Eurocode 9: Design of aluminium structures

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There are five Parts to Eurocode 9 covering the design of aluminium structures:

- BS EN 1999-1-1:2007 General structural rules
- BS EN 1999-1-2:2007 Structural fire design
- BS EN 1999-1-3:2007 Structures susceptible to fatigue
- BS EN 1999-1-4:2007 Cold-formed structural sheeting
- BS EN 1999-1-5:2007 Shell structures

The rules given in Parts 1-1 and 1-3 for structural and fatigue design are largely equivalent to those given in BS 8118-1:1991, Structural use of aluminium, Part 1: Code of practice for design. The material in the other three Parts was not previously covered by a British Standard in any great detail.

Eurocode 9, in common with other Eurocodes, makes considerable cross-reference to other European Standards. In particular, it is based on the principles contained in Eurocode 0 (Basis of structural design) and refers to Eurocode 1 for loading.

The design rules are inextricably linked to the rules for execution (the term that Eurocodes use for fabrication and erection) given in BS EN 1090-3: Execution of steel structures and aluminium structures, Part 3: Technical requirements for aluminium structures. BS EN 1090-3 will replace BS 8118-2:1991, Structural use of aluminium, Part 2: Specification for materials, workmanship and protection.

Each Part of Eurocode 9 has an accompanying national annex which gives UK-specific partial factors and choices. The use of the UK national annexes is a prerequisite for the use of Eurocode 9.

BSI is issuing two documents to assist UK designers using Eurocode 9 in the UK. These are:

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• PD 6702-1, *Structural use of aluminium, Part 1: Recommendations for the design of aluminium structures to BS EN 1999*
• PD 6705-3, *Structural use of aluminium, Part 3: Recommendations for the execution of aluminium structures to BS EN 1090-3*

These documents give important guidance on matters where choice is given in Eurocode 9 or BS EN 1090-3, together with additional background data referred to in the national annexes.

**BS EN 1999-1-1:2007 General structural rules**

Most of the rules in Part 1-1 of Eurocode 9 are similar to those in BS 8118 and are generally based on the same structural principles.

The rules are, however, more extensive and allow greater refinement of the design. This can lead to more economical structures when dealing with complex or very slender sections, albeit at the expense of more extensive and complex design checking. Comparative exercises between Eurocode 9 and BS 8118 have shown that the difference in allowable loads is small for static design of typical members and details. Presently many designers use commercial software or in-house spreadsheets for code compliance checking; consequently more complex checks are not necessarily an issue. In common with other Eurocodes, the additional clauses and the need to reference other standards increases the required design effort.

In the conversion from prENV 1999 (published in the UK in 2000 as a Draft for Development) considerable efforts were made to align the format and content of Eurocode 9 with Eurocode 3, on the basis that designers familiar with steel would more easily follow the aluminium code. This does, however, ignore the fact that aluminium is a different material that has its own properties that need to be exploited and worked with differently to steel if an economic structure is to be achieved.

Several of the notable aspects that are different to the design rules of BS 8118 are listed as follows.

• Eurocode 9 (clause 1.8) requires that a specification is prepared for execution of the work, whereas BS 8118-2 acted as the specification. There are various clauses in both Eurocode 9 and EN 1090-3 where there are alternatives and/or items that have to be specified by the designer. PD 6702-1
and PD 6705-3 give guidance and recommendations to help the designer to make appropriate choices.

- The concept of reliability differentiation is introduced. Varying quality requirements, and varying degrees of assurance that the work meets the specified quality level, are implemented by the use of service categories and execution classes. Again, PD 6702-1 and PD 6705-3 give guidance and recommendations to help the designer make appropriate choices. Note that the service categories given in these documents differ from those used in EN 1090-3. (See further commentary on this in the section on BS EN 1999-1-3 below.)

- The various partial safety factors in Eurocode 9 and Eurocode 0 have different values to those in BS 8118 – however the final combination of all of the factors on the loading and resistance sides of the equation give similar results. The use of common loads and load factors for application across the whole range of structural materials is welcome.

- Eurocode 9 introduces an additional class when classifying cross sections for buckling resistance. The additional class is for sections that can form a plastic hinge with the rotation capacity required for plastic analysis.

- Eurocode 9 generally gives higher weld strengths and allows the designer to calculate differing weld metal strengths to match the weld metal specified, whereas BS 8118 used a lower-bound figure. The Beta formula used for calculating stresses in a fillet weld is slightly different to that used in BS 8118, and this combined with the higher weld metal strengths prompted the UK national annex to specify a higher value for the partial safety factor (Gamma m) for welded joints.

