Mounted PV: steel foundations explored

Proven benefits of Magnelis® pre-coated steel for PV foundations of solar mounting structures

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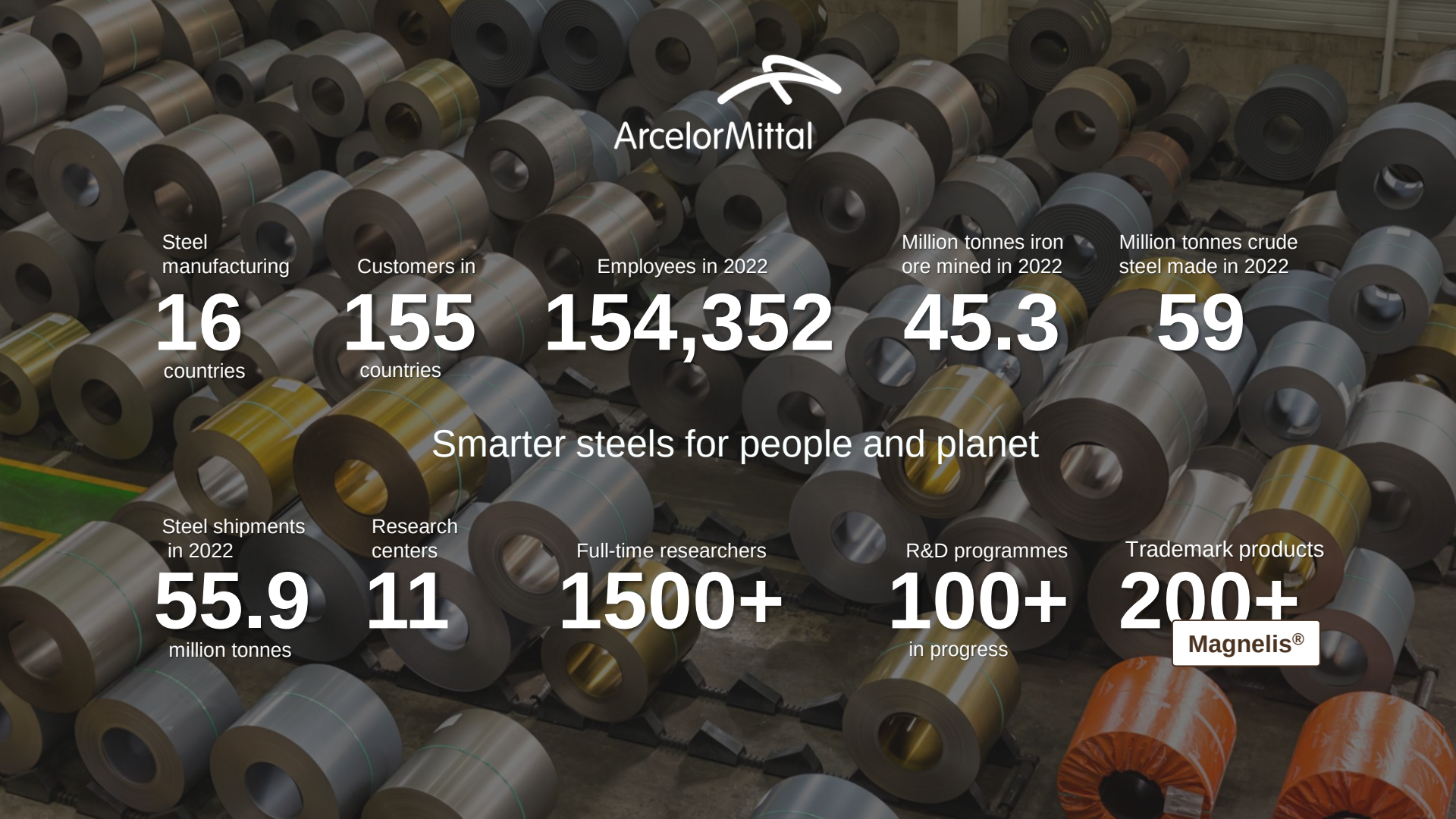
17 November 2023


ArcelorMittal
Steel manufacturing
16
countries
Customers in
155
countries
Employees in 2022
154,352
Million tonnes iron ore mined in 2022
45.3
Million tonnes crude steel made in 2022
59
Smarter steels for people and planet
Steel shipments in 2022
55.9
million tonnes
Research centers
11
Full-time researchers
1500+
R&D programmes
100+
in progress
Trademark products
200+
Magnelis®

Solar energy is crucial for us!

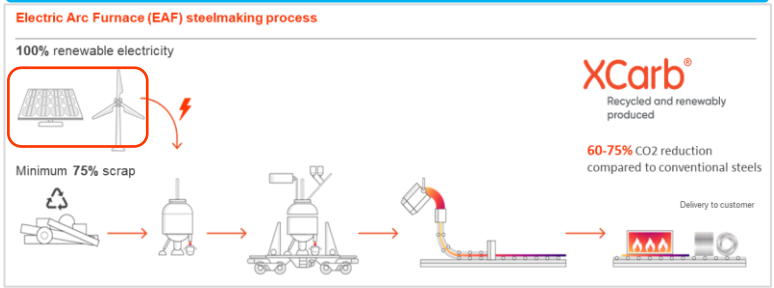
Steel is a vital enabler for the energy transition

Steel for ground mounted trackers & Fix tilt solar (poles, rails & tubes…)

Steel for rooftop solar (rails, wind deflectors…)

Steel for floating solar (rails, tubes, walk path…)

Renewable energy is a key ‘resource’ for decarbonised steelmaking

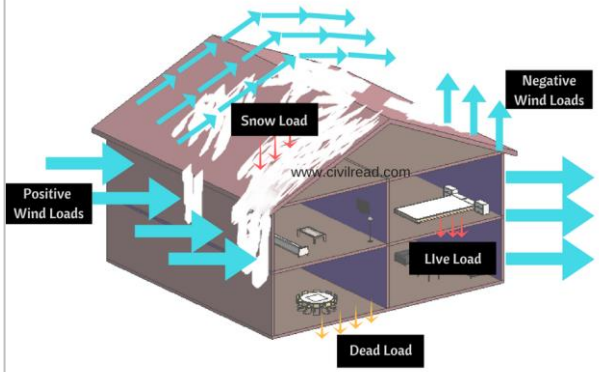


Solar panel installation at ArcelorMittal Green Energy (975 MW Solar+Wind for AMNS India)

For solar structures or for buildings, foundations play the same fundamental roles:

- Foundations ensure mechanical stability & safety + durability over the expected lifetime.
- Foundations bear the investment, while inspection & maintenance possibilities remain limited.

BUILDING



BRITISH STANDARD

Eurocode 7: Geotechnical design —

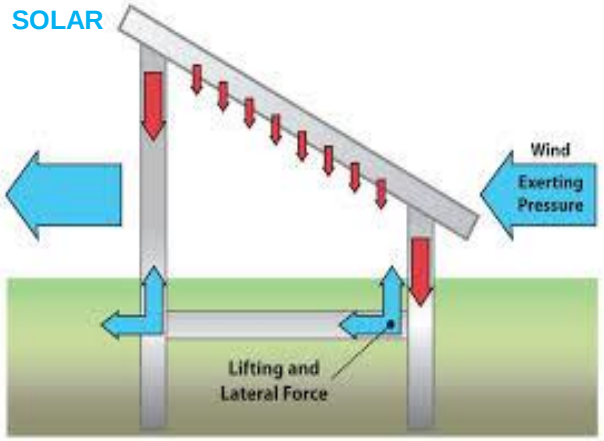
Part 1: General rules

BRITISH STANDARD

Eurocode 7 — Geotechnical design —

Part 2: Ground investigation and testing

SOLAR



Foundations are on the critical path of solar projects

Similar load cases:
Dead loads
Live additional loads
Wind loads (+ or -)
Snow loads
Seismic loads

Similar ground investigations needed:
Geological - Physical
Mechanical
Chemical
Electrical

For solar ground mounted structures, various solutions for foundations depending on:

soil hardness, load bearing capacity, aggressiveness & terrain “history”.

