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

SECTION 3 GENERAL DESIGN

PART 14

BD 13/04

**DESIGN OF STEEL BRIDGES. USE OF
BS 5400-3:2000**

SUMMARY

This Standard implements BS 5400-3:2000 Steel, concrete and composite bridges - Part 3 : Code of practice for design of steel bridges. It supersedes BD 13/90, Design of steel bridges, Use of BS 5400: Part 3: 1982 (DMRB 1.3), which is now withdrawn.

INSTRUCTIONS FOR USE

1. Remove BD 13/90 from Volume 1, Section 3 which is superseded by this Standard and archive as appropriate.
2. Insert BD 13/04 into Volume 1, Section 3.
3. Please 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



Llywodraeth Cynulliad Cymru
Welsh Assembly Government

WELSH ASSEMBLY GOVERNMENT
LLYWODRAETH CYNULLIAD CYMRU



THE DEPARTMENT FOR REGIONAL DEVELOPMENT
NORTHERN IRELAND

Design of Steel Bridges. Use of BS 5400-3:2000

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REGISTRATION OF AMENDMENTS

Amend No	Page No	Signature & Date of incorporation of amendments	Amend No	Page No	Signature & Date of incorporation of amendments

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Contents

Chapter

1. Introduction
2. Use of the British Standard
3. Additional Requirements
4. References
5. Enquiries

Annex A (Normative)	Amendments to BS 5400-3:2000 Code of Practice for Design of Steel Bridges
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1. INTRODUCTION

General

1.1 This Standard implements BS 5400-3:2000 Code of practice for design of steel bridges. It supersedes BD 13/90 Design of Steel Bridges Use of BS 5400: Part 3:1982 which is now withdrawn.

1.2 The amendments contained in Annex A result from a review of the Code by the BSI Working Group B525/10/WG3 over several years. Eurocodes are being used on a trial basis in a number of European countries and will supersede the equivalent National Standards in a few years, but until then there is a need to maintain BS 5400.

1.3 This Standard amends BS 5400-3:2000 by providing replacement and new clauses, including additions and deletions to existing clauses. The amendments are given in Annex A and follow the clause numbering used in BS 5400-3:2000. This Standard complements the Specification for Highway Works (MCHW 1).

1.4 This Standard has been produced to modify parts of BS 5400-3:2000 so that it meets the requirements of the Overseeing Organisations.

1.5 The main technical changes in BS 5400-3:2000 compared to the earlier version are:

- partial factor for bending resistance of beams is reduced to 1.05 at the Ultimate Limit State;
- the clauses on notch toughness now take account of the recent research carried out on the subject;
- lateral torsional buckling rules are modified;
- the rules on bracing systems and frame restraints including rules on U-frames are substantially modified;
- patch loading rules are modified.

Scope

1.6 This Standard covers the use of BS 5400-3:2000 for the design and strengthening of steel bridges and steel highway structures and it includes the Overseeing Organisations' requirements where these are either more comprehensive or differ from the British Standard.

1.7 The design of wires, cables, anchorages and saddles for suspension and cable stayed bridges and the design of orthotropic steel decks are not covered by this Standard. For guidance on the design of such items, designers should seek information from specialist literature.

Equivalence

1.8 The construction of highway structures will normally be carried out under contracts incorporating the Specification for Highway Works (MCHW 1). In such cases products conforming to equivalent standards or technical specifications of other states of the European Economic Area and tests undertaken in other states of the European Economic Area will be acceptable in accordance with the terms of the 104 and 105 Series of Clauses of that Specification. Any contract not containing these Clauses must contain suitable clauses of mutual recognition having the same effect.

Implementation

1.9 This Standard shall be used forthwith on all schemes for the design and strengthening of highway structures on trunk roads, including motorways. For schemes in preparation the Standard should be used provided that, in the opinion of the Overseeing Organisation, this would not result in significant additional expense or delay.

2. USE OF THE BRITISH STANDARD

2.1 The design and strengthening of all highway structures in steel shall be carried out in accordance with BS 5400-3:2000 as amended by this Standard. Reference to “bridges” or “highway bridges” in BS 5400-3:2000 shall be taken as a reference to all highway structures.

2.2 Where reference is made to any other British Standard this shall be taken as a reference to that part and edition implemented by the Overseeing Organisation.

2.3 The clauses in BS 5400-3:2000 that are expressed in the form of a recommendation using the word “should” or “may” shall be considered as mandatory unless provisions are given in the Code to deal with alternatives.

2.4 Annexes in BS 5400-3:2000 generally contain provisions not specifically covered in the Code. When these provisions are used in designs as alternatives or additional to the recommendations contained in the Code, the informative annexes shall be mandatory.

