High-strength weathering steel for bridge construction

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SSAB Europe
27.04.2022
Siltatekniikan päivät
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Patina formation process

- Frequent cycles of wet and dry weather conditions will speed up the patina formation process.
- To maintain an even patina, it’s recommended that water can run off freely and not stay on the surface. In a sheltered location with damp conditions, COR-TEN® may not adopt the intended color.
- The color changes from fresh, newly developed orange-brown, to light and eventually dark brown.

FAQ

How long does it take the patina to fully develop?

The speed of change and the final color of the steel depend on the atmospheric conditions of a site and the surrounding air quality. Expect 2-6 years for the patina to fully develop.
Corrosion aspects of Weathering & steel

• The corrosion resistance of weathering steels is based on preventing the penetration of water and oxygen to the steel surface.

• A more uniform and dense oxide layer, FeOOH, is formed. Enrichment of alloying elements are beneficial for oxide layer formation.

• The pores in the rust patina are plugged by the formation of insoluble sulphates originating from atmospheric pollutants SO$_2$.

• In ordinary steel the oxide layer is inhomogeneous. Fractures and pores enable rust to proceed gradually.
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Weathering steel for bridge construction in the world

► According to construct steel "It is estimated that up to 45% of steel bridges globally are constructed utilizing some form of weathering steel”

► Share of weathering steel bridges around the world

- USA ~40–50% of steel bridges (~10000)
- Japan ~20% of all bridges (~7000)
- UK ~10% of steel bridges
- Europe - Weathering steel’s usage in bridges is growing

Track record of weathering steel in bridges in Finland

> 90 weathering steel bridges built till date in Finland.
Weathering steel bridges have been performing very well in Finland for >45 years (Tervolan Silta).

Numbers of weathering steel bridges built in Finland

Source: Siltojen rakentamisen ja korjaamisen seuranta, 2005 & Väylävirasto ; * planned so far
Performance of weathering steel bridges in Finland

Bridges in Finland: Cumulative corrosion loss of 32 years (1982–2014), material COR-TEN B


Development of corrosion loss (µm/a) over the lifetime
Road bridge over lake subjected to de-icing salt – 0.6 tons of salt used /year

Built with COR-TEN® B
Where: Mikkeli, Finland Length: 148 Mtrs
Built in year: 1979
Road bridge over lake subjected to de-icing salt – 1,48 tons of salt used /year
Pedestrian bridge over road subjected to heavy de-icing salt since 42 years

Built with COR-TEN® B
Where: Helsinki Finland; Length - 158 mtrs; height -4.9 to 5.4 mtrs; Built in 1979
Longest weathering steel bridge in Finland, 496 mtrs

Built with COR-TEN® B
Where: Tervola, Finland
Built in year: 1975
Award-winning pedestrian bridge in Vantaa, Kuusijärvi

Built with SSAB Weathering 355
Thickness: up to 35 mm, 231 MT Length: 162.2 Mtr Where: Vantaa, Finland
Weathering steel bridge over rail lines in Hyvinkää

Constructed with SSAB Weathering 310 tn
Fabricator: Steelgroup Where: Hyvinkää, Finland Built in year: 2021
Upcoming high strength weathering steel (420ML) bridge in Jokikylä, Oulu

Source: Mt 8460 parantaminen Jokikylän sillan kohdalla, Oulu - Väylävirasto (vayla.fi)
Upcoming weathering steel bridge in Poikkimaantie, Oulu – over rail lines
Weathering steel Bridge over Baltic sea – Vårdö, Åland
Salt content 0,6%

Built with COR-TEN® B
Where: Vårdö, Åland (in Baltic sea)
Built in year: 1979
Suitability of weathering steel for upcoming Hailuoto bridge

- Salinity gradient in Baltic sea from south to north (Bay of Bothnia avg. salinity 1/10th of typical seawater; Baltic sea – 1/5th of typical seawater)

- Distance from coastline restriction to use weathering steel – not applicable to Bay of Bothnia & Baltic sea

- Benefits of considering weathering steel for Hailuoto bridge:
  - No pollution from paint: No risk of polluting Bay of Bothnia (in site painting, re-painting)
  - No pollution from old paint debris – before repainting
  - Less maintenance – no bridge closures for re-painting
  - Proven performance in bridge in Baltic sea (Vårö, Ahvenanmaa)
  - Lower Life cycle costs (LCC)

