
**VOLUME 1 HIGHWAY STRUCTURES:
 APPROVAL PROCEDURES
 AND GENERAL DESIGN**

SECTION 3 GENERAL DESIGN

PART 15

BA 84/02

**USE OF STAINLESS STEEL
REINFORCEMENT IN HIGHWAY
STRUCTURES**

SUMMARY

The document advises on use of stainless steel reinforcement in reinforced concrete highway structures to provide resistance to chloride attack. Advice is also relevant where stainless steel bars are embedded in concrete for other purposes.

INSTRUCTIONS FOR USE

This is a new Advice Note to be incorporated in the Manual.

1. Remove existing contents page for Volume 1, and insert new contents page for Volume 1, dated February 2002.
2. Insert BA 84/02, in Volume 1, Section 3, Part 15.
3. Archive this sheet as appropriate.

Note: A quarterly index with a full set of Volume Contents Pages is available separately from The Stationery Office Ltd.



THE HIGHWAYS AGENCY



SCOTTISH EXECUTIVE DEVELOPMENT DEPARTMENT



**THE NATIONAL ASSEMBLY FOR WALES
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**THE DEPARTMENT FOR REGIONAL DEVELOPMENT
NORTHERN IRELAND**

Use of Stainless Steel Reinforcement in Highway Structures

Summary: The document advises on use of stainless steel reinforcement in reinforced concrete highway structures to provide resistance to chloride attack. Advice is also relevant where stainless steel bars are embedded in concrete for other purposes.

REGISTRATION OF AMENDMENTS

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1. INTRODUCTION

Objective

1.1 This document advises on how stainless steel reinforcement can selectively be used instead of normal carbon steel reinforcement to reinforce concrete in those elements of highway bridges (and other concrete highway structures) most at risk from chloride attack. Such use will enhance durability and reduce maintenance and associated traffic delays.

1.2 This advice note provides designers with advice on:

- Where to use stainless steel reinforcement.
- The cost and benefits of using stainless steel reinforcement.
- Identifying structures and parts of structures that will benefit from the use of stainless steel reinforcement.
- Changes to the normal design for durability requirements for carbon steel reinforcement when using stainless steel reinforcement.
- Selecting and specifying the appropriate grade of stainless steel reinforcement for a given application. This advice is also relevant for bars embedded in concrete for other purposes.
- Use of stainless steel reinforcement for new construction.
- Use of stainless steel reinforcement for existing structures requiring repair or maintenance.

Scope

1.3 This document provides the necessary advice to support the use of stainless steel reinforcement as identified in BA 57 “Design for Durability” (DMRB 1.3.8).

1.4 Correctly specified stainless steel reinforcement should prevent chloride attack for the full design life of any structure. Designers will need to examine whether the additional expenditure is warranted by the enhanced durability of structures and availability of the network.

Implementation

1.5 This document should be implemented forthwith. This will then encourage and permit the use of stainless steel reinforcement as anticipated by BA 57.

1.6 Designers will need to decide whether the extra cost of stainless steel reinforcement is warranted.

1.7 Design Organisations should advise Overseeing Organisations where they propose to use stainless steel reinforcement.

Advantages of using stainless steel reinforcement

1.8 For the majority of structures on trunk roads the cost of selective use of stainless steel reinforcement will represent a small percentage of the overall cost of the bridge and can be justified especially where access is difficult.

1.9 Using appropriate stainless steel reinforcement in sound concrete with suitable cover should enable the full design life of a reinforced concrete structure component to be achieved without damage from chloride induced corrosion.

1.10 Stainless steel reinforcement is similar to normal carbon steel reinforcement in that no new skills are needed for design and use and the design, detailing and construction process is unchanged.

1.11 Stainless steel reinforcement is advised for the following locations:

- On parapet edge beams
- On substructures in splash zones adjacent to carriageways
- On substructures in marine environments (and superstructures subject to spray)
- Below movement joints and on associated bearing shelves (continuous decks and integral bridges are still the preferred solutions as opposed to bridges with movement joints)

1.12 Use of stainless steel reinforcement enables relaxations of durability requirements as detailed in Section 3.4 (including omission of silane application that may give environmental and programme benefits for bridge construction over environmentally sensitive rivers).

