Timber Engineering Notebook series

No. 7: Fire safety in timber buildings

This series is authored by the UKTFA

The UK Timber Frame Association (UKTFA) represents over 85% of the UK's timber structural frame supply industry and is a trade organisation that provides business and technical support to the industry. The Association provides peer reviewed outputs on subjects related to the timber industry such as health and safety, fabric and technical performance, fire safety, promotion and training. These documents and other information are available at www.uktfa.com

Plasterboard protection to timber frame panels – cut away shown

Introduction

Fire spread in buildings is a risk to life safety for which the Building Regulations (for England and Wales[1,2], Scotland[3] and Northern Ireland[4]) aims to reduce to acceptable levels. For the designer, there is a responsibility to specify materials, and to provide details that:

- reduce the potential for fire ignition
- limit the spread of fire
- stop the passage of hot gases and smoke

An appropriately designed building will allow people remote from the seat of a fire to escape and provide a building from which the fire service can deal with the fire safely and effectively.

Structural fire safety is achieved either by what is called 'passive protection' e.g. fire resistant lining boards and/or 'active protection' e.g. smoke ventilation, alarm systems and sprinklers. For the structural engineer, the material choice within the structural solution will influence the passive and active fire protection strategy.

The Eurocodes deal with specific aspects of passive fire protection in terms of designing structures and parts thereof for adequate robustness against fire ignition and in the load bearing resistance under fire time duration[5].

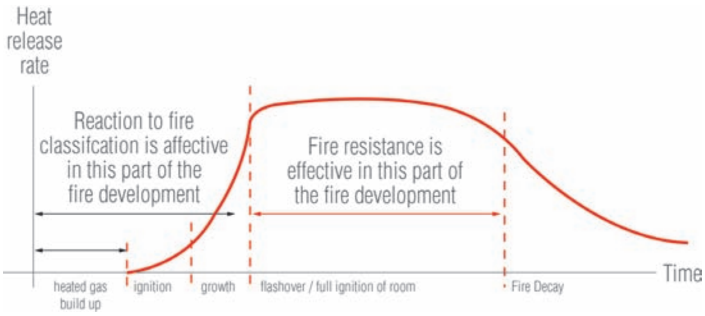
The structural engineer is not specifically involved in the design for active fire protection, or in the layouts for fire compartment sizes and escape routes. These aspects fall under the guidance of the architect and are an integral part of building design. A structural engineer must be aware of what is intended in this respect however, as fire safety design requires an integrated approach by all members of the design team.

The structural engineer, in specifying products, should take account of CE marking which, under the Construction Products Regulation[6] means that a product's fire safety is now an essential part of the declaration of performance.

The required level of fire performance for structures is typically given in terms of a reaction to fire classification and a fire resistance rating, as given in the Building Regulations.

This notebook provides an introduction to fire safety in relation to timber structures. Designers involved in fire engineering should be aware that it is a specialist subject and that this notebook is a top-level introduction to the scope of fire safety issues.

Figure 1
Fuel controlled fire curve



What is fire?

Fire is a chain reaction between oxygen, fuel and heat; requiring all three to be available. In most buildings there is adequate oxygen and it is the availability of fuel which dictates the initial growth of a fire.

The idealistic view of fire is given in Figure 1 which shows the heat release rate against time. Fig. 1 is for a fuel controlled fire and shows the two Building Regulation terms 'Reaction to fire' and 'Fire resistance' as they relate to the different stages of the fire's development. 'Heat release rate' is a term to show the amount of heat generated by fire. 'Reaction to fire' is a term used to classify how a material responds to heat and fire. 'Fire resistance' is a term used to measure the ability of a material (or combinations of materials) to resist the passage of fire from one distinct area to another.

Real behaviour of fires in buildings, where the doors and windows are closed, may be slightly different to Fig. 1, where the slope of the curve is not uniform as the fire development is intermittent, depending on the oxygen levels available. At the early stages there is adequate oxygen to mix with the heated gases, which results in fire growth. For relatively small rooms the oxygen level within the structure can be depleted and the fire will start to decay. When oxygen is introduced (usually via an opened door or window) the fire increases. The increase in oxygen levels (referred to as ventilation) can result in a rapid increase in fire growth, to a point called 'flashover' which is a fully developed compartment fire condition.

