TECHNICAL REPORT

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Fire-resistance tests — Guidance on the application and extension of results from tests conducted on fire containment assemblies and products —

Part 1: Loadbearing elements and vertical and horizontal separating elements

Essais de résistance au feu — Recommandations pour l'application et l'extrapolation des résultats d'essais réalisés sur les produits et assemblages d'endiguement du feu —

Partie 1: Éléments porteurs et éléments horizontaux et verticaux de séparation

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation on the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see the following URL: www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 92, *Fire safety*, Subcommittee SC 2, *Fire containment*.

A list of all parts in the ISO 12470 series can be found on the ISO website.

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 of buildings. For several decades, people have accepted, by means of test results only, the possibility of grading the components. Now, due to the enhancement of our knowledge and the complexity of buildings, it is necessary to be able to give a more accurate assessment of the components used in buildings, particularly with the growth of the use of functional approaches to designing fire safe structures.

The need to understand how the element will perform at a different size, with different levels of restraint, etc. is vital when applying the results of the fire tests in a life safety situation, especially those where the fire safe solution has been generated using fire safety engineering techniques rather than using a code compliant solution. This does not negate the need to predict any changes that may result from changes to the test construction when complying with building code solutions, but these codes may themselves provide solutions that take into account the influence or impact of changes, and indeed the guidance given in this document may be used by the code writers to produce such guidance.

Even with the knowledge available to assess the behaviour of a given constructional element, whatever its design or its size, we will still be some distance away from establishing the complete 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 actually behaves when heated. By studying and analysing the data from fire resistance tests, it will be possible, using the guidance within this document, to obtain a basic understanding of the influence of the main parameters on the element performance during fire resistance tests.

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

The original version of ISO/TR 12470 was published by ISO/TC 92/SC 2 in 1998. This Technical Report provided a methodology identifying how the results of fire resistance tests carried out in the standard furnaces could be modified to apply to the elements as they may be used in practice. In some cases, the results of the test may need to be reduced to reflect any increases in the degree of difficulty that the final application represents or alternatively, modifications/enhancements may need to be made to the construction in order to maintain the performance level(s).

In the intervening years since the original Technical Report was prepared, a greater understanding has developed as to what the changes are likely to be and how they may be quantified. Some of the work in Comité Européen de Normalisation (CEN) has aided this process and in particular, the principles given in Annex A remained unpublished by CEN but were developed in one of the technical Work Groups of CEN/TC 127. This revision represents the current state-of-art in respect of the objectives of the original 1998 version of ISO/TR 12470.

In this document, all assessments of extended application are based on standard time/temperature conditions and on isolated elements, with no interaction with the adjacent elements.

Also, ageing and weathering are not covered.

The ISO/TR 12470 series is published in two parts:

Part 1: Loadbearing elements and vertical and horizontal separating elements;

Part 2: Fire resistant door assemblies, glazing, services and service penetration.

This document is divided into two sections:

- Guidance on direct and extended application of test results for various elements used in buildings, the major parameters of which would be assessed by calculation or expert judgements based upon the methodology and discipline given in Annex A.
- Current state-of-art and possible 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.

Fire-resistance tests — Guidance on the application and extension of results from tests conducted on fire containment assemblies and products —

Part 1: Loadbearing elements and vertical and horizontal separating elements

1 Scope

This document explains a methodology to determine the applicability of the results of fire resistance tests to actual applications.

It is applicable to those loadbearing and simple vertical and horizontal separating elements for which there is an ISO standard test procedure based upon the ISO 834 series for determining the fire resistance of a representative sample of the construction proposed for use in a specific building or just for general use. These elements are:

- loadbearing elements;
- non-loadbearing elements:
  - partitions:
    - stud construction partitions;
    - composite panel/SIPS partitions;
  - ceiling membranes (horizontal partitions):
    - jointed ceilings;
    - composite panel ceilings.

Direct and extended applications of test results are the two possible ways to ensure that a modified element has an acceptable probability of obtaining the same fire rating as that of the original tested specimen. In both cases, these applications generally refer only to the fire rating that the building element can expect to reach if it, or a representative sample of it, were to be tested in a furnace according to the standard fire test conditions used in the reference test.

One of the most common variations is in respect of the size of the element in use. Fire resistance testing furnaces have size restrictions and as a consequence, there is little confidence that the result obtained on an element of construction tested in accordance with the standard methods will behave in a similar manner when installed in the final building.

This document does not provide guidance on the application and extension of results arising from testing carried out on door and window assemblies, linear gaps or service penetration seals, which is covered in ISO/TR 12470-2.

For some, but not all of the critical parameters, a summary of the possible influences is incorporated in the given examples.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 834 (all parts), *Fire resistance tests — Elements of building construction*

ISO 13943, *Fire safety — Vocabulary*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 834 (all parts) and ISO 13943 apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— IEC Electropedia: available at http://www.electropedia.org/

— ISO Online browsing platform: available at http://www.iso.org/obp

3.1
direct application
application that identifies the modifications that can be made to the design of the tested element without reducing its fire rating

Note 1 to entry: 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 material(s) used for the construction of the tested sample will not be changed.

Note 2 to entry: Direct application defines the variation(s) in the construction and the limits of use for the element which, without further analysis, are covered by the result of a test in accordance with the ISO 834 series. Direct application is arrived at by the application of simple *rules* (3.4) that are known, or considered by the fire community, to give equal or improved fire resistance performance by the users. The rules can be applied by non-fire experts.

Note 3 to entry: Only results from one test report can be used when considering a change of an element. Any combination and use of two or more tests reports or other technical sources should be regarded as *extended application* (3.2) and hence dealt with accordingly.

3.2
extended application
application that generally requires an assessment by a fire expert either in developing *rules* (3.4) of application for more general application by others, or evaluating the results of fire engineering calculations, or for making a judgement in specific cases

Note 1 to entry: In every case, it should 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.

Note 2 to entry: Extended application defines and specifies the variations in the construction and establishes the limits of use for an element that has been tested according to the appropriate ISO standard, based upon an analysis by fire experts. The extended application can use the results from one or more test reports and can be based upon rules, calculations and *expert judgement* (3.6). As a result of the extended application, the fire resistance classification of an element with respect to defined performance characteristics may be maintained, increased or decreased when used in practice.

3.3
project specific application
application that uses a mixture of established validated calculations/computer models (if they exist and are appropriate) together with judgements made by suitably qualified persons (normally a professional badged engineer or a corporate member of a learned professional body)

Note 1 to entry: Because the application will, in these circumstances, require an understanding of both the structural response and the fire dynamics of the building in question, it is inevitable that the solution will involve an element of fire safety engineering.

3.4
rule
quantitative *factor* (3.9) that can be applied to the result of tests when defining the limits of application for which justification exists as a result of research and testing

Note 1 to entry: Rules are primarily used in determining the *direct application* (3.1) of the result as its application does not generally require specialist knowledge.

Note 2 to entry: It is anticipated that these rules be established by the specialist (or ad hoc) groups preparing the specific standards based upon public domain knowledge and developed by industry consortia or trade associations for specific elements for which the members have appropriate interest and knowledge, particularly in Europe initially. After some experience, the results of calculations and judgements may become rules.

3.5
calculation in support of extended application
calculation method that can be applied to one or more parameters of a tested construction and which are based on existing physical laws or which have been empirically validated and which form part of the process of defining the *extended application* (3.2)

Note 1 to entry: If this term has a definition elsewhere, then it should be used but possibly modified to include this specific use.

