TUTORIAL KIT
OMEGA SEMESTER

PROGRAMME: BUILDING TECHNOLOGY

COURSE: BLD 532
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The contents of this document are intended for practice and leaning purposes at the undergraduate level. The materials are from different sources including the internet and the contributors do not in any way claim authorship or ownership of them. The materials are also not to be used for any commercial purpose.
Use the design data to answer questions 1-5
A timber beam with a clear span of 2.85 m supports a uniformly distributed load of 10 kN including self-weight of beam. Assume that the bearing length is 150 mm and that the ends of the beam are held in position and compression edge held in line. Determine;

1. A suitable section for the beam using timber of strength class C16 under service class 1.
2. The design moment on the beam
3. The deflection on the beam and ascertain that it is adequate
4. The lateral buckling experienced by the beam
5. That the bearing stress on the beam is adequate

Use the design data to answer questions 6-10
Design the timber floor joist for a domestic dwelling using timber of strength class C18 given that:

a) the joists are spaced at 400 mm centres;
b) the floor has an effective span of 3.8 m;
c) the flooring is tongue and groove boarding with a self-weight of 0.1 kN/m²;
d) the ceiling is of plasterboard with a self-weight of 0.2 kN/m².

Determine;

6. The design loading on the joists
7. The bending moments on the joists
8. The deflection on the joists and it’s adequacy
9. The adequacy of the lateral buckling resistance by the joists
10. The adequacy of the joists in resisting shear and buckling

11. The joists in the previous section are to be notched at the bearings with a 75 m deep notch as shown below. Check that thenotched section is still adequate.

12. Discuss the factors which influence the strength of timber and explain how the strength of timber is assessed in practice.
13. (b) A simply supported timber roof beam spanning 4 m supports a total uniformly distributed load of 12kN. Determine a suitable section for the beam using timber of strength class C16. Assume that the bearing length is 125 mm and that the compression edge is held in position.
14. (a) Give typical applications of timber in the construction industry and for each case discuss possible desirable properties.
15. (a) Discuss the factors accounted for by the modification factor $K_{12}$ in the design of timber compression members.
16. (b) Design a timber column of effective length 2.8 m, capable of resisting the following loading:
   i. Medium term axial load of 37.5 kN
   ii. Long term axial load of 30 kN and a bending moment of 300 kN mm.

17. 5. (a) Explain with the aid of sketches connection details which will give rise to the following end conditions:
   i. Restrained in position and direction
   ii. Restrained in position but not in direction
   iii. Unrestrained in position and direction.

18. (b) Design a stud wall of length 4.2 m and height 3.8 m, using timber of strength class C16 to support a long-term uniformly distributed load of 14 kN/m.

19. A symmetrically loaded internal column is required to support four beams as shown in Figure 7.29. The top can be considered to be held in position but not in direction, and the bottom to be restrained in both direction and position about both axes.

20. A lateral restraint is provided 2.2 m from the base as indicated. Assuming Service Class 2, check the suitability of a 75 mm × 150 mm, strength class C18 section to resist a long-term load of 12.0 kN and a medium-term load of 20.0 kN.

ANSWERS
Answers for questions 1-5

EFFECTIVE SPAN
Distance between centres of bearing (l) = 3000 mm

GRADE STRESS AND MODULUS OF ELASTICITY FOR C16
Values in N/mm² are as follows

<table>
<thead>
<tr>
<th>Bending parallel to grain</th>
<th>Shear parallel to grain</th>
<th>Compression perpendicular to grain</th>
<th>Modulus of elasticity</th>
</tr>
</thead>
<tbody>
<tr>
<td>σₘₙₐₙₜ</td>
<td>τₚ</td>
<td>σₘₙₜ</td>
<td>Eₗₘₙₜ</td>
</tr>
<tr>
<td>5.3</td>
<td>0.67</td>
<td>1.7</td>
<td>5800</td>
</tr>
</tbody>
</table>

MODIFICATION FACTORS
K₂, moisture content factor does not apply since the beam is subject to service class 1
K₃, duration of loading factor = 1.0
K₈, load sharing factor, does not apply since there is only a single beam

\[
k₇, \text{ depth factor } = \left( \frac{300}{h} \right)^{0.11}
\]
Assume h = 250, \( k₇ = 1.020 \)

1. BENDING

\[
M = \frac{Wl}{8} = \frac{10 \times 3}{8} = 3.75 \text{ kN m}
\]
\[
\sigma_{\text{r,adm}}(\text{assuming } h = 250) = \sigma_{\text{r,g}}(h) K₇ K₉ = 5.3 \times 1.0 \times 1.020 = 5.406 \text{ N/mm}²
\]
\[
Z_{\text{req}} \geq \frac{M}{\sigma_{\text{r,adm}}} = \frac{3.75 \times 10^6}{5.406} = 694 \times 10³ \text{ mm}³
\]
DEFLECTION