2.5 Where reference is made to the relevant or appropriate “Bridge Authority” this shall be taken to be the Technical Approval Authority appointed by the Overseeing Organisation.

2.6 Where reference is made to “The Specification for Highway Works”, this should be read to include Volume 1, “The Specification for Highway Works (MCHW 1)” and Volume 2, the “Notes for Guidance on the Specification for Highway Works”, (MCHW 2).

2.7 Clause references given in bold types in Annex A of this Standard refer to clauses in BS 5400-3:2000 as implemented by this Standard.

3. ADDITIONAL REQUIREMENTS

3.1 To make BS 5400-3:2000 contract neutral all references to the word “Engineer” shall be deleted.

3.2 Weathering Steel

3.2.1 The use of weathering steel in highway structures is covered in BD 7 (DMRB 2.3.8). The design of structures in weathering steel shall be carried out in accordance with BS 5400-3:2000 as implemented by this Standard and the following clauses.

3.2.2 The sectional properties to be used for global analysis (BS 5400-3:2000, 7.2) shall be calculated assuming either the specified sizes or the specified sizes less the allowance for the loss of thickness in accordance with BD 7.

3.2.3 All dimensions for checking the adequacy of sections shall be taken as the specified dimensions less the allowance for the loss of thickness in accordance with BD 7 and BS 5400-3:2000.

3.3 Notch toughness

When considering impact loading from over height vehicles the value of k_s to be used in 6.5.3.5 shall be taken as 1.0 providing that there is at least 5.3 m headroom available.

3.4 Strength of fasteners

3.4.1 For the application of 14.5.3.1, all connections that are subjected to live or wind load effects shall be considered to be “permanent main structural connections”.

3.4.2 HSFG bolts to BS 4395: Part 2 shall not be used to resist applied axial tension.

4. REFERENCES

The following documents are referred to in the Standard.

4.1 Design Manual for Roads and Bridges (DMRB). The Stationery Office

BD 13/90 Design of steel bridges. Use of BS 5400:Part 3: 1982 (DMRB 1.3)

BD 7 Weathering Steel for Highway Structures (DMRB 2.3.8)

4.2 Manual of Contract Documents for Highway Works (MCHW). The Stationery Office

Volume 1 (MCHW 1): Specification for Highway Works.

Volume 2 (MCHW 2): Notes for Guidance on the Specification for Highway Works.

5. ENQUIRIES

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

Chief Highway Engineer
The Highways Agency
123 Buckingham Palace Road
London
SW1W 9HA

G CLARKE
Chief Highway Engineer

Chief Road Engineer
Scottish Executive
Victoria Quay
Edinburgh
EH6 6QQ

J HOWISON
Chief Road Engineer

Chief Highway Engineer
Transport Directorate
Welsh Assembly Government
Llywodraeth Cynulliad Cymru
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Chief Highway Engineer
Transport Directorate

Director of Engineering
The Department for Regional Development
Roads Service
Clarence Court
10-18 Adelaide Street
Belfast BT2 8GB

G W ALLISTER
Director of Engineering

ANNEX A (NORMATIVE) AMENDMENTS TO BS 5400-3:2000 CODE OF PRACTICE FOR DESIGN OF STEEL BRIDGES

2 Normative references

Replace “BS 5135: 1984” as follows:

“BS EN 1011 Welding – Recommendations for welding of metallic materials

Part 1: General guidance for arc welding

Part 2: Arc welding of Ferritic steel”

4.5.6 Thickness of weathering steel

Delete the whole clause and substitute the following:

“To cater for the loss of structurally effective material due to the developing rust patina during the life of the structure, corrosion allowance should be made on each exposed surface, representing a loss of thickness of material used for structural purposes, as stated in Chapter 3 of BD 7 (DMRB 2.3.8). If weathering steel surfaces receive corrosion protective treatment, no corrosion allowance is necessary.”

5.7 Camber

Line 4, delete “or approved by the Engineer”

6.1.1 Performance

Line 1, delete “required by the Engineer”

Table 3-Fracture classification

Insert “, 2.8” after Detail type “2.7” under column 5, row 9

9.4.2.4. Effective areas of compression flanges or planes in compression

In the definition of k_h delete “not” after “holes”

9.6.1 General

Para 2, line 3, insert “equal to or” after “bending is”

9.6.4.1.1.1 Beams with fully effective lateral restraints at the level of a compression flange

Delete Para 2 and replace with:

“A discrete lateral restraint or a plan bracing system, may be taken as fully effective provided that it has a stiffness such that $\delta_R < \ell_R^3 / (40 EI_c)$ where δ_R , ℓ_R , and I_c are as defined in 9.6.4.1.1.2.”

