Timber Structures
(material, design & case study)

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Year 2 Architecture
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References

[www.trada.co.uk](http://www.trada.co.uk) – Timber Research and Development Association

Specific student resource area
Contents

• Material
• Timber products
• Design
• Case studies
Trees and wood

“The best friend of man is the tree. When we use the tree respectfully and economically, we have one of the greatest resources on the earth”

Frank Lloyd Wright

- Approximately 20% of world's land surface covered by trees
- 97% of all softwood used in Europe comes from European forests
- 30% increase in wooded area in Europe between 1990-2000
- Trees are on average 60-80 years old on harvest
- Primary softwoods used for construction are spruce (whitewood) and pine (redwood)
Forest distribution

www.earthobservatory.nasa.gov/Features/ForestCarbon/page1.php
Trees and carbon

- Wood is about 50% carbon (by dry mass)
- $\times 3.67$ to convert C to CO2
- Broadleaf forests 100-250 tC per ha
- Conifer plantations 70-90 tC per ha
- Carbon uptake 4 tC per ha per year in fast growing stands
## Trees and carbon

Table 6.6
Timber carbon content (tCO$_2$e m$^{-3}$), typical ranges of maximum mean annual volume increment (MMAI: m$^3$ ha$^{-1}$ year$^{-1}$) and ages of MMAI for a range of conifers and broadleaves grown in Britain or which might be considered for planting under anticipated climate change (after Edwards and Christie, 1981; Lavers, 1983).

<table>
<thead>
<tr>
<th>Conifers</th>
<th>Scientific name</th>
<th>Carbon content</th>
<th>MMAI</th>
<th>Age</th>
<th>Broadsleaves</th>
<th>Scientific name</th>
<th>Carbon content</th>
<th>MMAI</th>
<th>Age</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sitka spruce</td>
<td><em>Picea sitchensis</em> (Bong.) Carr.</td>
<td>0.62</td>
<td>8–24</td>
<td>64–46</td>
<td>Oak</td>
<td><em>Quercus robur</em> L., <em>Q. petraea</em> (Matt.) Liebl.</td>
<td>1.12</td>
<td>4–8</td>
<td>90–68</td>
</tr>
<tr>
<td>Norway spruce</td>
<td><em>Picea abies</em> L. Karst.</td>
<td>0.64</td>
<td>8–20</td>
<td>84–65</td>
<td>Birch</td>
<td><em>Betula pendula</em> (Roth.), <em>B. pubescens</em> (Ehrh.)</td>
<td>1.10</td>
<td>4–12</td>
<td>40–40</td>
</tr>
<tr>
<td>Scots pine</td>
<td><em>Pinus sylvestris</em> L.</td>
<td>0.84</td>
<td>6–12</td>
<td>82–69</td>
<td>Sweet chestnut</td>
<td><em>Castanea sativa</em> Mill.</td>
<td>0.84</td>
<td>4–10</td>
<td>50–41</td>
</tr>
</tbody>
</table>
Trees and carbon

• UK Forestry Commission report
  – UK woodland could provide 10% CHG abatement (Scotland already 12%).
  – UK ‘forest carbon sink’ reducing from 16mt CO2 in 2004 to 5mt CO2 in 2020.
  – Wood fuel potential to save 7mt CO2 in UK.
  – Wood substitution potential to save 4mt CO2 in UK.
  – Estimated 70mt CO2 stored in timber housing in UK.
UK government and trees

- Recognises that in 2007 forest in England removed 2.9mt CO2, but that this rate is falling.
- Recognises that a major woodland creation scheme is required, target of 10,000 ha per year for 15 years (to remove 50mt CO2 by 2050).
- Woodland creation can also help with employment creation, flood alleviation, water quality improvement and support for wildlife.
- Recognises that woodland resource (timber) needs to be used for fuel and construction.

