

ACBA 4007

STRUCTURAL DESIGN REPORT

Mariah Edwards
UWTSD | 2114464

Structural Design Procedure

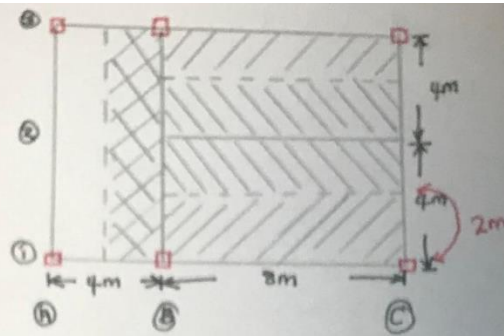
1. Structural Scheming- This is the initial design stage where the architect has produced their drawings and the next step is for the structural designer to select locations for structural members (the positioning of columns, beams, the spanning of slabs, etc.) based on building codes and recommendations being sure not to interfere with the architectural layout of drawings given.
2. Loading Schedule – at this stage the various loads, permanent (self-weight of structures, etc) and variable loads (wind, snow, etc) are considered including the future use of the structure. These values are assumed in the Eurocodes 1, NA to BS EN 1991-1-1:2002.
3. Durability- at this stage the materials that will be used to build the structure are chosen so that wear and tear would not cause it to work less than what was anticipated. Environmental considerations must be made to figure out the effects with regards to durability and the steps needed to protect materials.
The degree of deterioration can be estimated based on experience from prior construction, calculations, or both.
4. Structural Element Design- this is where the structural members (beams, columns, slabs) are designed by calculation factoring appropriate sizing, type of materials and loads (permanent and variable). If needed, these calculations can be verified by experiments.
5. Detailing- the location of structural elements is represented on drawings to specify requirements to the builder.

Types of loads to be considered when designing a building project

- Dead loads (G_k)/ Permanent actions (due to the fact they remain constant through the lifecycle of the structure) – EN 1991 -1-1-1:2002 defines a dead load as a gravity load. It is the self-weight of permanent structural members such as columns, beams, floors slabs, etc and the weight of any object attached to the structure (non-structural), e.g., roofing, partitions, linings, thermal insulation, etc. Dead loads are calculated by multiplying the unit weight of the material by the quantity of materials.
- Imposed load/ live loads (Q_k) – these are loads that are non-permanent and arise from occupancy, these loads are due to the movement of weight of people, furniture, equipment, etc. Live loads are unpredictable and are assessed based on assumptions observed from loading conditions. E.g., a hospital would need to be designed for a larger load than a small two-bedroom house as there would be more persons at a hospital, so the design must account for the expected occupancy.

The imposed loads on the structure are modelled as either uniformly distributed loads, concentrated point loads or a combination of both. Floors and roof areas are put in categories based on their intended use, e.g., domestic, and residential activities, shopping areas, heavy equipment in e.g., communal kitchens, boiler room, etc to determine the loading.

- Environmental loads (wind loads, snow loads, etc)- wind loads are not as important when designing low rise buildings but are very important when designing high rise buildings and need to be thought about early in the design process. Ground snow load zone maps and values are used to determine snow loads. The type of roof structure should also be considered as some roofs can affect snow build up. Snow loads are considered in BS EN 1991-1-3 and wind loads in BS EN 1991-1-4.
- Other loads are thermal, impact, vibration, etc.



225mm depth RC slab

→ expected support of finishes & ceiling load = 1.2 kN/m^2
imposed load = 4.5 kN/m^2

steel beam = 75 kg/m run

3m high column = 50 kg/m run

⇒ Unit weight of materials:

unit mass of reinforced concrete = 2400 kg m^{-3}

unit weight of reinforced concrete = 2400×10
= 24000 N/m^3
= 24 kN/m^3

unit mass of beam = 75 kg/m run

unit weight of beam = 75×10
= 750 N/m^{-1}
= $0.75 \text{ kN/m}^{-1} \text{ run}$

unit mass of column = 50 kg/m run

= 50×10
= 500 N/m^{-1}
= 0.50 kN/m run

⇒ loading

slab dead load (G_k) = self weight + finishes
= $0.225 \times 24 + 1.2$
= $5.4 + 1.2$
= 6.6 kN/m^2