3.6
expert judgement
qualitative process performed by fire experts when the complexity of the influence is beyond the scope of *rules* (3.4), to establish the resultant effect of a variation in one or more parameters, on the classification awarded

3.7
construction parameter
aspect of the design and construction of an element that may be varied and which may result in a change in the fire resistance performance, e.g. a change in one or more of the dimensions of a stud in a stud framed separating element

3.8
thermal and mechanical parameter
aspect of the conditions of a test that may vary in practice and influence the classification system given, e.g. the pressure differential that will exist at the top of a larger element than existed at the top of the specimen when tested

3.9
factor
one of the possible variations that may be applied to a parameter, e.g. a change in the stiffness as a result of a dimensional change in the member or a component within the element

3.10
factor influence
one of the potential causes of a change in the fire resistance recorded by test, with respect to one or more of the criteria, when a *factor* (3.9) is changed, e.g. an increase in the loadbearing capacity R as a result of an increase in stiffness

4 Principles of the field of application

The field of application from the result of a fire resistance test has at least three possible components: (1) direct application, (2) extended application and (3) project specific application.

The process of determining the direct application and extended application of the fire resistance rating of a tested construction normally assumes that the performance is evaluated against the temperature/time and differential pressure conditions given in the appropriate ISO fire resistance testing standard (based upon the ISO 834 series or the national, regional equivalent), as this is generally what is referenced in national prescriptive legislation. The variations between the tested specimen and the "as-built" construction will therefore be restricted to:

— variations in the size of the construction;

— variations in the materials and methods of construction;

— variations in the restraint and fixity;

— variations in the load carried (if any).

In this situation, only the constructional parameters given in A.2.2 need to be taken into account.

In practice, there will be a need to predict the performance of a structure when it is exposed to different fire exposure conditions, in terms of the temperatures reached after certain durations and with greater or lesser pressure differentials. Generally, the parameters will be analysed by means of a fire engineering analysis which is outside of the scope of this document, but the parameters listed in A.2.1 may be appropriate for use in an expert judgement analysis of these characteristics.

For each type of element of construction, the application of test results will be considered under three conditions: (1) direct application, (2) extended application and (3) project specific fields of application.

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 5.1 to avoid repetition. The user of this document should consider these aspects in all applications of results whether direct applications, extended applications, or project specific applications.

4.1 Direct application

The direct application will normally involve the application of "rules" that are given as part of the test standard or in a document directly associated with the test standard. It requires no knowledge of the process of determining the fire resistance other than an understanding of the criteria and the general terminology.

Where there is more than one change in any proposed construction/installation, two "direct application" rules should not be applied automatically and the two should be compared as part of an extended application.

4.2 Extended application

Determining the extended application of the fire resistance is a more complex matter and will generally need to be undertaken by "experts" who understand the mode of failure and the factors that lead to such a failure. There are three common methods used by practitioners to establish the extended application of the fire resistance of elements of construction and these are:

— application of locally validated rules, especially within Europe;

— use of established validated calculations/computer models, where they exist;

— use of technical judgement by suitably qualified persons.

NOTE In Europe, as part of the application of products within the context of the Construction Products Regulations (CPR), the extended application is determined by means of Extended Application (EXAP) standards, for use in the process of classification of products to enable CE marking. These EXAP standards cannot be used in the context of generating a fire safe environment without further analysis.

4.2.1 Rules of extended application

These would be applied universally even by persons without expertise in fire as part of the direct field of application of the test result for a given family or 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 document, 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 regulatory 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 values.

4.2.2 Calculations and computer programs used in extended applications

These would be used by an expert in determining the field of application 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;

— loadbearing elements: in addition to the properties permitted for non-loaded elements, calculation at elevated temperature could be permitted for the loadbearing capacity for well documented materials (steel, concrete, etc.) and for statically determined elements.

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

4.2.3 Judgements in extended applications

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 should be demonstrated that the interaction of a new component with other components will not adversely affect the performance of the tested construction. If the fire resistance obtained in a fire test is greater than the fire resistance time aimed at in the assessment, there is an overrun in fire resistance performance. If this overrun, obtained in the fire resistance test, is substantial, then it can be used as a trade-off, i.e. if a significant overrun has been achieved, it will generally be possible to allow for a greater change in the construction than if the claimed fire resistance time has only just been met in the fire resistance test.

In order to bring greater consistency to the judgemental process, it is recommended that this process follows the methodology given in Annex A.

4.3 Project specific application

This document has described the manner by which variations in the construction of an element which has been designed to provide fire resistance can be accepted or rejected, which utilizes the main parameters of the materials and components incorporated in the proving test. However, it may be possible in certain applications to provide more generous extensions to the field of application because it has been possible to utilize certain factors relating to the "in-use" application, e.g. significantly enhanced restraint or an uneven distribution of the applied load. In such cases, the derived direct or extended field of application is only valid for the specific project from which these inputs have been derived. Because of the bespoke nature of the inputs, the field of extended application only applies to the use of the element in question within the application for which it was designed. As a consequence, the field of application is known as project specific.

5 Common factors which influence the field of application of all elements

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

5.1 Manufacture and materials

5.1.1 General

For certain applications, even small changes in either the materials or the methods of manufacturing may result in large changes in fire resistance, e.g. the depth of the edge cover on monolithic fire resisting glasses. The result from a fire resistance test may be used to support an evaluation of the performance of a similar untested element or it may be used to justify an element in use without any further calculations, or the application of rules, if the manufacture of the element follows the guidance given in 5.1.2. 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 should 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 applications and extended applications has to be used for every construction element.

5.1.2 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.

6 Loadbearing elements

Basic loadbearing elements made from materials for which there is a large quantity of historical data giving the fire resistance with respect to the loadbearing capacity of these materials/structural elements in question, e.g. metal (and in particular steel), wood, concrete and masonry, are almost never the subject of fire resistance testing. The performance of such materials/elements is established by means of design codes which provide calculation methods for both the hot and ambient load cases which have their extended application built into the methodology of the design code(s).

As a consequence, no specific guidance is given in this document related to the direct and extended application of these basic forms.

Fire resistance testing does take place on non-separating elements, however, on various "materials" which are applied to the surface of elements which do need to have their natural fire resistance enhanced, e.g. intumescent coatings, boards and sprayed protective materials and these do need to have an extended field of application produced in order to establish the limit(s) of their contribution. These materials are relatively complex and most of them have bespoke extended application methods which are designed to permit variations in thickness or material characteristics to be used and provide cost-effective improvements to the loadbearing capacity of the original elements.

These bespoke methods do not have the same general principles as are used for non-loadbearing elements, but in Clause 8, there is a description of these bespoke methods and some limited guidance on their application.

Loadbearing walls and floors are, however, often tested, albeit masonry and concrete elements are less likely to be tested than site-assembled or pre-manufactured and transported elements which are again generally designed against material codes and standards. When no such guidance exists, then the following guidance is appropriate.

6.1 Walls

6.1.1 General

The results from a fire resistance test may be used to support an evaluation of the performance of variations to the construction of the tested loadbearing walls without any further calculations, the application of more complex rules or the use of judgements, if the construction complies with the statements given in 4.1. Where the construction does not comply with the direct application, then the calculations or the judgements need to be applied as indicated in 4.2 or, if in Europe, the appropriate extended application rules are applied if the product is to be CE marked.

The relevant performance criteria are loadbearing capacity, integrity (measured by gap gauge, ignition of cotton pad, or sustained flaming) and insulation (increase in the average and maximum unexposed face temperature).

Loadbearing walls come in a variety of common forms:

— brickwork or blockwork;

— cast-concrete;

— studded construction (manufactured off or on site) – low loads;

— composite panels/structural insulated panels (SIPS) – very low loads.

The guidance in respect of these has to reflect their different methods of construction.

6.2 Direct application

The results of a fire resistance test are deemed to be applicable to a similar form of untested vertical partition provided that all the following are satisfied.

6.2.1 Common parameters of all forms of wall construction

a) The height is not increased.

b) The edge conditions are unchanged and for a wall tested with all edges restrained, no increase in width is permitted.

c) For a wall only fixed at the top and bottom and tested at least with one edge free, wider elements are allowed.

d) Openings in walls should be controlled such that their size and number in any equivalent area are not increased, the method of protecting the opening is unchanged and their position relevant to any critical component of the construction (if there are any) is not decreased.