Woodland creation is a very cost-effective way of fighting climate change over the long term, but it requires an upfront investment.
Engineering materials

- 10 billion tonnes pa of engineering materials used globally
- 1.5t person pa, main components are concrete, wood, steel, asphalt, glass, brick
- Concrete is by far the dominant engineering material (factor 10) and responsible for some 5% of global CO2 emissions
- 10 billion tonnes pa of oil and coal used globally
UK construction materials

• 400mt construction materials annually
  – 1.4mt steel
  – 100mt concrete
  – 7.5mt timber

• UK is one of world’s largest importers of timber
Wood properties

• **Timber is anisotropic**
  - 5 to 10x weaker across the grain (similar to bundle of straws)

• **Affected by moisture**
  - 50% moisture content natural state, 12-20% in use (hygroscopic)
  - 20-40% loss in strength in damp conditions

• **Strength**
  - 100N/mm² defect free, typical 16-24N/mm² softwoods used in UK are designed using 6N/mm²
  - Direct correlation strength, stiffness and density
  - Best at resisting short terms loads, creeps under long term load (approx 40% weaker)
Sustainable timber

**The Forest Stewardship Council (FSC)**
Independent non-governmental organisation supported by WWF
www.fsc-uk.org

**Pan European Forest Certification Council (PEFC)**
Voluntary private sector initiative
www.pefc.co.uk
46 million hectares of managed European forest endorsed

**Forests Forever Campaign (FFC)**
Independent advisory body initiated by the Timber Trade Federation
www.forestsforever/org.uk
Embodied energy

Energy cost represents 10% of material cost

Energy cost represents 100% of material cost

Energy cost represents 1% of material cost
Structural performance and ECO2

- Timber beam 15kgCO2
- Concrete beam 50kgCO2
- Steel beam 60kgCO2
- But.....60kgCO2 stored in timber beam

- Timber CLT frame
- Concrete flat slab frame
- Steel frame and holorib concrete floor

embodied CO2 (kg/m2)
**CO2 stories for timber and concrete**

1m³ timber

-650kg CO2

1m³

+150kg CO2

+650kg CO2

+150kg CO2

1m³ concrete

+500kg CO2

2500KWhr

+700kg CO2

+1200kg CO2
Timber products

- Sawn timber
- Engineered timber
- Manufacture & fabrication
- Structural systems
Sawn timber

• Strength graded
  – C16 and C24 (spruce or pine typically)
  – D30 (oak)
  – Inherent defects in timber mean factor of safety in region of 3 used

• Dimensions limited
  – Typically up to 225mm deep sections
  – Kiln drying limits widths typically to 75mm and lengths to 6m
Engineered timber

- Reduces effect of defects
- Glues and mechanical fixing have played important role
- Different types:
  - Layer – Glulam, Plywood, CLT, LVL
  - Particle – Chipboard, PSL, OSB
  - Fibre – MDF, Hardboard
Engineered timber

• Layered/Laminated
  – Glue laminated timber (glulam)
  – Laminated veneer lumber (LVL)
  – Cross laminated timber panels (CLT)
• Particle
  – Orientated strand board (OSB)
  – Particle board (chipboard)

1. Sawing  2. Rotary peeling  3. Clipping
4. Drying  5. Gluing       6. Lay up
• **Statistics**
  - 2.95m wide (typical 2.4m)
  - 16.5m long (typical 13.5m)
  - Typical 50mm to 300mm thick (500mm thk possible)
  - Strength grade C24
  - Spruce
CLT product

- 12 European CLT manufacturers?
  - KLH 700,000m²
  - Stora Enso 500,000m²
  - Mayr-Melnhof Kaufmann 500,000m²
  - Binderholz 400,000m²
  - Merk Finnforest 200,000m²
  - Schilliger 200,000m²

- Total combined output say 3,000,000m²?
  - Equivalent to over 1,000,000m² of new buildings
  - Over 300,000tCO2 sequestered

- Approximately 40,000ha of forest required to support 3million m² of CLT production
Engineered timber