Source: Picture - Väylävirasto, Fakta om Bottniska viken, The Baltic Sea – FunkVeg (helsinki.fi), reddit, Marine Ecology Progress Series 340:121 (int-res.com), PSU = Practical Salinity Unit; 1 PSU = 1 g/1kg
Upcoming weathering steel bridge in Norway – YA bru

To be built with SSAB Weathering 355 ML

Designer: Norconsult; Fabricator: Prodtex;
Where: South of Trondheim; Length: 48 mtrs

Source: Arne Jørgen Myhre/Statens vegvesen & Prodtex
Upcoming first high strength weathering steel bridge in Norway - Elverhøybru on highway 70 over Driva, Sunndal

Source: https://www.vegvesen.no/vegprosjekter/riksveg/rv70elverhoybrua/
Upcoming weathering steel bridge in Sweden
Tullgarnsbron over Fyrisån, Uppsala

To be built with S355J2W+N from SSAB
Designer: Rundquist; Consultant: PEAB; Fabricator: Bröderna Jansson; Length: 48 mtrs

Source: Tullgarnsbron 11.01 OTB FU 210712 & 11.02 & R_Tullgarnsbron_11 02 FFU gestaltung
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Three ways SSAB high strength weathering steel can reduce environmental impact

► **Use better steel**
  - Reduce your footprint with low CO₂ steel

► **Use steel better**
  - SSAB high strength weathering steels reduces embodied carbon
  - Reduce CO₂ emissions over the life cycle by avoiding painting

► **Go fossil free**
  - Be part of a fossil-free value chain
  - Be the first to offer fossil-free products
Life cycle costs comparison
Carbon steel Vs High strength weathering steel

Source: SSAB’s analysis
Double the interval for maintenance painting
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ECCS guidelines for the use of weathering steel in bridge construction

The European design guide for the use of weathering steel in bridge construction, developed by ECCS (European Community for Bridge Construction and Engineering), provides guidelines for the use of weathering steel in bridge construction. Weathering steel offers many economic and ecological benefits, including reduced maintenance costs and improved durability. The guide outlines the necessary specifications and design considerations for using weathering steel in bridge construction, ensuring safety and sustainability. Key features include:

- Detailed recommendations for bridge design and construction
- Advice on material selection and testing
- Guidance on fabrication, installation, and inspection procedures
- Case studies and examples of successful projects

The guide is a valuable resource for engineers, architects, and construction professionals looking to incorporate weathering steel into their bridge designs. It is available online through various platforms, including steelconstruct.com.
Common considerations while designing bridge structures with weathering steel (1/2)

**FASTENING WITH OTHER MATERIALS**
- Usual fasteners can be used: hot dip galvanized, stainless steel bolts or weathering steel.
- No direct connection to more noble metals like copper to avoid galvanic corrosion. With stainless steel, only small parts like bolts are acceptable.
- When surfaces slide against each other, the surfaces must be insulated from each other by a Teflon strip.

**JOINT DETAILS**
- Correct bolt positioning and tension.
- Connections must be compact to prevent water penetration.
- Structure design: good ventilation between parts is recommended.

**RUST WATER STAIN**
- During the patination process, water in contact with the steel will become rusty until the patina layer is fully developed (typically in 2-6 years).
- Design & detailing to ensure rust water can be collected and lead to drainage in a controlled way.

**SURFACE PREPARATION**
- For hot-rolled products, it is recommended to remove mill scale from surfaces by picking or shot blasting.
Common considerations while designing bridge structures with weathering steel (2/2)

**WET & DRY CYCLES**
Weathering steels require alternating wet and dry conditions
- Avoid designs where water and dirt are collected.
- Avoid contact with soil or vegetation.
- Not suitable for burying or submerging in water.

**DISTANCE FROM SHORE**
Chlorides can destroy protective patina layer
- Minor problem in the area of Baltic sea: avoid direct splashes to surfaces.
- Minimum 1 km from the shoreline of ocean (depending on location).
- The corrosion rate of bare Weathering steels in chloride environments is similar to carbon steel.