6.2.1.1 Brickwork or blockwork walls

a) The thickness of the wall, including any cavity, if appropriate, should not be reduced.

b) The thickness of the individual bricks or blocks should not be reduced.

c) The number of mortar joints per m height should not be decreased.

d) The density of the individual bricks or blocks may not be reduced nor be increased by more than 25 %.

e) The strength of any mortar should not be reduced.

f) The number and strength of any ties in a twin leaf wall should not be reduced in strength and the number and the distribution of them should not be changed significantly.

g) The number of load application points should not be reduced.

6.2.1.2 Cast-in place or concrete slab walls

a) The density of the concrete should not be reduced or be increased by more than 25 %.

b) The nature and distribution of any reinforcing steel should not be less in quantity or strength.

c) The number of load application points should not be reduced.

6.2.1.3 Stud constructed partitions (metal and timber)

a) Thermal insulation between studs is not changed in type or reduced in thickness and density at any point.

b) The thickness of component materials (e.g. linings, boards, studs) is not reduced.

c) The slenderness ratio of the studs is not worse.

d) The stud spacing is not increased.

e) The size of any panel or board forming the lining should not be reduced, i.e. there should not be any more gaps/joints between boards.

f) On a board lined system, the distance between the fixings of the board edges is not increased.

g) The length of any fixing is not reduced.

h) The type and nature of any fixings are unchanged.

6.2.1.4 Composite panels/SIPS constructed partitions

a) The thickness (gauge) of any facing should not be reduced, nor should the facing material be changed.

b) The insulating core should not be changed in type/density but thickness may be increased.

c) The method of attaching the facings to the core remains unchanged.

d) The method of jointing panels to each other should be unchanged.

e) The number of load application points should not be reduced.

6.2.2 Extended application

6.2.2.1 Rules

Except in the context of classification in CEN (see EN 13501-2), it is not possible to extend the application of a test result on a wall by the application of pre-determined rules.

6.2.2.2 Fire engineering calculations

Calculations may be generated and applied for the following.

a) Temperature profile

Heat transfer through walls where the insulation and/or thickness of the wall has been changed may be calculated by using an accepted temperature analysis model that is appropriate to the form of construction, e.g. studded composite construction. Input data should 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 probably necessary to estimate, using relevant test results, the duration of exposure at which destruction or detachment of parts of the element (i.e. facings, insulation, etc.) will occur, as these will change the thermal exposure conditions.

b) Insulation performance

Compliance with the insulation criterion may be calculated using appropriate temperature profiles, as above.

c) Deflection due to thermal gradient and its impact on loadbearing capacity

Deflections may be calculated for walls where the physical properties and the relationships between stress and strain (including, if necessary, creep effect) are known as a function of temperature and where the temperature profile over the cross-section of the partition is known. This is a complex procedure for composite elements, both studded and SIPS.

6.2.2.3 Expert judgements

Changes may be made to the following construction parameters of the walls provided that expert judgement, based upon the methodology given in Annex A, is adopted.

6.2.2.3.1 General parameters relating to walls

a) Height

The height of the wall may be increased provided the behaviour of any lining or facing applied to any studded or composite panels can be demonstrated (by using the method given in Annex A) not to compromise the integrity.

b) Width

If the construction was tested with a free vertical edge to allow for deformation, it is possible to extend the width; this is covered by the direct application (see 4.1). If the partition was tested with four edges restrained, the width may be increased subject to the behaviour being evaluated in accordance with the method in Annex A.

c) Services

Services may be installed both in and passing through vertical walls of any of the construction forms, provided that the ability of the construction to satisfy the insulation and integrity criteria is not reduced.

d) Openings in walls

The size, shape and position of any opening in a loadbearing wall may be varied, subject to it being demonstrated that there is no adverse effect on the performance of the wall, e.g. the revised shape does not change the stiffness or the load distribution in the wall and the revised position does not cause different pressure differential conditions to exist which may influence integrity. The method of protecting the opening should satisfy the fire requirement at the revised size, shape or position (see the relevant subclauses of this document for guidance on the extended application for the appropriate components).

6.2.2.3.2 Parameters related to brickwork/blockwork walls

a) Thickness of blocks/bricks

The thickness of blocks and bricks used in the construction of a loadbearing wall may be reduced, assuming that the reduced thickness wall maintains its loadbearing capacity in the cold and hot states according to the appropriate design codes, subject to it being demonstrated by means of the methodology given in Annex A that

— the reduced thickness does not induce greater thermal movement that could generate an earlier integrity failure, and

— the increased temperature rise on the unexposed face does not exceed the criteria for insulation failure.

b) Density of blocks/bricks

The density of blocks or bricks used in the construction of a loadbearing wall may be changed, subject to the strength of the wall remaining adequate, subject to it being demonstrated by the methodology given in Annex A that the temperature rise on the unexposed face does not exceed the insulation criteria, or that any reduction in strength associated with the reduction in density does not produce a premature integrity failure.

6.2.2.3.3 Parameters related to cast concrete walls

a) Thickness of the case concrete wall slab

The thickness of the loadbearing wall slab may be reduced, assuming that the new thickness maintains its loadbearing capacity in the cold and hot states according to the appropriate design codes, subject to it being demonstrated by means of the methodology given in Annex A that the increased temperature rise on the unexposed face does not exceed the insulation criteria.

b) Nature of the aggregate

There is evidence that suggests the propensity for "spalling" is used in the construction. This is not a well-researched subject and expert judgement should be applied to any change in the aggregate, by desktop research, in order to prevent/reduce the risk of spalling. The methodology given in Annex A is unlikely to be of any value in this process due to a lack of data.

6.2.2.3.4 Parameters related to stud construction loadbearing walls

a) Thickness of framing members (e.g. studs) and linings

Reductions in thickness of vertical partitions should consider the influence on insulation performance and slenderness (which influences stability), and may affect the performance of linings and their impact on integrity.

b) Fixings between framing members and linings and framing members

Fixings may be changed in type and centres subject to the influence on the fire resistance being analysed according to Annex A.

c) Thermal and physical characteristics of lining materials

When fire protection materials are changed or increased in order to compensate for changes in the load case (dead load only) or cross-sectional area, it should be demonstrated (justified) that the connection between the protective material and the vertical partition will remain effective for a duration sufficient to achieve the fire resistance period.

d) Jointing materials and fixings

Joint materials and fixings systems may be changed, provided that it can be justified by the method given in Annex A that the changes do not adversely affect insulation or integrity.

6.2.2.3.5 Parameters relating to composite panels/SIPS

a) Thickness of the insulated core

The thickness of the insulated core may be changed (thinner/thicker) subject to the proposed change in thickness being demonstrated not to have a negative influence on the integrity or insulation criteria using the methodology given in Annex A.

b) Change in method of adhering the facings to the core

A change in the method of adhering the skins is only possible if there is direct evidence that in the case of glued facings, the parameters of the glue are sufficiently well known to carry out an analysis along the lines given in Annex A.

In the case of auto-adhered facings, it is not possible to approve any change in the method of foaming or the metal preparation which would influence the quality of the auto-adhesion without further testing.

6.3 Floors

6.3.1 General

The results from a fire resistance test may be used to support an evaluation of the performance of variations to the construction of the tested floors without any further calculations, the application of more complex rules or the use of judgements, if the construction complies with the principles given in direct application rules where they exist. Where the construction does not comply with the direct application, then the calculations or the judgements need to be applied as indicated in 4.2 or, if in Europe, the appropriate extended application rules are applied if the product is to be CE marked.

The relevant performance criteria are loadbearing capacity, integrity (measured by gap gauge, ignition of cotton pad, or sustained flaming) and insulation (increase in the average and maximum unexposed face temperature).

Floors come in three common forms:

— joisted construction (manufactured off or on site);

— reinforced concrete slabs generally supported by walls or by protected steel beams or concrete beams;

— edge supported, multiple composite panel assemblies (low loads only).

