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BRITISH STANDARD

BS 5268-4.1: 1978

Incorporating Amendment Nos. 1 and 2

Structural use of timber —

Part 4: Fire resistance of timber structures —

Section 4.1: Recommendations for calculating fire resistance of timber members

UDC 691.11:674.049.3:620.1.08

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The structural use of timber

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Amd. No.	Date of issue	Comments
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Foreword

BS 5268 supersedes the earlier code of practice CP 112 "*The structural use of timber*".

It is intended that BS 5268 will have the following Parts

— *Part 1: Limit state design*;

— *Part 2: Code of practice for permissible stress design, materials and workmanship*;

— *Part 3: Code of practice for trussed rafter roofs*;

— *Part 4: Fire resistance of timber structures*;

— *Section 4.1: Recommendations for calculating fire resistance of timber members*;

— *Section 4.2: Recommendations for calculating fire resistance of timber stud walls and joisted floor constructions*;

— *Part 5: Preservative treatments for constructional timber*;

— *Part 6: Code of practice for timber frame walls*;

— *Section 6.1: Dwellings not exceeding three storeys*[1)];

— *Part 7: Recommendations for the calculation basis for span tables*;

— *Section 7.1: Domestic floor joists*[1)];

— *Section 7.2: Joists for flat roofs*[1)];

— *Section 7.3: Ceiling joists*[1)];

— *Section 7.4: Ceiling binders*[1)];

— *Section 7.5: Domestic rafters;*[1)]

— *Section 7.6: Purlins*[1)];

— *Section 7.7: Purlins supporting sheeting or decking*.

The recommendations of Part 1 of BS 5268, preparation of which has not yet started, may entirely supersede those of Part 2 of BS 5268 after a limited number of years.

Section 4.1 of BS 5268-4 gives information for the calculation of fire resistance. Such calculations are possible because, in fire, the behaviour of timber is predictable with regard to the rate of charring and loss of strength. It is also free from rapid changes of state and has very low coefficients of thermal expansion and thermal conductivity. Timber treatments including impregnation to retard the surface spread of flame should not be assumed to affect the charring rate. Section 4.2 will deal with timber stud walls and joisted floor constructions.

Fire resistance relates to complete elements of construction and not to individual materials; the appropriate test is described in BS 476-20[1)]. The stability (resistance to structural failure), integrity and insulation criteria may all be applicable and the performance of an element is expressed in terms of the periods of time that the appropriate criteria are satisfied.

The methods given in this code for assessing by calculation the fire resistance of timber members, in relation to stability criteria, use stress modification factors (see **5.1.2** and **5.2.2**) which have been arrived at empirically and checked against the results of a number of fire resistance tests conducted in accordance with the appropriate British Standard.

[1)] The test methods specified in BS 476-8 have been revised and replaced by BS 476-20 to BS 476-23. The calculation methods of BS 5268-4 rely essentially on data gathered from tests to BS 476-8. In due course data will become available from the revised testing procedures which will then be incorporated into Section 4.1 of BS 5268. The definitions and terminology of BS 476-20 will be maintained until these data are available.

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It is current practice during the fire resistance test in accordance with BS 476-20 in the case of compression members, to apply an axial load only, because the limitations of the existing test equipment preclude other loading arrangements. The information given in this Part of the code, dealing with the assessment of fire resistance of compression members, relates to fire resistance tests, where limited loading arrangements have to be used.

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Summary of pages

This document comprises a front cover, an inside front cover, pages i to iv, pages 1 to 6, 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

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1 Scope

This Section of BS 5268 gives recommendations for assessing the fire resistance of flexural tension and compression members of solid or glued laminated timber and their joints.

2 References

The titles of the standards publications referred to in this Section of BS 5268 are listed on the inside back cover.

