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published separately
and incorporating
Corrigendum No. 1*

Structural use of steelwork in building

Part 6. Code of practice for design of light gauge profiled steel sheeting

ICS 91.080.10

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Committees responsible for this British Standard

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 British Cement Association
 British Constructional Steelwork Association Ltd.
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 Building Employers' Confederation
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 Department of the Environment (Construction Directorate)
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 Federation of Civil Engineering Contractors
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 Institution of Structural Engineers
 National Council of Building Material Producers
 Royal Institute of British Architects
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 British Steel Industry
 Cold Rolled Sections' Association
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Foreword

This Part of BS 5950 and Amendment No. 1 have been prepared under the direction of Technical Committee B/525, Building and Civil Engineering and Structures. BS 5950 comprises codes of practice which cover the design, construction and fire resistance of steel structures and specifications for materials, workmanship and erection.

It comprises the following Parts and Sections:

Part 1	<i>Code of practice for design in simple and continuous construction: hot rolled sections</i>
Part 2	<i>Specification for materials, fabrication and erection: hot rolled sections</i>
Part 3	<i>Design in composite construction</i>
Section 3.1	<i>Code of practice for design of simple and continuous composite beams</i>
Part 4	<i>Code of practice for design of composite slabs with profiled steel sheeting</i>
Part 5	<i>Code of practice for design of cold formed sections</i>
Part 6	<i>Code of practice for design of light gauge profiled steel sheeting</i>
Part 7	<i>Specification for materials and workmanship: cold formed sections</i>
Part 8	<i>Code of practice for fire resistant design</i>
Part 9	<i>Code of practice for stressed skin design</i>

This Part of BS 5950 gives recommendations for the design of light gauge profiled steel sheeting as roof decking, flooring, and cladding and its provisions apply to the majority of structures, although it is recognized that cases will arise when other proven methods of design may be more appropriate. It is intended to be compatible with BS 5950 : Parts 1 and 5 and, at the same time, to be as self-contained as possible.

This Part of BS 5950 is primarily equation orientated, so that the rules can be easily programmed on desk-top computers which are now familiar in design offices. However, to assist the designer in obtaining simple and rapid analysis, it is possible in many situations to use the various tables and graphs provided, instead of calculation via the equations.

This Part of BS 5950 does not apply to other types of steel structures for which appropriate British Standards exist.

It has been assumed in the drafting of this British Standard that the execution of its provisions is entrusted to appropriately qualified and experienced people and that construction and supervision are carried out by capable and experienced organizations.

A British Standard does not purport to include all the necessary provisions of a contract. Users of British Standards are responsible for their correct application.

Compliance with a British Standard does not of itself confer immunity from legal obligations.

Section 1. General

1.0 Introduction

1.0.1 Aims of economical structural design

The aim of structural design is to provide, with due regard to economy, a structure capable of fulfilling its intended function and sustaining the specified loads for its intended life. The design should facilitate fabrication, erection and future maintenance.

Each part of the structure should be sufficiently robust and insensitive to the effects of minor incidental loads applied during service that the safety of other parts of the structure is not prejudiced.

Although the ultimate strength recommendations within this standard are to be regarded as limiting values, the purpose in design should be to reach these limits at as many places as possible, consistent with the need to rationalize sheeting profiles and thicknesses, in order to obtain the optimum combination of material and fabrication.

1.0.2 Accuracy of calculation

For the purpose of deciding whether a particular recommendation is satisfied, the final value, observed or calculated, expressing the result of a test or analysis should be rounded off. The number of significant places retained in the rounded off value should be the same as in the value given in the recommendation.

1.1 Scope

This Part of BS 5950 gives recommendations for the design of light gauge profiled steel sheeting used as roof decking, flooring and roof and wall cladding, including the design of profiled steel sheeting as permanent formwork for composite slabs.

It covers single and double skin cladding, but not the design of cladding elements which are not required to carry wind or snow loading. It is primarily intended for a net thickness of steel material up to 2 mm. It does not cover the design of sections with large bend radii.

This Part of BS 5950 applies to profiled steel sheets which consist either of a series of stiffened or unstiffened trapezoidal flutes or of other ribbed profiles which behave in a substantially similar manner. Such sheets are generally made up of flat elements bounded either by free edges or by bends with included angles not exceeding 135°. It also applies to profiled steel sheets which are embossed for use in composite slabs.

Only resistance to out-of-plane loading is covered in this Part of BS 5950. For resistance to in-plane loading by diaphragm action see BS 5950 : Part 9.

For the design of composite slabs using profiled steel sheeting acting compositely with concrete see BS 5950 : Part 4.

NOTE.1. The recommendations given in this Part of BS 5950 assume that the standards of materials and workmanship are as specified in Part 7 of BS 5950.

1.2 References

1.2.1 Normative references

This Part of BS 5950 incorporates, by dated or undated reference, provisions from other publications. These normative references are made at the appropriate places in the text and the cited publications are listed on the inside back cover. For dated references, only the edition cited applies: any subsequent amendments to or revisions of the cited publication apply to this British Standard only when incorporated in the reference by amendment or revision. For undated references, the latest edition of the cited publication applies, together with any amendments.

1.2.2 Informative references

This British Standard refers to other publications that provide information or guidance. Editions of these publications current at the time of issue of this standard are listed on the inside back cover, but reference should be made to the latest editions.

1.3 Definitions

For the purposes of this Part of BS 5950 the following definitions apply.

1.3.1 capacity

Limit of force or moment which can be expected to be carried at a cross section without causing failure due to yielding, rupture or local buckling.

1.3.2 effective width

Flat width of an element that can be considered to resist compression effectively.

1.3.3 element

Distinct portion of the cross section of a sheet profile.

1.3.3.1 stiffened element

Flat element adequately supported at both longitudinal edges.

1.3.3.2 unstiffened element

Flat element adequately supported at only one longitudinal edge.

1.3.3.3 edge stiffened element

Flat element supported at one longitudinal edge by a web and at the other longitudinal edge by a lip or other edge stiffener.

1.3.3.4 multiple-stiffened element

Element adequately supported at both longitudinal edges and having one or more intermediate stiffeners.

1.3.4 buckling resistance

Limit of force or moment that a sheet can withstand without buckling.

1.3.5 local buckling

Buckling of one or more of the compression elements of a cross section, characterized by the formation of waves or ripples along the sheet, which modifies the effectiveness of the cross section.

1.3.6 intermediate stiffeners

Folds or bends within a flange or web providing increased resistance to local buckling.

1.3.7 limit state

Condition beyond which a structure ceases to be fit for its intended use.

1.3.8 strength

Resistance to failure; specifically, limiting value for stress.

1.3.9 roof decking

Roof construction in which the load carrying profiled sheeting is located below insulation and waterproofing layers.

1.3.10 profiled sheet

Sheet longitudinally formed with a cross section comprising regularly spaced trapezoidal or other ribbed profiles generally composed of flat elements, including substantially flat sheet with side overlapping profile, which can support load over a span.

1.3.11 intersection point

Point representing a corner for use in the calculation of element widths, generally the midpoint on a curve between adjacent flat elements (see figure 4) but optionally the intersection point of the elements if the bend radius is less than $5t$.

1.4 Symbols

For the purposes of this Part of BS 5950, the following symbols apply:

A_r	Total stiffened area comprising the flange stiffener plus the two adjacent effective portions of the flange
$A_{r,ef}$	Effective area of a flange stiffener
A_{sa}, A_{sb}	Area of the folded web stiffener plus the two adjacent effective portions of the web stiffener
$A_{sa,ef}, A_{sb,ef}$	Effective cross-sectional area of a web stiffener
a	Distance between centres of holes in a perforated element
B_f	Width of a flange for flange curling
b	Flat width of an element (see figure 4)
b_c	Width subject to compression at ultimate limit state
b_d	Developed width of a stiffened element
b_{eff}	Effective width of a compression element (see figure 4)
$b_{ef,1}$ to $b_{ef,n}$	Effective widths of parts 1 to n of web (see figure 4)
$b_{ef,ser}$	Effective width at serviceability limit state
$b_{ef,1,ser}$ to $b_{ef,3,ser}$	Effective widths at serviceability limit state
b_{eu}	Effective width of an unstiffened compression element
b_k	$b + b_r/2$
b_m	Width of central portion of a stiffened flange, with two or more stiffeners
b_r	Width of a stiffener
b_t	Width subject to tension at ultimate limit state
$b_{t,ser}$	Width subject to tension at serviceability limit state
D_p	Overall depth of the profile
D_w	Sloping distance between the intersection points of a web and flanges (see figure 4)
d	Diameter of a fastener
d_p	Diameter of a perforation
d_w	Diameter of a washer
E	Modulus of elasticity of steel
e_{max}	Maximum eccentricity of a web from its effective plane
e_{min}	Minimum eccentricity of a web from its effective plane
F_v	Shear force
F_w	Reaction or concentrated load on a web
f_a	Average stress in a flange
f_c	Applied compressive stress
$f_{c,1}$ to $f_{c,n}$	Applied compressive edge stress
f_{ser}	Compressive stress at serviceability limit state
$f_{1,ser}$ to $f_{n,ser}$	Compressive stress at serviceability limit state
f_t	Applied tensile stress
G	Shear modulus of steel
g, g_1	Corrections to element lengths for corner radii (see figure 4)
h	D_w/b
h_a	Vertical distance from edge of a web stiffener to the compression flange
h_b	Vertical distance from edge of second stiffener to the compression flange

h_{sa}	Vertical depth of first stiffener
h_{sb}	Vertical depth of second stiffener
I_{eff}	Effective second moment of area of a section
I_{min}	Minimum required second moment of area of an effective edge stiffener
I_r	Second moment of area of a flange stiffener, about its own centroid
I_{sa}, I_{sb}	Second moment of area of a web stiffener
I_{ser}	Effective second moment of area at serviceability limit state determined at midspan
K	Relative local buckling coefficient for an element
K_t	Statistical correction factor
K_w, K_{wo}	Restraint coefficients for flange stiffeners
k	Statistical factor
k_s	Reduction factor for the crushing strength of a stiffened web
k_{sa}, k_{sb}	Factors used to determine k
k_v	Shear buckling coefficient
L	Span of a member between centres of supports
L_b	Length of the buckling wave in a stiffener
M	Applied moment at a given point on a section
M_c	Moment capacity of a section
N	Length of a bearing
P_t	Tensile capacity of a fastener with failure not taking place in the fastener
P_{ft}	Tensile capacity of a fastener with failure taking place in the fastener
P_v	Shear capacity or shear buckling resistance
P_w	Web crushing resistance
p_{cr}	Local buckling strength of an element
$p_{eff,cr}$	Effective value of critical buckling strength
$p_{r,cr}$	Elastic critical buckling strength of a flange stiffener
$p_{s,cr}$	Elastic critical buckling strength of a single longitudinal web stiffener
p_v	Shear strength
p_y	Design strength of steel
R_p	Relative section properties coefficient
R_s	Relative strength coefficient
R_t	Relative thickness coefficient
R_y	Relative yield strength coefficient
r	Inside bend radius
r_m	Mean bend radius
s	Standard deviation
$s_a, s_b, s_c,$ s_n, s_{sa}, s_{sb}	Dimensions used in calculations for stiffened webs
s_1 and s_2	Defined at the point of use
s_r	Semi-perimeter of flange stiffener
s_p	Depth of largest flat element in a web
s_t	Total developed depth of web
T_m	Mean result of two or three tests
T_r	Test result

t	Net thickness of steel material
t_{eff}	Effective thickness of a perforated element
t_{nom}	Nominal thickness assumed in design
t_1	Thickness of component under screw head
t_2	Thickness of component remote from screw head
U_s	Minimum ultimate tensile strength of steel
u	Maximum deflection of a flange towards the neutral axis due to flange curling
w	Intensity of load at serviceability limit state
Y_s	Minimum yield strength of steel
y	Distance from the flange to the neutral axis
y_c	Distance of the compression flange from the neutral axis
y_t	Distance of the tension flange from the neutral axis
α	Coefficient of linear thermal expansion or elastic critical strength factor
β	Reduction factor for stiffener effectiveness
ε	$(280/p_y)^{0.5}$ (with p_y in N/mm^2)
γ_f	Overall load factor
γ_l	Variability of loading factor
γ_m	Material strength factor
γ_p	Structural performance factor
δ	Deflection
η	Perry coefficient
$\lambda, \lambda_1, \lambda_{\text{ser}}$	Dimensionless quantities used in effective width calculations
$\lambda_w, \lambda_{wa}, \lambda_{wb}$	Dimensionless quantities used in calculation of web shear capacity
θ	Angle between a web and a flange
ν	Poisson's ratio

Section 2. Limit state design

2.1 General principles and design methods

2.1.1 General

Profiled steel sheeting should be designed by considering the limit states at which it would become unfit for its intended use, by applying appropriate factors for the ultimate limit state and the serviceability limit state.

Examples of limit states relevant to cold formed steel structures are given in table 1 of BS 5950 : Part 5 : 1987.

All relevant limit states should be considered, but usually it will be appropriate to design on the basis of strength under ultimate loading and then to check that deflection is not excessive under serviceability loading.

The overall factor in any design has to cover variability of:

- material strength γ_m ;
- loading γ_l ;
- structural performance γ_p .

In this Part of BS 5950 the material factor γ_m is taken as 1.0 for profiled steel sheet (see 3.3.2). Depending on the type of load, values of γ_l and γ_p are assigned. The product of γ_l and γ_p is the factor γ_f by which the specified loads are to be multiplied in checking the strength and stability of a structure. Recommended values of γ_f are given in table 1.

2.1.2 Methods of design

2.1.2.1 General

The design should be carried out by one of the methods given in 2.1.2.2 to 2.1.2.4. In each case the details of the sheeting and its connections should be such as to realize the assumptions made in the design, without adversely affecting any other part of the structure.

2.1.2.2 Analytical design

In general, design should be based on an elastic analysis which assumes that the sheeting is either simply supported or continuous over one or more intermediate supports, as appropriate, using the design equations given in this code.

2.1.2.3 Design on the basis of tests

Alternatively, where design by calculation is not practical or is inappropriate, the strength and stiffness may be confirmed by loading tests in accordance with section 7.

2.1.2.4 Design assisted by testing

For profiled sheets continuous over more than one span, a hybrid design method may be used, based on elastic section properties and supplemented by information on the moment rotation properties of the section obtained from testing or finite element analysis.

NOTE. An appropriate method of design assisted by testing is given in CIRIA Technical Note 116 [1].

2.2 Loading

2.2.1 General

All relevant loads should be considered separately and in such realistic combinations as to comprise the most critical effects on the element concerned. Loading conditions during erection should receive particular attention.

2.2.2 Dead, imposed and wind loading

Dead, imposed and wind loads should be determined in accordance with BS 6399 : Part 1, BS 6399 : Part 3 and CP 3 : Chapter V : Part 2 or BS 6399 : Part 2¹⁾. Loads on agricultural buildings should be in accordance with BS 5502 : Part 22.

