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FIRE RESISTANCE TEST OF STRUCTURES

(First Revision)

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Indian Standard

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(First Revision)

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0. FOREWORD

0.1 This Indian Standard (First Revision) was adopted by the Indian Standards Institution on 25 September 1979, after the draft finalized by the Fire Safety Sectional Committee had been approved by the Civil Engineering Division Council.

0.2 This standard has been prepared with a view to determining the extent of resistance, in terms of fire, which the built-up elements of a building structure would offer to fire. This standard was first published in 1966. The present revision has been based on ISO 834-1975 ' Fire resistance tests — elements of building construction ' issued by the International Organization for Standardization.

0.3 In reporting the results of a test or analysis made in accordance with this standard, the final value, observed or calculated, is to be rounded off, it shall be done in accordance with IS : 2-1960*.

1. SCOPE

1.1 This standard specifies standard heating and pressure conditions, a test method and criteria for the determination of the fire resistance of elements of building construction of various categories, such as walls and partitions, columns, beams, floors, roofs, etc.

NOTE — The list is not exhaustive. Elements which fall into none of these categories may be tested by analogy with a similar element.

1.2 The test provides for the determination of fire resistance of elements of building construction on the basis of the length of time for which the test specimens of specified dimensions, satisfy the criteria laid down under the prescribed test conditions during the period of fire exposure.

*Rules for rounding off numerical values (*revised*).

2. APPARATUS

2.1 Furnace — It shall be capable of subjecting a specimen element to the standard heating and pressure conditions specified in **3**.

2.2 Loading Equipment — If necessary, this may preferably be of hydraulic loading system.

2.3 Thermocouples - For measuring the internal gas space temperature of the furnace and the unexposed surface and internal temperatures of the test specimens in conformity with the requirements of **3.1.2**, **3.1.3** and **3.1.4.**

2.4 Equipment for Measuring Overpressure in Furnaces — For testing walls and floors.

3. STANDARD HEATING AND PRESSURE CONDITIONS

3.1 Standard Heating Conditions

3.1.1 *Temperature Rise* — The temperature-rise within the furnace shall be controlled so as to vary with time within the limits specified in **3.1.3** according to the following relationship:

$$T - T_0 = 345 \log_{10} (8 t + 1)$$

where

T = furnace temperature at time t, expressed in degrees Celsius;

T_0 = initial furnace temperature, expressed in degrees Celsius; and

t = time, expressed in minutes.

The curve representing this function, known as the 'Standard time-temperature rise curve' is shown in Fig. 1. The relationship expressed gives the values shown in Table 1.

3.1.2 *Measurement of Furnace Temperature*

3.1.2.1 The furnace temperature is deemed to be the average of the temperatures recorded by thermocouples arranged within the furnace to give an approximation to its average temperature.

3.1.2.2 These thermocouples shall not be fewer than:

one to each 1·5 m^2 of surface for walls and floors,

two to each 1 m of length for beams, and

two to each 1 m of height for columns.

In any case, the number of thermocouples shall be not less than five.

