NSBA Uncoated Weathering Steel Manual
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Jennifer McConnell, Ph.D.
Uncoated Weathering Steel (UWS) Manual Background

- Sponsored by AISC/NSBA
- Research team:
  - U of Delaware
    - Jennifer McConnell, Ph.D.
  - Modjeski and Masters
    - Travis Hopper, P.E.
    - Ed Wasserman, P.E.
    - Thomas Murphy, Ph.D., P.E., S.E.
UWS Manual Scope

- Chapter 1 – Introduction
- Chapter 2 – Design Recommendations
- Chapter 3 – Fabrication and Construction
- Chapter 4 – In-Service Inspection
- Chapter 5 – Maintenance
- Chapter 6 – Repair and Rehabilitation

Recommendations given as minimum requirements, and improved performance
Context for Use of UWS

UWS provides:

- Minimal 1st cost
- Minimal life cycle cost
- When properly detailed, fabricated, etc.
- In most environments
Purpose of the Manual

- Need for broad guidance and collection of best practices
- Little published guidance on when and how to use Uncoated Weathering Steel
- FHWA Technical Advisory is long-in-the-tooth (1989)
- Owners and designers need basis for determining when use of UWS is appropriate
- FHWA is planning on updating the TA, Manual will serve as a more detailed companion guide
DESIGN RECOMMENDATIONS:
PART 1 – SITE SELECTION
Design Recommendations

- When to use UWS, and when to proceed cautiously
- Macro-environment
  - High Time of Wetness environments
  - Coastal environments
- Micro-environment
  - Deicing salt / tunnel-like situation
  - Low vertical clearance over water
  - Vegetation / shelter
Site Selection – UWS
Circa 1989 → 2018

Consider UWS “with caution” if:

Environment:
1. Marine coastal areas.  
2. Frequent high rainfall, high humidity or persistent fog (condensing conditions).
3. Industrial areas where concentrated chemical fumes may drift directly onto the structure.

Location:
1. Grade separations in “tunnel-like” conditions.
2. Low level water crossings.
   a. ≤ 10 ft. over stagnant, sheltered water.
   b. ≤ 8 ft. over moving water.
When to use UWS

Macro-Environment

- High Time of Wetness
  - Yes
  - Micro-environment that increases humidity or CI-?
  - Yes
  - Use UWS thoughtfully
    - Options:
      - UWS w/ sacrificial thickness
      - UWS w/ maintenance plan
      - Alternative CPS
    - UWS is ideal choice
  - No
  - UWS not recommended
- No
- Coastal?
  - Yes
  - Micro-environment that increases humidity or CI-?
  - Yes
  - Use UWS thoughtfully
    - Options:
      - UWS w/ sacrificial thickness
      - UWS w/ maintenance plan
      - Alternative CPS
    - UWS is ideal choice
  - No
- All Others
  - Yes
  - Micro-environment that increases humidity or CI-?
  - Yes
  - Use UWS thoughtfully
    - Options:
      - UWS w/ sacrificial thickness
      - UWS w/ maintenance plan
      - Alternative CPS
    - UWS is ideal choice
  - No
  - UWS not recommended
Macro-Environments and Micro-Environments: Overview of Concept

Macro-Environment = Regional Geography

Micro-Environment = Site Features
MACRO-ENVIRONMENT
Key Concepts

- Chlorides and Humidity
Overview of Qualitative Macro-Environments

- Rural → Benign
- Urban → Deicing Agents (Extreme) → Micro-environment
- Industrial → Mitigated
- Coastal →
Coastal Macro-Environment: How to Define It?

Figure credit: geology.com

Photo credit: valleycentral.com
Coastal Macro-Environment: Metrics to Quantify It?

v1: Time of Wetness

- Time of Wetness (TOW): # of hours per year that RH exceeds 80% and temperature is above freezing

<table>
<thead>
<tr>
<th>ISO Category</th>
<th>Time of Wetness, Upper Bound Limit (hr / year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>10</td>
</tr>
<tr>
<td>2</td>
<td>250</td>
</tr>
<tr>
<td>3</td>
<td>2500</td>
</tr>
<tr>
<td>4</td>
<td>5500</td>
</tr>
<tr>
<td>5</td>
<td>&gt;5500</td>
</tr>
</tbody>
</table>

- Recommendations:
  - High TOW + Good Micro-environment ➔ Use UWS
  - High TOW + Humid Micro-environment ➔ UWS not recommended
Coastal Macro-Environment: Metrics to Quantify It?
v2: Relative Humidity

Recommendations: Thoughtful use of UWS when at least 8 months of year literally “in the red” AND high chlorides

Source: NOAA Climate Atlas of the United States
Coastal Macro-Environment: Metrics to Quantify It?