The guidance in respect of these has to reflect their different methods of construction. Many of these forms of construction are constructed solely by means of material design codes, as discussed in the general introduction to Clause 6. Where the design is approved based solely on test evidence which is interpolated or extrapolated as needed, then the following subclauses apply.

6.3.2 Direct application

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

6.3.2.1 Common parameters of all floor constructions

a) The span is not increased.

b) The edge conditions are unchanged and for a floor tested with all edges restrained, no increase in width or length is permitted.

c) For a floor fixed at the ends of the primary span and tested at least with one edge free, wider elements are allowed.

d) The size and number of any fire resisting openings are not increased.

e) The proximity of any opening should not be any closer to critical components of the construction.

f) The method of protecting any such opening (e.g. rooflight/window/service penetration) is not changed.

g) The position of any opening relative to key features of the construction, e.g. panel joints, is unchanged.

6.3.2.2 Joisted floors — Medium

a) Any thermal insulation incorporated in the element is not increased or reduced at any point.

b) The thickness of component materials (e.g. linings/boards, floor decking) is not reduced.

c) The joist spacing is not increased.

d) On a lined, underdrawn boarded, joisted floor construction, the distance between the fixings retaining the boards is not increased.

e) The type, size, and nature of fixings are unchanged.

6.3.2.3 Edge supported, suspended multiple panel assemblies

a) The bearing provided for the edge(s) of each panel forming the membrane should not be reduced.

b) The suspension points for any supporting grid should not be at lesser centres than as tested.

c) The individual panels forming the membrane should not be greater in any linear dimension.

d) Any thermal insulation applied to the upper surface of the panels is not increased or decreased at any point.

e) Any fixings/clips used to restrain the panels against upward movement relative to the grid are not reduced/linear metre.

6.3.2.4 Composite panels/SIPS constructed floor/ceilings

a) The thickness (gauge) of any facing should not be reduced, nor should the material be changed.

b) The insulating core should not be changed in type/density but thickness may be increased.

c) The method of attaching the facings to the core is unchanged.

d) The method of jointing panels to each other should be unchanged.

6.3.2.5 Openings in floors

All openings in a fire-resistant floor of any construction need to be closed off or sealed by tested or assessed fire-resisting construction or seals.

a) The size and number of any fire resisting openings are not increased.

b) The position of any opening relative to key features of the construction, e.g. panel joints, is unchanged.

6.3.3 Extended application

6.3.3.1 Rules

Except in the context of classification in CEN (see EN 13501-2), it is not possible to extend the application of a test result by the application of pre-determined rules.

6.3.3.2 Fire engineering calculations

Calculations may be generated and applied for the following.

a) Temperature profile

Heat transfer through horizontal ceilings where the insulation and/or thickness of the ceiling construction has been changed may be calculated by using an accepted temperature analysis model that is appropriate to the form of construction, e.g. studded/composite construction. Input data should 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 probably necessary to estimate, using relevant test results, the duration of exposure at which destruction or detachment of parts of the element (i.e. facings, insulation, etc.) will occur, as these will significantly change the thermal exposure conditions.

b) Insulation performance

Compliance with the insulation criterion may be calculated using appropriate temperature profiles, as above.

c) Deflection due to thermal gradient

Deflections may be calculated for partitions where the physical properties and the relationships between stress and strain (including creep effect, if appropriate) are known as the function of temperature and where the temperature profile over the cross-section of the ceiling membrane is known. This is a complex procedure for composite elements, both joisted and SIPS. With non-loadbearing elements, these deflections do not form criteria in themselves, but the influence of the thermally generated movement/distortion should be considered when establishing compliance with the integrity criteria, i.e. due to the generation of gaps.

6.3.3.3 Expert judgements

Changes may be made to the following construction parameters of the horizontal ceiling membranes provided that expert judgement, based upon the methodology given in Annex A, is adopted.

6.3.3.3.1 General parameters relating to all forms of floor constructions

a) Span

The span of the floor may be increased provided the behaviour of any lining or facing applied to any joisted or composite panels can be demonstrated (by using the method given in Annex A) not to compromise the integrity or, if appropriate, the maximum temperature rise criteria, due to the production of hot spots.

b) Width

The width of any floor tested with a free edge is covered by the direct application (see 4.1.) but when the floor was tested with four edges restrained, the width may be increased subject to the fire behaviour being evaluated in accordance with the method in Annex A.

c) Services

Services may be installed both in and passing through floors of any construction, provided that the ability of the construction to satisfy the insulation and integrity criteria can be shown to be maintained by the use of the methods given in Annex A.

d) Openings in floor

The size, shape and position of any opening may be varied subject to it being demonstrated (by using the methods given in Annex A) that there is no adverse effect on the performance of the floor, e.g. the revised shape or area does not change the stiffness of the floor slab. The method of protecting any opening should satisfy the fire requirement at the revised size, shape or position; see the relevant subclauses of this document for guidance on the extended application for the appropriate components.

6.3.3.3.2 Parameters relating to joist constructed floors

a) Thickness/depth of framing members (e.g. joists) and of the protective linings

Reductions in the thickness/depth of floors as a result of changes in the dimensions of the framing members and/or linings should consider the influence on insulation performance using the methodology given in Annex A. Any changes in second moment of area (which influences stability) should be analysed to establish how this may affect the performance of linings and their associated influence on integrity.

b) Fixings between framing members and linings and framing members

Fixings may be changed in type and centres subject to the influence on the fire resistance being analysed according to Annex A.

c) Thermal and physical characteristics of applied lining materials

When fire protection materials are added or increased, possibly to compensate for changes in the load case (dead load only) or cross-sectional area, it should be demonstrated (justified) that the connection between the protection material and the ceiling membranes will remain effective for a duration sufficient to satisfy the required fire resistance period.

d) Jointing materials and fixings

Jointing materials and fixing systems may be changed, provided that it can be justified by the methods given in Annex A that the changes do not adversely affect insulation or integrity.

6.3.3.3.3 Parameters relating to floors constructed from structural insulated panels (SIPS)

Such floors are normally only carrying light loads made up of a restricted number of persons and/or light process equipment. Such floor panels are normally supported by walls at their edges, but are generally suspended, with the aid of “T” sections or “omega” elsewhere.

a) Thickness of the insulated core

The thickness of the insulated core may be changed (thinner/thicker) subject to the proposed change in thickness being demonstrated not to have a negative influence on the integrity or insulation criteria using the methodology given in Annex A. In the case of auto-adhered facings, it is not possible to approve any change in the method of foaming or the metal preparation which would influence the quality of the auto-adhesion without further testing.

b) Method of adhering the facings to the core

A change in the method of adhering the skins to the core is only possible if there is direct evidence that in the case of glued facings, the parameters of the glue are sufficiently well known to carry out an analysis along the lines given in Annex A.

c) Primary dimensions of composite/SIPS panels

The floor panels may be changed in their primary dimensions, or their aspect ratio be modified, as long as it can be demonstrated that any increase in dimensions does not result in increased deflections or shrinkage that could affect the integrity rating of the ceiling using the methodology given in Annex A.

d) Suspension system

The number of suspension points may be modified (reduced or increased) subject to it being proven using the methodology given in Annex A that any movement of the suspension system does not adversely affect the support that the system provides to the panels and hence its stability and its associated influence on integrity.

7 Non-loadbearing elements

7.1 Vertical partitions

7.1.1 General

The results from a fire resistance test may be used to support an evaluation of the performance of variations to the construction of the tested vertical partition without any further calculations, the application of more complex rules or the use of judgements, if the construction complies with the statements given in 7.1.2. Where the construction does not comply with the direct application, then the calculations or the judgements need to be applied as indicated in 7.1.3 or, in Europe, the appropriate extended application rules are applied if the product is to be CE marked.

The relevant performance criteria are integrity (measured by gap gauge, ignition of cotton pad, or sustained flaming) and insulation (increase in the average and maximum unexposed face temperature).

Vertical partitions come in two common forms:

— studded construction (manufactured off or on site);

— composite panels/structural insulated panels (SIPS).

The guidance in respect of these has to reflect their different methods of construction.