**DE-ICING SALT**
Chlorides can destroy protective patina layer
- Continuous use of deicing salt is a risk in tunnel like structure.
- Weathering steel seems to tolerate some amount of deicing salt.
- With proper design & detailing the negative effects can be minimised.
How to minimize the effects of de-icing salt on weathering steel structure

- By considering appropriate corrosion allowance
- By providing sufficient overhead clearance - 5,3 mtrs
- By avoiding tunnel-like construction
- By using less-corrosive salts and corrosion inhibitors (acetates), salt neutralizers near bridges
- Periodical water washing is useful for the maintenance of weathering steel bridges.

Source:
1. FRENCH CEMA Guide
No reduction of fatigue class necessary for welded structure made of weathering steel

Detection of fatigue cracks in weathering steel structures

- Patinated surface of ‘as rolled’ weathering steel has one fatigue class lower as per EN 1993:9:2005.
- Rough patina surface does cause a slight decrease in the fatigue strength of the plain section or sheet of weathering steel, but no reduction is required for the welded or bolted joints that are almost always decisive for the fatigue.

- Electromagnetic acoustic transducer (EMAT) can be a practical ultrasonic testing method.
- Cracks and scratches on flat surfaces can be detected from a depth of 0.3 mm.

Source: EN 1993-1-9:2005
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Introducing the high strength SSAB Weathering TM rolled heavy plates

<table>
<thead>
<tr>
<th>Grades</th>
<th>Euro Norm</th>
<th>Delivery condition</th>
<th>Thickness (mm)</th>
<th>YS (Mpa)</th>
<th>UTS min–max (Mpa)</th>
<th>% EA5 min</th>
<th>Inner bending radius up to 6 mm 90° (t=thickness) ***</th>
<th>Charpy-V impact toughness (Joules) min</th>
</tr>
</thead>
<tbody>
<tr>
<td>COR-TEN® B</td>
<td>N</td>
<td>5–40</td>
<td>345</td>
<td>485</td>
<td>-</td>
<td>19</td>
<td>3.0 x t</td>
<td>-</td>
</tr>
<tr>
<td>COR-TEN® B-D</td>
<td>N</td>
<td>5–40</td>
<td>345</td>
<td>485</td>
<td>-</td>
<td>19</td>
<td>3.0 x t</td>
<td>27J / -20°C</td>
</tr>
<tr>
<td>S355JOW+N</td>
<td>EN10025-5</td>
<td>N</td>
<td>5–100</td>
<td>355</td>
<td>470</td>
<td>630</td>
<td>20</td>
<td>~2 x t</td>
</tr>
<tr>
<td>S355J2W+N</td>
<td>EN10025-5</td>
<td>N</td>
<td>5–100</td>
<td>355</td>
<td>470</td>
<td>630</td>
<td>20</td>
<td>~2 x t</td>
</tr>
<tr>
<td>S355K2W+N</td>
<td>EN10025-5</td>
<td>N</td>
<td>5–100</td>
<td>355</td>
<td>470</td>
<td>630</td>
<td>20</td>
<td>~2 x t</td>
</tr>
<tr>
<td>SSAB Weathering S355NL</td>
<td>EN10025-5</td>
<td>N</td>
<td>5–100*</td>
<td>345*</td>
<td>470</td>
<td>630</td>
<td>20**</td>
<td>~2 x t</td>
</tr>
<tr>
<td>SSAB Weathering S355ML</td>
<td>EN10025-5</td>
<td>TM</td>
<td>8–65</td>
<td>345*</td>
<td>470</td>
<td>630</td>
<td>20**</td>
<td>~2 x t</td>
</tr>
<tr>
<td>SSAB Weathering S420ML</td>
<td>EN10025-5</td>
<td>TM</td>
<td>8–65</td>
<td>400*</td>
<td>520</td>
<td>660</td>
<td>17**</td>
<td>~2 x t</td>
</tr>
<tr>
<td>SSAB Weathering S460ML</td>
<td>EN10025-5</td>
<td>TM</td>
<td>8–65</td>
<td>440*</td>
<td>530</td>
<td>710</td>
<td>15**</td>
<td>~2 x t</td>
</tr>
</tbody>
</table>