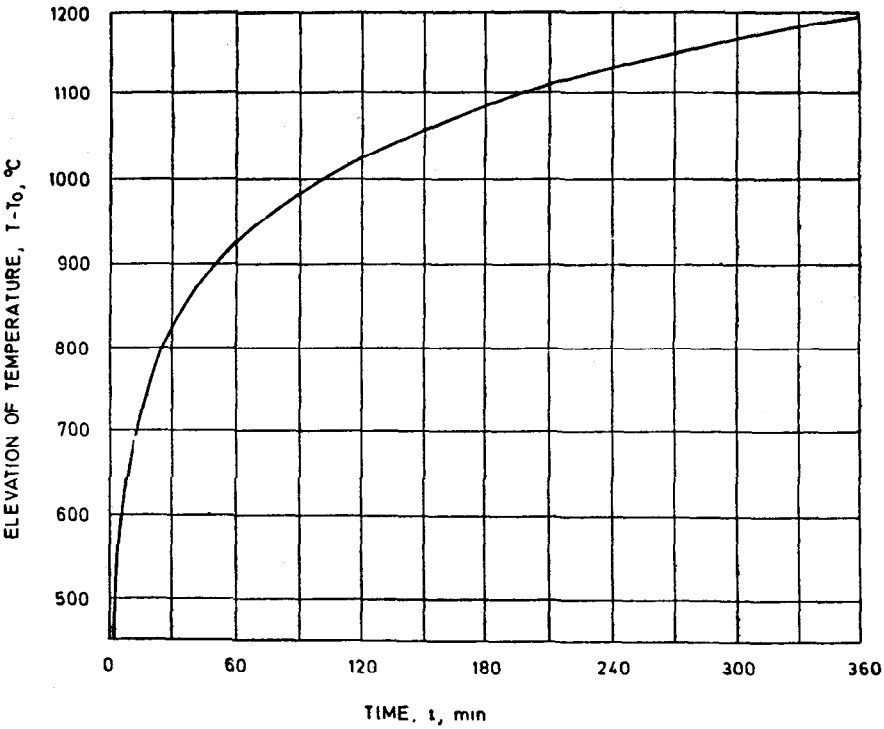

FIG. 1 STANDARD TIME-TEMPERATURE RISE CURVE

TABLE 1 TEMPERATURE RISE AS A FUNCTION OF TIME

TIME, t	ELEVATION OF FURNACE TEMPERATURE, $T-T_0$
min	°C
5	556
10	659
15	718
30	821
60	925
90	986
120	1 029
180	1 090
240	1 133
360	1 193

junction is 100 mm from the nearest point of the test specimen. This distance shall be kept as constant as possible during the test.

3.1.2.4 Sheathed thermocouples may be used provided that they have a sensitivity not less than and time-constant not greater than those of bare wire thermocouples.

3.1.2.5 The wires of the thermocouples shall be placed in open tubes of heat-resistant material, for example, porcelain, within approximately 25 mm from the hot junction.

3.1.3 *Tolerances*

3.1.3.1 *For mean deviation of furnace temperature rise* — The mean deviation of the furnace temperature rise is given as a percentage by the following expression:

$$\frac{A - B}{B} \times 100$$

where

A = integral value of the average furnace temperature as a function of time, and

B = integral value of $T - T_0$ from the equation defined in **3.1.1**.

The tolerances on the mean deviations shall satisfy the following conditions:

a) $\pm$15 percent during the first 10 minutes of test,

b) $\pm$10 percent during the first 30 minutes of test, and

c) $\pm$ 5 percent after the first 30 minutes of test.

3.1.3.2 *For temperature distribution within the furnace* — At any time after the first 10 minutes of test, the temperature, recorded by any thermocouple, shall not differ from the corresponding temperature of the standard time-temperature curve by more than $\pm$ 100°C. For specimens incorporating a significant amount of combustible material, the deviation of any one thermocouple shall not exceed 200°C.

3.1.4 *Measurement of Temperature of Test Specimens* — Surface temperatures of test specimens shall be measured by means of thermocouples with a wire diameter of not more than 0·7 mm.

3.1.4.1 Each thermocouple junction shall be attached to the centre of the face of a copper disk 12 mm in diameter and 0·2 mm thick, which is secured to the surface of the specimen at the required position.

3.1.4.2 The disks shall be covered with oven-dry square asbestos pads 30 × 30 mm and 2 mm thick. The asbestos material shall have a density of 100 kg/m³.

3.1.4.3 The disk and the pad may be fixed to the surface of the specimen by pins, tape or a suitable adhesive, depending on the nature of the material forming the side of the specimen.

3.1.4.4 For thermocouples for measuring the temperature in the interior of the test specimen, the wires shall, if possible, follow the isotherm through the hot junction as closely as possible along a distance of at least 30 mm from this junction.

3.2 Pressure Conditions — An over-pressure of 10 ± 5 Pa (1·0 ± 0·5 mmH_2O or 0·04 ± 0·02 in H_2O) shall exist in the furnace during the whole heating period of fire-resistance tests on separating elements of building construction. For vertical separating elements, this over-pressure shall exist over at least the bottom two-thirds of the height of the test specimen. When doors, windows or ventilators (of fire check types) are present, it shall be ensured that these are wholly situated in the over-pressure region. This over-pressure shall be measured and monitored as follows:

a) For horizontal elements — 100 mm from the underneath surface of the specimen, and

b) For vertical elements — at a point located approximately at three-quarters of the height of the element under test.

