

Structural use of steelwork in building —

Part 4: Code of practice for design of composite slabs with profiled steel sheeting

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- Association of Consulting Engineers
- British Cement Association
- British Constructional Steelwork Association Ltd.
- British Masonry Society
- Building Employers Confederation
- Department of the Environment (Building Research Establishment)
- Department of the Environment (Construction Directorate)
- Department of Transport
- Federation of Civil Engineering Contractors
- Institution of Civil Engineers
- Institution of Structural Engineers
- National Council of Building Material Producers
- Royal Institute of British Architects
- Timber Research and Development Association

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- British Industrial Fasteners Federation
- British Steel Industry
- Concrete Society
- Department of the Environment (Specialist Services)
- Society of Engineers Incorporated
- Steel Construction Institute

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Foreword

This Part of BS 5950 has been prepared under the direction of Technical Committee B/525, Building and civil engineering structures. BS 5950 comprises codes of practice which cover the design, construction and fire protection of steel structures and specifications for materials, workmanship and erection.

It comprises the following Parts and Sections:

- *Part 1: Code of practice for design in simple and continuous construction: hot rolled sections;*
- *Part 2: Specification for materials, fabrication and erection: hot rolled sections;*
- *Part 3: Design in composite construction;*
- *Section 3.1: Code of practice for design of simple and continuous composite beams;*
- *Part 4: Code of practice for design of composite slabs with profiled steel sheeting;*
- *Part 5: Code of practice for design of cold formed sections;*
- *Part 6¹⁾: Code of practice for design of light gauge profiled sheeting;*
- *Part 7: Specification for materials and workmanship: cold formed sections;*
- *Part 8: Code of practice for fire resistant design;*
- *Part 9: Code of practice for stressed skin design.*

This Part of BS 5950 gives recommendations for the design of composite slabs in which profiled steel sheeting acts compositely with concrete or acts only as permanent formwork.

This British Standard supersedes BS 5950-4:1982, which is withdrawn.

BS 5950-4:1982 was the first Part of BS 5950 to be issued. Most of the other Parts have since been issued or are expected to be published shortly. In addition BS 8110 has superseded CP 110. It was therefore necessary to update the cross-references in this document, add material related to composite beams and align the values of the partial safety factors for loads with those now recommended in BS 5950-1. A number of minor amendments have also been made as a result of experience in the use of the code.

The work on BS 5950-3 led to a survey of construction loads, which was also relevant to the recommendations of this Part and enabled the partial safety factors for these loads to be rationalized. In addition it had become apparent in the drafting of BS 5950-3 that some adjustments to terminology (such as “composite slab”) would be beneficial for clarity and some symbols needed additional subscripts to maintain compatibility with both BS 5950-3 and BS 5950-1. This revised terminology led to the modified title of Part 4.

A few further improvements have been made. These include recommendations on span-to-depth ratios and on end anchorage. The density of lightweight concrete covered has also been aligned with that in BS 5950-3.1.

The clauses on the design of profiled sheets have been replaced by cross-references to BS 5950-6¹⁾, rather than updated to align with Part 6. The need to adjust the clause numbers to allow for the various additions and omissions, has provided the opportunity to restructure the document in a manner compatible with that now used in the other Parts of BS 5950, with the type of clause numbering system now used in the other Parts of BS 5950.

¹⁾ In preparation.

Apart from the above changes, the technical content of the standard is unchanged.

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.

Summary of pages

This document comprises a front cover, an inside front cover, pages i to iv, pages 1 to 30, an inside back cover and a back cover.

This standard has been updated (see copyright date) and may have had amendments incorporated. This will be indicated in the amendment table on the inside front cover.

Section 1. General

1.0 Introduction

1.0.1 Aims of economical structural design

The aim of structural design of a composite slab is to provide, with due regard to economy, a slab capable of fulfilling its intended function and sustaining the specified loads for its intended life. The design should facilitate construction, both of the slab itself and of the structure of which it forms part.

The composite slab 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 economy, in order to obtain the optimum combination of material and construction costs.

1.0.2 Overall stability

The designer responsible for the overall stability of the structure should ensure compatibility of structural design and detailing between all those structural parts and components which are required for overall stability, even when some or all of the structural design and detailing of those parts and components is carried out by another designer.

1.0.3 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 composite slabs with profiled steel sheeting. It covers slabs spanning only in the direction of span of the profiled steel sheets.

