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Fire-resistance tests -- Guidance on the application and extension of results

Essais de résistance au feu -- Recommandations pour l'application et l'extrapolation des résultats

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Fire resistance tests — Guidance on the application and extension of results

Essais de résistance au feu — Recommandations pour l'application et l'extrapolation des résultats

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Foreword

ISO (the International Organization for Standardization) is a worldwide 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.

The main task of technical committees is to prepare International Standards, but in exceptional circumstances a technical committee may propose the publication of a Technical Report of one of the following types:

— type 1, when the required support cannot be obtained for the publication of an International Standard, despite repeated efforts;

— type 2, when the subject is still under technical development or where for any other reason there is the future but not immediate possibility of an agreement on an International Standard;

— type 3, when a technical committee has collected data of a different kind from that which is normally published as an International Standard ("state of the art", for example).

Technical Reports of types 1 and 2 are subjected to review within three years of publication, to decide whether they can be transformed into International Standards. Technical Reports of type 3 do not necessarily have to be reviewed until the data they provide are considered to be no longer valid or useful.

ISO/TR 12470, which is a Technical Report of type 2, was prepared by Technical Committee ISO/TC 92, *Fire safety*, Subcommittee SC 2, *Fire resistance*.

The primary objective of this Technical Report is to produce a harmonized approach to the extension of results obtained from fire resistance tests performed according to the time-temperature curve as given in ISO 834-1. Such an approach is usable by writers of fire testing standards to assist with the preparation of harmonized "field of direct application" statements. In addition it is of assistance to fire safety engineers/consultants who either need to establish the extended field of application of a tested construction, to establish whether a similar untested element would be expected to satisfy the test criteria where the variations between the tested and untested constructions are significant, or produce the rules governing the application.

The guidance as to whether the application can be extended is given in three forms. In the simplest form a rule may be used which may be based upon sound scientific facts or even just custom and practice. For quantifiable aspects it identifies where fire engineering calculations may be used. Where judgement needs to be exercised, it identifies the factors that need to be considered. The guidance given also allows a designer or the enforcing authority to assess the fire resistance of an element when it is of a size that cannot be tested due to the physical limitations of testing furnaces. Whether this is a valid use of this guidance document will depend upon the philosophy of a particular country's regulations and the way they use fire resistance tests in their building codes. In a complex building where the behaviour can only be established from first principles, a greater understanding of the limitations applying to a test result is critical.

Structural elements such as beams, girders, columns and floors are generally designed by using calculation methods applicable at room temperature and each element is more or less different from one another. These structural elements also need calculation methods that assess their fire behaviour and it is important that these are correlated by tests.

Annex A forms an integral part of this Technical Report. Annexes B and C are for information only.

Introduction

Fire resistance tests on building components are necessary to establish their behaviour against pre-determined criteria when exposed to a representative fully developed fire and to provide information that may be used in determining the fire safety level of buildings. For several decades people have accepted by means of test results only, the possibility of grading the components. Now, due to the improvement of knowledge and the sophistication of buildings, it is necessary to be able to give a more accurate assessment of the components used in buildings.

Because of the cost of the tests and the size limitations of the testing furnaces, it is not possible for any given building element to be tested at all of its various sizes or designs. As a consequence we need rules or even better mathematical models for predicting, from test results, the behaviour of elements which are changed in size, design and/or application. The performance of these elements is adjudged as a separate consideration and only against standard heating conditions as defined in ISO 834-1.

Even with the knowledge available to assess the behaviour of a given constructional element, whatever its design or its size, we will still be a long way from establishing the real behaviour of a building in a real fire.

The philosophy of only grading elements into different fire resistance categories may not give any indication about how the element behaves when heated. By studying and assessing the data from fire resistance tests, it will be possible, using the guidance within this Technical Report, to obtain a basic understanding of the influence of the main parameters on the element performance during a fire resistance test.

In practice, tests can give much useful information which can be used for interpolation and extrapolation of the results.

In the following, all of these assessments will be based on the one hand on the standard time/temperature conditions and, on the other hand, on isolated elements with no interaction with the adjacent elements.

Also ageing and weathering are not covered here.

This Technical Report is divided in two parts:

— guidance on direct use and extended application of test results for various elements used in buildings; the parameters which would be assessed by rules, calculation or only expert judgements are discussed.

— future evolution:

  • improvement of testing methodologies to give a better prediction of the performance of various sizes and designs of a given element,

- mathematical modelling which can be used by experts to give their judgement,
- expert systems which could take into account the interaction of various factors in an assessment.

In addition annexes A and B give an overview of current practices in various countries as far as application and extension of fire resistance test results are concerned. It is mentioned where agreement could be found and where more efforts have to be made for harmonization.

Annex C gives additional reading.

Fire resistance tests — Guidance on the application and extension of results

1 Scope

Direct and extended applications of test results are the two possible ways to ensure that a modified element will have a good possibility of obtaining the same fire rating as that of the original tested specimen. In both cases these applications refer only to the fire rating that the building element can expect to reach if it were to be tested in a furnace according to the standard fire used for the reference test.

