INTERNATIONAL STANDARD

ISO 834-6

First edition
2000-07-15

Fire-resistance tests — Elements of building construction —

Part 6: Specific requirements for beams

Essais de résistance au feu — Éléments de construction —

Partie 6: Exigences spécifiques relatives aux poutres

Reference number
ISO 834-6:2000(E)

ISO copyright office
Case postale 56 • CH-1211 Geneva 20
Tel. + 41 22 749 01 11
Fax + 41 22 749 09 47
E-mail copyright@iso.ch
Web www.iso.ch

Printed in Switzerland

Contents

Page

Foreword ... iv

Introduction ... v

1 Scope ... 1

2 Normative references ... 1

3 Terms and definitions ... 1

4 Symbols and abbreviated terms ... 2

5 Test equipment ... 2

6 Test conditions ... 2
6.1 General ... 2
6.2 Restraint and boundary conditions ... 2
6.3 Loading ... 2

7 Test specimen preparation ... 3
7.1 Specimen design ... 3
7.2 Specimen size ... 3
7.3 Number of test specimens ... 4
7.4 Specimen conditioning ... 4
7.5 Specimen installation and restraint ... 4

8 Application of instrumentation ... 5
8.1 Furnace thermocouples (plate thermometer) ... 5
8.2 Specimen thermocouples ... 5
8.3 Deformation measurement ... 6

9 Test procedure ... 6
9.1 Load application ... 6
9.2 Furnace control ... 6
9.3 Measurements and observations ... 6

10 Performance criteria ... 6

11 Validity of the test ... 7

12 Expression of results ... 7

13 Test report ... 7

Annex A (informative) General guidance on the test method ... 8

Annex B (informative) Direct application of results ... 11

Bibliography ... 12

Foreword

ISO (the International Organization for Standardization) is a world wide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 3.

Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this part of ISO 834 may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

International Standard ISO 834-6 was prepared by Technical Committee ISO/TC 92, *Fire safety*, Subcommittee SC 2, *Fire containment.*

ISO 834 consists of the following parts, under the general title *Fire-resistance tests — Elements of building construction:*

— *Part 1: General requirements*

— *Part 3: Commentary on test method and test data application*

— *Part 4: Specific requirements for loadbearing vertical separating elements*

— *Part 5: Specific requirements for loadbearing horizontal separating elements*

— *Part 6: Specific requirements for beams*

— *Part 7: Specific requirements for columns*

— *Part 8: Specific requirements for non-loadbearing vertical separating elements*

— *Part 9: Specific requirements for non-loadbearing horizontal separating elements*

— *Part 10: Method to determine the contribution of applied protection materials to structural metallic elements*

— *Part 11: Method to assess the contribution of applied protection materials to structural metallic elements*

Annexes A and B of this part of ISO 834 are for information only.

Introduction

This part of ISO 834 contains specific requirements for fire resistance testing which are unique to the elements of building construction described as beams. The requirements for these loadbearing elements are intended to be applied in appropriate conjunction with the detailed and general requirements contained in ISO 834-1.

Fire-resistance tests — Elements of building construction —

Part 6:
Specific requirements for beams

1 Scope

This part of ISO 834 specifies the procedures to be followed for determining the fire resistance of beams, when tested on their own.

Beams are normally tested with their underside and two vertical sides fully exposed to heating. However, when the exposure is from four sides or less than three sides, appropriate exposure conditions are necessary. Beams which are part of a floor construction are tested with the floor construction as described in ISO 834-5 and are subject to evaluation of integrity and insulation.

The application of this test to other untested forms of construction is acceptable when the construction complies with the direct field of application as given in this part of ISO 834 or when subjected to an extended application analysis in accordance with ISO/TR 12470. Since ISO/TR 12470 gives only general guidelines, specific extended application analyses are to be performed only by persons expert in fire-resistant constructions.

General guidance on this test method is given in annex A.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this part of ISO 834. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this part of ISO 834 are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of ISO and IEC maintain registers of currently valid International Standards.

