South Carolina
Department of Transportation

DM0901

September 5, 2001

MEMORANDUM TO TEAM LEADERS AND CONSULTANTS

SUBJECT: Weathering Steel

When structural steel is planned, the use of weathering steel shall be considered on all inland stream crossings and railroad crossings that are not adjacent to other overpasses. The end of beams/girders shall be painted 1.5 d (depth of beam/girder) from the expansion joints (see Figure 1). The beam/girder shall be painted one foot past the end wall at the beginning and end of bridge (see Figure 2). The paint system shall be NS2 with the color of paint being brown (Federal Shade No. 30045).

Guidelines found in the FHWA Technical Advisory, Uncoated Weathering Steel in Structures, T5140.22, dated October 3, 1989, shall be adhered to. These guidelines are attached for your convenience. If there is a question as to the use of weathering steel on a structure, contact the appropriate Assistant Bridge Design Engineer.

Bridges already designed and detailed should be brought to the attention of the appropriate Assistant Bridge Design Engineer and a decision will be made on a case-by-case basis.

Randy R. Cannon, P. E.
Bridge Design Engineer

Attachments

cc: Assistant Bridge Design Engineers
Bridge Construction Engineer
Gerald Schroeder, FHWA
Bridge Maintenance Engineer

File: PC/JLC

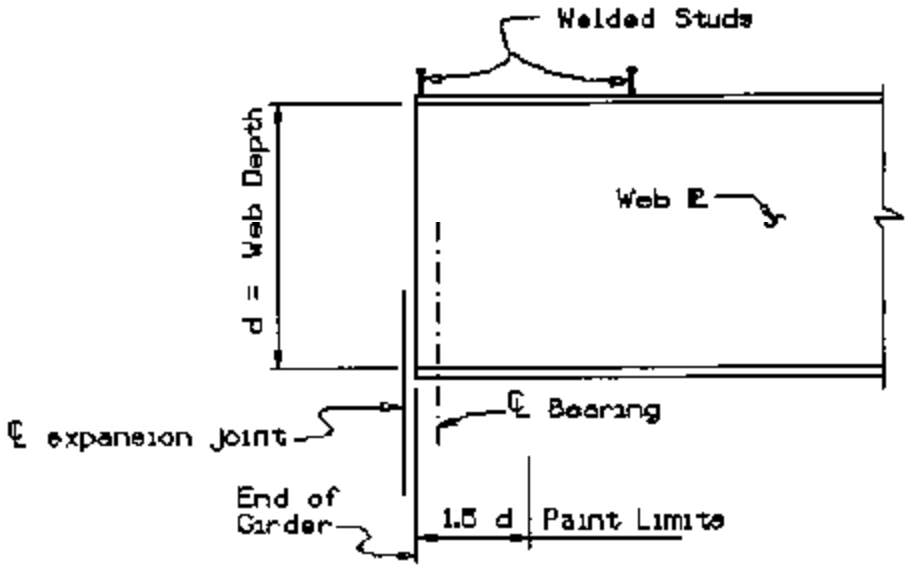

FIGURE 1

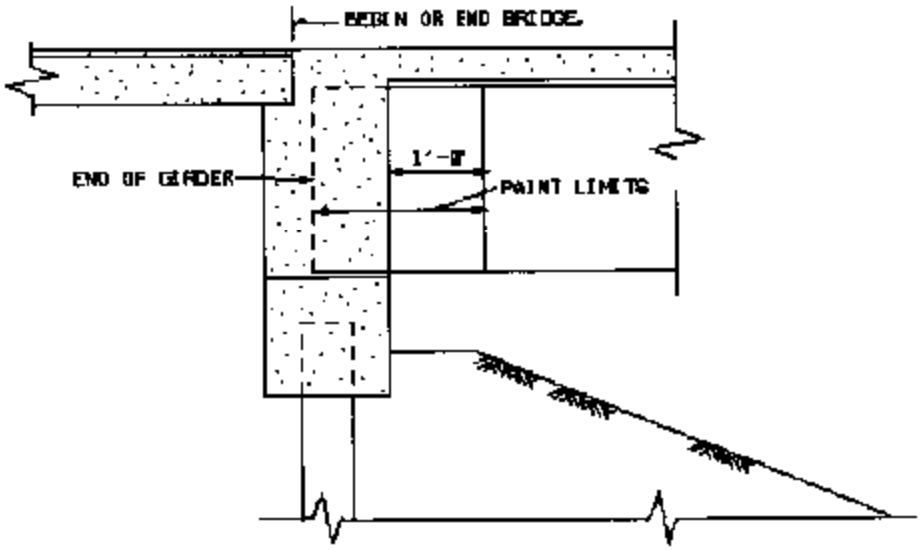

FIGURE 2

U.S. Department of Transportation
Federal Highway Administration

TECHNICAL ADVISORY

UNCOATED WEATHERING STEEL IN STRUCTURES

T 5140.22
October 3, 1989

Par.

