Lesson 6

Doubly Reinforced Beams

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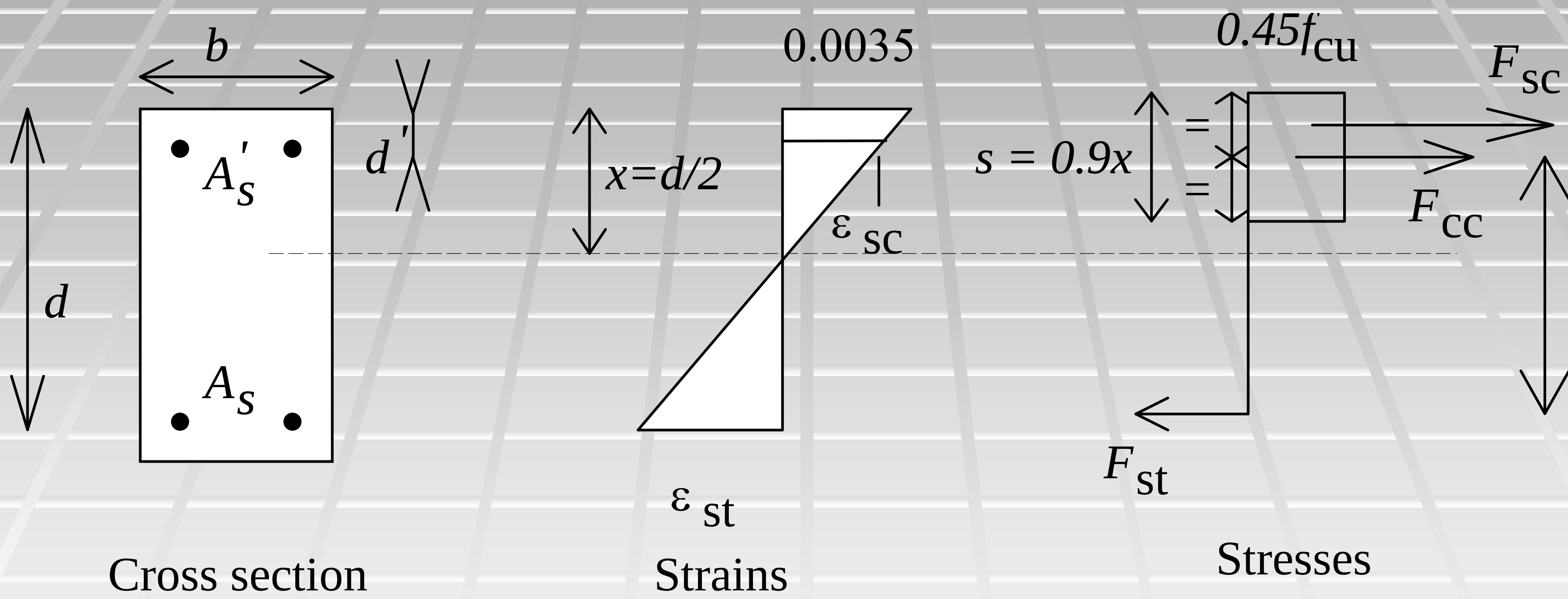
Introduction to Doubly R'fed beams

- M – moment calculated from formulae
- Mu – ult. Moment = $0.156 f_{cu} b d^2$
- If M > Mu
  - Concrete can no more withstand the actual moment.
  - Either increase the concrete strength,
  - Or doubly reinforced the beam
- Providing compression steel will resist the moment in excess of Mu

Stress – Strain blocks



Area of reinforcement

- Compression steel reinf. Is cal. Using

$$A'_s = \frac{M - M_u}{0.95 f_y (d - d')}$$

d': depth to the compression steel from the top surface

- Tension steel (k'=0.156)

