

# Fire tests on building materials and structures —

## Part 21: Methods for determination of the fire resistance of loadbearing elements of construction

ICS 13.220.50

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- Association of Builders Hardware Manufacturers  
British Steel Industry  
Department of the Environment (Building Research Establishment, Fire Research Station)  
Door and Shutter Association  
Electric Cable Makers' Confederation
- Guild of Architectural Ironmongers  
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| C2       | December 2024 | Supersession updated in Foreword |
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# Foreword

This part of BS 476 is published by BSI Standards Limited, under licence from The British Standards Institution.

This standard has been superseded by the current BS EN 1365-1, BS EN 1365-2, BS EN 1365-3 and BS EN 1365-4 and will be withdrawn on 2 September 2029.

This Part of BS 476 has been prepared under the direction of the Fire Standards Committee, and describes the specific equipment and procedures for determining the fire resistance of loadbearing elements of building construction. This Part should be read in conjunction with BS 476-20 which describes the general principles for these methods.

This Part has been prepared in such a way as to allow reference to be made to the appropriate method of determining the fire resistance of the designated element by clause number only. Therefore clauses 5 to 8 are self-contained and cross refer to BS 476-20 where necessary.

Methods for determining the fire resistance of non-loadbearing elements that have a finite fire resistance and of components that make a contribution to the fire resistance of a structure are described in BS 476-22 and BS 476-23 respectively.

Methods for determining the fire resistance of external beams and columns are under consideration in the International Organization for Standardization ISO/TC 92, Fire tests on building materials, components and structures.

The general changes made to the methods described in this Part compared with BS 476-8 are described in the foreword to BS 476-20. Appendix A gives guidance and background information that will assist the designer and the testing laboratory to select and evaluate specimens that are more representative of “in use” situations.

Attention is drawn to the Health and Safety at Work etc. Act 1974, and the need to ensure that the methods described in this standard are carried out under suitable environmental conditions to provide adequate protection to personnel against the risk of fire, and/or inhalation of smoke and/or toxic products of combustion.

**CAUTION.** The mechanical sawing of asbestos cement components attracts the provision of the Asbestos Regulations 1969. Adequate methods exist to control levels of dust during such operations and these are detailed in the Control and

Safety Guides<sup>1)</sup> issued by the Asbestos Research Council.

This Part, together with BS 476-20, BS 476-22, BS 476-23 and BS 476-24, supersedes BS 476-8:1972, which is withdrawn. However, the latter will still be made available on request, since it is referred to in the building regulations and other legislative documents.

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## Summary of pages

This document comprises a front cover, an inside front cover, pages i and ii, pages 1 to 16, 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.

<sup>1)</sup> Available from the Asbestos Information Centre, Sackville House, 40 Piccadilly, London W1V 9PA.

## 1 Scope

This Part of BS 476 describes procedures for determining the fire resistance of loadbearing elements of building construction when subjected to the heating and pressure conditions specified in BS 476-20. This Part provides requirements for specimen selection and/or its design and construction, loading and restraint conditions, equipment, procedures and criteria as they apply to loadbearing specimens. The methods are applicable to beams, columns, floors, flat roofs and walls.

The methods described are not applicable to suspended ceilings protecting steel beams which are described in BS 476-23 (see A.1). Owing to limitations imposed by both the furnaces and their method of control, structures employing water cooling techniques are not capable of being evaluated realistically by these procedures.

The methods described are not applicable to assemblies of elements, e.g. wall/floor combinations, although some guidance is provided in Appendix A for tests of this type (see A.1).

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

## 2 Definitions

For the purposes of this Part of BS 476, the definitions given in BS 476-20 and BS 4422 apply.

## 3 Test conditions

The test conditions shall be as specified in BS 476-20 except that, in the case of vertical, non-separating elements, the neutral pressure axis may be at a height of up to 2 000 mm above the notional floor level.

## 4 Apparatus

The apparatus for the test shall be as specified in BS 476-20.

## 5 Determination of the fire resistance of beams

### 5.1 General

**5.1.1** This clause describes a method for determining the fire resistance of beams with or without an applied fire protection insulation material and unventilated cavities.

**5.1.2** Beams that are incorporated in, or which act in, a composite manner with either a floor or a roof construction are normally deemed to be a part of those elements of construction and shall be tested in accordance with clause 7 (see A.3.1).

### 5.2 Test specimen

**5.2.1** *Number of specimens.* One specimen shall be tested.

**5.2.2** *Size of specimen.* The specimen shall be full size for beams with a span of up to 4 m. For elements that have a span in excess of 4 m, the minimum size of specimen exposed to the heating conditions of the furnace shall be not less than 4 m (see also 5.2.3).