1. PURPOSE. To provide engineers with suggested guidelines for proper application of uncoated (unpainted) weathering grade steels in highway structures and recommendations for maintenance to ensure continued successful performance of the steel.

2. BACKGROUND

   a. Uncoated weathering grade steels have been available to the bridge engineering profession for many years. The cost-effectiveness of use of this material has been demonstrated in both short and long-term savings. The additional cost of this grade of steel is offset by theelimination of the need for initial painting of the structure. These steels are currently supplied under American Association of State Highway and Transportation Officials (AASHTO) Specification M270 (ASTM A709 with grades 50, 70 and 100 available. Where enhanced atmospheric corrosion resistance is desired, the letter "W" follows the grade.

   b. Environmental benefits also result from the use of this material. The reduction in initial painting reduces emissions of volatile organic compounds (VOC) when oil based coatings are used. The elimination of removal of the coating and disposal of contaminated blast cleaning debris over the life span of the structure is another significant environmental benefit. There are documented cases where the estimated cost of the collection and disposal of materials from a structure repainting project were so great that the structure was either abandoned or replaced with a new bridge.

      (1) At the same time, there are documented cases where application of this material in improper locations or under improper conditions has resulted in less than desirable performance of the structure.

      (2) In most cases, this poor performance was the result of a lack of understanding of the limitations of weathering grade steels, or from poor detailing which caused exposure conditions which would cause distress in any structure, coated or uncoated, concrete or steel.

c. To better define the performance record of this material, the FHWA sponsored a Weathering Steel Forum in July of 1988 where knowledgeable speakers from across the nation were invited to present case histories and research data on the performance of this product in highway structures. The outgrowth of this forum was the suggested guidelines included herein. If these guidelines are followed, the potential for satisfactory performance and long-term durability of weathering grade steels in highway structures is greatly enhanced. Proceedings from this forum are available from the Federal Highway Administration Office of Implementation, HRT-10.

3. GUIDELINES. If the proposed structure is to be located at a site with any of the characteristics noted in paragraph 3a or 3b below, the use of uncoated (AASHTO M270 Weathering Grade steels) should be considered with caution and a study of both the macro-environment and micro-environment by a corrosion consultant may be required. In all environments, the designer must pay careful attention to detailing, specifically noted in paragraph 3c, and the owner should implement, as a minimum, the maintenance actions as noted in paragraph 3d.

   a. 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.

   b. Location

      (1) Grade Separations in "Tunnel-Like" Conditions.

      (2) Low Level Water Crossings.

         (a) Ten feet or less over stagnant, sheltered water.

         (b) Eight feet or less over moving water.

   c. Design Details. For uncoated steel in bridges and other highway structures, the following items should receive careful consideration:

      (1) Eliminate bridge joints where possible.

      (2) Expansion joints must be able to control water that is on the deck. Consider the use of a trough under the deck joint to divert water away from vulnerable elements.

      (3) Paint all superstructure steel within a distance of 1 1/2 times the depth of girder from bridge joints.

      (4) Do not use welded drip bars where fatigue stresses may be critical.

      (5) Minimize the number of bridge deck scuppers.

      (6) Eliminate details that serve as water and debris "traps".

      (7) "Hermetically seal" box members when possible, or provide weep holes to allow proper drainage and circulation of air.

      (8) Cover or screen all openings in boxes that are not sealed.

(9) Consider protecting pier caps and abutment walls to minimize staining.

(10) Seal overlapping surfaces exposed to water (to prevent capillary penetration action).

d. Maintenance Actions

(1) Implement maintenance and inspection procedures designed to detect and minimize corrosion.

(2) Control roadway drainage:

(a) Divert roadway drainage away from the bridge structure.