• **Timber cassettes**
  – Sometimes referred to as stressed skin
  – Can have insulation integrated (SIPs – structural insulated panels)
  – Beams positively connected (glued, screwed, nailed) to a top and/or bottom sheet material. Together the beams (web) and sheeting (flange) make for a highly efficient spanning element
  – Can be used as roof or floor elements
  – In UK longest recent cassette is 25m roof span over Darlaston Pool in Walsall in 2000.
Fixing technology
Cutting technology
The parts can also be drawn directly with the EKP program.
Structure types

**Framed**
Traditional column and beam frame with primary and secondary beam layouts.

**Platform**
Typically cellular construction built in situ with a series of wall studs supporting floor joist. Built up level by level.

**Panelised or Volumetric**
Pre-fabricated wall and floor panels fixed on site to give fast track construction.
Design

- Strength
- Stiffness
- Design codes
- Rules of thumb
Design

<table>
<thead>
<tr>
<th></th>
<th>Bending parallel to grain N/mm²</th>
<th>Tension parallel to grain N/mm²</th>
<th>Compression parallel to grain N/mm²</th>
<th>Compression perpendicular to grain N/mm²</th>
<th>Shear parallel to grain N/mm²</th>
<th>Modulus of elasticity MEAN N/mm²</th>
<th>Modulus of elasticity MINIMUM N/mm²</th>
<th>Density kg/m³</th>
</tr>
</thead>
<tbody>
<tr>
<td>C16 Spruce</td>
<td>5.3</td>
<td>3.2</td>
<td>6.8</td>
<td>2.2</td>
<td>0.67</td>
<td>8800</td>
<td>5800</td>
<td>370</td>
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<tr>
<td>D40 Oak</td>
<td>12.5</td>
<td>7.5</td>
<td>12.6</td>
<td>3.9</td>
<td>2.00</td>
<td>10800</td>
<td>7500</td>
<td>700</td>
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</table>

- Strength and stiffness depends on a number of factors:
  - Species of timber
  - Moisture content of timber
  - Duration of load
  - Direction of stress within timber
  - Defects present in timber
  - Slenderness
- Direct correlation between density and strength
### Load duration factors:
- Long term 1.00 (ie dead + live load)
- Medium term 1.25 (ie dead + snow load)
- Short term 1.50 (ie dead + live + snow load)
- Very short term 1.75 (ie dead + live + snow + wind load)

### Slenderness factors:
- 1.00 at slenderness ratio 0
- 0.75 at slenderness ratio 50 (ie 275mm wide column 4m long)
- 0.40 at slenderness ratio 100 (ie 275mm wide column 8m long)
- 0.10 at slenderness ratio 200 (ie 275mm wide column 12m long)

### Moisture content:
- 40% to 20% reduction in strength and stiffness for 20%+ moisture content

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### Maximum load-bearing capacity, uniformly distributed loads (tonnes)

