Review of Magnelis® coating performance as corrosion protection

Report to:	ArcelorMittal Flat Carbon Europe
Document:	RT1892
Version:	03
Date:	September 2021

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Version	Date	Purpose	Author	Reviewer	Approved
01	Aug-21	Issue to client (draft)	AW	GHC	
02	Aug-21	Issue to client (final)	AW	GHC	
03	Sep-21	Issue to client (final)	AW	GHC	GHC

EXECUTIVE SUMMARY

This report has been prepared by the SCI in response to a request from ArcelorMittal Flat Carbon Europe.

The most commonly used corrosion protection on strip steel in the UK and Ireland is Z275 zinc galvanising. However, some cold-formed steel product providers are considering using strip steel with the Magnelis® coating available from ArcelorMittal. 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® 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®, 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;

- Magnelis® ZM120 provides corrosion protection which is not less than the corrosion protection provided by Z275 coating.
- This conclusion applies to surface protection and to protection of cut edges.
- Magnelis® ZM120 is suitable for the same applications as the Z275 coating which is typically specified in UK and Irish construction.
- The design life predictions for the Z275 coating as stated in SCI publication P262 are also applicable to Magnelis® ZM120.

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1 BACKGROUND

This report has been prepared by the SCI in response to a request from ArcelorMittal Flat Carbon Europe.

The most commonly used corrosion protection on strip steel in the UK and Ireland is Z275 zinc galvanising. However, some cold-formed steel product providers are considering using strip steel with the Magnelis® coating available from ArcelorMittal. The Magnelis® coating is a ZM (zinc magnesium) coating in accordance with EN 10346[1].

Information on the performance of the Magnelis® coating is available from ArcelorMittal, however, for added comfort 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.

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

SCI has a history of carrying out reviews of this sought 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) 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[2].

The metallic corrosion protection coatings that are currently included 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.

2 SCOPE

The scope of the SCI's independent review of the performance of the Magnelis® 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®. 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.

SCI have 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 in this report, see Section 6.

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 what thickness of the Magnelis® coating could be considered to give an equivalent design life duration as a Z275 coating. 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® on cold formed sections used in light steel framing, which is typically a warm-frame environment with a Z275 coating design life of 250 years[3]. However, even in this application there are potentially different exposure conditions which need to be considered e.g. near or below ground level, ground floors, 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.

The 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®, other characteristics such as cost, environmental credentials, aesthetics and fabrication are not included.

3 INFORMATION PROVIDED

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

1) Magnelis® Brochure ‘Think Strategy’, ArcelorMittal, 17/12/2020, 56 pages
2) Magnelis® Technical Evaluation, CSTB, 03/02/2020, 9 pages
3) Magnelis® ZM310 Type Approval, RISE, 08/12/2020, 2 pages
4) Certification of Magnelis® by DIBT brochure, ArcelorMittal, 03/2020, 2 pages
5) Magnelis® Technical Approval, DIBT, 17/09/2019, 8 pages
6) Magnelis® ZM120 vs Z275 Presentation v8, ArcelorMittal, 01/2021, 43 pages
7) E35: Steels with Magnelis® brochure, ArcelorMittal, 2021, 15 pages
8) 10 years exposure of perforated panels (cut edges), ArcelorMittal, 2021, 6 pages
9) White rust and red rust evolution on Magnelis® in salt spray test, ArcelorMittal R&D, 2012, 6 pages
10) Exposure in marine atmosphere, Brest test site: Mass loss after 24 months of exposure, Institut de la Corrosion, 2011, 5 pages
11) Exposure in marine atmosphere, Brest test site: Mass loss after 5 years of exposure, Institut de la Corrosion, 2014, 5 pages
12) Up to 6-year outdoor exposure of metallic coated steel in marine atmosphere of Bohus-Malmön Kvarnvik (Sweden), Institut de la Corrosion, 2019, 7 pages

4 MAGNELIS® COATING

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 aspect. 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.