7.1.2 Direct application

The results of a fire resistance test are deemed to be applicable to a similar form of untested vertical partition provided that all the following are satisfied.

7.1.2.1 Common parameters of all partition forms of construction

a) The height is not increased.

b) The edge conditions are unchanged and for a partition tested with all edges restrained, no increase in width is permitted.

c) For a partition fixed at the top and bottom and tested at least with one edge free, wider elements are allowed.

7.1.2.2 Stud constructed partitions

a) The material of manufacture of the stud, e.g. steel *v* timber, should not be changed.

b) Thermal insulation is not changed in type or reduced in thickness and density at any point.

c) The thickness of component materials (e.g. linings, boards, studs) is not reduced.

d) The stud spacing is not increased.

e) The size of any panel or board forming the lining should not be reduced, i.e. there should not be any more gaps/joints between boards.

f) On a board lined system, the distance between the fixings of the boards is not increased.

g) The length of any fixing is not reduced.

h) The type and nature of any fixings are unchanged.

7.1.2.3 Composite panels/SIPS constructed partitions

a) The thickness (gauge) of any facing should not be reduced, nor should the material be changed.

b) The insulating core should not be changed in type/density but thickness may be increased.

c) The method of attaching the facings to the core is unchanged.

d) The method of jointing panels to each other should be unchanged.

7.1.2.4 Openings in partition

a) The size and number of any openings are not increased.

b) The method of protecting the opening (e.g. glazing, door, sealing systems) is not changed.

c) The position of any opening relative to key components of the construction (if there are any) is unchanged.

7.1.3 Extended application

7.1.3.1 Rules

Except in the context of classification in CEN (see EN 13501-2), it is not possible to extend the application of a test result on a partition by the application of pre-determined rules.

7.1.3.2 Fire engineering calculations

Calculations may be generated and applied for the following.

a) Temperature profile

Heat transfer through partitions where the insulation and/or thickness of the partition has been changed may be calculated by using an accepted temperature analysis model that is appropriate to the form of construction, e.g. studded composite construction. Input data should 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 probably necessary to estimate, using relevant test results, the duration of exposure at which destruction or detachment of parts of the element (i.e. facings, insulation, etc.) will occur, as these will change the thermal exposure conditions.

b) Insulation performance

Compliance with the insulation criterion may be calculated using appropriate temperature profiles, as above.

c) Deflection due to thermal gradient

Deflections may be calculated for partitions where the physical properties and the relationships between stress and strain (including, if necessary, creep effect) are known as a function of temperature and where the temperature profile over the cross-section of the partition is known. This is a complex procedure for composite elements, both studded and SIPS. With non-loadbearing elements, these deflections do not form criteria in themselves, but the influence of the thermally generated movement should be considered when establishing compliance with the integrity criteria.

7.1.3.3 Expert judgements

Being non-loadbearing, there are no design codes to follow when deriving extended application for a partition and so expert judgement is the most likely process to be used.

Changes may be made to the following construction parameters of the vertical partitions when that expert judgement is based upon the methodology given in Annex A.

7.1.3.3.1 General parameters relating to partitions

a) Height

The height of the partition may be increased, provided the behaviour of any lining or facing applied to any studded or composite panels can be demonstrated by the method given in Annex A not to compromise the integrity.

b) Width

The width of any construction tested with a free edge is covered by the direct application (see 4.1) but when the partition was tested with four edges restrained, the width may be increased subject to the behaviour being evaluated in accordance with the method in Annex A.

c) Services

Services may be installed both in and passing through vertical partitions of either construction, provided that the ability of the construction to satisfy the insulation and integrity criteria is not reduced.

d) Openings in partition

The size, shape and position of any opening may be varied subject to it being demonstrated that there is no adverse effect on the performance of the partition, e.g. the revised shape does not change the stiffness of the partition and the revised position does not cause different pressure conditions to exist which may influence integrity. The method of protecting the opening should satisfy the fire requirement at the revised size, shape or position.

7.1.3.3.2 Parameters related to stud constructed partitions

a) Thickness of framing members (e.g. studs) and linings

Reductions in thickness of vertical partitions should consider the influence on insulation performance and slenderness (which influences stability), and may affect the performance of linings and their impact on integrity.

b) Fixings between framing members and linings and framing members

Fixings may be changed in type and centres subject to the influence on the fire resistance being analysed according to Annex A. The possible factor influences for fixings of linings are presented in Table 1 below.

Table 1 — Summary of possible factor influences for fixings of linings

Parameter	Factor	Factor influence
Fixing centres	Closer centres	Influence: E – increase/neutral : I – neutral
	Increased centres	Influence: E – decrease/neutral : I – neutral
Fixing effectiveness	More effective/positive	Influence: E – increase : I – neutral
	Less effective/positive	Influence: E – decrease : I – neutral
Infill conductivity	More conducting	Influence: E – neutral : I – decrease
	Less conducting	Influence: E – neutral : I – increase

c) Thermal and physical characteristics of lining materials

When fire protection materials are changed or increased in order to compensate for changes in the load case (dead load only) or cross-sectional area, it should be demonstrated (justified) that the connection between the protective material and the vertical partition will remain effective for a duration sufficient to achieve the fire resistance period.

d) Nature and thickness of any infill

When insulation material is incorporated in the cavity of the partition in order to enhance the acoustic, thermal or fire resistance of the construction, then any change in the quantity or nature of these materials should demonstrate by the methods given in Annex A that the changes do not adversely affect the insulation and integrity ratings. The possible factor influences for infill in partitions are presented in Table 2 below.

Table 2 — Summary of possible factor influences for infill in partitions

Parameter	Factor	Factor influence
Infill combustibility	More combustible	Influence: E – decrease/neutral : I – decrease
	Less combustible	Influence: E –neutral : I – increase
Fixing effectiveness	Thicker	Influence: E – increase/neutral : I – increase
	Thinner	Influence: E – decrease/neutral : I – decrease
Fixing conductivity	More conductive	Influence: E – neutral : I – decrease
	Less conductive	Influence: E – neutral/increase : I – increase

e) Jointing materials and fixings

Jointing materials and fixings systems may be changed, provided that it can be justified by the method given in Annex A that the changes do not adversely affect insulation or integrity.

7.1.3.3.3 Parameters relating to composite panels/SIPS

a) Thickness of the insulated core

The thickness of the insulated core may be changed (thinner/thicker) subject to the proposed change in thickness being demonstrated not to have a negative influence on the integrity or insulation criteria using the methodology given in Annex A.

b) Change in method of adhering the facings to the core

A change in the method of adhering the skins is only possible if there is direct evidence that in the case of glued facings, the parameters of the glue are sufficiently well known to carry out an analysis along the lines given in Annex A.

In the case of auto-adhered facings, it is not possible to approve any change in the method of foaming or the metal preparation which would influence the quality of the auto-adhesion without further testing.

7.2 Horizontal “partitions” ceiling membranes

7.2.1 General

The results from a fire resistance test may be used to support an evaluation of the performance of variations to the construction of the tested horizontal ceiling membrane without any further calculations, the application of more complex rules or the use of judgements, if the construction complies with the statements given in 4.2.2. Where the construction does not comply with the direct application, then the calculations or the judgements need to be applied as indicated in 4.2.3 or, in Europe, the appropriate extended application rules are applied if the product is to be CE marked.

The relevant performance criteria are integrity (measured by gap gauge, ignition of cotton pad, or sustained flaming) and insulation (increase in the average and maximum unexposed face temperature).

Horizontal ceiling membranes come in three common forms:

— joisted construction (manufactured off or on site);

— edge supported, suspended, multiple panel assemblies;

— composite panels/structural insulated panels (SIPS).

The guidance in respect of these has to reflect their different methods of construction.

7.2.2 Direct application

The results of a fire resistance test are deemed to be applicable to a similar form of untested horizontal ceiling membrane provided that all the following are satisfied.