Fire resistance and reaction to fire in the Building Regulations

Reaction to fire is not storey height dependent, while fire resistance is. It also relates to the level at which the fire service can gain external level access for the fire fighting equipment. The Building Regulation approved documents provide time dependent requirements related to the storey heights above the external fire fighting platform, which will be covered later in the notebook.

The designer should refer to the Building Regulation in the country being considered as there are differences in approach.

Fire safety design considerations

Requirements for compartmentation

The spread of fire within a building can be restricted by sub-dividing it into compartments. These compartments are formed from walls and ceilings of fire-resisting construction with internal openings having equal fire resistant classifications. In timber frame buildings, fire resistance is typically achieved by providing fire resistant linings to compartment floors and walls; the fire resistant lining being a product that has been tested as an assembly to BS EN 1365-1[7] or assessed to BS EN 1995-1-2. In addition, the spread of fire through concealed cavities is restricted using cavity barriers; typically positioned in the external cavity walls between the timber frame structure and the cladding materials, and between a twin leaf compartment or separating walls. A cavity barrier is a material filling a gap that provides 30 minutes resistance to fire, as proven by fire tests or assessments.

Space separation

The Building Regulations require that the areas of openings and combustible surfaces in external wall construction are limited, to give adequate protection against the spread of fire from one building to another where certain boundary conditions are present. The boundary conditions are based on a separation distance to another building or to parts of the same building, in a similar way to the assessment of separating distances for timber frame buildings during construction[8]. For more information reference should be made to the applicable Building Regulations and in particular BRE Report 187[9].

Reaction to fire

'Reaction to fire' is the consideration of how materials react in the initial stages of a fire. How easy is it for the material to ignite and how can the product contribute to the growth of a fire? The reaction to fire is not something that can be calculated and tests and classification of products need to be established in any design of a building. Testing typically relates to products that are not predominately timber based. The predictability of timber products in fire is such that most timber products can be declared to known reaction to fire classifications (Table 1). The Euroclass classification is set out in EN 13501-1[10] and Table 2.

Within the CE marking process there is a requirement to declare the reaction to fire for timber products. However, as noted previously, timber has known performance under fire and it can be classified without further testing. The harmonised standard for the timber product will provide the classification of the product without testing.

The European harmonisation of fire classifications also addresses the smoke class (reference s1,2,3) and burning droplets classification (reference d0,1,2). This reference system is then used on products. For example, 9mm Plywood to EN636 and Glulam to EN 14080 with a minimum density of 380kg/m^3, minimum thickness of 40mm without the need to test, is referenced as:

$D\text{–}s2\text{–}d0$

Where:
D is the Euro class for timber
$s2$ is the smoke class
d is the burning droplets

A designer who is investigating claddings and products that are sensitive to reaction to fire should seek specialist advice.

Fire resistance

Fire resistance is typically presented as a duration of time.

The fire resistance of an element (wall, floor or roof) is a measure of its ability to withstand the effects of fire in one or more ways as follows (see Figure 2 also):

- Structural 'loadbearing capacity' to maintain the design loads under fire (R)
- 'Integrity' of the element which is the resistance to fire penetration (E)
- 'Insulation' which is the resistance to the transfer of heat to the face of the element remote for the fire (I)

Table 1
Approach to reaction to fire for timber structures

Type Of Structural Form	Reaction To Fire Rating Achieved By
Platform timber frame, wall and floor panels	Lining board over the structure and its euro class specification
Exposed timber structures	The euro class specification of the timber material or coating protection applied

Table 2
Test standards for reaction to fire

Euroclass	European Test Standard
A1 - non combustible	A1 - non combustible BS EN ISO 1182 (combustibility test) BS EN ISO 1716 (calorific potential test)
A2 - limited combustibility	BS EN ISO 1182 BS EN ISO 1716 BS EN 13832 (fire growth test)
B - reduced combustibility	BS EN 13832 BS EN 11925-2
C , D , E	BS EN 13832 BS EN 11925-2