Delete Para 3.

After Para 2, insert “NOTE” as follows:

“NOTE: Less conservative stiffness requirements may be obtained for a beam with n intermediate restraints by first deriving the value of M_R/M_{ult} from 9.8 for failure by buckling between restraints, with $\ell_c/\ell_w = 1.0$ and λ_{LT} calculated with $\ell_c = \ell_R$. The restraint stiffnesses may also be derived by selecting a value of ℓ_c such that with λ_{LT} calculated using the ℓ_c and with $\ell_c/\ell_w = \ell_c/L$ the same resistance for overall buckling is achieved. The required limit to δ_R is then $\ell_c^4 / [EI_c \ell_R (k_2 k_3 k_4)^4]$ in which the terms are as defined in 9.6.4.1.1.2.”

9.6.4.1.1.2 Beams with discrete lateral restraints to a compression flange which are not fully effective

In “a)” add at end “nor greater than L ”

In definition of “ ℓ_R ” insert (twice) “or nodes in a plan bracing system” after “intermediate restraint”

In definition of “ δ_R ” replace “the restraint” by “a lateral restraint”. Add “With a plan bracing system the deflection is to be taken as the deflection of a node relative to adjacent nodes.”

9.6.4.1.2 Beams with discrete torsional restraints

Line 3, insert “restraint” before “parameter” and replace parameter expression “ $v^4 L^3 / [EI_c \theta_R d_f^2]$ ” by

$$v_{eq}^4 \ell_w^3 / [EI_c \theta_R d_f^2 (1-i)]$$

Insert “for beams with distributed restraints ℓ_c ” after “but”.

Line 4, replace “0.6v” by “0.7v_{eq}”

Insert the definition:

“ ℓ_w is the assumed half wavelength of buckling. The value of ℓ_w should be taken as the span L or a sub multiple of the span, whichever gives the lowest value of limiting moment of resistance M_R in accordance with 9.8.”

Insert “NOTES” as follows at the end of the clause:

“NOTE 1 The effective length relationships in Figure 8 do not apply when considering buckling with a half-wavelength equal to ℓ_R (within which there are no restraints), for which $\ell_w = \ell_e = \ell_R$.”

NOTE 2 The resistance of a beam with $\ell_e < \ell_R$ and $\ell_w > \ell_R$ may be less than for buckling between restraints with $\ell_w = \ell_e = \ell_R$.

NOTE 3 For beams with a single central restraint, ℓ_w should be taken as equal to L , unless the restraint parameter derived from that value is such that it is to the right of the vertical arrow on the appropriate curve for the value of v_{eq} , in which case either:

a) ℓ_e and ℓ_w should be taken as $L/2$

or

b) ℓ_w should be taken as L and ℓ_e should be derived from Figure 8, whichever gives the lowest moment of resistance.”

Delete the existing definitions for “ θ_R ” and “ v ”, and substitute the following:

“ θ_R is the greatest value of the rotation of a restraint about the longitudinal axis of the beam, due to a torque equal to a unit torque multiplied by $1/n$, applied to each restraint. When restraint is provided by uniform diaphragms interconnecting beams, the value of θ_R should be taken as the greater of θ_{R1} and $\theta_{R1} + \theta_{R2}$ where:-

θ_{R1} is the rotation due to the flexibility of the diaphragm calculated as the greatest rotation about the longitudinal axis of a beam at a connection between the diaphragm and the beam under unit moments in the plane of the diaphragm multiplied by $1/n$, applied to each connection. Where θ_{R1} alone is to be determined, the directions of the moments should be in the opposite sense at each beam; where $\theta_{R1} + \theta_{R2}$ is to be determined,

the moments should be in the same sense at both beams. (see Figure 8 A)

θ_{R2} is the greatest value of rotation of a beam at the middle of a half wavelength of buckling due to the vertical deflections of the beams. A unit torque multiplied by $1/n$ should be applied to each beam at each diaphragm connection, the diaphragms being assumed to be rigid for this calculation, in directions of opposite sense in consecutive waves and in opposite directions on one beam relative to the other.

n is the number of restraints (= 1 for a single central restraint)

v_{eq} is a parameter that takes account of warping properties of the section and is calculated as follows:

a) for sections symmetrical about both their major and minor axis, $v_{eq} = v$ where the value of v is determined in accordance with 9.7.2

b) for sections symmetrical about their minor axis only,

$$v_{eq} = \left[\frac{2i\chi}{\left[\sqrt{4 + \tau\chi} + \psi_i \sqrt{\chi} \right]^2} \right]^{0.25}$$

where

$$\tau = 4i(1 - i) + \psi_i^2$$

i and ψ_i are as defined in 9.7.2

$$\chi = \frac{\pi^2 d_f^2 E I_y}{G J \ell_w^2}$$

I_y is the second moment of area of the beam about its minor axis

J is the St Venant Torsional Constant”