Driven pile

Ballasted

X-Anchor

Screw pile

Pre-drilled holes + concrete/gravels

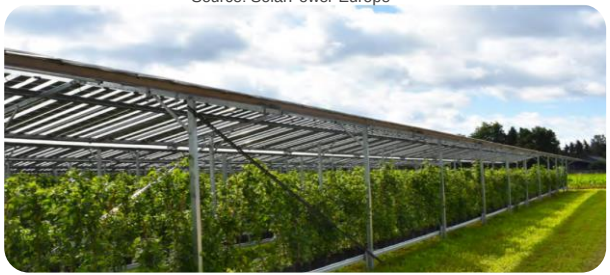
Embedded on concrete blocks

Screwed on concrete bases

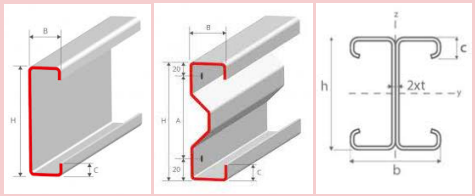
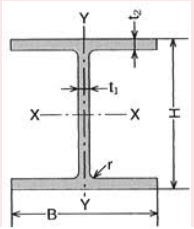
For Agri-PV, foundations play an even more important role, with additional specific constraints:

Higher poles + longer span + more corrosive environment
(presence of animals & machineries = supplementary chemical & physical aggression)

Source: SolarPower Europe



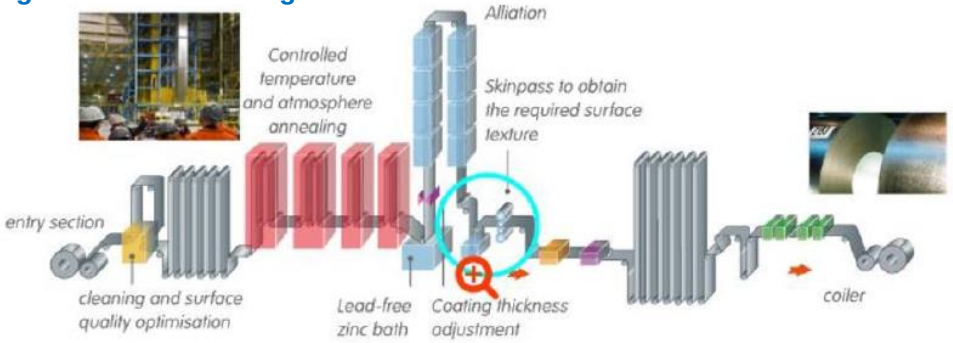
Cold formed C / Σ-channels piles can be designed more efficiently:
with a wide range of steel grades, more geometries & more protection options

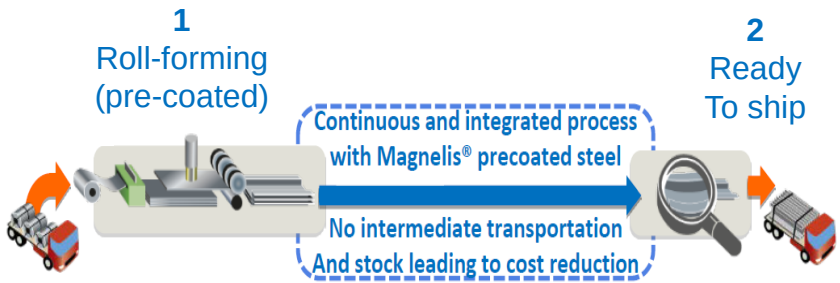
Production	Protection	Geometry	Grades
Cold formed C / Σ channels 	Continuously hot dip coated steel **Magnelis®** or Batch hot dip galvanised steel	Tailor-made section (height x width) Adjusted steel thickness with low tolerances	From S350 MPa Up to S700 MPa
Hot rolled sections W or H beams 	Only batch hot dip galvanised steel possible	Standard geometries Symmetrical section Heavy / oversized wall thickness	From S235 MPa Up to S460 MPa

Continuously pre-galvanised steel offers substantial benefits:

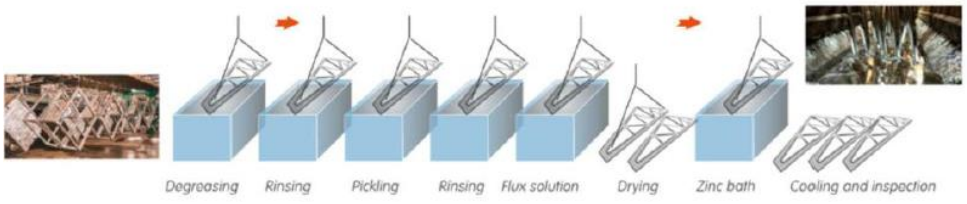
time saving (simplified logistics & project management), cost reduction, 100% online coating control, higher coating adhesion…

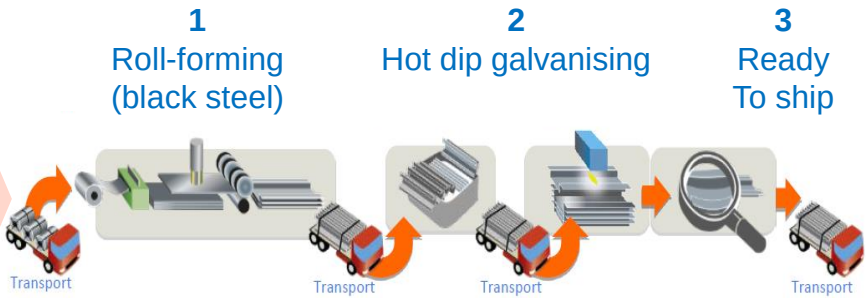
Continuously pre-galvanised steel Magnelis®





Batch hot dip galvanised steel



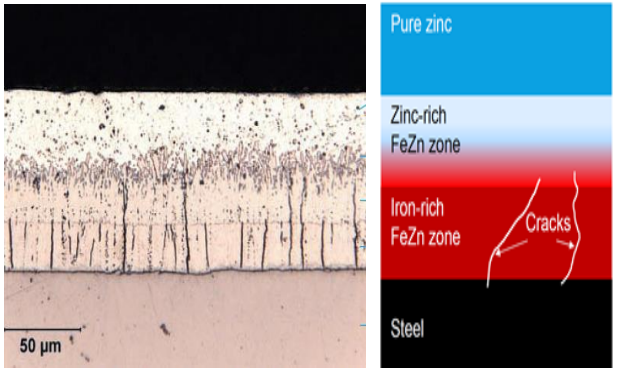


Different processes lead to different products and in-use properties

Batch hot dip galvanised steel cross section

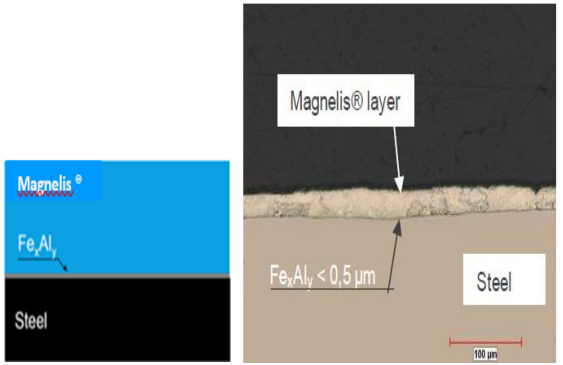
70 VH

179 VH



- Layered structure with successive Zn-Fe phases layers
- Upper pure zinc layer = only ~30% of the total thickness
- Properties depend on the %Fe within each layer

Magnelis® cross section



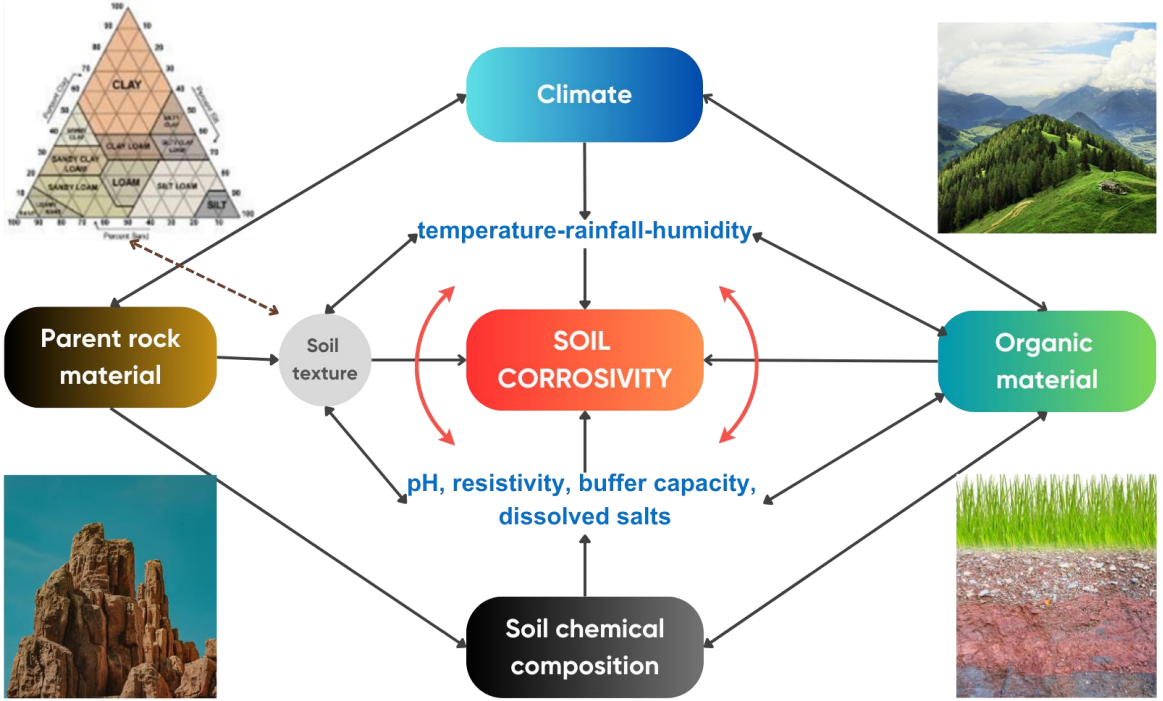
141 VH

- Homogeneously alloyed coating layer
- Uniform mechanical properties and corrosion resistance

Magnelis® surface hardness is much higher compared to the top Zn layer of batch hot dip galvanised steel, leading to a better resistance to abrasive wear and scratches.