¹⁾ In preparation.

2.2.3 Roof loads

2.2.3.1 Minimum imposed roof loads

A distinction is made in BS 6399 : Part 3 between imposed loads on roofs with access and without access. Where there is regular traffic for the maintenance of services and other elements of the building the choice between the two alternative loading intensities given in BS 6399 : Part 3 should be carefully considered. Generally, the greater loading requirement is recommended.

2.2.3.2 Equivalent line loads

For the purposes of this Part of BS 5950, the alternative concentrated loads of 0.9 kN and 1.8 kN, given in BS 6399 : Part 3, should be considered as equivalent to line loads of 1.5 kN/m and 3 kN/m respectively, in a direction transverse to the span of the sheeting. In multispan arrangements, the number and location of the line loads should be that combination which produces the greatest bending moment in the sheeting, subject to there being not more than one line load per span.

2.2.4 Construction loads

Where it is likely that construction loads will occur on roof decking or roof cladding designed for the minimum imposed roof loads for a roof with no access (see 2.2.3.1), the line load of 1.5 kN/m referred to in 2.2.3.2 should be increased to 2 kN/m.

2.2.5 Agricultural buildings

For buildings designed for reduced distributed imposed loads according to BS 5502 : Part 22, the line loads given in 2.2.3.2 may be reduced in proportion.

2.2.6 Local roof loads

Profiled sheets used as roof decking or roof cladding should also be capable of supporting the local unfactored load as defined in BS 5427.

2.3 Ultimate limit state

In checking the strength of a profiled steel sheet, the loads should be multiplied by the relevant γ_f factors given in table 1. The factored loads should be applied in the most unfavourable realistic combination for the sheet under consideration.

The load capacity of each sheet and its connections, as determined by the relevant provisions of this Part of BS 5950, should be such that the factored loads would not cause failure.

Loading	Factor γ_f
Dead load	1.4
Dead load restraining uplift or overturning	1.0
Dead load acting with wind and imposed loads combined	1.2
Imposed load	1.6
Imposed load acting with wind load	1.2
Wind load	1.4
Wind load acting with imposed load	1.2
Forces due to temperature effects	1.2

NOTE 1. Dead loads may be taken as zero for wall cladding.
NOTE 2. Construction loads are treated as imposed loads.

2.4 Serviceability limit state

2.4.1 Serviceability loads

In general, the serviceability loads should be taken as the full unfactored loads. When considering dead load plus imposed load plus wind load, only 80 % of the imposed load and wind load need be considered.

Construction loads should not be included in the serviceability loads.

2.4.2 Deflection

The deflections of a profiled steel sheet under serviceability loads should not impair the strength or efficiency of the sheeting or of its fixings or cause damage to flashings, insulation or waterproofing.

When checking the deflections the most adverse realistic combination and arrangement of serviceability loads should be assumed. Wind loading should normally be assumed to be uniform on all spans of multi-span sheeting.

Table 2 gives recommended deflection limits for various types of sheeting. Circumstances may arise where greater or lesser values would be more appropriate.

Table 2. Normal maximum permissible deflection¹⁾ for profiled sheeting under distributed loads		
Load condition	Permissible deflection as a multiple of span	
	Roof cladding	Wall cladding
Dead	L/500	—
Dead and imposed	L/200	—
Dead and wind	L/90	L/120

¹⁾ Excluding rooflights.

Section 3. Properties of materials and section properties

3.1 Range of thicknesses

The provisions of this Part of BS 5950 apply primarily to profiled steel sheet with a net thickness of steel base metal of not more than 2 mm. The recommended minimum thickness for steels with a nominal yield strength Y_s less than 280 N/mm² is given in table 3. For profiles in steel of thickness less than the recommended minimum, the manufacturer of the profiled sheets should demonstrate adequate resistance to denting due to construction and maintenance traffic.

Use	Minimum thickness mm
Roof decking	0.65
Roof cladding	0.65
Wall cladding	0.55

3.2 Design thickness

The design thickness of the material should be taken as the nominal base metal thickness exclusive of coatings.

3.3 Properties of materials

3.3.1 General

This Part of BS 5950 covers the design of profiled sheeting made from steel supplied to BS 1449 : Part 1, BS 6830, BS EN 10025, BS EN 10130, BS EN 10143 or BS EN 10147. Other steels may be used provided that due allowance is made for variation in properties, including ductility (see BS 5950 : Part 7).

NOTE. It is anticipated that BS 1449 and BS 6830 will eventually be superseded by further European Standards in the BS EN series.

3.3.2 Strength of steel

The design strength p_y should be taken as Y_s but not greater than $0.84U_s$ where:

- Y_s is the nominal yield strength (i.e. the higher yield strength, R_{eff} , or in the case of material with no clearly defined yield, either the 0.2 % proof stress, $R_{p,0.2}$, or the stress at 0.5 % total elongation, $R_{t,0.5}$ as specified in the relevant material standard);
- U_s is the nominal ultimate tensile strength (i.e. the minimum tensile strength, R_m as specified in the relevant material standard);

and R_{eff} , $R_{p,0.2}$, $R_{t,0.5}$ and R_m are as defined in BS EN 10002-1.

For steels complying with one of the British Standards listed in Table 4, the values R_{eff} , $R_{p,0.2}$, $R_{t,0.5}$ and R_m should normally be taken as specified in the relevant product standard for the steel sheet or strip and used for the formed sections. For information, the resulting values of Y_s and U_s are also given in Table 4 together with appropriate design strength p_y for the relevant grade.

NOTE. Formability grades have no guaranteed minimum strength, but can be expected to achieve a nominal yield strength of at least 140 N/mm².

Alternatively, for steels complying with any British Standard and supplied with specific inspection and testing to BS EN 10021, the values of R_{eff} , $R_{p,0.2}$, $R_{t,0.5}$ and R_m may be based on the values declared in an inspection certificate in accordance with BS EN 10204.

Reference should be made to BS 5950 : Part 7 for recommendations concerning the testing regime required to determine the characteristic properties of any steel not certified as complying with an appropriate British Standard.

The design strength p_y may be increased due to cold forming as given in 3.4.

Table 4. Yield, ultimate and design strengths

Type of steel	British Standard	Grade	Nominal yield strength ¹ Y_s N/mm ²	Nominal ultimate tensile strength ¹ U_s N/mm ²	Design strength P_y N/mm ²
Hot rolled steel sheet of structural quality	BS EN 10025	S 235 S 275 S 355	235 275 355	360 430 510	235 275 355
Continuous hot dip zinc coated carbon steel sheet of structural quality	BS EN 10147	S 220 G S 250 G S 280 G S 320 G S 350 G	220 250 280 320 350	300 330 360 390 420	220 250 280 320 350
Hot rolled steel sheet based on formability	BS 1449-1-1.8	HS 3 or HS 4	(170) ²	(280) ²	140
Hot rolled low carbon steel sheet for cold forming	BS EN 10111	DD 11 or DD 12	(170) ²	—	140
Hot rolled high yield strength steel for cold forming Thermomechanically rolled steels	BS EN 10149-2	S 315 MC S 355 MC S 420 MC	315 355 420	390 430 480	315 355 400 ³
Hot rolled high yield strength steel for cold forming Normalized and normalized rolled steels	BS EN 10149-3	S 260 NC S 315 NC S 355 NC S 420 NC	260 315 355 420	370 430 470 530	260 315 355 420
Cold rolled steel sheet based on minimum strength	BS 1449-1-1.5 (CR) or BS 1449-1-1.11 (CS)	34/20 37/23 43/25 50/35 40/30 43/35 40F30 43F35	200 230 250 350 300 350 300 350	340 370 430 500 400 430 400 430	200 230 250 350 300 350 300 350

¹ Nominal yield and ultimate tensile strengths are given for information only. For details see appropriate product standard.

² Figures in brackets are given for guidance only.

³ Design strength limited to $0.84U_s$.

3.3.3 Other properties of steel

The following values for the elastic properties should be used:

- modulus of elasticity $E = 205 \text{ kN/mm}^2$
- shear modulus $G = E/2.6$
(i.e. $G = 79 \text{ kN/mm}^2$ approx.)
- Poisson's ratio $\nu = 0.30$
- coefficient of linear thermal expansion $\alpha = 12 \times 10^{-6}/^\circ\text{C}$

3.4 Calculation of section properties

3.4.1 Method of calculation

When calculating the section properties of sheet profiles, it may be assumed that the material is concentrated at the mid-line of the sheet thickness, providing the flat width of all the elements is greater than $r/0.15$ or $20t$, whichever is the greatest.

where:

r is the inside bend radius

t is the net thickness of steel material.

The presence of corners and bends should be allowed for as recommended in table 5.

Table 5. Allowance for corners and bends	
Geometrical limit	Basis for calculation
$r \leq 5t$	Replace round corners by the intersects of the flat elements
$5t < r \leq 0.04tE/p_y$	Use actual geometric configuration of cross section
$r > 0.04tE/p_y$	For sections with large radii the carrying capacity is to be determined by testing
<p>Key</p> <p>r is the inside bend radius;</p> <p>t is the net thickness of steel material;</p> <p>E is the modulus of elasticity;</p> <p>p_y is the design strength.</p> <p>NOTE 1. $0.04tE/p_y = 29.3t (280/p_y)$ approx. (p_y in N/mm^2).</p> <p>NOTE 2. For the influence of corners on effective widths of flat elements see 4.3.2.</p>	

3.4.2 Gross section properties

When calculating the gross section properties of a sheet profile, holes for fasteners need not be deducted but allowance should be made for any large openings or arrays of small holes.

3.4.3 Net section properties

The net section properties of profiles with regular or irregular arrays of holes, other than holes required for fastening and filled with bolts or other mechanical fasteners, may be determined either by analytical methods (see 3.4.5) or by testing.

3.4.4 Profiles for composite slabs

Embossments and indentations designed to provide composite action with in-situ concrete may be ignored when calculating the section properties of the sheeting profile.

3.4.5 Profiles with acoustic perforations

The section properties of sheet profiles incorporating a regular pattern of acoustic perforations should be calculated using the design equations for non-perforated sheet given in this Part of BS 5950, but replacing the net thickness t in the perforated zones by an effective thickness t_{eff} .

Except where more favourable values can be justified on the basis of tests, provided that the ratio d_p/a is within the range $0.2 \leq d_p/a \leq 0.8$, the effective thickness should be determined from

$$t_{\text{eff}} = t \left\{ 1 - (d_p/a)^2 \right\}^{3/2}$$

where

- d_p is the diameter of the perforation;
- a is the distance between centres of holes.

3.4.6 Flange curling

Profiles with flanges which have high width to thickness ratios B_f/t are liable to exhibit the type of cross-sectional distortion known as 'flange curling' shown in figure 1.

Provided that B_f/t is not greater than 250ε the inward movement of each flange towards the neutral axis may be assumed to be less than $0.05D_p$, where D_p is the overall depth of the profile, and its occurrence may be neglected for structural purposes.

When necessary the maximum inward movement u of the flange towards the neutral axis should be determined from

$$u = 2 \frac{f_a^2 B_f^4}{E^2 t^2 y}$$

where

f_a is the average stress in the flange;

B_f is the width of the flange for flange curling equal to the overall flange width for an unstiffened or edge stiffened flange or half the overall flange width for a stiffened flange (see figure 1);

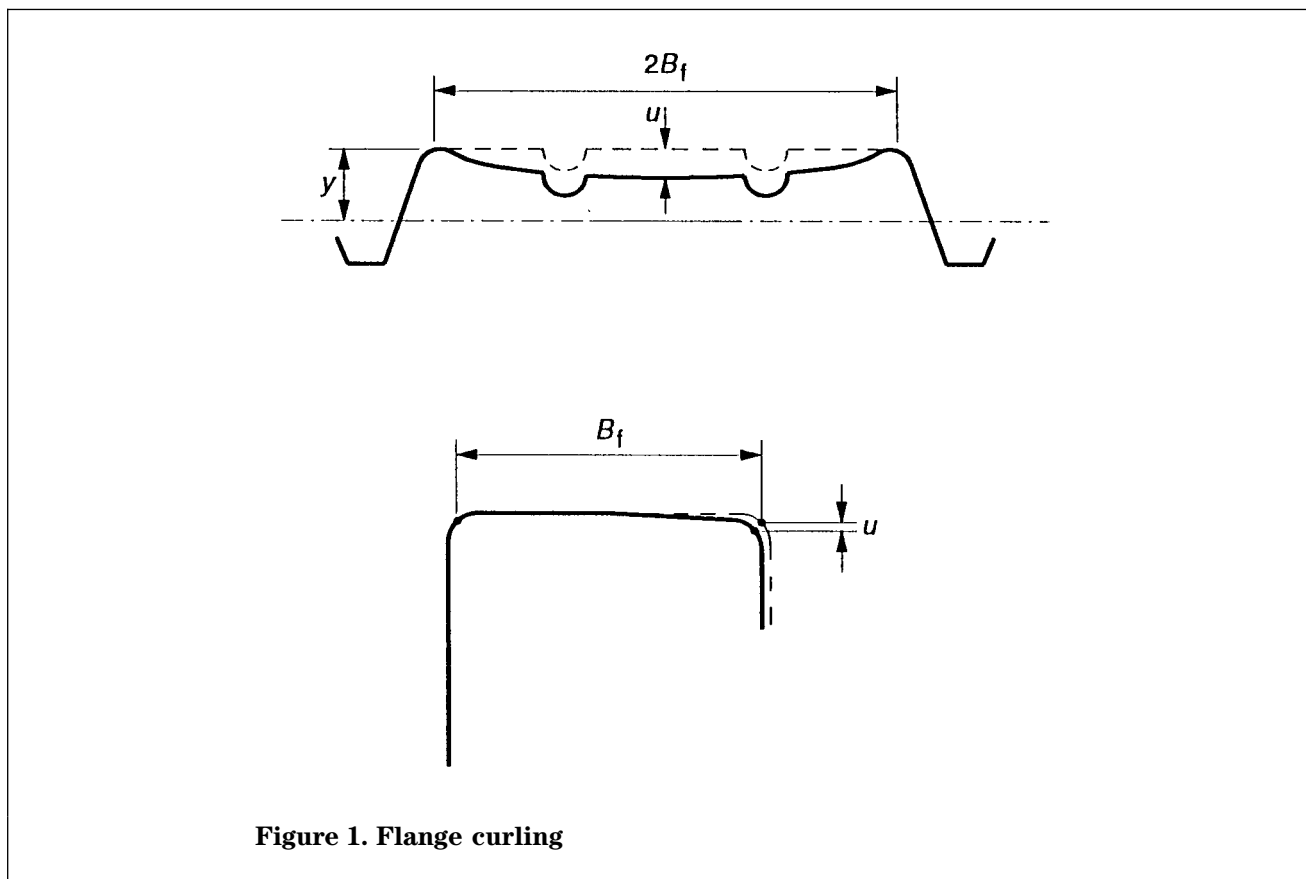
E is the modulus of elasticity;

t is the net thickness of steel material;

y is the distance from the flange to the neutral axis.

