ArcelorMittal

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International Conference on Roadside Safety
San Francisco

New Zinc-Aluminum-Magnesium (ZM) Metallic Coating for Guardrails

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Acknowledgements

ArcelorMittal/CRM Group

- Michael Gremling – coauthor & guardrail design
- Claudia Cofano – guardrail design

ArcelorMittal Europe

- Corinne Dieu – Magnelis® (ZnAlMg) product pilot
- Laurence Dosdat – corrosion expert

Outline

- Magnelis® Product Description & Production
- Hot Dipped Coating Comparison
- Unique Properties
- Corrosion Mechanisms
- Corrosion Performance
- Manufacturing
- Environmentally Friendly
- Performance
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- Specifications
- Guardrail Pilot & Evaluation Sites
- Light Poles
- Conclusions
- Questions

What is Magnelis®

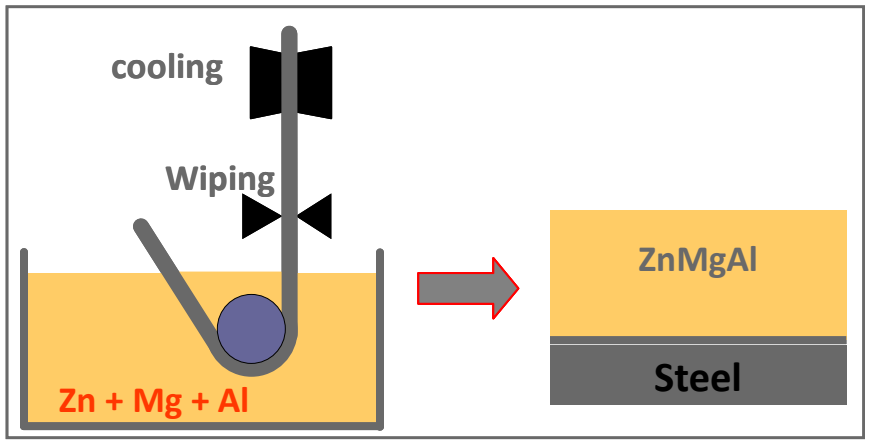
Product Description:

- Hot dip Zinc metallic coating with 3.5% Aluminium, & 3% Magnesium
- With improved corrosion performance (sacrificial & barrier) vs. pure zinc (sacrificial only)
- Coating designation is "**ZM**"

Has a natural dark grey, spangle-free smooth aesthetic surface

How are ZnAlMg Coatings Produced

Continuous Hot Dipped Metallic Coating Process



Key Benefits:

- Continuous automated process
- Online control, uniform coating
- Metallic coating layer of Zn, Al, Mg alloys
- Coating Weight expressed in g/m² (combined both sides)

Hot Dip Metallic Coatings Comparison ZM vs. GI (Galvanize)

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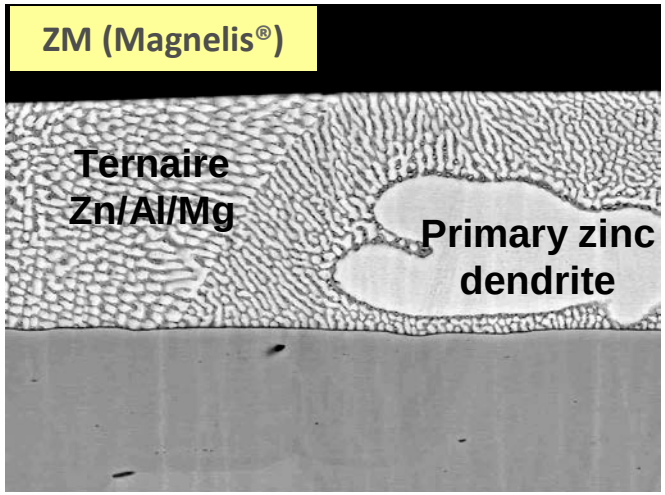
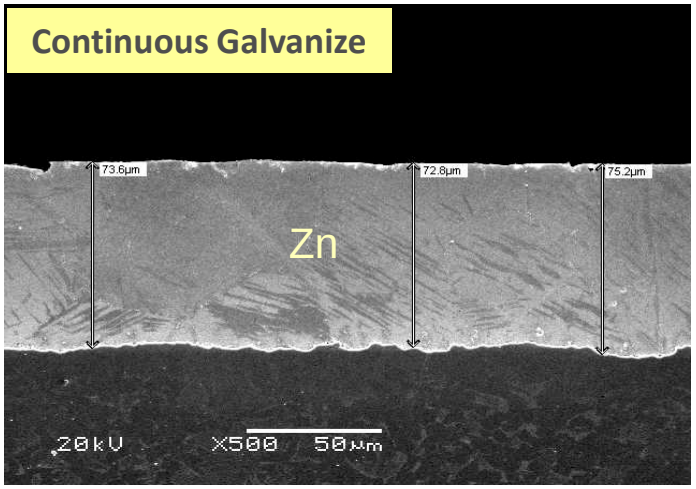
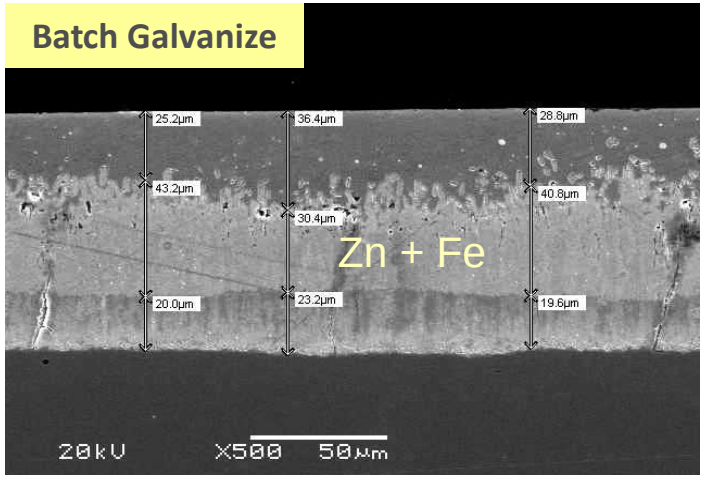
Hot dip metallic coatings morphology (not to scale or equivalent coating thickness)







