Design Manual for Roads and Bridges

Highway Structures & Bridges
Design

# CD 361
# Weathering steel for highway structures

(formerly BD 07/01)

Revision 0

**Summary**
This document provides requirements for use of weathering steel in highway structures.

**Application by Overseeing Organisations**
Any specific requirements for Overseeing Organisations alternative or supplementary to those given in this document are given in National Application Annexes to this document.

**Feedback and Enquiries**
Users of this document are encouraged to raise any enquiries and/or provide feedback on the content and usage of this document to the dedicated Highways England team. The email address for all enquiries and feedback is: Standards_Enquiries@highwaysengland.co.uk

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## Release notes

| Version | Date | Details of amendments |
|---|---|---|
| 0 | Sep 2019 | CD 361 replaces BD 07/01. The full document has been re-written to make it compliant with the new Highways England drafting rules. Improvements have been made to the presentation of the technical requirements to improve ease of use.<br>The main themes of the update include: 1) clarify and update of requirements for use of weathering steel; 2) alignment with BS EN 1993-2 and the UK National Annex to BS EN 1993-2; 3) removal of some general advice notes which are considered to be covered elsewhere by industry advice documents; 4) removal of content already covered by Series 1800 of the Specification for Highway Works; 5) removal of non-design related content; 6) new requirements for structure records. |

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# Foreword

## Publishing information

This document is published by Highways England.

This document supersedes BD 07/01, which is withdrawn.

## Contractual and legal considerations

This document forms part of the works specification. It does not purport to include all the necessary provisions of a contract. Users are responsible for applying all appropriate documents applicable to their contract.

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# Introduction

## Background

The use of this document enables the use of weathering steel in highway structures. It provides the design requirements to manage the risks associated with the use of this material.

## Assumptions made in the preparation of this document

The assumptions made in GG 101 [Ref 6.N] apply to this document.

## Mutual Recognition

Where there is a requirement in this document for compliance with any part of a "British Standard" or other technical specification, that requirement may be met by compliance with the Mutual Recognition clause in GG 101 [Ref 6.N].

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# Abbreviations

**Abbreviations**

| Abbreviation | Definition |
|---|---|
| AIP | Approval in Principle |

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# Terms and definitions

**Terms**

| Term | Definition |
|---|---|
| Weathering steel | Structural steels with improved atmospheric corrosion resistance, supplied in accordance with BS EN 10025-5 [Ref 5.N], and hot finished structural hollow sections in weather-resistant steels, supplied in accordance with BS 7668 [Ref 10.N]. |

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# 1. Scope

## Aspects covered

1.1 This document shall be used for the design of weathering steel used in highway structures.

## Implementation

1.2 This document shall be implemented forthwith on all schemes involving the use of weathering steel on the Overseeing Organisations' motorway and all-purpose trunk roads according to the implementation requirements of GG 101 [Ref 6.N].

## Use of GG 101

1.3 The requirements contained in GG 101 [Ref 6.N] shall be followed in respect of activities covered by this document.

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# 2. General requirements

2.1 The use of weathering steel, and the corrosion allowances to be adopted where weathering steel is used, shall be based on the environment that the weathering steel is to be exposed to, in accordance with the requirements of this document.

2.2 Weathering steel shall be designed in accordance with the relevant parts of BS EN 1993 [Ref 4.N] and the UK National Annexes, together with the additional requirements of this document.

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# 3. Weathering steel products

3.1 Weathering steel products shall be in accordance with Series 1800 [Ref 7.N], with the exception of structural hollow sections.

*NOTE* *For weathering steel, Series 1800 [Ref 7.N] describes requirements for structural steel products, welding consumables and mechanical fasteners.*

3.2 Structural hollow sections in weathering steel shall be in accordance with BS 7668 [Ref 10.N].

3.3 Where weathering steel structural hollow sections are used, details shall be provided in the structure specific Appendix 18/1.