NOTE 1 — The pressure difference may also be achieved by lowering the pressure on the unexposed face.

NOTE 2 — The condition of over-pressure is not mandatory for the first 10 minutes of the test.

NOTE 3 — 1 Pa = 1 N/m².

4. TEST SPECIMENS

4.1 Dimensions

4.1.1 The test specimens shall be full size.

4.1.2 Where this is not possible, the following shall be the minimum dimensions of the parts of a test specimen exposed in the furnace:

a) Walls and partitions	Height 3 m Width 3 m
b) Floors and roofs: Supported on two sides	Span 4 m Width 2 m
c) Floors and roofs: Supported on four sides	Span 4 m Width 3 m
d) Beams	Span 4 m
e) Columns	Height 3 m

4.2 Construction

4.2.1 The test shall be made on a test specimen representative of the complete element of construction on which information is required. Each type of element requires a different approach and an attempt shall be made to reproduce the boundary conditions and the method of fixing or support representative of that used in practice.

4.2.1.1 A test specimen shall include at least one of each representative type of joint. A specimen wall may include a beam or columns which form an integral part of the element to establish the performance of the composite assembly. A specimen may also include a door or glazing to establish the performance of the whole assembly.

4.2.1.2 When a ceiling treatment or a suspended ceiling is designed to contribute to the fire-resistance of a floor or a flat roof, the specimen shall incorporate the ceiling installed as in service.

4.2.1.3 When a specimen represents a column forming the side of an opening in a wall, it shall be suitably shielded on the unexposed face or faces to represent the protection provided by the wall.

4.2.2 The materials and standard of workmanship of the test specimen shall be representative of those applying in good practice, as defined by existing Indian Standards.

4.3 Conditioning — The test specimen shall be conditioned in such a way that it corresponds as closely as possible in temperature, moisture content and mechanical strength, to the expected state of a similar element in service.

4.3.1 *Moisture Content* — The test specimen shall not be tested until its moisture content is in dynamic equilibrium with an ambient atmosphere approximating to that expected in service. This dynamic equilibrium may be checked either on the test specimen itself or on a representative sample.

4.3.1.1 The drying of the test specimen may be by natural or artificial means but a temperature shall not be reached which could impair the fire-resisting properties of the element. It is recommended that a temperature of 60°C should not be exceeded.

4.3.1.2 When possible the moisture content of the principal material of the element shall be measured at the time of the test and the values shall be stated in the test report.

4.3.2 *Mechanical Strength* — For load-bearing elements, the constituent materials of the specimen shall have attained a mechanical strength close to that expected for a similar element in service.

5. TEST PROCEDURE

5.1 Test Conditions

5.1.1 *Restraint and Loading*

5.1.1.1 The role of the element in service shall be analyzed so that the methods adopted for supporting or restraining the ends or sides of a test specimen during a test are, as far as possible, similar in nature to those which would be applied to a similar element in service. If restraint is applied in the test, then the restraint conditions shall be specified with regard to free movements of the element and so far as possible, those external forces and moments which are transmitted to the element by restraint during the test.

5.1.1.2 For floors and beams with uncertain or variable boundary service conditions, the test specimen shall be simply supported all round the edges or at the ends. For columns and walls with complete or partial restraint to longitudinal elongation, for a full evaluation of the structural behaviour, it may be necessary to conduct a complementary test under longitudinal restraint conditions which are as close as possible to conditions in practice.

5.1.1.3 At least 30 minutes before heating, the load-bearing test specimen shall be subjected to a loading which, in the critical regions of the element, produces stresses of the same magnitude as would be produced normally in the full-size element when subjected to the design load (*see* **2.2** for load equipment). When it seems appropriate, a preloading shall be applied to the test element to guarantee a stabilization of the deformation and of the support and load equipment. The load application may be repeated a number of times for this stabilization.

5.1.1.4 The level and distribution of the applied loading shall be maintained constant during the test period.

5.1.1.5 Test specimens of non-load-bearing elements shall not be subjected to any external loading in the fire-resistance test.

NOTE — Where a specimen is cast in a frame it shall not be taken as providing restraint.

