Influence of pre-treatments on the corrosion of bare and painted AA6082 aluminium alloys for marine applications

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Introduction & State-of-the-Art

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- Aluminium parts for automotive, architecture and aerospace, are typically coated in production lines with chemical pre-treatment and automated paint application or powder coating.
- In many marine applications under atmospheric and splash zone exposure, no protective coatings will be required for aluminium from the corrosion point of view.
- However, due to other requirements, e.g. signal colours or uniform appearance, coatings are still applied and should have a high durability.
- As a consequence, in marine constructions aluminium will often have to be coated under harsher, less controlled conditions in a similar manner to the rest of the construction, i.e. by blast cleaning and spray coating.

Motivation

- Procedures for blast-cleaning and spray painting of structural aluminium (and coating repair in the field) do not exist and need to be developed.
- Pretreatments can have adverse effects on the corrosion resistance of the substrate due to severe mechanical deformation or transfer of contaminations from the blasting material.

  ➡ How do they effect corrosion of the bulk material and performance of paints?

- Garnet, the current standard blasting process, is not the most environmentally benign process, as the garnet needs to be disposed after use.

  ➡ Are alternative blasting processes with similar or better performance available?

- Sustainability, requires proper and long-lasting repair treatments.

  ➡ What are the best repair options?

Experimental: Pretreatments & Paint

Sample manufacturing/ preparation

- Deliver, clean, cut, mark, drill and thread all samples.
- Regarding the pre-experiments: approximately 400 samples

Surface pre-treatment

- Degrease, grind, brush and blast-clean all samples.

Sample coating/handling

- Clean prepared samples with compressed air
- Mark, sort, separate and fix samples for coating application
- Coating application
- Pack samples and delivery to the project partners in Europe

Experimental: Pretreatments & Paint

Six different pretreated AA6082 substrates with and with paint application were received from Muehlhan

Pretreatments

- Garnet blast-cleaning: GMA garnet; particle size: 0.25 to 0.60 mm, ground coverage: 25-30 m2/h, pressure 4 to 7 bar
- Hybrid blasting: GMA garnet; particle size: 0.25 to 0.60 mm + Dry-ice pellets; particle size: 2.0 to 3.0 mm, ground coverage: 6-8 m2/h, pressure 4 to 7 bar
- Glass-grit blasting: Abrasive VB4; particle size: 0.80 to 1.50 mm, ground coverage: 25-30 m2/h, pressure 4 to 7 bar
- Angle grinder with corundum (Al_2O_3) disc, 80 mesh, max. 12300 rotations/min
- Angle grinder with stainless steel cup brush, 0.3 mm wavy brushes, max. 8500 rotations/min
- Bristle-Blaster (stainless steel belt), 0.7 mm, 2500 rotations/min

Paint application

Spray coating: „Jotamastic 90“ (DNV Category II), 1-layer epoxy coating, 250 µm dry film thickness

Experimental & Characterisation Techniques

- Morphology: Tescan Vega microscope, equipped with EDX detector (eumeX Instrumentebau GmbH)
- Roughness: Laser scanning confocal microscope (LMS 800, Zeiss) with ConfoMap®ST software (ISO 4287)
- Adhesion: Elcometer F510-20T (ISO 4624)
- VDA: DIN EN ISO 11997-1, Zyklus B (formerly VDA cyclic climate test 621-415) **with neutral artificial seawater** (up to 12 weeks)**:**

  24 h SST acc. to DIN EN ISO 9227 NSS (artificial seawater)

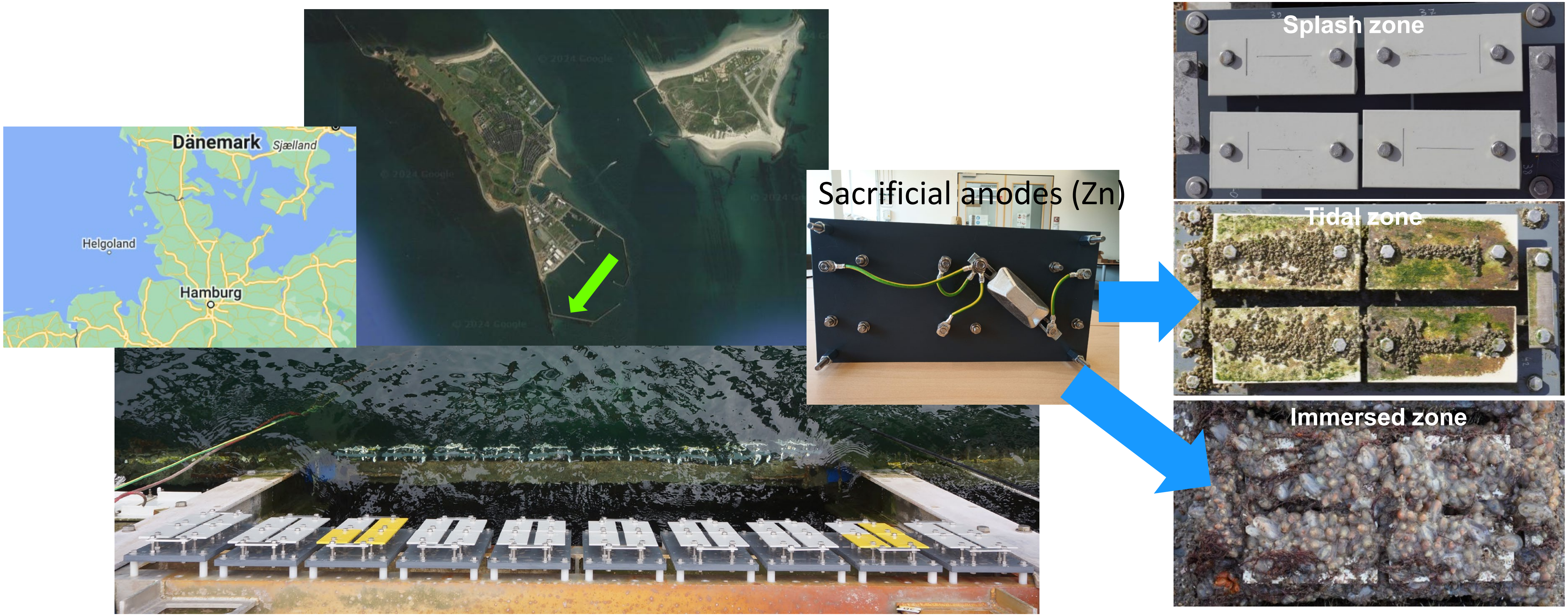
  96 h condensed water 40°C acc. to DIN EN ISO 6270-2 CH

  48 h standard climate 23°C acc. to DIN 50014

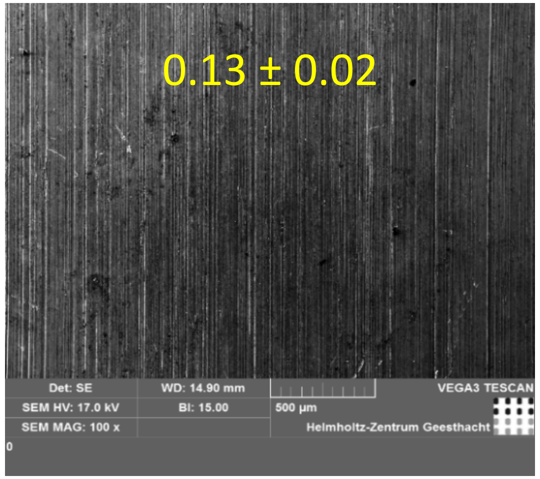
- Filiform corrosion (up to 6 weeks): ISO 4623-2
  (modified – HCL was dripped into the scratch and wiped-off after 1 min)

Experimental & Characterisation Techniques

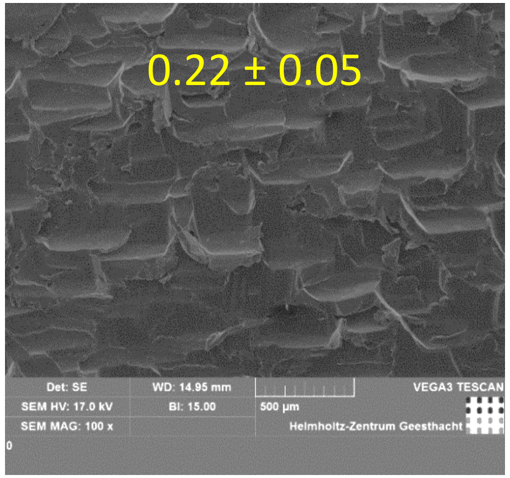
Outdoor exposure of selected coated specimens
(2 years Helgoland (harbour), north sea, Germany)