Insert "NOTES" as follows at the end of the clause:

"NOTE 4 Where, for distributed restraints, the value of $v_{eq}^4 \ell_w^3 / [EI_c \theta_R d_f^2 (1-i)]$ exceeds the maximum value shown in Figure 8, the equation given in G.7 may be used to derive the appropriate value of ℓ_e / ℓ_w ."

NOTE 5 When only pairs of beams are interconnected by diaphragms, θ_{R2} may be taken as $(m+1) \ell_w^3 / 24nEI_2 B^2$ where I_2 is the second moment of area of each beam about its major axis, B is the spacing of the beams and m is the number of restraints within the half wavelength."

Replace "Figure 8" by the following revised figure:

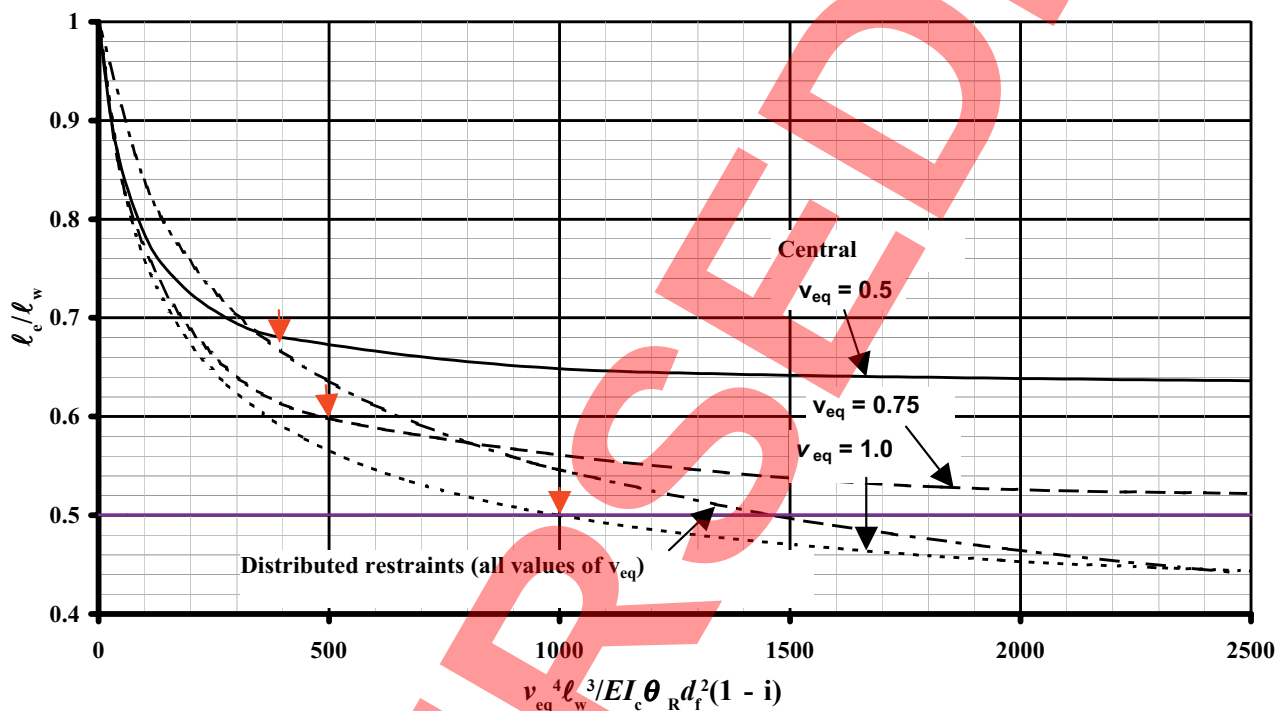
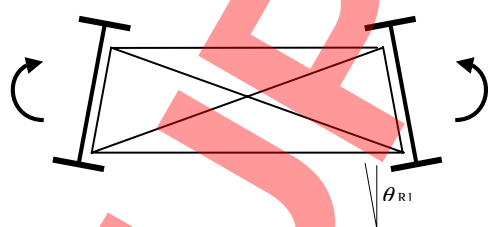
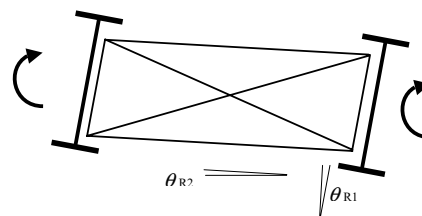


Figure 8 - Effective length of beams with discrete torsional restraints

Insert new "Figure 8A" as below:



Unit torque in the same sense



Unit torque in the opposite sense

Figure 8A – Directions of rotations of beams

9.7.1 General

Para, 2, line 1, add " ℓ_w " after "buckling".

