

# Structural use of steelwork in building —

## Part 8: Code of practice for fire resistant design

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# Committees responsible for this British Standard

The preparation of this British Standard was entrusted by the Civil Engineering and Building Structures Standards Policy Committee (CSB/-) to Technical Committee CSB/27, upon which the following bodies were represented:

- British Constructional Steelwork Association Ltd.
- British Railways Board
- British Steel Industry
- Department of the Environment (Building Research Establishment)
- Department of the Environment (Housing and Construction Industries)
- Department of the Environment (Property Services Agency)
- Health and Safety Executive
- Institution of Civil Engineers
- Institution of Structural Engineers
- Royal Institute of British Architects
- Steel Construction Institute
- Welding Institute

The following bodies were also represented in the drafting of the standard, through subcommittees and panels:

- Association of Structural Fire Protection Contractors and Manufacturers
- Department of the Environment (Fire Research station)

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## Foreword

This Part of BS 5950 has been prepared under the direction of the Civil Engineering and Building Structures Standards Policy Committee. BS 5950 is a document combining codes of practice to cover the design, construction and fire resistance of steel structures and specifications for materials, workmanship and erection.

It comprises the following Parts:

- *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;*
- *Section 3.2<sup>1)</sup>: Code of practice for design of composite columns and frames;*
- *Part 4: Code of practice for design of floors with profiled steel sheeting;*
- *Part 5: Code of practice for design in cold formed sections;*
- *Part 6<sup>1)</sup>: Code of practice for design in light gauge sheeting, decking and cladding;*
- *Part 7<sup>1)</sup>: Specification for materials and workmanship: cold formed sections;*
- *Part 8: Code of practice for fire resistant design;*
- *Part 9<sup>1)</sup>: Code of practice for stressed skin design.*

This Part of BS 5950 gives recommendations for evaluating the fire resistance of steel structures. Methods are given for determining the thermal response of the structure and evaluating the protection required, if any, to achieve the specified performance, although it is recognized that there are situations where other proven methods may be appropriate.

It has been assumed in the drafting of this British Standard that the execution of its provision will be entrusted to appropriately qualified and experienced people; also that construction, the application of any fire protection and supervision will be carried out by capable and experienced organizations.

This code of practice represents a standard of good practice and therefore takes the form of recommendations.

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<sup>1)</sup> In preparation.

The full list of organizations who have taken part in the work of the Technical Committee is given on the inside front cover. The Chairman of the Committee is Mr P R Brett and the following people have made a particular contribution in the drafting of the code.

Mr J T Robinson      Chairman of Drafting Panel  
Dr G M E Cooke  
Mr J I Hardwick  
Dr R M Lawson  
Mr G M Newman  
Dr C I Smith  
Mr A D Weller

NOTE The numbers in square brackets used throughout the text of this standard relate to the bibliographic references given in Appendix G.

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 vi, pages 1 to 26, 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 fire precautions

The aims of fire precautions are to safeguard life and to minimize fire damage to property and financial loss. These aims are principally achieved by:

- a) minimizing the risk of ignition;
- b) providing a safe exit for occupants;
- c) restricting the spread of fire;
- d) minimizing the risk of structural collapse.

This Part of BS 5950 is concerned with items c) and d).

### 1.0.2 Steel in fire

Steel progressively weakens with increasing temperature and eventually failure occurs in a member as a result of its inability to sustain the applied load, e.g. buckling in the case of a column or excessive deflection in the case of flexural members. The limiting temperature at which failure occurs varies and is dependent on the loading which the member is carrying, its support conditions, the change in its properties as the temperature rises, and the temperature gradient through the cross section.

## 1.1 Scope

This Part of BS 5950 gives recommendations for the two following methods of achieving the specified fire resistance for steel building members and sub-assemblies (see Appendix A).

- a) fire resistance derived from tests in accordance with BS 476-20 and BS 476-21;
- b) fire resistance derived from calculations.

NOTE 1 These methods may also be applied to members for which the required fire resistance has been derived from the consideration of natural fires.

NOTE 2 The titles of the publications referred to in this standard are listed on the inside back cover.

## 1.2 Definitions

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

### 1.2.1

#### critical element

the element of a section that would reach the highest temperature in fire conditions

NOTE The web of an I, H or channel section or the stalk of a T section, is not normally critical.

### 1.2.2

#### design temperature

the temperature that the critical element will reach at the end of the specified period of fire resistance in a test in accordance with BS 476-20 and BS 476-21

### 1.2.3

#### element

an element may be taken as one of the following:

- a) a flange of a rolled or built-up I, H or channel section;
- b) the web of a rolled or built-up I, H or channel section;
- c) a leg of an angle;
- d) the flange or the stalk of a T section;
- e) a side of a rectangular hollow section.