- Eurocode 9 gives simple design rules for the structural use of castings. In general, these are only applicable for static applications when impacts and fatigue consideration are not relevant. BS 8118 did not give any design rules for castings.

Eurocode 9 includes several informative annexes that introduce additional guidance or methods that were not covered explicitly in BS 8118. These include material on analytical models for stress–strain relationship, behaviour of materials beyond the elastic limit, plastic hinge method for continuous beams, shear lag effects and classification of joints.

Other informative annexes include and sometimes expand on information that was included in BS 8118 such as material selection, corrosion and surface protection, and properties of cross-sections.
The national annex to this Part of Eurocode 9 refers to PD 6702-1 and PD 6705-3 for additional guidance as noted above and for guidance on deflections and vibration limits in buildings. All of the informative annexes in this Part of Eurocode 9 are permitted and retain an informative status.

**BS EN 1999-1-2:2007 Structural fire design**

Structural fire design of aluminium structures was not previously covered by British Standards at all. This Part of Eurocode 9 gives comprehensive rules for determining the fire resistance of aluminium members in structures. Contrary to popular opinion, aluminium is classified as non-combustible and this section is a welcome addition to the suite of standards. Previously, knowledge of the subject was confined to a small group of experts.

The theory of the fire safety of structures in aluminium alloys is governed by the same principles and methods as those used for steel structures. Whilst most aluminium alloys start to lose some strength when held at temperatures above 100 °C and have lost a significant proportion by 350 °C, applications that need insulation for extended fire resistance are generally similar to those for steel structures.

Rules are given for structures that are unprotected, that are insulated by fire protection material or are protected by heat screens.

The national annex to this Part of Eurocode 9 does not change any of the recommended values. All of the informative annexes in this Part of Eurocode 9 are permitted and retain an informative status.

**BS EN 1999-1-3:2007 Structures susceptible to fatigue**

Eurocode 9 gives methods for calculation of fatigue life based on ‘safe life’ principles or on a damage-tolerant approach, whereas BS 8118 only gave guidance and methods for fatigue design based on ‘safe life’ principles.

The Eurocode also gives greater detail on items such as methods of structural analysis and stress concentrations applicable for fatigue design.

The methodology used by Eurocode 9 for the safe life approach is generally similar to that used in BS 8118. The basis of the design methodology is given both in the main text and Annex A of Eurocode 9 Part 1-3. The detail
category tables necessary to calculate the fatigue life are given in informative Annex J. The BSI mirror committee responsible for Eurocode 9 considered that some of the fatigue detail categories in Annex J could be subject to misinterpretation, or could give fatigue safe lives only achievable with unrealistic expectations regarding internal defects. The UK recommendation is not to use the detailed categories contained in the informative annex. Alternative detail category tables are therefore given in PD 6702-1, *Structural use of aluminium, Part 1: Recommendations for the design of aluminium structures to BS EN 1999.*

Realization of the predicted fatigue lives is dependent on achieving certain quality levels. However, it is recognized that there could be an economic penalty for over-specifying quality requirements for areas subject to static loading or low levels of cyclic stress. The alternative fatigue detail category tables are therefore associated with a series of quantified service categories that can be used with the recommendations in PD 6705-3, *Structural use of aluminium, Part 3: Recommendations for the execution of aluminium structures to BS EN 1090-3* to specify appropriate inspection regimes and acceptance criteria during execution. The alternative detailed category information is based on data previously issued in prENV 1999-2, published in the UK in 2000 as a Draft for Development.

The Eurocode also allows a damage-tolerant approach to fatigue design, i.e. some cracking is allowed to occur in service, provided that there is stable, predictable crack growth and that there is a suitable inspection regime in place. The UK recommendation is that design should be based on safe life principles whenever possible, but recognizes that there may be situations where achievement of minimum weight is a high priority and in circumstances where the necessary inspection regime is acceptable. Eurocode 9 places certain conditions on the use of the damage tolerant design method and these are reinforced and supplemented in PD 6701-2.

Informative Annex B gives guidance on assessment of crack growth by fracture mechanics. This is useful and can be used in damage tolerance calculations. Other annexes that the UK considered useful and/or acceptable for use include information on fatigue testing, stress analysis, adhesive joints and the effect of stress ratio.