In "b)", delete "and 9.6.4.1.1.2"

Delete "c)" and replace by the following:

- "c) Where intermediate lateral or U-frame restraints are provided which are not fully effective, in accordance with 9.6.4.1.1.2 or 9.6.4.1.3, ℓ_w should be determined by taking L/ℓ_w as the next integer below L/ℓ_e but not less than unity."

Add "d) For beams with torsional restraints, ℓ_w should be taken as defined in 9.6.4.1.2"

9.7.2 Uniform I, channel, tee or angle sections

In the definition of " λ_F " replace " ℓ_e " by " ℓ_w "

Table 9.

In "NOTE 1", replace " ℓ_e " by " ℓ_w "

9.8 Limiting moment of resistance

Replace the definition of " ℓ_w ", by "is the half-wavelength of buckling as defined in 9.7.1."

Replace the definition of " L " by "is as defined in 9.7.1."

Delete "NOTE.....taken as 1." at the end of the clause.

Replace Figures 11 a) and 11 b) by the following:

Figure 11 - Limiting moment of resistance M_R
a) Beams fabricated by welding

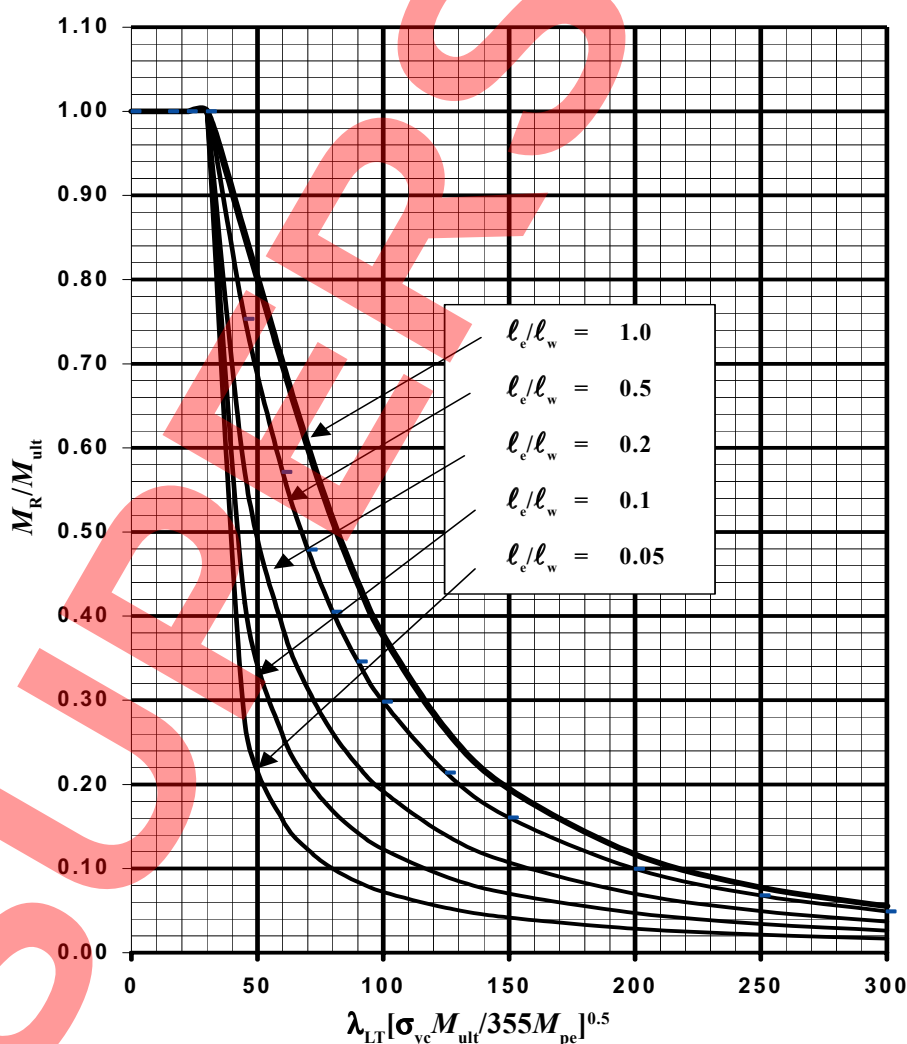
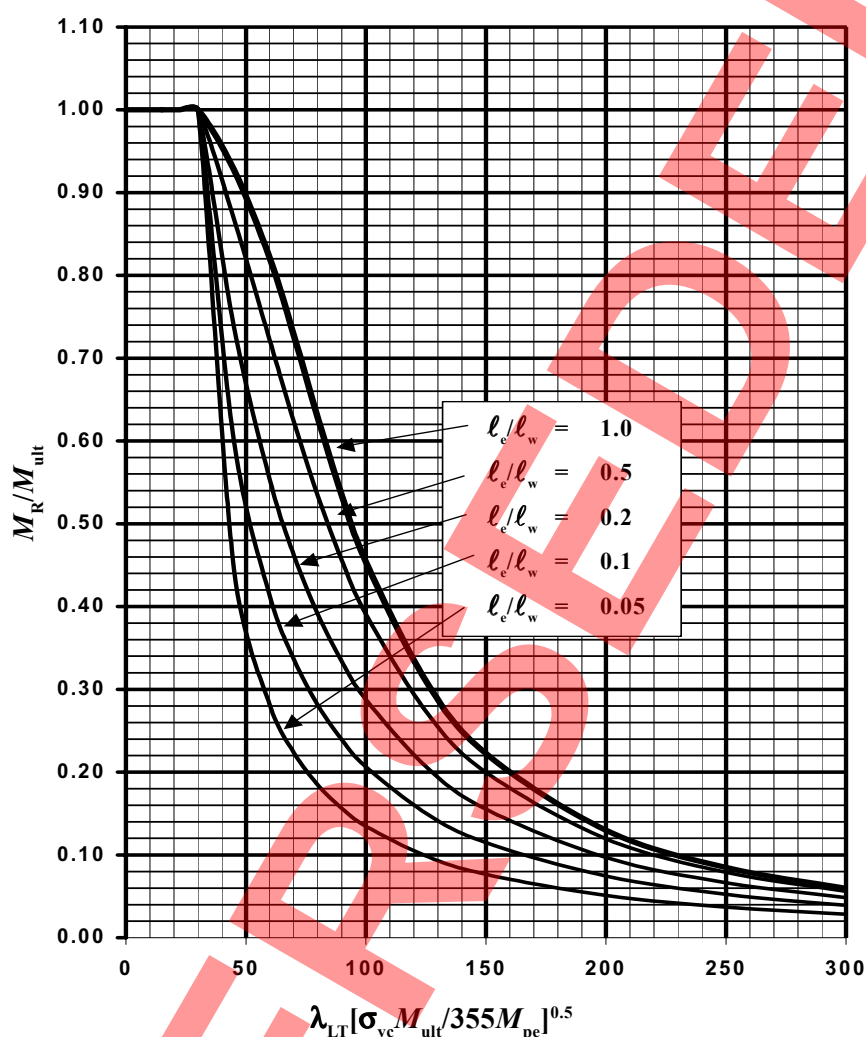


Figure 11 - Limiting moment of resistance M_R
b) All other sections



9.9.4.2 Buckling of beams

In the last sentence before “NOTE” delete “also”, after “should”