1.13 For a limited number of structures, more extensive use of stainless steel reinforcement throughout all elements may be justified. As the initial construction cost may be significantly greater this approach will need to be supported by a detailed Whole Life Cost analysis, with an estimate of traffic delay costs, and agreed with the Overseeing Organisation.

2. COST AND AVAILABILITY OF STAINLESS STEEL REINFORCEMENT

2.1 Current prices of stainless steel reinforcement should be obtained from suppliers. Stainless steel reinforcement costs are more volatile and variable than for carbon steel and are sensitive to bar length, diameter and the waste when cutting from relatively short stock bars. Prices may vary significantly between suppliers.

2.2 Sample prices were provided by a stockholder for the supply to site of Grade 1.4301 500N/mm² stainless reinforcement for a typical project with a mix of bent and straight bars.

Prices in September 2000:

Bars up to 20 mm diameter	£1680/tonne
Bars over 25 mm diameter	£2350/tonne

2.3 For comparison the price for supply to site of Grade 460 carbon steel reinforcement to BS4449 would be about £300/tonne (September 2000).

2.4 It is possible to substitute all carbon steel reinforcement on a structure with stainless steel reinforcement but this would nearly always be too expensive to justify. The preferred manner of using stainless steel reinforcement is to identify structures that are at high risk of chloride induced corrosion and then to identify those components most susceptible to corrosion and selectively use stainless steel reinforcement only at these locations.

2.5 The additional cost of stainless steel reinforcement depends directly on the extent of substitution of stainless steel reinforcement for carbon steel. Total substitution could add 50% to the overall cost of a structure. Partial substitution may add as little as 3% for a structure with few vulnerable elements. Additional costs would tend to the lower part of this range for the majority of highway bridges.

2.6 Stainless steel reinforcement bars to all grades in BS 6744 should be readily available given sufficient notice. Steel Designations 1.4301 and 1.4436 of Strength Grade 500 N/mm² are the most frequently used and should, dependant on quantity, be available from stock.

3. GUIDANCE ON LOCATIONS WHERE USE OF STAINLESS STEEL REINFORCEMENT IS RECOMMENDED

3.1 The following guidance on use of stainless steel reinforcement assumes structures are located on busy motorways or trunk roads. This may not be as appropriate for other parts of the UK road network where concrete repairs would be less disruptive and the structure more readily accessible. Extent of stainless steel reinforcement substitution should be agreed with the Overseeing Organisation.

Total substitution of stainless steel reinforcement for major components

3.2 Full substitution with stainless steel reinforcement may be appropriate for major components of new structures (including replacement decks to existing structures) where future repair and maintenance works would be very disruptive to traffic and very costly and total use of stainless steel reinforcement in that component can be justified by a whole life cost benefit analysis. Components that may meet these requirements include:

- a) Decks of bridges carrying heavily trafficked roads over busy railway lines with limited possessions for repair.
- b) Exposed piers and columns in centre reserves (but not deeply buried elements).
- c) Deck slabs where access for maintenance is going to be very difficult because of traffic levels.

3.3 Total replacement with stainless steel reinforcement should be limited to those major components where the consequences of future repair are likely to be highly disruptive and costly and the possibility of chloride attack is likely. This extent of stainless steel reinforcement use must be agreed with the Overseeing Organisation and would need to be justified by a whole life cost benefit analysis including an assessment of traffic delay costs.

Elements of new structures that are exposed to seawater or are in the seawater splash zones

3.4 Total substitution with stainless steel reinforcement is recommended for all structure elements above low water spring tide level to a height of 5 metres above high water spring tide. Consideration should also be given to using stainless steel reinforcement on soffits and edge beams above this level where they would be subject to spray.