Table 3
Approach to fire resistance

Type of Structural Form	Fire Resistance is achieved by	Comments and typical solutions
Platform timber frame, wall and floor panels.	Combination of the fire resistance of the lining boards fixed to the structural elements and other components where appropriate like insulation materials, air gaps and battens. *Note that the performance is dependent on thickness of materials, type of fixing and joints in the materials.*	In general, 30 minutes of fire resistance can normally be achieved for roof, floor and wall components made of solid timber, glulam or LVL by providing one 12.5mm thick layer of Type A gypsum plasterboard to **BS EN 520**. However, the required thickness depends on the density and some manufacturers recommend 15mm, so the plasterboard manufacturer's literature should be consulted. For floors made with prefabricated timber I-joists or metal open web type joists, 15mm thick plasterboard is always required. For 60 minutes resistance a minimum plasterboard thickness of 25mm is generally required. However, greater thickness is often required to satisfy acoustic requirements (usually 12.5+19mm on separating floor ceilings). In any board product it is how it is assembled that provides the fire resistance not the board itself and it is an important point that fire resistance cannot be considered to be provided by the boards alone. The load capacity of the frame behind the lining is also a function of the board thickness. In order for plasterboardto protect the underlying timber, all joints should be filled with plaster and taped, and the manufacturer's fixing specifications should be conformed to. Where two layers of plasterboard are used the joints should be staggered and the inner layer must be fully fixed to the manufacturer's specification with its own nails or screws which will be protected from heat by the outer layer.
Exposed timber structures	The charring resistance of the timber components and the strength of the resultant structure.	Strength of framing may be dependent on the protection of fixings and joints which may conduct heat.

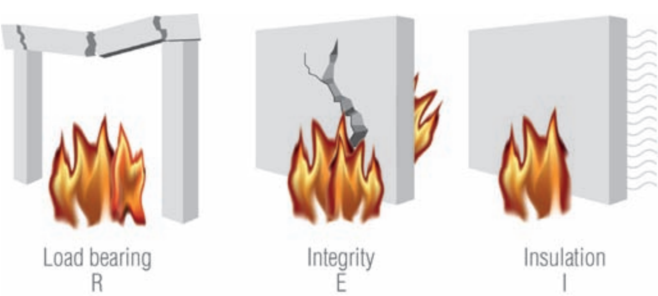


Figure 2
Criteria for fire resistance with European terminology (R E and I)[11]

The Building Regulation in the country being considered provides the time duration needed for fire resistance. For example, Appendix A2 of the *Building Regulations Approved Document B for England and Wales* require that any finished floor level that is more than 18m above the fire fighting platform level requires 90 minutes fire resistance to all elements of structure, with fire fighting shafts requiring 120 minutes. It must be assumed therefore, that the engineer takes these time limits for fire resistance designs (Table 3).

Figure 3
Furnace test

For platform timber frame structures, the engineer provides a check on the combination of protective materials and load bearing capacity, under which the fire resistance is declared.

Fire resistance of assemblies

Furnace tests are used to determine the duration of time that a structural assembly retains its stability, insulation and integrity (Figure 3). The test standards for fire resistance are the BS EN 1365 series. It should be noted that the furnace tests are comparative and do not relate to survival time in a structure or represent the real behaviour of a fire. The loaded fire tests take the design load or percentage of the design load for the structure and this is declared in the fire report.

Calculations can be used as presented in *BS EN 1995-1-2:2004 Section 5 Design procedures for wall and floor assemblies,* to predict fire resistance, but the methods are under review and limited to a maximum of 60 minutes. The calculations are dependent on material information and position of materials in the assembly. The calculation approach can be complex and requires both knowledge of the behaviour of the structural system at elevated temperatures and the importance of the structure - taking account of the consequences of failure. However, it is a common tool for product assessments and for determining the fire resistance of assemblies that have undergone similar (but not identical) tests.

Points to consider

- Consider fire resistance at the initial design stage because it may affect the size of members, the weight of the structure, the type of connections used and, in the case of party walls and floors, the type of construction
- The use of fire resistant linings under fire conditions, provides stability in timber members by both insulating them from reduction in section caused by charring and may, for slender sections, provide weak axis restraint to maintain the accidental load resistance during the fire
- Exposed timber sections can be designed with additional 'sacrificial' timber to a section, so that the part exposed to fire can protect the inner material from fire damage while the outer part chars at a slow, predictable rate
- Structural elements, including mechanical fasteners, can be insulated from heat by covering them with one or more layers of insulating material of a specified thickness. The most common material for this is gypsum plasterboard

Sacrificial timber method for fire resistance calculations using BS EN 1995-1-2:2004

Where a solid timber member is required to be wholly or partially exposed or if the plasterboard insulating materials are unable to provide the full fire resistance required, the timber member itself can be imbued with inherent fire resistance by designing in sacrificial timber, in the form of increased width and/or depth to the timber element under consideration.