Permissible deflection \( (\delta_p) \) = 0.003 \times \text{span}

The deflection due to shear \( (\delta_s) \) is likely to be insignificant in comparison to the bending deflection \( (\delta_i) \) and may be ignored in order to make a first estimate of the total deflection \( (\delta_t) \):

\[
\delta_{(\text{ignoring shear deflection})} = \frac{5WP}{384E_{\text{mf}}I_{\text{fx}}} \quad (\text{Table 6.9})
\]

\[
= \frac{5 \times 10^4 \times 3000^3}{384 \times 5800 \times I_{\text{fx}}}
\]

Since \( \delta_p \geq \delta_i \)

\[
0.003 \times 3000 \geq \frac{5 \times 10^4 \times 3000^3}{384 \times 5800 \times I_{\text{fx}}}
\]

\[
I_{\text{req}} \geq 67.3 \times 10^6 \text{ mm}^4
\]

From Table 6.8, section 75 \times 250 provides

\[
Z_{\text{xx}} = 781 \times 10^3 \text{ mm}^3 \quad I_{\text{xx}} = 97.7 \times 10^6 \text{ mm}^4 \quad A = 18.8 \times 10^3 \text{ mm}^2
\]

Hence total deflection including shear deflection can now be calculated and is given by

\[
\frac{5WP}{384E_{\text{mf}}I_{\text{xx}}} + \frac{12WI}{5E_{\text{mf}}A} = \frac{5 \times 10^4 \times 3000^3}{384 \times 5800 \times 97.7 \times 10^6} + \frac{12 \times 10^4 \times 3000}{5 \times 5800 \times 18.8 \times 10^3}
\]

\[
= 6.2 \text{ mm} + 0.7 \text{ mm} = 6.9 \text{ mm} \leq \delta_p = 0.003 \times 3000 = 9 \text{ mm}
\]

Therefore a beam with a 75 \times 250 section is adequate for bending and deflection.

LATERAL BUCKLING

Permissible \( \frac{d}{b} = 5 \) \quad (Table 6.10)

Actual \( \frac{d}{b} = \frac{250}{75} = 3.3 < \text{permissible} \)

Hence the section is adequate for lateral buckling.

SHEAR

Permissible shear stress is

\[
\tau_{\text{edn}} = \tau_\text{y}K_3 = 0.67 \times 1.0 = 0.67 \text{ N/mm}^2
\]

Maximum shear force is

\[
F_s = \frac{W}{2} = \frac{10 \times 10^3}{2} = 5 \times 10^3 \text{ N}
\]

Maximum shear stress at neutral axis is

\[
\tau_s = \frac{3F_s}{2A} = \frac{3 \times 5 \times 10^3}{2 \times 18.8 \times 10^3} = 0.4 \text{ N/mm}^2 < \text{permissible}
\]

Therefore the section is adequate in shear.

BEARING

Permissible bearing stress is

\[
\sigma_{\text{adm,L}} = \sigma_{\text{CFL,K}} = 1.7 \times 1.0 = 1.7 \text{ N/mm}^2
\]

End reaction, \( F \), is

\[
W = \frac{10 \times 10^3}{2} = 5 \times 10^3 \text{ N}
\]

\[
\sigma_{\text{CFL,L}} = \frac{F}{bL} = \frac{5 \times 10^3}{75 \times 150} = 0.44 \text{ N/mm}^2 < \text{permissible}
\]

Therefore the section is adequate in bearing. Since all the checks are satisfactory, use 75 mm \times 250 mm sawn C16 beam.

Answers for questions 6-10
DESIGN LOADING

Tongue and groove boarding = 0.10 kN/m²
Ceiling = 0.20 kN/m²
Joists (say) = 0.10 kN/m²
Imposed floor load for domestic dwelling (Table 2.2) = 1.50 kN/m²
Total load = 1.90 kN/m²

Uniformly distributed load/ joist (W) is

\[ W = \text{joist spacing} \times \text{effective span} \times \text{load} \]

\[ = 0.4 \times 3.8 \times 1.9 = 2.9 \text{ kN} \]

GRADE STRESSES AND MODULUS OF ELASTICITY FOR C18
Values in N/mm² are as follows

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<th>Compression perpendicular to grain</th>
<th>Shear parallel to grain</th>
<th>Modulus of elasticity E&lt;sub&gt;mean&lt;/sub&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \sigma_{n.d.1} )</td>
<td>( \sigma_{n.d.1} )</td>
<td>( \tau_g )</td>
<td>9100</td>
</tr>
<tr>
<td>5.8</td>
<td>1.7</td>
<td>0.67</td>
<td></td>
</tr>
</tbody>
</table>

MODIFICATION FACTORS

- \( K_s \), moisture content factor does not apply since joists are exposed to service class 2
- \( K_p \), duration of loading = 1.0
- \( K_d \), load-sharing system = 1.1
- \( K_h \), depth factor = \( \left( \frac{300}{h} \right)^{0.11} \)

where

- \( h = 225, K_h = 1.032 \)
- \( h = 200, K_h = 1.046 \)
- \( h = 175, K_h = 1.061 \)