(b) Clean troughs or reseal deck joints.

(c) Maintain deck drainage systems.

(d) Periodically clean and, when needed, repaint all steel with in a minimum distance of 1 1/2 times the depth of the girder from bridge joints.

(3) Regularly remove all dirt, debris and other deposits that trap moisture.

(4) Regularly remove all vegetation which can prevent the natural drying of wet steel surfaces.

(5) Maintain covers and screens over access holes.

4. DISCUSSION

a. General. Controlling the corrosion of steel highway bridges and other steel appurtenances and mitigating the corrosion related damage is a major problem facing bridge owners. A special aspect of the problem is ensuring that highway structures utilizing uncoated (AASHTO M270 Weathering Grade) steels are located in an environment, and incorporate details, that will ensure cost-effective performance over the expected service life of the structure. For existing weathering steelstructures, where proper guidelines have not been followed, another part of the problem is controlling the corrosion damage of uncoated steel. In a number of cases, bridges, light poles and guardrail have experienced excessive corrosion damage, and some have ultimately experienced loss of section and/or localized structural failure because of improper applications of this material. Further work is needed to quantify and understand the performance of uncoated weathering steel in a variety of circumstances and conditions. These guidelines are intended to aid the engineer in making a prudent decision to use coated or uncoated steel in highway environments and applications. A more precise technical evaluation of the suitability of uncoated weathering steel for a particular site may be obtained from a corrosion consultant, from conducting standardized environmental tests, or from both. If serious doubt remains after applying the guidelines in the selection process, then engineering judgment should lean towards coated steel.

(1) Application of these guidelines will be reflected in decisions to use uncoated versus coated steel for new structures, in decisions on geometrics and design, and also in future maintenance activities to control corrosion damage. Many of these guidelines apply to coated structures as well and represent good engineering practice for all steel structures. The guidelines are structured as follows:

(a) Environmental/Climatic factors effecting the selection of type of steel for new structures.

(b) Geometric and location features considered for new structures.

(c) Design details for new structures.

(d) Maintenance actions to maximize the service life of existing structures.

(2) Fatigue Damage - The question of fatigue damage to uncoated weathering steel members as a result ofcorrosion is not addressed by these guidelines. However, application of the guidelines will minimize unexpected corrosion damage and provide more fatigue resistant details. The question of fatigue life of uncoated steel is being addressed by an AASHTO Task Force.

b. Selection of Type (Uncoated or Coated) of Steel for Highway Structures

(1) Environment/Climate. The following situations represent conditions where uncoated weathering steel cannot be expected to perform as intended and continuing corrosion could result in significant damage:

(a) Marine Coastal Areas - Salt-laden air that is generated along the Atlantic, Pacific, and Gulf Coast may be transported inland by the prevailing winds. The level of chloride concentration caused by the salt-laden air and its effect on the performance of uncoated weathering steel structures depends on the direction of the prevailing winds, the distance from the shore line, and the topographical and environmental characteristics of the area. Thus, the weathering behavior of uncoated weathering steel structures can vary significantly from one location to another along the three coastlines. The suitability of uncoated weathering steel for use at a specific site in marine coastal areas can be determined from the behavior of neighboring metal and concrete structures and, when necessary, by measuring the average daily ambient chloride concentration as determined by the ASTM Test G92 "Characterization of Atmospheric Test Sites," Method B, using the "Wet Candle" method. This method is extracted from a referenced paper in the ASTM Specification. ASTM is currently balloting for approval of the "wet candle" test procedures. In the interim, the International Standards Organization draft proposal ISO/DIS #9225, "Corrosion of Metalsand Alloys-Corrosivity of Atmospheres-Methods of Measurement of Pollutants," can be utilized. The United Kingdom Department of Transport Standard BD/7/81, "The Use of Weathering Steel for Highway Structures," suggests that uncoated steel should not be used when the chloride level exceeds 0.1 mg/100 cm^2/day, average.

However, corrosion rates in the United States are substantially lower than in the United Kingdom, presumably because of lower latitude and, therefore, shorter times of wetness in the United States. Therefore, a higher level of chloride contamination can be tolerated in the United States. It is known for example, that at the 250 meter lot at Kure Beach, North Carolina, where average chloride levels are determined by wet candle tests, over a 30-year period, ambient levels range from 0.8 to 1.8 and average 1.0 mg/100 cm^2/day. Under these conditions weathering steels perform satisfactorily in this location when boldly exposed as flat panels, although the performance may be marginal for actual structures containing crevices and sheltered areas. Based on available information, it is estimated that weathering steels can be used safely in the United States at chloride levels up to at least 0.5 mg/100 cm^2/day, average.