The quantity of sacrificial timber required is dependent on the charring rate of the timber section, which in turn varies depending on the density of the timber material. For initial design, BS EN 1995-1-2:2004 Table 3.1 provides design charring rates for a variety of timber materials as indicated in Table 4. The charring rates shown apply to each face exposed to fire. So both the breadth and the depth of a softwood column exposed on all four sides to 30 minutes of fire would require 2x30x0.8 = 48mm of sacrificial timber on each of its width and depth. For larger members in shorter fire durations, little or no additional timber may be required.
The table gives rates for what is called two dimensional charring (Figure 4). If the product being considered was a flat surface as in a Cross Laminated Slab[12] or rim beam, then the charring rates are reduced to one dimensional charring (Figure 5).

Figure 4
Two dimensional charring

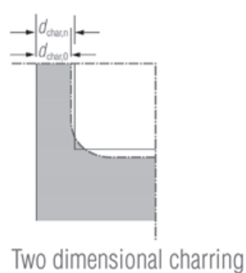


Figure 5
One dimensional charring

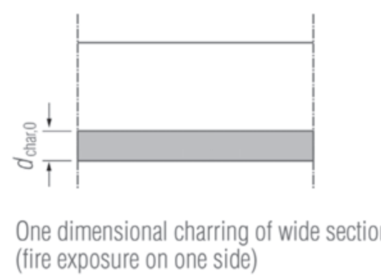


Table 4
Notional charring rates for timber materials (based on BS EN1995-1-2 Table 3.1)

Notional Charring rates (based on EC5 - 1-2 Table 3.1)	
Material	**Charring rate per exposed face βn (mm/min)**
Softwood timber	0.8
Softwood glulam and LVL to **BS EN 14374**	0.7
Hardwood timber and hardwood glulam	0.55
Panel products	See EC5-1-2

Timber notebook

Structural fire design using the reduced cross section method to EN 1995-1-2 General principles of designing timber elements for fire:

Calculation of design effect of actions

Fire is an accidental design situation, for which the following design rules apply:

- Design values of actions should be calculated in accordance with the combination of actions given in BS EN 1990:2002(Expression 6.11b). The value A_d is omitted because it does not apply to the situation after the commencement of a fire:

$$\sum_{i>1} G_{k,j} + (A_d) + \psi_{1,1} Q_{k,1} + \sum_{i>1} \psi_{2,i} Q_{k,i}$$

- As the design values of combinations for normal temperature design are likely to have already been calculated, BS EN 1995-1-2:2004 Clause 2.4.2(3) gives an a expression to modify the design vaues under normal temperature design to obtain the design values of combinations for fire design as follows:

$$E_{d,fi} = \eta_{fi} E_d$$

Where:
E_d = the design effect of actions for normal temperature design
η_{fi} = a reduction factor for the design load in the fire situation which may be taken as 0.6 except for imposed loads according to Category E of BS EN 1991-1.2-2002 when a value of 0.7 should be used.

Calculation of design values of material properties

- The twentieth percentile characteristic strength (f_{20}) and stiffness properties (E_{20}, G_{20}) are used, which are calculated in accordance with BS EN 1995-1-2:2004 Clause 2.3 as indicated:

Twentieth percentile characteristic strength and stiffness properties are calculated from the fifth percentile values as follows:

$$f_{20} = k_{fi} f_k$$
$$E_{20} = k_{fi} E_{0.05}$$
$$G_{20} = k_{fi} G_{0.05}$$

Where:
f_{20} is the design (20% fractile) value of a strength property
E_{20} and G_{20} are the design values of elastic and shear modulus respectively
k_{fi} is a factor taken from Table 2.1 of BS EN 1995-1-2:2004 as shown in Table 5 which upgrades characteristic 5th percentile values f_{05} to the f_{20} values

Table 5: Values of k_{fi} (taken from Table 2.1 of BS EN 1995-1-2:2004)