Other informative annexes covering low cycle fatigue, detail category tables and hot spot stresses are not recommended for use in the UK and alternative data are given in PD 6701-2.
BS EN 1999-1-4:2007 *Cold-formed structural sheeting*

Aluminium cold-formed structural sheeting has a light weight and excellent corrosion resistance and is widely used for cladding framed structures.

This Part of Eurocode 9 covers construction where cold-formed sheeting contributes to the overall strength of a structure and also in situations where it simply acts as a cladding component that only transfers load to the structure. It is therefore suitable for the full range of calculations necessary for stressed skin design and gives specific applicable rules for this application.

BS EN 1999-1-5:2007 *Shell structures*

This Part of Eurocode 9 applies to the structural design of shell or monocoque assemblies with particular reference to cylindrical, conical, torisherial and toriconical structures. The scope includes stiffened and unstiffened shells and the associated plates, section rings and stringers that form the complete structure.

The basic premise is that analysis is carried out by finite element methods to compute stresses in the shell. The code gives criteria for the treatment of geometry and boundary conditions in the finite element models.

The structure capacity is based either on yield or buckling criteria and rules are given for the use of results from a variety of types of computer analysis incorporating linear or non-linear geometric and material properties. Formulae for critical buckling stresses for simple cylindrical and conical shapes are given in an appendix. The code also allows the user to determine the critical buckling stress from linear elastic bifurcation (eigenvalue) analysis.

Reference is made to the different levels of geometric tolerances given in BS EN 1090-3 *Execution of steel structures and aluminium structures, Part 3: Technical requirements for aluminium structures* and factors are included in the formulae for buckling strength to allow for the imperfection levels as these can have a large impact on the resultant buckling strength.
Annex A. Design of an LVL garage beam conforming to BS EN 1995-1

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NOTE This annex is to be read with chapter/section 5: Eurocode 5: Design of timber structures.

Figure A.1. Roof structure
The garage beam spans 2.58 m and is located above B, where it supports a first floor load-bearing partition and a 600 mm wide strip of the first floor.

A.1 General data

Consider an LVL beam 2580 mm long × 51 mm wide × 260 mm deep.

Material properties from BS EN 14374

\[ f_{m,0,\text{edge},k} = 44.0 \text{ N/mm}^2 \]

\[ s \text{ (used to calculate the depth factor for bending) } = 0.12 \]

\[ f_{v,0,\text{edge},k} = 4.1 \text{ N/mm}^2 \]

\[ E_{\text{mean}} = 13800 \text{ N/mm}^2 \]

\[ E_{0.05} = 11700 \text{ N/mm}^2 \]

\[ \rho_k = 480 \text{ kg/m}^3 \]

Geometrical properties

\[ b = 51 \text{ mm} \]

\[ h = 260 \text{ mm} \]

\[ \ell = 2580 \text{ mm} \]

\[ A = bh = 51 \times 260 = 13260 \text{ mm}^2 \]

\[ W = bh^2/6 = 51 \times 260^2/6 = 574.6 \times 10^3 \text{ mm}^3 \]

\[ I = bh^3/12 = 51 \times 260^3/12 = 74.70 \times 10^6 \text{ mm}^4 \]

Material factors for LVL (Service class 2 – unheated garage) from BS EN 1995-1-1

\[ k_{\text{mod}} = 0.60 \text{ permanent loads} \]

\[ k_{\text{def}} = 0.8 \text{ floor imposed – medium-term according to the UK national annex to the Eurocode} \]

\[ k_h = \min[(300/b)^{0.12}, 1.2] \text{ BS EN 1995-1-1 Clause 3.4(3)} \]

\[ k_h = \min[(300/260)^{0.12}, 1.2] = \min[1.02, 1.2] = 1.02 \]

\[ \gamma_M = 1.2 \text{ for LVL} \]

Load factors

For dead and imposed loads BS EN 1990 gives partial factors of 1.35 and 1.5 respectively. Partial load factors from BS EN 1990 National Annex Table A1.1 in the national annex to BS EN 1990 are as follows:
\[ \psi_0 = 0.7 \text{ for floor imposed loads} \\
\psi_1 = 0.5 \text{ for snow} \\
\psi_2 = 0.3 \text{ for floor imposed loads} \\
\psi_2 = 0.0 \text{ for snow} \]