NOTE.1. This equation applies to both compression and tension flanges with or without stiffeners.

NOTE.2. If the stress in the flange has been calculated on the basis of an effective width, b_{eff} , then f_a can be obtained by multiplying the stress on the effective width by the ratio of the effective flange area to the gross flange area.



Section 4. Local buckling

4.1 General

The effects of local buckling in reducing the moment capacity and stiffness of a profiled steel sheet should be allowed for through the use of effective cross-sectional properties as described in 5.2 and 5.6. These should be determined making use of:

- the effective widths of individual flat elements wholly or partly in compression; and
- the effective areas of intermediate stiffeners.

For flat stiffened elements (1.3.3.1), the effective width consists of two portions, one adjacent to each edge (see figure 2).

For flat unstiffened elements (1.3.3.2), the whole of the effective width is located adjacent to the supported edge.

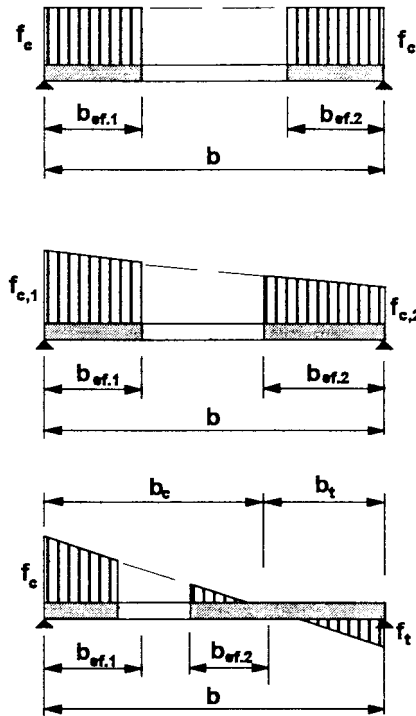


Figure 2. Effective width for a stiffened element

4.2 Maximum width to thickness ratios

4.2.1 General

For compression elements, the maximum values of element flat width to thickness ratio b/t covered by the design procedures given in this Part of BS 5950 are as follows:

- stiffened elements with one longitudinal edge connected to a flange or web element and the other stiffened by any stiffener satisfying 4.2.2: 90ε ;
- stiffened elements with both longitudinal edges connected to other elements: 50ε ;
- unstiffened compression elements: 60ε

where

- ε is $(280/p_y)^{0.5}$;
 p_y is the design strength of the steel.

NOTE. Unstiffened compression elements that have width to thickness ratios b/t exceeding 30ε and stiffened compression elements that have b/t ratios exceeding 250ε are likely to develop noticeable deformations at the full working load, without affecting the ability of the member to carry this load.

4.2.2 Edge stiffener

For a flat compression element to be considered a stiffened element, it should be supported along one longitudinal edge by a web, and along the other by a web, or by a lip or other edge stiffener which has adequate flexural rigidity to maintain the straightness of this edge under load.

Irrespective of its shape, the second moment of area of an edge stiffener, about an axis through the mid-thickness of the element to be stiffened, should not be less than I_{\min} determined from

$$I_{\min} = \frac{tb^3}{375}$$

where

- b is the width of the element to be stiffened;
 t is the thickness.

Where a compression element is stiffened by simple lip, the lip should be at an angle of not less than 70° from the element to be stiffened.

Where the stiffener consists of a simple lip at right angles to the element to be stiffened, a width of lip not less than one-fifth of the element width b , as indicated in figure 3, may be taken as satisfying this condition.

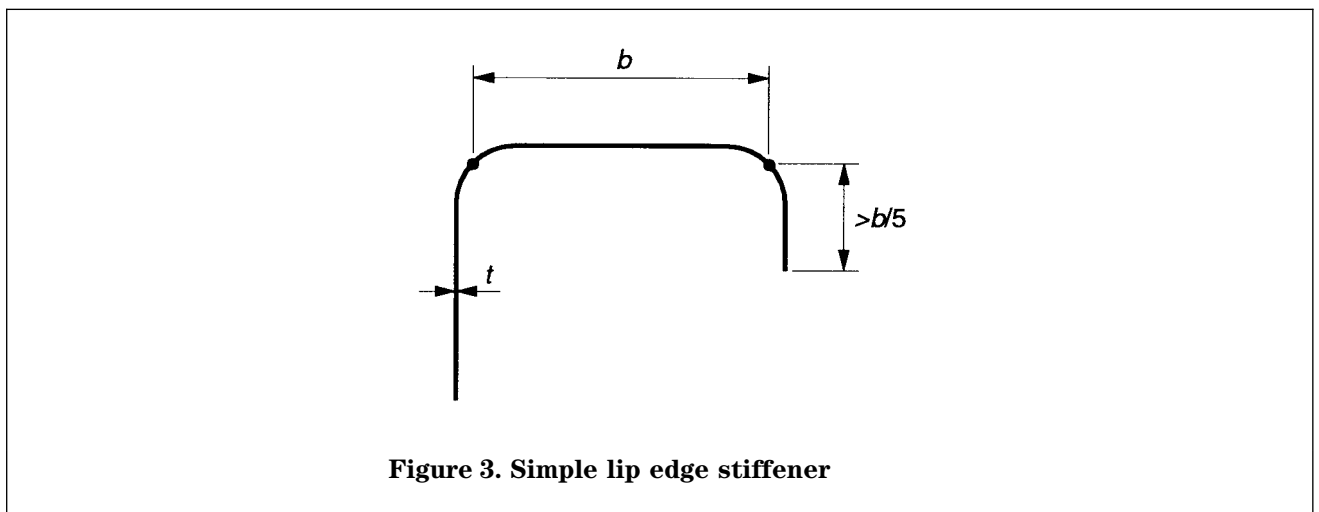


Figure 3. Simple lip edge stiffener

4.3 Effective width for strength calculations

4.3.1 Basic effective width

The ratio of the effective width b_{eff} to the flat width b of an element in compression should be determined from the following.

a) For $f_c/p_{\text{cr}} \leq 0.123$:

$$b_{\text{eff}}/b = 1$$

b) For $f_c/p_{\text{cr}} > 0.123$:

$$b_{\text{eff}}/b = \left\{ 1 + 14 \left(\sqrt{f_c/p_{\text{cr}}} - 0.35 \right)^4 \right\}^{-0.2}$$

where

f_c is the applied compressive stress in the effective element;

p_{cr} is the local buckling strength of the element.

The local buckling strength p_{cr} (in N/mm^2) of an element should be determined from

$$p_{\text{cr}} = 0.904EK(t/b)^2$$

where

K is the relevant local buckling coefficient;

t is the net thickness of the steel material;

b is the flat width of the element.

The local buckling coefficient K depends upon the type of element and the geometry of the profile (see 4.3.3 and 4.3.4).

4.3.2 Effect of bend radius

The effective width of a flat element should generally be calculated on the assumption that each element extends to the mid-point of the corners.

When the inside bend radius r of a corner exceeds $5t$, the effective width of each of the flat elements meeting at that corner should be reduced by $r_m \sin(\theta/2)$ (see figure 4).

NOTE. For the effect of bends and corners on the calculation of gross and net section properties see 3.4.1.

4.3.3 Effective width of a flat stiffened flange element

The effective width of a flat stiffened element (1.3.3.1) forming a compression flange should be determined in accordance with 4.3.1, using the appropriate value of K .

For flanges stiffened at both longitudinal edges the value of the buckling coefficient K may conservatively be taken as 4. Alternatively a more precise value of K may be obtained from figure 5 or determined from

$$K = 7 - \frac{1.8h}{0.15 + h} - 0.091h^3$$

where

$$h = D_w/b;$$

D_w is the sloping distance between the intersection points of a web and the flanges;

b is the flat width of the flange.

For stiffened flanges with $K = 4$ in profiles made of steel with yield strength $Y_s = 280 \text{ N/mm}^2$, the effective width b_{eff} determined in accordance with 4.3.1 with $f_c = 280 \text{ N/mm}^2$, may be obtained from the product of the ratio b_{eff}/b given in table 6 and the flat width of the flange b .

For K values other than 4, or profiles made of steel with Y_s other than 280 N/mm^2 , the effective width b_{eff} may be obtained using table 6 with a modified b/t ratio, determined by multiplying the actual value of b/t by

$$\sqrt{(4/K) (p_y/280)}$$

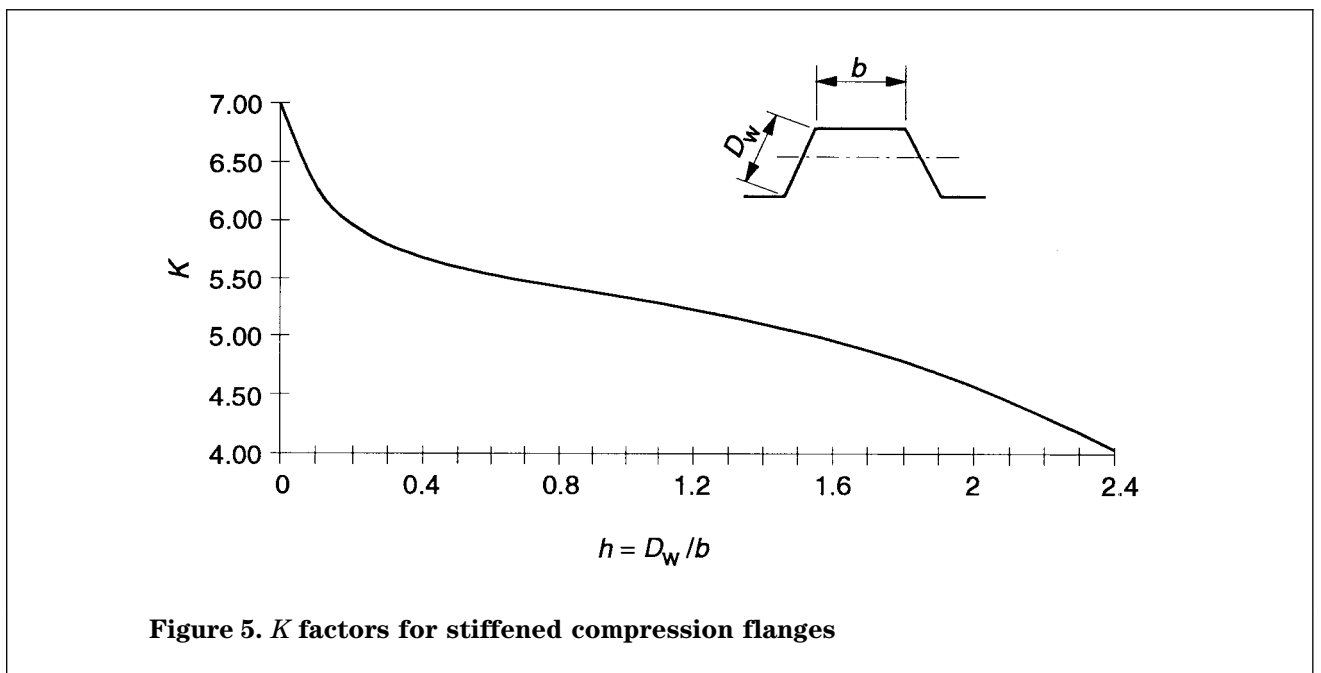
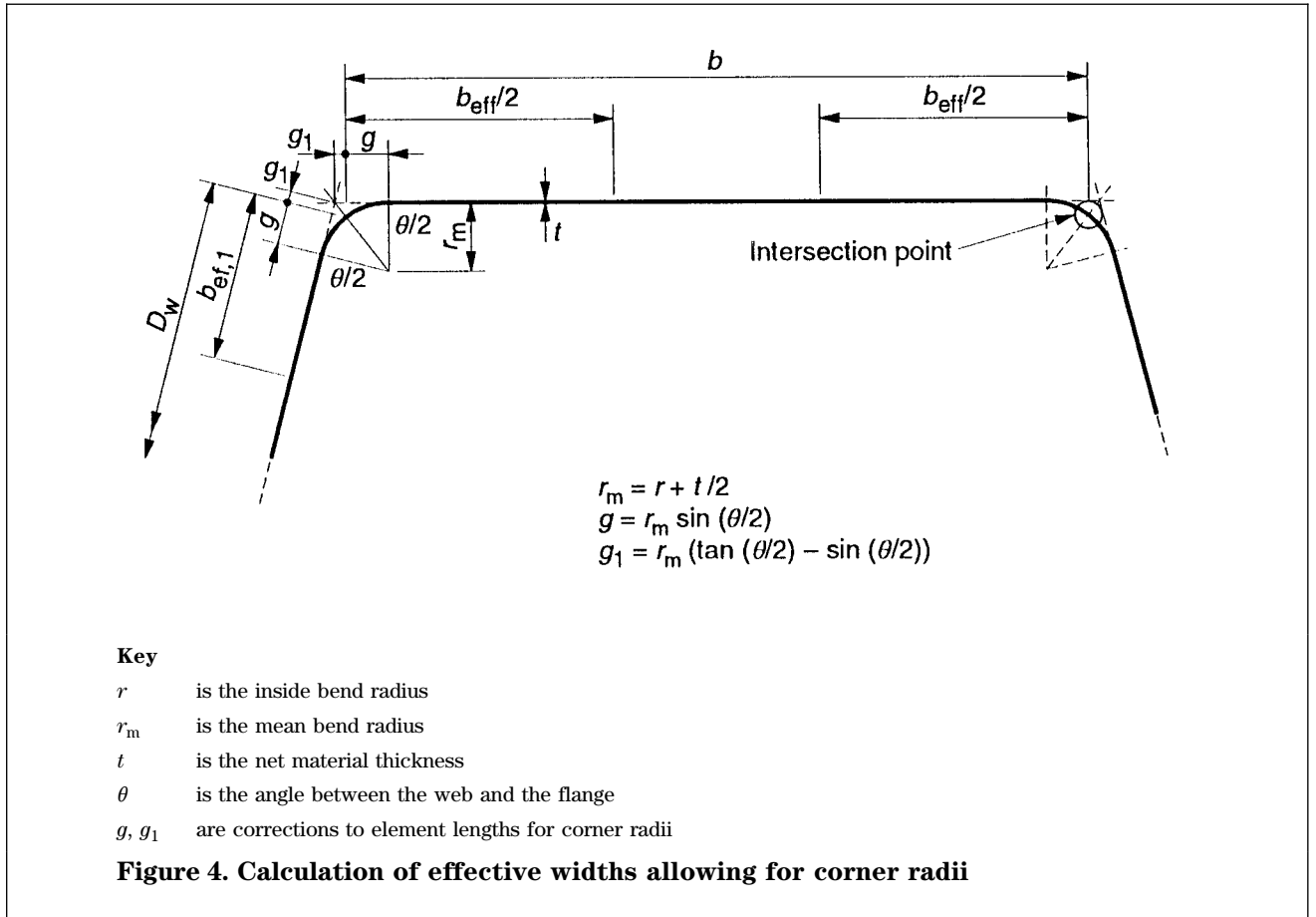