(b) Areas of Frequent High Rainfall, High Humidity or Persistent Fog - These climatic conditions can result in excessive condensation and prolonged periods of wetness of the steel. Selection of uncoated steel for use in areas where these conditions persist should not be made without an evaluation of the expected time of wetness of the steel at the particular bridge site. This factor can be evaluated by employing ASTM Test G84, "Time of Wetness Determination (On Surfaces Exposed to Cyclic Atmospheric Conditions)." Some areas in the Pacific Northwest, West of the Cascade Mountains, are examples of these conditions where high annual rainfall can contribute to excessive corrosion of uncoated steel. If the yearly average time of wetness exceeds 60 percent, caution should be used in the use of bare weathering steel (see ISO/DIS draftproposal #9223, "Corrosion of Metals and Alloys - Classification of Corrosivity of

Atmospheres).

(c) Industrial Areas - in heavy industrial areas with chemical and other manufacturing plants, the air may contain chemical impurities that can be deposited on and decompose the steel surfaces. The United Kingdom Department of Transport Standard BD/7/8l advises that when the threshold level for sulfur trioxide exceeds 2.1 mg/100 cm^2/day average, uncoated weathering steel should not be used.

(d) If necessary, the suitability of uncoated weathering steel for a particular site can be determined by a corrosion consultant.

(2) Location and Geometrics - the following factors have a major impact on the performance of steel highway structures and should be carefully considered in the decision to use uncoated or coated steel:

(a) Grade Separations - the so-called "tunnel effect" is produced by the combination of narrow depressed roadway sections between vertical retaining walls, narrow shoulders, bridges with minimum vertical clearances and deep abutments adjacent to the shoulders as are found at many urban/suburban grade separations. These roadway/bridge geometrics combine to prevent roadway spray from being dissipated by air currents and can result in excessive salt in the spray being deposited on the bridge steel. The illustration below is representative of situations where use of uncoated weathering steel should be avoided where winter deicing salt use is significant.

Depressed Roadway: Tunnel-like Condition 

Note: Where the longitudinal extent of the vertical walls is limited to the deep abutment (i.e., short or no approach retaining walls) there is no evidence of salt spray causing excessive corrosion.

(b) Low Level Water Crossings - sufficient clearance over bodies of water must be maintained so that spray or condensation of water vapor does not result in prolonged periods of wetness of the steel. Clearance to bottom flange of at least 10 feet over sheltered, stagnant water and at least 8 feet over running water is recommended.

c. Design Details - Proper design of structural features and details will eliminate many conditions which lead to excessive oxidation of steel structures. The following guidance should be applied to both coated and uncoated steel but it is most critical in the case of uncoated weathering steel:

(1) Controlling Roadway Drainage - This is the first line of defense against localized corrosion -eliminating the exposure of the steel to contact with drainage from the roadway above, especially in areas where roadway salts are used.

(a)Joints:

1 To the extent possible, bridge joints should be eliminated. Jointless steel bridges have been used to lengths of 400 feet and greater (and up to 1600 feet with joints only at the ends) in some States with no problems identified due to lack of joints. Virtually every bridge with joints has problems (corrosion, rideability, maintenance) attributable to the joint.

2 Extensive experience has shown that obtaining a permanent water-tight bridge joint is an elusive goal. Therefore, when joints are necessary, the assumptionshould be that the joints will leak and that drainage will contact the

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steel. Therefore, all steel within a minimum distance of 1 1/2 times the depth of the girder from the joint should be coated. In addition, measures must be incorporated to control the water that passes through the joint. Properly designed and maintained troughs beneath the joints will intercept most drainage runoff and prevent damage to superstructure and substructure elements.

3 Drip bars on the top and bottom of the lower flanges can be effective in intercepting drainage and preventing it from running long distances along the flange and causing corrosion of the uncoated steel. However, welding of any attachment to the tension flange should be considered only after a thorough analysis of the impact of the attachment on fatigue life of the member.

