and high frequency induction welding is recommended.

5 REVIEW OF PERFORMANCE DATA

The SCI review of the Magnelis® ZM310 corrosion protection performance is based on the information provided by ArcelorMittal as listed in Section 3. The information contains various different types of testing and research which has been carried out by ArcelorMittal and is discussed below.

5.1 Accelerated tests

ArcelorMittal have carried out several accelerated corrosion tests where samples were subjected to different types of environmental conditions on fixed cycles in a laboratory.

5.1.1 Cyclic corrosion tests

Cyclic tests were performed on samples of steel coated with Magnelis® ZM310, and samples with Z600 for comparison [Refs. 5, 6]. The tests were carried out by Arcelor Global Research and Development in Gent, Belgium. The samples were subjected to an accelerated corrosion cycle consisting of three stages:

a) 1 day of salt spray in accordance with ASTM B117[10] or ISO 9227[11]

b) 4 days of humidity in accordance with DIN EN 6270-2 E[12]

c) 2 days at room temperature.

The samples were placed horizontally in the corrosion chamber and the edges were protected with tape. Before the tests the coating thicknesses were measured and are given in Table 5.1. The surface passivation of each sample was examined before the test. The Z600 sample had passivation containing chromium, manganese and phosphor, while the passivation on the Magnelis® ZM310 sample contained chromium and phosphorus.

Table 5.1 Sample properties

Nominal coating designation (g/m^2)	Nominal coating thickness	Measured coating thickness
ZM310	25 µm	22 µm
Z600	42 µm	45 µm

After each cycle, the samples were observed and photographs were taken. A qualitative ranking scale of 0 to 5 was used to define the condition of the samples. However, the coating thickness was not measured. The test was stopped after 11 weeks.

The Z600 sample quickly showed the initiation of white rust which propagated quickly and covered the whole surface after 4 weeks. However, no red rust from the substrate was seen at 11 weeks.

The Magnelis® ZM310 sample also showed some white layer from the first week, but the presence of white rust increased very slowly. After 11 weeks, only part of the sample was covered with white rust.

5.1.2 Salt spray tests

Salt spray tests were performed on samples cut from the same sheets as used for the samples described in Section 5.1.1, steel coated with ZM310 and steel coated with Z600 [Ref. 6]. The samples were subjected to an accelerated corrosion cycle consisting of a continuous salt spray of 5% NaCl-solution in demineralized water at 35°C. Testing was in accordance with ASTM B117 and ISO 9227.

The samples were placed horizontally in the corrosion chamber and the edges were protected with tape.

After each cycle, the samples were observed and photographs were taken. A qualitative ranking scale of 0 to 5 was used to define the condition of the samples. However, the coating thickness was not measured. The test was stopped after 14.5 weeks.

After 2 weeks, the appearance of white rust was quite similar for both the Z600 sample and the Magnelis® ZM310 sample.

After 3.5 weeks, the white rust on the Z600 sample evolved at a faster rate than previously and covered the complete surface of the sample after about 10 weeks.

White rust development on the Magnelis® ZM310 sample was less rapid than on the Z600 sample. White rust development on the Magnelis® ZM310 sample had only reached a rating of 3 out of 5 by the end of the test (14.5 weeks), whereas the Z600 sample reached a rating of 3 after 7 weeks.

No red rust was observed on the samples.

5.1.3 Samples with press nut attachments

Steel plate samples with press nut attachments installed were subjected to salt spray testing as described in Section 5.1.2 [Refs. 5, 7]. The tests were carried out by Arcelor Global Research and Development in Gent, Belgium. In this case the samples were placed in the corrosion chamber at an inclined angle rather than horizontally. As before the samples were Magnelis® ZM310, and Z600 for comparison. The samples used were both e-passivated, but the types of passivation layers were slightly different for Magnelis® ZM310 and Z600.

After 1 week, there was some white rust forming on the surface of the Z600 sample and almost no white rust on the surface of the Magnelis® ZM310. There was white rust on both samples around the junction of the press nuts and the steel plate.

After 2.8 weeks, there was considerable white rust forming on the surface of the Z600 sample and some white rust on the surface of the Magnelis® ZM310. The white rust on both samples around the junction of the press nuts and the steel plate had also become more significant.