7.2.2.1 Common parameters of all horizontal membrane forms of construction

a) The span is not increased.

b) The edge conditions are unchanged and for a ceiling tested with all edges restrained, no increase in ceiling width or length is permitted.

c) For a ceiling fixed at the ends of the primary span and tested at least with one edge free, wider elements are allowed.

d) The size and number of any fire resisting openings are not increased.

e) The method of protecting any such opening (e.g. rooflight/window/service penetration) is not changed.

f) The position of any opening relative to key features of the construction, e.g. panel joints, is unchanged.

7.2.2.2 Joisted ceiling membranes

a) Any thermal insulation incorporated in the element is not increased or reduced at any point.

b) The thickness of component materials (e.g. linings/boards, joists) is not reduced.

c) The joist spacing is not increased.

d) On a lined, underdrawn boarded ceiling joisted construction, the distance between fixings for retaining the boards is not increased.

e) The type, size, and nature of fixings are unchanged.

7.2.2.3 Edge supported, suspended multiple panel assemblies

a) The bearing provided for the edge(s) of each panel forming the membrane should not be reduced.

b) The suspension points for any supporting grid should not be at lesser centres than as tested.

c) The individual panels forming the membrane should not be greater in any linear dimension.

d) Any thermal insulation applied to the upper surface of the panels is not increased or decreased at any point.

e) Any fixings/clips used to restrain the panels against upward movement relative to the grid are not reduced/linear metre.

7.2.2.4 Composite panels/SIPS constructed ceiling membrane

a) The thickness (gauge) of any facing should not be reduced, nor should the material be changed.

b) The insulating core should not be changed in type/density but thickness may be increased.

c) The method of attaching the facings to the core is unchanged.

d) The method of jointing panels to each other should be unchanged.

7.2.2.5 Openings in ceiling membrane

a) The size and number of any fire resisting openings are not increased.

b) The position of any opening relative to key features of the construction, e.g. panel joints, is unchanged.

7.2.3 Extended application

7.2.3.1 Rules

Except in the context of classification in CEN (see EN 13501-2), it is not possible to extend the application of a test result by the application of pre-determined rules.

7.2.3.2 Fire engineering calculations

Calculations may be generated and applied for the following.

a) Temperature profile

Heat transfer through horizontal ceilings where the insulation and/or thickness of the ceiling construction has been changed may be calculated by using an accepted temperature analysis model that is appropriate to the form of construction, e.g. studded/composite construction. Input data should 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 probably necessary to estimate, using relevant test results, the duration of exposure at which destruction or detachment of parts of the element (i.e. facings, insulation, etc.) will occur, as these will significantly change the thermal exposure conditions.

b) Insulation performance

Compliance with the insulation criterion may be calculated using appropriate temperature profiles, as above.

c) Deflection due to thermal gradient

Deflections may be calculated for partitions where the physical properties and the relationships between stress and strain (including, creep effect, if appropriate) are known as the function of temperature and where the temperature profile over the cross-section of the ceiling membrane is known. This is a complex procedure for composite elements, both joisted and SIPS. With non-loadbearing elements, these deflections do not form criteria in themselves, but the influence of the thermally generated movement/distortion should be considered when establishing compliance with the integrity criteria, i.e. due to the generation of gaps.

7.2.3.3 Expert judgements

As with partitions, expert judgement is the most likely method for deriving an extended application for this type of element.

Changes may be made to the following construction parameters of the horizontal ceiling membranes provided that expert judgement, based upon the methodology given in Annex A, is adopted.

7.2.3.3.1 General parameters relating to all forms of ceiling membranes

a) Span

The span of the ceiling membrane may be increased, provided the behaviour of any lining or facing applied to any joisted or composite panels can be demonstrated using the method given in Annex A not to compromise the integrity or, if appropriate, the maximum temperature rise criteria, due to the production of hot spots. The possible factor influences for variations in span are presented in Table 3 below.

Table 3 — Summary of possible factor influences for variations in span

Parameter	Factor	Factor influence
Lining board joints	More joints	Influence: E – decrease/neutral : I – neutral
	Less joints	Influence: E – neutral : I – increase
Deflection[a]	More deflection	Influence: E – decrease : I – neutral
	Less deflection	Influence: E – increase : I – neutral/increase

[a] Deflection may be maintained the same despite the longer spans if compensation is achieved by other changes to the construction.

b) Width

The width of any ceiling tested with a free edge is covered by the direct application [see 7.2.2.1 b)] but when the ceiling membrane was tested with four edges restrained, the width may be increased subject to the fire behaviour being evaluated in accordance with the method in Annex A.

c) Services

Services may be installed both in and passing through horizontal ceiling membranes of either construction, provided that the ability of the construction to satisfy the insulation and integrity criteria can be shown to be maintained by the use of the methods given in Annex A.

d) Openings in ceiling

The size, shape and position of any opening may be varied subject to it being demonstrated by the methods in Annex A that there is no adverse effect on the performance of the ceiling, e.g. the revised shape or area does not change the stiffness of the ceilings. The method of protecting the opening should satisfy the fire requirement at the revised size, shape or position; see the relevant subclauses of this document for guidance on the extended application for the appropriate components.

7.2.3.3.2 Parameters relating to joist supported ceiling membranes

a) Thickness/depth of framing members (e.g. joists) and of the linings

Reductions in the thickness of horizontal ceilings as a result of changes in the dimensions of the framing members and/or linings should consider the influence on insulation performance using the methodology given in Annex A. Any change in slenderness ratio (which influences stability) should be analysed to establish how this may affect the performance of linings and their associated influence on integrity.

b) Fixings between framing members and linings and framing members

Fixings may be changed in type and centres subject to the influence on the fire resistance being analysed according to Annex A.

c) Thermal and physical characteristics of applied lining materials

When fire protection materials are added or increased, possibly to compensate for changes in the load case (dead load only) or cross-sectional area, it should be demonstrated (justified) that the connection between the protection material and the ceiling membranes will remain effective for a duration sufficient to satisfy the required fire resistance period. The possible factor influences for applied lining materials are presented in Table 4 below.

Table 4 — Summary of possible factor influences for applied lining materials

Parameter	Factor	Factor influence
Lining density	More dense (heavier)	Influence: E – decrease[a] : I – decrease
	Less dense (lighter)	Influence: E – increase/neutral : I – increase
Lining stiffness	More stiff	Influence: E – increase : I – neutral
	Less stiff	Influence: E – decrease : I – neutral
Lining strength	Stronger	Influence: E – increase : I – neutral
	Less strong	Influence: E – decrease : I – neutral/decrease

[a] The extra weight of the lining will have a greater propensity to fall when attached to structural framing made of timber or metal and in the case of timber framing, charring would be expected to start earlier.

d) Jointing materials and fixings

Jointing materials and fixing systems may be changed, provided that it can be justified by the methods given in Annex A that the changes do not adversely affect insulation or integrity.

7.2.3.3.3 Parameters relating to edge supported, suspended, multiple panel ceiling membranes

a) Thickness of the panels forming the membrane

The thickness of the panels may be decreased or increased subject to the influence that this would have on the integrity, and the insulation of the ceiling membrane is demonstrated by the methodology given in Annex A not to be detrimental to the performance.

b) Change in the primary dimensions of the individual panels forming the membrane

The panels may be increased or decreased in their primary dimensions, or their aspect ratio be modified, as long as it can be demonstrated that any increase in dimensions does not result in increased defections or shrinkage that could affect the integrity rating of the ceiling, using the methodology given in Annex A.

c) Change in the suspension system support

The number of suspension points may be modified (reduced or increased) subject to it being proven using the methodology given in Annex A that any movement of the suspension system does not adversely affect the support that the system provides to the panels and hence its stability and its associated influence on integrity.