<table>
<thead>
<tr>
<th>Glulam section in mm</th>
<th>2.0</th>
<th>2.5</th>
<th>3.0</th>
<th>3.5</th>
<th>4.0</th>
<th>4.5</th>
<th>5.0</th>
<th>5.5</th>
<th>6.0</th>
<th>6.5</th>
<th>7.0</th>
<th>7.5</th>
<th>8.0</th>
<th>8.5</th>
<th>9.0</th>
<th>9.5</th>
<th>10.0</th>
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<tbody>
<tr>
<td>56 x 225</td>
<td>2.37</td>
<td>1.88</td>
<td>1.44</td>
<td>1.04</td>
<td>0.78</td>
<td>0.60</td>
<td>0.48</td>
<td>0.38</td>
<td>0.31</td>
<td>0.26</td>
<td>0.21</td>
<td>0.17</td>
<td>0.14</td>
<td>0.12</td>
<td>0.10</td>
<td>0.08</td>
<td>0.06</td>
</tr>
<tr>
<td>66 x 315</td>
<td>5.53</td>
<td>4.40</td>
<td>3.64</td>
<td>3.10</td>
<td>2.63</td>
<td>2.05</td>
<td>1.64</td>
<td>1.34</td>
<td>1.11</td>
<td>0.93</td>
<td>0.79</td>
<td>0.67</td>
<td>0.58</td>
<td>0.50</td>
<td>0.44</td>
<td>0.38</td>
<td>0.32</td>
</tr>
<tr>
<td>90 x 315</td>
<td>7.54</td>
<td>5.99</td>
<td>4.97</td>
<td>4.23</td>
<td>3.58</td>
<td>2.80</td>
<td>2.24</td>
<td>1.83</td>
<td>1.51</td>
<td>1.27</td>
<td>1.07</td>
<td>0.92</td>
<td>0.79</td>
<td>0.68</td>
<td>0.59</td>
<td>0.52</td>
<td>0.45</td>
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<tr>
<td>90 x 360</td>
<td>8.86</td>
<td>7.67</td>
<td>6.36</td>
<td>5.42</td>
<td>4.72</td>
<td>4.17</td>
<td>3.40</td>
<td>2.78</td>
<td>2.31</td>
<td>1.94</td>
<td>1.65</td>
<td>1.42</td>
<td>1.23</td>
<td>1.07</td>
<td>0.94</td>
<td>0.82</td>
<td>0.73</td>
</tr>
<tr>
<td>90 x 405</td>
<td>9.95</td>
<td>9.61</td>
<td>7.97</td>
<td>6.80</td>
<td>5.92</td>
<td>5.24</td>
<td>4.69</td>
<td>4.01</td>
<td>3.34</td>
<td>2.82</td>
<td>2.40</td>
<td>2.07</td>
<td>1.80</td>
<td>1.57</td>
<td>1.38</td>
<td>1.22</td>
<td>1.08</td>
</tr>
<tr>
<td>115 x 405</td>
<td>12.72</td>
<td>12.27</td>
<td>10.18</td>
<td>8.68</td>
<td>7.56</td>
<td>6.69</td>
<td>5.99</td>
<td>5.12</td>
<td>4.26</td>
<td>3.60</td>
<td>3.07</td>
<td>2.65</td>
<td>2.30</td>
<td>2.01</td>
<td>1.77</td>
<td>1.56</td>
<td>1.39</td>
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<tr>
<td>115 x 630</td>
<td>19.80</td>
<td>19.80</td>
<td>19.80</td>
<td>19.80</td>
<td>17.86</td>
<td>15.83</td>
<td>14.20</td>
<td>12.87</td>
<td>11.76</td>
<td>10.82</td>
<td>10.01</td>
<td>9.31</td>
<td>8.70</td>
<td>8.16</td>
<td>7.16</td>
<td>6.39</td>
<td>5.73</td>
</tr>
</tbody>
</table>
Rules of thumb

- Typical span/depth ratios
  - Domestic floors
  - Office floors
  - Rafters
  - Beams
  - Arch
  - L/20
  - L/15
  - L/24
  - L/10 to 15
  - L/50

- Typical span/depth ratios
  - Triangular trusses
  - Rectangular trusses
  - Stressed skin panels
  - Solid timber panels
  - L/5 to 8
  - L/10 to 15
  - L/30 to 40
  - L/30
Timber beam design example

A glulam timber floor beam spanning \( l = 7.5 \text{m} \)
Spacing of beams is 3m
Lightweight floor construction = 1 kN/m²
Office floor loading = 2.5 kN/m²
ie: beam loading \( w = 3 \text{m} \times (1 + 2.5) = 10.5 \text{kN/m} \)

**Shear force diagram:**

\[
\text{SF} = \frac{wl}{2}
\]

\[
39.4 \text{kN}
\]

**Bending moment diagram:**

\[
\text{BM} = \frac{wl^2}{8}
\]

\[
73.8 \text{kNm}
\]