3 Definitions

3.1 For the purposes of this section of BS 5268 the definitions given in BS 565, BS 4422, BS 5268-2 and BS 6100-4 apply, together with the following additional definitions.

residual section
the section of the uncharred timber that would be left after a given period of exposure to the fire conditions described in the test in BS 476-20, assuming a steady rate of charring, with allowance for accelerated charring at exposed arrises where recommended herein (see **4.3**)

3.2 In addition, the definition of **stability** used throughout Part 4 is based on that given in BS 476-20, which for the purpose of this section of BS 5268 is taken as:

a) the ability to sustain the applied load throughout the period of the fire test and,

b) also, in the case of flexural members, ability to resist deflection during the fire test, to $\frac{\text{span}}{20}$

NOTE It should be noted that this may differ from the normal structural engineering interpretation.

4 Behaviour of timber in fire

4.1 General. For the purposes of this British Standard, charring can be assumed to occur at a steady rate in the fire resistance test described in BS 476-20. The timber beneath the charred layer does not lose significant strength because the thermal conductivity is low.

These characteristics make it possible to predict the performance in a fire resistance test of certain flexural tension and compression members thus reducing the need for testing.

The criteria of BS 476-20 are applicable to elements of building construction as follows.

a) Flexural members (beams): stability, (strength and deflection).

b) Compression members (columns): stability.

c) Tension members: stability.

Where members are built into, or form part of, a fire resisting construction, the insulation and integrity requirements may also be applicable.

4.2 Resistance to charring

4.2.1 *Solid members.* Calculation of residual section of solid members should be based on the values given in Table 1. These values should be modified in the case of fully exposed columns and tension members as set out in **5.2.2** a) and **5.3.2** a) respectively.

Table 1 — Notional rate of charring for the calculation of residual section

Species	Charring in 30 min	Charring in 60 min
	mm	mm
a) All structural species listed in Appendix A of BS 5268-2:1989 except those noted in items b) and c)	20	40
b) Western red cedar	25	50
c) Hardwoods having a nominal density not less than 650 kg/m^3 at 18 % moisture content	15	30

NOTE Linear interpolation or extrapolation for periods between 15 min and 90 min is permissible.

Notional charring rates for particular species and longer periods of time not presently included in Table 1 may be established by an appropriate authority.

4.2.2 *Glued laminated members.* The charring rates given in **4.2.1** may be applied to members laminated with the following thermosetting phenolic and aminoplastic synthetic resin adhesives: resorcinol-formaldehyde, phenol-formaldehyde, phenol-resorcinol-formaldehyde, urea-formaldehyde, and urea-melamine-formaldehyde. Where other adhesives are used, guidance should be sought from an appropriate authority.

4.2.3 *Finger joints.* Finger joints manufactured in accordance with the requirements of BS 5291 using adhesives specified in **4.2.2** may be considered to char at the rates given in Table 1.

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4.2.4 *Sections built up with metal fasteners* (see Figure 2). The charring rates in **4.2.1** may only be applied to the section as a whole if metal fasteners on which the structural performance of the built-up member depends are fully protected from the effects of fire (see **5.4.2**). Where such protection is not given, local structural weaknesses may occur and the member can only be assessed for fire resistance by applying the residual section calculation, assuming charring on all faces of each component of the built-up member, or by conducting a fire resistance test.

4.3 Increased rate of charring on exposed arrises. Arrises will become progressively rounded during fire exposure. The radius of this rounding is equal to the depth of charring and the centre lies equidistant from the two aspect faces at a distance of twice the charring depth (see Figure 1).

For periods of fire exposure not exceeding 30 min, where the least dimension of the rectangular residual section is not less than 50 mm, rounding is insignificant and may be disregarded.

5 Design considerations

5.1 Flexural members

5.1.1 *Stability criteria*

a) *Strength.* The residual section should be such that the member will support the appropriate loads that would be applied if the component were tested in accordance with the requirements of BS 476-20 to either the maximum permissible design load or the loads based on those which the member is required to support in normal service.

b) *Deflection.* The deflection under the appropriate design load should not exceed 1/20 of the clear span. Consideration should be given to the effect of deflection on the stability and integrity of other parts of the structure.