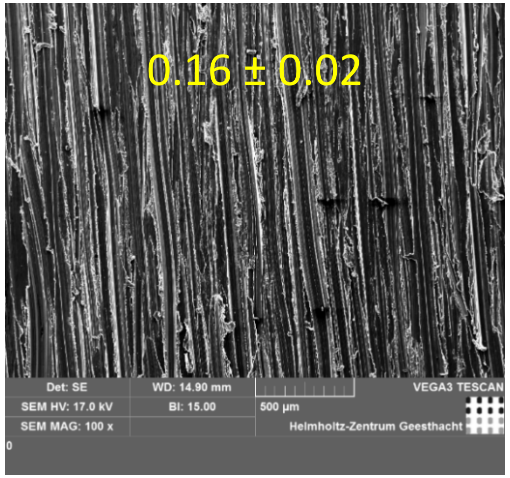
Surface pre-treatment methods: Morphology and iron content



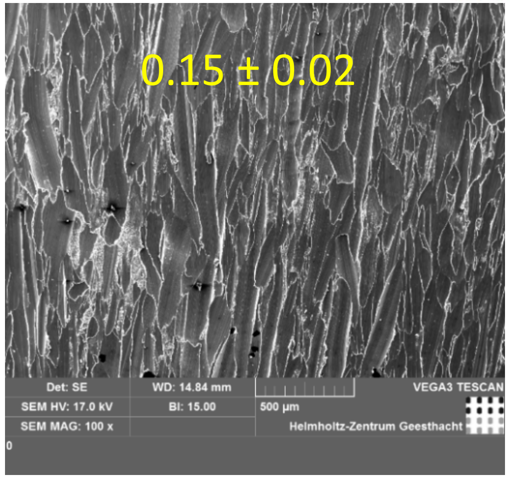
As received



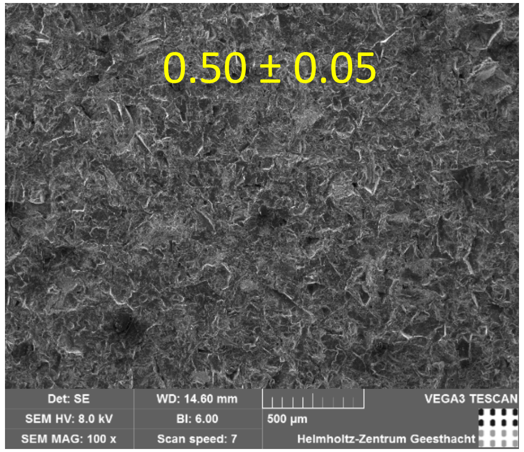
Bristle-Blaster



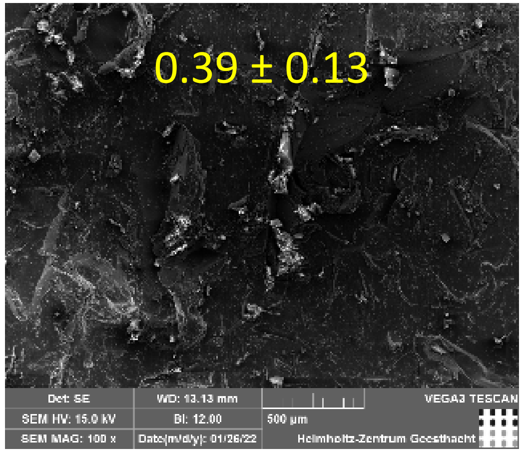
Grinding disc



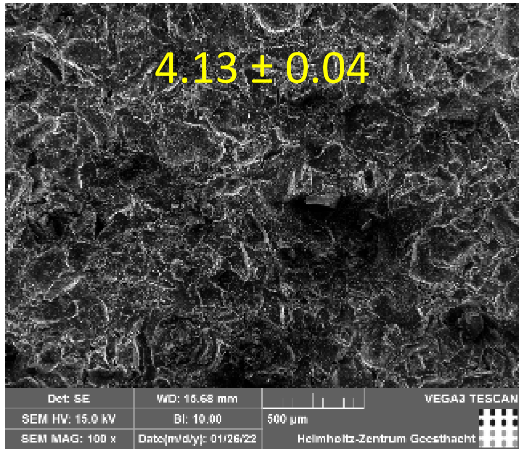
Steel brush



Hybrid blasting
(Garnet & Dry Ice)