Element	k_{fi}
Solid timber	1.25
Glulam and wood based panel products	1.15
LVL	1.10
Connections with fasteners in shear with outer members of wood or wood based panels	1.15
Connections with fasteners in shear with outer members of steel, and connections with axially loaded fasteners	1.05

- Design values for strength in the fire condition are calculated as:

$$f_{d,fi} = k_{\mathrm{mod},fi} \frac{f_{20}}{\gamma_{M,fi}}$$

- Partial factors for materials and connections are $\gamma_{M,fi} = 1.0$

- The strength modification factors for fire take into account the reduction in strength and stiffness properties of the timber at elevated temperatures and a factor $k_{mod,fi}$, which is taken as 1.0, replaces the modification factor for normal temperature design k_{mod} given in EN 1995-1-1.

- The effect of the deflection of flexural members on other structural members and on the integrity of protecting elements such as plasterboard should be taken into consideration. It is recommended that the deflection of members which are protected by attached plasterboard should not exceed span/20, unless the fire resistance of the assembly for the period of fire resistance required has been demonstrated by test:

$$w_{inst} \leq span/20$$

Where:
w_{inst} is instantaneous deflection due to permanent plus variable loads

Deflection calculations should be based on the residual section of the flexural member.

Calculation of the reduced cross section

The reduced cross-section of a timber element following a period of fire should be determined as shown in Figure 6.

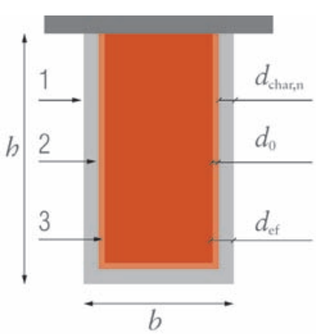


Figure 6
Definitions of charring dimensions

Notes
1 Initial surface of element
2 Border of residual cross-section
3 Border of effective residual cross-section
$d_{char,n}$ Notional charring depths (allows for the detrimental effects of arises and fissures)
d_0 Depth of layer with assumed zero strength and stiffness
d_{ef} Depth to unaffected, full strength material

For structural members exposed to fire on more than one side for more than 20 minutes, the effective charring depth is calculated as:

$$d_{ef} = d_{char,n} + d_0$$

Where:
$d_{char,n} = \beta_n t$
d_0 = 7mm
β_n = notional charring rate (Table 4)
t = time from start of charring (minutes)

Charring will occur to this depth on all exposed surfaces as shown in Fig. 4. Hence, in the example shown where the upper face of a beam is protected by an adequate thickness of plasterboard, the effective residual section will measure $(h - d_{ef})$ x $(b - 2d_{ef})$. It may be assumed that this section retains the strength and stiffness properties appropriate to the service class at normal temperatures.

For structural members exposed on only one side to fire, or initially protected from fire, or exposed to fire for less than 20 minutes, reference should be made to BS EN 1995-1-2:2004 clauses 3.4.2, 3.4.3 or 4.2.2 respectively.

Rules for the analysis of reduced cross sections:

- The effects of fire on compression perpendicular to grain may be disregarded
- The effects of fire on the shear strength of solid members may be disregarded. For notched beams the engineer should verify that the residual cross section in the vicinity of the notch is at least 60% of the cross section required for normal temperature design
- Bracing members made of timber or wood-based panels may be assumed not to fail if their residual cross sectional area or thickness is at least 60% of its initial value and they are fixed with nails, screws, dowels or bolts
- Where the bracing of a beam or column is predicted to fail, its stability should be analysed as though without lateral restraint

Fire resistance of connections

Most connections in timber are made with metal components such as nails, screws and bolts, sometimes used in conjunction with steel plates. As steel quickly loses its strength at elevated temperatures, steel connections between timber elements, even if the steel is only partially exposed, are vulnerable in a fire.

Rules for the fire resistance of typical fasteners where the heads of these fasteners are exposed or 'unprotected' are given in Section 6 of BS EN 1995-1-2:2004. Where the spacings and edge and end distances comply with BS EN 1995-1-1, Table 6.1 of BS EN 1995-1-2:2004 indicates that unprotected connections will only achieve a fire resistance period of between 15 and 20 minutes. Where the fasteners do not have projecting heads, BS EN 1995-1-2:2004 clause 6.2.1.1(2) gives a calculation procedure for 'protected connections' whereby the fire resistance period may be increased up to 30 minutes by increasing the thickness of the timber members and edge and end distances.