This code applies to the design of composite slabs in buildings. It does not apply to highway or railway bridges, for which reference should be made to BS 5400-5.

For the design of composite steel beams with a composite slab as the concrete flange, reference should be made to BS 5950-3.1.

Diaphragm action produced by the capacity of the composite slab (or of the profiled steel sheets at the construction stage) to resist distortion in its own plane is not within the scope of this Part of BS 5950.

For the design of profiled steel sheeting as a stressed skin diaphragm, reference should be made to BS 5950-9.

1.2 References

1.2.1 Normative references

This Part of BS 5950 incorporates, by reference, provisions from specific editions of other publications. These normative references are cited at the appropriate points in the text and the publications are listed on the inside back cover. Subsequent amendment to, or revisions of, any of these publications apply to this Part of BS 5950 only when incorporated in it by amendment or revision.

1.2.2 Informative references

This Part of BS 5950 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

composite slab

a slab consisting of profiled steel sheets and a concrete slab, with steel reinforcement where necessary

1.3.2

composite action

the structural interaction which occurs when the components of a composite slab interact to form a single structural element

1.3.3

permanent shuttering

profiled steel sheeting designed to support wet concrete, reinforcement and construction loads

1.3.4

negative moment

bending moment causing compression at the bottom of the slab

1.3.5

positive moment

bending moment causing tension at the bottom of the slab

1.3.6

longitudinal reinforcement

reinforcement of a composite slab, running parallel to the corrugations of the profiled steel sheets

1.3.7**transverse reinforcement**

reinforcement of a composite slab, running perpendicular to the corrugations of the profiled steel sheets

1.4 Symbols

a	Distance from a concentrated load to the nearer support
A_p	Cross-sectional area of profiled steel sheeting
B_s	Width of composite slab
b_a	Mean width of trough (open sheet profile)
b_b	Minimum width of trough (sheet profile)
b_{eb}	Effective width of slab (bending)
b_{er}	Effective width of slab (shear)
b_m	Effective load width
b_o	Width of concentrated load
D_p	Overall depth of profiled steel sheets
D_s	Overall depth of composite slab
d_s	Effective depth of slab to centroid of profiled steel sheets
E	Modulus of elasticity of profiled steel sheets
F_a	End anchorage force per shear connector
F_b	Beam longitudinal shear force per shear connector
f_{cm}	Concrete cube strength (observed value)
f_{cu}	Characteristic concrete cube strength
h_{agg}	Nominal maximum size of aggregate
I_{CA}	Second moment of area of the composite slab about its centroidal axis (in equivalent steel units)
k_r	Empirical parameter (intercept of reduction line from parametric tests)
L_p	Effective span of profiled steel sheets, which is the smaller of: a) distance between centres of permanent or temporary supports, and b) clear span between permanent or temporary supports plus overall depth of profiled sheets D_p
L_s	Effective span of composite slab, which is the smaller of: a) distance between centres of permanent supports, and b) clear span between permanent supports plus effective depth of composite slab d_s

L_v	Shear span of composite slab
N	Number of shear connectors attached to the end of each span of sheets, per unit length of supporting beam
m_r	Empirical parameter (slope of reduction line from parametric tests)
P_a	End anchorage capacity per shear connector
P_b	Capacity per shear connector for composite beam design
p_{yp}	Design strength of profiled steel sheets
Q_k	Characteristic resistance per shear connector
$R_{e,min}$	Specified yield strength of profiled steel sheets
t_f	Thickness of finishes above concrete slab
u	Critical perimeter for punching shear
$\bar{V}_a$	Shear capacity per unit width of composite slab due to the end anchorage provided by the shear connectors
$\bar{V}_c$	Total longitudinal shear capacity per unit width of composite slab
V_E	Maximum experimental shear force
V_P	Punching shear capacity of composite slab
V_s	Shear-bond capacity of composite slab
$\bar{V}_s$	Shear-bond capacity of composite slab per unit width
V_v	Vertical shear capacity of composite slab
v_c	Design concrete shear stress
W_c	Applied load capacity of composite slab
W_f	Reaction or concentrated load
W_{ser}	Serviceability load
W_{st}	Failure load
W_w	Anticipated value of the applied load
x_c	Depth of concrete in compression at midspan
z	Lever arm
γ_f	Partial safety factor for loads
γ_m	Partial safety factor for resistances
δ	Deflection

Section 2. Limit state design

2.1 General principles

Composite slabs should be designed by considering the limit states at which they would become unfit for their intended use. Appropriate safety factors should be applied for the ultimate limit state and the serviceability limit state.

