DESIGN OF CONCRETE STRUCTURES -1

Topics to be covered:

- Design of Rectangular Doubly Reinforced Sections by Working Stress Method.
- Practice Questions and Problems

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DESIGN OF RECTANGULAR DOUBLY REINFORCED SECTIONS BY WSM

In some situations, it may not be possible to provide the required depth of the beam as singly-reinforced either due to restrictions given by the architects or due to functional requirements. In such cases, the designer has to satisfy the structural requirement with a depth less than that of a singly-reinforced section. This is done by providing steel reinforcing bars in the compression side along with the tensile steel in the tension side of the beam. These beams are designated as doubly-reinforced beams.

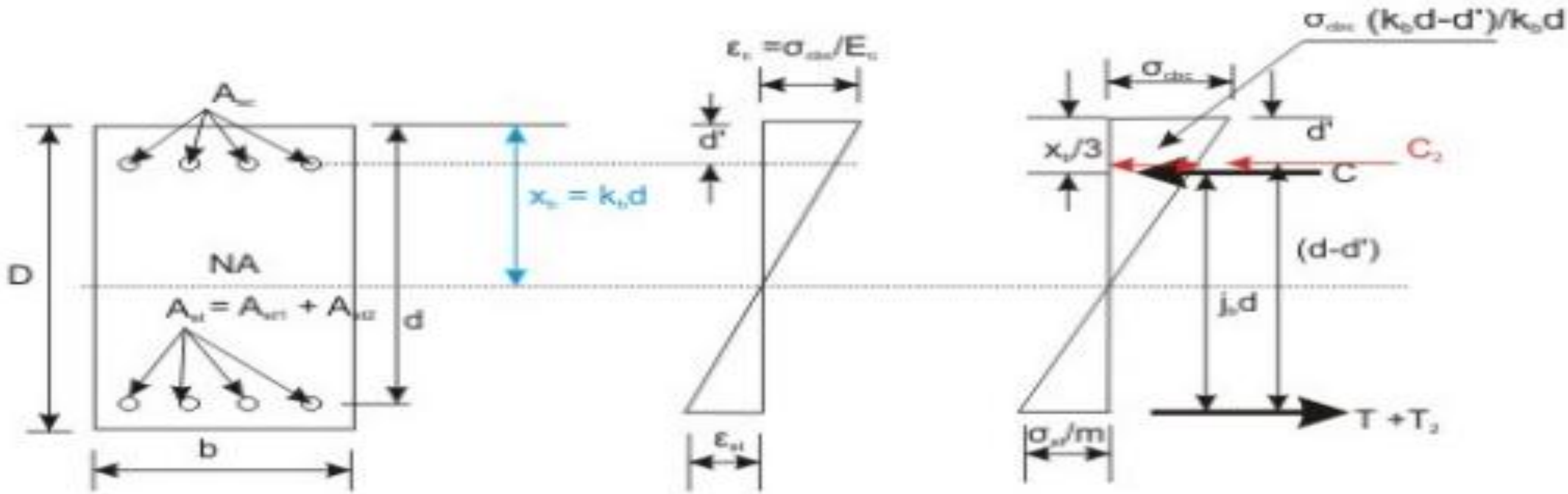

Fig. 13.34.4(a): Section Fig. 13.34.4(b): Strain profile Fig. 13.34.4(c): Stress distribution

Figures a to c show the cross-section, strain profile and stress distribution of a doubly-reinforced section. Since, the design moment is more than the balanced moment of resistance of the section, we have M = Mb + M′.

The additional moment M′ is resisted by providing compression reinforcement Asc (= pcbd/100) and additional tensile reinforcement Ast2. The modular ratio of the compression steel is taken as 1.5 m, where m is the modular ratio.

Figure c shows that the stress of concrete at the level of compression steel is σcbc (kbd - d′) / kdd. Accordingly, the stress in the compression steel reinforcement is 1.5m σcbc (kbd - d′) / kbd.

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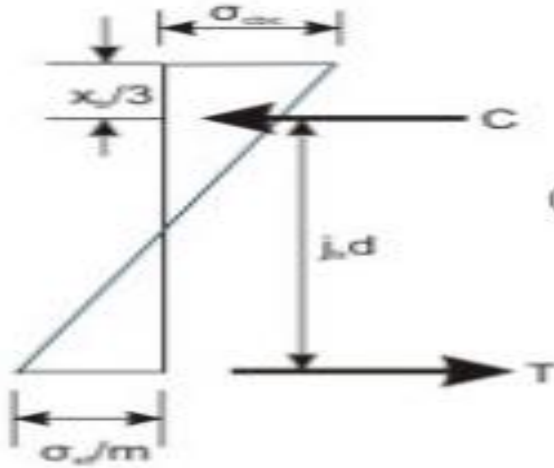

