Theory of structure

1- Introduction

2- Stability and determinacy of:
   • Beam
   • Frame
   • Truss

3- Analysis of statically determinate trusses

4- Axial, shear and bending moment diagram for frames and arches

5- Influence lines of statically determinate structure

References

1- Structural analysis by R.C Hibbeler (Text book)

2- Elementary theory of structures by Yuan Yu Hsieh
Introduction

A structure refers to a system of connected parts used to support a load.

Examples in civil engineering

- Buildings
- Bridges
- Towers

Loads on structure

- **Dead loads**: Dead loads consist of the weights of the various structural members and the weights of any objects that are permanently attached to the structure. Hence, for a building, the dead loads include the weights of the columns, beams, and girders, the floor slab, roofing, walls, windows, plumbing, electrical fixtures, and other miscellaneous attachments.
See also Table 1-3 Minimum design dead load

<table>
<thead>
<tr>
<th></th>
<th>psf</th>
<th>kN/m²</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Walls</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4-in. (102 mm) clay brick</td>
<td>39</td>
<td>1.87</td>
</tr>
<tr>
<td>8-in. (203 mm) clay brick</td>
<td>79</td>
<td>3.78</td>
</tr>
<tr>
<td>12-in. (305 mm) clay brick</td>
<td>115</td>
<td>5.51</td>
</tr>
<tr>
<td><strong>Frame Partitions and Walls</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Exterior stud walls with brick veneer</td>
<td>48</td>
<td>2.30</td>
</tr>
<tr>
<td>Windows, glass, frame and sash</td>
<td>8</td>
<td>0.38</td>
</tr>
<tr>
<td>Wood studs 2 × 4 in., (51 × 102 mm) unplastered</td>
<td>4</td>
<td>0.19</td>
</tr>
<tr>
<td>Wood studs 2 × 4 in., (51 × 102 mm) plastered one side</td>
<td>12</td>
<td>0.57</td>
</tr>
<tr>
<td>Wood studs 2 × 4 in., (51 × 102 mm) plastered two sides</td>
<td>20</td>
<td>0.96</td>
</tr>
<tr>
<td><strong>Floor Fill</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cinder concrete, per inch (mm)</td>
<td>9</td>
<td>0.017</td>
</tr>
<tr>
<td>Lightweight concrete, plain, per inch (mm)</td>
<td>8</td>
<td>0.015</td>
</tr>
<tr>
<td>Stone concrete, per inch (mm)</td>
<td>12</td>
<td>0.023</td>
</tr>
<tr>
<td><strong>Ceilings</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Acoustical fiberboard</td>
<td>1</td>
<td>0.05</td>
</tr>
<tr>
<td>Plaster on tile or concrete</td>
<td>5</td>
<td>0.24</td>
</tr>
<tr>
<td>Suspended metal lath and gypsum plaster</td>
<td>10</td>
<td>0.48</td>
</tr>
<tr>
<td>Asphalt shingles</td>
<td>2</td>
<td>0.10</td>
</tr>
<tr>
<td>Fiberboard, (\frac{1}{2})-in. (13 mm)</td>
<td>0.75</td>
<td>0.04</td>
</tr>
</tbody>
</table>

• **Live Loads.** Live loads can vary both in their magnitude and location
  
  ✓ **Building Loads.** The floors of buildings are assumed to be subjected to uniform live loads, which depend on the purpose for which the building is designed.
  
  ✓ **Highway Bridge Loads.** The primary live loads on bridge spans are those due to traffic.

• **Impact Loads**
  
  ✓ Vehicle impact
  
  ✓ Debris impact

• **Wind Loads.** When structures block the flow of wind, the wind’s kinetic energy is converted into potential energy of pressure, which causes a wind loading
• **Snow Loads.** In some countries, roof loading due to snow can be quite severe, and therefore protection against possible failure is of primary concern.

![Excessive snow and ice loadings act on this roof.](image)

• **Earthquake Loads.** Earthquakes produce loadings on a structure through its interaction with the ground and its response characteristics. These loadings result from the structure’s distortion caused by the ground’s motion and the lateral resistance of the structure.
Idealized structure

actual structure

idealized structure

idealized framing plan

real

Idealized

Equations of equilibrium

\[
\begin{align*}
\Sigma F_x &= 0 \\
\Sigma F_y &= 0 \\
\Sigma M_O &= 0
\end{align*}
\]

2D

\[
\begin{align*}
\Sigma F_x &= 0 \\
\Sigma F_y &= 0 \\
\Sigma F_z &= 0 \\
\Sigma M_x &= 0 \\
\Sigma M_y &= 0 \\
\Sigma M_z &= 0
\end{align*}
\]

3D
The compound beam shown in figure below is fixed at A. Determine the reaction at A, B and C. Assume that the connection at B is a pin and C is a roller.

Segment BC:
- \[ \sum M_c = 0 \]
  \[-8 + By(4.5) = 0 \rightarrow By = 1.78 \text{ kN} \]
- \[ \sum F_y = 0 \rightarrow -1.78 + Cy = 0 \rightarrow Cy = 1.78 \text{ kN} \]
- \[ \sum F_x = 0 \rightarrow Bx = 0 \]

- **Segment AB:**
- \[ \sum M_B = 0 \]
  \[ M_A - 36(3) + 1.78(6) = 0 \]
  \[ M_A = 973 \text{ kN.m} \]
- \[ \sum F_y = 0 \]
  \[ Ay - 36 + 1.78 = 0 \rightarrow Ay = 34.2 \text{ kN} \]
- \[ \sum F_x = 0 \rightarrow Ax - 0 = 0 \rightarrow Ax = 0 \]
- **Another solution:**

  **All body:**
  \[ \sum M_c = 0 \]
  \[-36(7.5) + 8 - M_A + Ay(10.5) = 0 \]
  \[10.5 Ay - M_A = 262 \ldots \ldots 1\]

- **Segment AB**

  \[ \sum M_B = 0 : \]
  \[-MA + 6Ay - 36(3) = 0 \]
  \[6Ay - MA = 108 \ldots \ldots (2)\]
  \[MA = 6Ay - 108 \text{ sub in } \ldots \ldots (1)\]
  \[10.5 Ay - 6Ay + 108 = 262 \]
  \[4.5 Ay = 154 \rightarrow Ay = 34.2 \text{ kN} \]
  \[MA = 6(34.2) - 108 \rightarrow MA = 97.3\]
Determine the reactions at points A and C.

**Solution**

- **Segment AB:**
  \[ \sum M_B = 0 \]
  \[ R_A = 0 \]

- **All body**
  \[ \sum F_y = 0 \]
  \[ R_A + R_c = 10 \]
  \[ 0 + R_c = 10 \rightarrow R_c = 10 \text{ KN} \]

- **Another method:**
  Segment BC:
  \[ \sum M_B = 0 \]
  \[ 10(2) = C_y(4) \rightarrow C_y = 5 \text{ KN} \]

Compare with the first solution!!