After 7.5 weeks, there was some spots of red rust forming on the surface of the Z600 sample and some white rust on the surface of the Magnelis® ZM310.

5.2 White rust

White rust is a corrosion product of zinc formed from hydrated zinc carbonate / zinc hydroxide under specific conditions of exposure.

As described in SCI-P262 [Ref. 3], although the white rust may be found over a large area, it does not necessarily mean that the steel has suffered corrosion. In normal exposure conditions white rust does not usually indicate a serious degradation of the zinc coating or that the product life has reduced. It is acceptable to ignore thin films of white rust present in normal environments unless the steel surface needs to be painted.

Removal of white rust will accelerate the loss of zinc. However, white rust should not be ignored in severe environments, where other corrosion is evident or where there are heavy deposits of white rust, which indicates the continual presence of moisture.

To inhibit the formation of white rust during material transport or storage, a passivation film, or oil film, can be applied to the galvanized steel during manufacture. The passivation slightly reduces the rates of surface corrosion. The performance of the passivation can be variable and the effect of the passivation on the corrosion rate will depend on the type of passivation. Results from passivated and non-passivated coupons are included in SCI-P262 for comparison.

5.3 Role of magnesium

The Magnelis® coating contains 3% magnesium. The significant proportion of magnesium in the Magnelis® coating means that it is particularly effective at providing corrosion resistance in salt / marine / coastal environments. However, the vast majority of locations where Z600 or Magnelis® ZM310 are likely to be used will not be these types of environments. Therefore, drawing direct comparisons from accelerated tests which include salt spray as part of the corrosion cycle can be misleading. The following warning is included in the introduction of ISO 9227.

"*There is seldom a direct relation between resistance to the action of salt spray and resistance to corrosion in other media, because several factors influencing the progress of corrosion, such as the formation of protective films, vary greatly with the conditions encountered. Therefore, the test results should not be regarded as a direct guide to the corrosion resistance of the tested metallic materials in all environments where these materials might be used. Also, the performance of different materials during the test should not be taken as a direct guide to the corrosion resistance of these materials in service.*"

Therefore, it is more appropriate to draw conclusions from the performance of samples placed in natural exposure conditions over a longer period of time, such as those carried out by ArcelorMittal and described in Section 5.4.

5.4 Natural exposure tests

5.4.1 Coating corrosion rates

ArcelorMittal and other steel manufacturers have conducted research into the long term atmospheric corrosion rates of hot dip galvanised steel and zinc-aluminium-magnesium coated steel [Refs. 5, 8]. Metallic coated steel samples have been exposed for 6 years at twelve different weathering sites worldwide. The mass losses of the coatings have been measured after 1, 2, 4, and 6 years of exposure.

Details of the exposure sites are given in Figure 5.1. Many of the sites are less than 500 m to the sea and are therefore considered coastal environments. As explained in Section 5.3, it is accepted that magnesium is beneficial for corrosion protection in coastal environments. Therefore, this SCI report will focus on the results of the other exposure sites (highlighted with red in Figure 5.1) as non-coastal environments are more typical for the expected use of Magnelis® in the UK. It is accepted that some of the non-coastal sites are in more tropical and warmer environments than the UK so the performance from these sites is not necessarily directly applicable to the UK environment.

				Corrosivity Class ISO 9223	
Exposure site	**Distance to the sea (m)**	**Long.**	**Lat.**	**C-steel**	**Zinc**
Brest (France)	<5	4°33′W	48°21′N	C5	C3
Bohus-Malmön Kattesand (Sweden)	300	11°20′ E	58°20′N	C3	C3
Bohus-Malmön Kvarnvik (Sweden)	<5	11°20′ E	58°20′N	CX (C5)	C5 (C3)
Ijmuiden (The Netherlands)	2,600	52°30′E	4°37′N	C3	C3
Cadiz (Spain)	750	6°12′W	36°32′”N	C2	C3
Jiangjin (China)	~ 900 km	106°15′E	29°19′N	C3	C3
Dubai (Emirates)	2,000	55°02′ E	24°58′ N	C2	C4
Daytona Beach (USA)	100	80°55′W	29° 5′N	CX	C4
Qingdao (China)	10	120°44′E	36°05′N	C2	C3
Wanning (China)	100	110°30′	18°58′N	CX	C4
Bangkok (Thailand)	35 km	100°34′E	13°50′N	C2	C2
Singapore	10	103°51′E	1°12′N	C3	C3

Note: Corrosivity according to ISO 9223. The data were obtained the first year of exposure. Values between brackets represent the second year of exposure and are only shown if different from the first year.