Chlorides

Background:
- The amount of chloride that is problematic is uncertain, and likely variable
- More readily available data: $=f(\text{distance to coast})$
- Ongoing FHWA research…
- FL study…

Recommendations:
- 2 miles from coast + not high humidity $\rightarrow$ Use UWS
- 2 miles from coast + high humidity + good micro-environment $\rightarrow$
  Thoughtful use of UWS
- 2 miles from coast + high humidity + humid or high chloride micro-environment $\rightarrow$
MICRO-ENVIRONMENT
Micro-Environments Overview

Micro-environment should be assessed to screen for features that:

- Increase **humidity**
- Increase **chloride** exposure

Such consideration can be made by assessing:

- Crossing type
- Site vegetation
- Shelter from sunlight at site
## Micro-Environment: Consideration of Crossing Types

<table>
<thead>
<tr>
<th>Crossing Type</th>
<th>Concern</th>
<th>Conclusion</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Grade Separations</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Over HEAVILY salted roadways</td>
<td>Chloride</td>
<td>Use UWS thoughtfully</td>
</tr>
<tr>
<td>Other</td>
<td>Benign</td>
<td>UWS is ideal choice</td>
</tr>
<tr>
<td><strong>Rail Crossings</strong></td>
<td>Benign</td>
<td>UWS is ideal choice</td>
</tr>
<tr>
<td><strong>Water Crossings</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Most water crossings</td>
<td>Benign</td>
<td>UWS is ideal choice</td>
</tr>
<tr>
<td>w/ low clearance over water</td>
<td>Humidity, Flooding</td>
<td>Depending on macro-environment, use UWS or use thoughtfully</td>
</tr>
<tr>
<td>Over salt water</td>
<td>Chloride + Humidity</td>
<td>Do not use if wave action present</td>
</tr>
</tbody>
</table>
## Micro-Environment: Other Considerations

<table>
<thead>
<tr>
<th>Site Feature</th>
<th>Concern</th>
<th>Conclusion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dense Vegetation</td>
<td>Humidity</td>
<td>TOW 1 – 4 + not low clearance → Use UWS</td>
</tr>
<tr>
<td></td>
<td></td>
<td>High TOW or low clearance → Do not use UWS</td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>Rough definition: vegetation in, or nearly in, contact with UWS</em></td>
</tr>
<tr>
<td>Excessive Shelter</td>
<td>Humidity</td>
<td>TOW 1 – 4 + not low clearance → Use UWS</td>
</tr>
<tr>
<td></td>
<td></td>
<td>High TOW or low clearance → Do not use UWS</td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>Rough definition: in shadow for at least 6 hours per day</em></td>
</tr>
</tbody>
</table>
Micro-Environment: More Specifics

- “Heavily salted roadways” = f(...
  - High ADT (and travel speeds) AND
  - Average annual snowfall >= 20 inches AND
  - Vertical clearance <= 20 feet AND
  - Possibly: bridge width, number of travel lanes)

- Tunnel-like environments – understanding is evolving
- Low clearance waterways – current guidance thought to be conservative
When to Use UWS

**Macro-Environment**
- High Time of Wetness
  - Yes
  - Micro-environment that increases humidity or CI-?
  - Yes
    - Micro-environment that increases humidity or CI-
    - Yes
      - UWS not recommended
    - No
      - Use UWS thoughtfully
        - Options:
          - UWS w/ sacrificial thickness
          - UWS w/ maintenance plan
          - Alternative CPS
  - No
  - Coastal?
    - Yes
      - Micro-environment that increases humidity or CI-
      - Yes
        - UWS is ideal choice
      - No
        - UWS not recommended
    - No
      - All Others
        - Yes
          - Micro-environment that increases humidity or CI-
          - Yes
            - UWS is ideal choice
          - No
            - UWS not recommended
        - No
          - UWS not recommended

- No
## Table of UWS Use

<table>
<thead>
<tr>
<th>Micro-Environment</th>
<th>Macro-Environment</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>All Others</td>
</tr>
<tr>
<td></td>
<td>High Time of Wetness</td>
</tr>
<tr>
<td></td>
<td>Coastal</td>
</tr>
<tr>
<td>All Others</td>
<td>UWS is ideal choice</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Highway Crossings with Extreme Salt Use</td>
<td>Use UWS thoughtfully</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Water Crossings with Low Vertical Clearance</td>
<td>If minimal vegetation, use UWS thoughtfully; if dense vegetation, UWS not recommended</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Sites with Dense Vegetation or Shelter</td>
<td>UWS is ideal choice, if vegetation can be maintained and, for water crossings, adequate vertical clearance over water provided</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>
DESIGN RECOMMENDATIONS:
PART 2 – STRUCTURAL DESIGN
Design Recommendations

- Eliminate joints wherever possible!
- Integral abutment jointless, semi-integral abutments, moving joints behind the back walls, link slabs, etc.
- Attention needs to be paid to the drainage system
- Experience is clear – water directly discharging on steel is bad!
Detailing to Avoid Corrosion