**Design:**

Choose initial beam size based on span to depth ratios
For timber beams span to depth ratios of 10-15 are recommended, therefore \( 7.5 \text{m} / 12.5 = 600 \text{mm} \)
From glulam supplier information try a beam 115mm x 630mm & C24 timber grade

**Allowable stresses:**

As the glulam beam is made from C24 grade timber we use C24 timber allowable stresses:
Allowable bending stress = \( 7.5 \text{N/mm}^2 \times K_7 \times K_{15} = 9.6 \text{N/mm}^2 \)
Modulus of elasticity = \( 10,800 \text{N/mm}^2 \times K_{20} = 11,550 \text{N/mm}^2 \)

*Allowable stresses in glulam beams are affected by a number of factors (number of laminations, depth of beam etc.)
Assumed that beam is fully restrained by floor against lateral torsional buckling

**Bending check:**

Bending stress in beam = \( \frac{BM}{z} = 73.8 \times 6 = 9.7 \text{N/mm}^2 \)
Where \( z = \) elastic modulus = \( \frac{bd^2}{6} \)
115x630²

Applied stress is marginally higher than allowable

**Deflection check:**

Deflection = \( \frac{5wl^4}{384EI} = \frac{5 \times 10.5 \times 7500^4 \times 12}{384 \times 11,550 \times 115 \times 630^3} = 15.6 \text{mm} \)
Where \( l = \) second moment area = \( \frac{bd^3}{12} \)

Allowable deflection = 0.003 x span = 22.5mm

**Embodied CO2:**

\( = 0.115 \times 0.63 \times 160 \)
\( = 12 \text{kgCO2/m} \)

**Sequestered CO2:**

\( = 0.115 \times 0.63 \times 650 \)
\( = 47 \text{kgCO2/m} \)
Connections

- Direct bearing
- Mechanical
- Glued
Connections

- Glued connections strongest and stiffest
- Connections with multiple small fixings (i.e., nails or screws) are also efficient
• Preservative treatments
• Fire
Durability

- Timber durability relates to resistance to fungal or insect attack
- Fungal attack can only occur where moisture content of timber is 20%+
- BS 5268 and Eurocode 5 define 3 service classes:
  - service class 1 internal heated environment (tmc 12%)
  - service class 2 covered heated/unheated (tmc 15-18%)
  - service class 3 external (tmc 20%+)
- Service class 1 and 2 timber should be protected from weather on site and not exceed moisture content of 20% and 24% respectively
Durability

Timber Durability
BS EN 350-2 : 1994 lists the natural durability of solid wood to wood-destroying fungi for selected species. A five class system is used to define the resistance of heartwood:

- Very durable
- Durable
- Moderately durable
- Slightly durable
- Not durable (includes all sapwood)

Hazard Class
BS EN 335-2 : 1992 lists the various hazard classes:

- Internal dry, insect risk
- Internal, risk of wetting
- External, above ground, frequent wetting
- Direct soil or fresh water contact
- Marine situations