Why do we Like It

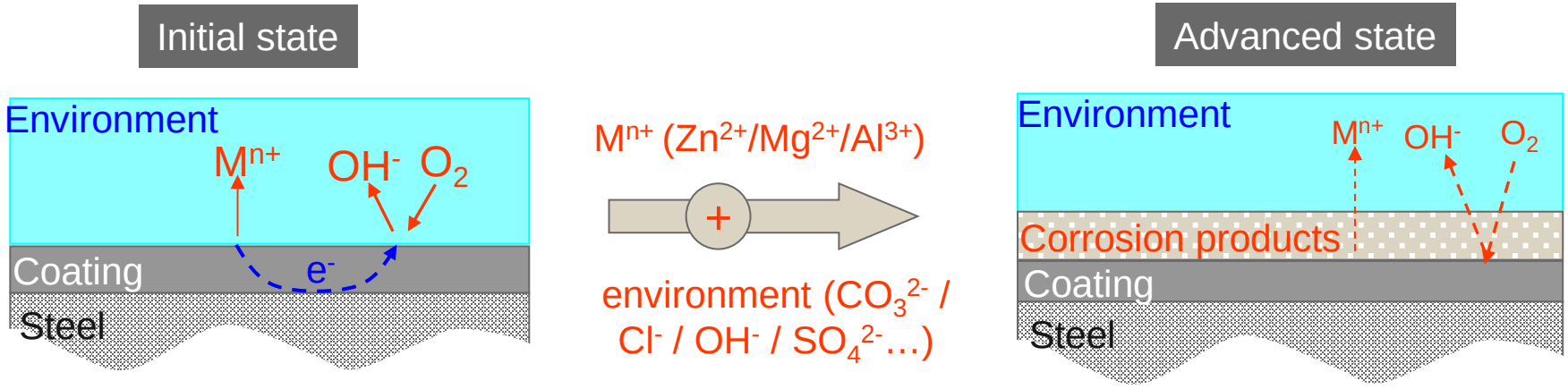
Unique Properties Magnelis® (ZM) vs. Hot Dip Galvanize (GI)

- Superior corrosion protection (sacrificial & barrier) even in aggressive environments (chloride, ammonia, alkaline, soils, wet concrete)
- Less coating mass required (2 to 3 times) while achieving equivalent/better corrosion performance than GI
- Environmentally friendly (less Zinc runoff & usage).
- Improved cut-edge protection/self healing
- Low coefficient of friction & powdering results in excellent roll forming, bending, punching, & less Zinc tool buildup
- Similar weldability to GI
- Alternative to heavy coating post dip/batch Galvanize and other metals

ZM performance better or equivalent to GI

Corrosion Mechanisms

Improved Corrosion Resistance: **Barrier Oxides**



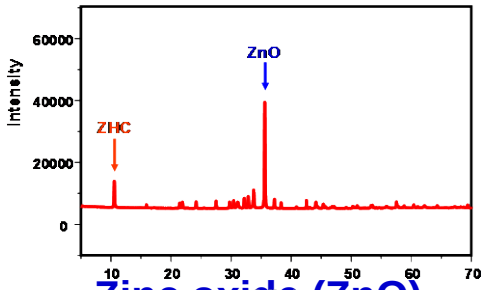
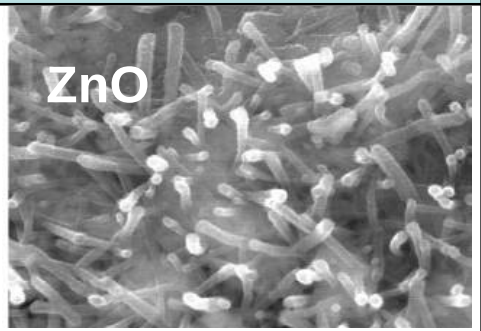
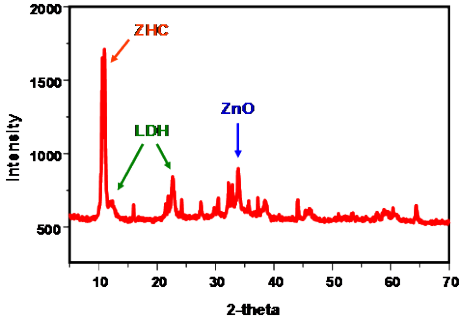
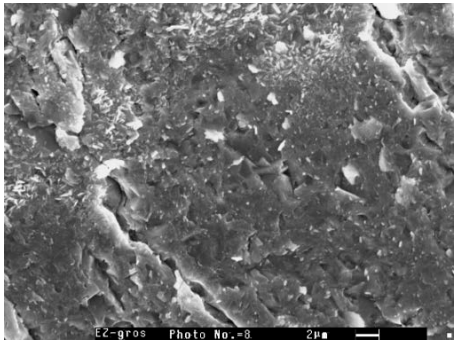
- When the metallic coating (M) corrodes, the corrosion resistance is closely linked to the inhibiting (barrier) properties of corrosion products that precipitate both on steel and coating surfaces
- The more compact and stable the corrosion product layer is, the greater the limiting effect on oxygen reduction resulting in a slower corrosion rate

- For ZM coatings, alloying elements (Al & Mg) contribute to the precipitation of compact and stable corrosion products which strongly inhibits oxygen flow
- 3% Mg in the coating insures a stable barrier effect*

** study at Tsukuba University /Japan- March 2010*

ZM & GI Corrosion Mechanisms

Corrosion products formed during accelerated corrosion testing

Coating	Main corrosion products	Structure	Characteristic
GI coating (10µm)	 **Zinc oxide (ZnO)**		**Porous corrosion products** **Low inhibition**
ZM coating (10µm)	 **Simonkolleite (ZHC) and AlMg basic salt (LDH)**	 **ZHC / AlMg LDH**	**Compact corrosion products** **High inhibition**

➲ *ZM product with 3.5% Al & 3% Mg is an ideal coating composition* which results in compact corrosion products and exceptional corrosion performance