4 Fascia Girders - there is no evidence that coating the entire fascia girder will add to the service life of an otherwise uncoated bridge. On the other hand, coating the fascia girder does create future maintenance needs and aesthetic concerns.

(b)Scuppers:

1 The spacing between drainage scuppers should be maximized in accordance with established maximum hydrologic and hydraulic design. The FHWA Report No. FHWA/RD/87/014 "Bridge Deck Drainage Guidelines," provides sound recommendations in this regard. As scupper spacing increases, the volume of water required to pass through each scupper increases, thus creatingvelocities high enough to flush outlets clogged by deposits from low volume rainfalls. Where open (finger type) expansion joints are used, they will function as a drain. Again, increased flow into the joint will flush the below deck drainage trough.

2 Scupper downspouts should be designed and placed such that drainage will not contact the steel surface. However, details used to connect scuppers to drain pipes have often created more problems than they have prevented, by providing flat runs of piping and elbows which clog or connections that separate. Careful detailing is critical.

3 Scupper drain pipes should not be routed through closed box sections where leakage inside of the box is possible, and may go undetected for long periods of time.

(2)Other Features:

(a) Water Traps - all details must be designed to provide natural drainage. Small copes in corners of plates or small drain holes are easily plugged, and should not be relied on to provide drainage.

(b) Box Sections -

1 Box sections which are too small to provide for adequate visual inspection and access for maintenance personnel should be hermetically sealed, or provide weep holes to allow proper drainage and circulation of air.

2 Larger boxes should be detailed to minimize the entrance of water, debris and dirt which can promote corrosion. They must also provide for natural drainage ofwater that may enter and adequate access for inspection, cleaning and maintenance when necessary. Precautions should include:

a Locked covers or screens over access holes to prevent the entry of

animals and birds or unauthorized personnel. Covers over manholes should be on hinges and provided with a lock to allow easy access by inspection personnel.

b Provision of positive drainage and adequate ventilation to minimize the wetting of the interior surfaces from water or condensation.

(c) Concrete Surfaces - after passing over uncoated weathering steel, drainage leaves dark, nonuniform and often unsightly stains on concrete surfaces. This problem can be mitigated, if desired, by using one or more of the following approaches:

1 Wrapping the piers and abutments during construction to minimize staining while the steel is open to rainfall.

2 Allowing/requiring the contractor to remove staining with a commercial solvent after completion of construction.

3 Applying epoxy or some other material to coat and/or seal the concrete surfaces against staining.

(d) Overlapping surfaces - if water is allowed to flow over overlapping joints, capillary action can draw the water into the joint and cause "rust-pack" to form. Therefore, the contact surfaces of overlapping joints must be protected from intrusion of rainfall and runoff. This applies to nonslip-critical bolted joints as well as to overlapped joints such as those in tapered high mast lighting poles. The faying surfaces should be painted or sealed to prevent the capillary penetration. In slip-critical bolted splices, "rust-pack" should not occur when the bolts are spaced as per AASHTO specifications.

d. Maintenance Actions - effective inspection and maintenance programs are essential to ensure that all bridges reach their intended service life. This is especially true in the case of uncoated weathering steel bridges. The following maintenance actions should be routine:

(1) Inspection - implement inspection procedures that recognize the unique nature of uncoated weathering steel and the conditions resulting from excessive corrosion damage. Develop inspection guidelines that highlight the structural features to be inspected and also illustrate the difference between the desired oxide coating and excessive rust scaling.

(2) Controlling Roadway Drainage - to the extent feasible the following should be done:

(a) Divert approach roadway drainage away from the bridge structure.

(b) Clean troughs of open (finger) joints and reseal "watertight" deck joints.

(c) Maintain deck drainage systems (scuppers, troughs, etc.) in order to divert deck drainage away from the superstructure steel and substructure units.

(d) Periodically clean and repaint all steel within a minimum distance of 1 1/2 times depth of the girder from bridge joints.

(3) Other Maintenance

(a) Remove dirt, debris and other deposits that hold moisture and maintain a wet surface condition on the steel. In some situations, hosing down a bridge to remove debris andcontaminants may be practical and effective. Some agencies have a regularly scheduled program to hose down their bridges.

(b) Maintain screens over access holes in box sections to prevent entrance by animals and birds.

(c) Remove growth of nearby vegetation that prevents the natural drying of surfaces wet by rain, spray or other sources of moisture.

Thomas O. Willett, Director
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