Figure 5.1 Locations and characteristics of exposure sites (from Ref. 8)

For all sites, the samples have been exposed in an external environment at an inclination of 45° to the horizontal and facing either south or towards the corroding source (sea) for coastal locations.

Samples were withdrawn for analysis after 1, 2, 4, and 6 years of exposure. The coating mass loss was calculated for the samples in g/m^2. There were 3 types of samples:

1) Z275 without passivation (Density = 7.14 g/cm^3)
2) Z600 with passivation layer (Density = 7.14 g/cm^3)
3) Magnelis® ZM250 without passivation (Density = 6.19 g/cm^3).

In this series of tests the coating mass loss is being calculated so the nominal coating thickness at the start of the tests is less significant because previous tests by ArcelorMittal [Ref. 5] have demonstrated that the coating corrosion rate is not significantly affected by the coating thickness. However, the passivation layer can be significant, particularly in the first months of exposure. Therefore, comparisons of sample 1) Z275 without passivation and sample 3) Magnelis® ZM250 without passivation are the most appropriate.

The results of coating mass loss recorded across all sites show:

a) There is much less variation of the amount of coating loss with the Magnelis® coating compared to the variation recorded with the two zinc coatings. This indicates that there is less sensitivity to environmental factors of Magnelis® compared with zinc.

b) The mass loss of the Magnelis® coating is always lower than that of Z275 coating or that of the passivated Z600 coating.

c) The largest improvements in corrosion protection of using Magnelis® compared to the Z275 coating occurred at the coastal exposure sites (as expected).

Reference 8 compares the performance of Z275 with Magnelis® ZM250 by presenting the ratio of thickness loss for the different sites and exposure periods. Considering only the non-coastal sites the ratios of the corrosion values of Z275 compared with Magnelis® ZM250 are shown in Table 5.2. The ratios given in Table 5.2 are ratios of thickness losses in µm which are taken from Reference 8, and have been calculated from the mass losses and the coating densities. These ratios can be used to determine the ratio of Z to ZM coating thickness required to give the same expected life of the coating. From the data available it is not possible to state the absolute thickness of coating required before the onset of corrosion of the core steel. Therefore, the performance is expressed in terms of the expected life of the coating. Design life values given in SCI publication P262 are based on the duration when 50% of the original coating thickness can be expected to have been lost. It has been assumed that the percentage thickness remaining that defines the design life is independent of the coating type.

Table 5.2 Ratio of thickness losses of Z275 compared with Magnelis® ZM250

Exposure site (non-coastal)	Exposure time in years				Mean	Minimum
	1	2	4	6		
Ijmuiden (Netherlands)	2.4	2.6	2.4	2.7	**2.5**	**2.4**
Dubai (Emirates)	4.9	2.4	2.5	1.4	**2.8**	**1.4**
Cadiz (Spain)	1.7	1.6	1.3	1.5	**1.5**	**1.3**
Bangkok (Thailand)	1.7	5.8	3.3	3.3	**3.5**	**1.7**
Jiangjin (China)	1.6	1.7	2.0	2.1	**1.9**	**1.6**
Mean	**2.5**	**2.8**	**2.3**	**2.2**	**2.4**	**2.2**
Minimum	**1.6**	**1.6**	**1.3**	**1.4**	**1.5**	**1.3**

NOTE: The coating consumption does not depend on the initial coating weight for both Z and ZM coatings.

Reference 8 suggests that values at the Dubai site may have been influenced by additional coating loss caused by sand abrasion.