5.1.2 *Assessment of fire resistance*

a) *Residual section.* The residual section should be computed by subtracting from the appropriate faces the notional amount of charring assumed to occur during the required period of fire exposure, making allowance for the rounding on the exposed arrises, where necessary.

b) *Strength.* The load-bearing capacity of a flexural member should be calculated in accordance with normal practice, using the residual section and stresses of 2.25 × permissible long-term dry stresses given in BS 5268-2, when the minimum initial breadth of the section is 70 mm or greater and 2.00 × permissible long term dry stress, when this dimension is less than 70 mm.

c) *Deflection.* Deflections should be calculated using the residual section and the dry value of the modulus of elasticity taking the mean or minimum values, as used in the original design. The resulting deflection should not exceed the limit defined in **5.1.1**.

5.2 Compression members

5.2.1 *Stability criterion.* The residual section should be such that the member will support the appropriate loads such as would be applied if the component were tested in accordance with the requirements of BS 476-20, to either the maximum design compressive load or loads based on those which the member is required to support in normal service.

5.2.2 *Assessment of fire resistance*

a) A column that is exposed to the fire on all faces [including a column which abuts on or forms part of a wall that does not have fire resistance, as in Figure 3(b) and Figure 4(b)], should be assumed to char equally on all faces during the whole period of fire exposures. To determine the residual section of such columns, the rates of charring given in Table 1 should be multiplied by 1.25.

Where a column abuts on or forms part of a wall which provides fire resistance from either side not less than that of the column, charring on all faces is unlikely. Calculations should therefore be based on charring of the column occurring on the side of the wall on which the column has the greater surface exposure, using the rates of charring given in Table 1 [see Figure 3 (a) and Figure 4 (a)].

Care should be taken to ensure that the junctions between the wall and the column will be adequate as a barrier to fire so that the integrity of the construction is unimpaired.

Where a column abuts on or forms part of a wall, which is required to provide fire resistance from one side only (such as in an external wall) and which has fire resistance not less than the column, charring on the faces of the column which can be exposed to fire need only be considered and the rates of charring given in Table 1 should be used. In establishing the vulnerable column faces, due regard should be given to the protection afforded by the walling materials.

Care should be taken to ensure that the junctions between the wall and the column will be adequate as a barrier to fire so that the integrity of the construction is unimpaired.

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b) No restraint in direction at the ends (as distinct from positional restraint) should be assumed in determining the effective length of residual column sections unless consideration of the residual joint (as indicated in **5.4**) shows that a degree of restraint would be provided.

c) The maximum slenderness ratio based on the residual section should not exceed 250 (this limitation replaces those given in BS 5268-2) and the stress modification factor for long-term loading for the slenderness ratio of the residual column should be derived from Table 20 of BS 5268-2.

d) The strength of a compression member should be calculated using the appropriate residual section, in accordance with BS 5268-2 as modified by **5.2.2** b) and **5.2.2** c) with the compressive stress parallel to the grain of 2.00 × the permissible long-term dry stress.

e) The strength of compression members subject to bending should be calculated in accordance with **15.6** of BS 5268-2 using the stresses derived in **5.1.2** b) and **5.2.2** d) in place of the permissible stresses.

5.3 Tension members

5.3.1 *Stability criteria.* The residual section should be such that the member will support the appropriate loads.

5.3.2 ***Assessment of fire resistance***

a) To determine the residual section of a tension member the rates of charring given in Table 1 should be multiplied by 1.25.

b) The load-bearing capacity of a tension member should be calculated in accordance with normal practice using the residual section and a stress of 2.00 × permissible long term dry stress given in BS 5268-2.

c) The load-bearing capacity of a tension member subject to bending should be calculated in accordance with **3.15.2** of Part 2 of this code using the permissible stresses derived in **5.1.2** b) and **5.3.2** b).