Slab imposed load (Q_k) = 4.5 kN/m^2

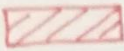
Ultimate slab load = $1.4 G_k + 1.6 Q_k$ (Eurocode 2)
= $1.4 \times 6.6 + 1.6 \times 4.5$
= $9.24 + 7.2$
= 16.44 kN/m^2

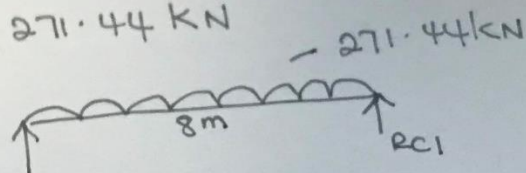
Beam dead load = self weight = 0.75 kN/m run
 " ultimate " = $1.4 g_k \times \text{self weight}$
 $= 1.4 \times 0.75$
 $= 1.05 \text{ kN/m run}$

Column dead load = self weight = 0.50 kN/m run
 " ultimate " = $1.4 g_k \times \text{self weight}$
 $= 1.4 \times 0.50$
 $= 0.70 \text{ kN/m run}$

a) Estimate design load.

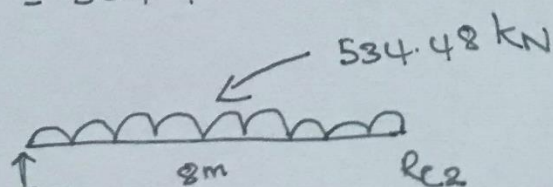
Each beam on grid 1-8 supports a UDL from the width of slab plus their self-weight.

B1-C1  slab load + self weight of beam
 (from a 2m width) $= 16.44 \times 8 \times 2 + 1.05 \times 8$
 $= 263.04 + 8.4$
 $= 271.44 \text{ kN}$



Symmetrically loaded so $R_{B1} = R_{C1}$
 $= \frac{271.44}{2}$
 $= 135.72$

B2-C2  slab load + self weight of beam
 (from a 4m width) $= 16.44 \times 8 \times 4 + 1.05 \times 8$
 $= 526.08 + 8.4$
 $= 534.48 \text{ kN}$



Symmetrically loaded
 So $\rightarrow R_{B2} = R_{C2}$
 $= \frac{534.48 \text{ kN}}{2} = 267.24 \text{ kN}$

B1-B3
(from a 2m width)

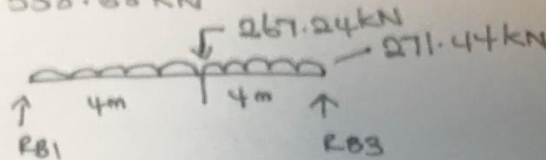


= UDL from slab plus self weight of beam + point load from reaction R_{B2} .