Elements of new structures adjacent to the carriageway exposed to chlorides from road de-icing salts

3.5 Most trunk road bridges would have components in this category. For structures on motorways and trunk roads elements are likely to include bearing shelves and other elements below road joints, the faces of abutment or pier supports adjacent to carriageways and parapet edge beams (integral bridges without deck joints will have a smaller potential need for stainless steel reinforcement).

3.6 Stainless steel reinforcement should be limited to those elements of bridges where significant main route traffic management or lane closures would be needed for remedial works.

Where stainless steel reinforcement is not appropriate

3.7 Stainless steel reinforcement is not appropriate for most highway bridge and structure components if any of the following apply:

- a) components are remote from the highways.
- b) are unlikely to be regularly exposed to high concentrations of chlorides.
- c) will not need traffic management for maintenance.

3.8 For structures on the motorway and major trunk road network this category is likely to include foundations, piles, buried structures and elements protected by waterproofing.

3.9 Superstructure elements for accommodation bridges and footbridges over the carriageway will usually fall in this category (but substructures may be suitable for stainless reinforcement if close to the carriageway).

Repair and Modification of Existing Structures

3.10 The use of stainless steel reinforcement may be justified for the repair and replacement of corrosion-damaged elements that may have suffered widespread chloride-induced corrosion. The objective is to avoid repeating similar repairs. Stainless steel reinforcement should also be considered for modifications or strengthening works. Stainless steel reinforcement may be appropriate for repairs and structure modifications especially in areas that will be difficult to access or maintain. The stainless steel reinforcement should not be lapped onto bars where corrosion has already started (or where chloride levels or half cell readings would indicate corrosion may be imminent). There are concerns that corrosion resistance may be impaired in this situation.

4. SELECTION OF STAINLESS STEEL REINFORCEMENT TYPE AND GRADE

Standard BS 6744 for stainless steel reinforcement

4.1 BS 6744: 2001 “Stainless steel bars for the reinforcement of and use in concrete” covers both austenitic stainless and duplex stainless reinforcing steels and describes the materials, mechanical properties and preferred sizes.

4.2 The intention is to modify the “Specification for Highway Works” to ensure stainless steel reinforcement suppliers will hold a valid CARES (or fully equivalent scheme) certificate of approval.

4.3 To specify a bar to BS 6744: 2001 it is necessary to state:

- a) Steel Designation defined by chemical composition to Table 5 BS 6744 (see Table 4.1 for Steel Designations)

- b) Strength Grade of 200, 500 or 650 corresponding to the 0.2 % proof stress to Table 7 BS 6744 (Table 4.2)
- c) nominal size from Table 3 BS 6744: 2001 (Table 4.3)
- d) product form (plain round or ribbed bar)

Material grades for use in concrete

4.4 The Steel Designation depends on the environment to which it will be exposed. Guidance on steel grade to be selected is given in Table 4.1.

4.5 For the majority of structures Steel Designation 1.4301 Strength Grade 500N/mm² ribbed bars will be appropriate.

Exposure Condition	Steel Designation to BS 1088 (as identified by BS 6744:2001)	Former British Standard Grade Designation
Stainless steel reinforcement embedded in concrete with normal exposure to chlorides in soffits, edge beams, diaphragm walls, joints and substructures	1.4301	304S31
As above but where design for durability requirements are relaxed in accordance with Table 4.6	1.4301	304S31
As above but where additional relaxation of design for durability is required for specific reasons on a given structure or component ie <i>where waterproofing integrity cannot be guaranteed over the whole life of the structure.</i>	1.4436	316S33
Direct exposure to chlorides and chloride bearing waters for example dowel bars, holding down bolts and other components protruding from the concrete	1.4429 1.4436	No equivalent 316S33
Specific structural requirements for the use of higher strength reinforcement and suitable for all exposure conditions.	1.4462 1.4429	318S13 No equivalent

Table 4.1 Material Designation Selection for Exposure Condition

Strength Grades

4.6 Strength Grades are defined in Table 4.2. Materials from Table 4.1 are typically available in all the three Strength Grades in Table 4.2. The 200 grade steel is only available as plain bar. It should be noted that the Duplex Steel Designation 1.4462 is only available in 650 grade up to 25mm diameter.