ISO 834-1:1999, *Fire-resistance tests — Elements of building construction — Part 1: General requirements.*

ISO/TR 12470, *Fire resistance tests — Guidance on the application and extension of results*.

ISO/IEC 13943, *Fire safety — Vocabulary*.

3 Terms and definitions

For the purposes of this part of ISO 834, the terms and definitions given in ISO 834-1 and ISO 13943 and the following apply.

3.1
beams
all horizontally oriented structural members employed in building construction and known variously as beams, joists or girders

NOTE They may be integral with or separate from the structure that they support.

3.2
composite construction
steel or composite steel/concrete beams supporting a reinforced concrete slab so interconnected that the beams and the slab act together to carry the load

3.3
exposed length
length of the specimen exposed to the heating effects of the test furnace

3.4
span
distance between the centres of support

3.5
specimen length
overall length of the test specimen

4 Symbols and abbreviated terms

Symbols and designations appropriate to this test are given in ISO 834-1 and below.

L_{exp}	Length of test specimen exposed to heating	mm
L_{sup}	Length of test specimen between centres of supports	mm
L_{spec}	Length of test specimen	mm

5 Test equipment

Equipment employed in the conduct of this test consists of a furnace, loading equipment, restraint and support frames and instrumentation as specified in ISO 834-1.

6 Test conditions

6.1 General

The heating and pressure conditions, the furnace atmosphere and the loading conditions shall conform to those specified in ISO 834-1.

6.2 Restraint and boundary conditions

Restraint and boundary conditions shall comply with the requirements given in ISO 834-1 and the requirements of this part of ISO 834.

6.3 Loading

6.3.1 All beams shall be tested when subjected to loads calculated in accordance with subclause 6.3 a), b) or c) of ISO 834-1:1999, in consultation with the sponsor to produce the conditions the structure is designed to accommodate. The material properties utilised in the calculation of the load shall be clearly indicated and their source given.

6.3.2 When the proposed test specimen is smaller than the element in practice, it is important that the size of the test specimen, the type and level of loading and the support conditions be selected such that the same type of failure (for instance, a bending failure, a shear failure or a bond or an anchorage failure) will be decisive for the test specimen as for the construction it represents; i.e. the load applied during the test shall provide the same load level as the real construction. For cases in which the decisive type of failure is difficult to predict, two or more tests, individually designed to cover in total all relevant types of failure, shall be required.

6.3.3 The magnitude and the distribution of the load shall be such that the maximum moments and shear forces produced are representative of or higher than those expected in practice.

6.3.4 The loading system shall be capable of applying the required load uniformly distributed or by a point loading system as appropriate. When point loads are used to produce bending moments in a distribution corresponding to a uniformly distributed load, these shall be not less than two in number with a minimum separation of 1 m. When a four-point loading system is used, the points shall be normally located at 1/8, 3/8, 5/8 and 7/8 of the span (L_{sup}) from either end. The load shall be transferred to the beam through distribution plates not wider than 100 mm. The loading system shall not inhibit the free movement of air above the top surface and, other than at the loading point, no part of the loading apparatus shall be closer than 60 mm from the surface.

6.3.5 The loading system shall be capable of compensating for the maximum allowable deformation of the test specimen.

7 Test specimen preparation

7.1 Specimen design

7.1.1 For test constructions with beams intended for test with a floor or roof assembly representative of actual construction, such an assembly can be an integral part of the test construction forming a “Tee” beam arrangement. With steel beams, the slab is permitted to be of dense or lightweight concrete. The results of the former cannot be applied to the latter.

7.1.2 For test constructions with beams intended for test representative of the actual floor or roof that will be supported, the slab thickness shall reflect the design construction. The width of the actual floor shall be at least three times the beam width or at least 600 mm, whichever is the greater. The actual width selected will depend on the furnace design.