9.10.2.3 Strength of longitudinal flange stiffeners

Replace expressions in “a)” and “b)” with the following:

$$\begin{aligned} \text{“a) } \sigma_a + 2.5\tau_1 k_{s1} &\leq \frac{k_{11}\sigma_{ys}}{\gamma_m \gamma_{f3}} \\ \text{b) } \sigma_a + 2.5\tau_1 k_{s2} &\leq \frac{k_{12}\sigma_{ye}}{\gamma_m \gamma_{f3}} \text{”} \end{aligned}$$

In the definition of “ y_{Bs} ”, add at the end, “taken as positive when the neutral axis of the beam lies in the same direction from the centroid of the stiffener as that to the centroid of the beam cross-section”

9.11.4 Buckling of web panels

In “Figure 21 b), delete the column with the heading “w2 for use in D.2”

9.11.4.3.3 Shear Coefficient K_q

Line 3, delete the expression for “ K_q ” and replace by the following:

$$\text{“ } K_q = 435000 \left(\frac{t_w}{b} \right)^2 \frac{[1 + (b/a)^2]}{\sigma_{yw}} \text{”}$$

9.11.4.4 Interaction buckling criterion

Insert “NOTE” as follows at the end of the clause:

“NOTE In evaluating m_c and m_q in 9.11.4.4 when the values of K_1 and K_q are limited to 1.0 by the Figures 23(a) and (b) respectively, values greater than 1.0 may be used following the equations given in 9.11.4.3.2 for K_1 and 9.11.4.3.3 for K_q for low values of λ .”