Corrosion Performance – Self Healing

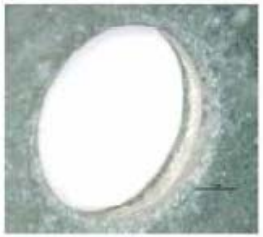
Cut edge protection

Self Healing Mechanism

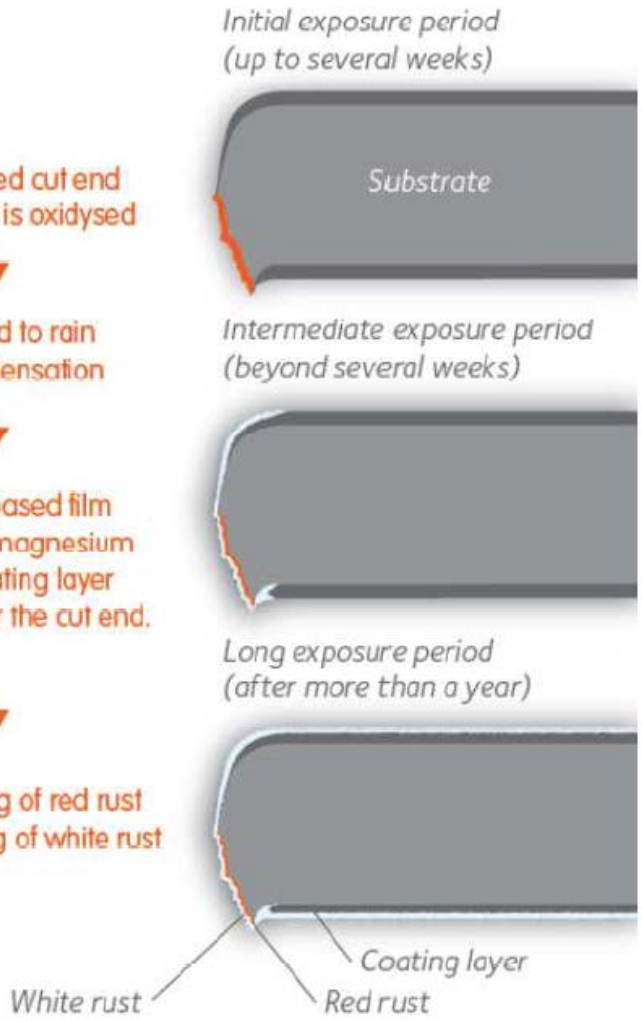
The exposed cut end of substrate is oxidysed

Subjected to rain and condensation

The zinc-based film containing magnesium on the coating layer migrates over the cut end.



Disappearing of red rust and increasing of white rust



Corrosion Performance – Self Healing

Cut edge protection

Self-healing cut edge affect

6 months
30-40% red rust - 60% white rust

16 months
10% red rust - 70% white rust

Outdoor exposure over different time periods of Magnelis® ZM250 with 2 mm thickness in Brest (France)
Marine category C5-M (the most severe)
Institut Français de la Corrosion

Corrosion Performance

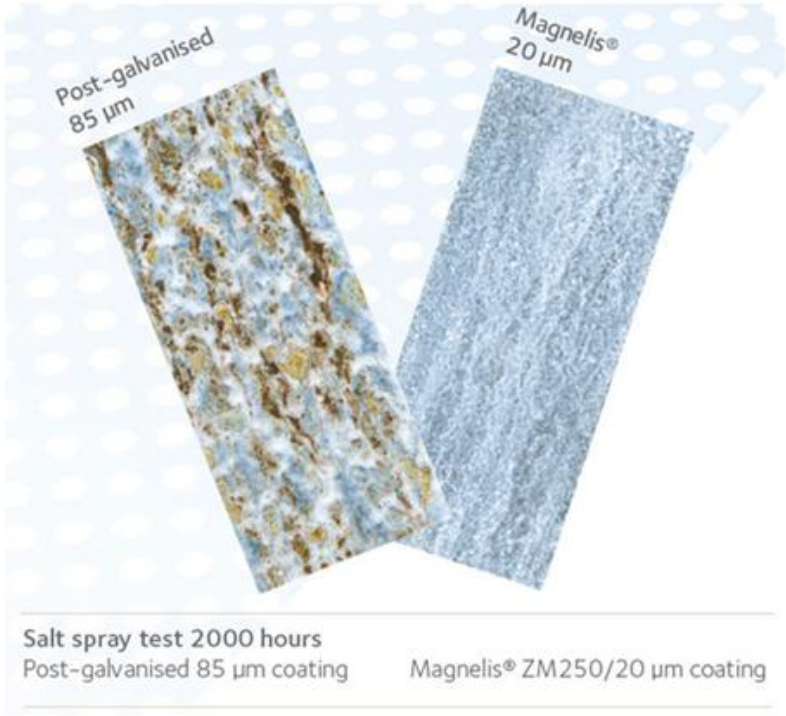
Corrosion Resistance: *Salt Spray Test*

ZM250 (20µ) compared with Z275 (G90) pre galvanized (20µ)

Salt Spray test

GI after 6 weeks ZM after 34 weeks

ZM250 (20µ) compared with Z1170 (G380) post/batch galvanized (85µ)



Salt spray test 2000 hours

Post-galvanised 85 µm coating Magnelis® ZM250/20 µm coating

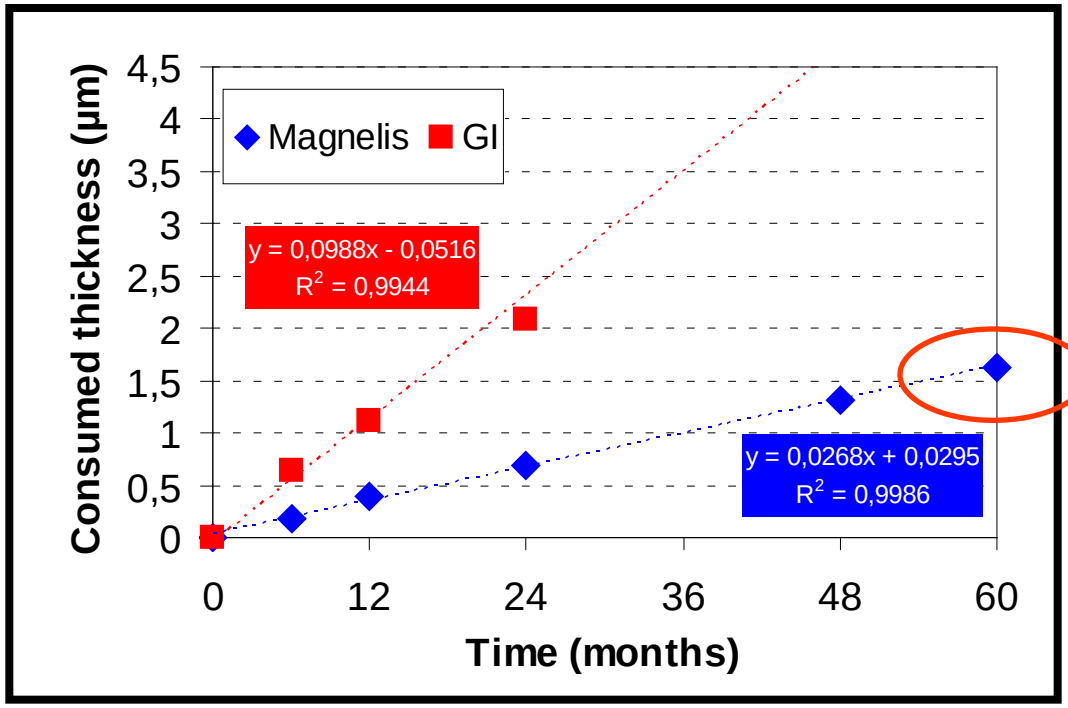
ZM (Magnelis®) outperforms standard continuous and batch galvanized (GI) materials