A.2 Loads

A.2.1 Roof loads

Characteristic permanent load on roof on plan
\[ = 0.75 / \cos 37^\circ = 0.939 \text{ kN/m}^2 \]

Characteristic short-term load on roof on plan
\[ = 0.75 = 0.75 \text{ kN/m}^2 \]

Design permanent load on roof on plan
\[ = 1.35 \times 0.939 = 1.267 \text{ kN/m}^2 \]

Design short-term snow load on plan
\[ = 1.5 \times 0.75 = 1.125 \text{ kN/m}^2 \]

 Loads on A to B (3.85 m) per metre parallel to the beam

Characteristic permanent load
\[ = 0.939 \times 3.85 = 3.62 \text{ kN/m} \]

Characteristic short-term load
\[ = 0.75 \times 3.85 = 2.89 \text{ kN/m} \]

Design permanent load
\[ = 1.35 \times 3.62 = 4.88 \text{ kN/m} \]

Design short-term load
\[ = 1.5 \times 2.89 = 4.33 \text{ kN/m} \]

 Loads on B to C (3.04 m) per metre parallel to the beam

Characteristic permanent load
\[ = 0.939 \times 3.04 = 2.85 \text{ kN/m} \]

Characteristic short-term load
\[ = 0.75 \times 3.04 = 2.28 \text{ kN/m} \]

Design permanent load
\[ = 1.35 \times 2.85 = 3.85 \text{ kN/m} \]

Design short-term load
\[ = 1.5 \times 2.28 = 3.42 \text{ kN/m} \]

A.2.2 Rafters and ceiling joists

Characteristic weight of timber A to B per metre parallel to beam
\[ = 370 \times 9.81 \times \left[(3850 \times 44 \times 170) + (3850 \times 44 \times 145 / \cos 37^\circ)\right] / [0.45 \times 10^{12}] = 0.480 \text{ N/mm} \]

Design permanent load from A to B per metre parallel to beam
\[ = 1.35 \times 0.480 = 0.648 \text{ N/mm} \]
Annex A. Design of an LVL garage beam conforming to BS EN 1995-1

Characteristic weight of timber B to C per metre parallel to beam = \(370 \times 9.81 \times (3040 \times 44 \times \frac{145}{\cos 37^\circ}) / [0.45 \times 10^{12}]\) = 0.196 N/mm

Design permanent load from B to C per metre parallel to beam = 1.35 \times 0.196 = 0.265 N/mm

A.2.3 First floor timber frame partition

Weight of timber frame partition (Manual for the design of timber building structures to Eurocode 5, IStructE/TRADA, Table 4.5) = 0.24 kN/m²

Hence characteristic load from timber frame partition per metre along the beam = 0.24 \times 2350 / 1000 = 0.564 kN/m

Design permanent timber frame partition load per metre on the beam = 1.35 \times 0.564 = 0.762 N/mm

A.2.4 First floor dead weight

22 mm chipboard @ 600 kg/m³ = 600 \times 22 \times 9.81 / 10^6 = 0.129 kN/m²

12.5 mm firecheck plasterboard @ 850 kg/m³ = 850 \times 12.5 \times 9.81 / 10^6 = 0.104 kN/m²

200 mm Rocksilk mineral wool @ 20 kg/m³ = 20 \times 200 \times 9.81 / 10^6 = 0.039 kN/m²

Total dead weight = 0.272 kN/m²

Assuming beam replaces a floor joist spaced at 600 mm centres characteristic dead load on 600 mm = 0.6 \times 0.272 = 0.163 kN/m

Design permanent load from floor = 1.35 \times 0.163 = 0.220 kN/m

A.2.5 First floor imposed load

First floor joists at 600 mm centres support imposed floor load of 1.5 kN/m²

Hence characteristic imposed floor load per metre on the beam = 1.5 \times 0.6 = 0.90 kN/m

Design medium-term imposed floor load per metre on the beam = 1.5 \times 0.9 = 1.35 kN/m
A.2.6. Self-weight of beam

Characteristic weight of beam = \(480 \times 9.81 \times 13260/10^9\) = 0.062 kN/m
Design permanent weight of beam = 1.35 \times 0.062 = 0.084 kN/m

A.2.7 Characteristic loads on beam

\[ \sum G_k, \text{characteristic permanent load} = 0.5(3.62 + 2.85 + 0.48 + 0.196) + 0.564 + 0.163 + 0.062) = 4.36 \text{ kN/m} \]

\[ Q_{k,2}, \text{characteristic medium-term load} = 2.5 = 0.90 \text{ kN/m} \]

\[ Q_{k,1}, \text{characteristic short-term load} = 0.5(2.89 + 2.28) = 2.58 \text{ kN/m} \]