5.1.2 *Exposure to Heat*

5.1.2.1 Free-standing columns shall be tested by applying heat on all sides over their whole height. Beams shall be tested by applying heat to three sides of the beam.

5.1.2.2 Separating elements represented by test specimens of elements which have the function of separating spaces shall be heated

over the whole or one face only. Those which may be required to resist fire in one direction only shall be tested in that direction. Those which may be required to resist fire in either direction shall be tested in the direction considered to possess the lower resistance by the testing authority. When this cannot be prejudged, each face shall be tested on separate test specimens.

5.2 Observations During Test — The fire resistance of a load-bearing structure or structural element shall be judged by the criterion of load-bearing capacity, that of a separating element by the criteria of insulation and integrity, and that of a load-bearing and separating element by the criteria of load-bearing capacity, insulation and integrity whichever occurs or manifest itself first. In most cases, only a small loss of integrity (initial integrity failure) can be accepted, in other cases, a larger loss of integrity (ultimate integrity failure) can be accepted. In all cases of separating structural elements, the initial integrity failure shall be determined.

5.2.1 *Load-Bearing Capacity and Deformation*

5.2.1.1 For a load-bearing test specimen, the time at which the specimen can no longer support the test load shall be measured and used to assess the performance.

5.2.1.2 Where possible, the following properties and characteristics shall also be noted during the whole test period:

a) Deformations which can facilitate an analysis of the structural behaviour of the element and an application of the test results;

b) Free movements of the element;

c) Forces and moments transmitted to the element by restraint, according to **5.1.1.1**; and

d) Other phenomena which are of importance for the load-bearing capacity of the element, such as cracking, splitting and structural transformations of materials.

When needed for an application of the test results, the temperature distribution in the interior of the test specimen shall be determined by means of thermocouples placed in such a manner that they provide a satisfactory basis for estimating the function and the behaviour of the specimen during the test.

5.2.1.3 For a separating element, such deformations as may have substantial effects on the function of the element shall be measured and noted during the whole test period. Note shall be made of the time when the test specimen no longer fulfils its functional requirements.

5.2.2 *Insulation*

5.2.2.1 *Average temperature of unexposed face* — In the case of elements with an unheated surface, the temperature of the unexposed face shall be measured by means of not fewer than five thermocouples, one placed approximately at the centre of the face and the others approximately at the centres of the straight lines joining the centre and corners. Any additional thermocouples shall be disposed as uniformly as possible over the unexposed face of the specimen. None of these thermocouples intended for measurement of mean temperature rise shall be fixed in position with through-metal connections or closer than 100 mm to edge of the test specimen. In the case of structures comprising composits elements, the arrangement of the test specimen shall ensure that the joints do not coincide with the points of measurement specified above. The average of the temperatures measured at the points specified above, omitting temperatures measured at joints, is deemed to be the temperature of the unexposed face.

5.2.2.2 *Maximum temperature of unexposed face* — In addition, the temperature shall be measured at the point that appears to be the hottest at any time during the test. This temperature shall not be used in the calculation of average temperature, unless the point at which this temperature occurs corresponds to one of the locations specified in **5.2.2.1**, but shall be taken into account in determining whether the maximum temperature criterion has been complied with.

5.2.3 *Integrity*

5.2.3.1 For the determination of the time of initial integrity failure, pressure differences according to **3.2** shall exist between the exposed and unexposed sides of the test element. Observations shall be made of any sustained flaming on the unexposed face and of the ignition of a cotton pad held for not less than 10 seconds and not more than 30 seconds at a distance of between 20 and 30 mm from any opening on the unexposed side, indicating the ignition by hot gases. The pad shall not be re-used if it has absorbed any moisture or become charred during a previous application.

The cotton pad, measuring approximately 100 mm square × 20 mm thick, shall consist of new undyed soft cotton fibres, without any admixture of artificial fibres, and shall have a mass between 3 and 4 g. The pad shall be conditioned by drying in an oven at 100°C for at least 0·5 hour. The pad shall be attached by wire clips to a 100 × 100 mm frame of 1 mm diameter wire to which a wire handle approximately 750 mm long is fixed. Note shall be made of the time when the first ignition of the cotton pad occurs and the position where this takes place.