$$= 16.44 \times 2 \times 8 + 1.05 \times 8 + 267.24 \text{ kN}$$

$$= 268.04 + 8.4 + 267.24$$

$$= 538.68 \text{ kN}$$



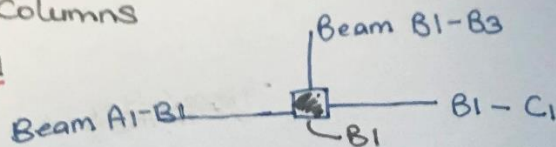
symmetrically loaded $R_{B1} = R_{B3}$

$$= \frac{538.68}{2}$$

$$= 269.34 \text{ kN}$$

=> Columns

B1



- Reaction due to B1-C1 = 135.72 kN

B1-B3 = 269.34 kN

* A1-B1 support only its self weight = $1.05 \times 4 = 4.2 \text{ kN}$

hence the reaction at B1 due to A1-B1 = $\frac{4.2 \text{ kN}}{2}$

$$= 2.10 \text{ kN}$$

- column height = 3m

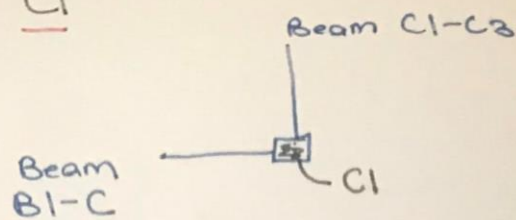
- Self weight of column = 0.70×4

$$= 2.80 \text{ kN}$$

Design load : $135.72 + 269.34 + 2.10 + 2.80$

$$= 409.96 \text{ kN}$$

Column C1



- reaction due to B1-C1 = 185.72 kN
- C1-C2 support reaction from B2-C2 = 267.24 kN
- self weight = $1.05 \times 8 = 8.40$ kN
- hence reaction at C1 = $\frac{(267.24 \text{ kN} + 8.40 \text{ kN})}{2}$

Self-weight = 137.82 kN

Self-weight = 0.70×4
= 2.80 kN

Design load = $185.72 \text{ kN} + 137.82 \text{ kN} + 2.80 \text{ kN}$
= 276.34 kN.

$$\begin{aligned}
 b.) \quad M &= w l^2 / 8 \\
 &= \frac{16.44 \text{ kN} \times 8^2}{8} \\
 &= 131.52 \text{ kN/m}
 \end{aligned}$$

$$\begin{aligned}
 d &= h - \cancel{\frac{d}{2}} - c \\
 &= 225 - \cancel{\frac{12}{2}} - 25 \\
 &= 225 - 6 - 25 \\
 &= 194 \text{ mm}
 \end{aligned}$$

$$\begin{aligned}
 k &= \frac{131.52 \times 10^6}{1000 \times 194^2 \times 30 \text{ Nmm}^2} \\
 &= \frac{31520000}{1129080000}
 \end{aligned}$$

$$= 0.0279$$

$$K \leq K'$$

$$K \leq 0.156$$

$$Z = \frac{d}{2} (1 + \sqrt{1 - 3.53k}) \leq 0.95(d)$$

$$= \frac{d}{2} (1 + \sqrt{1 - 3.53(0.0279)})$$

$$= \frac{d}{2} (1.949)$$

$$= \frac{1.949 \times d}{2}$$

$$= 0.9745d$$

$$Z = 0.9745 \times 194$$

$$= \underline{189.053 \text{ mm}}$$

$$\begin{aligned}
 M &= 131.52 \text{ kN/m} \\
 f_{cu} &= 30 \text{ N/mm}^2 \\
 \text{design life} &= 50 \\
 \text{Exposure: moderate} \\
 \text{cover} &= 25 \text{ mm} \\
 b &= 1000 \text{ mm} \\
 h &= 225 \text{ mm}
 \end{aligned}$$

$$\begin{aligned}
 \rightarrow f_{yd} &= 500 \text{ N/mm}^2 \\
 m &= 131.52 \times 10^6 \text{ Nmm}
 \end{aligned}$$

$$A_s = \frac{131.52 \times 10^6 \text{ Nmm}}{500 \text{ N/mm}^2 \times 189.053}$$

$$= \frac{131.52 \times 10^6}{94526.50}$$

$$= 1391.386 \text{ mm}^2$$

spacing - 10 mm bar @
50 mm c/c

$$\text{minimum reinforcement} = 0.13\% \times A_c$$

$$\frac{0.13}{100} \times 225 \times 1000$$

$$= \frac{0.13}{100} \times 225000$$

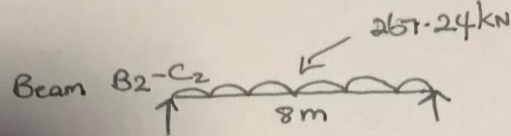
$$= 292.5 \text{ mm}^2$$

$$\text{maximum} = 0.4\% \times A_c$$

$$= \frac{0.4}{100} \times 225 \times 1000$$

$$= 900 \text{ mm}^2$$

ii.) Steel Beam Design



$$M = 131.52 \times 10^6 \text{ N/mm}$$

(fy)
Permissible bending stress
 $= 460 \text{ N/mm}^2$

$W = M/f_y \rightarrow$ find section modulus required.

$$= \frac{131.52 \times 10^6}{460}$$

$$= 285913.044 \text{ mm}^3$$

$$= 285.9 \text{ cm}^3$$

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