A.2.8 Design loads on beam (from A2.7)

\[ \sum G_d, \text{design permanent load} = 1.35 \times 4.36 = 5.89 \text{ kN/m} \]

\[ Q_{d,2}, \text{design medium-term load} = 1.5 \times 0.90 = 1.35 \text{ kN/m} \]

\[ Q_{d,1}, \text{design short-term load} = 1.5 \times 2.58 = 3.88 \text{ kN/m} \]

Total permanent duration design load = 5.89 kN/m
Total medium-term design load = 5.89 + 1.35 = 7.24 kN/m
Total short-term design load = 5.89 + 1.35 + 3.88 = 11.12 kN/m

Dividing the three design values by the values of \(k_{\text{mod}}\) for the corresponding load durations (0.6, 0.8, 0.9) we obtain 9.82, 9.05 and 12.36, so it can be seen that the short-term load case is critical.

A.3 Critical short-term load case – normal design situation

A.3.1 Design values of load and strength properties

The design value of the load for the short-term load case

\( (\text{BS EN 1990} \ (6.10)) = \sum G_d + Q_{d,1} + \psi_{0.2} Q_{d,2} = 5.89 + 3.88 + 0.7 \times 1.35 = 10.72 \text{ kN/m} \)
Design values of strength properties for the short-term load case
\[ f_{m,d} = f_{m,k} \times k_h \times k_{mod}/\gamma_M = 44.0 \times 1.02 \times 0.90/1.2 \quad = 33.7 \text{ N/mm}^2 \]
\[ f_{v,d} = f_{v,k} \times k_{mod}/\gamma_M \quad = 3.08 \text{ N/mm}^2 \]

A.3.2 Shear force and bending moment

\[ F_{v,d}, \text{ maximum design shear force} = 10.72 \times 2580/2 \quad = 13830 \text{ N} \]
\[ M_{d}, \text{ maximum design bending moment} = 10.72 \times 2580^2/8 \quad = 8.92 \times 10^6 \text{ Nmm} \]

A.3.3 Shear strength

Design shear stress \( \tau_d = 1.5 F_{v,d}/A = 1.5 \times 13830/13260 = 1.56 \text{ N/mm}^2 \)

\( f_{v,d} \) of 3.08 > 1.56, therefore shear strength is adequate

A.3.4 Bending strength

Design bending stress \( \sigma_{m,d} = M_d/W_y = 8.92 \times 10^6/574.6 \times 10^3 = 15.52 \text{ N/mm}^2 \)

\( f_{m,d} \) of 33.7 > 15.52, therefore bending strength is adequate

A.3.5 Bearing strength

This will be governed by the bearing area required in the blockwork wall.

A.3.6 Deflection

Serviceability load on beam (partial factors = 1.0)
(BS EN 1990 (6.14b))
\[ p_{ser} = \Sigma G_k + Q_{k,1} + Q_{k,2} = 4.36 + 2.58 + 0.9 \quad = 7.84 \text{ N/mm} \]
Quasi-permanent creep load on beam (BS EN 1990 (6.16b))
\[ p_{creep} = k_{def}(\Sigma G_k + \psi_{2,1}Q_{k,1} + \psi_{2,2}Q_{k,2}) = 0.8(4.36 + 0 \times 2.58 + 0.3 \times 0.9) \quad = 3.70 \text{ N/mm} \]
Hence final bending deflection

\[ = 5(p_{ser} + p_{creep})^{ε^4/384E_{mean}I} \]

\[ = 5 \times (7.84 + 3.70) \times 2580^{4}/(384 \times 13800 \times 74.70 \times 10^6) \]

\[ = 6.46 \text{ mm} \]

Final deflection limit for members with attached plasterboard from the UK national annex to BS EN 1995-1-1

\[ = \ell/250 = 2580/250 \]

\[ = 10.32 \text{ mm} \]

10.32 > 6.46 therefore the bending stiffness is adequate.

(A shear deflection calculation is unnecessary since shear deflection is normally < 10% bending deflection.)

The next smaller standard depth of LVL is 200 mm. This would deflect by

\[ 6.46 \times (260/200)^3 = 14.19 \text{ mm} \]

which exceeds the recommended deflection limit of 10.32 mm.