Glass grit blasting

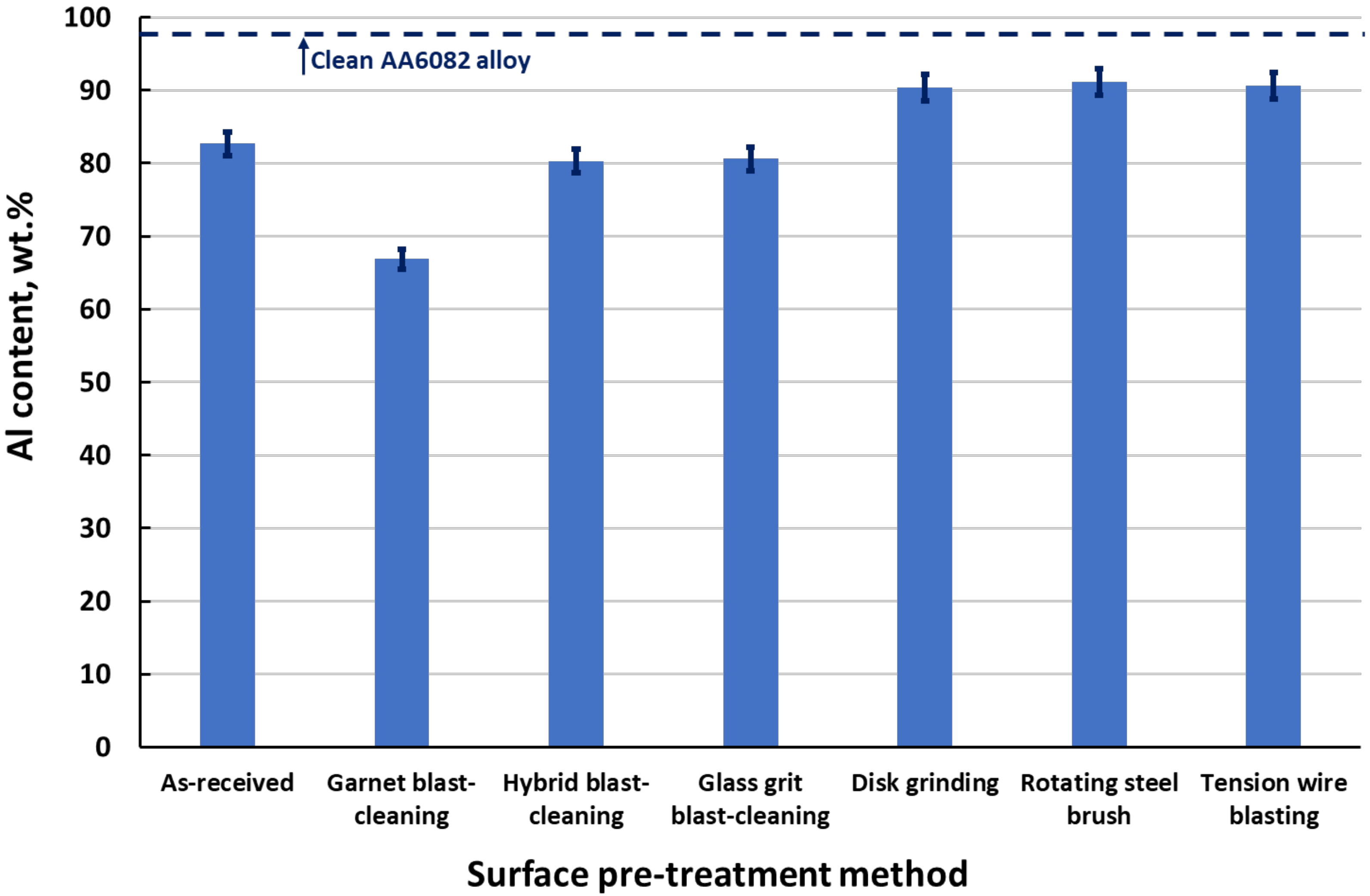


Garnet blasting

Iron content in wt.%,
5 points average,
ca. 1.5 x 2 mm area

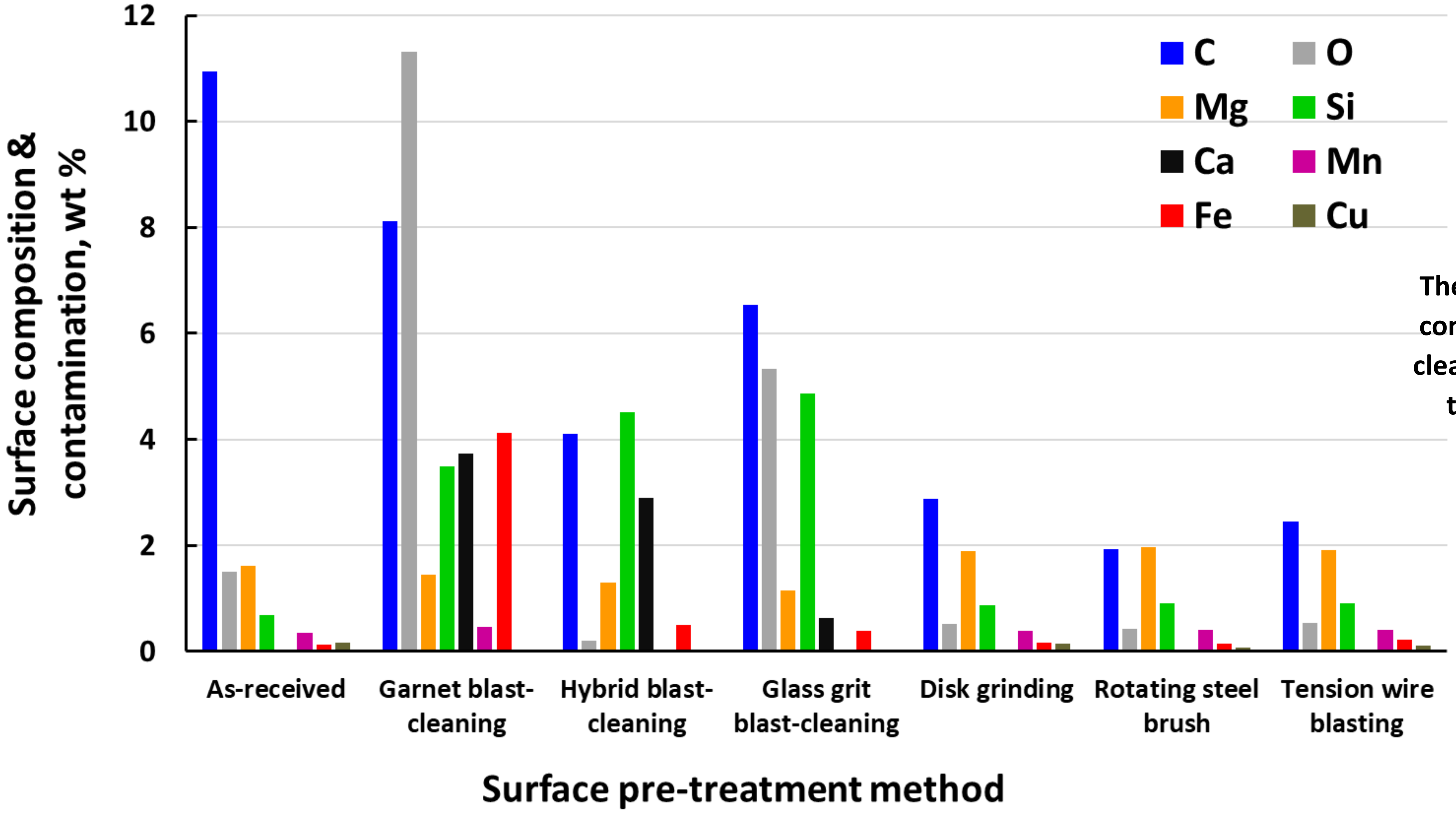
Repair:directed, anisotropic surface morphologies
Blasting: irregular, isotropic surface morphologies

Surface pre-treatment methods: Surface analysis with EDX



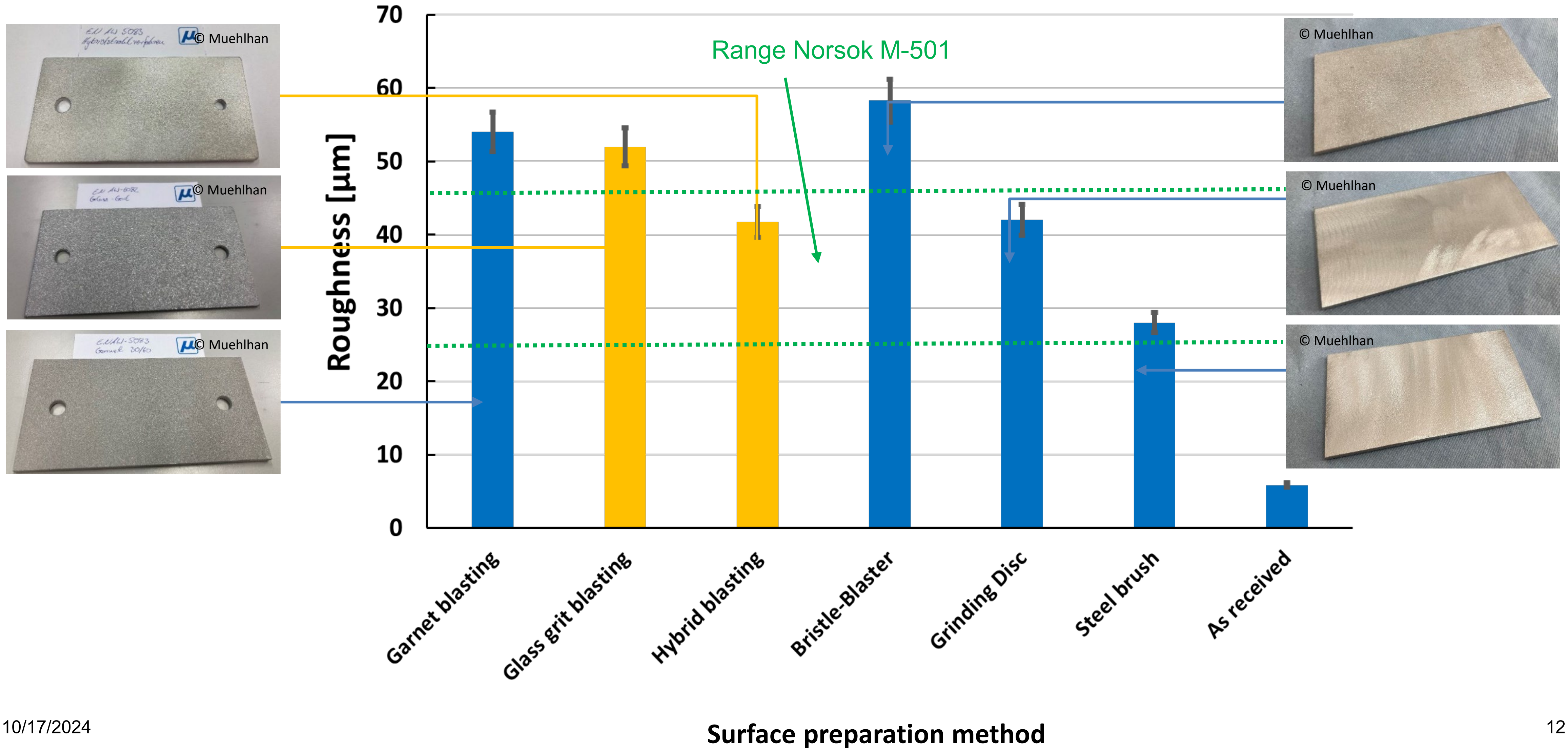
The clean alloy has an Al content of 95.2 to 98.3%