BENDING

Bending moment (\( M \)) = \( \frac{Wl}{8} \) = \( \frac{2.9 \times 3.8}{8} \) = 1.4 kN m

\( \sigma_{n.d.1} \) (ignoring \( K_p \)) = \( \sigma_{n.d.1} K_p K_h \) = 5.8 \times 1.0 \times 1.1 = 6.38 N/mm²

\[ Z_{\text{req}} \geq \frac{M}{\sigma_{n.d.1}} = \frac{1.4 \times 10^6}{6.38} \]

\[ = 219 \times 10^3 \text{ mm}^3 \]

From Table 6.8 a 47 x 200 mm joist would be suitable (\( Z_n = 313 \times 10^3 \text{ mm}^3, I_n = 31.3 \times 10^6 \text{ mm}^4, A = 9.4 \times 10^3 \text{ mm}^2 \)). Hence \( K_h = 1.046 \). Therefore

\[ Z_{\text{req}} = \frac{219 \times 10^3}{1.046} = 209 \times 10^3 \text{ mm}^3 < \text{provided} \quad \text{OK} \]
DEFLECTION
Permissible deflection = 0.003 x span
= 0.003 x 3800 = 11.4 mm

Total deflection (\(\delta_t\)) = bending deflection (\(\delta_{b,\text{m}}\)) + shear deflection (\(\delta_s\))

\[
\delta_t = \frac{5Wl^3}{384EI_{xx}} + \frac{12WL}{5E_{\text{mean}}A}
\]

\[
= \frac{5 \times 2.9 \times 10^3 \times (3.8 \times 10^3)^3}{384 \times 9.1 \times 10^3 \times 31.3 \times 10^6} + \frac{12 \times 2.9 \times 10^3 \times 3.8 \times 10^3}{5 \times 9.1 \times 10^3 \times 9.4 \times 10^3}
\]

= 7.3 mm + 0.3 mm = 7.6 mm < permissible

Therefore 47 mm x 200 mm joist is adequate in bending and deflection.

LATERAL BUCKLING
Permissible \(\frac{d}{b}\) = 5 (Table 6.10)

Actual \(\frac{d}{b}\) = \(\frac{200}{47}\) = 4.3 < permissible

Therefore joist is satisfactory in lateral buckling.

SHEAR
Permissible shear stress is

\[\tau_{edm} = \tau_s K_y K_b = 0.67 \times 1.0 \times 1.1 = 0.737 \text{ N/mm}^2\]

Maximum shear force is

\[F_s = \frac{W}{2} = \frac{2.9 \times 10^3}{2} = 1.45 \times 10^3 \text{ N}\]

Maximum shear stress at neutral axis is

\[\tau_s = \frac{3 F_s}{2 A} = \frac{3}{2} \times \frac{1.45 \times 10^3}{9.4 \times 10^3} = 0.23 \text{ N/mm}^2 < \text{permissible}\]

Therefore joist is adequate in shear.

BEARING
Permissible compression stress perpendicular to grain is

\[\sigma_{c,\text{adm}} = \sigma_{c,g,\perp} K_y K_b = 1.7 \times 1.0 \times 1.1 = 1.87 \text{ N/mm}^2\]

Maximum end reaction is

\[F = \frac{W}{2} = \frac{2.9 \times 10^3}{2} = 1.45 \times 10^3 \text{ N}\]

Assuming that the floor joists span onto 100 mm wide wall plates the bearing stress is given by

\[\sigma_{c,\perp} = \frac{F}{b l_b} = \frac{1.45 \times 10^3}{47 \times 100} = 0.31 \text{ N/mm}^2 < \text{permissible}\]

Therefore joist is adequate in bearing.

CHECK ASSUMED SELF-WEIGHT OF JOISTS
From Table 6.3, the average density of timber of strength class C18 is 380 kg/m³. Hence, self-weight of the joists is

\[\frac{(47 \times 200 \times 10^{-3}) \times 380 \text{ kg/m}^3 \times 9.81 \times 10^{-3}}{0.4} = 0.088 \text{ kN/m}^2 < 0.10 \text{ kN/m}^2 \text{ (assumed)}\]

Since all the checks are satisfactory use 47 mm x 200 mm C18 sawn floor joists.
The presence of the notch affects only the shear stresses in the joists. For a notched member the permissible shear stress is given by

\[ \tau_{adm} = \tau_y K_s K_g \]

where

\[ K_s = \frac{h_n}{h} = \frac{125}{200} = 0.625 \text{ > min. (} = 0.5 \text{)} \]

Hence

\[ \tau_{adm} = 0.67 \times 1.0 \times 0.625 \times 1.1 = 0.46 \text{ N/mm}^2 \]

Applied shear parallel to grain, \( \tau_y \) (from above) is

0.23 N/mm\(^2\) < permissible

Therefore the 47 mm × 200 mm sawn joists are also adequate when notched with a 75 mm deep bottom edge notch at the bearing.