7.2.3.3.4 Parameters relating to composite panels/SIPS

a) Thickness of the insulated core

The thickness of the insulated core may be changed (thinner/thicker) subject to the proposed change in thickness being demonstrated not to have a negative influence on the integrity or insulation criteria using the methodology given in Annex A.

b) Method of adhering the facings to the core

A change in the method of adhering the skins to the core is only possible if there is a direct evidence that in the case of glued facings, the parameters of the glue are sufficiently well known to carry out an analysis along the lines given in Annex A.

c) Primary dimensions of composite/SIPS panels

The panels may be changed in their primary dimensions, or their aspect ratio be modified, as long as it can be demonstrated that any increase in dimensions does not result in increased deflections or shrinkage that could affect the integrity rating of the ceiling using the methodology given in Annex A.

d) Suspension system

The number of suspension points may be modified (reduced or increased) subject to it being proven using the methodology given in Annex A that any movement of the suspension system does not adversely affect the support that the system provides to the panels and hence its stability and its associated influence on integrity.

In the case of auto-adhered facings, it is not possible to approve any change in the method of foaming or the metal preparation which would influence the quality of the auto-adhesion without further testing.

8 Evolution of testing and summary of quantifiable approaches

For many decades, it was sufficient to have a rating system for elements forming the built environment that was based on the fire resistance of construction products when exposed to heat according to the ISO 834 series and to then have confidence in the fire safety level of buildings using construction products of the same construction. During this period, the vast majority of buildings were fairly simple in design and construction.

Over the last couple of decades, the improvement in knowledge and advances in modelling of fire actions and fire response have made it feasible to focus upon the actual behaviour of constructions and construction products in real fire situations.

As explained in the Introduction, it is not yet possible to obtain easily all of the data needed, but, as stated in the previous clause, it is becoming possible to generate a larger extrapolation of test results to the sizes used in buildings and replicating the fixity and restraint in use by using existing knowledge in conjunction with mathematical modelling experience and judgement.

Also, using improved instrumentation and enhanced specimen design, it is possible to obtain more information on the behaviour of the product from standard fire tests than has been the case up to now.

Proposals on how to obtain this extra information are given in the following subclauses regarding:

— improvement of testing methodologies to generate additional experimental data;

— possible mathematical modelling for calculation;

— expert system to provide more consistency in expert judgements.

8.1 Improvement of testing methodologies

To a large degree, tests have only been performed in order to obtain the necessary information to demonstrate compliance with the three main criteria in fire resistance:

— maximum deflection/deformation or rate of deflection for loadbearing resistance;

— cotton pad test and use of gap gauges for determining the integrity period;

— insulation failure either expressed as:

  — maximum rise of temperature of 180 °C for insulation, or

  — mean rise of temperature of 140 °C.

Accordingly, measurements performed during tests are often limited to the parameters required to demonstrate conformity with the relevant criteria.

In addition, the initial purpose of many fire testing standards was to give a fire rating for an individual construction product, assuming that it was sufficiently representative of what was used in practice. In reality, it is well known that for each tested specimen, there are many possibilities for changing size, restraint, loads, individual components and other design details. It is important that for certifying the performance of a construction in end-use applications, it should be demonstrated that the results of the test can be interpolated or extrapolated to cover the application in question. The processes described in this document assist in determining the field of application.

Of course, by considering extended application of results, it is possible to give some guidelines on the possible changes in the design of the tested specimen but it is a fact that test standards have not generally been written, certainly until recently, with the aim of having a wider range of application of results.

For the purpose of producing a wider field of application for the results derived for a tested construction which may have a variety of applications, it is possible to identify three types of activity that can be taken to improve the knowledge about the behaviour of the specimen:

— further improvements of existing test methods;

— additional supplementary small-scale tests to be performed;

— selection of more representative specimen(s) of the construction products to be tested.

A Technical Report (ISO/TR 22898) has been produced identifying particular improvements in the tests used for establishing the fire resistance of a construction and this should be consulted if enhanced testing procedures are to be adopted.

8.1.1 Existing test methods

Improvement can be made in order to have more and better knowledge of the fire behaviour of a specimen and the necessary data for using numerical model for simulation of physical phenomena.

For instance, it could be very valuable to have:

— better understanding of heat flux to the specimen over the whole fire exposure in the furnace;

— recorded temperatures within the specimen (between layers of different materials, in voids, in the various parts of loadbearing element, etc.) and in structural elements;

— recorded heat flux from a separating element;

— measured deformation of separating elements at several locations.

Greater accuracy in the characterization of the element and of the material used in the specimen and more data of their thermophysical properties at elevated temperature should also be of great interest for numerical simulation especially when a component is changed.

Regarding loadbearing elements, the actual end conditions of the specimen are often difficult to determine accurately. In this respect, it would be useful to quantify the restraint with load cells. The recording of plastic deformation of the specimen, after the fire test, could also provide interesting data.

It is also recommended to continue fire tests until all three failure criteria are fulfilled and even, if possible, up to the real collapse of the specimen. It is only when the exact behaviour is known that extrapolation of results can be made with accuracy.

Alternatively, for loadbearing elements, after reaching the failure criteria, if there is no risk to the laboratory staff, the loading can be reduced to continue the test and to record additional data on temperature in the element.

As before, possible improvements in testing are covered in detail in ISO/TR 22898.

8.1.2 Test using reduced-size specimen (reduced-scale test)

A reduced-size specimen (reduced-scale test) means a test on a specimen of about 1,20 m × 1,20 m in size.

When a specimen of a particular form of construction has been tested at full size, it can subsequently be possible to perform only a small-scale test to investigate the influence in the change of one of the parameters of this specimen.

These small-scale tests are generally useful for assessing the effect of certain parameters on the heat transfer by taking into account the side effects which can be due to different boundary conditions as far as heat loss is concerned. This is mainly the case for assessing the effect of protective coatings on structural elements such as steel, concrete, timber or composite sections where a testing package normally consists of a large scale beam specimen with a number of short members, vertical and horizontal tested simultaneously to determine the influence of the A_m/V ration of the section.

The reduced-scale fire test facilitates reducing the influence of random variations (see Annex A, ISO 834-3:2012, Commentary on test method and guide to the application of the outputs from the fire-resistance test), if compared to a full scale fire test. The reason for this is that variables that have a negative influence on the reproducibility and repeatability of the results, can be better controlled in a reduced-scale fire test.

The reduced-scale test allows the influence of random variations to be reduced by improved control. The use of a small scale test, set up to particularly establish the influence of a single parameter on the fire resistance rating, will obviously give a more reliable result if the variables are eliminated or reduced. This principle has been exploited to fall in the ISO/TR 10295-3 test method where reduced scale tests are used in order to establish the influence of parameters such as seal/sealant depth, conductor diameter, hole dimensions on the field of application of the test results for penetration sealing materials.

They are less appropriate for assessing mechanical behaviour since with such small samples, it is impossible to obtain realistic loading conditions for both flexural effect and shear effect. Additionally, the boundary conditions in terms of rotational capacity and restraint to elongation are of greater importance. Nevertheless, such small-scale tests can be used in some cases when results are not directly used but are taken as data for checking the ability of numerical models to predict, with enough accuracy, the tested phenomena.

An additional benefit of reduced scale tests is that they are more environmentally friendly when compared to full scale test, albeit this should never override the need for technical validity.

8.1.3 Selection of the specimen

When it is intended to cover, as far as fire resistance performance is concerned, the full range of use of a construction product before testing, it is desirable to have a clear view of the possible changes in the size, components and design of this construction product so that the specimen can incorporate some or all of the relevant parameters.

Being aware of the possible variations in the product design, it is easier to choose the right specimens to be tested. In this respect, several options can be selected: either to test the specimen leading to the most onerous conditions when it is possible to define it, or to test two or more specimens of various designs to cover the full range of use.

Of course, this way is only possible if the changes in the design are not too many. Current examples are

— tests on the smaller and the larger sizes of a door, a damper or the cross-section of a duct when the design of these elements is exactly the same, and

— tests on various sizes of steel sections insulated by various thicknesses of a given coating material.

Because the fire resistance ratings may differ from one specimen to another, the assessment of results generally requires the use of agreed methods to derive the rating for intermediate specimens.