Surface pre-treatment methods: Surface analysis with EDX

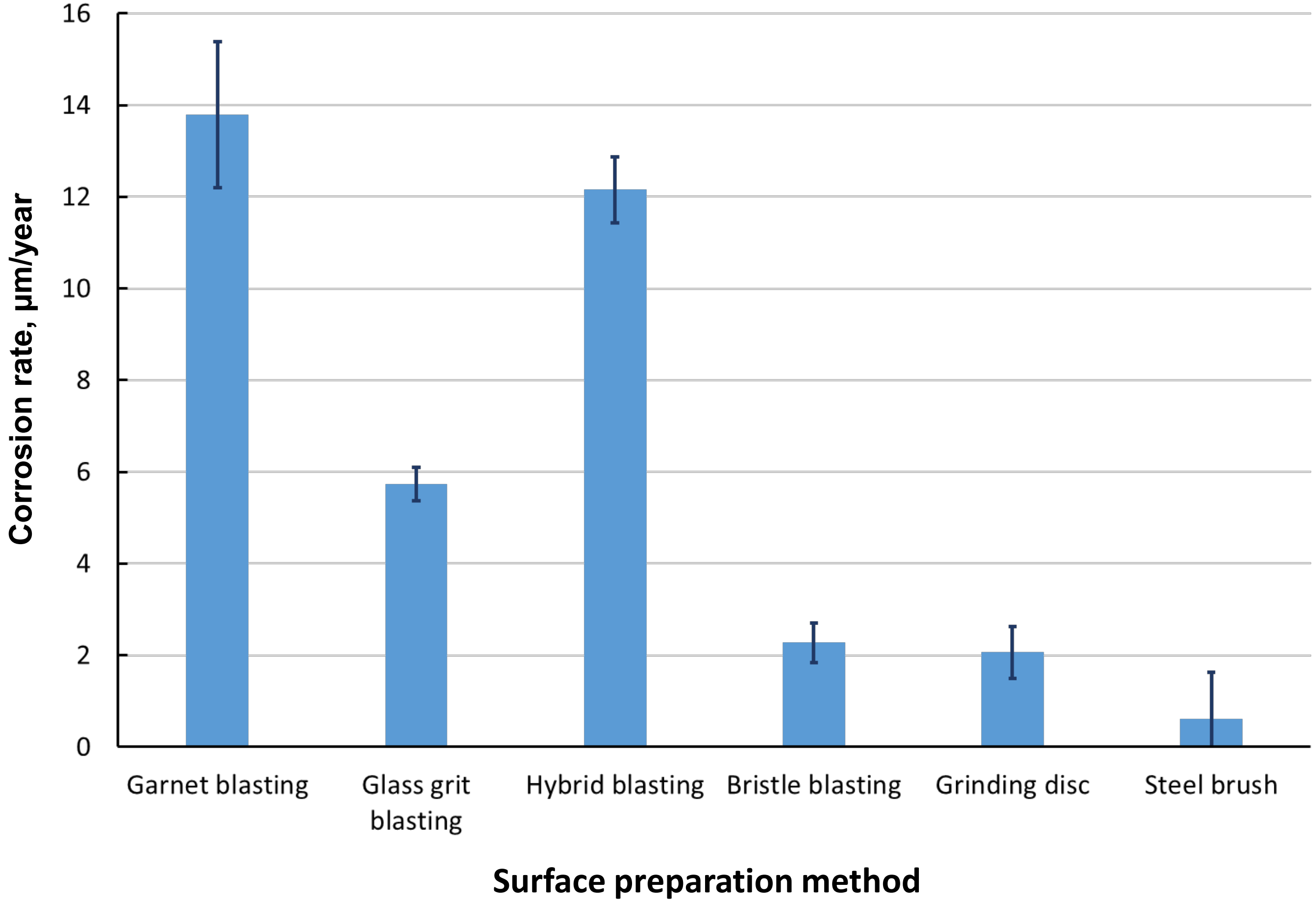


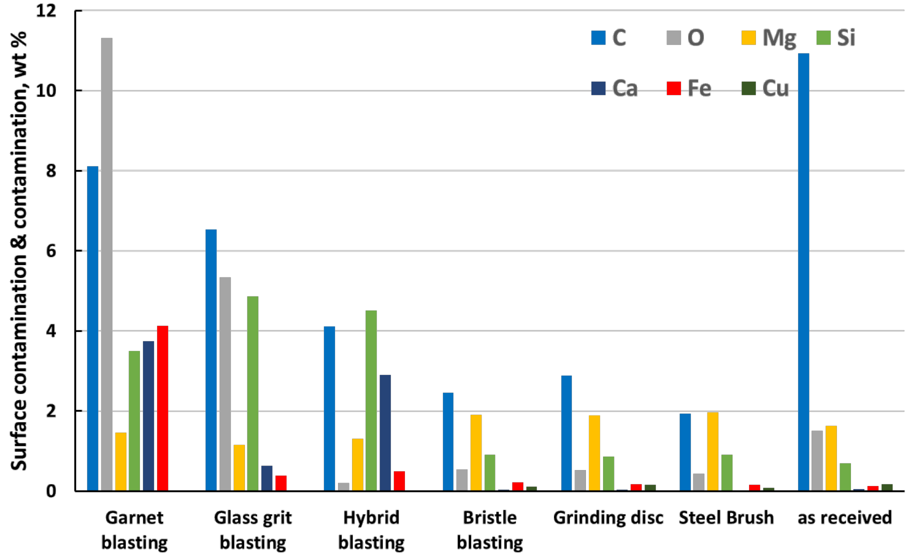
The as received condition is not clean: carbon on the surface

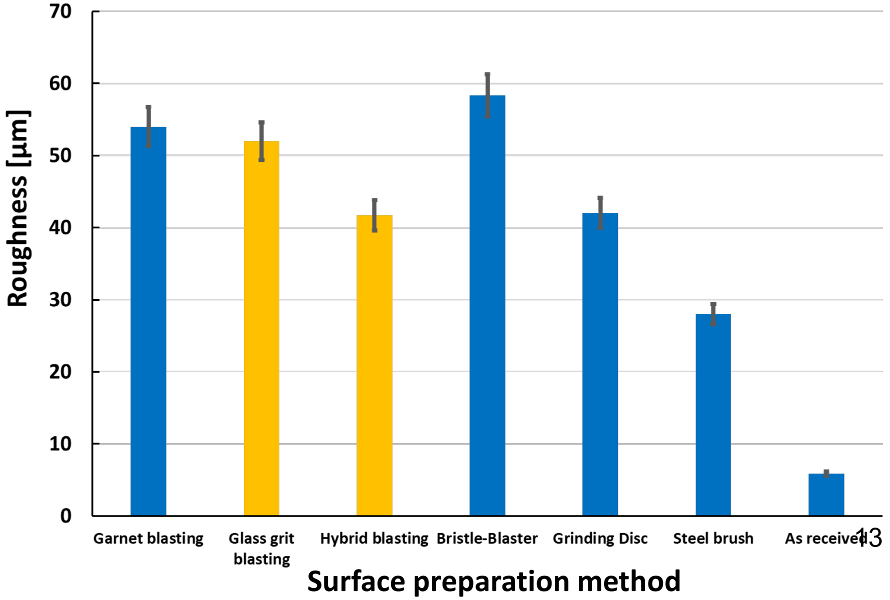
Surface roughness after different surface pre-treatments



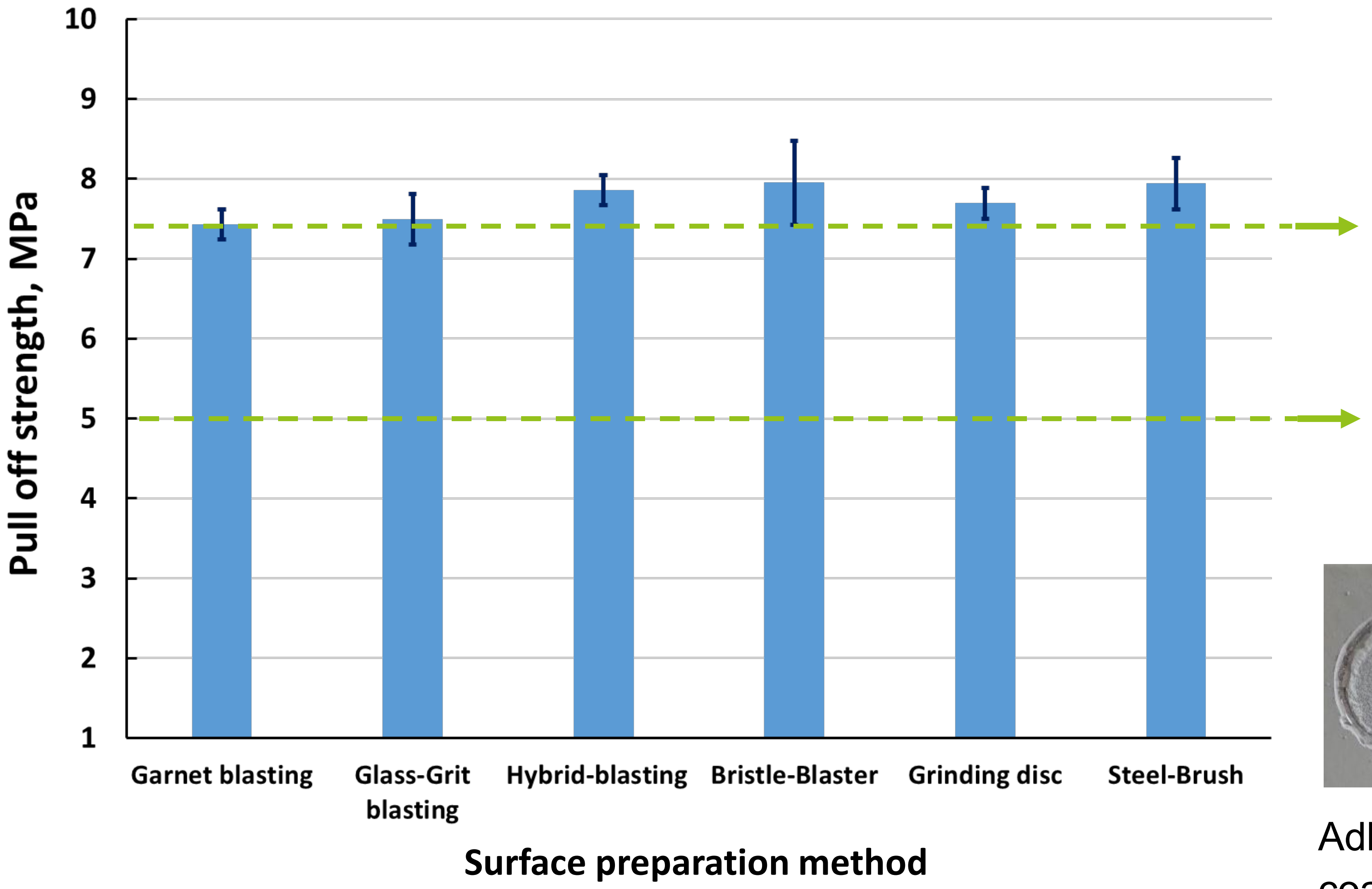
SST (VDA): Results for prepared surfaces