9.11.5.2 Strength of longitudinal web stiffeners

In the definition of “ A_{sc} ” replace “action” by “section”

9.12.2 Elements providing discrete intermediate restraints

In a), replace Para 2 by the following:

“For a lateral restraint or plan bracing system to be fully effective it should comply with the requirements in 9.6.4.1.1.1

In b), para 3, replace the expressions after “The forces F_R should be taken as:” by the following:

“1) for lateral restraints

$$F_R = \left(\frac{\sigma_{fc}}{\sigma_{ci} - \sigma_{fc}} \right) \frac{\ell_w}{667\delta_{R\theta}}$$

but not greater than

$$F_R = \left(\frac{\sigma_{fc}}{\sigma_{ci} - \sigma_{fc}} \right) \frac{(n+1)EI_c}{16.7n\ell_R^2}$$

2) for torsional restraints

$$F_R = \left(\frac{\sigma_{fc}}{\sigma_{ci} - \sigma_{fc}} \right) \frac{\ell_w}{667\delta_{R\theta}}$$

or when $\ell_w > 13.3D$

$$F_R = \left(\frac{\sigma_{fc}}{\sigma_{ci} - \sigma_{fc}} \right) \frac{D}{50\delta_{R\theta}}$$

Modify the existing definitions as follows:

“ ℓ_w , L are as defined in 9.7.1”

“ θ_R , d_f , n and v_{eq} are as defined in 9.6.4.1.2”

In the definition for “ δ_R ” delete the text “for lateral restraints ... torsional restraints”

Insert the new definition:

$$\delta_{R\theta} = n\theta_R D d_f$$

where D is the overall depth of the beam”

Insert “NOTE” as follows at the end of the clause:

“NOTE Where torsional restraints are provided by diaphragms between two beams and the half wavelength (as given in 9.7.1) is the distance between support restraints L , the additional vertical forces and bending moments arising from the application of forces F_R may be derived assuming that the equal and opposite transverse forces F_R on each beam are shared between the restraint positions. (That is, there is in total only a single couple ($=F_R \times d_f$) on each beam.)”

9.13.5.3 Buckling of effective stiffener section

In the definition of “ P , M_{xs} ”, 3rd line, replace “fiven” by “given”

12.6 Lateral bracing

Last sentence, replace “cords” by “chords”

14.5.4.4

Last line, delete “to the satisfaction of the Engineer”

14.6.1 General

Line 1, replace “BS 5135:1984” by “BS EN 1011”

14.6.3.8 Effective length of fillet welds

Line 1, replace “BS 5135” by “BS EN 1011”

14.6.3.9 Effective throat of a fillet weld

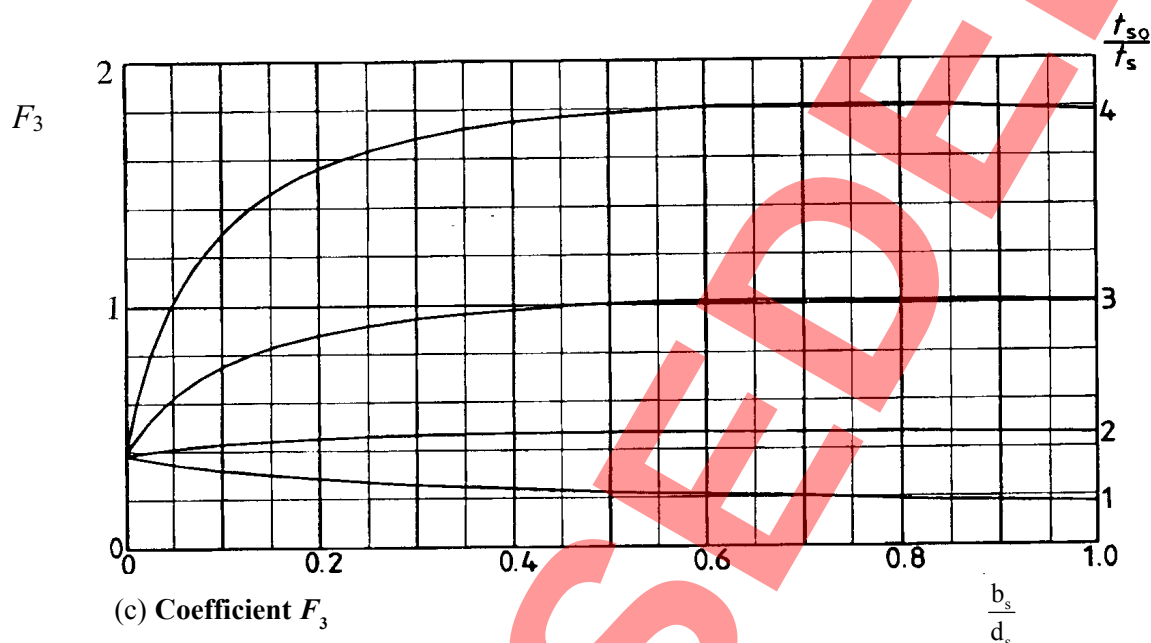
Para 2, line 2, delete “to the satisfaction of the Engineer”