All limit states covered in BS 5950-1:1990 or in BS 8110-1:1985 should be considered.

The recommendations given in this Part of BS 5950 should be followed for the ultimate limit states of strength and stability and for the serviceability limit state of deflection.

2.2 Loading

2.2.1 General

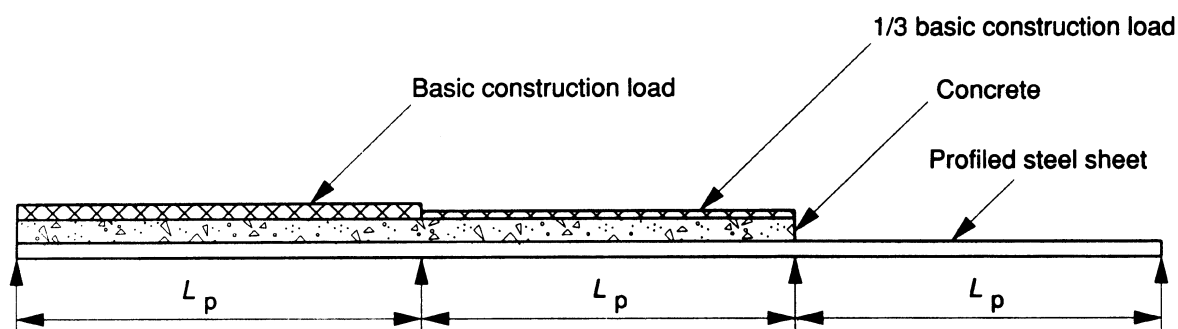
All relevant loads should be considered separately and in such realistic combinations as to cause the most critical effects on the components and on the composite slab as a whole.

Loading conditions during construction should also be considered (see 2.2.3).

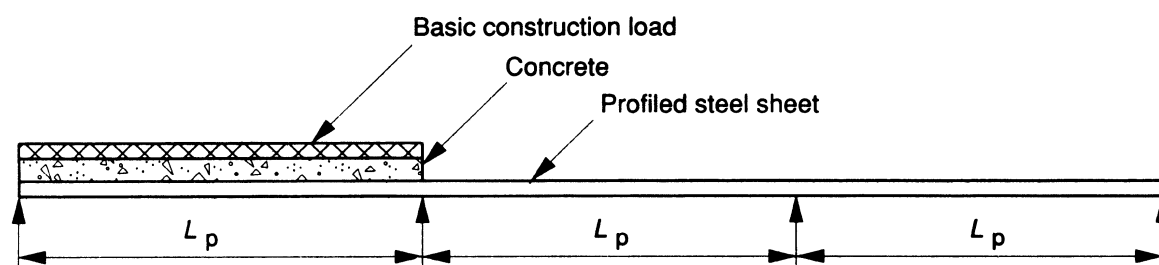
2.2.2 Dead, imposed and wind loading

Reference should be made to BS 6399-1:1984, BS 6399-3:1988 and CP 3:Chapter V-2:1972 for the determination of the dead, imposed and wind loads.

The weight of the finished slab should be increased if necessary to allow for the additional concrete placed as a result of the deflection of the profiled steel sheeting (see 5.3).



a) Arrangement for maximum negative moment



b) Arrangement for maximum positive moment

NOTE 1. The arrangements shown in this figure are for equal values of the effective span L_p . In all cases the most critical arrangement of construction loads should be used.

NOTE 2. For propped construction L_p is the prop spacing (see 1.4).

Figure 1 — Arrangement of construction loads

2.2.3 Construction loads

2.2.3.1 Basic construction loads

Construction loads should be considered in addition to the weight of the wet concrete slab.

In general purpose working areas the basic construction load on one span of the sheeting should be taken as not less than 1.5 kN/m^2 . The other spans should be taken as either loaded with the weight of the wet concrete slab plus a construction load of one-third of the basic construction load, or unloaded apart from the self-weight of the profiled steel sheets, whichever is the more critical for the positive and negative moments in the sheeting (see Figure 1).