Adhesion of not corroded coated specimens



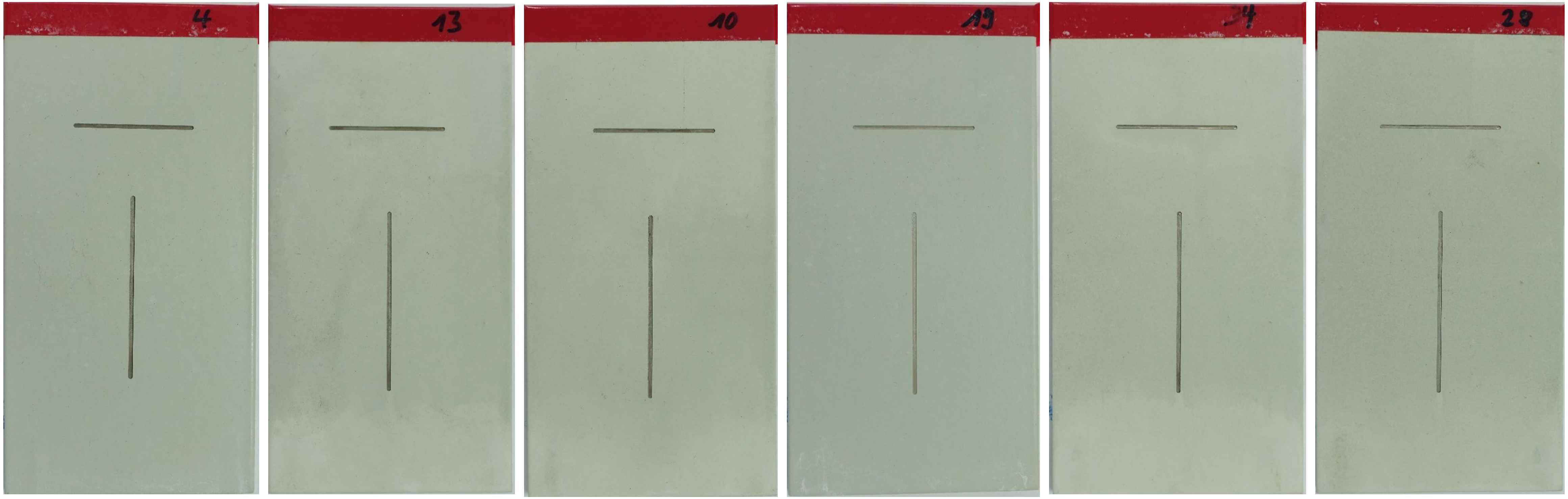
Garnet used as a reference for other methods

Limit: 5.0 MPa
(ISO 12944-9)
(Norsok M-501)

Adhesion failure close to the metal coating interface for all specimen

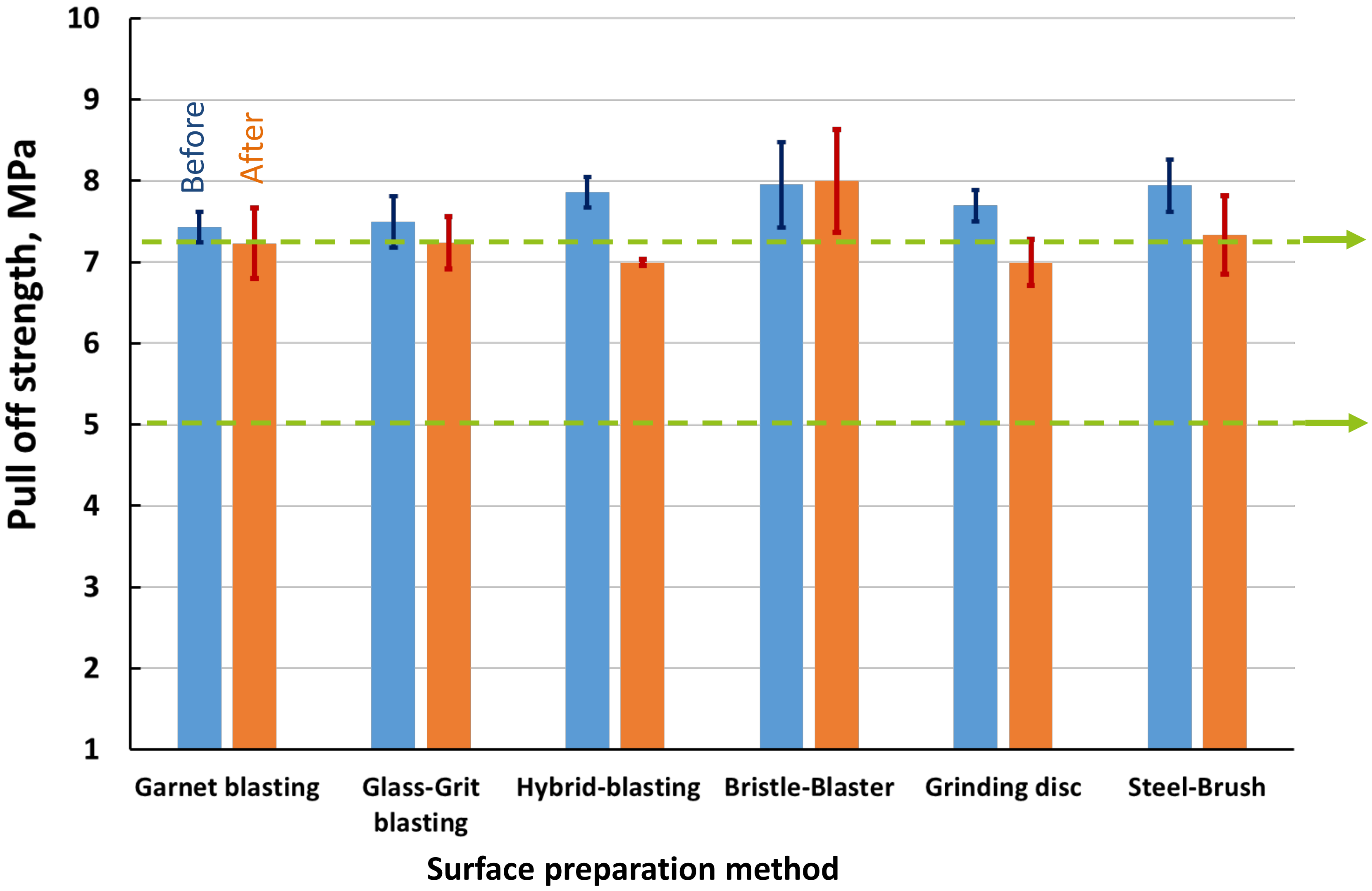
Coated surfaces after VDA testing (3000 hours)

Garnet blasting | Glass grit blasting | Hybrid blasting | Bristle-Blaster | Grinding disc | Steel Brush



5 cm

Coated surfaces after VDA testing (3000 hours)