Fig. 13.34.4(d): Singly-reinforced balanced stress distribution

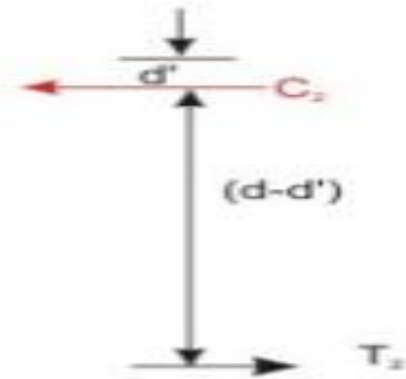

Fig. 13.34.4(e): Additional forces

Figure d and e present separate stress distribution for the balanced beam (c) and the compressive and tensile forces of compressive and tensile reinforcing bars C2 and T2, respectively. The expression of the additional moment M′ is obtained by multiplying C2 and T2 with the lever arm (d - d′), where d′ is the distance of the centroid of compression steel from the top fibre. We have, therefore,

$C_2 = A_{sc} (1.5m - 1) \sigma_{cbc} (kd - d') / kd$ ---------------------------(a)

$T_2 = (p_t - p_{t,bal}) (bd / 100) \sigma_{st}$ -----------------------------------(b)

$M' = C_2 (d - d') = (p_c bd /100) (1.5m - 1) \sigma_{cbc} (kd - d')/ kd (d - d')$

or, $M' = (p_c / 100)(1.5m - 1) \sigma_{cbc} (1 - d' / kd)(1 - d' /d)bd^2$-----------------------------(c)

also, $M' = T_2 (d - d') d = (p_t - p_{t,bal}) (bd / 100)\sigma_{st} (d - d')$

or, $M' = (p_t - p_{t,bal}) / 100 \sigma_{st} (1 - d' /d) bd^2$--(d)

Equating $T_2 = C_2$ from Eqs. (a) and (b),

we have $(p_t - p_{t,bal}) \sigma_{st} = p_c (1.5m - 1) \sigma_{cbc} (1 - d' / kd)$ ----------------------------(e)

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The total moment M is obtained by adding Mbal and M′ ,

as given below:

$M = M_{bal} + (p_t – p_{t,bal}) / 100\ \sigma_{st} (1- d′ / d)\ bd^2$ ------------------(f)

The total tensile reinforcement Ast has two components

Ast1 + Ast2 for Mbal and M′ , respectively.

The equation of Ast is:

$A_{st} = A_{st1} + A_{st2}$--(g)

where $A_{st1} = p_{t,bal} (bd / 100)$--(h) and

$A_{st2} = M′ / \sigma_{st} (d - d′)$ --(i)

The compression reinforcement Asc is expressed as a ratio of additional tensile reinforcement Ast2,

as given below:

$(A_{sc} / A_{st2}) = \{p_c /(p_t – p_{t,bal})\}$

or, $(A_{sc} / A_{st2}) = \sigma_{st} / \{\sigma_{cbc} (1.5m – 1) (1 - d′ / kd)\}$ -----------(j)

Table below presents the values of Ast /Ast2 for different values of d′ / d and σcbc for two values of σst =140 N/mm2 and 230 N/mm2 . Selective values are furnished in Table 13.5 as a ready reference. Tables 72 to 79 of SP-16 provide values of pt and pc for four values of d′ / d against M/bd2 for four grades of concrete and two grades of steel.

σ_{st} (N/mm^2)	σ_{cbc} (N/mm^2)	d'/d			
		0.05	0.10	0.15	0.20
140	7.0	1.20	1.40	1.68	2.11
	8.5	1.22	1.42	1.70	2.13
	10.0	1.23	1.44	1.72	2.15
230	7.0	2.09	2.65	3.60	5.54
	8.5	2.12	2.68	3.64	5.63
	10.0	2.14	2.71	3.68	5.76

PRACTICE QUESTIONS AND PROBLEMS

Q.1: Justify the name working stress method of design.

Q.2: How are the permissible stresses of concrete in direct tension, bending compression, direct compression and average bond for plain bars in tension related to the factor of safety in the working stress method of design?

Q.3: How is the permissible stress of steel in tension related to the factor of safety in the working stress method of design?

Q.4: Is it possible to increase the permissible stress? If yes, when is it done?

Q.5: State the assumption for the design of members by working stress method.

Q.6: Explain the concept of modular ratio.

Q.7: Draw a cross-section of a singly-reinforced rectangular beam, the strain and stress distributions along the depth of the section.

Q.8: What do you mean by balanced rectangular beam? Establish the equations for determining the moment of resistance and percentage of tension steel in a balanced rectangular beam.

Q.9: Establish the equations for determining the depth of neutral axis, moment of resistance and area of tension steel of an under-reinforced rectangular beam.

Q.10: Write down the steps for solving the analysis type of problems of singly reinforced rectangular beams.

Q.11: Write down the steps for solving the design type of problems of singly reinforced rectangular beams.

Q.12: When do we go for doubly-reinforced beams? Establish the equation for determining areas of steel for the doubly reinforced rectangular beams.

"Thank you"

Have Any Query ?

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