Table 6. Effective width ratios b_{eff}/b for stiffened elements with $Y_s = 280 \text{ N/mm}^2$

b/t	b_{eff}/b	b/t	b_{eff}/b	b/t	b_{eff}/b	b/t	b_{eff}/b
20	1	60	0.673	100	0.405	300	0.151
21	1	61	0.662	105	0.387	305	0.149
22	1	62	0.652	110	0.370	310	0.147
23	1	63	0.641	115	0.355	315	0.145
24	0.999	64	0.631	120	0.341	320	0.143
25	0.999	65	0.621	125	0.328	325	0.141
26	0.998	66	0.612	130	0.316	330	0.139
27	0.997	67	0.603	135	0.305	335	0.138
28	0.996	68	0.594	140	0.295	340	0.136
29	0.994	69	0.583	145	0.286	345	0.134
30	0.992	70	0.577	150	0.277	350	0.133
31	0.989	71	0.569	155	0.269	355	0.131
32	0.985	72	0.561	160	0.262	360	0.130
33	0.981	73	0.553	165	0.254	365	0.128
34	0.976	74	0.545	170	0.248	370	0.127
35	0.969	75	0.538	175	0.241	375	0.125
36	0.962	76	0.531	180	0.235	380	0.124
37	0.955	77	0.524	185	0.230	385	0.122
38	0.946	78	0.517	190	0.224	390	0.121
39	0.936	79	0.511	195	0.219	395	0.120
40	0.926	80	0.504	200	0.215	400	0.119
41	0.915	81	0.498	205	0.210	405	0.117
42	0.903	82	0.492	210	0.206	410	0.116
43	0.891	83	0.486	215	0.201	415	0.115
44	0.878	84	0.480	220	0.197	420	0.114
45	0.865	85	0.475	225	0.194	425	0.113
46	0.852	86	0.469	230	0.190	430	0.112
47	0.838	87	0.464	235	0.186	435	0.111
48	0.824	88	0.459	240	0.183	440	0.109
49	0.811	89	0.454	245	0.180	445	0.108
50	0.797	90	0.449	250	0.177	450	0.107
51	0.784	91	0.444	255	0.174	455	0.106
52	0.771	92	0.439	260	0.171	460	0.106
53	0.757	93	0.435	265	0.168	465	0.105
54	0.745	94	0.430	270	0.165	470	0.104
55	0.732	95	0.426	275	0.163	475	0.103
56	0.720	96	0.421	280	0.160	480	0.102
57	0.708	97	0.417	285	0.158	485	0.101
58	0.696	98	0.413	290	0.156	490	0.100
59	0.684	99	0.409	295	0.153	495	0.099
60	0.673	100	0.405	300	0.151	500	0.098

4.3.4 Effective width of a flat unstiffened flange element

The effective width b_{eu} of a flat unstiffened element (1.4.3.2) under uniform compression should be determined from

$$b_{eu} = 0.89 b_{eff} + 0.11b$$

where

- b_{eff} is determined from the basic effective width determined in accordance with 4.3.1;
- b is the flat width of the element.

The value of K may conservatively be taken as 0.425 for any unstiffened element. Alternatively a more precise value of K may be obtained from figure 6 or determined from

$$K = 1.28 - \frac{0.8h}{2 + h} - 0.0025h^2$$

where

$$h = D_w/b;$$

D_w is the sloping distance between the intersection points of a web and the flanges;

For profiles made of steel with Y_s equal to 280 N/mm² and having $K = 0.425$, the effective width determined in accordance with 4.3.1 and modified as above with $f_c = 280$ N/mm² may be obtained using table 7.

The effective width b_{eff} may be obtained from the product of the ratio b_{eff}/b given in table 7 and the actual element width b .

For profiles made of steel with p_y other than 280 N/mm², or having K values other than 0.425, the effective width may be obtained using table 7 by using a modified b/t ratio, determined by multiplying the actual value of b/t by $(p_y/660K)^{0.5}$ where p_y is the design strength of the material.

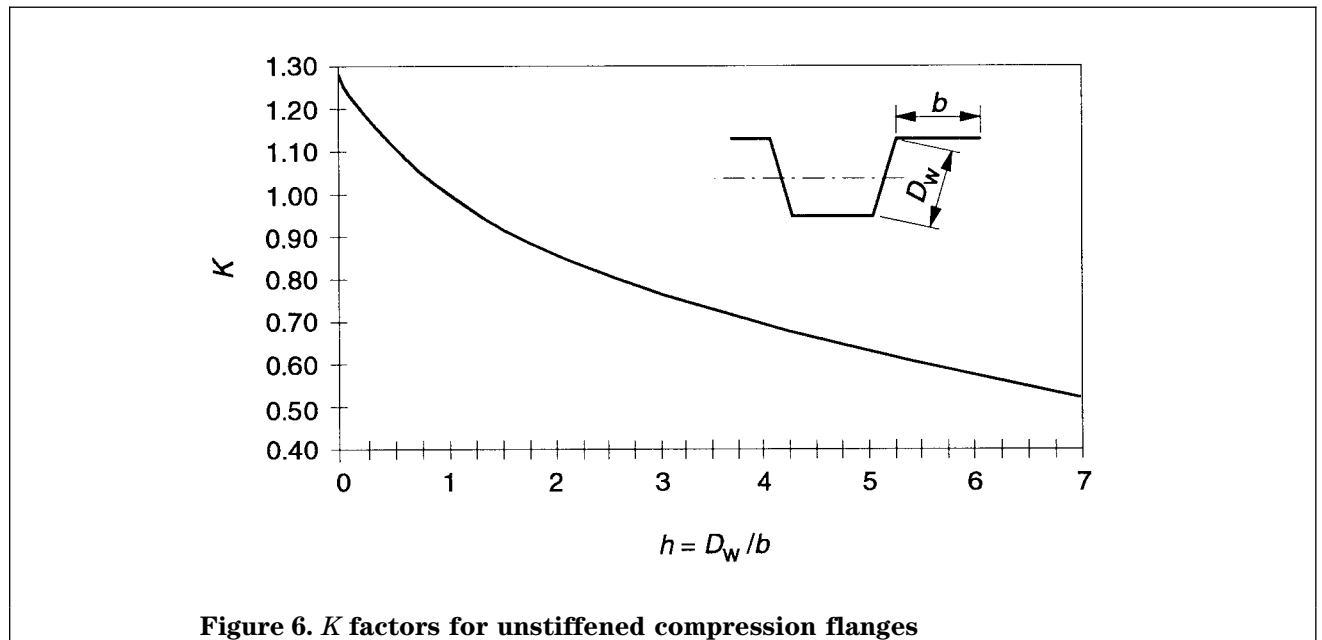


Table 7. Effective width ratios b_{eu}/b for unstiffened elements with $Y_s = 280 \text{ N/mm}^2$

b/t	b_{eu}/b	b/t	b_{eu}/b
1	1	31	0.489
2	1	32	0.477
3	1	33	0.466
4	1	34	0.456
5	1	35	0.447
6	1	36	0.438
7	1	37	0.429
8	0.999	38	0.422
9	0.997	39	0.414
10	0.991	40	0.407
11	0.980	41	0.400
12	0.961	42	0.394
13	0.935	43	0.388
14	0.903	44	0.382
15	0.868	45	0.376
16	0.831	46	0.371
17	0.794	47	0.366
18	0.759	48	0.361
19	0.726	49	0.356
20	0.696	50	0.352
21	0.668	51	0.348
22	0.643	52	0.343
23	0.619	53	0.339
24	0.598	54	0.336
25	0.578	55	0.332
26	0.560	56	0.328
27	0.544	57	0.325
28	0.528	58	0.322
29	0.514	59	0.319
30	0.501	60	0.315

4.3.5 Effective width of a flat web element

Webs of trapezoidal profiles in which the web depth to thickness ratio $D_w/t \leq 70\varepsilon$ may be taken as fully effective. In all other cases the effective width of a web in which the stress varies linearly as shown in figure 7, should be obtained in two portions, one adjacent to each edge as follows.

a) Both edges in compression (see figure 7a):

$$b_{ef,1} = 0.76t \sqrt{E/f_{c,1}}$$

$$b_{ef,2} = (1.5 - 0.5f_{c,2}/f_{c,1})b_{ef,1}$$

where

- $f_{c,1}$ is the larger compressive edge stress;
- $f_{c,2}$ is the smaller compressive edge stress;
- $b_{ef,1}$ is the portion of the effective width adjacent to the more compressed edge;
- $b_{ef,2}$ is the portion of the effective width adjacent to the less compressed edge;
- E is the modulus of elasticity;
- t is the net thickness of the steel material.

If $b_{ef,1} + b_{ef,2} \geq D_w$ the whole web is effective.

D_w is the sloping distance between the intersection points of a web and flanges (see Figure 4).

b) One edge in tension (see figure 7b):

$$b_{ef,1} = 0.76t \sqrt{E/f_{c,1}}$$

$$b_{ef,3} = b_t + 1.5b_{ef,1}$$

where

- b_t is the width subject to tension;
- $b_{ef,3}$ is the portion of the effective width adjacent to the tension edge.

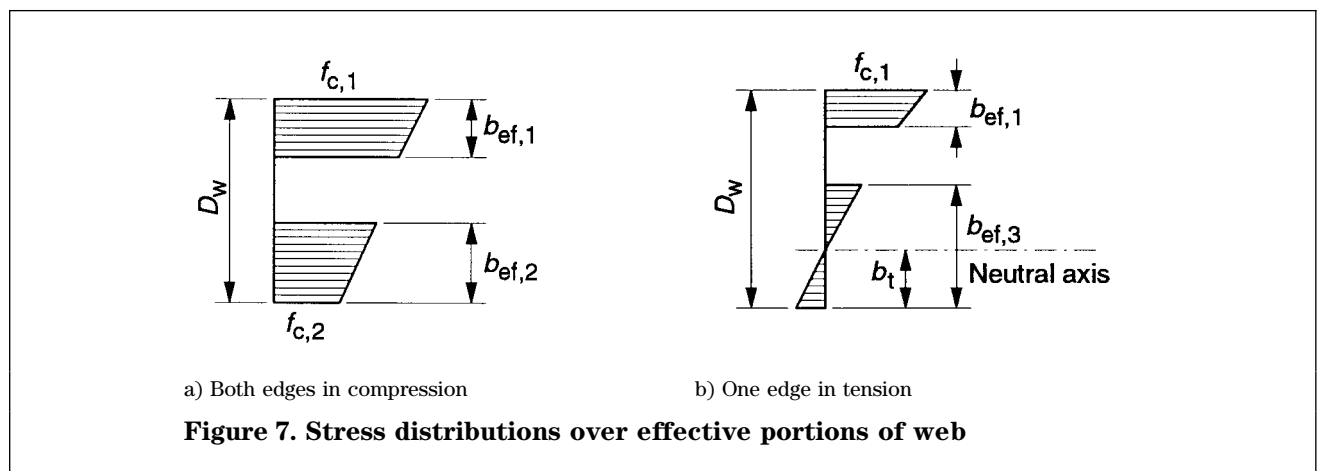
If $b_{ef,1} + b_{ef,3} \geq D_w$ the whole web is effective.

c) Both edges in tension:

The whole web is effective.

If the location of the neutral axis is determined iteratively, using effective section properties (rather than assuming the web to be fully effective), then $b_{ef,1}$ in items a) and b) above should be determined from

$$b_{ef,1} = 0.95t(E/f_{c,1})^{0.5}$$



4.4 Effective cross section of a multiple-stiffened flange

4.4.1 Flange with a single stiffener at the centre

4.4.1.1 General

The effective cross section of a multiple-stiffened flange with a single central stiffener should be obtained in the form of the separate portions indicated in figure 8 as follows:

- two effective portions each of effective width $b_{\text{eff}}/2$, one adjacent to each web, where b_{eff} is the effective portion of a flat width of the flange element b , determined in accordance with 4.3.1; and
- the effective area of the flange stiffener $A_{\text{r,ef}}$ (see 4.4.1.2).

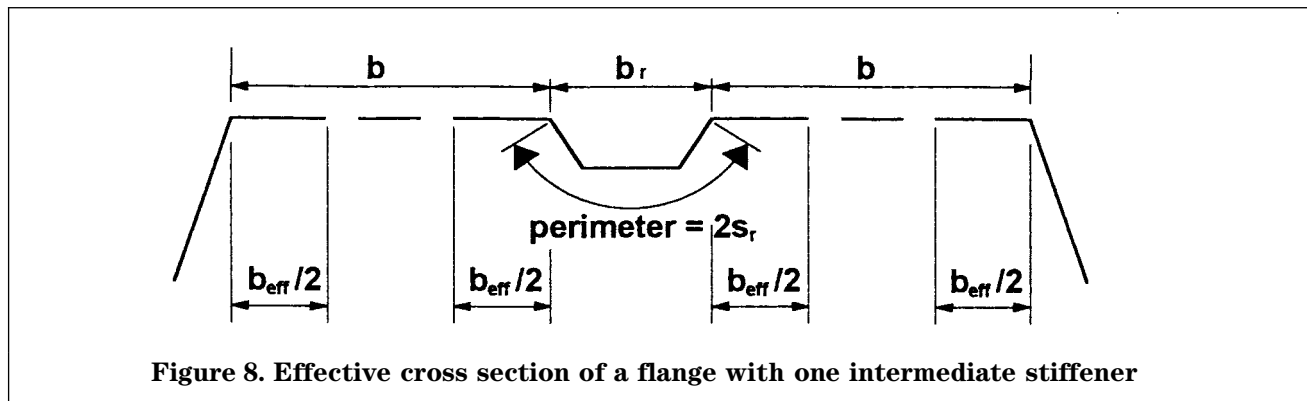


Figure 8. Effective cross section of a flange with one intermediate stiffener

4.4.1.2 Effective area of the flange stiffener

The effective area $A_{\text{r,ef}}$ of the flange stiffener should be determined from

$$A_{\text{r,ef}} = \beta A_{\text{r}}$$

where

A_{r} is the total stiffened area comprising the flange stiffener itself plus the two adjacent effective portions of the flange each with an effective width $b_{\text{eff}}/2$ (see figure 8); and

β is the reduction factor for stiffener effectiveness.

A reduction of the cross sectional area of the stiffener may be treated as a reduction in sheet thickness of the stiffener.

The reduction factor β for stiffener effectiveness should be determined from the following.