In comparison with atmospheric conditions, soils are complex environments with a specific corrosivity phenomenon (uniform & pitting corrosion)

Since 2006, ArcelorMittal has developed extensive expertise in soils, including collaborations with external laboratories, enabling us to study solar projects globally.



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German standard DIN 50929-3:2018 to categorize corrosion load of soils

March 2018

	DIN 50929-3	DIN

ICS 77.060

Supersedes
DIN 50929-3:1985-09

Corrosion of metals –
Corrosion likelihood of metallic materials when subject to corrosion from the outside –
Part 3: Buried and underwater pipelin
English translation of DIN 50929-3:20

Korrosion der Metalle –
Korrosionswahrscheinlichkeit metallener Werk
Teil 3: Rohrleitungen und Bauteile in Böden und
Englische Übersetzung von DIN 50929-3:2018-

Obtained from a Geotech analysis

Table 2 — Information relating to the assessment of soil

Z	Parameters/ Measurands	Requirement or criterion	Test	Unit	Measurement range	Rating
	Soil samples					
Z_1	type of soil — cohesion	proportion of elutriable matter	method as in DVGW GW 9: 2011-09, Annex B, Module 5	mass fractions in %	< 10 10 to 30 30 to 50 50 to 80 > 80	+4 +2 0 −2 −4
	— contamination	DIN EN 12501-2:2003-08, Table 1				−12
Z_2	specific electrical soil resistivity	lowest resistivity after addition of water, measured in the cell	method as in DVGW GW 9: 2011-09, Annex B, Module 2	Ω m	> 500 200 to 500 200 to 50 20 to 50 10 to 20 < 10	+4 +2 0 −2 −4 −6
Z_3	moisture content of soil and reference for Z_6 to Z_{10}	water content after drying at 105 °C	method as in DVGW GW 9: 2011-09, Annex B, Module 1	mass fractions in %	< 20 > 20	0 −1
Z_4	pH value	pH value for 50 % water content	method as in DVGW GW 9: 2011-09, Annex B, Module 2	—	> 9 6 to 9 4 to 6 < 4	+2[a] 0 −1 −3

Table 3 — Classification of soils, corrosion load and likelihood of free corrosion of unalloyed and low-alloy ferrous materials

B_0 or B_1 values	Soil category	Corrosion load[a]	Likelihood of corrosion based on the B_1 value	
	based on the B_0 value		Pitting corrosion	Uniform corrosion
≥ 0	Ia	very low	very low	very low
−1 to −4	Ib	low	low	very low
−5 to −10	II	medium	medium	low
< −10	III	high	high	medium

The order of magnitude of the corrosion rate to be expected is specified in Table 1. In the case of pipes and tanks, priority shall be given to the assessment of permanent leak tightness. In this case, the rate of pitting corrosion is to be considered. In the case of structural components, priority shall be given to the assessment of permanent strength. In this case, the rate of uniform corrosion is to be considered.

[a] The corrosion load corresponds to the likelihood of free corrosion in the absence of extensive concentration cells (see 6.1.2).

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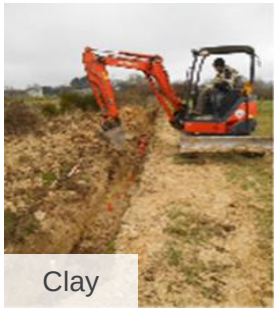
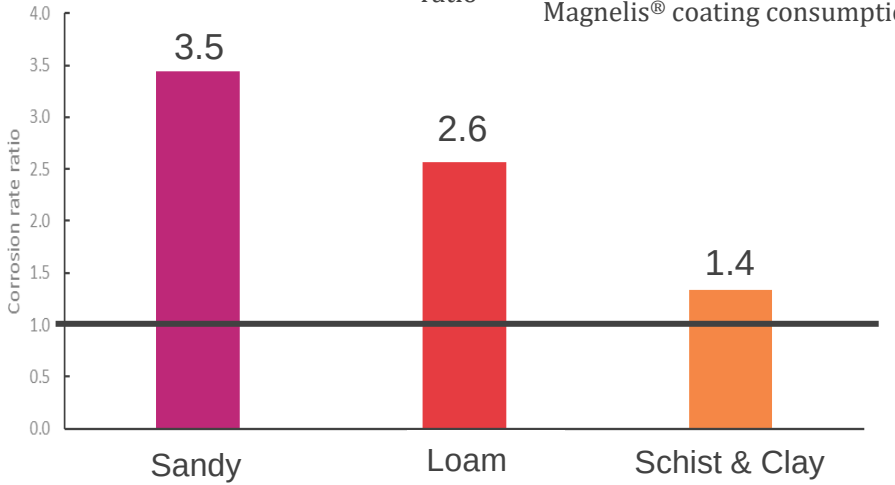
Tested in real soil fields, Magnelis® shows lower corrosion rates than batch hot dip galvanised steels



© ArcelorMittal, French Corrosion Institute

Corrosion rate measured after 1 year testing in real soils

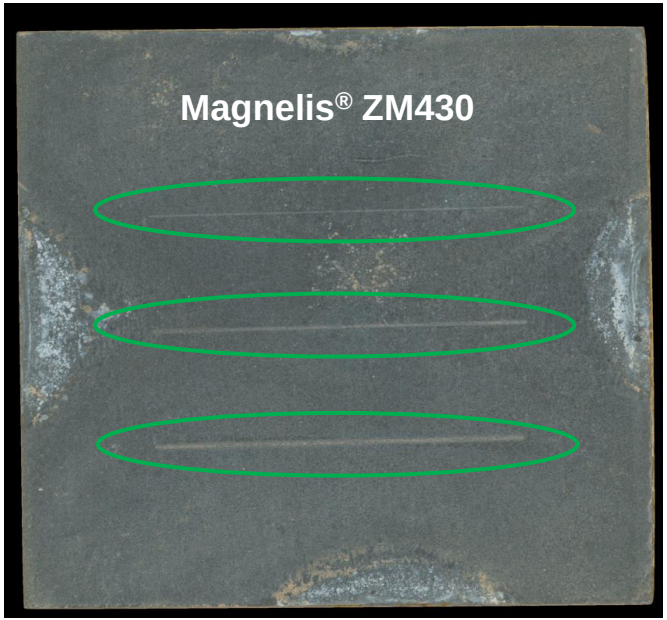
$$\text{ratio} = \frac{(\text{batch hot dip coating consumption})}{\text{Magnelis® coating consumption}}$$



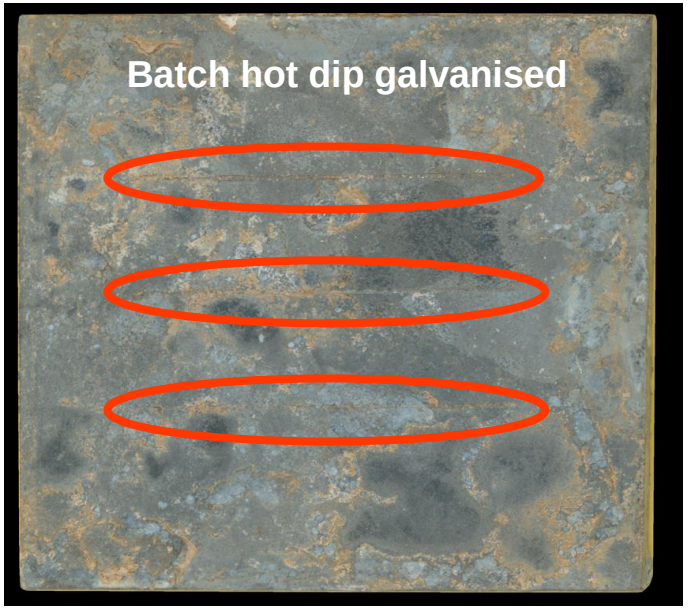
Magnelis® exhibit lower corrosion rates compared to batch hot dip galvanised steel, Improvement ratio up to 3.5

Even if scratched,
Magnelis® is less affected by corrosion than batch hot dip galvanised material

Samples scratched with different loads leading to different damaged widths,
after 2 years testing in a real loamy soil