Where more than 30 minutes fire resistance is necessary, 'protected connections' will be required and can be achieved by:

- Recessing the head of the fastener and filling the recess with a glued-in timber plug
- Covering a group of fasteners with a wood-based or gypsum panel

For connections that use internal steel plates, BS EN 1995-1-2:2004 clause 6.2.1.1(2) gives rules for the required thickness and edge protection to the steel to achieve fire resistance periods of up to 60 minutes.

Worked example

A 190 x 405mm glulam beam of Grade GL28H spans 4.5m and carries a fire-protected floor structure in SC1 service conditions. The beam is exposed to fire on three of its faces and is required to maintain its load-bearing capacity for 60 minutes in accordance with UK Building Regulations Approved Document B – Volume 2 – Appendix A2. The beam supports a floor width of 3.0m and uniformly distributed floor loads of 2.00 kN/m² (permanent, including an allowance for the beam self-weight) and 3.00 kN/m² (medium term load duration). Check that the flexural resistance of the beam is acceptable in both the normal temperature and fire design situations, in accordance with the reduced cross section method of BS EN 1995-1-2:2004 Eurocode 5.

CALCULATION OF THE FIRE RESISTANCE OF AN EXPOSED TIMBER BEAM

1. ANALYSIS AT NORMAL TEMPERATURES

APPLIED PERMANENT ACTION $G_k = 3.0 \times 4.5 \times 2.00 = 27.0$ kN

APPLIED VARIABLE ACTION $Q_k = 3.0 \times 4.5 \times 3.00 = 40.5$ kN

DESIGN ACTION
$$F_d = \gamma_G G_k + \gamma_Q Q_k = 1.35(27.0) + 1.50(40.5) = 97.2 \text{ kN}$$

DESIGN BENDING MOMENT
$$M_d = F_d \times L/8 = 97.2 \times 4.5/8 = 54.7 \text{ kNm}$$

NORMAL SECTION MODULUS
$$Z_{norm} = bd^2/6 = 190 \times 405^2/6 = 5.19 \times 10^6 \text{ mm}^3$$

DESIGN BENDING STRESS
$$\sigma_{m,d} = 54.7 \times 10^6 / 5.19 \times 10^6 = 10.5 \text{ N/mm}^2$$

2. PARTIAL FACTORS FROM EC5-1-1

MODIFICATION FACTOR FOR MEDIUM TERM LOAD DURATION AND SC1 (TABLE 3.1 BS EN 1995-1-1) $k_{mod} = 0.8$

DEPTH MODIFICATION FACTOR FOR GLULAM (EXP 3.2 BS EN 1995-1-1)
$$k_h = \min\begin{cases}(600/d)^{0.1}\\1.1\end{cases} = \min\begin{cases}(600/405)^{0.1}\\1.1\end{cases} = 1.04$$

MATERIAL PARTIAL SAFETY FACTOR FOR GLUED LAMINATED TIMBER (TABLE NA.3 OF UK NA TO BS EN 1995-1-1) $\gamma_M = 1.25$

CHARACTERISTIC BENDING STRENGTH FOR GLULAM (BS EN 1194:1999 TABLE 1) $f_{m,k} = 28 \text{ N/mm}^2$

$\therefore$ DESIGN BENDING STRENGTH $f_{m,d} = 28.0 \times 0.8 \times 1.04/1.25 = 18.6 \text{ N/mm}^2 > 10.5 \text{ N/mm}^2$

$\therefore$ BENDING STRENGTH AT NORMAL TEMPERATURES IS ACCEPTABLE

3. ANALYSIS AT t = 60 MINUTES

DESIGN CHARRING RATE OF GLULAM OF DENSITY > 290 kg/m² (BS EN 1995-1-2 TABLE 3.1) $\beta_n = 0.7$ mm/min

NOTIONAL DESIGN CHARRING DEPTH AT t = 60min (EXP 3.2 BS EN 1995-1-2)
$$d_{char,n} = \beta_n t = 0.7 \times 60 = 42 \text{ mm}$$

4. THE REDUCED CROSS SECTION METHOD

(CLAUSE 4.2.2 BS EN 1995-1-2)