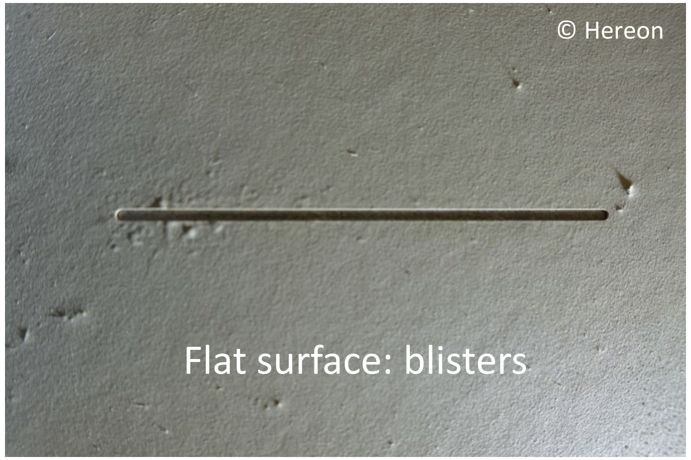


Garnet used as a reference for other methods

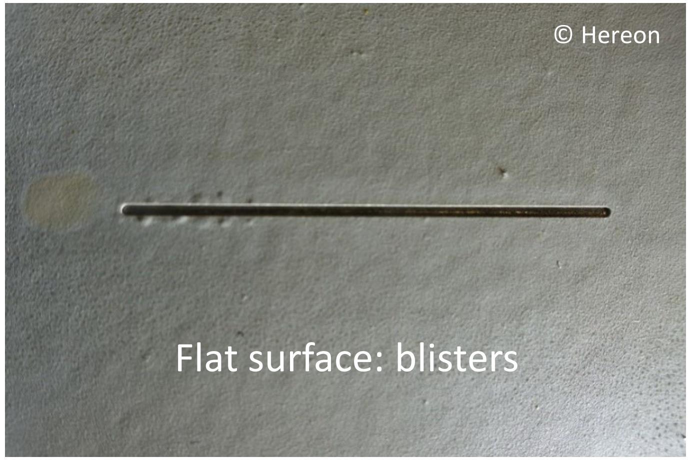
Limit: 5.0 MPa
(ISO 12944-9)
(Norsok M-501)

Filiform tests on prepared coated AA6082 substrates (delaminated area in %)