*NOTE* *The Sample Contract Specific Appendix 18/1 is given in Series NG 1800 [Ref 9.N].*

3.4 The availability of weathering steel products shall be confirmed prior to the commencement of design.

*NOTE* *Some weathering steel products are not always readily available or can be subject to excessive lead times, which can impact on construction programmes.*

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# 4. Environmental classification

4.1 Prior to design, a site-specific atmospheric corrosivity classification (C1 to CX) shall be determined for the structure location.

4.2 The atmospheric corrosivity classification shall be determined in accordance with BS EN ISO 9223 [Ref 1.N] using one of the following methods, dependant on the structure location:

1) method 1: corrosivity estimation for carbon steel based on the measurement of environmental information in accordance with BS EN ISO 9225 [Ref 3.N];
2) method 2: corrosivity determination based on corrosion rate measurement of standard carbon steel specimens in accordance with BS EN ISO 9226 [Ref 2.N];
3) method 3: corrosivity estimation based on a description of exposure conditions in accordance with BS EN ISO 9223 [Ref 1.N].

4.2.1 The design programme should allow for the minimum time period required to obtain a representative average value for the atmospheric corrosivity classification.

*NOTE* *BS EN ISO 9225 [Ref 3.N] (method 1) and BS EN ISO 9226 [Ref 2.N] (method 2) require measurements to be taken over a minimum period of one year to obtain representative average values.*

4.2.2 Where method 1 or method 2 are used for the site-specific atmospheric corrosivity classification, the location chosen for taking measurements should closely replicate the exposure conditions that the structure is to experience when in use.

4.3 Corrosivity estimation based on the description of exposure conditions in accordance with BS EN ISO 9223 [Ref 1.N] (method 3) shall not be used unless all the following apply:

1) the structure is to be located more than 15km inland from a coast;
2) the structure is to be located in an area where it is not likely to be exposed to high levels of atmospheric pollution or high levels of industrial fumes;
3) where the design programme does not permit either of the other two methods of classification (method 1 or method 2) to be used; and
4) where agreement has been obtained from the Overseeing Organisation.

4.3.1 Where corrosivity estimation based on the description of exposure conditions in accordance with BS EN ISO 9223 [Ref 1.N] (method 3) is used, a site visit should be undertaken to assess the nature of the structure location to inform the atmospheric corrosivity classification.

4.4 For structures that are to be located up to 15km inland from a coast, the airborne salinity level shall be determined in accordance with BS EN ISO 9223 [Ref 1.N] using the method described in BS EN ISO 9225 [Ref 3.N] based on a measuring period of one year.

4.4.1 The location chosen to determine the airborne salinity level should closely replicate the exposure conditions that the structure is to experience when in use.

4.5 For structures that are to be located in an area where there can be high levels of atmospheric pollution or high levels of industrial fumes, the airborne pollution level (as represented by $SO_2$) shall be determined in accordance with BS EN ISO 9223 [Ref 1.N] using the method described in BS EN ISO 9225 [Ref 3.N] based on a measuring period of one year.

*NOTE* *The pollution level classification is based on levels of atmospheric sulphur compounds.*

4.5.1 The location chosen to determine the atmospheric pollution level should closely replicate the exposure conditions that the structure is to experience when in use.

4.5.2 Where a source of atmospheric pollution other than atmospheric sulphur compounds is suspected, such as high levels of a specific industrial pollutant, special investigations should be undertaken to determine whether the use of weathering steel is viable.

4.6 The following atmospheric corrosivity classifications shall be used:

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1) internal surfaces of enclosed sections that are sealed against the ingress of moisture: C1;
2) internal surfaces of enclosed sections that are not sealed against the ingress of moisture: C2;
3) internal surfaces of enclosed sections where one or more elements of the section is of concrete: C3;
4) structures that carry a trafficked road which is subject to the use of de-icing salts: minimum C3;
5) structures that cross or are adjacent to a trafficked road which is subject to the use of de-icing salts: minimum C4.