4.7 The preferred Strength Grade is 500.

4.8 650 Strength Grade stainless steel may suffer hydrogen embrittlement (as may higher strength carbon steels) if cathodic protection or electrochemical chloride extraction were to be used on a structure in the future.

Strength Grade	0.2% proof strength ($R_{p0.2}$ N/mm ²)	Stress ratio $R_m / R_{p0.2}$ (min) N/mm ²	Elongation at fracture, A_5 (min) %	Total elongation at maximum force A_{gt} (min) %
200	200	1.10	22	5
500*	500	1.10	14	5
650	650	1.10	14	5

* Recommended grade

Table 4.2 Minimum Tensile properties

Nominal bar sizes and available lengths

4.9 Preferred bar sizes are stated in BS6744 as follows in Table 4.3.

Strength Grade	Nominal size (mm)
200	3, 4, 5, 6, 7, 8, 10, 12, 14, 16, 20, 25, 30, 35, 40, 50
500	6, 7, 8, 10, 12, 14, 16, 20, 25, 32, 40, 50
650	3, 4, 5, 6, 7, 8, 10, 12, 14, 16, 20, 25

Table 4.3 Preferred Bar Sizes

4.10 Commercially available bar lengths are stated in BS 6744 as follows in Table 4.4:

Nominal Bar Size (mm)	Commercially available length (m)
20 or less	Up to 12m
Greater than 20	Up to 9m*

* Where longer bars may be desirable suppliers should be consulted on availability

Table 4.4 Preferred Bar Length

Material properties

4.11 Stainless steel reinforcement of Strength Grade 500 can be substituted directly for Grade 460 HYS carbon steel, as the material properties are equivalent or exceeded.

Coefficient of thermal expansion

4.12 The coefficient of thermal expansion for different grades of stainless steel is shown in Table 4.5. The fact that the coefficient of expansion for some grades is generally greater than that of concrete should have no detrimental effect on the overall behaviour of the element.

Material	Coeff. Of Thermal Expansion (Temperature range 20°C – 100°C)
1.4301	16.0 x 10 ⁻⁶
1.4436	16.0 x 10 ⁻⁶
1.4429	16.0 x 10 ⁻⁶
1.4462	13.0 x 10 ⁻⁶

Table 4.5 Coefficient of Thermal Expansion

Fatigue behaviour

4.13 The fatigue performance of stainless steel as a material is equivalent to carbon steel and the fatigue testing requirements in BS 6744 are similar to BS 4449 for carbon steel bars.

4.14 Stainless steel reinforcement should be designed for fatigue performance as for carbon steel reinforcement (to BD 24 as modified by Interim Advice Note IM5 or other document).

5. RELAXATIONS TO DURABILITY REQUIREMENTS

5.1 The use of corrosion resistant reinforcement such as stainless steel reinforcement allows the durability requirements developed for carbon steel to be relaxed. Where stainless steel reinforcement is used it is recommended that design for durability requirements are relaxed as given in Table 5.1.

Design condition	Relaxation
Cover	Cover for durability can be relaxed to 30mm where stainless steel reinforcement is used irrespective of the concrete quality or exposure condition.*
Design crack width	Allowable crack width increased to 0.3mm
Silane treatment	Not required on elements with stainless steel reinforcement.**

Table 5.1 Changes to Design for Durability Requirements

* The requirement in BD 57 “Design for Durability” for an extra 10 mm cover to reinforcement should be omitted only if the 30 mm cover can be realistically maintained.

** The requirements of “BA 57 Design for Durability” and BD33 “Impregnation of Concrete Highway Structures” are superseded.

6. NOMINAL STEEL REQUIREMENTS

6.1 Minimum steel should be provided as stated in BS 5400 Part 4 for 460 N/mm² HYS when using 500N/mm² stainless steel reinforcement. Guidance is not provided for other grades.