### 1.2.4

#### fire protection material

a material, which has been shown by fire resistance tests in accordance with BS 476-20 and BS 476-21, to be capable of remaining in position and providing adequate thermal insulation for the fire resistance period under consideration

### 1.2.5

#### insulation

the ability of a separating component to restrict the temperature rise of its unexposed face to below specified levels

### 1.2.6

#### integrity

the ability of a separating component to contain a fire to specified criteria for collapse, freedom from holes, cracks and fissures and sustained flaming on its unexposed face

### 1.2.7

#### limiting temperature

the temperature of the critical element of a member at failure under fire conditions

### 1.2.8

#### load capacity

limit of force or moment which may be applied without causing failure due to yielding or rupture

### 1.2.9

#### structural member

part of a structure designed to resist force or moment, such as a steel section formed by hot rolling, cold forming or welding sections and/or plates together

### 1.2.10

#### fire resistance

the length of time for which the member or other component is required to withstand exposure to the fire regime given in BS 476-20 without the load capacity falling below the fire limit state factored load or loss of integrity and/or insulation

**1.2.11****thermal expansion**

increase in length, cross-sectional area or volume of a material per degree increase in temperature

**1.3 Major symbols**

|            |                                                                                          |
|------------|------------------------------------------------------------------------------------------|
| $A$        | Gross cross-sectional area of a section                                                  |
| $F_f$      | Applied axial load at the fire limit state, using the factored loads given in <b>3.1</b> |
| $H_p$      | Heated perimeter (see Table 3)                                                           |
| $M_f$      | Applied moment at the fire limit state, using the factored loads given in <b>3.1</b>     |
| $M_{cf}$   | Moment capacity at the required period of fire resistance                                |
| $M_c$      | Moment capacity at 20 °C                                                                 |
| $\theta_L$ | Limiting temperature                                                                     |
| $\theta_D$ | Design temperature                                                                       |
| $\gamma_f$ | Load factor                                                                              |
| $\gamma_m$ | Material strength factor                                                                 |

## Section 2. Steel in fire

### 2.1 Properties at elevated temperature

The following properties apply to hot finished structural steels complying with BS 4360 at elevated temperatures and are for use in fire calculations. Properties at ambient temperature are given in BS 5950-1.

- a) coefficient of linear thermal expansion =  $14 \times 10^{-6}$  per °C above 100 °C;
- b) specific heat = 520 J/kg °C;
- c) thermal conductivity = 37.5 W/m °C;
- d) Poisson's ratio = 0.3.

These values may also be assumed to apply to cold finished steels complying with BS 2989.

### 2.2 Strength reduction factors

The strength reduction factors for grade 43 and 50 steels complying with BS 4360 are given in Table 1. The appropriate value of strain should be determined from 2.3. The factors are expressed as fractions of the room temperature design strength and may be applied to tension, compression or shear.

Strength reduction factors for cold finished steels complying with BS 2989 are given in Appendix B.

**Table 1 — Strength reduction factors for steel complying with grades 43 to 50 of BS 4360**

| Temperature<br>°C                                                                                                        | Strength reduction factors at a strain<br>(in %) of: |       |       |
|--------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------|-------|-------|
|                                                                                                                          | 0.5                                                  | 1.5   | 2.0   |
| 100                                                                                                                      | 0.97                                                 | 1.00  | 1.00  |
| 150                                                                                                                      | 0.959                                                | 1.000 | 1.000 |
| 200                                                                                                                      | 0.946                                                | 1.000 | 1.000 |
| 250                                                                                                                      | 0.884                                                | 1.000 | 1.000 |
| 300                                                                                                                      | 0.854                                                | 1.000 | 1.000 |
| 350                                                                                                                      | 0.826                                                | 0.968 | 1.000 |
| 400                                                                                                                      | 0.798                                                | 0.956 | 0.971 |
| 450                                                                                                                      | 0.721                                                | 0.898 | 0.934 |
| 500                                                                                                                      | 0.622                                                | 0.756 | 0.776 |
| 550                                                                                                                      | 0.492                                                | 0.612 | 0.627 |
| 600                                                                                                                      | 0.378                                                | 0.460 | 0.474 |
| 650                                                                                                                      | 0.269                                                | 0.326 | 0.337 |
| 700                                                                                                                      | 0.186                                                | 0.223 | 0.232 |
| 750                                                                                                                      | 0.127                                                | 0.152 | 0.158 |
| 800                                                                                                                      | 0.071                                                | 0.108 | 0.115 |
| 850                                                                                                                      | 0.045                                                | 0.073 | 0.079 |
| 900                                                                                                                      | 0.030                                                | 0.059 | 0.062 |
| 950                                                                                                                      | 0.024                                                | 0.046 | 0.052 |
| NOTE 1 Intermediate values may be obtained by linear interpolation.                                                      |                                                      |       |       |
| NOTE 2 For temperatures higher than the values given, a linear reduction in strength to zero at 1 300 °C may be assumed. |                                                      |       |       |

Strength reduction factors for other grades of steel should be established on the basis of elevated temperature tensile tests.