*NOTE 1* *Series 1800 [Ref 7.N] requires all internal surfaces of enclosed sections that are sealed against the ingress of moisture to be identified in the structure specific Appendix 18/1, and any joints to be leak tested. (The Sample Contract Specific Appendix 18/1 is given in Series NG 1800 [Ref 9.N])*

*NOTE 2* *Examples of structures considered as being adjacent to a trafficked road include structures in, or over, a verge or an embankment next to a road that are likely to be affected by salt laden spray generated by passing vehicles.*

4.7 The atmospheric corrosivity classification adopted for design shall be recorded in the structure's AIP and structure records.

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# 5. Limitations on the use of weathering steel

5.1 Weathering steel shall not be used in highway structures without an additional corrosion protection treatment where any of the following exposure conditions apply:

1) where the atmospheric corrosion classification has been determined as C5 or CX;
2) where the airborne salinity level has been determined as S3;
3) where the atmospheric pollution level has been determined as P3;
4) where a source of atmospheric pollution other than atmospheric sulphur compounds has been identified that makes the use of weathering steel unviable due to the extent of corrosion that is likely to occur;
5) where the weathering steel is likely to be continuously wet or damp;
6) where the whole or part of the structure is likely to be subject to high concentrations of de-icing salts that can lead to substantial deposits of chloride on weathering steel surfaces, such as wide structures over salted roads, structures over salted roads at below the minimum standard headroom, structures located within 10.0 metres horizontally of a salted carriageway, or where salt-laden water could flow directly over the weathering steel;
7) for crossings over water where the headroom is less than 2.5 metres; and
8) where weathering steel is close to or in contact with the ground.

*NOTE* *Weathering steel surfaces can be continuously wet or damp where adjacent trees, bushes or other obstructions prevent the natural drying process.*

5.1.1 Where the limitations apply to isolated parts of a structure, weathering steel may be used provided that a corrosion protection treatment is applied to those isolated parts in accordance with Series 1900 [Ref 8.N].

*NOTE* *Isolated parts of a structure that could benefit from local application of a corrosion protection treatment include parts adjacent to expansion joints.*

5.1.2 Weathering steel may be encased in concrete without additional corrosion protection, provided that the concrete cover exceeds that required for durability.

5.1.3 Where a corrosion protection treatment is proposed to protect isolated weathering steel parts adjacent to unprotected weathering steel, the colour of the finish coat to the corrosion protection treatment should be chosen to harmonise with the anticipated final colour of the exposed weathering steel.

5.2 Details of any current or planned obstructions or works that could prevent the drying of weathering steel shall be obtained and used in the decision of whether to use weathering steel in a structure.

*NOTE* *Weathering steel surfaces can be prevented from drying and remain wet or damp for extended periods where adjacent trees, bushes or other obstructions prevent the natural drying process.*

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# 6. Corrosion allowances

## General requirements

6.1 The corrosion allowances given in this section shall be applied to all highway structures with a design life of up to and including 120 years.

6.2 A corrosion allowance shall be applied to each exposed surface of weathering steel in a structure to cater for the loss of structurally effective material due to the rust patina that develops over the design life of the structure.

6.2.1 A corrosion allowance should be applied to fillet welds and partial penetration butt welds.

*NOTE* *Full penetration butt welds do not normally require any corrosion allowance, because an allowance has been applied to the parent material thickness.*

6.2.2 A corrosion allowance should not be applied to mechanical fasteners.

6.2.3 Where a corrosion protection treatment is applied to a weathering steel surface in accordance with Series 1900 [Ref 8.N], the treated surface is protected from corrosion and no corrosion allowance should be applied to the affected surface.

6.3 Corrosion allowances shall be applied to weathering steel surfaces in accordance with Table 6.3, based on the atmospheric corrosivity classification of the environment that the weathering steel is to be exposed to.

**Table 6.3 Corrosion allowances**

| Atmospheric corrosion classification BS EN ISO 9223 [Ref 1.N] | Corrosion allowance applied (mm) |
|---|---|
| C1 | 0.0 |
| C2 | 0.5 |
| C3 | 1.0 |
| C4 | 1.5 |
| C5 or CX | Not appropriate to use weathering steel without an additional corrosion protection treatment. |

6.4 The corrosion allowances adopted for design shall be recorded in the structure's AIP and within the structure records.