Corrosion Performance

Corrosion Resistance: *Marine/Chloride Environment*

Test Area: Brest, C5M environment
(marine, 2 meters from the sea)

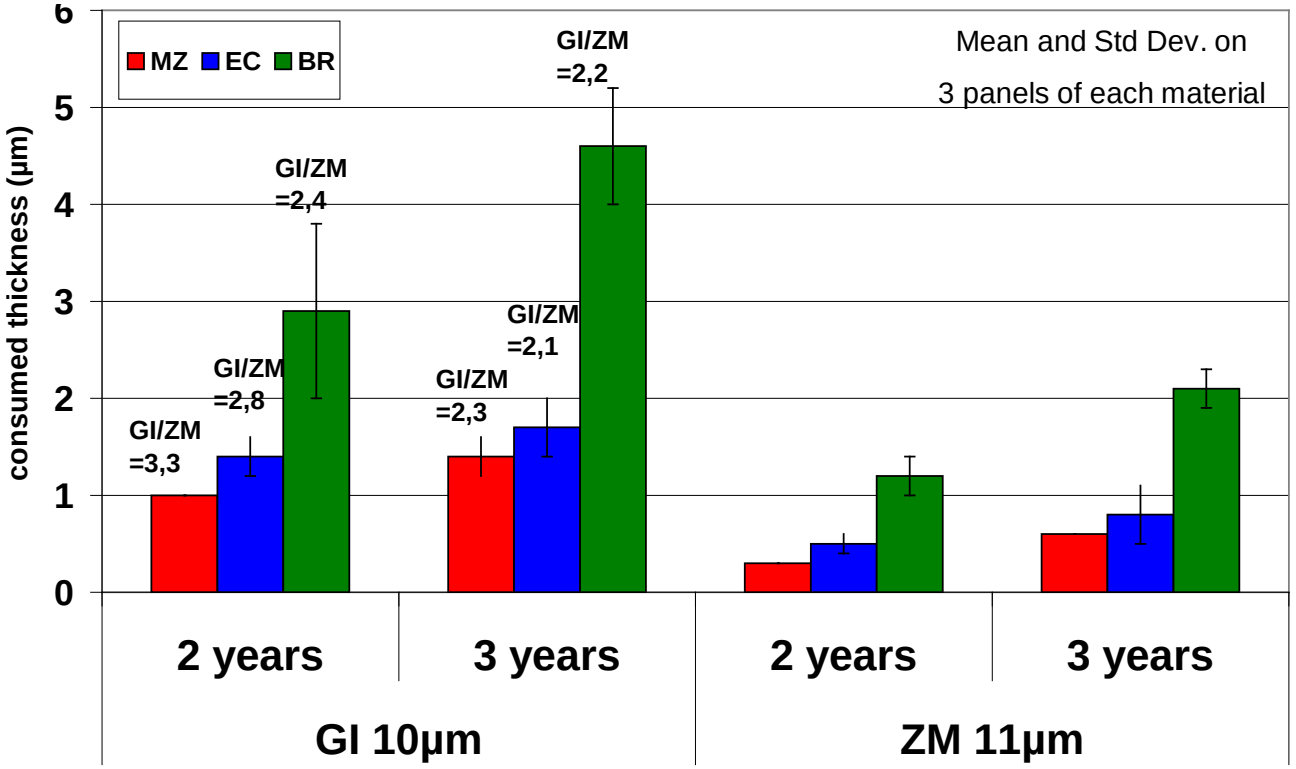
Similar test done in Daytona Beach (C4/C5 environment) with even better results



In Marine/Chloride environments Galvanized (GI) steel corrodes 3 times faster than Magnelis® (ZM)

Corrosion Performance

GI (Z) & ZM Mass Loss after 2 & 3 Years – Outdoor Sites:

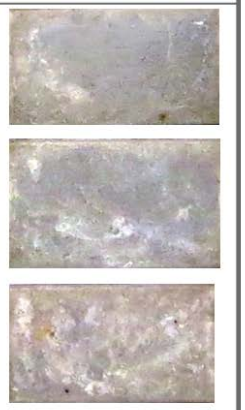
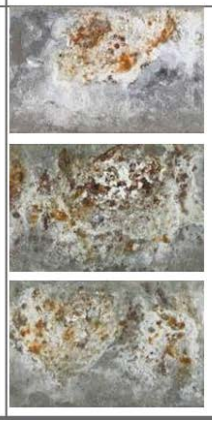
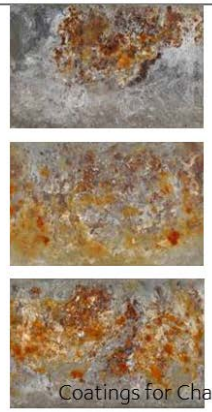
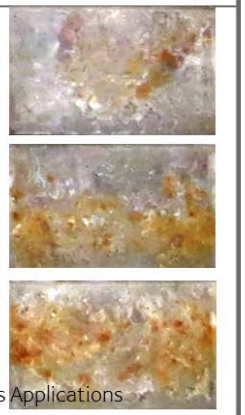


- Magnelis®(ZM) appears to be the best coating in all environments - mass loss ~2-3 times less than GI
- With chlorides - marine site Brest, France (BR) or without chlorides - rural Maizières, France (MZ) or urban East Chicago, IN (EC) sites

Corrosion Performance

Mobile Exposure on a Truck (in Europe):

Flat test panels

	1 year	2 years	3 years
ZM 10um (ZM120)			
GI 10um (Z140, G45)			

28/11/2016

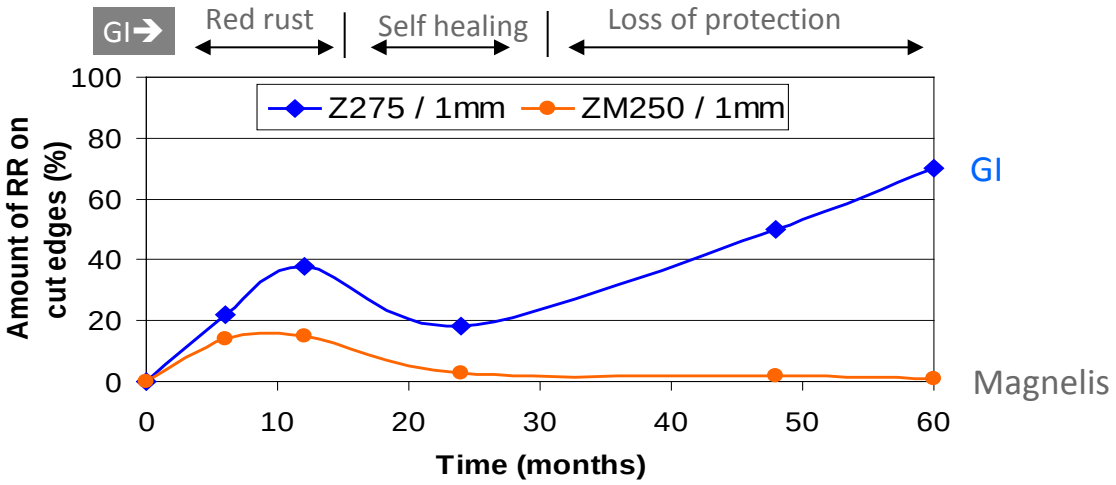
Coatings for Chassis Applications

Truck driven more than 150,000 km/year, (93,000 mi/yr) in various environments (road salts,…)