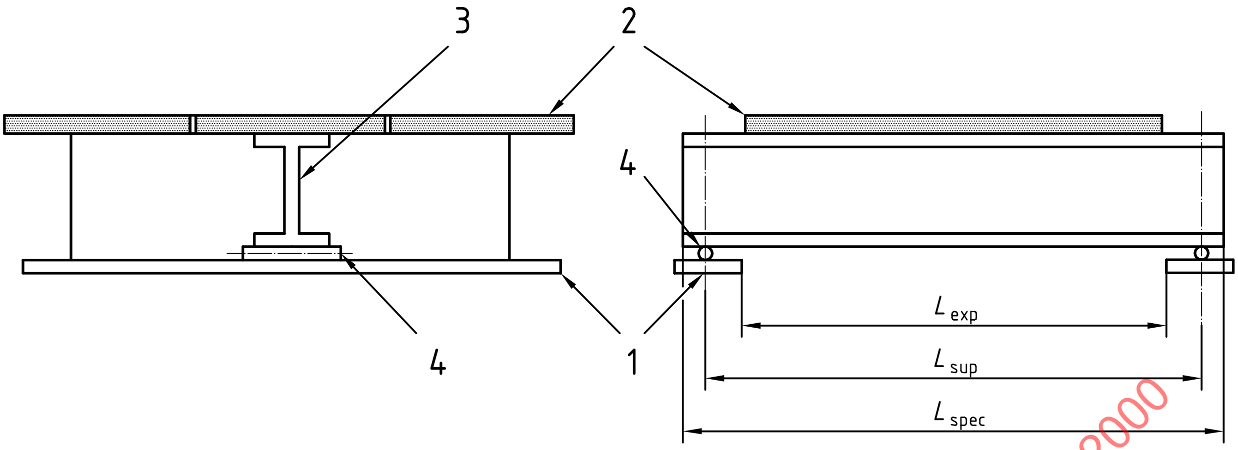
7.1.3 For test constructions that do not include a representation of the actual floor or roof, the beams shall support a symmetrically placed standardized topping defined as follows: a topping designed and manufactured in discrete sections, with discontinuous reinforcements when used, to avoid any composite action between it and the beam which might give additional strength and stiffness to the beam. The topping shall be made from aerated concrete slabs having a density of (650 ± 200) kg/m^3, each having a maximum length of 1 m and a thickness of at least (150 ± 25) mm. The width of the topping shall be at least three times the beam width or at least 600 mm, whichever is the greater. The actual width selected will depend on the furnace design.

7.1.4 Beams with hollow encasement shall have their ends blocked to prevent any flow of hot gases away from the beam. The mounting of the test specimen shall be such that the encasement does not terminate in the heating zone or is likely to collapse due to restraint to expansion that is contrary to its use in practice.

7.1.5 When in practice a 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.

7.2 Specimen size

7.2.1 For beams supported on rollers, the exposed length (L_{exp}) shall not be less than 4 m. The span between supports (L_{sup}) shall be the exposed length (L_{exp}) plus up to a maximum of 100 mm at each end. The specimen length (L_{spec}) shall be the exposed length (L_{exp}) plus up to a maximum of 200 mm at each end. A general arrangement of a simply supported beam in the furnace is shown in Figure 1.



Key

1 Support
2 Topping
3 Beam
4 Roller

Figure 1 — Example of a simply supported test specimen

7.2.2 For beams representative of conditions in practice, the exposed length (L_{exp}) shall not be less than 4 m when the exposed length of the beam in practice is longer than can be accommodated in the furnace. For beams designed to have an exposed length in practice of less than 4 m, the actual exposed length shall be tested. The length of the bearing shall not exceed that in practice. The specimen length (L_{spec}) shall be the exposed length (L_{exp}) plus up to a maximum of 200 mm at each end.

For restrained beams, a 4 m minimum span is inadequate because only a portion of the span would be expected to be in bending mode, the remainder being partially supported by the restraint mechanism. Therefore, when testing a restrained beam, a longer span in which at least 4 m is subjected to positive bending moments shall be selected. If X % of the beam is expected to be in positive bending mode, the overall length shall be given by $L_{exp} = 4 \times 100/X$ m.

7.3 Number of test specimens

The number of test specimens shall comply with the requirements given herein and in ISO 834-1.