- If $\alpha \leq 0.65$: $\beta = 1.0$
- If $0.65 < \alpha \leq 1.38$: $\beta = 1.47 - 0.723\alpha$
- If $\alpha > 1.38$: $\beta = 0.66/\alpha$

where

α is the elastic critical strength ratio:

for trapezoidal elements with flat web elements, the value α is determined from:

$$\alpha = \sqrt{p_{\text{y}}/p_{\text{r,cr}}}$$

NOTE. For the value of α in a trapezoidal profile with multiple-stiffened web and flange elements see 5.2.4.

4.4.1.3 Buckling strength of a single central flange stiffener

The elastic critical buckling strength $p_{r,cr}$ of a single central stiffener plus the two adjacent effective portions of the flange, treated as a strut supported by an elastic medium, should be determined from

$$p_{r,cr} = \frac{4.2K_w E}{A_r} \sqrt{\frac{I_r t^3}{8b^3(1 + 3s_r/b)}}$$

where

- A_r is defined in 4.4.1.2;
- I_r is the second moment of area of the area A_r about its own centroidal axis, parallel to the centre line of the flange;
- s_r is the semi-perimeter of the stiffener (see figure 8);
- E is the modulus of elasticity;
- b is the flat width of the flange between stiffeners;
- t is the net thickness of the steel material.

The value of the web restraint coefficient K_w may conservatively be taken as 1.0, representing nil restraint. Alternatively a more precise value of K_w for a single central stiffener may be obtained from 4.4.1.4.

4.4.1.4 Restraint coefficient K_w for a single central stiffener

A more precise value of K_w for a flange with a single central stiffener should be determined from the following.

- a) If $L_b/D_w > 2$:

$$K_w = K_{w0}$$

- b) If $L_b/D_w \leq 2$:

$$K_w = K_{w0} - (K_{w0} - 1) \left\{ 2L_b/D_w - (L_b/D_w)^2 \right\}$$

where

$$K_{w0} = \left(\frac{D_w + 2b_d}{D_w + 0.5b_d} \right)^{0.5};$$

L_b is the length of the buckling wave in a stiffener, determined from

$$L_b = 3.65 \left\{ I_r (b/t)^3 (1 + 3s_r/b) \right\}^{0.25};$$

D_w is the sloping distance between the intersection points of a web and flanges (see Figure 17);

b_d is the developed width of the stiffened element, given by $b_d = 2(b + s_r)$;

b_r is the width of the stiffener (see figure 8);

b is the flat width of the flange element between the web and the flange stiffener.

4.4.2 Flange with two stiffeners

4.4.2.1 General

The effective cross section of a multiple-stiffened flange with two intermediate stiffeners should be obtained in the form of the separate portions shown in figure 9, as follows:

- a) two effective portions each of effective width $b_{eff}/2$, one adjacent to each web, where b_{eff} is the effective portion of a flat width of the flange element b , determined in accordance with 4.3.1; and
- b) two effective portions each of effective area $A_{r,ef}$ determined in accordance with 4.4.2.2.

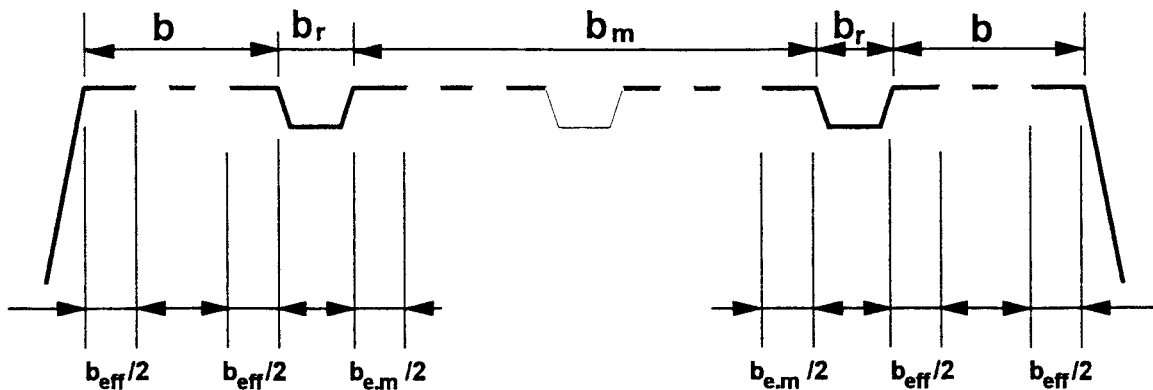


Figure 9. Effective cross section of a flange with two or three intermediate stiffeners

4.4.2.2 Effective area of a flange stiffener

The effective area $A_{r,ef}$ of a flange stiffener should be determined from

$$A_{r,ef} = \beta A_r$$

where

A_r is the total stiffened area of one stiffener, comprising the flange stiffener itself together with the two adjacent effective portions of the flange, one effective width $b_{eff}/2$ in accordance with 4.4.2.1, plus one effective width $b_{e,m}/2$ for the central flat element of width b_m in accordance with 4.3.1 (see figure 9);

β is the reduction factor for stiffener effectiveness.

The reduction factor β for stiffener effectiveness should be determined in accordance with 4.4.1.2, but the value of the elastic critical strength ratio a for a trapezoidal profile with flat web elements should be determined using the value of the elastic critical buckling strength $p_{r,cr}$ determined in accordance with 4.4.2.3.

NOTE. For the value of a in a trapezoidal profile with multiple-stiffened web and flange elements see 5.2.4.

4.4.2.3 Buckling strength of a flange stiffener

The elastic critical buckling strength $p_{r,cr}$ of one flange stiffener plus its adjacent effective portions of the flange, treated as a strut supported by an elastic medium, should be obtained from

$$p_{r,cr} = \frac{4.2K_w E}{A_r} \sqrt{\frac{I_r t^3}{8b_k^3(3b_d/b_k - 4)}}$$

where

$$b_k = b + b_r/2;$$

b_d is the developed width of the stiffened element, given by $b_d = 2(b + 2s_r) + b_m$;

I_r is as defined in 4.4.1.3.

The value of the web restraint coefficient K_w may conservatively be taken as 1.0, representing nil restraint. Alternatively a more precise value of K_w for a flange with two stiffeners may be determined in accordance with 4.4.2.4.

4.4.2.4 Restraint coefficient K_w for a flange with two stiffeners

A more precise value of K_w for a flange with two intermediate stiffeners may be determined from the following.

a) If $L_b/D_w > 2$:

$$K_w = K_{w0}$$

b) If $L_b/D_w \leq 2$:

$$K_w = K_{w0} - (K_{w0} - 1)\{2L_b/D_w - (L_b/D_w)^2\}$$

where

$$K_{w0} = \left\{ \frac{(2b_d + D_w)(3b_d - 4b_k)}{b_k(4b_d - 6b_k) + D_w(3b_d - 4b_k)} \right\}^{0.5};$$

L_b is the length of the buckling wave in a stiffener, determined from

$$L_b = 3.65\{I_r(b_k/t)^3(3b_d/b_k - 4)\}^{0.25};$$

D_w is the sloping distance between the intersection points of a web and flanges (see Figure 4)

b_k and b_d are as defined in 4.4.2.3.

4.4.3 Flange with three or more stiffeners

When there are three or more intermediate flange stiffeners, only two flange stiffeners, one adjacent to each web, should be considered effective for calculation purposes. The effective portions of the flange are as shown in figure 9 determined in accordance with 4.4.2.

4.5 Effective cross section of a multiple-stiffened web

4.5.1 Webs with a single stiffener

4.5.1.1 General

The effective cross section of an intermediately stiffened web under stress gradient, with a single longitudinal stiffener comprising two folds as shown in figure 10, should be obtained in the form of the separate portions indicated in figure 10, as follows.

a) An effective portion of width $b_{ef,1}$ adjacent to the compression flange, where $b_{ef,1}$ is determined in accordance with 4.3.5.

b) The effective area $A_{sa,ef}$ determined in accordance with 4.5.1.2, based on the stiffened area A_{sa} , where A_{sa} is the area of the folded web stiffener of width s_{sa} plus the two adjacent effective portions of the web stiffener, with effective widths of $b_{ef,2}$ and $b_{ef,3}$ respectively (see figure 10a), determined from

$$b_{ef,2} = b_{ef,1} (1 + 0.5h_a/y_c)$$

$$b_{ef,3} = b_{ef,1} (1 + 0.5(h_a + h_{sa})/y_c)$$

where

h_a and h_{sa} are as shown on figure 10;

y_c is the distance of the compression flange from the neutral axis.

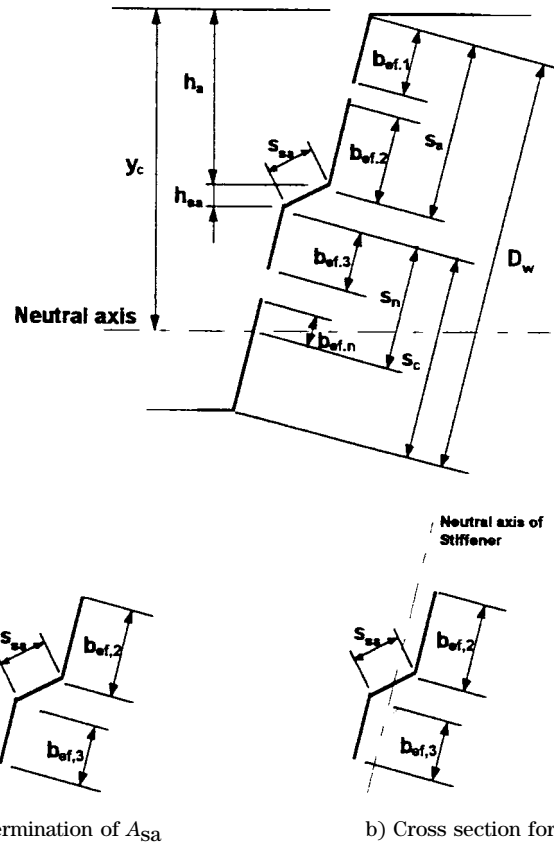
If $b_{ef,1} + b_{ef,2} > s_a$ (see figure 10), the whole of s_a is effective. In this case the value of $b_{ef,2}$ included in A_{sa} should be reduced from $b_{ef,2}$ to $b_{ef,2}s_a/(b_{ef,1} + b_{ef,2})$.

If $b_{ef,3} + b_{ef,n} > s_n$ (see figure 10), the whole of s_n is effective. In this case the value of $b_{ef,3}$ included in A_{sa} should be reduced from $b_{ef,3}$ to $b_{ef,3}s_n/(b_{ef,3} + b_{ef,n})$.

c) An effective portion of width $b_{ef,n}$ adjacent to the neutral axis, determined from

$$b_{ef,n} = 1.5b_{ef,1}$$

d) The portion of the web in tension.

a) Cross section for determination of A_{sa} b) Cross section for determination of I_{sa} **Figure 10. Effective portions of a web with a single intermediate stiffener****4.5.1.2 Effective cross-sectional area of a single stiffener**

The effective cross-sectional area $A_{sa,ef}$ of a single longitudinal stiffener should be determined from

$$A_{sa,ef} = A_{sa} \beta [1 - (h_a + h_{sa}/2)/y_c] \text{ but } A_{sa,ef} \leq A_{sa}$$

where

β is the reduction factor for stiffener effectiveness determined in accordance with 4.4.1.2 but with the elastic critical strength ratio α for the web stiffener determined in accordance with 4.5.1.3.

A reduction of the cross sectional area of the stiffener may be treated as a reduction in sheet thickness of the stiffener.

A_{sa} is the total stiffened area as defined in 4.5.1.1;

h_a and h_{sa} are as shown on figure 10;

y_c is the distance of the compression flange from the neutral axis.

NOTE. For a trapezoidal profile with multiple-stiffened flange and web elements see 5.2.4.

If the centroid of a single longitudinal web stiffener lies in the tension zone:

$$A_{sa,ef} = A_{sa}$$

4.5.1.3 Elastic critical strength ratio

The elastic critical strength ratio α is given by:

$$\alpha = (p_y/p_{s,cr})^{0.5}$$

where

p_y is the design strength of the steel;

$p_{s,cr}$ is the elastic critical buckling strength of a single longitudinal web stiffener, treated as a strut supported by an elastic medium, determined from

$$p_{s,cr} = \frac{1.05E(I_{sa}s_1t^3)^{0.5}}{A_{sa}s_2(s_1 - s_2)}$$

- I_{sa} is the second moment of area of the stiffener plus two effective portions each of width $b_{ef,1}$ about its own centroidal axis parallel to the flat portions of the web (see figure 10b). In calculating I_{sa} , any difference in slope between the flat portions of the web on either side of the longitudinal stiffener may be neglected;
- $s_1 = 0.9(s_a + s_{sa} + s_c)$;
- $s_2 = s_1 - s_a - s_{sa}/2$;
- t is the net material thickness.

4.5.2 Webs with two stiffeners

The effective cross section of an intermediately stiffened web under stress gradient, with two longitudinal stiffeners, each comprising two folds as shown in figure 11, should be obtained in the form of the separate portions indicated in figure 11, as follows:

- a) an effective portion of width $b_{ef,1}$ adjacent to the compression flange, where $b_{ef,1}$ is determined in accordance with 4.3.5;
- b) the effective area $A_{sa,ef}$, determined in accordance with 4.5.1.2 based on the area A_{sa} of the folded web stiffener of width, s_{sa} plus the two adjacent effective portions of the web with effective widths $b_{ef,2}$ and $b_{ef,3}$ (see figure 11) respectively determined from

$$b_{ef,2} = b_{ef,1} (1 + 0.5h_a/y_c)$$

$$b_{ef,3} = b_{ef,1} \{1 + 0.5(h_a + h_{sa})/y_c\}$$

where h_a , h_{sa} and y_c are as shown in figure 11.

If $b_{ef,1} + b_{ef,2} > s_a$ (see figure 11) the whole of s_a is effective. In this case the value of $b_{ef,2}$ included in A_{sa} should be reduced from $b_{ef,2}$ to $s_a \{b_{ef,2}/(b_{ef,1} + b_{ef,2})\}$.

If $b_{ef,3} + b_{ef,4} > s_b$ (see figure 11) the whole of s_b is effective. In this case the value of $b_{ef,3}$ included in A_{sa} should be reduced from $b_{ef,3}$ to $s_b \{b_{ef,3}/(b_{ef,3} + b_{ef,4})\}$.

When calculating the value of $p_{s,cr}$ (4.5.1.3) s_1 should be taken as $s_a + s_{sa} + s_b + 0.5(s_{sb} + s_c)$;

- c) the effective area $A_{sb,ef}$ based on the area A_{sb} of the folded web stiffener of width, s_{sb} , plus the two adjacent effective portions of the web with effective widths $b_{ef,4}$ and $b_{ef,5}$ (see figure 11) respectively determined from

$$b_{ef,4} = b_{ef,1} (1 + 0.5h_b/y_c)$$

$$b_{ef,5} = b_{ef,1} \{1 + 0.5(h_b + h_{sb})/y_c\}$$

where h_b , h_{sb} and y_c are as shown in figure 11.