7. BENDING, FIXING AND WELDING REINFORCEMENT

Bending

7.1 Bending and forming of stainless steel reinforcement is straightforward. Bending radii, shapes and lap lengths are specified for stainless steel reinforcement in *BS 8666:2000*.

Fixing of stainless steel reinforcement

7.2 Stainless steel reinforcement should be fixed as for carbon steel reinforcement. Tying wire should be 1.2mm diameter softened, Steel Designation 1.4301 stainless steel in accordance with the Specification for Highway Works.

Anchorage and lapping of stainless steel reinforcement

7.3 Stainless steel reinforcement can be anchored or lapped as for carbon steel reinforcement. The allowable anchorage bond stress may be determined using the guidance in *BS 5400 Part 4* for Type 2 deformed bars.

7.4 200 Strength Grade bar is only available as a plain bar. Higher grades (500 grade is recommended) should usually be specified as ribbed bars.

7.5 Coupling of bars using stainless steel connectors is permitted, however approval must be sought on an individual basis and test data will be required to show adequate mechanical properties and fatigue resistance.

Welding

7.6 Welding of all stainless steel reinforcement is not recommended because it may detrimentally affect the physical characteristics of the material.

Bimetallic contact

7.7 In most applications stainless steel reinforcement will be used in conjunction with carbon steel reinforcement and in many instances the two materials will be in contact. There is therefore a theoretical risk of bimetallic corrosion causing accelerated damage to the carbon steel. However, research has shown that in practice this risk does not occur. It is therefore unnecessary to provide electrical isolation between the different steels when both bars are cast in new concrete. For repairs and strengthening to existing concrete see Section 8.0.

8. STAINLESS STEEL REINFORCEMENT IN STRENGTHENING AND REPAIR WORK

8.1 Stainless steel reinforcement is an appropriate material for strengthening or repair provided the stainless steel reinforcement is not in contact with carbon steel in areas where the existing concrete has high chloride levels or low alkalinity. At these locations the remaining carbon steel may already be active and thus vulnerable to bi-metallic corrosion with the stainless steel reinforcement (this does not apply to new construction but to concrete where corrosion has commenced).

8.2 Very localised repairs may not justify the use of stainless steel reinforcement, as adjacent carbon steel would still be vulnerable.

9. SPECIFICATION

9.1 For general use the following material specification clause will be adequate:

Stainless steel reinforcement shall be ribbed bar Steel Designation 1.4301 (or other number as appropriate) and strength grade 500 (or 200 or 650) complying with the requirements of BS 6744:2001¹.

10. METHOD OF MEASUREMENT

10.1 When compiling Bills of Quantity, designers should modify the item coverage for stainless steel reinforcement to explicitly state the material and strength grade of steel used in the design. For example:

*Steel Designation 1.4436 (or other Steel Designation)
Strength Grade 500 (or 200 or 650) ribbed (or plain)
stainless steel bar reinforcement nominal size 16mm
and under and not exceeding 9 metres in length*

x tonnes

11. REFERENCES

11.1 Design Manual for Roads and Bridges

Volume 1: Section 3: General Design

Part 1 BD24 (as modified by IM5) The
Design of Concrete Bridges
and Structures:
Use of BS 5400: Part 4: 2000

Part 7 BD57 Design for Durability

Part 8 BA57 Design for Durability

Volume 2: Section 4: Paints and other Protective
Coatings

Part 2 BA33 Impregnation of Concrete
Highway Structures

11.2 British Standards

BS 6744:2001 Stainless steel bars for the
reinforcement and use in concrete - Requirements
and test methods.

BS EN 10088-1:1995 Stainless steels. List of
stainless steels.

BS 8666:2000 Specification for scheduling,
dimensioning, bending and cutting of steel
reinforcement for concrete.

11.3 Other Documents

Concrete Society Technical Report 51 "Guidance
on the Use of Stainless Steel Reinforcement",
The Concrete Society, 1998.

12. ENQUIRIES

All technical enquiries or comments on this Advice Note should be sent in writing as appropriate to:

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