Considering only the non-coastal sites the results show:

a) The absolute amount of coating loss is lower for Magnelis® compared to zinc.

b) The mean ratio of the thickness losses of Z275 compared with Magnelis® ZM250 after 6 years is 2.2. This is also the minimum mean value recorded across all of the exposure periods.

c) The minimum ratio of the thickness losses of Z275 compared with Magnelis® ZM250 after 6 years is 1.4. However, the minimum ratio of 1.3 occurred at the 4 year exposure period.

d) The closest exposure site physically and in terms of environmental conditions to the UK is the Ijmuiden site in The Netherlands. For this site the minimum thickness loss ratio was 2.4.

e) It can be seen from Figure 5.2 that the minimum thickness loss ratio for all non-coastal exposure sites is fairly consistent over all the exposure periods with an average value of 1.5. Whereas the general trend of the mean thickness loss ratio is that it reduces slightly as the exposure period increases.

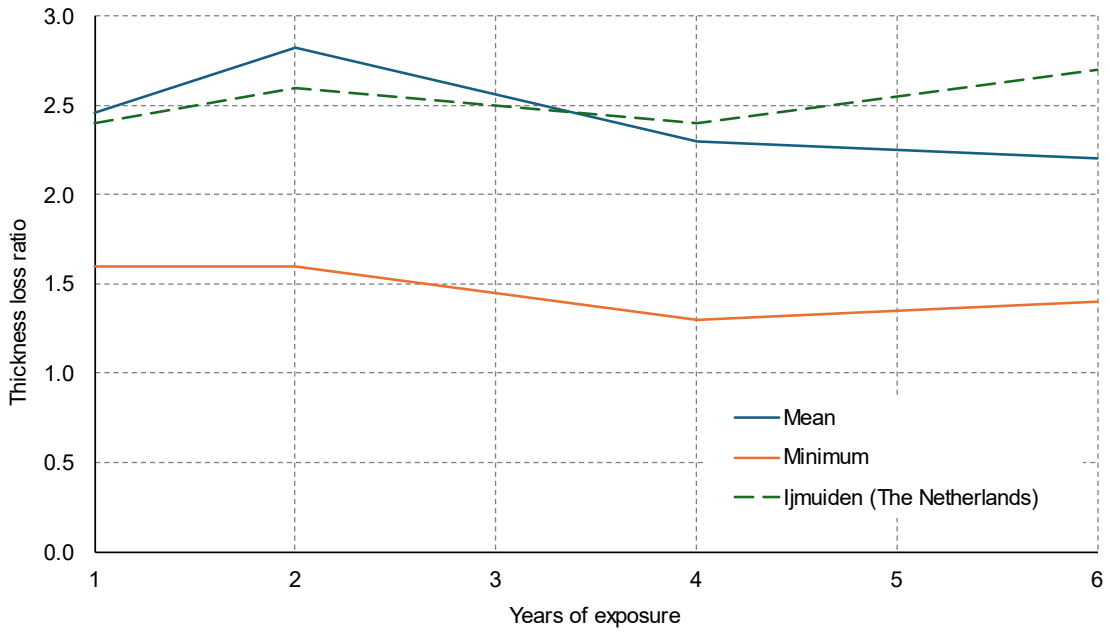


Figure 5.2 Variation of thickness loss ratios with exposure period for non-coastal exposure sites

Table 5.3 presents the equivalent Magnelis® coating to Z600 based on different thickness loss ratios. For Magnelis® ZM310 to be at least equivalent to Z600 the thickness loss ratio would need to be no less than 1.7. Based on data presented in Table 5.2 and Figure 5.2 a thickness loss ratio of 1.5 is more appropriate for all the non-coastal exposure sites. However, as the data from the Ijmuiden site in The Netherlands is most applicable to the UK a thickness loss ratio of 1.7 could be accepted for applications in the UK.

Table 5.3 Equivalent coatings of Z600 and Magnelis® based on different thickness loss ratios

Hot dipped galvanising	Zinc thickness per side	Thickness loss ratio	Equivalent Magnelis® thickness	Equivalent Magnelis® weight	Basis for the thickness loss ratio
Z600	42 µm	1.3	32 µm	401 g/m^2	The minimum value of minimum values from Table 5.2
Z600	42 µm	1.5	28 µm	347 g/m^2	The mean minimum value from Table 5.2
Z600	42 µm	1.7	25 µm	306 g/m^2	Presented to achieve equivalence of ZM310

Figure 5.3 shows the variation of coating mass and coating thickness based on a thickness loss ratio of 1.7 for Z600 to Magnelis® ZM310. It can be seen that both coatings have the same life duration.