* For 355, thicknesses 16.01 – 40.00 mm min. 345 MPa, thicknesses 40.01 – 60.00 mm, min. 335 MPa
For 420ML thicknesses 8.00–16.00 mm min 420 MPa, thicknesses 40.01-63 mm min 390 MPa
For 460ML thicknesses 8.00–16.00 mm min 460 MPa, thicknesses 40.01-63 mm min 430 Mpa
**For 355ML thicknesses 40.01 – 60.00 mm min 19%
For 420ML thicknesses 40.01 – 63.00 mm min 16%
For 460ML thicknesses 40.01 – 63.00 mm min 14%
*** Transverse to rolling direction and up to 20 mm for EN grades

NL – Normalized;
ML – Thermo-mechanically rolled
## SSAB Weathering product range – Tubes & sections

<table>
<thead>
<tr>
<th>Grades</th>
<th>Thickness (mm)</th>
<th>Yield strength min (MPa)</th>
<th>Tensile strength min – max (MPa)</th>
<th>Elongation (min %)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SSAB Weathering Tube 355WH</td>
<td>2.0 – 12.5</td>
<td>355</td>
<td>470</td>
<td>630</td>
</tr>
<tr>
<td>SSAB Weathering Tube 500WH</td>
<td>2.0 – 12.5</td>
<td>500</td>
<td>580</td>
<td>-</td>
</tr>
<tr>
<td>COR-TEN® B Tube</td>
<td>2.0 – 12.5</td>
<td>355</td>
<td>510</td>
<td>680</td>
</tr>
<tr>
<td>COR-TEN® A Tube</td>
<td>1.0 – 3.0</td>
<td>310</td>
<td>450</td>
<td>-</td>
</tr>
</tbody>
</table>

### Hollow sections* (SSAB Weathering Tube 355WH, SSAB Weathering Tube 500WH, COR-TEN B Tube)

<table>
<thead>
<tr>
<th>Section</th>
<th>Diameter</th>
</tr>
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<tbody>
<tr>
<td>Circular</td>
<td>48.3 – 323.9 mm</td>
</tr>
<tr>
<td>Square</td>
<td>40 x 40 – 300 x 300 mm</td>
</tr>
<tr>
<td>Rectangular</td>
<td>50 x 30 – 400 x 200 mm</td>
</tr>
</tbody>
</table>

### Open sections* (SSAB Weathering 355WH, COR-TEN® A, COR-TEN® B)

<table>
<thead>
<tr>
<th>Section</th>
<th>Material thickness</th>
<th>Band width</th>
<th>Wall thickness</th>
</tr>
</thead>
<tbody>
<tr>
<td>U-, L-, C-, Z-sections and special shapes</td>
<td>1.5 – 12 mm</td>
<td>27 – 820 mm</td>
<td>1.0 – 3.0 mm</td>
</tr>
</tbody>
</table>

### Precision tubes* (COR-TEN® A Tube)

<table>
<thead>
<tr>
<th>Section</th>
<th>Diameter</th>
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</thead>
<tbody>
<tr>
<td>Circular</td>
<td>16 – 88.9 mm</td>
</tr>
<tr>
<td>Square</td>
<td>20 x 20 – 70 x 70 mm</td>
</tr>
<tr>
<td>Rectangular</td>
<td>25 x 15 – 100 x 40 mm</td>
</tr>
<tr>
<td>Wall thickness</td>
<td>1.0 – 3.0 mm</td>
</tr>
</tbody>
</table>

### Spiral welded tubes (S355J2W, S355K2W)

<table>
<thead>
<tr>
<th>Section</th>
<th>Diameter</th>
<th>Thickness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diameter</td>
<td>406.4 – 1220 mm</td>
<td>6.3 – 15 mm</td>
</tr>
</tbody>
</table>

* Other shapes and sizes are available upon request. Always check availability with Tubes & Sections organization.
Some restrictions

► C5 corrosion category
► Salt laden water flowing into superstructure – Can be addressed with sufficient detailing and design
► Marine atmosphere – distance from costal line < 1 km*
► Tunnel like bridge constructions (if road under the bridge is subjected to de-icing salt)

*Depends on sea salt content and local regulations.
If the conditions are optimal and design and detailing are sufficient:

Weathering steel = economical and environmental friendly option for bridge construction.

For further information, pls contact:

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E-mail:

Mobile: +358-(0)50-314 2970
A stronger, lighter and more sustainable world