**5.2.3** *Design of specimen or test construction.* When selecting a test specimen or designing a representative construction, the following points shall be considered.

a) If the beam incorporates a mechanical joint along its length, this shall be incorporated as in practice or at mid-span. When joints occur in fire protective claddings, specimens incorporating such protection shall include representative joints (see A.3.2.2).

b) Where a beam in practice is only exposed to the effects of fire on three sides, e.g. where the top surface is supporting a floor construction, the specimen shall be provided with an associated construction as in practice. If the construction carried on the top surface of the beam is in continuous thermal contact with the beam, this shall be simulated by a dense aggregate concrete slab of 135 mm thickness. The topping construction shall extend at least 200 mm on each side of the beam.

c) Any associated construction provided to the top surface of the beam for the purpose of a test shall be designed and constructed such as not to provide any significant strength or stiffness to the beam. Any joints in the associated construction, or between the associated construction and any furnace closures, shall be sealed with a resilient gasket of adequate fire performance.

d) If fire protection material is applied or fixed to the beam, this shall be undertaken after the associated construction has been installed, unless in practice the protection is installed before installation of the supported construction. It shall extend over the length of the beam that is to be exposed to the heating conditions of the test, plus sufficient additional length at each end to terminate the protection outside the furnace. Where a void is created within the fire protection system (e.g. hollow box protection to steel beams) this void shall be sealed at the positions where the beam exits from the furnace chamber. The projecting ends of any beam that extend beyond the furnace chamber shall be insulated by wrapping with a single thickness of 100 mm thick mineral wool, with a density of at least 100 kg/m<sup>3</sup>.

**5.2.4 Test construction and condition.** The construction and condition of the specimen including any associated construction shall be in accordance with BS 476-20.

### 5.3 Support and loading conditions

**5.3.1** The method used for supporting the ends of the test construction shall be similar to that which would apply in service. When the end conditions are not known, the test construction shall be installed as a simply supported beam.

**5.3.2** The magnitude of the test loading taking into account the beam end conditions that apply to the test construction shall be calculated. The recommendations given in BS 476-20 shall be used in determining the test loading (see **A.3.3.2**). The span of the beam, if simply supported, shall be taken as the distance between the supports at the commencement of the test.

### 5.4 Examination of specimen

**5.4.1** Establish the dimensions and relevant properties of the materials used in the manufacture of the test construction in accordance with BS 476-20 (see **A.3.4.1**).

**5.4.2** Mount the specimen horizontally on top of the furnace, in its support frame if used, such that it is subjected to the heating conditions of the method in a manner similar to that occurring in practice, i.e. from the underside.

**5.4.3** Position the furnace control thermocouples as specified in BS 476-20 at not less than two thermocouples for each metre length of test construction, or part thereof, with not less than six thermocouples for beams of less than 3 m span. Distribute the thermocouples uniformly with no thermocouple closer than 500 mm from the furnace wall so that their hot junctions are  $100 \pm 10$  mm horizontally away from the sides of the specimen and level with the soffit of the beam including any applied protection, with a tolerance of  $\pm 10$  mm.

**NOTE** The position of the hot junction should not vary by more than 50 mm from this position during test.

**5.4.4** When the timing control thermocouple is not one of the furnace temperature control thermocouples, install a timing thermocouple as specified in BS 476-20.

**5.4.5** Position at least one pressure sensing head in the furnace such that the pressure conditions in the furnace are measured and controlled in accordance with BS 476-20, at a position 100 mm below the top of the beam or the soffit of the topping construction.

Ensure that the pressure sensing head(s) does not interfere with the deflection of the test construction.

**NOTE** The head is not required to be maintained at a fixed distance from the surface of the specimen during test.

**5.4.6** If additional measurements are to be made of the temperature of any part of the test construction not related to the criteria, fix any thermocouples that have not been built into the specimen in accordance with BS 476-20 (see **A.3.4.2**).

**NOTE** As these beams are not separating elements there is no requirement to attach surface temperature monitoring thermocouples nor is there a need to set up the ambient temperature measuring equipment.

**5.4.7** Install the equipment to measure the maximum vertical deflection of the specimen. For simply supported constructions assume this to be at mid-span but for non-symmetrical constructions or unevenly distributed loading, take deflection measurements at more than one position in order to determine the maximum deflection.

**5.4.8** If the ends of the test construction require any special provisions to achieve an initial fixity, attach any equipment and/or apply any forces as required.