Therefore the selected 51 mm × 260 mm section is adequate.

4 Fire – accidental design situation

4.1 Charring rates

According to BS EN 1995-1-2 Clause 3.4.3.3(2), 12.5 mm thick Type A or Type F gypsum plasterboard will provide 21 min of full fire protection for any type of softwood beam. After this a beam protected by Type A plasterboard will char at a rate of 0.8 mm/min (see Table 3.1 of BS EN 1995-1-2) on all sides exposed to fire, and a beam protected by Type F (firecheck) plasterboard will char at a rate of 0.775 × 0.8 = 0.62 mm/min (BS EN 1995-1-2 Clause 3.4.3.2(1) and (2)). The beam will be designed with initial protection from fire to withstand 30 min of fire.

4.2 Charring depth

Using the reduced cross-section method in BS EN 1995-1-2 Clause 4.2.2 as specified in the UK national annex,

\[ d_{ef} = \text{effective charring depth on each face} = d_{char,n} + d_0 \]

where \( d_{char,n} = \beta_{ui} \text{ mm} \)
Annex A. Design of an LVL garage beam conforming to BS EN 1995-1

\[ d_0 = 7 \text{ mm} \]
\[ \beta_n = \text{notional charring rate} = 0.62 \text{ mm/min as calculated above} \]
\[ t = \text{time from start of charring} = 9 \text{ min} \]

Hence \[ d_{ef} = 0.62 \times 9 + 7 = 12.58 \text{ mm} \]
So the width of 51 mm decreases by \( 2 \times 12.58 \text{ mm} \) to 25.84 mm.
The depth of 260 mm decreases by 12.58 mm to 247.4 mm.

### 4.3 Properties and factors

**Geometrical properties**

\[ A_{\text{fi}} = 25.84 \times 247.4 = 6393 \text{ mm}^2 \]
\[ W_{\text{fi}} = 25.84 \times 247.4^2/6 = 263.6 \times 10^3 \text{ mm}^3 \]
\[ I_{\text{fi}} = 25.84 \times 247.4^3/12 = 32.61 \times 10^6 \text{ mm}^4 \]

Factors for LVL (Accidental loading, fire) from BS EN 1995-1-1 and BS EN 1995-1-2

\[ K_{\text{mod,fi}} = 1.0 \quad \text{(BS EN 1995-1-2 Clause 4.2.2(5))} \]
\[ k_{\text{def}} = 0.8 \]
\[ k_{h,\text{fi}} = \min[(300/h)^{0.12}, 1.2] \quad \text{(BS EN 1995-1-1 Clause 3.4(3))} \]
\[ = \min[(300/247.4)^{0.12}, 1.2] = \min[1.61, 1.2] = 1.2 \]
\[ \gamma_{M,\text{fi}} = 1.0 \text{ for LVL} \]

Partial load factors from BS EN 1990 National Annex Table A1.1

\[ \psi_1 = 0.2 \text{ for snow} \]
\[ \psi_2 = 0.3 \text{ for floor imposed loads} \]

### 4.4 Design values of load and strength properties

Design load for accidental situations:

\[ = \Sigma G_k + \psi_{1,1} Q_{k,1} + \psi_{2,1} Q_{k,2} \quad \text{(BS EN 1990 expression (6.11b))} \]

As before:

\[ \Sigma G_k = 4.36 \text{ kN/m (dead)} \]
\[ Q_{k,1} = 2.58 \text{ kN/m (snow)} \]
\[ Q_{k,2} = 0.90 \text{ kN/m (floor imposed)} \]

Hence design load for fire = \( 4.36 + 0.2 \times 2.58 + 0.3 \times 0.90 = 5.15 \text{ kN/m} \)
20% fractile strength properties for LVL are obtained by increasing the character- 
istic values by a factor of 1.1 (BS EN 1995-1-2 Clause 2.3(3)).