EFFECTIVE CHARRING DEPTH FOR t > 20 minutes, $k_0 = 1.0$ (TABLE 4.1 BS EN 1995-1-2)
$$d_{ef} = d_{char,n} + k_0 d_0 = 42 + (1.0 \times 7) = 49 \text{ mm}$$

DESIGN MOMENT IN THE FIRE CONDITION (EXP 2.8 BS EN 1995-1-2)
$$M_{d,fire} = \eta_{fi} M_{d,norm}$$

WHERE $\eta_{fi} = 0.6$ (NOTE 2, FIG 2.1 BS EN 1995-1-2)

(η_{fi} CAN ALSO BE CALCULATED MORE ACCURATELY AS 0.57 FROM FIG 2.1 OF BS EN 1995-1-2 WHERE ψ_{fi} = 0.7 FOR CATEGORY C VARIABLE ACTIONS)

$$M_{d,fire} = 0.6 \times 54.7 = 32.8\ \text{kNm}$$

5. CALCULATION OF REDUCED SECTION PROPERTIES

WIDTH AT t = 60 MINS $\quad b_{fire} = 190 - (2 \times 49) = 92\ \text{mm}$

DEPTH AT t = 60 MINS $\quad d_{fire} = 405 - 49 = 356\ \text{mm}$

SECTION MODULUS AT t = 60MINS $\quad z_{fire} = b_{fire} d_{fire}^2/6 = 92 \times 356^2/6 = 1.94 \times 10^6\ \text{mm}^3$

DESIGN BENDING STRESS $\quad \sigma_{m,d,fire} = 32.8 \times 10^6 / 1.94 \times 10^6 = 16.9\ \text{N/mm}^2$

6. PARTIAL FACTORS FROM EC5-1-2

MODIFICATION FACTOR FOR THE FIRE DESIGN SITUATION (BS EN 1995-1-2 CLAUSE 4.2.2(5)) $\quad k_{mod,fi} = 1.0$

MATERIAL PARTIAL SAFETY FACTOR FOR THE FIRE DESIGN SITUATION (UK NA TO EN 1995-1-2 NA2.2) $\quad k_{M,fi} = 1.0$

COEFFICIENT k_{fi} FOR GLULAM STRENGTH PROPERTIES (TABLE 2.1, EN 1995-1-2) $\quad k_{fi} = 1.15$

∴ DESIGN BENDING STRENGTH IN THE FIRE SITUATION $\quad f_{m,d,fire} = 28.0 \times 1.15 \times 1.0/1.0 = 32.2\ \text{N/mm}^2 > 16.9\ \text{N/mm}^2$

∴ THE FLEXURAL RESISTANCE OF THE BEAM IS ADEQUATE AT BOTH THE NORMAL TEMPERATURE AND AT THE FIRE DESIGN CONDITION AT t = 60MINS

A SEPARATE CHECK SHOULD BE CARRIED OUT FOR THE SHEAR STRESS OF THE BEAM AT THE NORMAL TEMPERATURE AND FOR THE DEFLECTION OF THE BEAM AT BOTH THE NORMAL AND FIRE SITUATION ($\delta \not> \text{SPAN}/20$)

Relevant codes of practice

BS EN 520: Gypsum plasterboards. Definitions, requirements and test methods.

BS EN 1365-2-2000: Fire resistance tests for loadbearing elements - Part 2 Floors and roofs

BS EN 1990:2002: Eurocode 0: Basis of structural design

BS EN 1991-1.2-2002: Eurocode 1: General actions - Actions on structures exposed to fire

BS EN 1995-1-1: Eurocode 5: Design of Timber Structures – Part 1-1: General – Common rules and rules for buildings

BS EN 1995-1-1: UK National Annex to Eurocode 5: Design of Timber Structures – Part 1-1: General – Common rules and rules for buildings

BS EN 1995-1-2:2004: UK National Annex to Eurocode 5: Design of Timber Structures – Part 1-2: General – Structural fire design

PD6693-1:2012: UK Non-Contradictory Complementary Information (NCCI) to Eurocode 5: Design of timber structures

BS EN 14374:2004 Timber structures: Structural laminated veneer lumber. Requirements. London BSI 2004

References and further reading

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Further reading

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