- On flat bare panels, no red rust on ZM after 3 years vs. GI red rust at the same coating thickness.
- ZM much better than GI

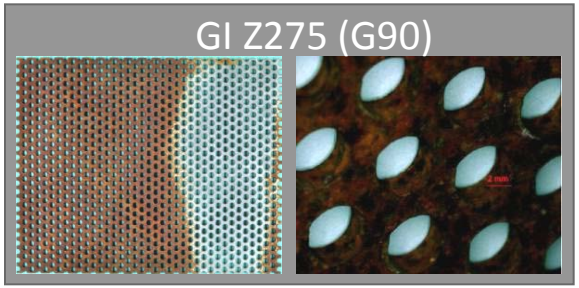
Corrosion Performance

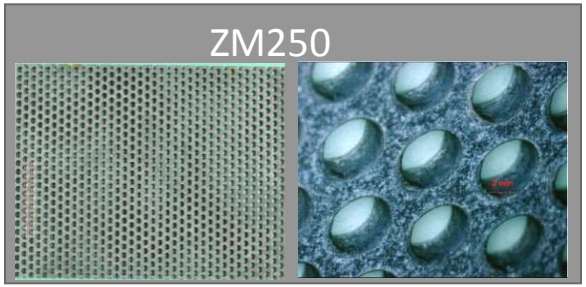
GI (Z) & ZM Cut Edge /Hole Corrosion after 5 years exposure - seashore:



- Sample evaluation at Brest (France) - Seashore
- GI (Z): Self healing observed after 1 year, but protection only lasted 1 year
- ZM: Self healing observed after 1 year, and continues to last at least 5 years
- *ZM self healing duration increased by a factor of 4 compared to GI*