8.2 Mathematical modelling of thermal and mechanical response

There is a growing interest in mathematical modelling. This modelling may be used for assessing, from test results, what would be the fire resistance of differently designed elements. In the near future, modelling may be used for assessing the real fire behaviour of elements within a building.

Most modelling of structural behaviour under fire conditions currently tends to be deterministic in nature. This form of modelling is based on assumed specific relationships and formulae which can be used to predict in an unambiguous way the outcome for a given fire scenario. Design is based on physical, chemical and thermodynamic properties which are well known or derived from science or empiricism.

A probabilistic, also known as a stochastic, approach to modelling is less developed but more suited to the randomness of the available fire scenarios. There is a need to have knowledge of the probability distributions associated with the events that affect the fire development, involving factors such as growth rate, duration and temperatures achieved. The response of the structure, sometimes in terms of a notional fire resistance, also can be assigned a probability distribution, particularly in the case of complex structures or works. The outcome is not a precise definition of failure time but a likelihood that failure will occur, usually matched against a degree of acceptability for the outcome.

In the following, the structure of the related deterministic models is described with reference to five levels with varying degrees of complexity.

8.2.1 Level 1 — Numerical regression analysis

This is a curve-fitting methodology for interpolation between measured values. It usually has no direct relation to the physical phenomena. It can be used when only a few parameters change from one tested specimen to another.

This technique cannot provide data outside the range of tested assemblies or for temperature-time curves other than the one used. It is mainly used for interpolation between test results. Level 1 represents the most basic way of developing an extended application.

8.2.2 Level 2 — Graphical approach

The graphical approach is a methodology originally developed to enable characterization of the performance of intumescent coatings applied to structural steel following testing. The methodology can also be used to analyse other scenarios, not just the performance of intumescent coatings applied to structural steel.

The graphical approach is explained in ISO 834-11. It is based upon the plotting of lines or curves of best fit. Intersects of the lines or curves with an x-value of interest are then established. It is then possible to use linear interpolation between the intersects to determine the variation in performance for the x-value of interest.

8.2.3 Level 2 — 3D interpolation

The 3D interpolation method is an assessment method originally developed for the characterization of intumescent coatings for the protection of structural steelwork against fire, but the methodology can also be used to analyse other scenarios, not just the performance of intumescent coatings applied to structural steel. The 3D interpolation method is explained in ISO 834-11. The 3D interpolation method uses the factual data from fire tests and projects measured performance times in a three-dimensional space. Each of the test specimens is represented by a dot (x,y,z) in the three-dimensional space. Three dots form a plane and the mathematical equation of the plane facilitates calculation of the performance time *t* (z-value) for any combination of a variable plotted on the x-axis and a variable plotted on the y-axis within the boundaries of the plane. The combination of a large number of intersecting planes forms a landscape of “rolling hills”, identifying the performance with great precision three-dimensionally.

8.2.4 Level 3 — Physical equation analysis

The physical phenomena (mainly in terms of heat transfer and loadbearing resistance) are expressed by analytical formulae, the validity of which is established by analysis of experimental results.

Since these analytical formulae are based on the physical parameters influencing the fire behaviour of the components, it is possible to use them outside the range of experimental evidence. Sometimes reference to other fire curves is possible.

Regarding heat transfer, such formulae are currently used for unprotected steel sections, for assessing the fire protection of steel sections, and for determining the temperature within concrete or composite elements.

Regarding loadbearing resistance, simple plastic theory is used, taking into account the effect of temperature on the strength of materials, which leads to the possibility of determining the ultimate loadbearing capacity of sections subjected to fire.

Some other examples can be found concerning, for instance, thermal bowing and charring rate.

8.2.5 Level 4 — Finite element methods

Such methods can simulate in a realistic manner the evolution of physical phenomena in a given element during fire exposure and generally also for the complete structure. This is probably the most advanced method of determining the application of the test data to a field of application for the product.

As for Level 2, it is necessary to differentiate between temperature analysis and mechanical response analysis. It may be possible in the near future to model also such phenomena as cracks, spalling, bond and anchorage.

a) Temperature analysis

Depending upon their complexity, it is possible to use computer programs based on the finite element method (or on the finite difference method) handling one-, two- or three-dimensional heat flow. Cross-sections of elements may consist of different materials and the thermal properties (thermal conductivity, specific heat) can be expressed in terms of a non-linear relationship versus temperature.

Both heat transfer (by convection and radiation) to the element and heat transfer (by conduction) within the element are taken into account. Cavities in the member can also be considered.

The heat exposure is modelled either as a gas temperature-time curve or as a prescribed time-heat flux-time relationship. In some computer programs, mass transfer is taken into account which allows more accurate results for elements containing moisture.

The limits of application of such computer programs are mainly due to the lack of knowledge about the effective thermal properties of the materials and their behaviour in real fires.

b) Mechanical response analysis

By using finite element method, it is possible to simulate the deformations of members during a fire exposure. The field of temperature needs to be known as well as the mechanical properties at the relevant temperatures of the materials. Numerical models for two- or three-dimensional behaviour currently exist. They are able to simulate the evolution of stresses and deformations within members due to interaction between them and redistribution of external actions.

Some of them are based on shell and plate theory, but the majority are based on beam/column members.

This can be illustrated by the following example using a three-dimensional steel frame consisting of four legs, stiffened with braces in horizontal and vertical planes. At the top, it is fitted with a lattice girder. On the top of one leg, a vertical load is applied. Fire is applied at the floor level near the loaded leg. The asymmetry in load and heating yields significant load distribution capability. The response history anticipated is as follows.

1) The leg and adjacent diagonals are subjected to a rapid temperature rise. Due to thermal expansion of the brace, the leg below the joint is subjected to additional compression forces initially. Above the joint, the leg compression force decreases. Thus, the effect of thermal expansion is intermediately to cause transfer of a fraction of the vertical load to the lattice girder and the brace.

2) After a while, the leg starts to fail due to reduction in yield stress and elastic modulus. As a consequence, part of the leg compressive force has to be taken up by tension in the diagonal brace, thus counteracting the effect of thermal expansion. This causes a transfer of leg load from heated leg to other legs of the structure.

3) As the temperature increases further, the loadbearing resistance of both the diagonal and the leg is reduced so much that some of the vertical load has to be transferred to adjacent legs by mobilization of the lattice girders at the top. Eventually, the compression brace in the lattice girder close to the top of the heated leg fails by buckling, resulting in a global collapse.

8.2.6 Level 5 — Integrated interactive analysis

This level deals with the full package of mathematical models to simulate the behaviour of a whole building on fire in a holistic manner and goes far beyond applying the output from tests. The following models need to be available for a complete analysis:

— model for thermal actions, to simulate fire development, taking into account type and size of fire load, ventilation conditions, surrounding separating elements, etc., and to simulate propagation of fire through different compartments, either due to failure of separating elements or due to failure of penetrating services such as ducts, dampers, sealed penetrations, pipes, etc.;

— model for heat transfer to structural and surrounding elements (using mainly the analysis approach mentioned in Level 3);

— model for mechanical response of the structural elements within the building with respect to such phenomena as redistribution of forces and moments, progressive collapse (using mainly of numerical computer programs mentioned in Level 3);

— model for effectiveness of fire separation.

Such integrated analysis requires an interaction between the different models, in order to estimate when failure of surrounding separating elements can occur, leading to a propagation of fire and consequently to redefine the actions on the structural loadbearing elements.

Additionally, integrated analysis can take into account interaction between fire exposure and fire extinguishment and even between fire and explosion.

Different codes specify fire as an accidental event which is to be designed for in the limit state of progressive collapse. In contrast to the traditional, ultimate state criterion allows for local failures in the form of buckling, yielding, etc., provided that the structural integrity is not put in jeopardy.

8.3 Expert system based upon the use of performance coefficients

8.3.1 Concept

There are many situations where mathematical modelling is not appropriate for predicting performance. Modelling works best when there are only two or three variables and where only one