7.4 Specimen conditioning

At the time of the test, the strength and moisture content of the test specimens shall approximate the conditions expected in normal service. This includes any in-fills and jointing materials. Guidance on conditioning is given in ISO 834-1. After equilibrium has been achieved, the moisture content or state of cure shall be determined and recorded.

7.5 Specimen installation and restraint

7.5.1 A general arrangement of a simply supported beam in the furnace is shown in Figure 1. The test arrangement shall provide lateral stability.

Beams are either subjected to fire exposure while resting on roller supports (simply supported) or simulating the end conditions as in practice. When support and restraint represent in-practice conditions, those conditions shall be described in the report and the test results shall be reported as restricted.

7.5.2 Test specimens representing beams shall normally be tested on roller supports. When the end conditions are known, the test construction may be installed as in practice with smooth concrete or steel plate bearing surfaces.

7.5.3 Simply supported specimens shall be positioned to allow freedom for longitudinal movement and vertical deflection and remove any fixity induced by frictional resistance.

7.5.4 The apparatus utilized for providing restraint to thermal expansion, axially or rotationally, shall be designed or adapted for the forces to be expected as a consequence of thermal expansion and the required restraint.

7.5.5 When a test incorporates more than one beam, each beam shall be exposed to the specified test conditions and shall be loaded to act independently.

7.5.6 Any joints in the topping and gaps at the boundaries shall be sealed with a non-restraining, non-combustible material.

7.5.6 Resilient material of adequate fire performance shall seal and protect the beam supports and prevent the leakage of hot gases having any influence on end conditions during the test.

7.5.7 The ends of beams extending beyond the furnace chamber, for support purposes, shall be insulated either by the applied fire-protection material itself, or by wrapping with a single thickness of (100 ± 10) mm thick mineral wool with a density of (120 ± 30) kg/m^3.

7.5.8 Test specimens representing continuous beams, restrained above one or two supports, shall be erected such that the deflection angle above the support in the direction of the non-heated part remains consistent with that which would be experienced in practice.

7.5.9 When testing beams to four-sided exposure, the minimum distance from the top of the beam to the furnace cover slab shall be at least equal to the width of the beam.

NOTE Special arrangements may need to be made when testing asymmetrical beams or beams restrained at one end only.

8 Application of instrumentation

8.1 Furnace thermocouples (plate thermometer)

8.1.1 Plate thermometers shall be provided to measure the temperature of the furnace and shall be distributed to give a reliable indication of the temperature in the region of the test specimen. There shall be at least two plate thermometers for each metre length, or part thereof, of exposed length of beam. These plate thermometers shall be constructed and located in accordance with ISO 834-1.

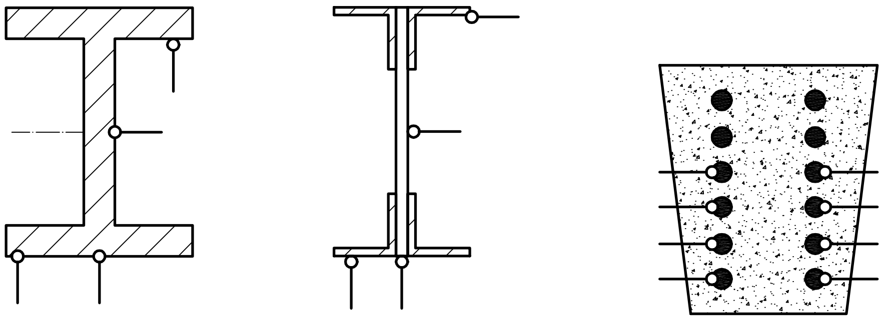
8.1.2 The plate thermometers shall be no more than 1,5 m apart, each positioned (100 ± 50) mm below the plane of the underside of the beam and (100 ± 50) mm from the edges on each side of the beam. Each plate thermometer shall be oriented so that side “A” faces either the floor of the furnace or the furnace side walls. On each side of the beam, there shall be an equal number of the plate thermometers facing the floor as facing the nearer parallel side wall.

8.1.3 When the depth of the beam is 500 mm or more, additional plate thermometers shall be provided and positioned as in 8.1.2, but at the mid-height of the beam instead of below the beam.