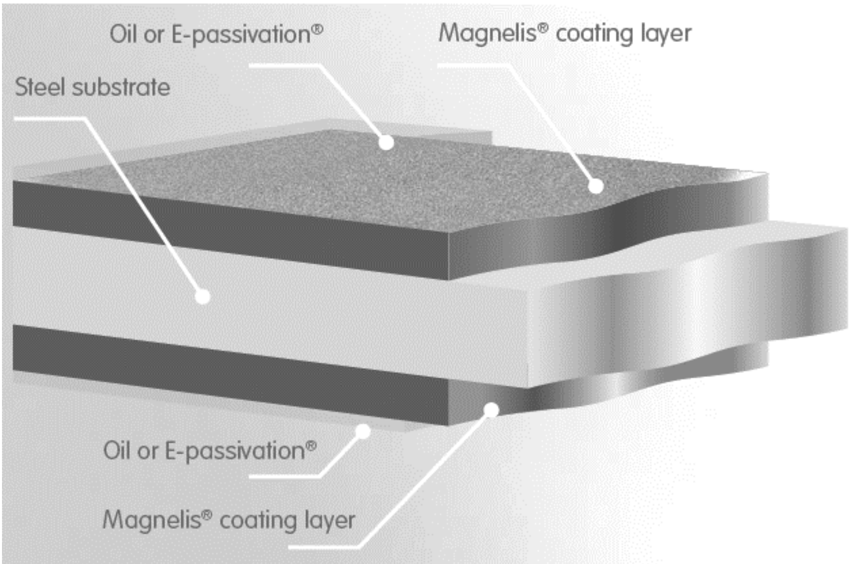

Figure 4.1 Magnelis® coating layers

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 35 µm/per side (ZM430). 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
Coating Mass (total both sides)	g/m²	70	90	120	175	200	250	310	430
Coating Thickness	(µm/per side)	5	7	10	14	16	20	25	35

Figure 4.2 Magnelis® coating availability

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

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 keep the material dry and to prevent the formation of condensation.

Forming

The forming techniques currently used for galvanised steel are also suitable for 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.

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 PERFORMANCE DATA REVIEW

The SCI review of the Magnelis® 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.

The zinc hot-dipped galvanising coating Z275 is the standard coating in the UK and Ireland and the coating on which previous durability research carried out by SCI (see SCI publication P262[3]) is based. Therefore, the performance of Z275 is the benchmark against which Magnelis® will be compared for the purposes of the SCI review.

5.1 Exposure tests

5.1.1 Corrosion at cut edges

The corrosion protection performance of Magnelis® of cut edges has been compared with zinc galvanising through a series of exposure tests of samples over a period of 10 years. The samples used were perforated steel samples of 2 mm thickness with Z275 and ZM250 coatings (20 µm coating on each side). Perforated steel was used to maximise the cut edges on the samples. Three different standard perforation arrangements were included within the tests.

The results showed that the amount of red rust on the Magnelis® samples did not exceed the amount of red rust on the Z275 samples. The Magnelis® samples showed that after some initial growth of the amount of red rust, over time the amount of red rust actually reduces as the self-healing effect of the coating becomes established and is virtually zero after 10 years.

A separate series of tests compared Magnelis® ZM120 with Z275 coated 2 mm steel samples over a period of 5 years. Visual inspection of the samples showed that there were similar levels of edge corrosion on all samples. Therefore, it can be concluded that the performance of Magnelis® ZM120 is at least equivalent to Z275 at cut edges.

It is recognised that a thicker steel substrate will require a higher coating weight to achieve the same level of self-healing at cut edges and that the level of self-healing is dependent on the local conditions. However, the performance of Magnelis® was at least equal to that of Z275 so the same cut edge practices can be applied to Magnelis® as for Z275. In the majority of situations and applications in the UK and Ireland, additional corrosion protection does not need to be applied to cut edges.

5.1.2 Surface corrosion

The corrosion protection performance of Magnelis® on surfaces has been compared with zinc galvanising through a series of exposure tests of samples over periods of up to 6 years.

In these tests the cut edges were protected so the tests were only measuring the performance of the corrosion protection on the surface of the samples. Samples were 150 x 200 mm steel with coatings of Z275 and Magnelis® which were exposed to external environmental conditions.

The results showed that the amount of coating loss over time for the Z275 samples was consistently greater than the amount of Magnelis® coating loss over time. The amount of Z275 coating loss compared to Magnelis® varied by a factor of between 2.5 to 4.0 for different locations and durations of exposure.

Similar exposure tests were conducted to determine if the coating weight of Magnelis® affected the rate of surface protection corrosion. Tests on samples with ZM100, ZM130, ZM140 and ZM 290 were conducted over a period of 2 years with measurements taken at 6 months, 12 months and 24 months. The results showed that all the samples had similar levels of consumed thickness at each time period. Therefore, the rate of corrosion is independent of the initial coating thickness for coatings greater than ZM100.

5.1.3 Coating on deformed elements

The performance of the Magnelis® compared with Z275 coating has been investigated by comparing components which were formed from flat coated plate and left exposed to an external environment. After 1 year of external exposure there was no visible difference between the Z275 coating performance and Magnelis® ZM120 coating. No measured quantitative data was available for performance on deformed elements and visual comparison data for after the initial 1 year of exposure is not available.