- UWS needs dry cycles to function properly
- Trapped debris retains moisture
- Continuous moisture prevents patina formation
Haunched Girders

- Haunches can trap debris and moisture
- Clips and drain holes needed
Stiffener Clips

- The larger the clip, the better for drainage control
- Many states use 2” clips
- 3” is better to avoid clogging with debris
Tactical Painting

- Painting beam ends near joints is a common practice that has proven to be successful.
- Painting over interior piers sometimes performed.
- Beam ends encased in concrete should be painted – condensation and capillary action.
Drainage control

- Water flowing down flanges can collect and cause damage, staining
- Drip bars are one way of controlling this drainage
- Welded, or bonded with epoxy
Drainage details

- Scupper
- Barrier
- Downspout
- Brace
- Extend below girder bottom flange
Box Girders

- Interior of closed shapes can be problematic
- Efforts to eliminate water ingress often not successful
- Need to provide drainage to allow water a way out
- Water can sit for long periods of time if not appropriately drained
Dissimilar Metals - Fasteners

- Make sure the appropriate fasteners are specified and used
- Non-weathering grades of fasteners can quickly corrode
- Area ratios important
Galvanized Components

- Weathering action will drive corrosion in galvanized components
- Stops when patina fully forms
- Use depends on specific conditions
- Consider electrical isolation
Fabrication Considerations

- Weathering steel appearance can be a major advantage
- Patina formation takes time
- Uniform shop blasting ensures a consistent appearance during lifespan
- Leaving mill scale can lead to mottled appearance
- Markings left in place can stain surface
- Material handling considerations
Construction Considerations

- Run-off from girders can stain concrete surfaces
- Greatest risk is during initial patina formation

Solutions

- Wrapping concrete substructures during construction
- Drip pans
- Concrete coatings
- Zone painting near piers

- Do not neglect storage requirements
Inspection of Weathering Steel Bridges

- Guidance provided on evaluating the patina on existing bridges
- Information on the “Tape Test” is provided
- Examples of good performing patina and poor performance provided

Good performance

Poor performance
Maintenance Practices

- Joint sealing
- Drainage system clearing
- Girder washing
# Maintenance Best Practices

<table>
<thead>
<tr>
<th>Region</th>
<th>Component/Element</th>
<th>Activity</th>
<th>Description</th>
<th>Interval (Years)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deck</td>
<td>• Roadway and shoulders&lt;br&gt;• Expansion joints and drainage troughs&lt;br&gt;• Drainage grates, scuppers, and pipes&lt;br&gt;• Sidewalks, medians, curbs&lt;br&gt;• Rails and parapets</td>
<td>Sweep / Compressed Air Blow / Dry Clean</td>
<td>Remove and dispose of dirt, salt, and other debris using dry methods.</td>
<td>1-2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Wash / Flush</td>
<td>Remove residual material after sweeping/blowing by washing. Flush all deck drainage systems.</td>
<td>1-2</td>
</tr>
<tr>
<td>Super-structure</td>
<td>• Bearings&lt;br&gt;• Bottom flanges of beams and girders above roadways&lt;br&gt;• Ends of beams and girders under deck joints within a distance of 1 to 1.5 times the girder depth on each side of the joint&lt;br&gt;• End diaphragms and cross frames&lt;br&gt;• Truss members in the Splash Zone; truss members at or below the road level</td>
<td>Compressed Air Blow / Brush / Dry Clean</td>
<td>Remove and dispose of dirt, salt, and other debris using dry methods.</td>
<td>1-2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Wash</td>
<td>Remove and dispose of dirt, salt, and other debris by washing.</td>
<td>2-4</td>
</tr>
<tr>
<td>Sub-structure</td>
<td>• Abutment seats, backwalls, and pier seats&lt;br&gt;• Pier and abutment regions in the Splash Zone</td>
<td>Compressed Air Blow / Brush / Dry Clean</td>
<td>Remove and dispose of dirt, salt, and other debris using dry methods.</td>
<td>1-2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Wash</td>
<td>Remove and dispose of dirt, salt, and other debris by washing.</td>
<td>2-4</td>
</tr>
<tr>
<td>All</td>
<td>• As applicable</td>
<td>Vegetation Removal</td>
<td>Cut, remove, and dispose of vegetation that is in, or nearly in, contact with structure</td>
<td>1-2</td>
</tr>
</tbody>
</table>
Drainage system health

- Drainage systems often a neglected bridge component
- Key system for obtaining desired service life
- Needs regular maintenance and repair
Repair and Rehabilitation

- If UWS not performing as expected, can be painted
- Need only paint those areas with poor performance
Repair

- Coating the entire structure also a viable option
- Primer coat quantities will be higher due to uneven surface
- Successful examples of coating weathering steel after years of exposure
- Even if coated in the field, still a success on initial and life cycle costs
QUESTIONS?