8.2 Specimen thermocouples

8.2.1 When the beam is manufactured from steel or another material for which high temperature property information is known, measurement of specimen temperatures will assist in the prediction of failure and enable the result to be used for possible assessment techniques. The use of screws, welding or peening are suitable means of attaching thermocouples to steel. Care shall be taken to ensure that a minimum of 50 mm of both thermocouple wire leads remains in a region isothermal to the thermo-junction.

8.2.2 Thermocouples shall be located at mid-span and at two other locations midway between the mid-span and a point 500 mm from the furnace edge. Typical thermocouple positions at each location are shown in Figure 2.



a) Steel beam   b) Steel joist   c) Concrete beam

Figure 2 — Typical positions for specimen thermocouples

8.2.3 Thermocouples located to determine temperature gradients throughout the concrete will assist in the prediction of failure and enable the result to be used for possible assessment techniques. Locate thermocouples on each of the tension reinforcing elements, unless there are more than eight such elements, in which case place thermocouples on eight elements selected in such a manner as to obtain representative temperatures of all elements. (See Figure 2.)

8.3 Deformation measurement

8.3.1 The zero point for the test is the deflection measured after the load has been applied at the beginning of the test before commencement of heating and after the deflection has stabilized.

8.3.2 The vertical deflection along the longitudinal axis of the beam shall be measured at mid-span.

8.3.3 Deflection measurements shall be taken at multiple positions to determine maximum movement.

9 Test procedure

9.1 Load application

Apply and control the load to the beam in accordance with ISO 834-1 and 6.3 of this part of ISO 834.

9.2 Furnace control

Measure and control the furnace temperature and pressure conditions in accordance with ISO 834-1.

9.3 Measurements and observations

Monitor the specimen for compliance with the criterion of loadbearing capacity and make relevant measurements and observations in accordance with ISO 834-1.

10 Performance criteria

The fire resistance of the beam shall be judged against the loadbearing capacity criteria as specified in ISO 834-1.

11 Validity of the test

The test shall be considered to be valid when it has been conducted within all of the specified limits of the requirements pertaining to: the test equipment, test conditions, test specimen preparation, instrument application and test procedure according to this part of ISO 834.

The test shall also be considered for acceptance when the fire exposure conditions relating to furnace temperature, pressure and ambient temperature are in excess of the upper limits of the tolerances specified in this part of ISO 834.

12 Expression of results

The results of the fire resistance test shall be expressed in accordance with ISO 834-1.

When a test has been performed on a specimen which has been subjected to a service load intended for a specific application less than the maximum which would be applied in consideration of a recognized structural code, the loadbearing capacity shall be qualified in the result by the term “restricted”. Full details shall be provided in the test report concerning its derivation.

13 Test report

The report shall be in accordance with ISO 834-1.

Annex A
(informative)

General guidance on the test method

A.1 General

In practice, beams support floor slabs or roof decks. In some applications, the connection between them and the beam can be such that they act in a composite manner. In these cases the assembly may be tested either as a beam or as a floor assembly in which the applied loads are adjusted to take into account the total stiffness of the construction.

Where it is required to evaluate performance with respect to integrity and insulation, a separate test should be carried out according to ISO 834-5.

The evaluation of the fire resistance of a beam is concerned with effects arising from attack by a fire to the underside, sides and perhaps the top surface of a beam, with no account being taken of heat loss into the ends of the beam.

Whilst the procedures are written with respect to beams that will normally be subjected to bending stress, the principles are applicable to the testing of tensile members.

A.2 Test specimen construction

Beams are unlikely to incorporate structural joints other than over vertical supports. Certain forms of beam construction may well incorporate joints, e.g. finger joints in glue-laminated timber beams. Where such joints exist, a representative number of joints should be included in the test specimen.

Special attention should be made when the beam protrudes from the furnace chamber to ensure that there is no interference with any deflection that occurs.