Design values of strength properties:
\[
f_{m,d} = 1.1 f_{m,k} \times k_{h,fi} \times k_{mod,fi}/\psi_{M,fi} = 1.1 \times 44.0 \times 1.2 \times 1.0/1.0 = 58.1 \text{N/mm}^2
\]
\[
f_{v,d} = 1.1 f_{v,k} \times k_{mod,fi}/\psi_{M,fi} = 1.1 \times 4.1 \times 1.0/1.0 = 4.51 \text{N/mm}^2
\]

4.5 **Shear force and bending moment**

\[
F_{v,d,fi}, \text{maximum design shear force} = 5.15 \times 2580/2 = 6644 \text{N}
\]
\[
M_{d,fi}, \text{maximum bending moment} = 5.15 \times 2580^2/8 = 4.29 \times 10^6 \text{Nmm}
\]

4.6 **Shear strength**

Design shear stress \( \tau_d = 1.5 F_{v,d,fi}/A_{fi} = 1.5 \times 6644/6393 = 1.56 \text{N/mm}^2 \)

\( f_{v,d} \) of 4.51 > 1.56, therefore the shear strength is adequate.

4.7 **Bending strength**

Design bending stress \( \sigma_{m,d} = \frac{M_{d,fi}}{W_{fi}} = \frac{4.29 \times 10^6}{263.6 \times 10^3} = 16.27 \text{N/mm}^2 \)

\( f_{m,d} \) of 58.1 > 16.27, therefore the bending strength is adequate.

4.8 **Bearing strength**

This will be governed by the bearing area required in the blockwork wall. BS EN 1995-1-2 states that for fire design the effects of compression perpendicular to the grain may be ignored.

4.9 **Deflection**

There are no recommended deflection limits for fire design according to BS EN 1995, and deformation has to be considered only where it affects the means of protection or the design criteria for separating elements (BS EN 1995-1-2 Clause 2.1.1(3)). In this case the plasterboard is required to retain its integrity for the first 21 min of a fire.
As previously calculated, in normal design the serviceability load is 7.84 N/mm and the quasi-permanent creep load is 3.70 N/mm giving a total design load of 11.54 N/mm and a final bending deflection of 6.46 mm with an $I$ value of $74.70 \times 10^6$ mm$^4$.

In fire design the reduced design load is 5.15 N/mm and the quasi-permanent creep load is 3.70 N/mm giving a total design load of 8.85 N/mm. The final $I_f$ value is $32.61 \times 10^6$ mm$^4$.

By scaling the bending deflection at 21 min =

$$6.46 \times 8.85 / 11.54 = 4.95 \text{ mm}$$

$10.32 > 4.95$ so the plasterboard should not crack at this stage.

By scaling the final bending deflection in fire with a reduced cross-section =

$$4.95 \times 74.70 / 32.61 = 11.34 \text{ mm}$$

This is only a little over the recommended final deflection limit of 10.32 mm previously calculated for members with attached plasterboard, so it is unlikely to cause any serviceability problem. Therefore the bending stiffness is adequate.

Therefore the selected 51 mm $\times$ 260 mm LVL beam should be protected by one layer of 12.5 mm Type F gypsum plasterboard with all joints filled before skimming.
Web contact details for further information and training

Aluminium matter
http://aluminium.matter.org.uk/content/html/eng/default.asp?catid=&pageid=1

BSI
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http://www.eurocode6.org/
eurocode7.com
http://eurocode7.com/

Eurocode expert
http://www.eurocodes.co.uk/

International Masonry Society
http://www.masonry.org.uk/

Joint Research Centre
http://eurocodes.jrc.ec.europa.eu/

The Concrete Centre
http://www.concretecentre.com/

The Concrete Society
http://www.concrete.org.uk/

The Institution of Civil Engineers
http://www.ice.org.uk/homepage/index.asp

The Institution of Structural Engineers
http://www.istructe.org/
The Society for Earthquake and Civil Engineering Dynamics
http://www.seced.org.uk/

The Steel Construction Institute
http://www.steel-sci.org/

TRADA
http://www.trada.co.uk/
The Essential Eurocodes Transition Guide

Edited by John Roberts

Structural Eurocodes are a suite of design codes which will harmonize technical specifications for building and civil engineering works across Europe.

Their introduction in March 2010 requires the withdrawal of more than 50 British Standards. The change has been described as the single most important change to construction standards ever. It is expected that Eurocodes will not just dominate building design in the UK and Europe, but also have a major impact on many other parts of the world.

The Essential Eurocodes Transition Guide brings together leading experts from the Eurocode community to share key insights into the use and application of the new codes, focusing on how users can make the transition as quickly and efficiently as possible.

In addition to coverage of the underlying structure, and industry view of the Eurocodes, individual chapters address the technical aspects of each Eurocode and will be an invaluable aid to practising civil and structural engineers, as well as regulators, academics and students and all those involved with the structure and design of public sector dwellings.

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