<table>
<thead>
<tr>
<th>Common name</th>
<th>Durability class</th>
<th>Movement class</th>
<th>Density range &amp; mean density Kg/m³</th>
<th>Treatability class</th>
<th>Relative price</th>
</tr>
</thead>
<tbody>
<tr>
<td>Opepe ²</td>
<td>Very durable</td>
<td>Small</td>
<td>740-750-780</td>
<td>High</td>
<td></td>
</tr>
<tr>
<td>Iroko ³</td>
<td>Very durable</td>
<td>Small</td>
<td>630-650-670</td>
<td></td>
<td></td>
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<tr>
<td>Robinia ⁴</td>
<td>Highly durable or durable</td>
<td>Medium</td>
<td>720-740-800</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sweet chestnut</td>
<td>Durable</td>
<td>Small</td>
<td>540-590-650</td>
<td></td>
<td></td>
</tr>
<tr>
<td>European oak</td>
<td>Durable</td>
<td>Medium</td>
<td>670-710-760</td>
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<tr>
<td>Western red cedar</td>
<td>Durable</td>
<td>Small</td>
<td>330-370-390</td>
<td></td>
<td>High</td>
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<tr>
<td>Douglas fir</td>
<td>Moderately durable</td>
<td>Small</td>
<td>510-530-550</td>
<td></td>
<td>Medium</td>
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<tr>
<td>European larch ¹</td>
<td>Moderately durable</td>
<td>Small</td>
<td>570-600-650</td>
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<td></td>
</tr>
<tr>
<td>Western red cedar</td>
<td>Moderately durable</td>
<td>Small</td>
<td>330-370-390</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hemlock/Scots pine ³</td>
<td>Moderately durable</td>
<td>Medium</td>
<td>560-590-540</td>
<td></td>
<td>Low</td>
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<tr>
<td>Douglas fir</td>
<td>Moderately durable or slightly durable</td>
<td>Small</td>
<td>470-510-520</td>
<td>4 2-3</td>
<td>Medium</td>
</tr>
<tr>
<td>Lodgepole pine ⁵,⁶</td>
<td>Moderately durable or slightly durable</td>
<td>Small</td>
<td>420-460-470</td>
<td>3-4 1</td>
<td>Low</td>
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<tr>
<td>Norway spruce</td>
<td>Slightly durable</td>
<td>Medium</td>
<td>440-460-470</td>
<td>3-4 1</td>
<td>Low</td>
</tr>
<tr>
<td>European elm ⁶</td>
<td>Slightly durable</td>
<td>Small</td>
<td>610-650-680</td>
<td>2-3 2</td>
<td>Low</td>
</tr>
<tr>
<td>Japanese or hybrid larch ⁷</td>
<td>Slightly durable</td>
<td>Small</td>
<td>470-600-650</td>
<td>4 2</td>
<td>High</td>
</tr>
<tr>
<td>Western hemlock ⁸</td>
<td>Slightly durable</td>
<td>Small</td>
<td>470-490-510</td>
<td>2 3 1</td>
<td>Low</td>
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<tr>
<td>Sitka spruce ⁹</td>
<td>Not durable (heartwood)</td>
<td>Small</td>
<td>400-440-450</td>
<td>3 2-3</td>
<td>Low</td>
</tr>
</tbody>
</table>

Key:

- Approach 1: Using natural durability
  - The heartwood of these species is generally suitable for use as external cladding without preservative treatment or a water repellent coating. Sapwood should always be removed.

- Approach 2: Using timber preservation
  - The standard approach to using these species for external cladding is to pressure treat the timber with a suitable preservative. Sapwood is not removed. Species that can be easily treated with preservatives are preferred.

- Approach 3: Using careful detailing combined with measures that reduce water uptake
  - An alternative, but more uncertain approach is to use careful detailing to promote drainage and ventilation, combined with a water repellent, but moisture vapour permeable, coating. The sapwood is not removed and so the use of a species with relatively impermeable sapwood may also reduce moisture uptake. Regular maintenance is essential with this approach.
Durability

• Treatments
  – New regulation has mean the introduction of new products.
  – Chemical treatment (pressure impregnation or surface applied)
  – Thermowood (heat treated, no chemical treatment)
  – Accoya (modified wood)
**Fire**

- **Recent high profile cases**
  - Colindale – during construction

- **Fire resistance**
  - Large sections char at rate of 0.6-0.7mm/min
  - Oversize timber sections to provide structural integrity during fire (ie timber can be unprotected)

- **Spread of flame**
  - For large sections treatment is still required by building regulations
Case studies

• UK projects
  - Faculty of Education, Cambridge
  - SmartLife Building Academy, Cambridge
  - Mossbourne Academy, London
  - British Geological Survey, Nottingham
  - St John Fisher School, Peterborough
  - Open Academy
  - City Academy
Faculty of Education, Cambridge
HOMERTON COLLEGE – HIDDEN JOIST CONNECTION

THE BUILDING DESIGN FEATURED EXPOSED STRUCTURAL TIMBER THROUGHOUT. IN PARTS THIS REQUIRED HIDDEN CONNECTION DETAILS TO OPTIMISE THE TIMBER DESIGN’S AESTHETIC QUALITIES AND PROVIDE 1HR FIRE PROTECTION.