The density of the concrete used in the test construction has a direct relationship with its thermal inertia properties. Low density concrete has a lower thermal conductivity than high density concrete. This is particularly important to note when testing protected steel beams when dense concrete is used in the associated construction. Higher heat transmission could occur between the steel and the dense concrete and give the potential for a reduced rate of rise of temperature of the specimen. This phenomenon influences the direct field of application of test results obtained under such conditions.

The width of the actual floor representation (7.1.2) or standardized topping (7.1.3) should be sufficient to deflect any gases that might pass through the gap away from the load application frame. It should not impede any deflection of the beam under test.

A.3 Support and loading conditions

A.3.1 Mounting of the test specimen onto the furnace

When a specimen is to be provided with fixity against rotation at its support, this can be achieved by cantilevering over its supports and fixing it in position. The degree of fixity can be determined from the cantilever arm and the force recorded by the load cell resisting the rotation moment. The position of the cantilever arm should be constant. Accordingly, the force recorded by the load cell on the cantilever arm will vary according to the thermal attack on the test specimen.

A.3.2 Loading

When a beam is tested at a span less than that to be used in practice, then, with the same loading, different types and magnitudes of stresses will be induced into the specimen than would exist in the full size element. The practicability of testing a beam of a specific cross section at a reduced span should be carefully studied to ensure that the critical stresses developed in the test specimen are of the same type that would exist in the full size element and that excessive shear stresses are not being produced by higher loading over reduced spans. This consideration could influence the choice and method of loading used to develop the required stresses.

Since this evaluation is concerned with beams as flexural members, it is important that the bending stress in a simply supported construction equates that occurring in practice. This should not be compromised by other considerations introduced by the artificial test configurations, e.g. that bending stress level is not reduced because of requirements concerned with torsional restraint.

A.4 Effect of restraint and loading conditions

Restraint to thermal expansion, axially or rotationally, may be applied in a number of ways.

In the least sophisticated equipment, the test specimen is mounted within a restraining frame of such proportions that it is capable of reacting to the axial thrust of specimen structural members without significant deflection. In some cases this axial thrust has been measured by calibrating the restraining frame. In other cases a degree of control has been exercized by leaving expansion gaps between the ends of the structural member and the restraining frame. Such arrangements also provide rotational resistance because of the contact and hence quasi-fixing of the end of the structural member over its depth and the depth of the restraining frame.

In more sophisticated arrangements, restraint and its measurement is provided by the use of hydraulic jacks arranged axially and normal with respect to the structural member(s).

In those cases where restraint to thermal expansion occurs, the heating during a fire-resistance test gives rise to an axial, compressive force in the members concerned. In most cases this force occurs at a position in the cross section of the member such that the corresponding bending moment tends to counteract the bending moment due to the applied load. This can lead to an increased loadbearing capacity and fire resistance unless the potential for spalling or instability failure outweighs this favourable effect.

A.5 Temperature measurement

The placement of specimen thermocouples should be such that maximum useful information on the temperature profile of the beam is gained.

Where composite constructions are used (e.g. H-section steel beams filled with concrete between the flanges), knowledge of the temperature of the individual components as well as the temperature gradient across the construction is useful and can permit further evaluation of the data.

Thermocouples can be used to measure temperatures between beams and fire protective cladding. Information gained in this way may be extrapolated to the fire protection, with the same protective material, of other beam materials and types with different critical temperatures.

A.6 Characterization of test specimen

As the cold strength of a simple element, such as a beam, is one of the most crucial properties of the construction, wider applicability can be obtained from the test if the test loading is related to the actual strength of the materials used, rather than the typical values available for the material.

On fully homogeneous materials, such information can be obtained from off-cuts, and often a loading test at ambient temperature, prior to the fire resistance test can quantify actual stress/strain relationships. The ambient temperature test should not, however, exceed the elastic limit of the material as this will affect the subsequent yield strength. Other factors that will have a significant effect on the fire resistance are as follows:

a) changes in the cross-sectional area along the length of the beam (checking at several positions is recommended);

b) the density of the beam material, any component parts, any protective cladding or applied coating;

c) the average thickness and variability of any protection material;

d) the moisture content of any hygroscopic materials used in the construction of the beam, protective coating or cladding.