If $b_{ef,3} + b_{ef,4} > s_b$ (see figure 11) the whole of s_b is effective. In this case the value of $b_{ef,4}$ included in A_{sb} should be reduced from $b_{ef,4}$ to $s_b \{b_{ef,4}/(b_{ef,3} + b_{ef,4})\}$.

If $b_{ef,5} + b_{ef,n} > s_n$ (see figure 11) the whole of s_n is effective. In this case the value of $b_{ef,5}$ included in A_{sb} should be reduced from $b_{ef,5}$ to $s_n \{b_{ef,5}/(b_{ef,5} + b_{ef,n})\}$.

It may be assumed that the area so determined is fully effective.

- d) an effective portion of width $b_{ef,n}$ determined in accordance with 4.5.1.1c);
- e) the portion of the web in tension.

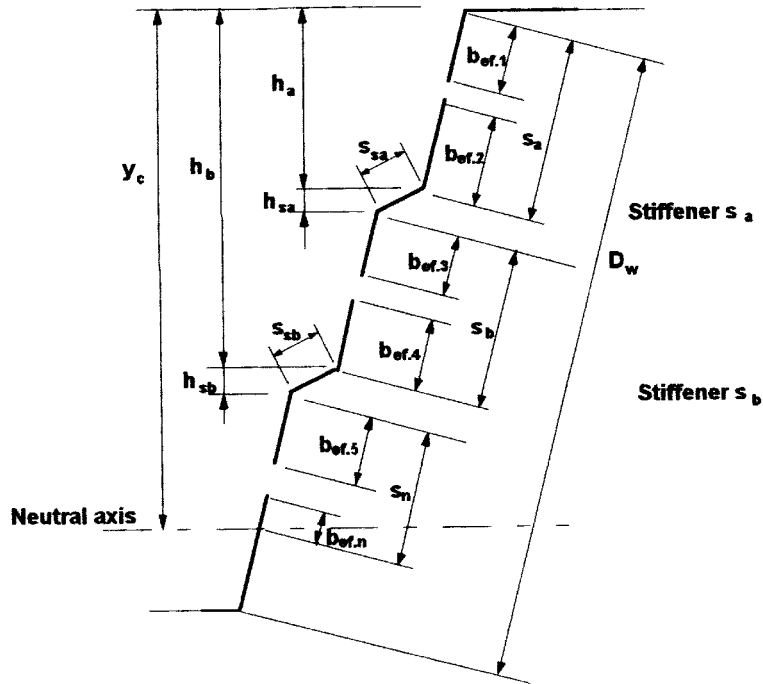


Figure 11. Effective portions of a web with two intermediate stiffeners

4.6 Effective width for deflection calculations

4.6.1 Flat flange elements

When calculating deflections, the serviceability limit state value of the basic effective width $b_{\text{ef,ser}}$ for a stiffened or unstiffened flat flange element should be determined from the following.

a) When $\lambda_{\text{ser}} \leq \lambda_1$:

$$b_{\text{ef,ser}} = 1.27b/(\lambda_{\text{ser}})^{2/3} \text{ but } b_{\text{ef,ser}} \leq b$$

b) When $\lambda_1 < \lambda_{\text{ser}} \leq \lambda$:

$$b_{\text{ef,ser}} = b_{\text{ef,1,ser}} + (b_{\text{eff}} - b_{\text{ef,1,ser}}) (\lambda_{\text{ser}} - \lambda_1) / (\lambda - \lambda_1)$$

where

$$b_{\text{ef,1,ser}} = 1.27b/(\lambda_1)^{2/3} \text{ but } b_{\text{ef,1,ser}} \leq b;$$

$$\lambda = \frac{2b/t}{\sqrt{K}} \sqrt{(p_y/E)};$$

$$\lambda_1 = 0.51 + 0.6\lambda;$$

$$\lambda_{\text{ser}} = \frac{2b/t}{\sqrt{K}} \sqrt{(f_{\text{ser}}/E)};$$

b_{eff} is the basic effective width determined in accordance with 4.3.1;

f_{ser} is the compressive stress in the effective element under serviceability loading;

K is the relevant local buckling coefficient determined in accordance with 4.3.3 or 4.3.4.

4.6.2 Flat web elements

When calculating deflections, webs of trapezoidal profiles with a web depth to thickness ratio $D_w/t \leq 150\epsilon$ may be taken as fully effective at the serviceability limit state.

Where this limit is exceeded, the serviceability limit state value of the effective width of a web in which the stress varies linearly, as shown in figure 7, should be obtained in two portions, one adjacent to each edge as follows.

a) Both edges in compression (see figure 7a):

$$b_{\text{ef,1,ser}} = 0.95t \sqrt{E/f_{1,ser}}$$

$$b_{\text{ef,2,ser}} = (1.5 - 0.5f_{2,ser}/f_{1,ser})b_{\text{ef,1,ser}}$$

where

$f_{1,ser}$ is the larger compressive edge stress due to serviceability loading;

$f_{2,ser}$ is the smaller compressive edge stress due to serviceability loading;

$b_{\text{ef,1,ser}}$ is the portion of the effective width adjacent to the more compressed edge;

$b_{\text{ef,2,ser}}$ is the portion of the effective width adjacent to the less compressed edge.

b) One edge in tension (see figure 7b):

$$b_{\text{ef,1,ser}} = 0.95t \sqrt{E/f_{1,ser}}$$

$$b_{\text{ef,3,ser}} = b_{\text{t,ser}} + 1.5b_{\text{ef,1}}$$

where

$b_{\text{t,ser}}$ is the width subject to tension at serviceability limit state;

$b_{\text{ef,3,ser}}$ is the portion of the effective width adjacent to the tension edge.

If $b_{\text{ef,1,ser}} + b_{\text{ef,3,ser}} \geq D_w$ the whole web is effective at the serviceability limit state.

c) Both edges in tension:

The whole web is effective at the serviceability limit state.

4.6.3 Multiple-stiffened flange elements

When calculating deflections, the serviceability limit state effective cross section of a multiple-stiffened compression flange should normally comprise the effective portions of the flat elements, determined in accordance with 4.4.1 plus the full cross-sectional area of the flange stiffeners.

Stiffeners which protrude outwards from the flanges, away from the centreline of the sheet, should not be included.

In the case of flanges stiffened by more than two intermediate stiffeners, only the two stiffeners adjacent to the webs as in 4.4.3 should be considered. The flange areas should be those given in 4.4.3.

4.6.4 Multiple-stiffened web elements

In calculating deflections, the effective cross section should include the stiffeners and the effective portions of the elements between them. The effective widths should be determined in accordance with 4.5.1 and 4.5.2 but with $b_{ef,1}$ determined in accordance with 4.6.2. The full cross-sectional area of the stiffeners should be included.

Section 5. Design for lateral loading

5.1 General

Profiled steel sheet should be designed for lateral loading by verifying the resistance of a single profile to bending, shear and crushing, acting separately and in combination.

The moment capacity should be determined using an effective cross section incorporating the effective widths of those elements partly or wholly in compression and the effective areas of any stiffeners. The moment capacity should be based on the attainment of a limiting compressive stress equal to the design strength p_y in the effective cross section. In cases where the tensile stress reaches the design strength p_y before the compressive stress, plastic redistribution of tensile stresses may be taken into account.

Where the use of effective section properties results in a web being only partly effective, improved properties may be obtained through the use of iteration to locate the position of the neutral axis of the effective cross section.

When calculating deflections under serviceability loading, the effective section properties of those elements partly or wholly in compression should be determined from 4.6.

5.2 Moment capacity

5.2.1 Trapezoidal profiles without stiffeners

The effective cross section of a trapezoidal sheeting profile comprising flat web elements and flat flange elements, as indicated in figure 12, should be determined as follows.

- The neutral axis should initially be located on the basis of fully effective webs, a fully effective tension flange and the effective width of compression flange determined in accordance with 4.3.3 using a compressive stress f_c equal to the design strength p_y .
- The effective widths of the webs should be determined in accordance with 4.3.5.
- If the web is not fully effective, the position of the neutral axis may optionally be adjusted iteratively.
- The moment capacity M_c should be determined from the following.

If $y_c \geq y_t$:

$$M_c = p_y I_{\text{eff}} / y_c$$

where

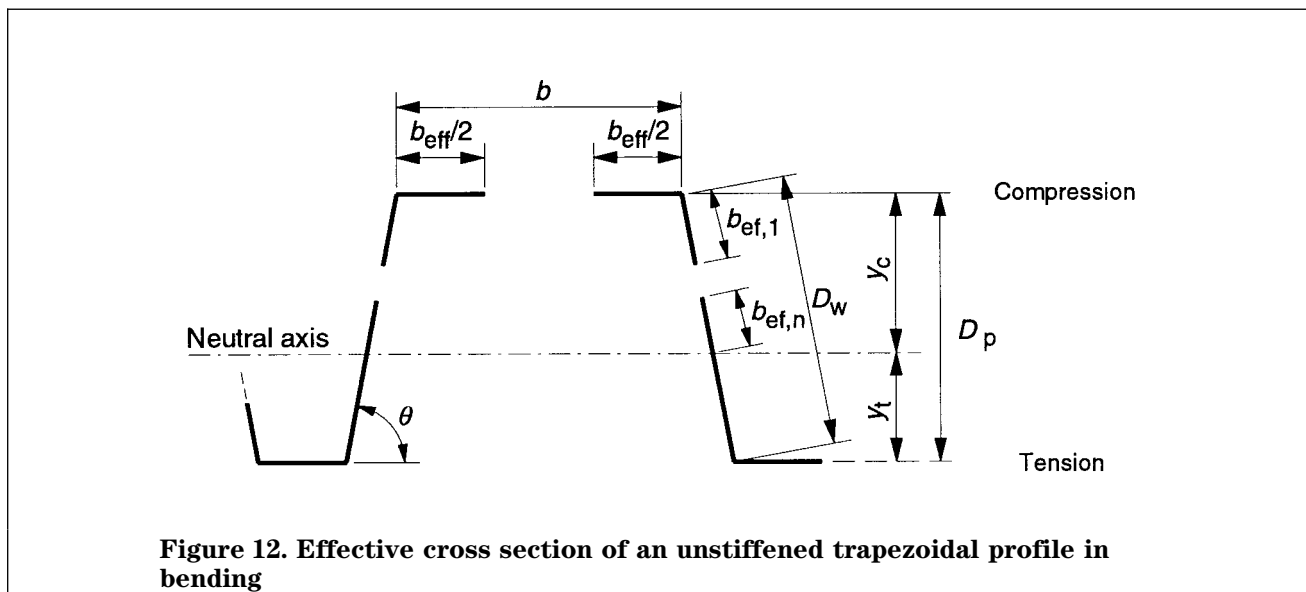
I_{eff} is the second moment of area of the effective cross section;

y_c and y_t are as shown on figure 12.

If $y_c < y_t$ either:

1) adopt the elastic stress distribution shown in figure 13a in which the effective width of the compression flange b_{eff} is determined from 4.3.4 using a compressive stress f_c equal to the design strength p_y , then determine M_c from $M_c = p_y I_{\text{eff}} / y_t$; or adopt the elastic stress distribution shown in figure 13b in which the effective width of the compression flange b_{eff} is determined from 4.3.4 using the calculated compressive stress f_c in the compression flange, then determine M_c from $M_c = p_y I_{\text{eff}} / y_t$; or

2) adopt the stress distribution shown in figure 13c in which b_{eff} is based on p_y and sufficient plasticity develops in the tension zone to permit f_c to reach p_y , adjusting the position of the neutral axis to maintain equilibrium between tension and compression on the effective cross section, then determine M_c from the resulting stress diagram.



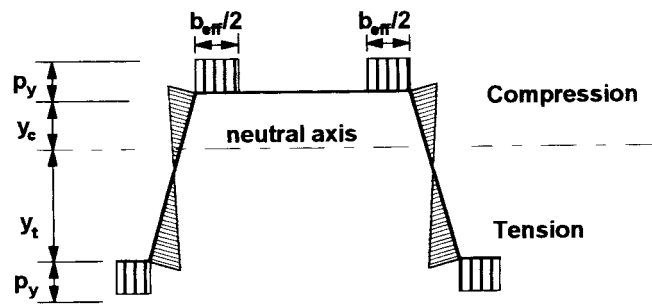
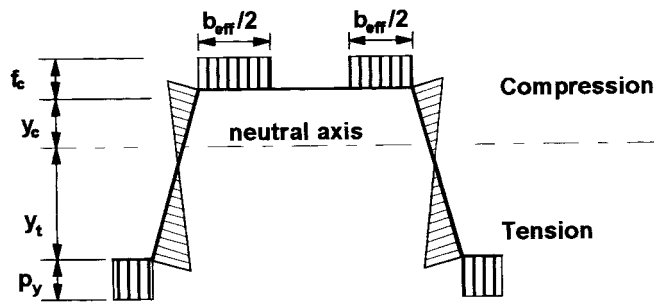
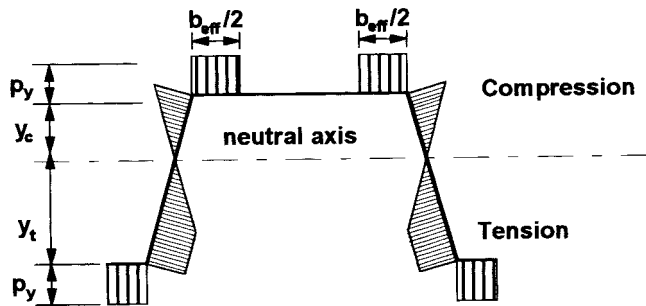
a) Elastic stress distribution: b_{eff} based on p_y b) Elastic stress distribution: b_{eff} based on f_c c) Partial plasticity in tension zone: b_{eff} based on p_y

Figure 13. Alternative methods for determining the moment capacity when $y_c < y_t$

5.2.2 Trapezoidal profiles with flange stiffeners

For trapezoidal profiles with multiple-stiffened flanges as shown in figure 14, the moment capacity should be obtained as in 5.2.1 except that the effective cross section of the compression flange should be determined in accordance with 4.4.

5.2.3 Trapezoidal profiles with web stiffeners

For trapezoidal profiles with multiple-stiffened webs as shown in figure 15, the moment capacity should be determined as in 5.2.1 except that the effective cross sections of the webs should be determined in accordance with 4.5.