## Corrosion allowances in analysis

6.5 Sectional properties used in global analysis for load effects shall be based on either the nominal dimensions of the material, or on the nominal dimensions minus the thickness of the corrosion allowances.

6.6 Sectional properties for stress analysis shall be based on the nominal dimensions of the material minus the thickness of the corrosion allowances.

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# 7. Detailing requirements

7.1 Weathering steel structures shall be detailed to ensure that the weathering steel performs as intended and that long term durability is achieved.

7.2 Weathering steel structures shall be detailed:

1) to allow the natural drying process to occur for all parts and elements in order to enable the protective rust patina to develop;
2) to avoid features that allow water or debris to collect, leading to prolonged wetness of weathering steel surfaces;
3) so that weathering steel surfaces are not affected by water runoff;
4) to prevent unsightly staining of substructures; and
5) to restrict unauthorised access to weathering steel surfaces to reduce the likelihood of graffiti being applied to them.

7.2.1 The following should be provided when designing and detailing joints in weathering steel structures:

1) expansion joints that prevent water flowing directly over weathering steel surfaces;
2) joints located to ensure water does not run over weathering steel surfaces should a joint fail; and
3) ventilation at and around support areas and beneath joints to avoid weathering steel surfaces from remaining wet or damp for extended periods.

7.2.2 The following details should be used for drainage systems in weathering steel structures:

1) positive drainage systems;
2) drip details to the edges of concrete decks in composite weathering steel bridges; and
3) for box girders, extended web plates below their associated bottom flange (including any welds) to form drip details.

7.2.3 The following should be provided when detailing stiffeners in weathering steel structures:

1) drainage passages through stiffeners or cleats that are welded to bottom flanges;
2) a minimum cope radius of 50mm for stiffeners that are welded to the bottom flange;
3) stiffeners not welded to bottom flanges to be cut off at a minimum of 30mm above the top surface of the bottom flange; and
4) drainage passages at intersections between horizontal and vertical stiffeners.

7.2.4 The following should be avoided when detailing weathering steel structures:

1) undrained overlaps, pockets, crevices and flat areas; and
2) butt welds to the bottom flanges of "I" beams that are not ground flush on the top surface.

7.3 Where enclosed sections are not sealed against the ingress of moisture, provision shall be made for free drainage of the enclosed section and to allow inspection of all weathering steel surfaces.

*NOTE 1* *Series 1800 [Ref 7.N] requires all internal surfaces of enclosed sections that are sealed against the ingress of moisture to be identified in the structure specific Appendix 18/1, and any joints to be leak tested. (The Sample Contract Specific Appendix 18/1 is given in Series NG 1800 [Ref 9.N])*

*NOTE 2* *Sections are not considered to be sealed against the ingress of moisture where one or more of the sides of the enclosed section is concrete.*

7.4 A non-conductive barrier shall be provided where a dissimilar metal is in contact with weathering steel and bimetallic corrosion can have a detrimental effect on the parts that are in contact.

*NOTE 1* *Accelerated corrosion can occur in local areas where there are dissimilar metals directly in contact with weathering steel parts.*

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*NOTE 2* *Electrical isolation between a dissimilar metal and weathering steel can be provided by the use of a separator made from a durable non-conductive material or a non-conductive corrosion protection treatment.*

*NOTE 3* *Series 1800 [Ref 7.N] requires the treatment necessary for surfaces of non-weathering steels in contact with weathering steels to be specified in the structure specific Appendix 18/1. (The Sample Contract Specific Appendix 18/1 is given in Series NG 1800 [Ref 9.N]).*

7.4.1 Mechanical fasteners in connections between weathering steel parts should be made of weathering steel material.

*NOTE* *Series 1800 [Ref 7.N] describes requirements for weather resistant mechanical fastener assemblies.*

7.5 A suitable sealant shall be detailed:

1) along all interfaces between weathering steel and concrete; and
2) where there is a potential for crevice corrosion to occur.