For each type of element of construction, the application of test results will be considered under two sub-headings.

a) Direct application: this section identifies the modifications that can be made to the design of the tested element without reducing its fire rating. These possible modifications are based on obvious knowledge and do not need further evaluation. In every case it is, at least, assumed that the basic materials used for the tested sample will not be changed. The results obtained from tests performed using standard configurations are valid for the field of application derived from that configuration, regardless of any specific advice given in the following chapters.

b) Extended application: this will require in every case an assessment by a fire expert either in developing rules of application or evaluating the results of fire engineering calculations or making a judgement. In every case it will be taken into consideration that extended application may take into account the difference between the result of the original test and the fire resistance required for the untested element.

A judgement is the result of a qualitative process, normally carried out by experts. Judgements are used to justify a change of design or method of construction which may use, for example, empirical data derived from tests, established physical properties, hot and cold state calculations, a knowledge of fire exposure, fire behaviour and response of the construction, either in isolation or in combination.

1) Rules of application: these would be applied universally even by persons without expertise in fire as part of the "field of application" of the test result for a given family of products. These rules may require cold state calculation. The quantification of these rules would be agreed universally based upon validated experience related to generic constructions or components. This could cover size changes, number of joints, size of glazing etc.

   Throughout this Technical Report the clauses covering rules frequently express the acceptable change in terms of un-quantified percentages indicated by the letter "X" and an appropriate suffix.

   This allows national code authorities to insert their own acceptable limits which will relate to their established fire safety philosophy.

   Authorities are encouraged to support the necessary research towards internationally harmonized validated value.

2) Fire engineering calculations: these would be used by an expert in giving advice but will mainly be restricted to the properties indicated below:

- non-loaded elements: this would be restricted to the calculation of temperature rise and deflection of "simple" components and elements;
- loaded element: in addition to the properties permitted for non-loaded elements, calculation at elevated temperature could be permitted for the load-bearing capacity for well-documented materials (steel, concrete, etc.) and for statically determined elements.

In every case the calculation models used by the experts, whatever their source (purchased from software manufacturers or developed in the institution) have to be fully validated by comparison with existing test results and by sensitivity analysis of the various parameters.

3) judgements: for a test result to be extrapolated to cover changes outside those for which calculations or written rules are applicable, the result may still apply subject to some expert judgement being made. The section on judgements highlights the matters that need to be considered and to be explained by the body or person responsible for making such judgements. Generally, components of a construction element could be changed, provided it can be shown that this does not reduce the fire resistance. It must be demonstrated that the interaction of a new component with other components will not affect adversely the performance of the tested construction. When resistance time is higher than required time, it will generally be possible to have a greater change than with only the necessary safety level.

Changes in materials and methods of construction can have significant influences on the fire resistance. Because the advice and recommendations are common to all elements, those aspects are dealt with separately under 2.1.1 "manufacture and materials" to avoid repetition. The user of this Technical Report should consider these aspects in all applications of results whether direct or extended.

2 Common factors

The advice in this clause applies to all subsequent groups of elements.

2.1 Manufacture and materials

2.1.1 General

For certain applications, even small changes in either the materials or the methods of manufacturing may result in large changes in fire resistance (for example glazing, intumescent coatings, primers). The results from a fire resistance test may be used to support an evaluation of the performance of a similar untested element or they may be used to justify an element in use without any further calculations, or the application of rules, if the manufacture of the element complies with the guidance given in 2.1.2. Where the construction is not covered by the direct application then the calculations or application rules need to be applied as indicated.

Additionally there are quality control and certification schemes in some countries. Control procedures ensure that the untested construction is equivalent to the tested construction. Any relaxation of these procedures may only be undertaken if it can be established that they only influence non-critical aspects of the construction (e.g. colour, texture, etc.) Evidence of the effect must be available if the control of the 'critical' processes or materials is involved. Reduced scale fire resistance tests may be used for this purpose subject to the changes not affecting distortion.

The information given for direct and extended applications has to be used for every construction element.

2.1.2 Direct application

a) The quality control procedures are not reduced.

b) The manufacturing/construction procedures remain unchanged.

c) Constituent materials, admixtures, preservatives, flame retardants, adhesives, etc. remain unchanged.

2.1.3 Extended application

2.1.3.1 Rules

As a general rule the quantity of any constituent material may be varied by up to a certain percentage (to be defined for each family of material) from that used in the original specification that was tested without the need for further consideration.

2.1.3.2 Fire engineering calculations

Where, for certain materials, calculation methods have evolved and been documented it may be possible to calculate the influence that changes in material and manufacturing may have on the fire resistance.

2.1.3.3 Judgements

a) Materials

It may be possible to change constituent materials, or add constituents such as preservatives or flame retardants without significantly affecting the fire resistance. Evidence of the effect that this may have should be available or its effect should be able to be calculated to demonstrate that these changes will not reduce the fire resistance. Reduced scale fire resistance tests may be suitable for this purpose. If the additional constituents may be expected to influence distortion patterns, then a full scale test may be required.

b) Manufacturing procedures

The effect of any change in the manufacturing procedure shall be established to show that it does not reduce the fire resistance of the element before such changes are accepted.