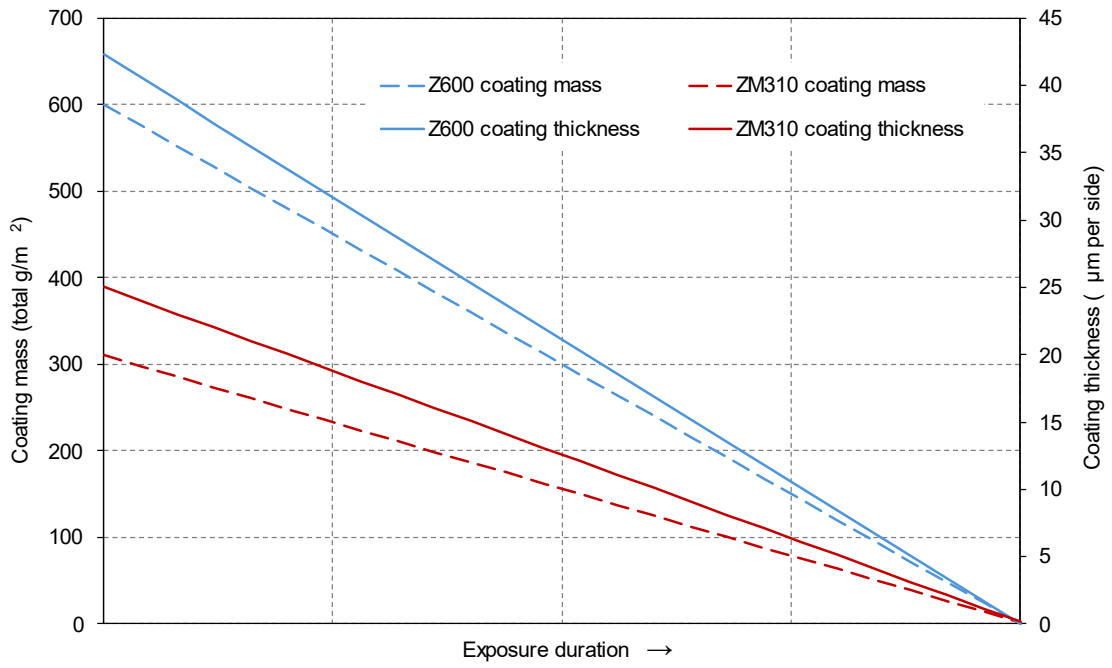


Figure 5.3 Variation of coating mass and thickness based on a thickness loss ratio of 1.7 for Z600 to Magnelis® ZM310

5.4.2 Cut edge protection

The protection provided to the cut edges of hot-dipped galvanised thin gauge steel is well established [Ref. 3]. Protection at cut edges is provided through galvanic or sacrificial protection of the zinc coating on the faces of the steel and in typical exposure conditions it is not necessary to provide additional corrosion protection at cut edges.

ArcelorMittal have carried out a series of outdoor exposure tests to demonstrate the 'self-healing' behaviour of Magnelis® at cut edges [Refs. 5, 9].

The process that occurs at cut edges for Magnelis® is:

1) Initial exposure period (up to several weeks*) - The exposed cut edge of the substrate is oxidised and forms red rust.
2) Subjected to rain / condensation / moisture (beyond several weeks*) - The Magnelis® coating layer migrates over the cut end.
3) Long exposure period (after more than a year*) - Disappearing of red rust and increasing of white rust on cut edge.

Note: * The speed of the self-healing will depend on the environmental conditions.

During stages 1) and 2) there can appear to be significant red rust on the cut edges, over time this will reduce and the appearance of the cut edge will improve.

Exposure tests were carried out on samples with exposed cut edges. The exposure site was in Brest in France which is a marine coastal environment. As discussed in 5.3, the coastal environment is advantageous for Magnelis® in comparison to zinc coated samples. The tests demonstrated that the cut edges of samples with the Magnelis® ZM310 coating performed well over a 5 year exposure period on 2 mm and 4 mm thick samples. However, it is recognised that for thicker steel, the weight of coating per unit area of exposed edge will be lower when a thinner coating is used therefore care must be taken when extrapolating this conclusion.