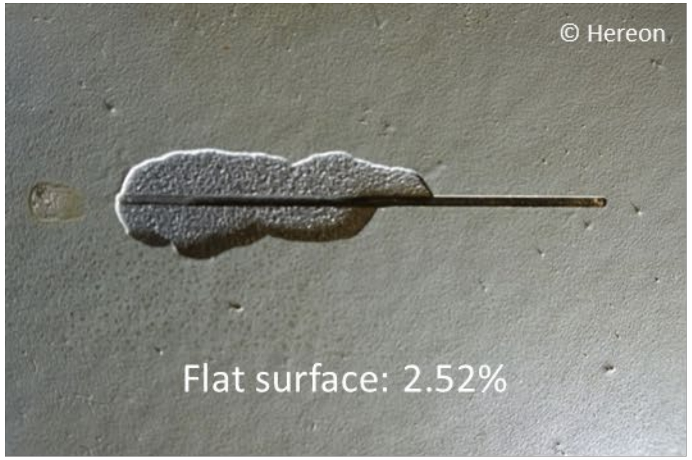
Glass blast-cleaning



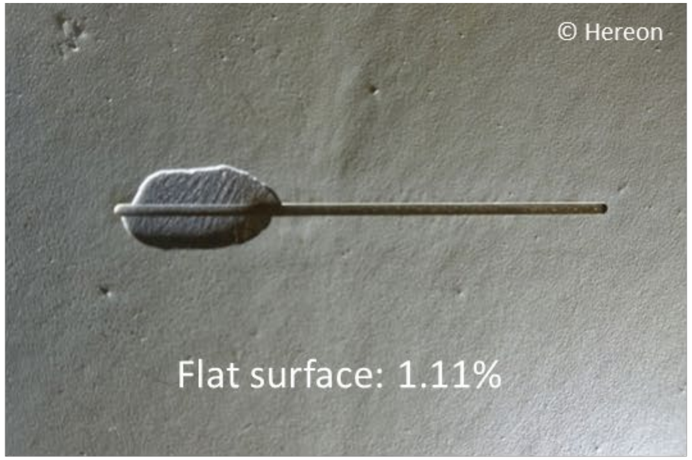
Garnet blast-cleaning



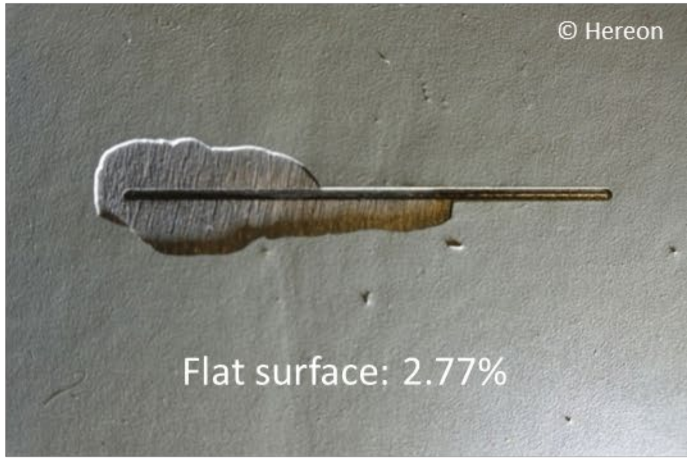
Hybrid blasting



Bristle Blaster

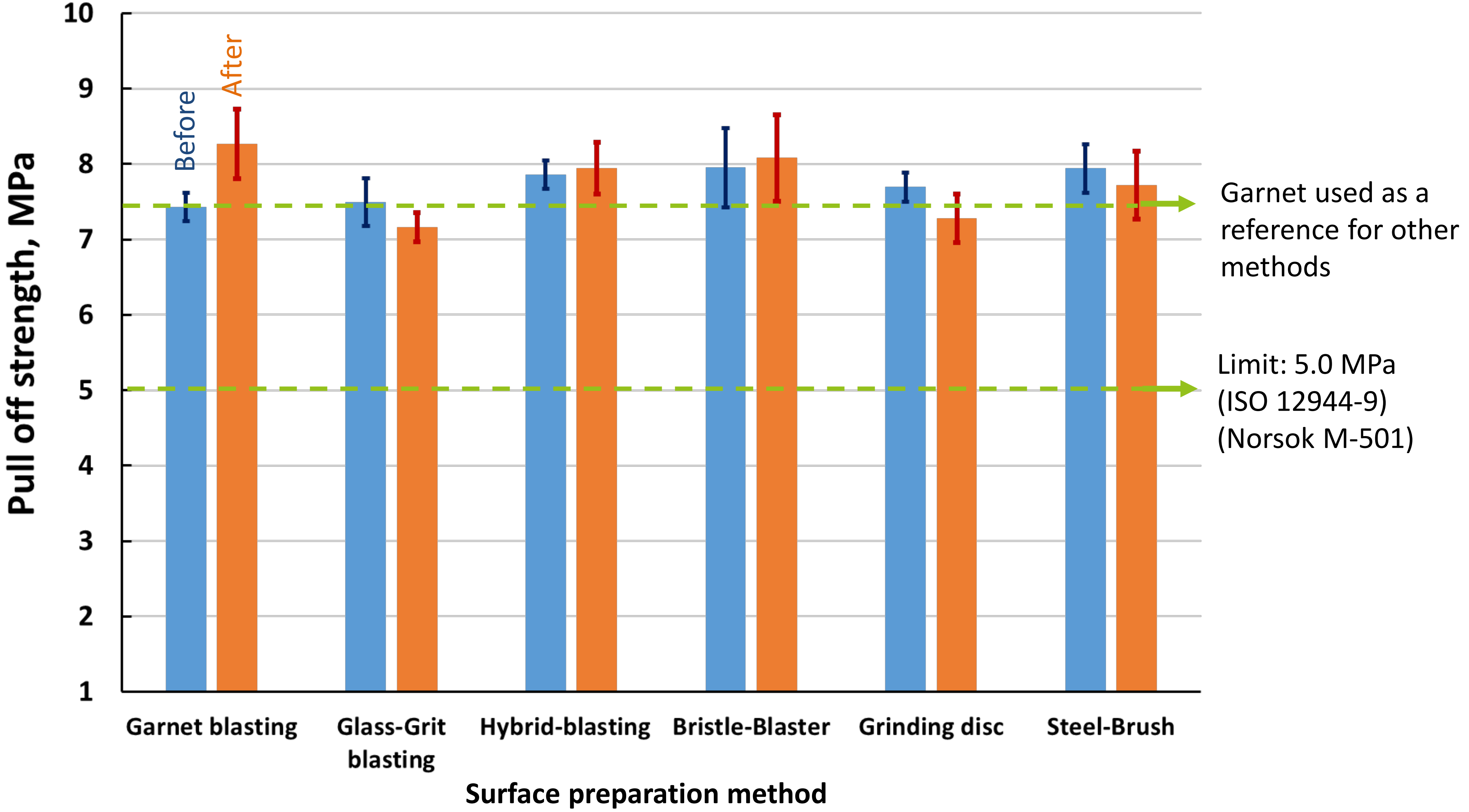


Steel Brush



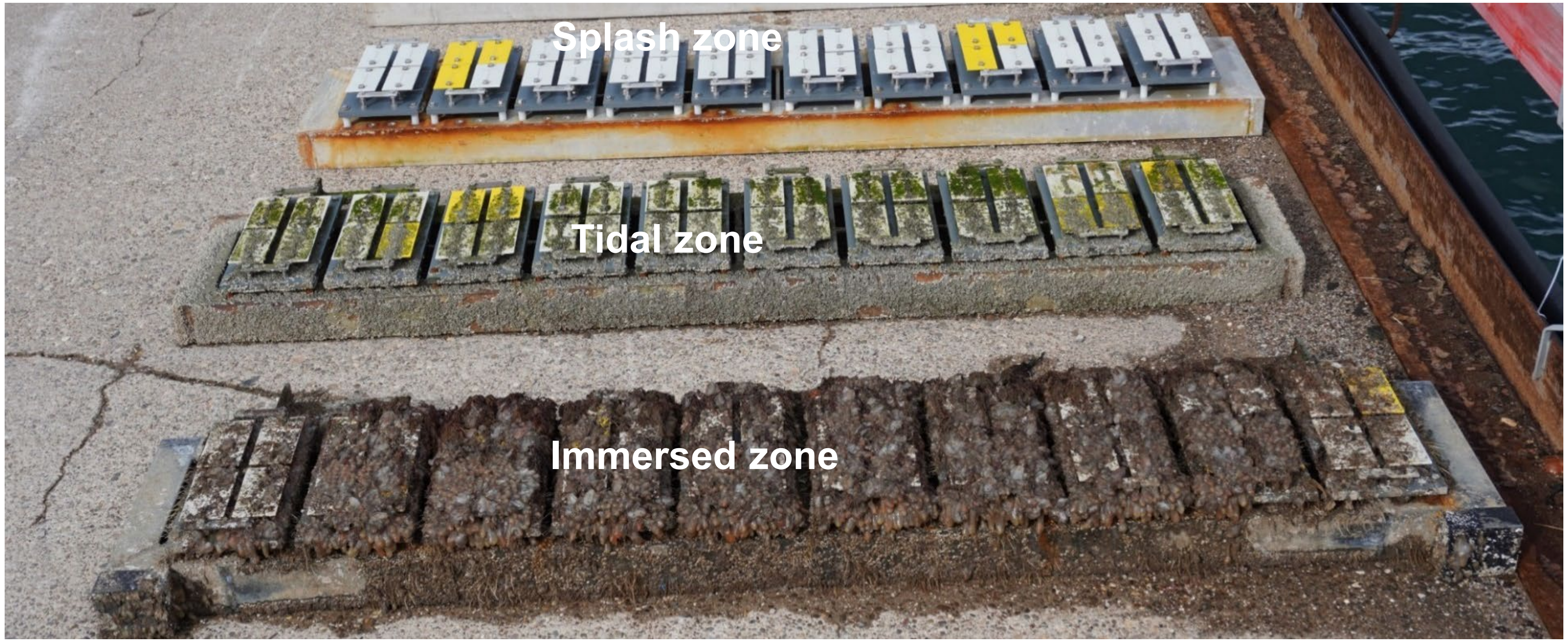
Rotating disc

Coated samples after filiform corrosion testing



Field test Helgoland

Samples at Fraunhofer Test Side at Helgoland after 24 months of exposure



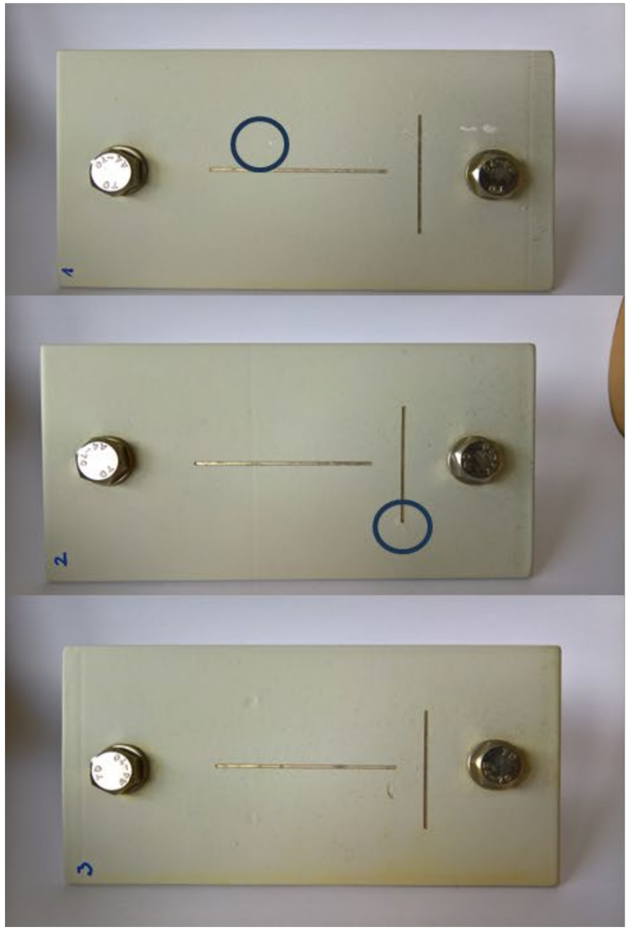
Splash zone: Coated panels with garnet blasting, hybrid blasting and bristle blaster pretreatment

Tidal zone: Coated panels with garnet blasting and bristle blaster pretreatment

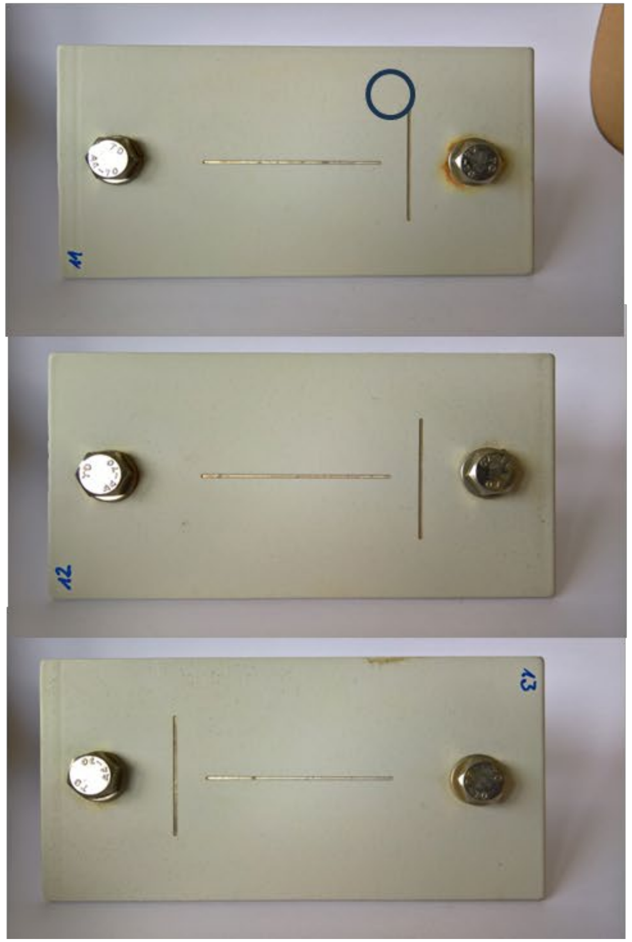
Immersed zone: Repair is not likely and no comparision was done

Coated surfaces after outdoor exposure (Helgoland, splash zone, 2 years)

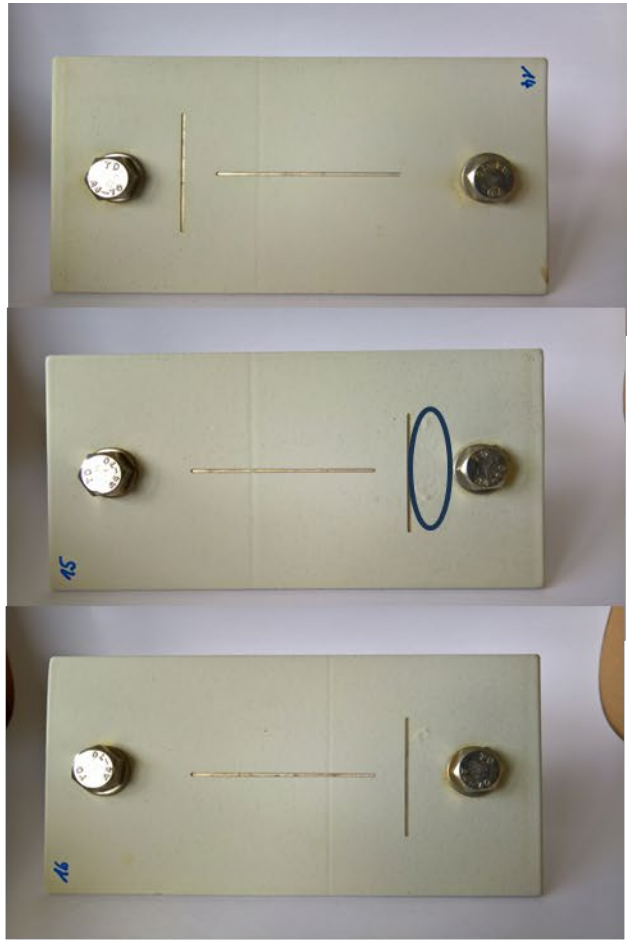
Garnet blasting



Hybrid blasting



Bristle-Blaster



Minor defects (blister) in all coatings – no significant differences for the pretreatments