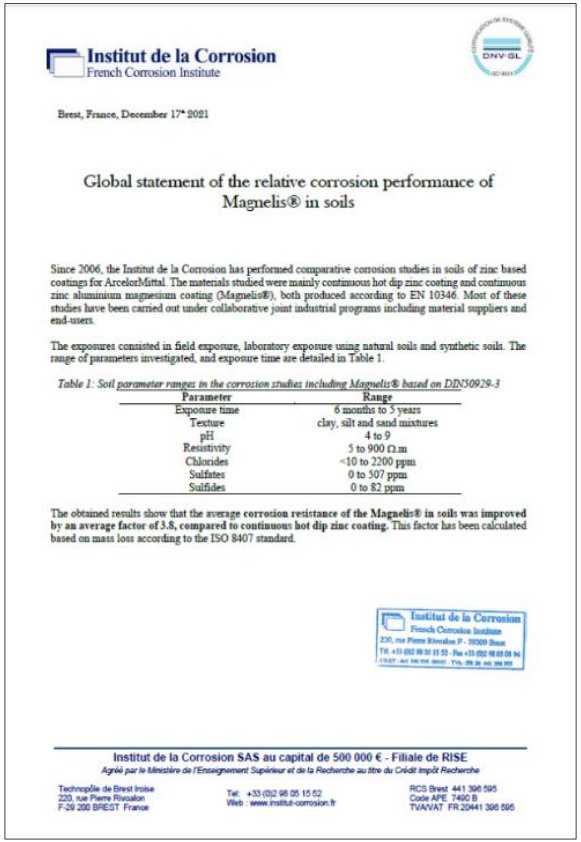


Scratches are visible, but no corrosion initiation



Scratches are barely visible, confused with the overall corrosion of the surface.
Red rust visible inside the scratches.

Improved protection of Magnelis® in soils was assessed by a third party



Institut de la Corrosion
French Corrosion Institute

Brest, France, December 17th 2021

Global statement of the relative corrosion performance of Magnelis® in soils

Since 2006, the Institut de la Corrosion has performed comparative corrosion studies in soils of zinc based coatings for ArcelorMittal. The materials studied were mainly continuous hot dip zinc coating and continuous zinc aluminium magnesium coating (Magnelis®), both produced according to EN 10346. Most of these studies have been carried out under collaborative joint industrial programs including material suppliers and end-users.

The exposures consisted in field exposure, laboratory exposure using natural soils and synthetic soils. The range of parameters investigated, and exposure time are detailed in Table 1.

Table 1: Soil parameter ranges in the corrosion studies including Magnelis® based on DIN50929-3

Parameter	Range
Exposure time	6 months to 5 years
Texture	clay, silt and sand mixtures
pH	4 to 9
Resistivity	5 to 900 Ω.m
Chlorides	<10 to 2200 ppm
Sulfates	0 to 507 ppm
Sulfides	0 to 82 ppm

The obtained results show that the average **corrosion resistance of the Magnelis® in soils was improved by an average factor of 3.8, compared to continuous hot dip zinc coating.** This factor has been calculated based on mass loss according to the ISO 8407 standard.

Institut de la Corrosion
French Corrosion Institute

Institut de la Corrosion SAS au capital de 500 000 € - Filiale de RISE
Agréé par le Ministère de l'Enseignement Supérieur et de la Recherche au titre du Crédit Impôt Recherche

Technopôle de Brest Iroise
220, rue Pierre Rivoalon
F-29 200 BREST France

Tel: +33 (0)2 98 05 15 52
Web : www.institut-corrosion.fr

RCS Brest 441 396 595
Code APE 7490 B
TVA/VAT FR 20441 396 595

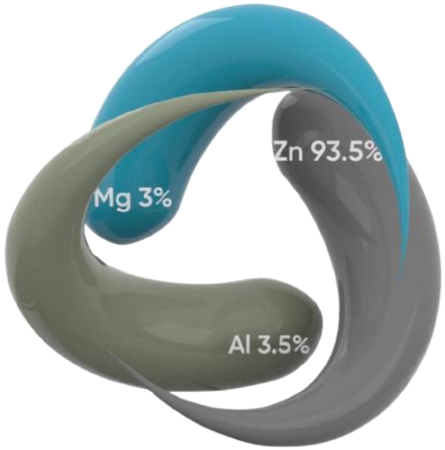
*"Corrosion resistance of Magnelis® in soils was **improved by an average factor of 3.8** compared to continuous hot dip zinc coating."*

Statement from French Corrosion Institute. This lab, subsidiary of RISE Research Institutes of Sweden AB, is among the largest laboratories in the field of corrosion and corrosion protection of materials in the world. https://www.institut-corrosion.fr/?lang=en

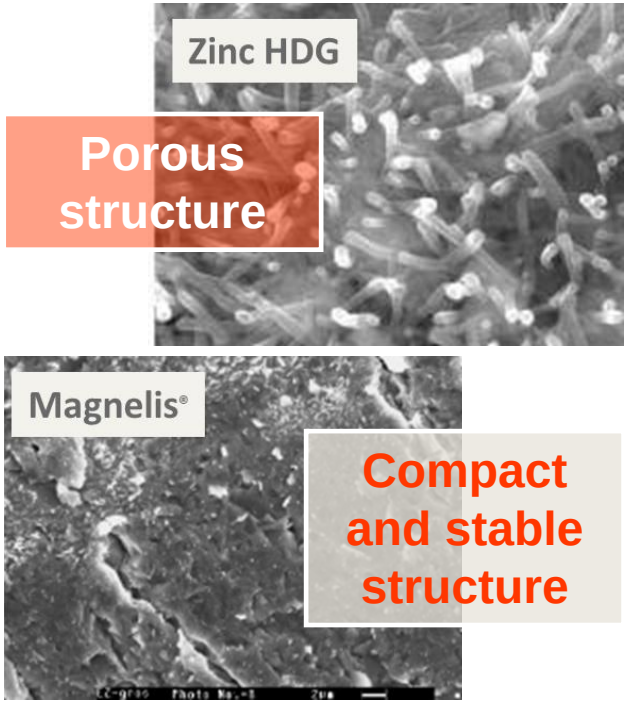
Details including data and types of soils are specified in the French Corrosion Institute's statement available on our website

Magnelis® is the answer to durable solar foundations

Continuous process
Automated on-line control



A unique composition
A full range of grades
and thicknesses



Specific corrosion products

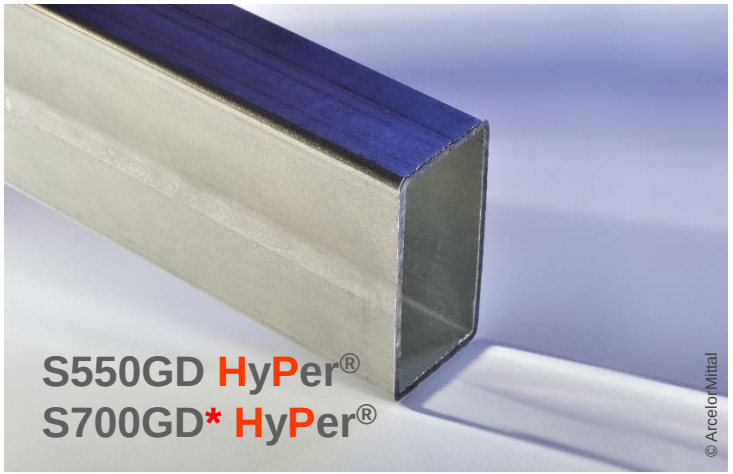
Magnelis® range enlargement for solar foundations

ZM310

ZM430

ZM620

ZM800



** Feasibility on request*

Enlarged range of coating weights

Enlarged range of high strength steels protected with Magnelis®

Depending on the soil corrosion load, calculated thanks to DIN standard, select the best solution for your solar foundations. We can support you in the selection.

What do our customers say?
Testimonies

alusínsolar
solarstructures

SOLARPORT

Solar structure designer, manufacturer and installer.
Long-term users of Magnelis® for super structures.
Early adopters of Magnelis® heavy coatings for underground structures.

…. and many others!

