Application of High Performance Weathering Steel in Bridges

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Introduction

- Steel bridges require corrosion protection during service life
- Repainting bridges increases maintenance cost and can cause environmental, traffic control/delay, worker’s safety issues
Weathering Steel

- **Enhanced resistance to corrosion under atmospheric conditions**
- **Protective rust layer forms to protect from further corrosion**

**Painted carbon steel**

- Corrosion progresses through steel
- Minimize Cl penetration
- Repaint

**(unpainted) Weathering steel**

- Protective rust layer forms
- Dense stable rust layer
- NO paint
- Protective rust (No repaint)
Weathering Steel

Weathering steel in our life
Weathering Steel

Can you tell the difference

<Wood>
<Weathering Steel>
<Wood>
<Painted Steel>
<Painted Steel>
<Wood>
<Weathering Steel>
<Weathering Steel>
<Weathering Steel>
<Weathering Steel>
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<Weathering Steel>
Weathering steel have been widely used in bridges since the 1960’s
- (USA) 4500+ bridges since 1964, HPS based in weathering steel
- (Japan) 7000+ bridges since 1967, 20~25% of new bridges designed using weathering steel
- (UK) 100+ bridges since 1967 (significantly increased after ’01, restriction of 7.5m clearance removed)
Applications

- 30 bridges built using weathering steel in Korea (SMA)
- 1st high performance weathering steel used in railway bridges (HSB-W)

<Yangsoo Bridge ‘98>

<Oweol Bridge ‘99>
High performance Weathering Steel (HSB-W)

- Weathering steel with increased strength, low temperature toughness and weldability (KS D 3868)
- Produced in TMC process (Thermo-mechanically Controlled Process)

<table>
<thead>
<tr>
<th>Type</th>
<th>HSB380W</th>
<th>HSB460W</th>
<th>HSB690W</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max. thickness</td>
<td>100mm</td>
<td>100mm</td>
<td>80mm</td>
</tr>
<tr>
<td>Tensile strength</td>
<td>500MPa</td>
<td>600MPa</td>
<td>800MPa</td>
</tr>
<tr>
<td>Yield strength*</td>
<td>380MPa</td>
<td>460MPa</td>
<td>690MPa</td>
</tr>
<tr>
<td>Low temp. toughness</td>
<td>-5°C 47J</td>
<td>-20°C 47J</td>
<td></td>
</tr>
<tr>
<td>C&lt;sub&gt;eq&lt;/sub&gt;</td>
<td>0.47</td>
<td>0.47</td>
<td>0.60</td>
</tr>
<tr>
<td>P&lt;sub&gt;cm&lt;/sub&gt;</td>
<td>0.22</td>
<td>0.22</td>
<td>0.27</td>
</tr>
<tr>
<td>Production method</td>
<td>TMC</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Weathering index</td>
<td>6.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Equivalent spec.</td>
<td>HPS345W, A709-50W, A588-Gr.B, S355J2W</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Constant yield strength for all thickness

<table>
<thead>
<tr>
<th>Type</th>
<th>Yield strength</th>
<th>Tensile strength</th>
<th>Low temp. toughness</th>
</tr>
</thead>
<tbody>
<tr>
<td>SMA275BW</td>
<td>245~275</td>
<td>410</td>
<td>0°C 27J</td>
</tr>
<tr>
<td>SMA355BW</td>
<td>325~355</td>
<td>490</td>
<td>0°C 27J</td>
</tr>
<tr>
<td>SMA460W</td>
<td>420~460</td>
<td>570</td>
<td>0°C 47J</td>
</tr>
</tbody>
</table>

P<sub>cm</sub> = 0.26~0.27
Performance Evaluation

**Long-term corrosion performance**

: Stable corrosion rate compared to carbon steel

![Accelerated corrosion tests](image1)

Accelerated corrosion tests

- 1% salt water CCT (Japan Weathering Test Center JWTCS1001)

![On-site weathering tests](image2)

On-site weathering tests

- Located at 4 different areas (distance from ocean 1-12km)

![Graph](image3)

<Weight loss due to corrosion (cycle)>

![Graph](image4)

<Corrosion rate (yr)>

SM520
HSB500W
HSB600W

ACM (Atmospheric Corrosion Monitor)

Conventional steel
HSB380W
HSB460W

1% salt water CCT (Japan Weathering Test Center JWTCS1001)
Performance Evaluation