5.2.4 Trapezoidal profiles with flange and web stiffeners

For trapezoidal profiles with multiple-stiffened flanges and multiple-stiffened webs, as indicated in figure 16, the moment capacity M_c should be obtained as in 5.2.1, as modified by 5.2.2 and 5.2.3, except that the reduction factor β for stiffener effectiveness should be determined using a modified value of the elastic critical strength ratio a determined from

$$a = \sqrt{p_y/p_{\text{eff,cr}}}$$

where

$p_{\text{eff,cr}}$ is the effective value of the elastic critical buckling strength determined from

$$p_{\text{eff,cr}} = \frac{p_{r,\text{cr}}}{(1 + \{[1 - (h_a + h_{\text{sa}}/2)/y_c](p_{r,\text{cr}}/p_{s,\text{cr}})^4\}^{0.25}};$$

$p_{r,\text{cr}}$ is determined in accordance with 4.4.1.3;

h_a and h_{sa} are determined in accordance with 4.5.1 and figure 11;

$p_{s,\text{cr}}$ is determined in accordance with 4.5.1.3.

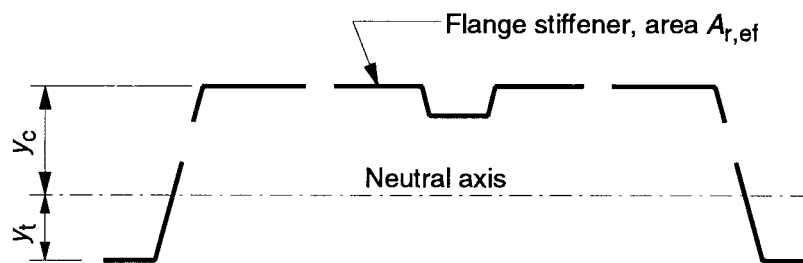


Figure 14. Effective cross section of a sheeting profile with a multiple-stiffened flange

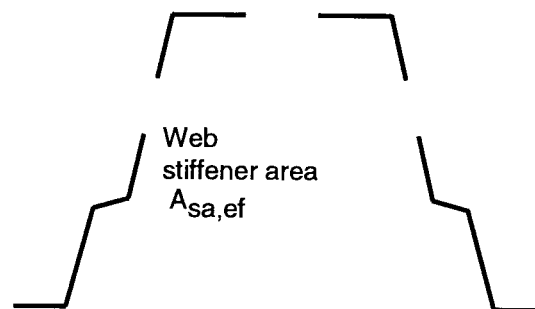


Figure 15. Effective cross section of a sheeting profile with a stiffened web

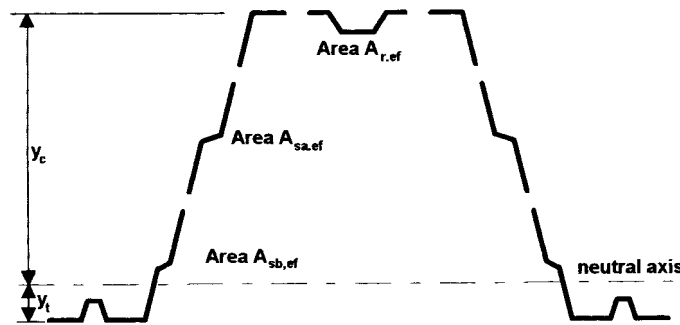


Figure 16. Effective cross section of a sheeting profile with web and flange stiffeners

5.3 Web crushing resistance

5.3.1 General

The crushing resistance P_w of a web at a point of support, or at the point of application of a concentrated load, should be determined in accordance with 5.3.2 or 5.3.3 as appropriate.

5.3.2 Web without longitudinal stiffeners

The crushing resistance P_w of a web without longitudinal stiffeners should be determined from

$$P_w = 0.15\Omega t^2 \sqrt{E p_y} (1 - 0.1 \sqrt{r/t}) \left(0.5 + \sqrt{\frac{N}{50t}} \right) \{2.4 + (\theta/90)^2\}$$

where

- r is the inside bending radius;
- N is the length of stiff bearing, which should be at least 10 mm, lengths greater than 200 mm should be taken as 200 mm;
- θ is the inclination of the web ($45^\circ \leq \theta \leq 90^\circ$) (see figure 17);
- E is the modulus of elasticity;
- p_y is the design strength of steel;
- t is the net thickness of steel material;
- Ω = 1.0 if the applied load or support reaction has its nearest edge at a distance of not less than $1.5D_w$ from the end of the sheet;
- Ω = 0.5 if the nearest edge of the applied load or support reaction is at a distance of less than $1.5D_w$ from the end of the sheet;
- D_w is the sloping distance between the intersection points of a web and flanges (see figure 17).

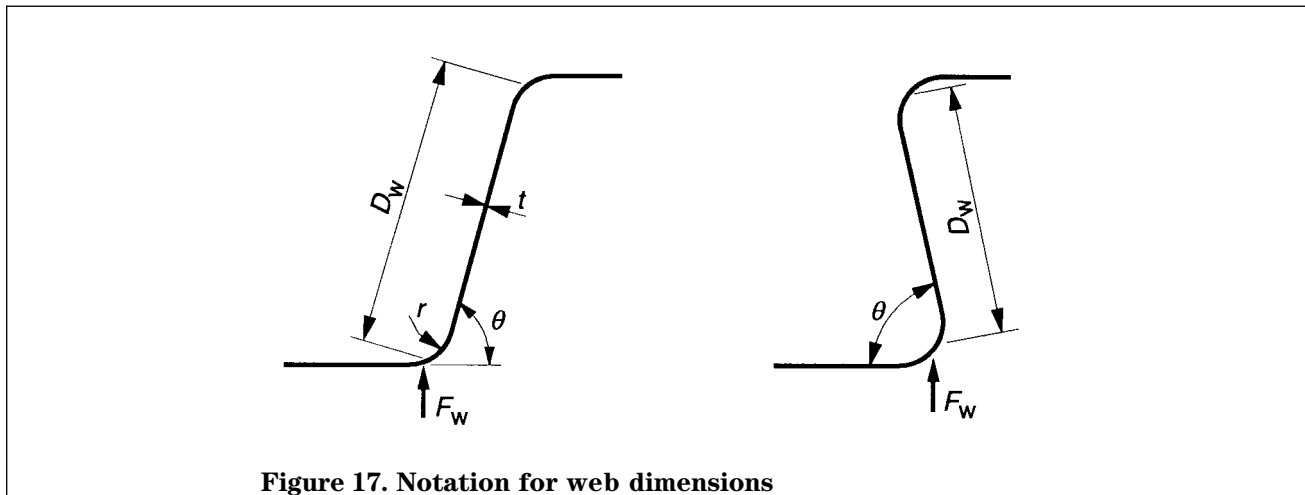


Figure 17. Notation for web dimensions

5.3.3 Webs with longitudinal stiffeners

The crushing resistance P_w of a web with one or more longitudinal stiffeners, each comprising two folds in the web as shown in figure 18, should be determined by multiplying the value determined in accordance with 5.3.2 by a reduction factor k_s .

For webs with stiffeners formed in an arrangement which provides eccentricity on both sides of the effective plane of the web, represented by a straight line joining the points of intersection of the centrelines of the web and the flanges as shown in figure 18, provided that $2 \leq e_{\max}/t$ then k_s should be taken as the smaller of k_{sa} or k_{sb} determined from

$$k_{sa} = 1.45 - 0.05e_{\max}/t$$

$$k_{sb} = 0.95 + \frac{35\,000t^2e_{\min}}{b^2s_c}$$

where

- e_{\max} is the maximum eccentricity of the web from its effective plane (see figure 18);
- e_{\min} is the minimum eccentricity of the web from its effective plane (see figure 18);
- b is the width of the flange through which the load or reaction is applied;
- s_c is the distance between the loaded flange and the nearest fold.

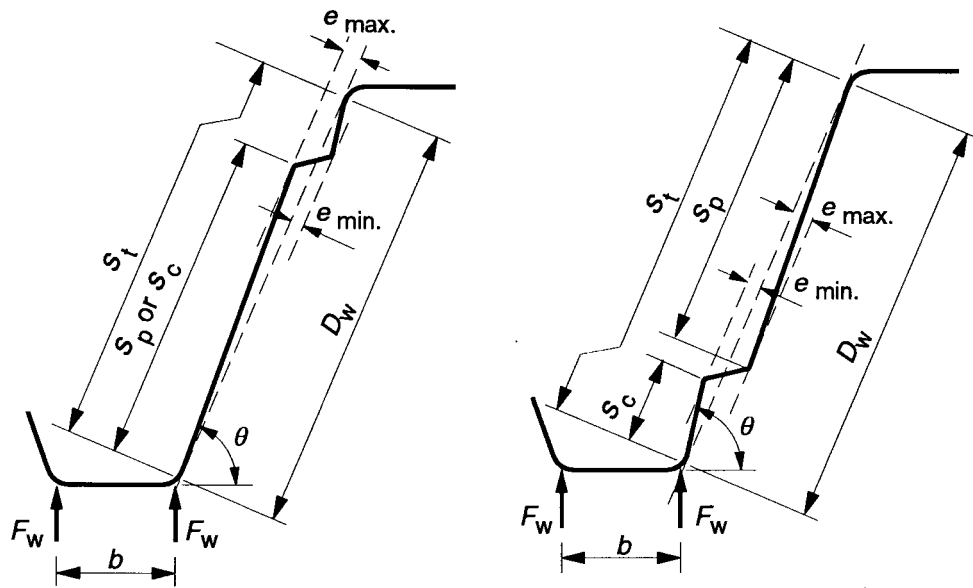


Figure 18. Notation for dimensions of a stiffened web

5.4 Web shear capacity

The shear capacity P_v of an inclined web should be determined from

$$P_v = p_v t (D_p - t)$$

where

p_v is the shear strength;

D_p is the overall depth of the profile

The shear strength p_v should be determined from the following.

- If $\lambda_w \leq 2.33$: $p_v = 0.6p_y$
- If $2.33 < \lambda_w \leq 4.0$: $p_v = 1.4p_y/\lambda_w$
- If $\lambda_w > 4.0$: $p_v = 5.6p_y/\lambda_w^2$

where λ_w is the web slenderness determined from the following.

a) For a web without longitudinal stiffeners:

$$\lambda_w = (D_w/t) \sqrt{p_y/E}$$

b) For a web with longitudinal stiffeners:

λ_w should be taken as the lesser of λ_{wa} and λ_{wb} determined from

$$\lambda_{wa} = \frac{2.31s_t}{t \sqrt{k_v}} \sqrt{p_y/E}$$

$$\lambda_{wb} = s_p/t \sqrt{p_y/E}$$

where

k_v is the shear buckling coefficient = $5.34 + (2.1/t)(I_{sa}/s_t)^{1/3}$;

I_{sa} is the second moment of area of the stiffener and the adjacent effective portion of the web determined in accordance with 4.5.1.3. If there are two or more stiffeners, I_{sa} may be taken as the total of the values for the individual stiffeners;

- s_t is the total developed depth of the web, as indicated in figure 18;
 s_p is the depth of the largest flat element in the web, as indicated in figure 18;
 p_y is the design strength of steel.

5.5 Combined effects

5.5.1 Combined bending and web crushing

Webs of sheets subject to a combination of bending moment and concentrated load or reaction should be so proportioned that the following relationships are all satisfied:

$$\begin{aligned}
 F_w &\leq P_w \\
 M &\leq M_c \text{ and} \\
 F_w/P_w + M/M_c &\leq 1.25
 \end{aligned}$$

where

- F_w is the reaction or concentrated load;
 P_w is the web crushing resistance from 5.3;
 M is the moment at the point where F_w is applied;
 M_c is the moment capacity from 5.2.

5.5.2 Combined bending and shear

Webs of sheets subject to a combination of bending moment and shear should be so proportioned that the following relationship is satisfied:

$$(F_v/P_v)^2 + (M/M_c)^2 \leq 1$$

where

- F_v is the shear force;
 P_v is the shear capacity from 5.4;
 M is the moment at the same section as F_v ;
 M_c is the moment capacity from 5.2.

5.6 Calculation of deflections

5.6.1 General

Deflections should be calculated using elastic analysis. Due allowance should be made for the effects of non-uniform loading. The effective cross section for deflection calculations should be determined in accordance with 4.6. The effective second moment of area I_{ser} of the profile may be assumed to be constant throughout each span.

Recommended deflection limits are given in 2.4.2.

5.6.2 Single spans

For a uniformly loaded single span, the deflection δ should be determined from

$$\delta = \frac{5}{384} \frac{wL^4}{EI_{ser}}$$

where

- w is the intensity of loading at the serviceability limit state;
 L is the span between the centres of supports;
 I_{ser} is the effective second moment of area of the profile for serviceability loading, determined at midspan.

5.6.3 Sheeting continuous over two or more spans

5.6.3.1 Type of loading

When calculating deflections due to imposed gravity loads, the possibility of pattern loading between different spans should be considered.

However when calculating deflections of profiled sheeting used as permanent shuttering for slabs the weight of the wet concrete may be taken as uniformly distributed on all spans.

Uniform loading on all spans may also be taken when calculating deflections of cladding and roof decking subject to wind load only.

5.6.3.2 Calculation of deflections

Unless a detailed analysis is undertaken the following approximations may be assumed to cover the extent of loading most likely to be met in practice, providing that the spans do not vary by more than 15 % of the greatest span.

The maximum deflection due to uniformly distributed load on all spans may be determined from

$$\delta = \frac{1}{185} \frac{wL^4}{EI_{\text{ser}}}$$

The maximum deflection δ due to pattern loading may be determined from

$$\delta = \frac{3}{384} \frac{wL^4}{EI_{\text{ser}}}$$

where

L is the greatest span between centres of supports.

Section 6. Connections

6.1 General recommendations

6.1.1 General

Connections should be designed on the basis of a realistic assumption of the distribution of internal forces, having due regard to relative stiffness. This distribution should correspond with direct load paths through the elements of connections. It is essential that equilibrium is maintained with the factored external loads.

Ease of fabrication and erection should also be considered in the design of joints and splices. Attention should be paid to the clearances necessary for tightening of fasteners, welding procedures, subsequent inspection, surface treatment and future maintenance.

The ductility of steel assists the distribution of forces within a joint. Residual stresses and stresses due to tightening of fasteners and normal accuracy of fit-up need not be calculated.

6.1.2 Strength of individual fasteners

The strength of individual fasteners may be determined by calculation according to the following clauses. Alternatively the strength of individual fasteners may be determined by testing.

NOTE. Suitable procedures for the testing of fasteners are given in ECCS Publications No. 21 [2] and No. 42 [3].

6.1.3 Forces in individual fasteners

The shear forces in individual fasteners in a connection may be assumed to be equal.

6.1.4 Joints subject to vibration and/or load reversal

Where a connection is subject to impact or vibration, either welding, or fasteners which will not work loose in service, should be used.

6.2 Connections with screws and blind rivets

6.2.1 General

The recommendations in 6.2 apply to self-tapping screws, including thread-forming, thread-cutting or self-drilling screws, and to blind rivets. The diameter d of the screw or rivet is assumed to be in the range

$$3.0 \text{ mm} \leq d \leq 7.5 \text{ mm}$$

If components of different thickness are connected, the head of the screw or the preformed head of the rivet should be in contact with the thinner component.