5.4 Joints

5.4.1 *General.* The charring rates given in Table 1 may be applied provided that in all cases the faces of the abutting pieces of timber are held in close contact and that special attention is paid to the placement or protection of metal fasteners and components (see **5.4.2** and **5.4.3**).

The methods of calculation given previously are directly applicable to the performance of individual flexural, tension and/or compression members. Junctions between members may be particularly vulnerable to the effects of fire and require special consideration. Where a compressive force is transferred by direct timber-to-timber bearing, the loss in strength of the joint is unlikely to be significant where members have been designed in accordance with the recommendations of this code.

However, where a structure is designed to have joints that transfer forces from one member to another, special account should be taken of the behaviour of such joints. An assessment should be made of the residual timber after the specified period, with particular attention to the effects of any metal connectors and the probability of rounding at abutting arrises (as indicated in **4.3**). In redundant structures, charring may alter the relative stiffness of various parts of the structure and result in a redistribution of forces, and account should be taken of complete or partial yielding of the joints as this may change the structural action. The structure with redistributed forces should be assessed for fire resistance as detailed in **5.1**, **5.2** and **5.3**.

5.4.2 *Metal fasteners.* Where any part of a nail, screw or bolt becomes exposed to heating during a fire, rapid heat conduction will lead to localized charring and loss of anchorage. Where this effect is likely to lead to the failure of a structural member which is required to have fire resistance, protection of the fastener should be provided by any one of the following methods.

a) Ensuring that every part of the fastener is embedded in the timber so that it remains within the residual section as shown in Figure 2. Any holes should be fully and securely plugged with timber glued in position. Advice on the use of alternative plugging materials should be sought from an appropriate authority.

b) Covering the exposed part of the fastener with a suitable protecting material, e.g. timber, plasterboard, or equivalent. Special attention should be paid to the fixing of such protection to ensure that it remains in position for the required period of fire resistance. Unprotected nails, screws or staples may be used in this case to fix this insulation.

c) Any appropriate combination of the methods outlined in a) and b).

5.4.3 *Steel hangers for joists or beams.* Where steel hangers are fully protected for the required period of fire resistance either by a ceiling membrance or locally with a protecting material, they will be satisfactory in fire.

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For floor construction up to and including 30 min fire resistance, joist hangers of the strap or shoe type, formed fr/m 1 mm steel, may be used with ceiling construction which affords 20 min pr/tection, e.g. 12 mm plasterboard.

For floor construction up to and including 30 min fire resistance, joist hangers of the substantial shoe type with gusset or strap bracing, formed fr/m at least 3 mm steel, may be used without protection.

For 1 h fire resisting floors, a ceiling has to be used affording at least 45 min protection, e.g. 31 mm plasterboard.

5.4.4 *Metal plates and other metal connectors.* Metal connectors and metal connector plates may be used without restriction in trussed rafter construction when no fire resistance requirements exist. When a member incorporating exposed nail plates is required to have fire resistance, the provisions /f **5.4.2** apply.

When the bolts of other types of metal connectors, e.g. toothed plates, split rings, etc., are likely to become exposed during a fire, additional protection as outlined in **5.4.2** should be provided. All other types of joints should be referred to an appropriate authority.