Benefits of using high strength steels for rammed piles

Less deformation at the **top/head** of the piles →

355 MPa steel grade
Severe deformations at the top of the piles →

500 MPa steel grade
Reduced deformation at the top of the piles →

700 MPa steel grade
Almost no deformation at the top of the piles →

Benefits of using high strength steels for rammed piles

Less deformation at the **bottom** of the piles →

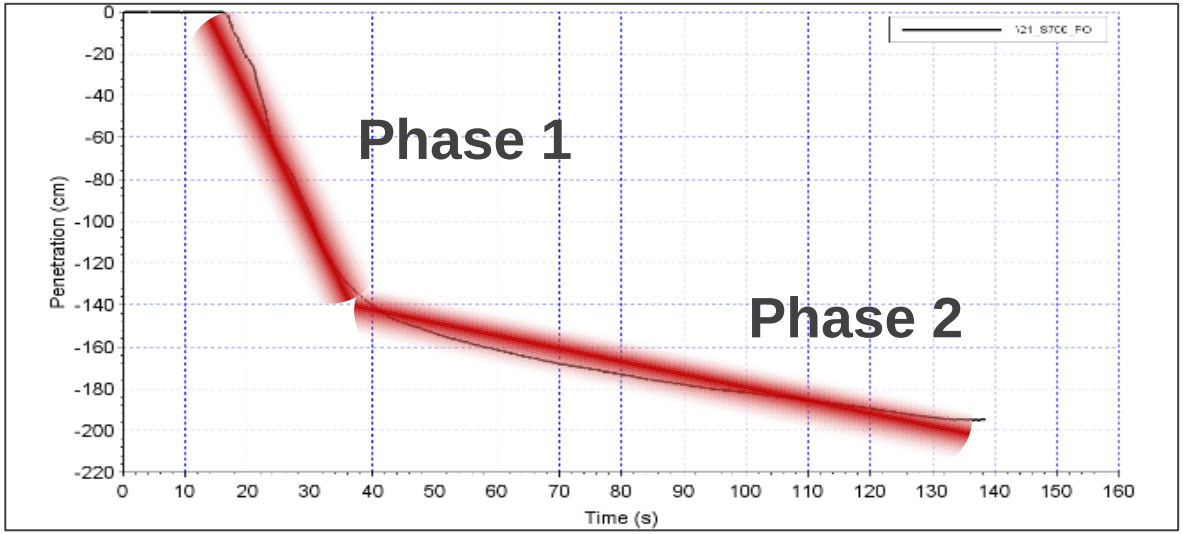
355 MPa steel grade
Severe deformations at the bottom of the piles →

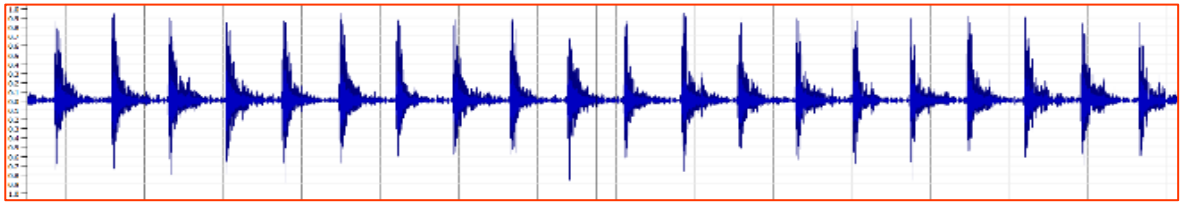
500 MPa steel grade
Reduced deformation at the bottom of the piles →

700 MPa steel grade
Limited deformation at the bottom of the piles →

Benefits of using high strength steels for rammed piles

Typical experimental penetration curve





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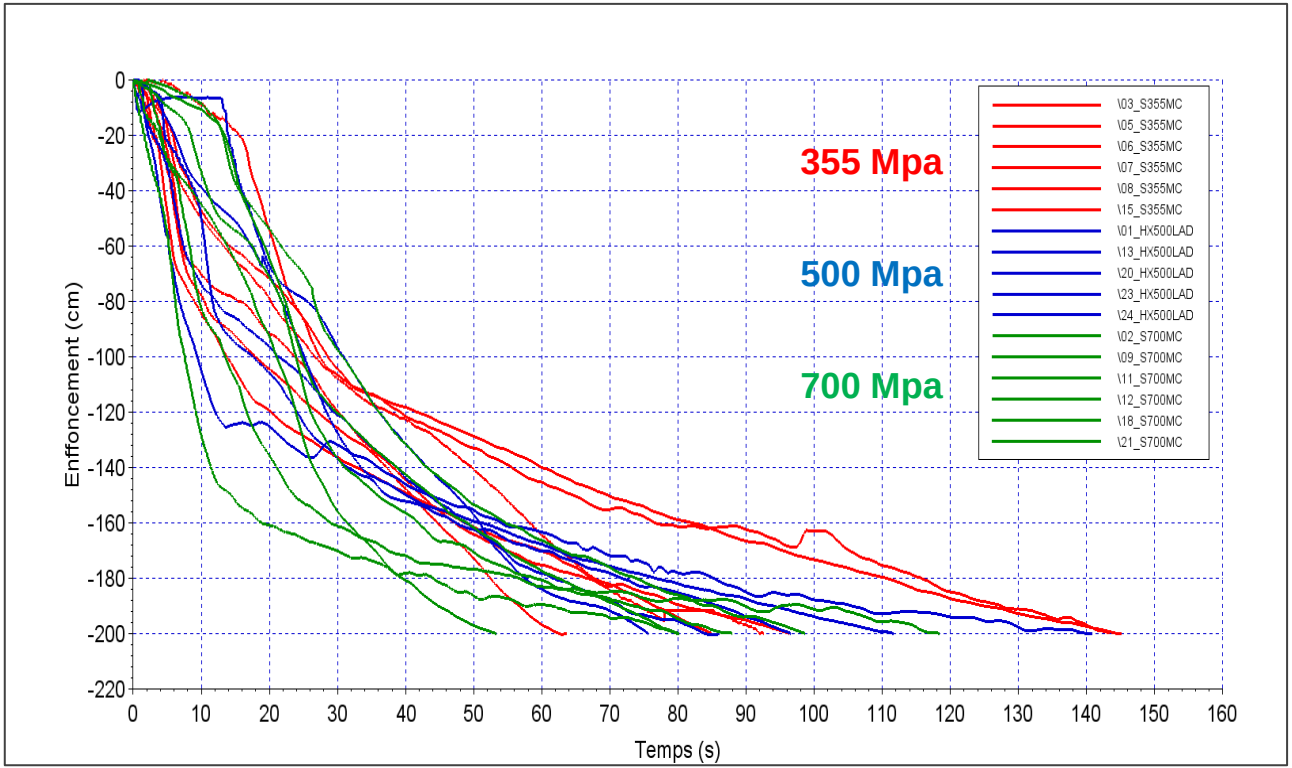
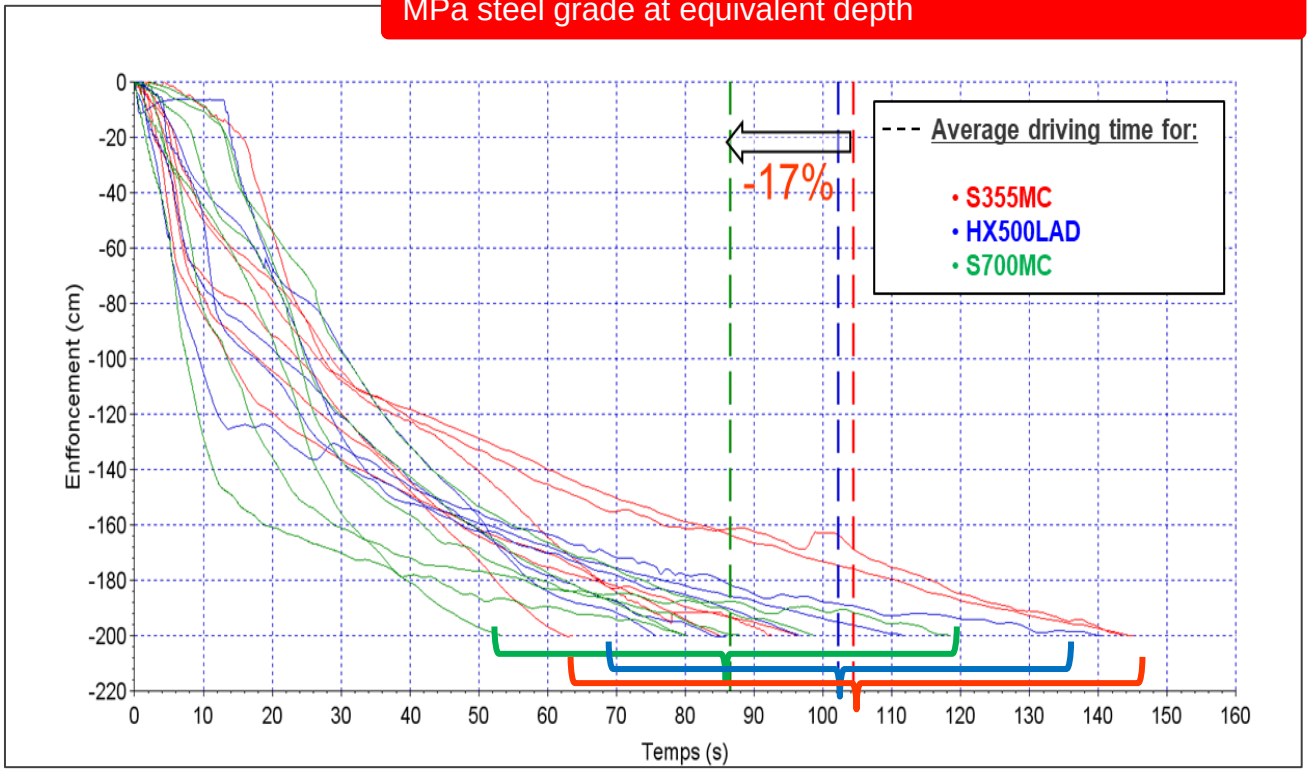
Benefits of using high strength steels for rammed piles