The diameter of pre-drilled holes should be strictly in accordance with the manufacturer's recommendations.

6.2.2 Minimum pitch

The distance between centres of fasteners should be not less than $3d$.

6.2.3 Minimum edge and end distances

The distance from the centre of a fastener to the edge of any part should not be less than $3d$. If the connection is subjected to force in one direction only, which is such as to cause shear of the fastener, the minimum edge distance may be reduced to $1.5d$ or 10 mm, whichever is the smaller, in the direction normal to the force.

6.2.4 Calculation of capacity under tensile loading

Blind rivets should not be used to carry significant tensile forces.

For screws which carry significant tensile forces, the head of the screw, or washer if present, should have an overall diameter d_w of at least 8 mm and should have adequate rigidity.

The tensile capacity P_t at a screwed connection may be taken as the smallest of the following:

- a) pulling of the connected material over the screw head or washer:

For connected material of thickness t_1 less than 2.0 mm and washer size d_w less than 25 mm

$$P_t = 1.1t_1d_w p_y$$

where t_1 is the thickness of the component in contact with the screw head or the preformed rivet head.

For other configurations the tensile capacity should be determined by testing.

b) pull out from the base material:

Provided that $t_2 \geq 0.9$ mm:

$$P_t = 0.65dt_2p_y$$

where t_2 is the thickness of the component remote from the screw head or preformed rivet head.

c) tensile failure of the screw:

The tensile capacity P_{ft} of the screw itself can only be determined by testing and should normally be guaranteed by the manufacturer. In order to avoid brittle failure the size of the fastener should be such that P_{ft} is not less than $1.25P_t$.

6.2.5 Capacity under shear loading

The recommendations for screws and blind rivets in shear given in BS 5950 : Part 5 should be used.

6.3 Powder actuated fasteners

6.3.1 General

The recommendations in 6.3 apply to powder actuated fasteners with a diameter d in the range:

$$3.5 \text{ mm} \leq d \leq 4.5 \text{ mm}$$

The thickness and strength grade of the components to be joined should be within the range recommended by the fastener manufacturer. The base material into which powder actuated fasteners are fixed should normally be hot finished steel sections with a minimum thickness of 6 mm unless specifically recommended otherwise by the fastener manufacturer.

6.3.2 Minimum pitch

The distance between centres of powder actuated fasteners should be not less than $4.5d$.

6.3.3 Minimum edge and end distances

The distance from the centre of a powder actuated fastener to the edge of any component should not be less than $4.5d$.

6.3.4 Calculation of capacity under tensile loading

Powder actuated fasteners should not be used to carry significant tensile forces unless they are used with a suitable washer of adequate rigidity and of minimum diameter 8 mm.

The tensile capacity P_t of a fastener may be taken as the smallest of the following:

a) pulling of the connected material over the washer:

For connected parts of thickness t_1 less than 2.0 mm and for washer size d_w less than 25 mm:

$$P_t = 1.1t_1d_wp_y$$

where

t_1 is the thickness of the component in contact with the washer;

d_w is the diameter of the washer.

b) pull out from the base material:

The tensile capacity P_t should be determined by testing.

c) tensile failure of the fastener:

The tensile capacity P_{ft} of the powder actuated fastener itself can only be determined by testing. It should normally be taken as the value guaranteed by the fastener manufacturer. In order to avoid brittle failure the size of the fastener should be such that P_{ft} is not less than $1.25P_t$.

6.3.5 Capacity under shear loading

The recommendations for powder actuated fasteners in shear given in BS 5950 : Part 5 should be followed.

6.4 Bolted connections

The design procedures for bolted connections in thin steel material given in BS 5950 : Part 5 should also be used for bolted connections between profiled steel sheets and for bolted connections between sheeting and supporting members.

6.5 Weld detail and design

The design procedures for welds in thin steel material given in BS 5950 : Part 5 should also be used for welds between profiled steel sheets and for welds connecting sheeting to supporting members.

Section 7. Tests

7.1 General

Testing and the interpretation of results should be in accordance with the requirements of Part 5.

Additional requirements for the testing of sheeting are given in 7.2.

7.2 Testing of sheeting

7.2.1 Direction of loading

When the profile of the sheet is asymmetric it is generally necessary to test in both directions. Gravity loading may be used to simulate wind loading by inverting the sheeting. Alternatively wind uplift may be simulated by loading from below.

When it is necessary to investigate local behaviour at a fastener, appropriate tests should be carried out.

NOTE. Suitable procedures for the testing of fasteners are given in ECCS Publication No. 21.

7.2.2 Cross section of test specimen

The test specimen should normally consist of a complete cover width as used in practice. The number of flutes should not be less than that shown in Figure 19. The specimen should be arranged in such a way that there are no free edges in compression. To comply with this, it may be necessary to remove part of a corrugation at one or both longitudinal edges.

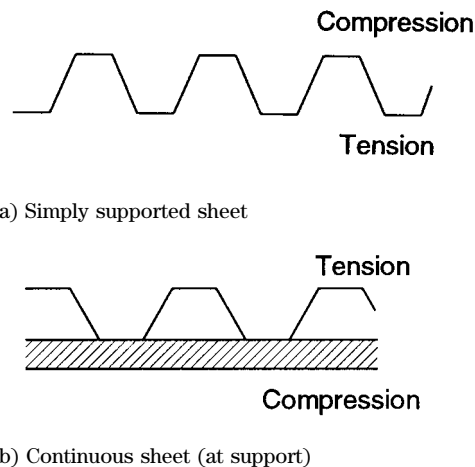


Figure 19. Test arrangements

7.2.3 Test arrangements

The appropriate span for a test specimen depends on the type of test (see 7.2.4). The span is defined as the distance between the centres of the supports.

The supports to the sheet under test should either simulate practical conditions of installation or else be arranged in such a way that they offer less restraint than arrangements used in practice. In particular, supports should allow free rotation of the specimen and should ensure vertical reactions at all stages of loading.

Uniformly distributed loading should preferably be applied by pressure bag or vacuum chamber or uniformly distributed gravity load, but may be replaced by at least two or preferably four equal line loads. Line loads should normally be applied to the troughs of the corrugations. Test specimens may require to be fitted with transverse ties to simulate the normal fixing conditions in order to prevent spreading of the corrugations.

7.2.4 Test procedures

7.2.4.1 Test series

A comprehensive test series should normally include:

- midspan bending under distributed loading (see 7.2.4.2);
- bending at a support under distributed loading (see 7.2.4.2);
- shear at end support (see 7.2.4.4);
- local roof loads (see 2.2.6);

7.2.4.2 Midspan bending under distributed loading

The purpose of this test is to obtain information regarding the moment capacity of the specimen at sections where the shear force is negligible.

The span of the test specimen should be the maximum span likely to be used in practice.

7.2.4.3 Bending at a support under distributed loading

The purpose of this test is to obtain information regarding the load carrying capacity at an internal support where the specimen is subject to a combination of bending moment and support reaction. The test should be arranged in such a way that the distributions of bending moment and shear force are representative of the conditions obtained in practice when a continuous member passes over an intermediate support. In particular, the width of the support should reflect the width of a typical supporting member. Two alternative arrangements are available:

- testing of a sheet which is continuous over two spans where the length of each span reflects the minimum span likely to be used in practice;
- testing of a single span sheet subject to a line load. The span of the specimen should be 0.4 times the minimum span likely to be used in practice and the central line load should be applied through a steel plate of width equal to that of a typical supporting member.

7.2.4.4 Shear at end support

The purpose of this test is to obtain information regarding the flexibility and load carrying capacity of a sheet at its simply supported end. This test should be conducted by applying a line load across a simply supported span as shown in Figure 20. The test support should be provided by a steel plate 50 mm wide fixed at an inclination to the horizontal of at least 1:20. The clear distance between the edge of the test support and the loading plate should be at least equal to the depth D_p of the profile. The clear distance between the loading plate and the other support should be at least $3D_p$, and should be chosen to ensure that failure occurs at the test support, not at the loading plate. Troughs of corrugations should not be fixed to the inclined support but may be fitted with a transverse tie.

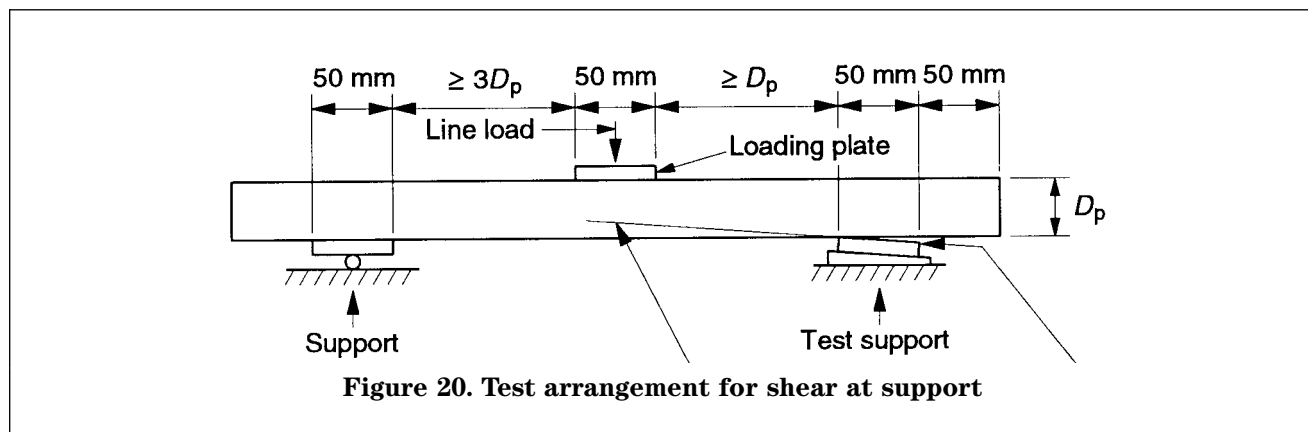


Figure 20. Test arrangement for shear at support

7.2.4.5 Number of tests

For a given steel quality, the minimum number of tests of each type should be determined as follows.

- If the test series includes only one profile shape and one thickness, at least four tests should be carried out. If one of these tests results in a failure load that differs from the mean by more than 10% of the mean, at least two further tests should be performed.
- If the test series includes one nominal profile shape but several thicknesses where the difference between the actual thicknesses is greater than 0.1 mm at least two tests shall be carried out for each thickness. The total number of tests in the series shall be at least six.
- If there is reason for suspecting that an individual test result is non-representative due to variation of the material or geometrical properties of the specimen, this test may be rejected if it is replaced by two or more equivalent tests. Any test not included shall, however, be detailed in the report and the reason for its rejection clearly stated.

List of references (see 1.2)

Normative references

BSI publications

BRITISH STANDARDS INSTITUTION, London

BS 1449 :	<i>Steel plate, sheet and strip</i>
BS 1449 : Part 1	<i>Carbon and carbon-manganese plate, sheet and strip</i>
BS 1449 : Section 1.2 : 1991	<i>Specification for hot rolled steel plate, sheet and wide strip based on formability</i>
BS 1449 : Section 1.4 : 1991	<i>Specification for hot rolled wide material based on specified minimum strength</i>
BS 1449 : Section 1.5 : 1991	<i>Specification for cold rolled wide material based on specified minimum strength</i>
BS 1449 : Section 1.8 : 1991	<i>Specification for hot rolled narrow strip based on formability</i>
BS 1449 : Section 1.10 : 1991	<i>Specification for hot rolled narrow strip based on specified minimum strength</i>
BS 1449 : Section 1.11 : 1991	<i>Specification for cold rolled narrow strip based on specified minimum strength</i>
BS 5427 : 1976	<i>Code of practice for performance and loading criteria for profiled sheeting in building</i>
BS 5502	<i>Buildings and structures for agriculture</i>
BS 5502 : Part 22 : 1993	<i>Code of practice for design, construction and loading</i>
BS 5950 :	<i>Structural use of steelwork in building</i>
BS 5950 : Part 5	<i>Code of practice for design of cold formed sections</i>
BS 6399	<i>Loading for buildings</i>
BS 6399 : Part 1 : 1984	<i>Code of practice for dead and imposed loads</i>
BS 6399 : Part 2 ²⁾ :	<i>Code of practice for wind loading</i>
BS 6399 : Part 3 : 1988	<i>Code of practice for imposed roof loads</i>
CP 3	<i>Code of basic data for the design of buildings</i>
CP 3 : Chapter V :	<i>Loading</i>
CP 3 : Chapter V : Part 2 : 1972	<i>Wind loads</i>
BS EN 10002 :	<i>Tensile testing of metallic materials</i>
BS EN 10002-1 : 1990	<i>Method of test at ambient temperature</i>
BS EN 10025 : 1993	<i>Hot rolled products of non-alloy structural steels — Technical delivery conditions</i>
BS EN 10147 : 1992	<i>Specification for continuously hot-dip zinc coated structural steel sheet and strip — Technical delivery conditions</i>
BS EN 10149-2	<i>Specification for hot-rolled flat products made of high yield strength steels for cold forming. Delivery conditions for thermomechanically rolled sheets</i>
BS EN 10149-3	<i>Specification for hot-rolled flat products made of high yield strength steels for cold forming. Delivery conditions for normalized rolled sheets</i>

²⁾ In preparation.

Informative references

BSI publications

BRITISH STANDARDS INSTITUTION, London

BS 5950	<i>Structural use of steelwork in building</i>
BS 5950 : Part 4 : 1994	<i>Code of practice for design of composite slabs with profiled steel sheeting</i>
BS 5950 : Part 7 : 1992	<i>Specification for materials and workmanship: cold formed sections</i>
BS 5950 : Part 9 : 1994	<i>Code of practice for stressed skin design</i>
BS 6830 : 1987	<i>Specification for continuously hot-dip aluminium/zinc alloy coated cold rolled carbon steel flat products</i>
BS EN 10130 : 1991	<i>Specification for cold rolled low carbon steel flat products for cold forming: technical delivery conditions</i>

Other references

- [1] CONSTRUCTION INDUSTRY RESEARCH AND INFORMATION ASSOCIATION. Technical Note 116. *Design of profiled sheeting as permanent formwork*. London: CIRIA, 1984
- [2] EUROPEAN CONVENTION FOR CONSTRUCTIONAL STEELWORK. Publication No. 21. *European recommendations for steel construction: the design and testing of connections in steel sheeting and sections*. Brussels: ECCS, 1983³⁾.
- [3] EUROPEAN CONVENTION FOR CONSTRUCTIONAL STEELWORK. Publication No. 42. *European recommendations for steel construction: mechanical fasteners for use in steel sheeting and sections*. Brussels: ECCS, 1983³⁾.

³⁾ Available from: Steel Construction Institute, Silwood Park, Buckhurst Road, Ascot, Berkshire SL5 7QN.

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