For spans of less than 3 m, the basic construction load should be increased to not less than $4.5/L_p \text{ kN/m}^2$, where L_p is the effective span of the profiled steel sheets in metres.

Allowance is made within these values for construction operatives, impact and heaping of concrete during placing, hand tools, small items of equipment and materials for immediate use. The minimum values quoted are intended for use in general purpose working areas, but will not necessarily be sufficient for excessive impact or heaping of concrete, or pipeline or pumping loads. Where excessive loads are expected, reference should be made to BS 5975:1982.

Reference should also be made to 5.3 for possible increased loading due to ponding at the construction stage.

2.2.3.2 Storage loads

Where materials to be stored temporarily on erected sheeting (or on a recently formed slab before it is self-supporting) produce equivalent distributed loads in excess of the basic construction loads, provision should be made in the design for the additional temporary storage loads.

2.2.4 Accidental loads

Accidental loads should be treated as recommended in BS 5950-1.

2.3 Design methods

2.3.1 General

The following methods may be used for the design of composite slabs:

- composite design in which the concrete and the profiled steel sheets are assumed to combine structurally to support loads (see section 6);
- design as a reinforced concrete slab as recommended in BS 8110-1:1985, neglecting any contribution from the profiled steel sheets;
- design by specific testing (see 2.3.2.1).

In all cases the profiled steel sheeting should be designed for use as permanent shuttering during construction (see section 5).

Table 1 — Values of γ_f for ultimate limit states

Combination	Type of load	γ_f
Dead and imposed load	Dead load (see note)	Maximum Minimum 1.4 1.0
	Imposed load	1.6
Dead and wind load	Dead load (see note)	Maximum Minimum 1.4 1.0
	Imposed load	1.4
Dead, imposed and wind load	Dead load (see note)	Maximum Minimum 1.2 1.0
	Imposed load	1.2
	Wind load	1.2
Construction stage (temporary erection condition)	Dead load of wet concrete (see note)	Maximum Minimum 1.4 0.0
	Construction loads (see 2.2.3)	1.6
NOTE For dead loads, the minimum γ_f factor should be used for dead loads that counteract the effects of other loads causing overturning or uplift.		

2.3.2 Testing

2.3.2.1 Specific tests

Where testing is used as an alternative to calculation methods of design, the load carrying capacity of a composite slab may be determined directly from the results of specific tests as recommended in 8.2.

2.3.2.2 Parametric tests

In the calculation method for composite design given in section 6, the shear-bond capacity should be determined using the empirical parameters obtained from the results of parametric tests as recommended in 8.3.

2.4 Ultimate limit states

2.4.1 Limit state of strength

In checking the strength of a composite slab, the loads should be multiplied by the appropriate value of the partial safety factor for loads γ_f given in Table 1. The factored loads should be applied in the most unfavourable realistic combination for the part or effect under consideration.

2.4.2 Stability against overturning

The factored loads, considered separately and in combination, should not cause the composite slab (or the profiled steel sheeting at the construction stage) to overturn, slip or lift off its seating. The combination of dead, imposed (or construction) and wind loads should be such as to have the most severe effect.

2.4.3 Strength of materials

In the design of the profiled steel sheeting before composite action with the concrete slab is developed, the design strength of the profiled steel sheets should be taken as specified in BS 5950-6²⁾.

For the design of the composite slab, the design strength p_{yp} of the profiled steel sheets should be taken as 0.93 times the specified yield strength $R_{e,min}$ (see 3.1.1), or 0.93 times the characteristic strength for the grade of steel used.

NOTE The value 0.93 represents $1/\gamma_m$, where γ_m is a partial safety factor allowing for tolerances.

The modulus of elasticity E of profiled steel sheets should be taken as 210 kN/mm².

The properties of concrete and reinforcement to be used in design should follow the recommendations of BS 8110.

2.5 Serviceability limit states

2.5.1 Serviceability loads

Generally, the serviceability loads should be taken as the unfactored values (i.e. $\gamma_f = 1.0$). 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.

2.5.2 Deflections

Deflections under serviceability loads should not impair the strength or efficiency of the structure or cause damage to the finishings.

The recommendations given in 5.3 should be followed for profiled steel sheeting at the construction stage and those given in 6.6 should be followed for the deflection of the composite slab.