→ **Faster** ramming leading to **reduced installation time & costs**



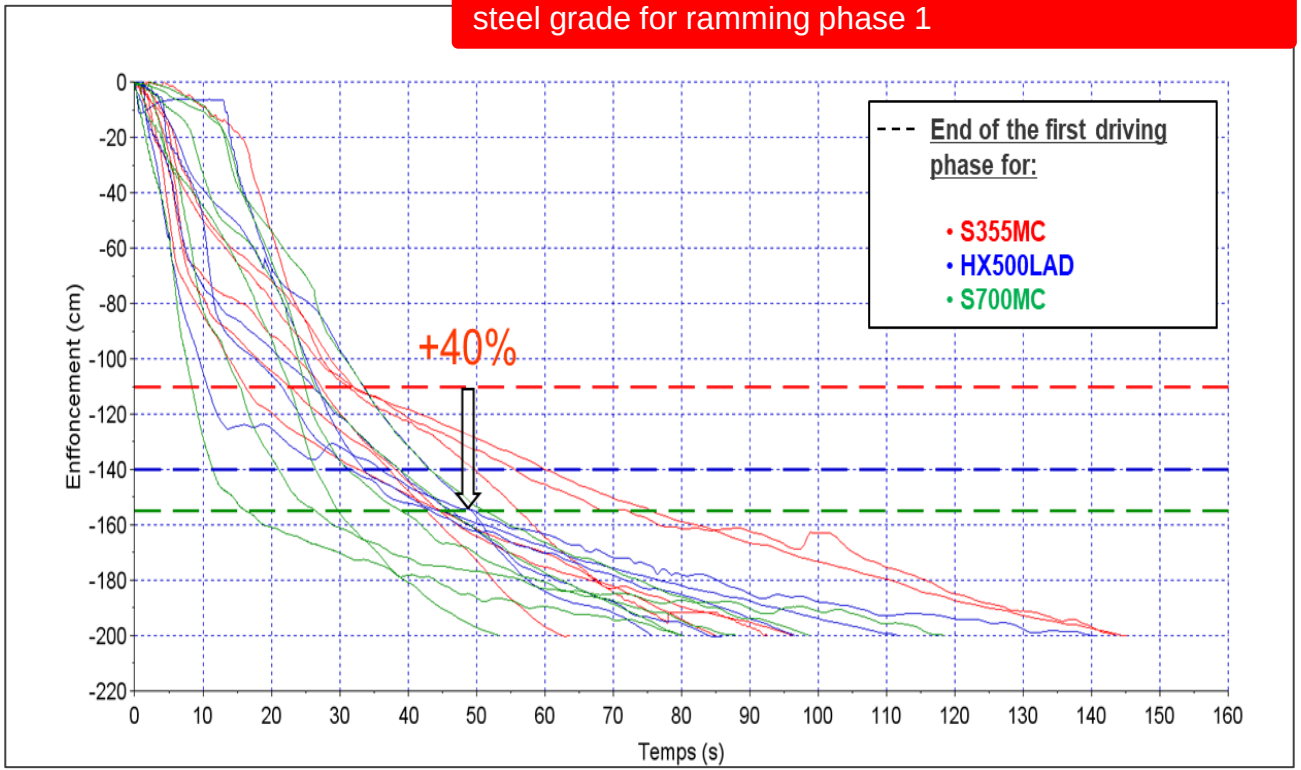
Benefits of using high strength steels for rammed piles

→ Faster ramming: **-17% time saving** from S355 to S700 MPa steel grade at equivalent depth



Benefits of using high strength steels for rammed piles

→ **+40% penetration depth** from S355 to S700 MPa steel grade for ramming phase 1



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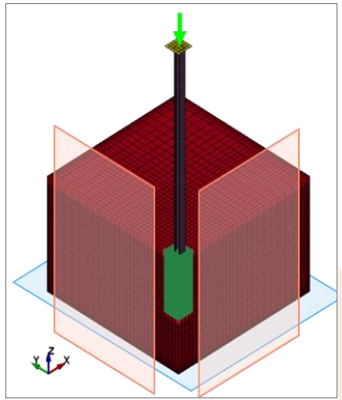
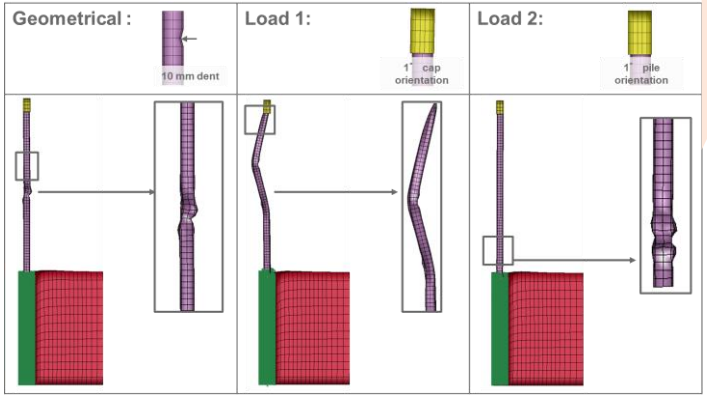
Benefits of using high strength steels for rammed piles

Modeling of Ramming

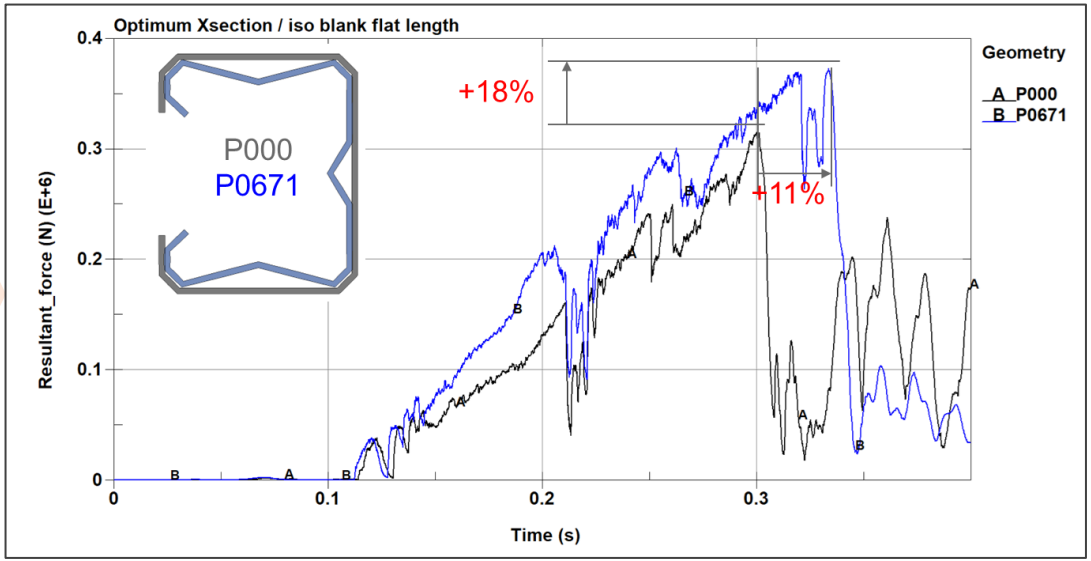
Influence of:

Steel grade
Steel thickness
Section geometry





→ **+18% load increase** with improved geometry at equivalent thickness



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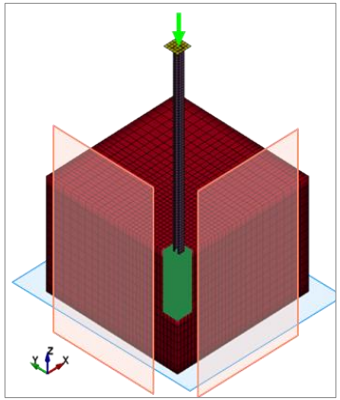
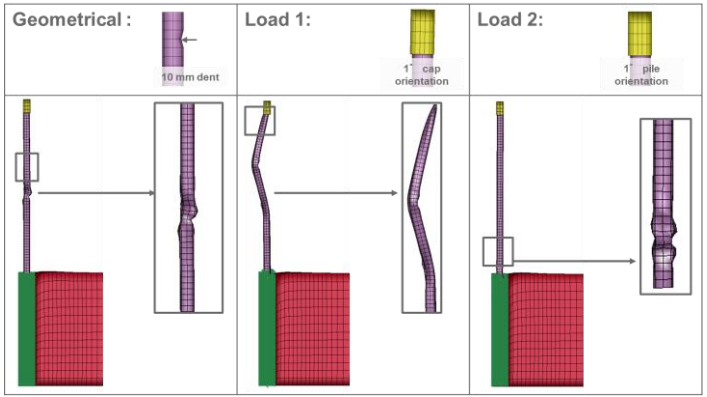
Benefits of using high strength steels for rammed piles