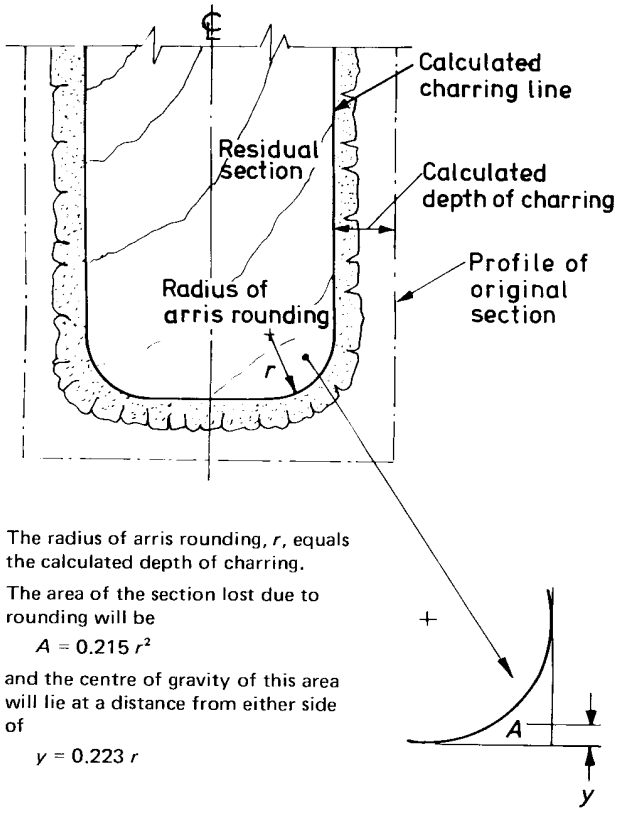

Figure 1 — Radius of arris r/unding

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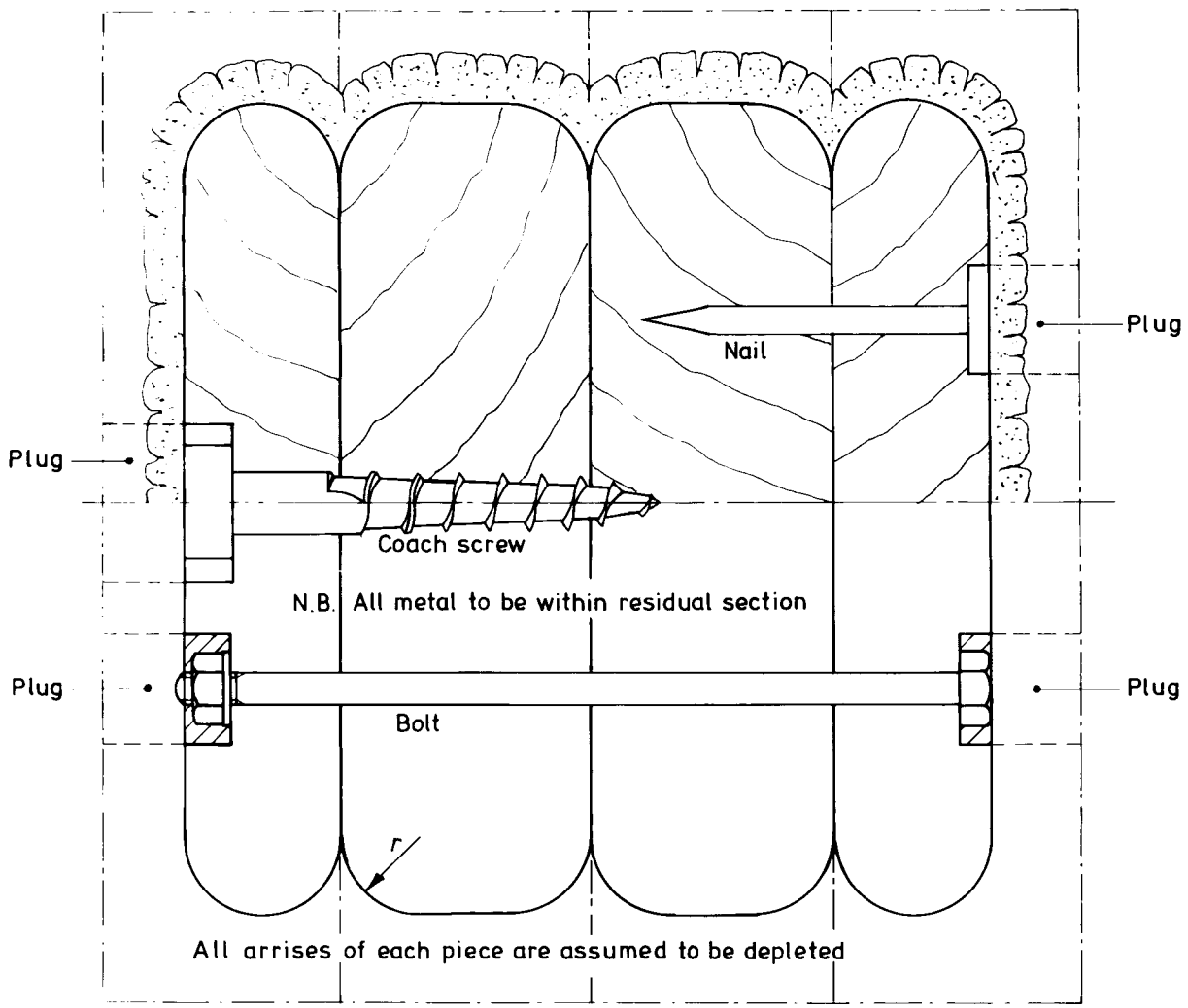