### 5.5 Test procedure

**5.5.1** Carry out the loading procedure in accordance with BS 476-20. Record the time prior to the commencement of the heating that the loading is completed.

**5.5.2** Monitor the specimen for loadbearing capacity and make observations of the behaviour of the specimen in accordance with clause 9 of BS 476-20:1987.

### 5.6 Criteria of failure, expression of results and test report

**5.6.1 Criteria of failure.** The fire resistance of loadbearing horizontal elements without any separating function shall be determined with respect to loadbearing capacity. The criteria of failure shall be as given in **10.2.3** of BS 476-20:1987.

**5.6.2 Expression of results.** The result shall be stated in terms of the elapsed time, to the nearest minute, between the commencement of heating and the termination of heating or failure to satisfy the criterion of loadbearing capacity in accordance with BS 476-20.

**NOTE** An example of the method of expressing the results is given in **A.11** of BS 476-20:1987.

**5.6.3 Test report.** The test report shall include the result (see **5.6.2**) and any observations, including the mode of failure, together with the other requirements given in clause 12 of BS 476-20:1987.

## 6 Determination of the fire resistance of columns

### 6.1 General

**6.1.1** This clause describes a method for determining the fire resistance of fully exposed columns used as separate elements of construction. The column may be provided with an applied fire protection media with or without an unventilated cavity.

**6.1.2** Columns that are incorporated in, or that act in, a composite manner with a wall construction are deemed to be a part of those elements of construction and shall be tested in accordance with clause 8 (see A.4.1).

### 6.2 Test specimen

**6.2.1** *Number of specimens.* One specimen shall be tested. Where the column may be used in practice with different end restraint conditions or different slenderness ratios, more than one test may be necessary to establish the effects of these conditions.

**6.2.2** *Size of specimen.* The specimen shall be full size for columns with a height of up to 3 m. For elements that have a height in excess of 3 m, the minimum size of specimen exposed to the heating conditions of the furnace shall be not less than 3 m. The overall height shall be such as to allow a capping and the loading equipment to be fixed at each end with adequate protection from the furnace atmosphere and from the conduction of excessive heat through the specimen.

**6.2.3** *Design of specimen or test construction.* When selecting a test specimen or designing a representative construction, the following points shall be considered.

- a) When joints occur in fire protection claddings, any specimen that incorporates such protection shall include representative joints.
- b) The specimen shall be essentially straight. Where suitable material design codes exist, any non-linearity shall be within the specified tolerances. Where no such codes exist, material selection or the manufacturing process shall be such that the specimen has a linearity representative of that to be found in practice.
- c) The ends of the specimen shall be adequately designed and detailed for the proper transmission of the test load from the loading platens to the specimen with the required conditions of fixity.

Provision shall be made for the attachment of protecting collars at each end of the specimen. These shall be designed to provide location and an adequate means of sealing with the furnace walls and shall be suitably attached and supported so that they remain effective and in position throughout the heating period. The method adopted to provide the seal shall allow the test specimen to move within the furnace walls without significantly affecting the load transmitted from the loading rig to the specimen or the fixity at the ends of the specimen (see A.4.2.1).

d) Provision shall be made for the proper positioning and alignment of the specimen in the rig and for ensuring uniform distribution of the loading over the ends of the specimen.

### 6.2.4 Test construction and condition

**6.2.4.1** The test construction shall be manufactured in accordance with BS 476-20.

**6.2.4.2** Operations required by this method, such as the provision of protection at the ends of the specimen and the installation of thermocouple measuring junctions for monitoring internal temperatures, shall be undertaken at appropriate stages during the construction.

**6.2.4.3** The condition of the test construction, including the associated collar and capping (see A.4.2.2) shall be in accordance with BS 476-20.

### 6.3 Support and loading conditions

**6.3.1** The specimen shall normally be tested with fixed end conditions as in practice but shall be free to expand during the test. Adequate provision shall be made in the design of the loading rig to ensure that fixed end conditions are maintained throughout the test. If a test construction is to be tested under any other conditions of fixity, e.g. pin ended, adequate provision shall be made to ensure that the required end conditions are maintained throughout the test.

**6.3.2** The test loading shall be calculated on the basis of axial loading unless otherwise specified (see A.4.3.2).

**6.3.3** When calculating the test loading for a column, the overall height of the specimen shall be used when restraint is applied to the ends of the specimen only [see Figure 1 (a)].

When restraint is applied along the height of the specimen, e.g. by the use of concrete collars, the height of the column shall be assumed for calculation purposes to be the distance between the restrained area [see Figure 1(b)].

The test load shall be calculated taking into account the relevant buckling length.