Modeling of Ramming

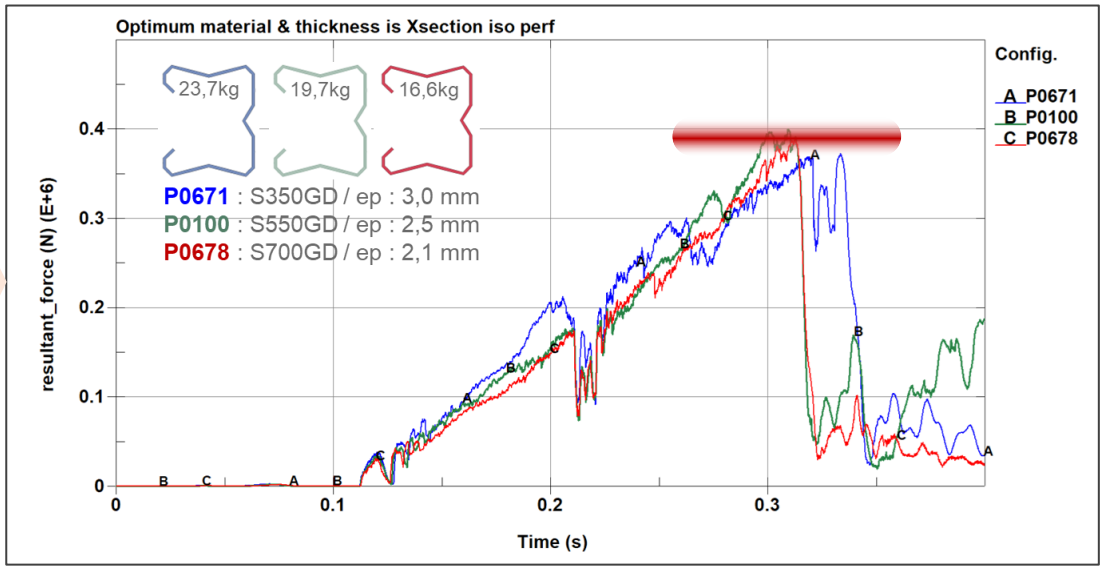
Influence of:

Steel grade
Steel thickness
Section geometry





→ **-16% to -30% thickness reduction** from S350 to S550 & to S700 MPa, at equivalent ramming force until buckling.



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Solar PV industry needs & deserves sustainability

Analyzing PV in the Circular Economy

Learn how NREL is applying its modeling and analysis expertise to PV in the circular economy.

Supply chain transparency on the rise – Where is the solar industry?

Integration of environmental, social and governance considerations in PV projects

The Solar Stewardship Initiative (SSI) is a solar-specific sustainability assurance programme by SolarPower Europe and Solar Energy UK which combines supply chain integrity with enhanced Environmental Social and Governance (ESG) performance. The Initiative is supported by more than 60 solar companies covering the whole solar value chain and a significant share of the European (including UK) solar market.

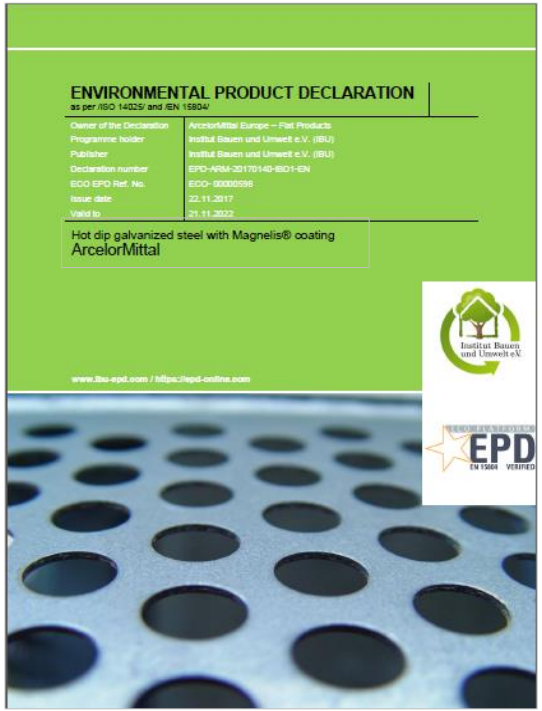
Flagship Solar Supply Chain Sustainability Initiative Launches Public Consultation

Today, the Solar Stewardship Initiative (SSI) has opened a process for interested organisations to provide feedback on its development.

MAY 17, 2023 SOLARPOWER EUROPE

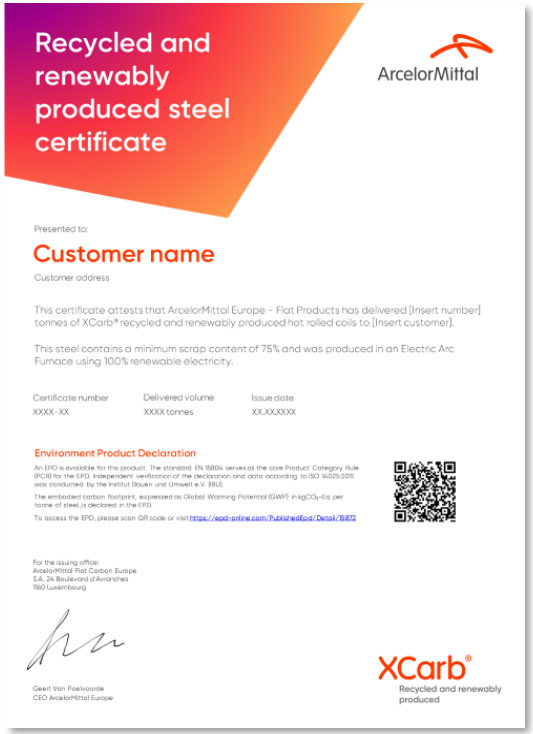
PARIS2015
UN CLIMATE CHANGE CONFERENCE
COP21·CMP11

1st environmental benefit: at design stage, Magnelis® can be produced with -70% less global warming potential thanks to our XCarb® recycled and renewable offer



Standard Magnelis® global warming potential

2570 kg CO_2e/ tonne



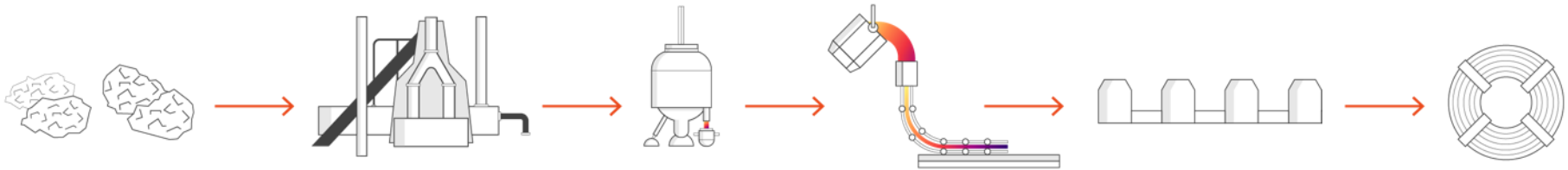
- 70%

XCarb® Magnelis® global warming potential

797 kg CO_2e/ tonne

ArcelorMittal

From the traditional steel making route based on mining…



1.

Iron ore / coal

Iron ore is processed to sinter and pellets

Coal is being transformed into coke.

2.

Blast furnaces

In the blast furnaces, iron is produced by reducing iron ore with coke and coal.

Transforming the iron making process is at the core our decarbonisation strategy

3.

Basic oxygen steel plant

By blowing pure oxygen into the liquid iron, iron is transformed into steel.

4.

Casters

In the continuous casters, liquid steel is poured into slabs of steel.

5.

Hot strip mill and cold mill

The steel slabs are rolled into coils of steel.

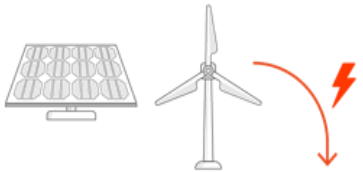
6.

Coil of steel.