Figure 2 — Sections built up with metal fasteners

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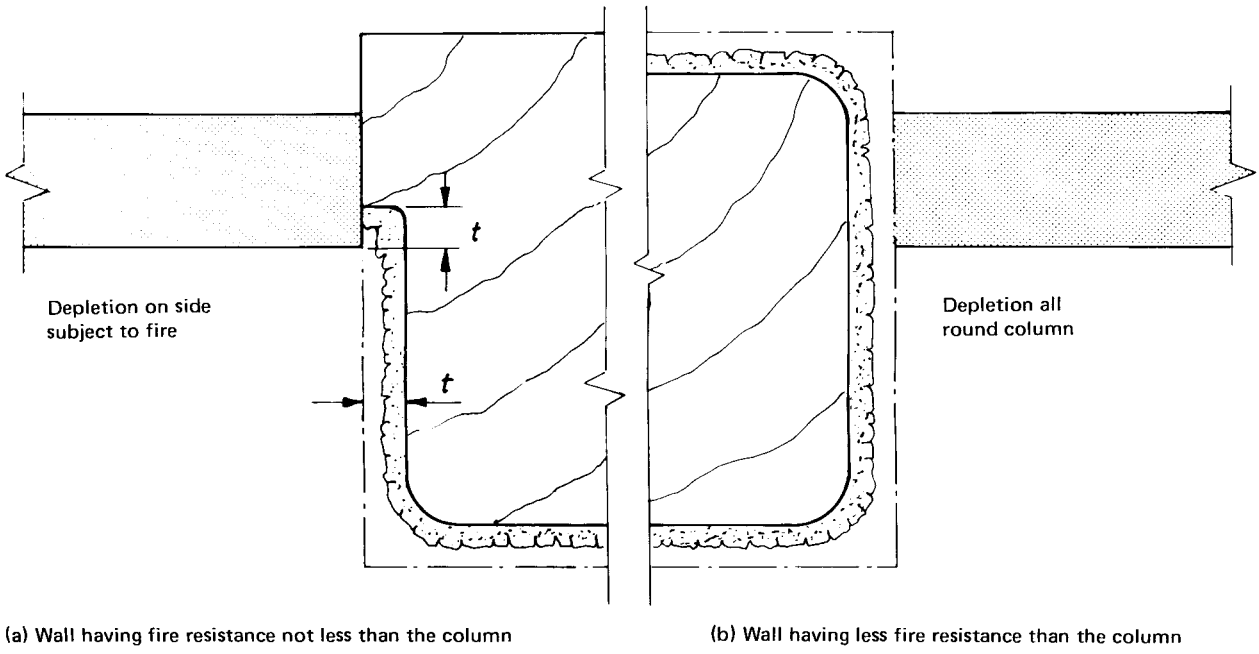