14.7.2 Other combinations

Line 3, delete “to the satisfaction of the Engineer”

Annex C (Informative)

Replace “Figure C.1 – Coefficients for torsional buckling” by the following:



NOTE For basis of curves, see G.18.

Figure C.1 – Coefficients for torsional buckling

Annex G

G.1 General.

Add “with the exception of that in G.7” after “equations”.

Annex G.7 Figure 8 – Effective length of beams with discrete torsional restraints

Replace the entire Annex by the following:

“For beams with distributed torsional restraints

$$\ell_e = L \left[1 + \frac{v_{eq}^4 L^3}{\pi^4 EI_c d_f^2 \theta_R (1-i)} \right]^{(-0.25)}$$

The relationships in Figure 8 for beams with a single central restraint have been derived from the following equation:

$$2\pi^2(1-v_{eq}^4) \left[\frac{mL \cos \frac{mL}{2} + 2\mu nL \cosh \frac{nL}{2} - \alpha \left(-(mL)^3 \cos \frac{mL}{2} + 2\mu(nL)^3 \cosh \frac{nL}{2} \right)}{-\left(\sin \frac{mL}{2} + 2\mu \sinh \frac{nL}{2} \right)} \right] = \frac{v_{eq}^4 L^3}{\theta_R EI_c d_f^2 (1-i)}$$

where

$$mL = \sqrt{-\frac{1}{2\alpha} + \sqrt{\frac{1}{4\alpha^2} + \frac{\pi^2 c^2 (1+\pi^2 \alpha)}{\alpha}}}$$

$$nL = \sqrt{\frac{1}{2\alpha} + \sqrt{\frac{1}{4\alpha^2} + \frac{\pi^2 c^2 (1+\pi^2 \alpha)}{\alpha}}}$$

$$\alpha = \frac{v_{eq}^4}{\pi^2 (1-v_{eq}^4)} \text{ for } v_{eq} \leq 0.999 \text{ or otherwise } = 25$$

$$\mu = - \frac{mL \cos\left(\frac{mL}{2}\right)}{2nL \cosh\left(\frac{nL}{2}\right)}$$

$$c = \sqrt{\frac{L}{\ell_e}}$$

NOTE This may be used directly to derive the restraint stiffness parameter required to achieve a given effective length for buckling with a half wavelength equal to L .

The value of the effective length at which the critical buckling moment for a beam with a central restraint and a half-wavelength equal to L equals that for buckling in the second mode with a half-wavelength equal to $L/2$ is given by:

$$\frac{\ell_e}{L} = \left[\frac{1 + \pi^2 \alpha}{4(1 + 4\pi^2 \alpha)} \right]^{0.25}$$

These values are shown by vertical arrows on Figure 8 for three values of ν_{eq} .

Annex G.8

Replace the existing heading by the following:

“G.8. Limiting moment of resistance M_R ”

Insert below the heading “Figures 11a) and 11b) - The basis for Figures 11a) and 11b) is as follows:”

Line 1, replace “when $\beta \ell_w / \ell_e > 30$ ” by “when $\beta > 30$ ”

Line 2, replace “when $\beta \ell_w / \ell_e \leq 30$ ” by “when $\beta \leq 30$ ”

In definition of “ η ”

replace “ $0.008(\beta \ell_w / \ell_e - 30)$ ” by “ $0.008 \beta \ell_w / \ell_e$
($1 - 30/\beta$)”

replace “ $0.0035(\beta \ell_w / \ell_e - 30)$ ” by “ $0.0035 \beta \ell_w / \ell_e$
($1 - 30/\beta$)”

G.12 Figure 23 –Buckling co-efficients K_1, K_2, K_q, K_b

Insert “NOTE” as follows at the end:

“NOTE In using the interaction buckling criterion in 9.11.4.4 the values of K_1, K_q may be increased to a value greater than 1.0 using equations in 9.11.4.3.2 and 9.11.4.3.3 respectively.”