

*Implementing
Amendment No. 1 not
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and incorporating
Corrigendum No. 1*

Structural use of steelwork in building

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

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 Institution of Structural Engineers
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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.

Table 1. Load factors and combinations	
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.

Table 3. Recommended minimum nominal steel thickness	
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 $\alpha = 12 \times 10^{-6}/^\circ\text{C}$