2.6 Durability

2.6.1 Corrosion protection of profiled steel sheets

The exposed surface at the underside of the profiled steel sheets should be adequately protected to resist the relevant environmental conditions, including those arising during site storage and erection. Reference should be made to BS 5493:1977 for the recommended protective systems. Any damage to zinc coating or other surface protection should be made good.

NOTE 1 Due to the possibility of corrosion caused by road de-icing salts or sea salt, composite slabs with zinc coated profiled steel sheeting may not be appropriate for use without special measures in car park structures, or in the vicinity of seawater or seawater spray.

NOTE 2 Dilute acids from process industries (which are sometimes airborne) may corrode galvanized surfaces.

2.6.2 Concrete durability

For the durability of the concrete in the composite slab, the relevant recommendations in BS 8110 should be followed.

2.6.3 Fire resistance

The recommendations in section 7 should be followed.

²⁾ In preparation.

Section 3. Materials

3.1 Profiled steel sheets

3.1.1 Specification

The steel used to manufacture the profiled steel sheets should have a specified yield strength $R_{e,min}$ of not less than 220 N/mm² and should generally be in accordance either with BS 2989:1992 or with BS EN 10147:1992. Steels conforming to other specifications may alternatively be used provided that they have similar properties.

3.1.2 Sheet thickness

The structural thickness of the profiled steel sheets, to which the stresses and section properties apply, should be taken as the “bare metal thickness” of the sheets excluding any protective or decorative finish such as zinc coating or organic coating.

The nominal bare metal thickness of the sheets should not normally be less than 0.75 mm except where the profiled steel sheets are used only as permanent shuttering (see 4.1). Thinner sheets should not be used unless adequate theoretical evidence and test data are available to justify their use.

3.1.3 Zinc coating

The zinc coating should conform to the requirements of BS 2989:1992 or BS EN 10147:1992 as appropriate. A coating of 275 g/m² total, including both sides (coating type G 275 in accordance with BS 2989) is normally specified for internal floors in a non-aggressive environment, but the specification may be varied depending on service conditions.

NOTE A 275 g/m² coating adds approximately 0.04 mm to the bare metal thickness, 0.02 mm on each side. The nominal bare metal thickness is thus 0.04 mm less than the nominal thickness of the sheet.

Before a zinc coating heavier than 275 g/m² is specified, confirmation should be obtained from the proposed manufacturer of the profiled steel sheets that the proposed coating thickness is compatible with the forming operations involved.

All zinc coatings should be chemically passivated with a chromate treatment to minimize wet storage stains (white rusting) and reduce chemical reaction at the concrete/zinc interface.

3.2 Steel reinforcement

3.2.1 Specification

The type of reinforcement used should satisfy the recommendations of BS 8110 and should conform to BS 4449:1988, BS 4482:1985 or BS 4483:1985, subject to the recommendations in 3.2.2.

3.2.2 Ductility of reinforcement

Wherever account is taken in design of the efficiency of continuity over a support, to ensure that the reinforcement has adequate ductility the steel fabric or reinforcing bars used as support reinforcement should satisfy the minimum elongation requirement specified in 10.1.2 of BS 4449:1988.

This recommendation should be applied to the following:

- reinforcement used to resist negative moments in continuous spans or cantilevers;
- distribution steel for concentrated loads or around openings in the slab;
- reinforcement used to increase the fire resistance of the composite slab.

However it need not be applied to the following:

- secondary transverse reinforcement;
- nominal continuity reinforcement over supports;
- tensile reinforcement in the span.

3.3 Concrete

3.3.1 General

Concrete should follow the recommendations given in BS 8110.

3.3.2 Lightweight concrete

The dry density of lightweight aggregate structural concrete should normally be not less than 1 750 kg/m³.

Other densities can be used, but all references to lightweight concrete elsewhere in this Part of BS 5950 assume a dry density of at least 1 750 kg/m³. Where lightweight concrete of less than 1 750 kg/m³ dry density is used, due allowance should be made for variations in properties of concrete and their effect on the resistances of shear connectors.

3.3.3 Density

In the absence of more precise information, the nominal density should be taken as follows.

- For design of the profiled steel sheeting (wet density):
 - 2 400 kg/m³ for normal weight concrete;
 - 1 900 kg/m³ for lightweight concrete.
- For design of the composite slab (dry density):
 - 2 350 kg/m³ for normal weight concrete;
 - 1 800 kg/m³ for lightweight concrete.

NOTE For lightweight concrete the density may be found in manufacturers' literature.