Fabrication, weldability and structural evaluation for bridge applications

Fabrication

- Tensile tests
- Bend test
- Macro test
- Charpy Impact test
- Hardness test
- <Welding procedure qualifying tests>

Structural performance

- <Fatigue tests of weathering steel girder>
- <Flexural tests of weathering steel girder>
- <Fatigue tests of welded joints>
Considerations when using weathering steel

- **Environment / Location / Details**
  - Not recommended in:
    - marine environment (Cl)
      - excessive de-icing salt
    - repeated wet & dry (O)
    - continuous wet/damp cond. (X)
    - atmospheric pollution (SO₂)

- **Environment approach**
  - Airbone salinity
  - Time of wetness
  - Atmospheric sulphur dioxide pollution

- **Corrosion rate**
  - 1yr exposed test (EN ISO 9226)

- **Distance**
  - Distance from coast
  - Vertical distance

<table>
<thead>
<tr>
<th>Environment category</th>
<th>Typical environment</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1</td>
<td>Interior environments only.</td>
</tr>
<tr>
<td>C2</td>
<td>Atmospheres with low levels of pollution. Mostly rural areas.</td>
</tr>
<tr>
<td>C3</td>
<td>Urban and Industrial atmospheres with moderate sulphur dioxide pollution. Coastal areas with low salinity.</td>
</tr>
<tr>
<td>C4</td>
<td>Industrial areas and coastal areas with moderate salinity.</td>
</tr>
<tr>
<td>C5-I</td>
<td>Industrial areas with high humidity and aggressive atmospheres.</td>
</tr>
<tr>
<td>C5-M</td>
<td>Coastal and offshore areas with high salinity.</td>
</tr>
</tbody>
</table>

<Corrosion allowance EN ISO 9223>

<Sufficient vertical clearance>
Design / Fabrication considerations

- **Thickness reduction for long term corrosion performance**
  - 0.5mm/surface for service life 50~100 yrs.

- **Remove mill scale (shot blast the surface) during fabrication**
  - Uniform protective rust to form

- **Manage water**
  - Details for drainage to avoid water trapping
  - Drip detail to prevent rust water drip

![Images of design and fabrication considerations](image)
Partially painted
- at expansion joints
- (optional) exterior girder / lower flange
**Value Engineering**

- **Reduce paint (& maintenance costs)** (vs. regular painted carbon steel)
  - Similar initial cost, maintenance cost can be reduced significantly

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**Case Study**

- **L=180m (55+70+55m), W=12.6m (2 lanes)**
  - Steel box girder (Highway)
- **HSB380 (painted) vs. HSB380W (weathering)**

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<table>
<thead>
<tr>
<th></th>
<th>Painted steel</th>
<th>Weathering steel*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steel Weight</td>
<td>100%</td>
<td>101.3%</td>
</tr>
<tr>
<td>Painted area</td>
<td>100%</td>
<td>2.6%</td>
</tr>
</tbody>
</table>

* Partially painted (@ near expansion joints / top)

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**Value engineering**

- **Initial cost -2.6%**: Steel + fabrication ↑ / Paint ↓
  - Steel: 100%
  - Fabrication (weld+bolt): 100%
  - Erection: 100%
  - Paint: 97.4%

  - **Painted Steel**:
    - Erection: 100%
    - Fabrication (weld+bolt): 100%
    - Steel: 100%
    - Paint: 97.4%

  - **Weathering Steel**:
    - Erection: 97.4%
    - Fabrication (weld+bolt): 97.4%
    - Steel: 97.4%
    - Paint: 97.4%

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**<Initial cost>**

**<Maintenance cost>**

- **Painted Steel**
  - Initial cost: 100%
  - Service Life: 120%
- **Weathering Steel**
  - Initial cost: 97.4%
  - Service Life: 120%
1st Application of HSB-W (3,200 ton)
- Sabgyo-goga, L = 8@50m = 400m, B = 10.9m Railway
- 3 steel box girder + concrete deck
- Fab.: Heung Hwa Ind.
HSB-W Application

<Blasted Surface> <Corrosion Developing> <Painted>
**Maintenance-free steel bridge**

- Reduce maintenance during service life (paint + expansion joints & shoe)
- No partial paint needed at joints with weathering steel

**Integral abutment (jointless bridge)**

**Jointless bridge**

Full integral / Semi-integral

**Continuous / Simple made continuous**

Simple for dead load continuous for live load
Thank you

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