6 ADDITIONAL DATA

6.1 National Standards

An important source of additional data is the guidance given in national standards.

The draft revision to EN 1090-4, the execution standard for cold-formed steel, prEN 1090-4: 2023[13] includes useful information on the expected duration of protection provided by continuous hot-dip coatings (without an organic coating). The information in the draft document has been taken directly from the current German standard DIN 55634-1: 2018[14].

It can be seen from Table 6.1 that the expected duration of protection provided by Z600 and ZM310 given in prEN 1090-4: 2023 and DIN 55634-1 are the same. Coatings Z275 and ZM120 have been included in Table 6.1 for comparison.

Table 6.1 Examples of the expected protection time of continuous hot-dip coatings (without organic coating) from prEN 1090-4: 2023 and DIN 55634-1

Coating	Expected duration of protection (see EN ISO 12944-1)														
	C2			C3			C4			C5-I			C5-M		
	L	M	H	L	M	H	L	M	H	L	M	H	L	M	H
Z275	X	X		X											
ZM120	X	X		X											
Z600	X	X	X	X	X	X	X	X		X			X		
ZM310	X	X	X	X	X	X	X	X		X			X		

Notes:
Corrosion categories C2 to C5 are defined in EN ISO 12944-2.
Durability ranges low (L), medium (M), high (H) are defined in EN ISO 12944-1.

7 CONCLUSIONS

In the opinion of SCI, based on the information reviewed;

a) In UK environments for typical light steel framing applications and similar warm-frame applications Magnelis® ZM310 can be expected to provide corrosion protection which is not less than the corrosion protection provided by Z600.

b) Conclusion a) applies to surface protection and to protection of cut edges.

8 REFERENCES

1 SCI RT1892
Review of Magnelis® coating performance as corrosion protection (ZM120)
SCI, 2021

2 EN 10346:2015
Continuously hot-dipped coated steel flat products for cold forming. Technical delivery conditions.
BSi, 2015

3 SCI P262
Building Design using Cold Formed Steel Sections - Durability of Light Steel Framing in Residential Building - Second Edition
SCI, 2009

4 NHBC Standards
Chapter 6.10 for light steel frame buildings
NHBC, 2024

5 Magnelis ZM310 VS Z600 - Presentation to SCI - Slides summarising relevant research data.
ArcelorMittal, 2024

6 CMO Service Report 65116 01 - ArcelorMittal report on corrosion test comparing HDG and Magnelis.
ArcelorMittal, 2024

7 CMO Service Report 65048 01 - ArcelorMittal report on corrosion tests on different metallic coatings with press nuts.
ArcelorMittal, 2024

8 Long-term atmospheric corrosion rates of hot dip galvanised steel and zinc aluminium magnesium coated steel. Technical article. Materials and Corrosion.
WILEY-VCH Verlag GmbH & Co. KGaA, Weinheim, 2019

9 2021 CMO - Research Report 125612 Brest Outdoor exposure - ArcelorMittal presentation slides of Magnelis® versus HDG in outdoor exposure - Outdoor exposure Brest – 5 years evaluation, including cut edges.
ArcelorMittal, 2024

10 ASTM B117 - Standard Practice for Operating Salt Spray (Fog) Apparatus.
ASTM International, 2019

11 EN ISO 9227:2022+A1:2024 - Corrosion tests in artificial atmospheres. Salt spray tests.
BSi, 2024

12 ISO 6270-2 - Paints and varnishes - Determination of resistance to humidity - Part 2: Condensation (in-cabinet exposure with heated water reservoir).
ISO, 2017

13 prEN1090-4: 2023 - Execution of steel structures and aluminium structures. Part 4: Technical requirements for cold-formed structural steel elements and cold-formed structures for roof, ceiling, floor and wall applications.
CEN, 2023

14 DIN 55634-1: 2018. Paints, varnishes and coatings - Corrosion protection of supporting thin-walled building components made of steel - Part 1: Requirements and test methods.
Deutsches Institut Fur Normung E.V. (German National Standard), 2018

END OF REPORT