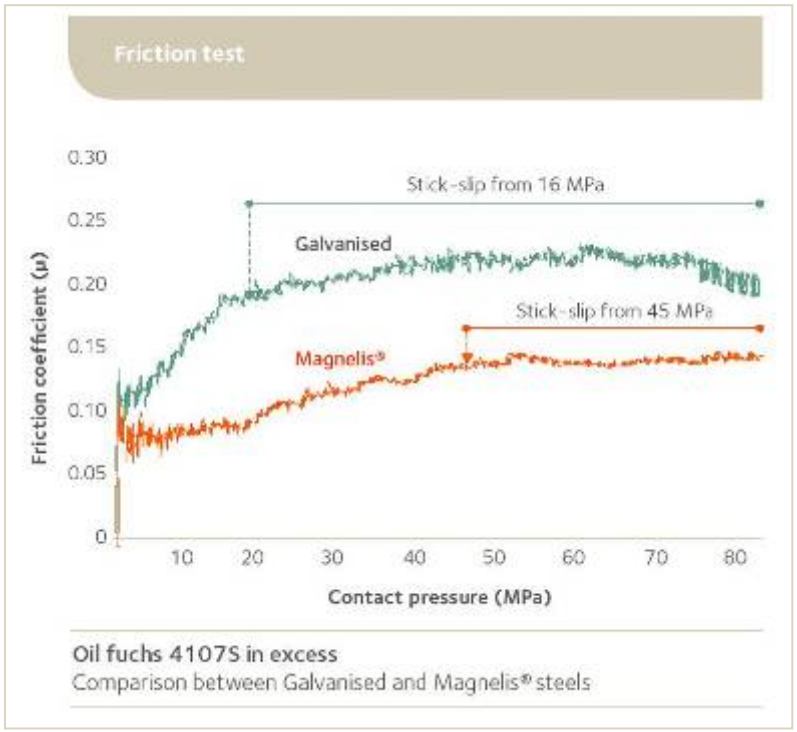
Pictures after 5 years

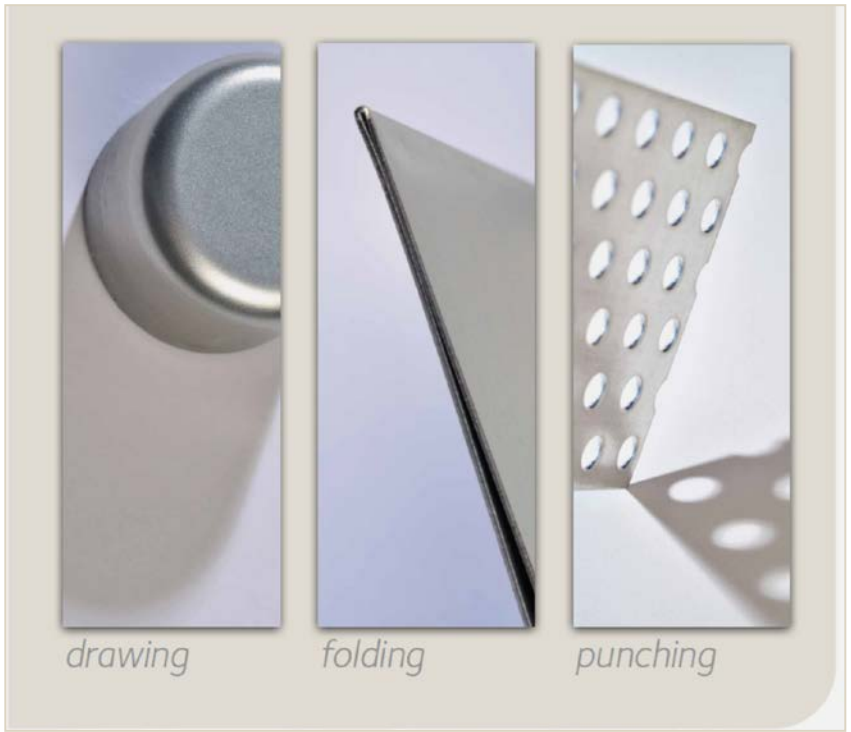




Manufacturing

Formability: *Excellent workability*



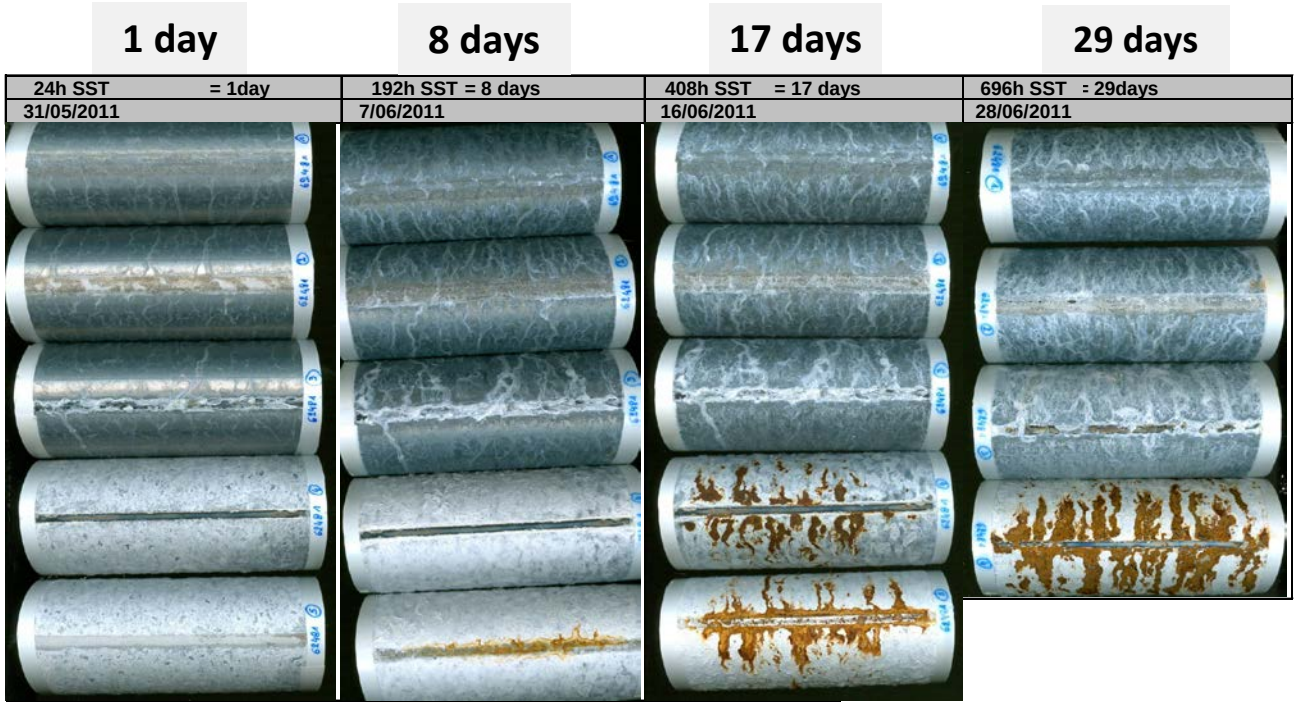


Low friction coefficient and low powdering behavior results in excellent drawing, rolling forming, bending & punching with less tool buildup

Roll Forming

Welding

Corrosion resistance in Salt Spray test:



Samples description

- **ZM** with 85% Zn -15% Al weld post coating
- **ZM** with Al - Al weld post coating
- **ZM** without weld post coating
- **GI** without weld post coating
- **GI** with Al - Al weld post coating

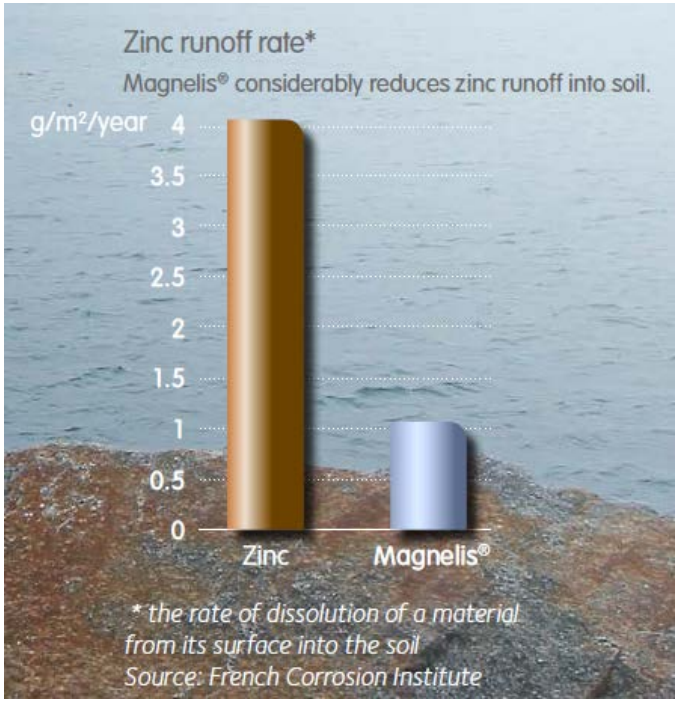
Samples were salt spray tested until they exhibited 5% Red Rust

- Magnelis® ZM120 (10µ) HFI welded tubes are far more corrosion resistant than GI Z275 [G90] (20µ) HFI welded tubes due to Self Healing effect

Environmentally Friendly

Zinc runoff in soils

The application of Magnelis® ensures the preservation of natural resources since it uses less zinc than pure zinc coatings. Magnelis® reduces considerably the zinc runoff in soils



Durability

Sand abrasion

- Coating hardness has a direct impact on the abrasive wear resistance of the coating

Material	Hardness Index (HV)
Continuous Galvanize	64
Batch Galvanize	70
Galvalume® (Aluzinc)	129
Magnelis®	141

- Magnelis® hardness is much higher (harder) than standard zinc coatings (GI & AZ)
- To date, desert field exposure in Dubai, in collaboration with the French Corrosion Institute, has shown ZM to have 3 times less abrasion/corrosion loss vs. batch galvanize

Performance Comparison

HDG (GI) vs. Magnelis® (ZM)

Product Features	HDG GI	ZM
Anti-Corrosion Properties		
In a chloride environment (marine site, roadside)	Reference	+++
In an ammonia environment (barn, farm, greenhouse)	Reference	++
In an SO_2 environment (acid/industrial)	Reference	+
Temporary protection (transport, storage)	Reference	+++
Edge protection (heavy gauge, perforated sheet)	Reference	+++
Corrosion of a deformed part (bent or stamped)	Reference	++
Forming Properties		
Bending & roll forming	Reference	+
Drawing	Reference	+
Assembling Properties		
Spot welding (equivalent thickness)	Reference	=
Aspect		
Visual Appearance	Reference	=