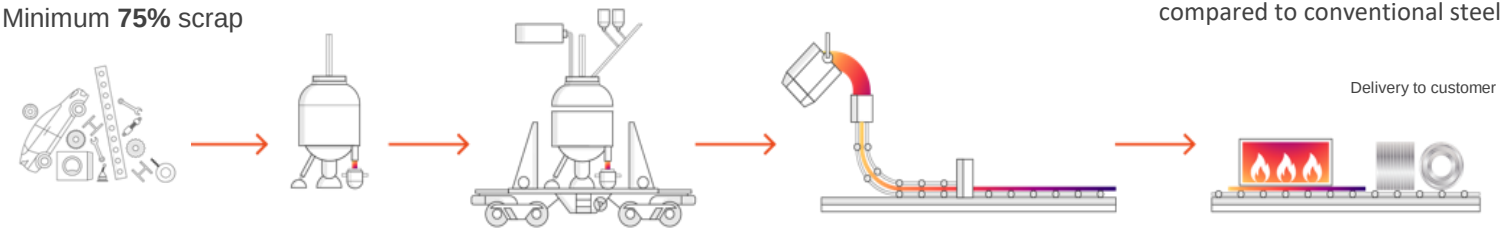
… to XCarb® recycled and renewably produced

Electric Arc Furnace (EAF) steelmaking process

100% renewable electricity



Minimum **75%** scrap



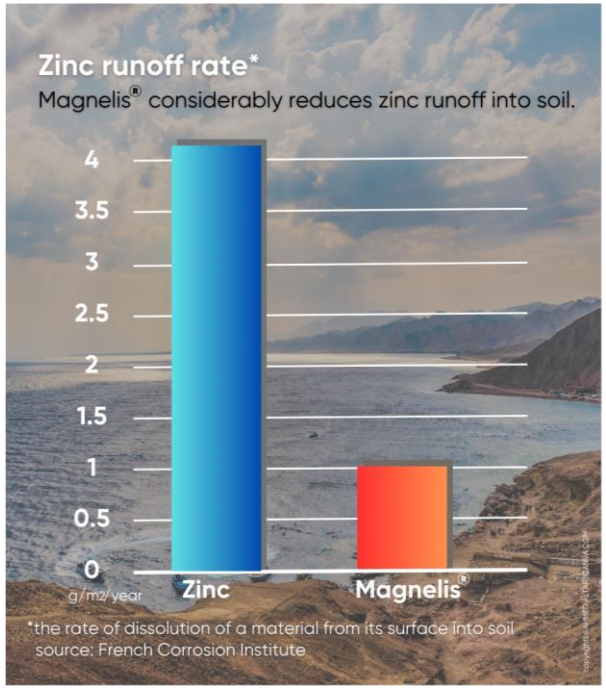
XCarb®
Recycled and renewably produced

60-75% CO2 reduction compared to conventional steels

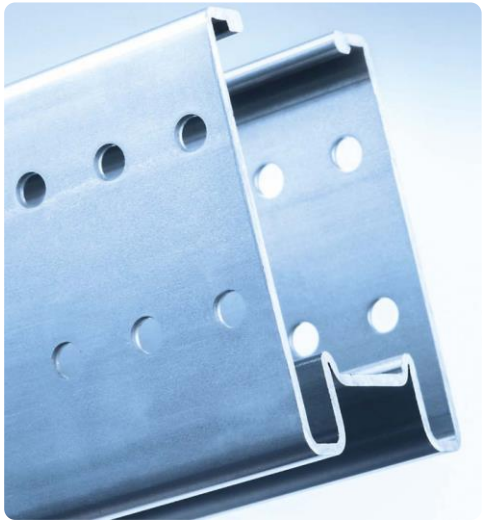
Delivery to customer

ArcelorMittal

2nd environmental benefit:
during service lifetime, Magnelis® properties drastically limit run-off in soils



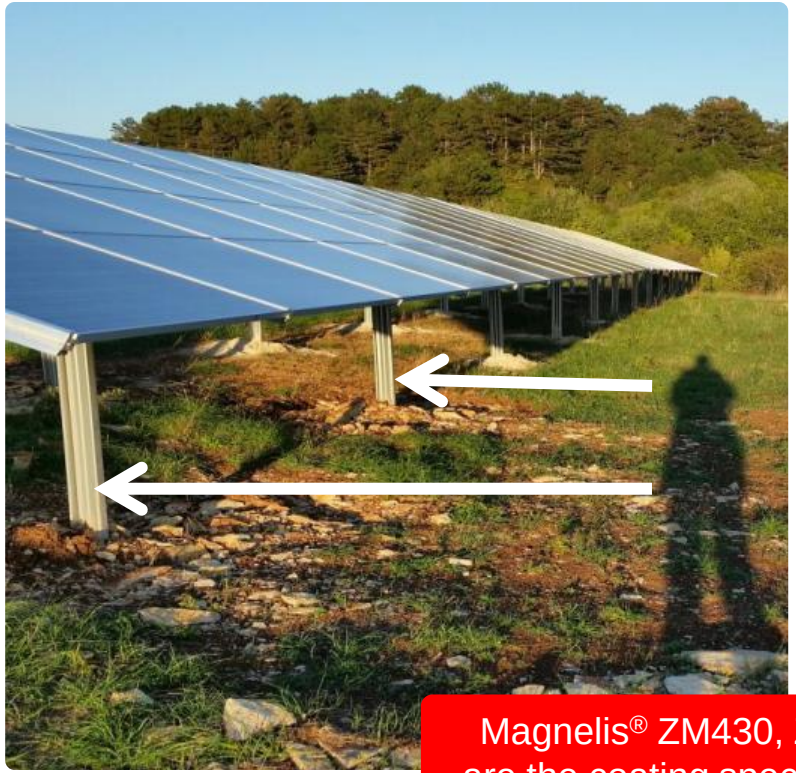
3rd environmental benefit:
steel is indefinitely recyclable and Magnelis® is REACH compliant



Protected by Magnelis®

COMPLIANT · COMPLIANT REACH

Magnelis® continuously hot dip coated steels can be used for any type of foundations: driven piles, embedded into concrete pads, etc.

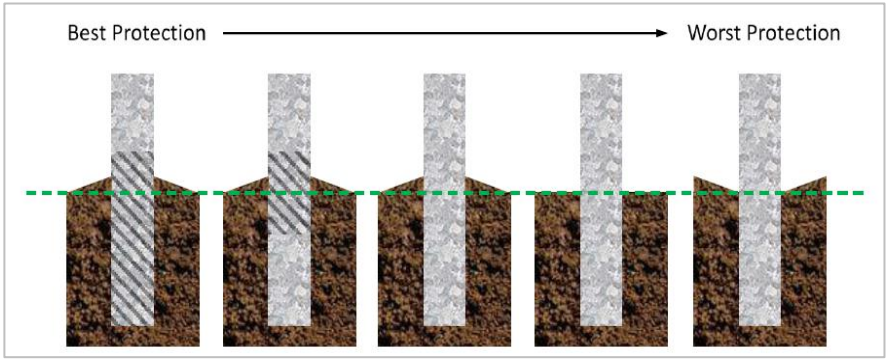


Magnelis® ZM430, ZM620 or ZM800 are the coating specifications for poles

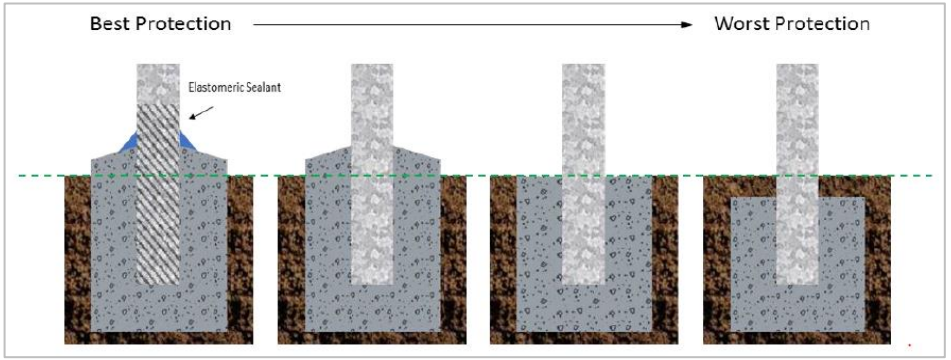
Valid for pre- or post- galvanised poles in soils or in concrete.

Good practices to ensure longer durability of piles

Driven piles



In concrete



In concrete:

- Avoid accumulation of water at the bottom of piles by creating slope of concrete surface
- Due to contraction of concrete, dilatation of steel, apply sealant at the steel / concrete interface

In soils: apply surface treatment (epoxy mastics, elastomeric polyurethan or bituminous paint ….) in the transition area

At the top / head of driven piles: apply Zinc rich paint (spray or brush)

Magnelis® continuously hot dip coated steel is becoming a global product

→ 5 production lines in Europe + 2 new lines in Brazil & India (AM-NS) in 2024

→ Large capacity offer for the largest solar projects

Magnelis® is available globally via ArcelorMittal's international sales network

Proven benefits of Magnelis® continuously hot dip coated steel for PV foundations rammed poles

Take-aways!

1. **Foundations are key for solar mounting structures and deserve special care:**
   - Mechanical stability
   - Durability versus corrosion
   - Project timing management (1st to be installed onsite)
   - Costs (≈1/3 of structure weight)

2. **Magnelis® pre-coated steels can advantageously replace traditional batch hot dip galvanised poles.**
   - Magnelis® is a more efficient protective coating than pure Zinc / layered coating
   - Magnelis® combined with High Strength Steels offers a lot benefits for driven piles: faster ramming, delayed refusal, less deformation at the top & less repairs. Optimising the C-channel section, allows further material saving.
   - It exhibits lower Zn run-off. Further CO_2 reduction achievable thanks to XCarb® recycled and renewably produced low-carbon emissions steel.

3. **Magnelis® for poles has already been adopted by multiple mounting structure companies.**

4. **Magnelis® availability is enlarging in Europe, Brazil & India in 2024.**

Do not hesitate to contact us to optimise your next projects!

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