2.2 Moisture content

Since it is difficult to measure the moisture content of many elements prior to the test, it is better to try to reach an equilibrium before testing. However when for various reasons this is not possible and if information is available on the assumed moisture content, the following correction can be used.

If the fire resistance with respect to insulation criterion of a specimen is known at one moisture content, then the insulation rating at some other moisture content can be corrected according to the following equation[1]:

$$T_d^2 + T_d \left(4 + \frac{1}{15} b\phi - T_\phi\right) - 4T_\phi = 0$$

where

ϕ is the volumetric moisture content,

T_ϕ is the fire resistance, in minutes, of the element at a moisture content of ϕ,

T_d is the fire resistance, in minutes, of the element in oven-dry condition,

b is a factor, in minutes, which varies with the permeability.

This formula can be used for correcting the insulation criteria relating to a homogeneous structural element such as concrete slabs, brick walls, with some limits of application. It is not applicable to timber and gypsum products.

1) T.Z. HARMATHY, "*Fire Safety Design and Concrete*". Longman Scientific & Technical, 1993.

2.3 Increasing size

A non-loadbearing separating element having obtained a given fire rating could be used for a lower fire rating application at a bigger size than that allowed in an application requiring the obtained fire rating. The reason for this is that to achieve a better performance than that required it is necessary to produce a more stable element to ensure reduced distortion and/or deformation and hence less erosion of any constitutive materials.

3 Loadbearing elements

In practice few structural elements are covered by direct application because there is always a difference in size or strength of material used.

For protected load bearing elements, please refer also to 5.2.

For simple elements, it is normal to use design codes which take fire into account.

3.1 Beams

3.1.1 General

The results from a fire resistance test may be used to support an evaluation of the performance of another beam without any further calculations or the application of rules or judgements if the construction complies with the guidance given in 3.1.2. Where the construction does not comply with the direct application, then the calculations or application rules or judgements need to be applied as indicated.

The relevant performance criterion is the loadbearing resistance (loadbearing capacity: determined by maximum deflection and maximum rate of deflection).

3.1.2 Direct application

The results of a fire resistance test are deemed to be applicable to a similar untested beam provided that all the following are true.

a) The span is not increased.

b) The load is not increased and the location and distribution of the load are unchanged.

c) The rotational and longitudinal restraint are unchanged.

d) The dimensions of the cross-section are not reduced.

e) Characteristic strength and density of any basic materials are unchanged.

f) The number of heated surfaces is unchanged.

g) The length of the unheated part of the construction is not reduced.

h) There is no change in the design of the cross-section (e. g. reinforcing bars within the cross-section).

i) Lining or decorative materials not influencing the fire resistance may be changed or added.

3.1.3 Extended application

3.1.3.1 Rules

Rules can be given for the following.

a) Dimensions and loading (length of span, level and type of load)

The length and load (level and distribution) may be changed as long as it can be calculated that the stresses (bending and shearing) within the section are not increased, and providing that failure mode at room temperature does not change (the span could be increased if the load is reduced and vice versa).

b) Reinforcement for reinforced concrete beams (not relevant for prestressed concrete beams)

A change in the location of reinforcement is possible as long as its temperature is not increased, the total cross-section is not reduced, and the distance between the reinforcement and the centroid of the compressive zone is not reduced.

c) Number of heated surfaces

The number of heated surfaces may be reduced for beams made of materials where this is not detrimental to the performance.

d) Services

Holes for services may be incorporated if they are perpendicular to the span and in the zone of the neutral axis, provided that they are protected at their borders in the same way as the beam itself.

e) Lining materials

Lining or decorative materials not influencing the fire resistance may be changed or added.

3.1.3.2 Fire engineering calculations

Calculations may be used for the following.

a) Temperature profile

Heat transfer through beams may be calculated by using an accepted temperature analysis model. Input data must be based on values for specific heat capacity and thermal conductivity as a function of temperature for all materials included in the element. For composite elements it is necessary to estimate, using relevant test results, the time of exposure at which destruction or detachment of parts of the element (i.e. boards, insulation etc.) will occur.

b) Load bearing resistance (load bearing capacity)

The load bearing resistance may be calculated for beams where the physical properties are known as a function of temperature and where the temperature profile over the cross-section of the beam is known. For timber the charring rate and hence the reduction in cross-section also need to be known.

c) Deflection

The deflection may be calculated for beams where the relationships between stress and strain (including, if necessary, creep effect) as a function of temperature are known, in addition to the above properties. It should be noted that the calculated deflections need to take into account deflections due to both the thermal and load induced strains.

3.1.3.3 Judgements

Changes may be made to the following aspects of the beams provided that expert judgement is based on the appropriate considerations mentioned below.

a) Supporting conditions

The supporting conditions may be changed, provided that this will not increase the load effect, reduce the rotational restraint, or increase the longitudinal restraint or the thermal conditions.