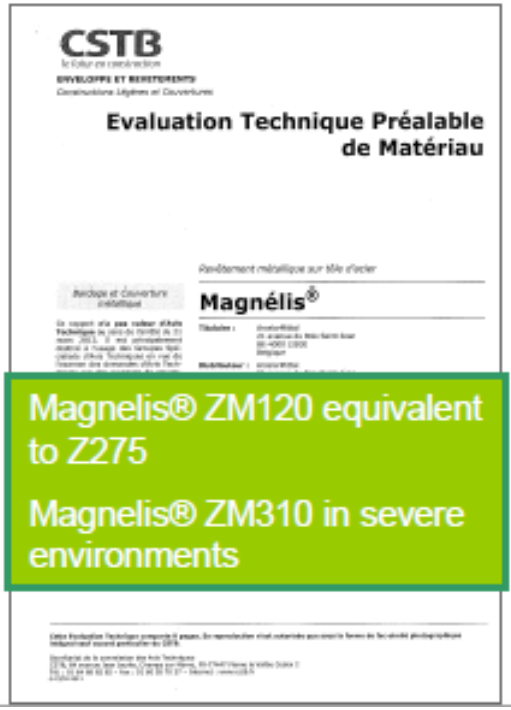
= *Equivalent* + *Superior* − *Inferior*

ZM performance better or equivalent to HDG (GI)

Certifications

Corrosion Performance:

CSTB (France)

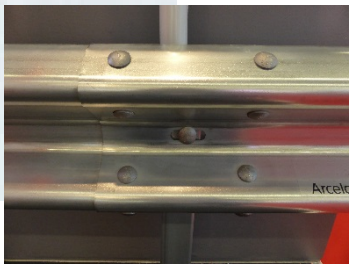


DIBT (Germany)

SP (Sweden)

Magnelis® is the first metallic coating C5 certified
(certified for 20 years in the most aggressive environments)

Awards



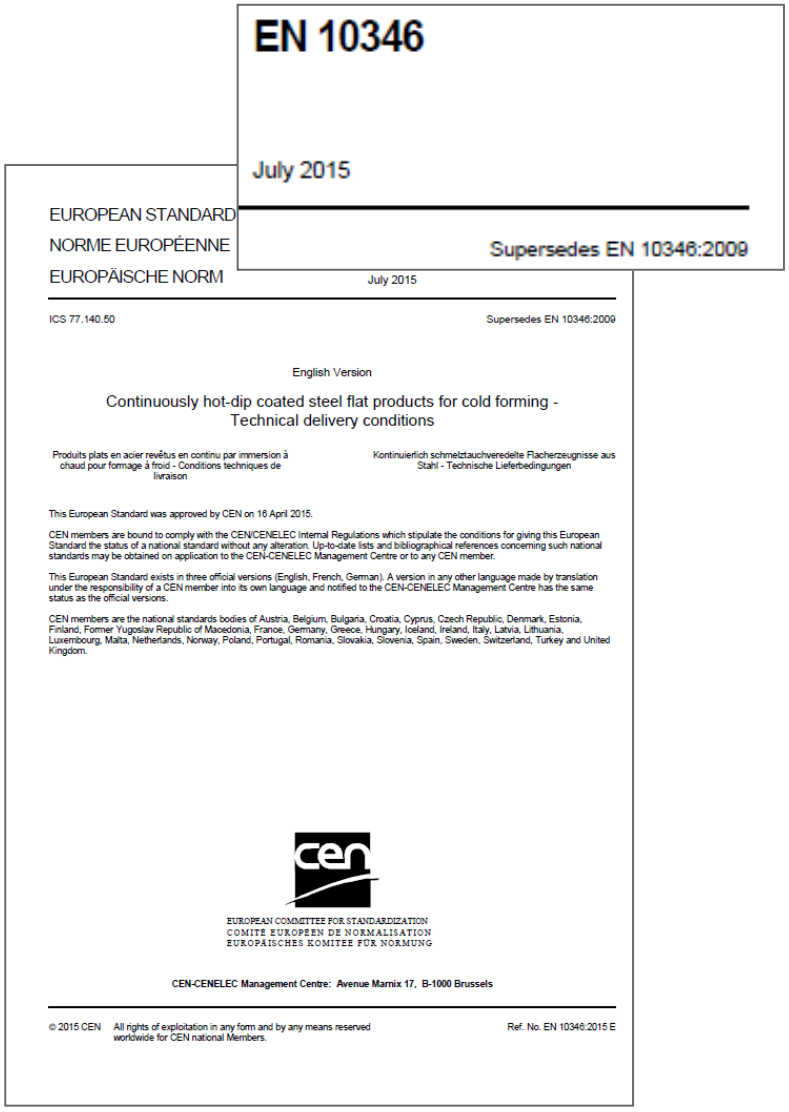
In March 2014, ArcelorMittal received the "**Intertraffic Innovation Award 2014**" in the **Infrastructure Category**

for the development and use of

"Magnelis® Zinc-Magnesium-Aluminum coating with High Strength Low Alloy Steel"

Specifications – ZM Coatings

EU EN10346 & US ASTM A1046, Type 2



EN 10346

July 2015

EUROPEAN STANDARD
NORME EUROPÉENNE
EUROPÄISCHE NORM

Supersedes EN 10346:2009

July 2015

ICS 77.140.50

Supersedes EN 10346:2009

English Version

Continuously hot-dip coated steel flat products for cold forming - Technical delivery conditions

Produits plats en acier revêtus en continu par immersion à chaud pour formage à froid - Conditions techniques de livraison

Kontinuierlich schmelztauchveredelte Flacherzeugnisse aus Stahl - Technische Lieferbedingungen

This European Standard was approved by CEN on 16 April 2015.