$$A_s = \frac{M}{0.95 f_y z} + A'_s$$

$$z = d\left[0.5 + \sqrt{(0.25 - K'/0.9)}\right]$$

Assumption

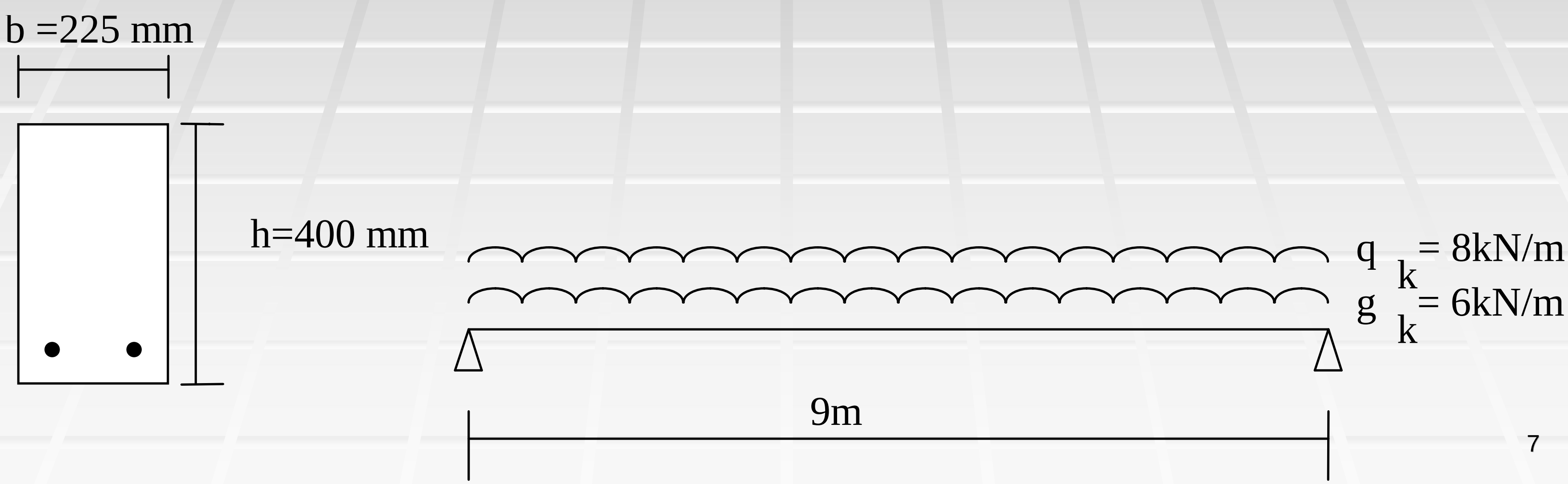
- Compression steel has yielded i.e. steel stress = 0.95 *fy*, but this will only apply if

$$\frac{d'}{x} < 0.43 \quad \text{OR} \quad \frac{d'}{d} < 0.215 \quad \text{where} \quad x = \frac{d - z}{0.45}$$

- If $d'/x > 0.43$ - compression steel will be at a stress less than yield, in which case this stress can be found from the elasto-plastic stress strain curve shown above

Worked example

- A simply supported rectangular beam of 9m span carries a characteristic dead (g_k) load (inc. Self wt. of beam), and imposed (q_k) loads of 6 kN/m and 8 kN/m respectively. Check whether it is a SRB or DRB



Doubly Reinforced Beam??

Worked example

- The beam dimensions : *b*= 225mm, *h*= 400mm, fcu =30MPa and *fy* =460N/mm2 calculate the area of reinforcement required.

$$\text{Ultimate load } (w) = 1.4g_k + 1.6q_k$$
$$= 1.4 \times 6 + 1.6 \times 8 = 21.2 \text{ kN / m}$$

$$\text{Design Moment } (M) = \frac{wl^2}{8} = \frac{21.2 \times 9^2}{8} = 214.65 \text{ kNm}$$

$$\text{Assuming bar diameter} = 25mm$$
$$\text{Effective depth } d = h - 25/2 - \text{cover}$$
$$(\text{say 40mm to main steel inc. link } \phi)$$
$$= 348mm$$

$$\text{Ultimate Moment } (M_u) = 0.156 f_{cu} b d^2$$
$$= 0.156 \times 30 \times 225 \times 348^2$$
$$= 127.5 \times 10^6 \text{ Nmm}$$
$$= 127.5 \text{ kNm}$$

- Since M>Mu, doubly r'fed

Worked example

- Compression steel calculation

$$d' = \text{cover} + \phi / 2 = 40 + 20/2 = 50mm$$

$$z = d(0.5 + \sqrt{(0.25 - K'/_{0.9})})$$

$$= 348(0.5 + \sqrt{(0.25 - 0.156/_{0.9})})$$

$$z = 270mm$$

$$x = \frac{(d-z)}{0.45} = \frac{348-270}{0.45} = 173$$

$$\frac{d'}{x} = \frac{50}{173} = 0.289 < 0.43 \therefore \text{Compression steel has yielded}$$

Worked example

$$A'_s = \frac{M - M_u}{0.95 f_y (d - d')} = \frac{87.15 \times 10^6}{0.95 \times 460 \times (348 - 50)} = 669 mm^2$$

- Choose appropriate reinforcement diameters

$$A_s = \frac{M_u}{0.95 f_y z} + A'_s = \frac{127.5 \times 10^6}{0.95 \times 460 \times 270} + 669$$

Design methodology

- **a). Calculate K from M/fcubd2**
  - K` = 0.402(bb – 0.4) – 0.18(bb – 0.4)2
  - If K < K’, compression steel is not required, beam shall be designed as a singly reinforced one.
  - If K > K’, compression steel is required.
- **b). Calculate x = (bb – 0.4)d**
  - If d’/x < 0.37, the compression steel has yielded and fsc = 0.95fy
  - If d’/x > 0.37, calculate the steel compressive strain esc and hence fsc
- **c). Calculate the area of compression steel,**
  - **As’ = (K – K’)fcubd2/(fsc(d – d’))**

Design methodology

- **d). Calculate the area of tension steel from**
  - As = K'fcubd2/(0.95fyZ)   + Asc'fsc/0.95fy
  - Where Z = d – 0.9x/2
- **e). Links**
- The links should pass round the corner bars and each alternate bar.
- The link size should be at least one-quarter the size of the largest compression bar.
- The spacing of links should not be greater than twelve times the size of the smallest compression bars.
- NO compression bar should be more than 150mm from a restrained bar.