Coated surfaces after outdoor exposure (Helgoland, tidal zone, 2 years)

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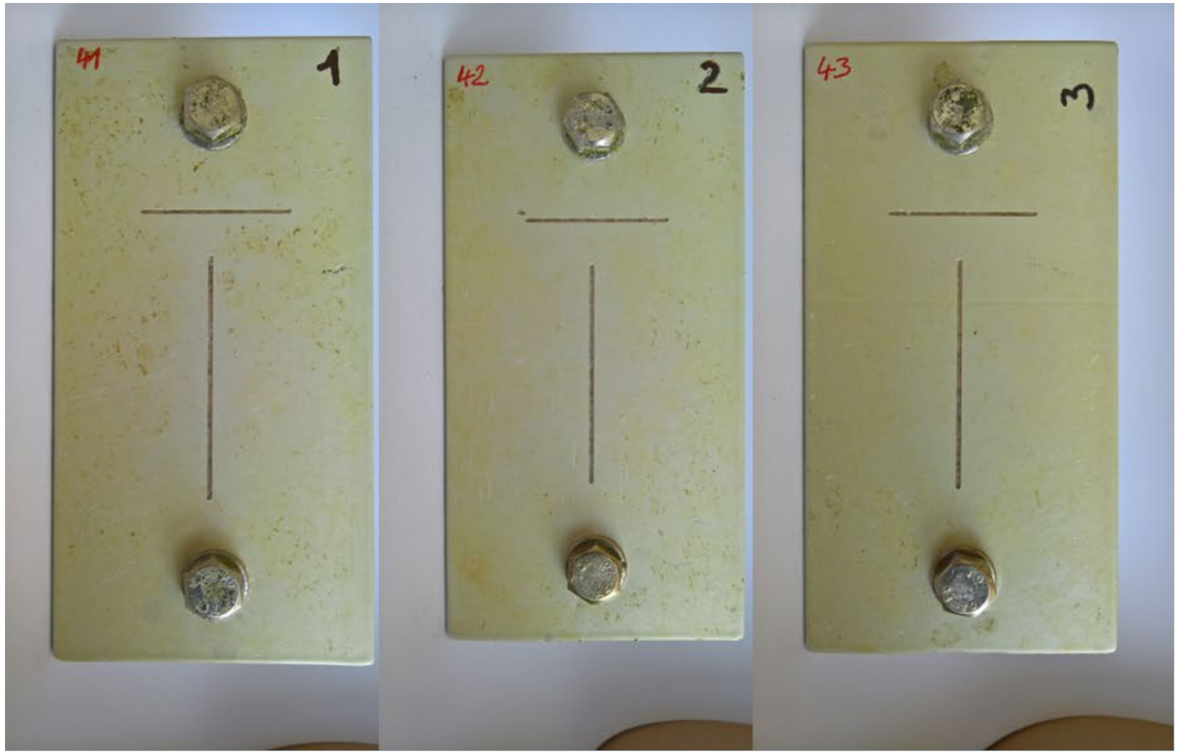
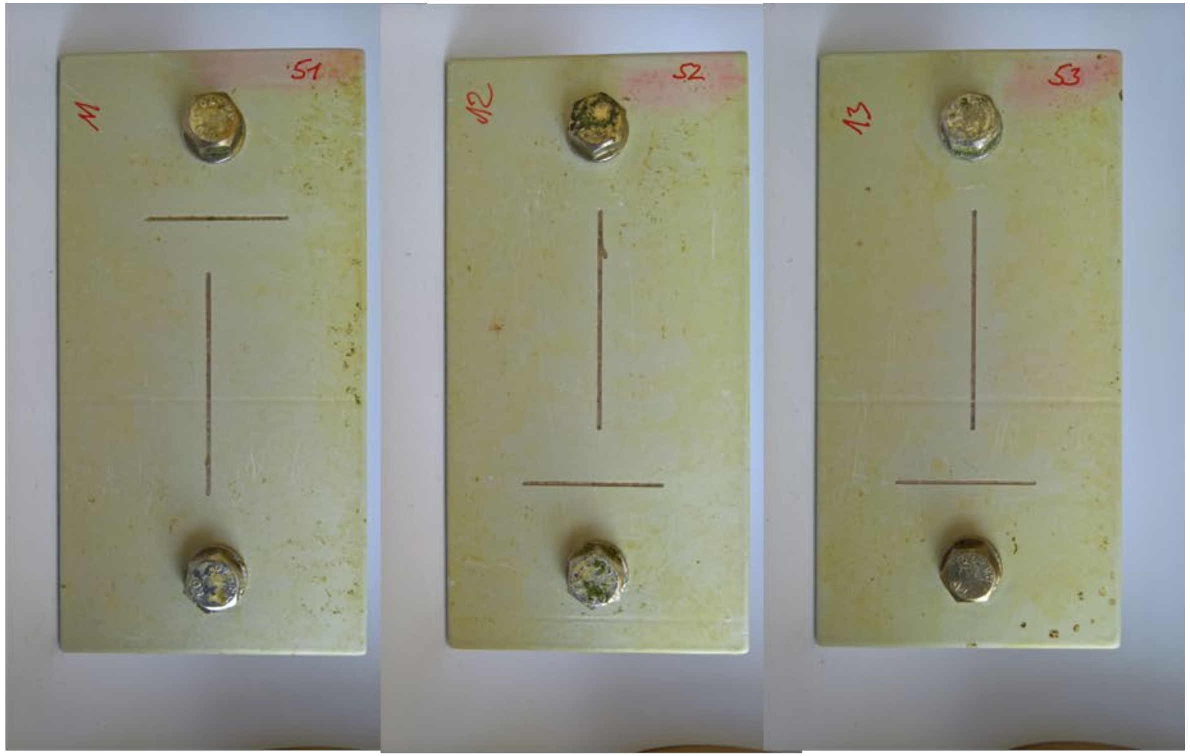
Garnet blasting



Bristle-Blaster



7.5 cm

No defects at all in the tidal zone

Conclusions – Bare substrate

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- The pretreatments do have an influence on the surface morphology and composition of the aluminium surface:

  Grinding tools: cleaner surface, more regular, directed surface morphologies

  Blasting processes: less clean surfaces, because of up-take of the blasting components, irregular surface morphologies

- Corrosion: performance after blasting is worse, but unsure if it is related to the surface roughness or the impurities, overall performance is still excellent in the VDA test
- Paint adhesion: no clear influence of the pretreatments prior to corrosion testing

Conclusions – Coatings

Lab testing

- Only the filiform test allows a differentiation between blasting processes (blisters around the artificial scratch) and grinding tools (total loss of adhesion close to the defect) – larger damaged area in the case of grinding processes
- The more regular directed surface morphologies are more prone to underpaint migration (Lab)

Field testing

- Conditions in the splash zone are more severe than in the tidal zone
- Corrosion damage in the field is less severe than in the filiform lab test

Lab vs. Field testing

- VDA test is too mild and filiform test to severe compared to the field test; Latter allows to indicate trends of performance and mechanisms

General Conclusions – Coatings

- The AA6082 alloy is quite tolerant regarding the surface condition prior painting.
- Substrate corrosion has, if at all, only minor influence on the paint performance.
- Mechanical interlocking seems to be more important than the cleaner surface, remains of blasting material is neglectable regarding paint performance.
- Overall, alternatives exist for Garnet blasting to reduce environmental impact, but all three repair methods show a more detrimental performance based on filiform test.
- A similar more detrimental performance was not seen in the field tests. Significant differences between blasting and repair processes could not be confirmed.
- Sacrificial anodes (Zn) can prevent corrosion and paint degradation of scribed panels in the tidal zone.

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Many thanks for your attention!

- Are there any questions?

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SINTEF

Hydro