5.2 Accelerated tests

In addition to the exposure tests described above, ArcelorMittal have carried out several accelerated corrosion tests where samples were subjected to different types of environmental conditions on fixed cycles in a laboratory.

5.2.1 Salt spray tests

In order to evaluate the corrosion resistance of Magnelis® coatings and comparison with Z275, a neutral salt spray test according to ISO 9227[4] was used. Three types of sample where subjected to the salt spray tests, i) Magnelis® ZM250 + E-passivation, ii) Magnelis® ZM120 + E-passivation, iii) Z275 + Passivation.

Evaluation of performance was based on the analysis of the quantity of red rust and its evolution over time. The Magnelis® ZM120 coating provided significantly more corrosion protection than the Z275 coating by a factor of almost 4 for the time required to reach 50% red rust on the surface. The Magnelis® ZM250 coating provided even greater corrosion protection than Magnelis® ZM120 and Z275, Magnelis® ZM250 only had approximately 10% red rust in the same time as the Magnelis® ZM120 reached 50% red rust.

In a different set of salt spray tests the difference between Z275 and Magnelis® ZM120 was a factor of 10 for the duration required to reach 5% red rust on the surface.

Salt spray tests were also carried out on deformed elements with Magnelis® ZM120 coating and Z275. In the time required for the Z275 coated element to reach 100% red rust on the surface the Magnelis® ZM120 coated element had less than 10% red rust on the surface.

The results demonstrate an improved performance of Magnelis® ZM120 over Z275. Although, the degrees of improvement obtained in these tests of the ZM120 coating over the Z275 coating are not necessarily representative of the improvements that would be expected in non-accelerated exposure.

5.2.2 Cyclic corrosion test - VDA 621-415

The VDA 621-415 cyclic laboratory test, is a three-phase cyclic corrosion test commonly used in the automotive industry. This test method was used by ArcelorMittal to investigate the corrosion resistance of Magnelis® coatings compared to Z275. The test involves a salt spray phase, followed by a wet phase and a dry phase which are repeated in a defined order for specific durations.

The performance of Z275 and Magnelis® ZM120 coated samples was tested. The difference between Z275 and Magnelis® ZM120 was again a factor of approximately 10 for the duration required to reach the initiation of red rest and 5% red rust on the surface.

The results demonstrate an improved performance of Magnelis® ZM120 over Z275. Although, the degrees of improvement obtained in these tests of the ZM120 coating over the Z275 coating are not necessarily representative of the improvements that would be expected in non-accelerated exposure.

5.2.3 Cyclic corrosion test - ECC1

The ECC1-D172028 cyclic laboratory test, is a multi-phase cyclic corrosion test commonly used in the automotive industry. This test method was used by ArcelorMittal to investigate the corrosion resistance of Magnelis® coatings compared to Z275. The test involves a salt spray phase, followed by two dry phases (at different relative humilities), a wet phase and another dry phase. The phases are repeated in a defined order for specific durations.

The performance of Z275 and Magnelis® ZM120 coated samples was tested. The difference between Z275 and Magnelis® ZM120 was significant with the consumed thickness of Z275 coating being 4 times the consumed thickness of Magnelis® for the same number of cycles. The percentage of red rest on the surface was also higher for the Z275 coating than the Magnelis® coating.

The results demonstrate an improved performance of Magnelis® ZM120 over Z275. Although, the degrees of improvement obtained in these tests of the ZM120 coating over the Z275 coating are not necessarily representative of the improvements that would be expected in non-accelerated exposure.

5.2.4 Welded tube salt spray tests

A series of welded tubes were subjected to salt spray tests, primarily to investigate the performance of different treatments applied to the weld zone. Tubes formed from steel coated with Magnelis® ZM120 and Z275 coating were included in the tests. Based on the development of red rust on the surface, the results show that Magnelis® ZM120 provides greater corrosion resistance that Z275 coating in these salt spray tests.

6 CONCLUSIONS AND RECOMMENDATIONS

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

- Magnelis® ZM120 provides corrosion protection which is not less than the corrosion protection provided by Z275 coating.
- This conclusion applies to surface protection and to protection of cut edges.
- Magnelis® ZM120 is suitable for the same applications as the Z275 coating which is typically specified in UK and Irish construction.
- The design life predictions for the Z275 coating as stated in SCI publication P262 are also applicable to Magnelis® ZM120.

7 REFERENCES

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

2 NHBC Standards
Chapter 6.10 for light steel frame buildings
NHBC, 2020

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

4 ISO 9227: 2017
Corrosion tests in artificial atmospheres - Salt spray tests
BSi, 2017