5.2.3.2 To obtain the time of ultimate integrity failure, the test shall be continued beyond the initial integrity failure and further observations and measurements made of enlargement of cracks, holes or other openings through which flames or gases could pass. The full or partial collapse of non-load-bearing separating elements shall be noted as this will constitute ultimate integrity failure (*see* **6.2.3.2**).

5.2.4 *Additional Observations* — Throughout the test, observations shall be made of all changes and occurrences which are not criteria of performance but which could create hazards in a building, including, for emission of smoke or noxious vapours from the unexposed face of a separating element.

5.3 Duration of Test

5.3.1 Normally, the test specimen shall be heated in the prescribed manner until failure occurs under any one of the relevant test requirements, namely:

load-bearing capacity (*see* **5.2.1**),

insulation (*see* **5.2.2**), and

integrity (*see* **5.2.3**).

5.3.2 In tests other than those on test specimens judged only by the criterion of load-bearing capacity (*see* **5.2.1**) the testing may be continued after failure under either of the other two conditions (*see* **5.2.2** and **5.2.3**) by prior agreement between the sponsor of the test and the testing authority, until failure occurs under the other conditions, provided that collapse of the specimen has not already occurred.

5.3.3 Alternatively, the test may be concluded after a period determined by prior agreement between the sponsor and the testing authority, even if no failure under any of the conditions has occurred at the end of that time.

5.3.4 The length of time from the commencement of heating for which the test specimen complies with the relevant requirement(s) shall be expressed in minutes.

6. PERFORMANCE CRITERIA

6.1 Fire Resistance — The fire resistance of test specimens shall be the time, expressed in minutes, of the duration of the heating in accordance with **3.1.1** until failure occurs, under the conditions — load-bearing capacity, insulation, integrity — appropriate to the specimen.

6.2 Criteria for Fire Resistance — The functional criteria of fire resistance comprise requirements with regard to load-bearing capacity for a load-bearing structural element, insulation and integrity for a separating element, and load-bearing capacity as well as insulation and integrity for a load-bearing and separating element.

6.2.1 *Load-Bearing Capacity* — For load-bearing elements of structure, the test specimen shall not collapse in such a way that it is no longer performs the load-bearing function for which it was constructed.

6.2.2 *Insulation* — For elements of structure such as walls and floors which have the function of separating two parts of a building:

a) the average temperature of the unexposed face of the specimen shall not increase above the initial temperature by more than 140°C.

b) the maximum temperature at any point of this face: shall not exceed the initial temperature by more than 180°C, and shall not exceed 220°C irrespective of the initial temperature.

6.2.3 *Integrity*

6.2.3.1 For elements of structure such as walls and floors which have the function of separating two parts of a building, the presence and formation in the test specimen of cracks, holes or other openings through which flames or hot gases can pass so as to cause initial integrity failure, shall not occur.

6.2.3.2 Initial integrity failure shall be deemed to have occurred when the cotton pad referred to in **5.2.3.1** is ignited or when sustained flaming, having a duration of at least 10 seconds, appears on the unexposed face of the test element.

6.2.3.3 Ultimate integrity failure shall be deemed to have occurred when collapse of the specimen takes place.

NOTE— The words 'insulation', 'integrity' or 'load-bearing capacity' shall follow the time, expressed in minutes, denoting the period of successful compliance under each of these headings.

7. TEST REPORT

7.1 The test report shall include the following information:

a) Name of the testing laboratory;

b) Name of the sponsor;

c) Date of the test,

d) Name of the manufacturer and the trade-name (if any) of the product;

e) Moisture content of the specimen;

f) Details of construction and conditioning of the test specimens, including detailed information on the relevant physical and mechanical properties of the materials used, together with drawings illustrating the essential features;

g) Methods of fixing, support and restraint as appropriate for the type of specimen;

h) For load-bearing specimens, the methods used for calculating the test load and its relationship to the maximum permissible load;

j) For asymmetrical separating elements, the direction in which the specimen was tested and the reason for adopting this procedure;

k) Observations made during the test according to **5.2**; and

m) Test results as required by **6.1**. Where the test is terminated before the occurrence of failure under the relevant criteria, this shall be reported.

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