Figure 3 — Columns built into walls

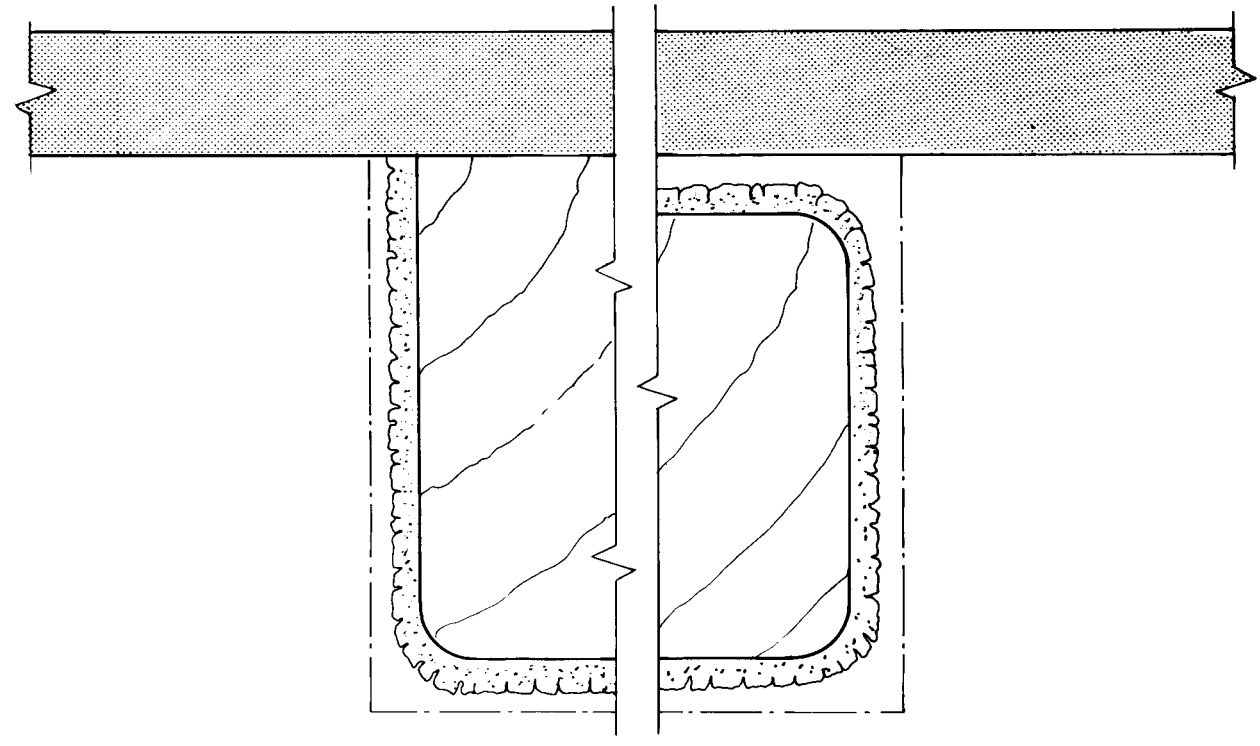

Figure 4 — Columns abutting on walls

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Publications referred to

BS 476, *Fire tests on building materials and structures.*
BS 476-8, *Test methods and criteria for the fire resistance of elements of building construction.*
BS 476-20, *Method for determination of the fire resistance of elements of construction (general principles).*

BS 4422, *Glossary of terms associated with fire.*
BS 4422-2, *Building materials and structures.*
BS 5268, *Structural use of timber.*
BS 5268-2, *Code of practice for permissible stress design, materials and workmanship.*
BS 5291, *Finger joints in structural softwood.*
BS 6100, *Glossary of building and civil engineering terms.*
BS 6100-4, *Forest products.*

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