GLULAM TIMBER JOIST

JOIST ENDS MACHINED TO TAKE HIDDEN FIXING SYSTEM

STEEL FIXING INSERTS

FIT FLUSH WITH BEAM TOPS

GLULAM PRIMARY BEAMS

600mm

JOISTS

GLULAM TIMBER COLUMN

NOTCHED FOR FLUSH FIT

FIXING SCREWS

25mm T7G PLYWOOD

30mm ROCKWOOL RW2 MINERAL WOOL

45mm LVL SOFFIT LINING

FLOOR CONSTRUCTION

RAISED FLOOR

FLOOR VOID

450mm

65mm

45mm

JOISTS
SmartLife, Cambridge
Section: 1:50 @ A3

- Typical roof rafters: 50x175mm at 600 c/c, Span 3.0m. Note possible snow drift loading.
- Glulam framing to flat roof: 160x190mm C7 cantilever cut to pick up wall.
- Typical glulam tie beams: 115x225mm C7.
- Glulam columns to edge of floor: 165x180mm C7 fire barrier, 265x225mm C7 exposed.
- Glulam tie beam: 115x225mm C7.
- ECI floor joists: 241/9065 d=241mm, 300mm centres.

- Roof design data:
  - DL 0.75 kPa
  - LL 0.19 kPa

- Floor design data:
  - DL 2.50 kPa
  - LL 3.00 kPa
  - 4.00 kPa: corridors & lecture theatre.

- Timber roof jasps: 205x150mm C16 at 600 c/c, Span 2.5m.
- Glulam roof purlins: 195x225mm C7, Span 4.0m, Spacing 4.5m.
- Glulam bowling roof: 205x220mm C17, Span 4.5m, Spacing 4.7m.
- Glulam spliced strand: 10mm, 1m below & rafter.

- OSB or plywood floor plate acting as stressed skin, providing stability, fixed and screwed to floor beam. 605x 15mm link.
- ECI floor joists: 241/9065 d=241mm, 300mm centres, Span 3.75m. Supporting heavy floor finishes and imposed load.
- Glulam floor beam: 140x340mm C27, 1hr fire design, Span 8.0m, Spacing 4.1m.

- 750x750x400mm mass concrete base with HD bolts, C25 concrete subject to S1 results.
- 1250x125x600mm mass concrete base with cast in H.D. bolts to timber frame. C25 concrete subject to S1 investigation results.
- 60mm thick r.c. ground bearing slab laid off compacted sub-base. Typical A613 mesh. Subject to ground investigation results and movement joints.

- Glulam column C27: 270x400mm continuous over 2 storys, 1hr fire design, spacing 4.1m.

- Whitbybird
  Engineering
  SKE
  Job No: 5112
  Job Title: SmartLife
  15/08/23
  Date
  Ref. SECTION
Mossbourne Academy, London
Timber concrete composite floor
St John Fisher School, Peterborough
Open Academy, Norwich
City Academy, Norwich
Structural frame options

- Loadbearing Facade
- Crosswall
- 'Hybrid' (steel/CLT)
Other timber structures

• Buildings
• Bridges
• Etc.
Buildings
Tamedia office building - Zurich
by Shigeru Ban Architects
L’Aquila, Italy

- Earthquake rebuilding
  - 381 apartments in 2 phases
  - 11,000m³ of cross laminated timber
  - Fast track construction
Skelleftea, Sweden

- Mixed use timber building
  - 141 space multi-storey car park
  - Cross laminated timber
  - Fire engineered
Bridges
Other....