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EUROPEAN COMMITTEE FOR STANDARDIZATION
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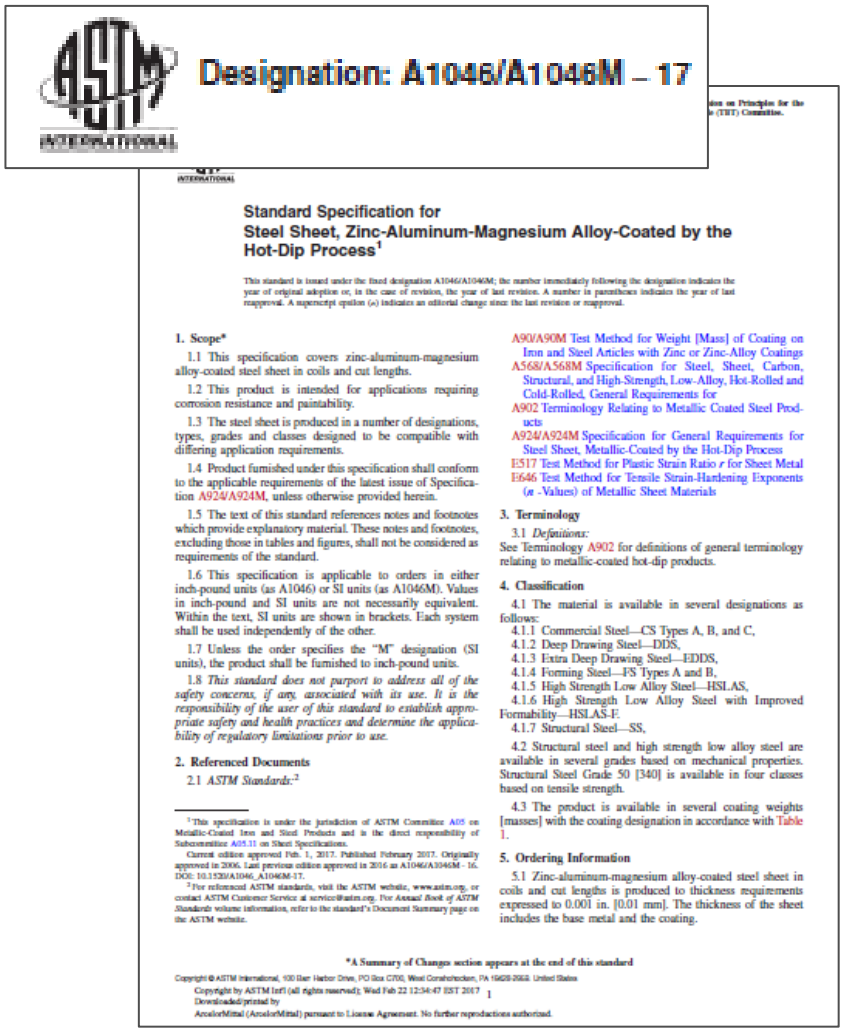
Ref. No. EN 10346:2015 E



Designation: A1046/A1046M – 17

Standard Specification for Steel Sheet, Zinc-Aluminum-Magnesium Alloy-Coated by the Hot-Dip Process[1]

This standard is issued under the fixed designation A1046/A1046M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 This specification covers zinc-aluminum-magnesium alloy-coated steel sheet in coils and cut lengths.

1.2 This product is intended for applications requiring corrosion resistance and paintability.

1.3 The steel sheet is produced in a number of designations, types, grades and classes designed to be compatible with differing application requirements.

1.4 Product furnished under this specification shall conform to the applicable requirements of the latest issue of Specification A924/A924M, unless otherwise provided herein.

1.5 The text of this standard references notes and footnotes which provide explanatory material. These notes and footnotes, excluding those in tables and figures, shall not be considered as requirements of the standard.

1.6 This specification is applicable to orders in either inch-pound units (as A1046) or SI units (as A1046M). Values in inch-pound and SI units are not necessarily equivalent. Within the text, SI units are shown in brackets. Each system shall be used independently of the other.

1.7 Unless the order specifies the "M" designation (SI units), the product shall be furnished to inch-pound units.

1.8 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

A90/A90M Test Method for Weight [Mass] of Coating on Iron and Steel Articles with Zinc or Zinc-Alloy Coatings
A568/A568M Specification for Steel, Sheet, Carbon, Structural, and High-Strength, Low-Alloy, Hot-Rolled and Cold-Rolled, General Requirements for
A902 Terminology Relating to Metallic Coated Steel Products
A924/A924M Specification for General Requirements for Steel Sheet, Metallic-Coated by the Hot-Dip Process
E517 Test Method for Plastic Strain Ratio *r* for Sheet Metal
E646 Test Method for Tensile Strain-Hardening Exponents (*n*-Values) of Metallic Sheet Materials

3. Terminology

3.1 *Definitions:*
See Terminology A902 for definitions of general terminology relating to metallic-coated hot-dip products.

4. Classification

4.1 The material is available in several designations as follows:
4.1.1 Commercial Steel—CS Types A, B, and C,
4.1.2 Deep Drawing Steel—DDS,
4.1.3 Extra Deep Drawing Steel—EDDS,
4.1.4 Forming Steel—FS Types A and B,
4.1.5 High Strength Low Alloy Steel—HSLAS,
4.1.6 High Strength Low Alloy Steel with Improved Formability—HSLAS-F,
4.1.7 Structural Steel—SS,

4.2 Structural steel and high strength low alloy steel are available in several grades based on mechanical properties. Structural Steel Grade 50 [340] is available in four classes based on tensile strength.

4.3 The product is available in several coating weights [masses] with the coating designation in accordance with Table 1.

5. Ordering Information

5.1 Zinc-aluminum-magnesium alloy-coated steel sheet in coils and cut lengths is produced to thickness requirements expressed to 0.001 in. [0.01 mm]. The thickness of the sheet includes the base metal and the coating.

[1] This specification is under the jurisdiction of ASTM Committee A05 on Metallic-Coated Iron and Steel Products and is the direct responsibility of Subcommittee A05.11 on Sheet Specifications.
Current edition approved Feb. 1, 2017. Published February 2017. Originally approved in 2006. Last previous edition approved in 2016 as A1046/A1046M – 16. DOI: 10.1520/A1046_A1046M-17.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

*A Summary of Changes section appears at the end of this standard

Guardrail Pilot Site – Izola, Slovenia

* Note: Pictures of Magnelis® (ZM) guardrail in Izola, Slovenia near the Adriatic Sea

Guardrail Evaluation Site – Spain

* Note: Pictures of Magnelis® (ZM) guardrail

Guardrail Installation

Approved Countries:

- ✓ *Belgium*
- ✓ *Chile*
- ✓ *Czech Republic*
- ✓ *Norway*
- ✓ *Spain*
- ✓ *Approval for other countries in progress*

New Installations:

- ✓ *Czech Republic* - Two newly rebuilt sections of the Czech Republic's D1 motorway from Jihlava to Velký Beranov and from Velká Bíteš to Devět křížů, will be equipped with safety barriers using Magnelis® coating. A total of 23 km of one and two-way traffic barriers will be installed between June and November 2017.

Light Poles – Gent, Belgium

* Note: Pictures of Magnelis® (ZM) light poles in Gent, Belgium

Conclusions

Magnelis® (ZM) offers:

- ✓ *Superior corrosion protection (sacrificial & barrier) even in aggressive environments with less coating mass*
- ✓ *Less coating mass required (2 to 3 times less) while achieving equivalent/better corrosion performance than GI*
- ✓ *Edges protection thanks to the self healing effect*
- ✓ *Good weldability (similar to GI)*
- ✓ *Excellent formability and durability*
- ✓ *Environmental friendly coating (less zinc runoff)*
- ✓ *The first C5 (severe environment) certified metallic coating*
- ✓ *An alternative solution to batch galvanized products and other metals*

Questions?

From steel to safety

Much more than steel …