*NOTE* *Sealants are needed as a barrier to moisture to prevent excessive corrosion of embedded weathering steel within the concrete cover zone and to prevent crevice corrosion in joints.*

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# 8. Structure records requirements

## General requirements

8.1 Structure records shall be produced as part of the design of a weathering steel structure.

*NOTE* *The purpose of the structure records is to provide design information that is relevant to the management of the structure throughout its service life.*

8.2 The structure records shall include the following information:

1) the atmospheric corrosivity classification used in the design, including the basis and any assumptions for this determination;
2) the corrosion allowances for sectional loss over the design life of the structure which have been used in the design;
3) a summary of key detailing practices applied to the weathering steel elements;
4) a summary of design details or elements which could be susceptible to increased corrosion;
5) a description of critical areas requiring detailed examination during future inspections;
6) the specified locations for corrosion monitoring and residual thickness measurements to be undertaken immediately following construction and during future inspections;
7) a table to record residual thickness measurements at the specified corrosion monitoring locations; and
8) a table to record visual inspection notes on colour and grain consistency of the rust patina along with reference photographs.

**Visual inspection requirements to be included in the structure records**

8.3 The structure records shall state the anticipated inspection periods and list critical areas in the structure that require particular attention during future inspections, including:

1) steelwork in the vicinity of 'fixed' and 'expansion' joints;
2) steelwork near or adjacent to drainage pipes;
3) near flat surfaces or corners of steelwork;
4) steelwork surrounding drainage passages through stiffeners;
5) steelwork near drip details;
6) bolted connections; and
7) sealants along concrete and weathering steel interfaces.

**Corrosion monitoring requirements to be included in the structure records**

8.4 To provide a satisfactory corrosion monitoring programme, exact locations for future residual thickness measurements of weathering steel in a structure shall be identified at the design stage and be recorded in the structure records.

8.5 The locations for future residual thickness measurements shall be at locations on the structure critical for, or sensitive to:

1) strength;
2) differences in exposure;
3) debris accumulation, prolonged wetness or condensation; and
4) vulnerability to joint or drainage leakage.

8.6 Details of the residual material thickness monitoring locations and requirements for initial thickness measurements shall be provided in the structure specific Appendix 18/1.

*NOTE* *The Sample Contract Specific Appendix 18/1 is given in Series NG 1800 [Ref 9.N].*

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# 9. Normative references

The following documents, in whole or in part, are normative references for this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

| | |
|---|---|
| Ref 1.N | BSI. BS EN ISO 9223, 'Corrosion of metals and alloys - Corrosivity of atmospheres - Classification, determination and estimation' |
| Ref 2.N | BSI. BS EN ISO 9226, 'Corrosion of metals and alloys - Corrosivity of atmospheres - Determination of corrosion rate of standard specimens for the evaluation of corrosivity' |
| Ref 3.N | BSI. BS EN ISO 9225, 'Corrosion of metals and alloys - Corrosivity of atmospheres - Measurement of environmental parameters affecting corrosivity of atmospheres' |
| Ref 4.N | BSI. BS EN 1993 , 'Eurocode 3: Design of steel structures' |
| Ref 5.N | BSI. BS EN 10025-5, 'Hot rolled products of structural steels. Technical delivery conditions for structural steels with improved atmospheric corrosion resistance.' |
| Ref 6.N | Highways England. GG 101, 'Introduction to the Design Manual for Roads and Bridges' |
| Ref 7.N | Highways England. Series 1800, 'Series 1800 - Structural Steelwork. Manual of Contract Documents for Highway Works. Volume 1 - Specification for Highway Works' |
| Ref 8.N | Highways England. Series 1900, 'Series 1900 - Protection of Steelwork Against Corrosion. Manual of Contract Documents for Highway Works. Volume 1 - Specification for Highway Works' |
| Ref 9.N | Highways England. Series NG 1800, 'Series NG 1800 - Structural Steelwork. Manual of Contract Documents for Highway Works. Volume 2 - Notes for Guidance on the Specification for Highway Works' |
| Ref 10.N | BSI. BS 7668, 'Weldable structural steels. Hot finished structural hollow sections in weather resistant steels. Specification.' |

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