RC Beam Design Procedure – Section Design for Moment

Initial Design:
Choose the initial section dimensions. Factors to be considered are the basic span/depth ratio, the minimum requirements for durability and fire resistance. Remember to take account of cover and the size of the shear links in determining the overall depth, h, and the effective depth, d. A rough guide for the width of the section is about half the depth.

Analysis:
Analyse the structure using standard structural analysis techniques. Choose the location of the section to be designed and read the moment, M, that the section must resist from the bending moment diagram.

Design Procedure:

1. Calculate $K = M / f_{cu}bd^2$
2. Check K:
   - $\leq K'$ design as singly reinforced section ($K' = 0.156$)
   - $> K'$ design as doubly reinforced section

Singly Reinforced Section Design:

1. Calculate $z = d\,[\,0.5 + \sqrt{(0.25 - K / 0.9)}\,]$. If $K \leq 0.043$ then $z = 0.95d$
2. Calculate $A_s = M / 0.95f_yz$

Doubly Reinforced Section Design:

1. Calculate $z = d\,[\,0.5 + \sqrt{(0.25 - K / 0.9)}\,]$
2. Calculate $x = (d - z) / 0.45$
3. Check d' / x:
   - ≤ 0.43 continue on to stage 4
   - > 0.43 compression reinforcement elastic
4. Calculate $A_s' = (K - K')f_{cu}bd^2 / 0.95f_y(d - d')$
5. Calculate $A_s = K'f_{cu}bd^2 / 0.95f_yz + A_s'$

Choosing Reinforcement:
Select the number & diameter of bars to provide an area not less than, and as close as practicable to, the calculated values of A_s and A_s'.

Specific Detailing Requirements:
Check these requirements are met:

1. Min & max areas of rebar.
2. Number of bars in a bundle ≤ 4.
3. Spacing between bars.

Bar Area Tables:

Cross Sectional areas of groups of bars (mm^2)

Bar Size (mm)		6	8	10	12	16	20	25	32	40
Number of bars	1	28	50	79	113	201	314	491	804	1257
	2	57	101	157	226	402	628	982	1608	2513
	3	85	151	236	339	603	942	1473	2413	3770
	4	113	201	314	452	804	1257	1963	3217	5027
	5	141	251	393	565	1005	1571	2454	4021	6283
	6	170	302	471	679	1206	1885	2945	4825	7540
	7	198	352	550	792	1407	2199	3436	5630	8796
	8	226	402	628	905	1608	2513	3927	6434	10053
	9	254	452	707	1018	1810	2827	4418	7238	11310
	10	283	503	785	1131	2011	3142	4909	8042	12566
Circumference		18.8	25.1	31.4	37.7	50.3	62.8	78.5	100.5	125.7

Cross Sectional areas of bars per metre width (mm^2)

Bar Size (mm)		6	8	10	12	16	20	25	32	40
Pitch of bars	75	377	670	1047	1508	2681	4189	6545	10723	16755
	100	283	503	785	1131	2011	3142	4909	8042	12566
	125	226	402	628	905	1608	2513	3927	6434	10053
	150	188	335	524	754	1340	2094	3272	5362	8378
	175	162	287	449	646	1149	1795	2805	4596	7181
	200	141	251	393	565	1005	1571	2454	4021	6283
	225	126	223	349	503	894	1396	2182	3574	5585
	250	113	201	314	452	804	1257	1963	3217	5027
	275	103	183	286	411	731	1142	1785	2925	4570
	300	94	168	262	377	670	1047	1636	2681	4189

Percentages of Reinforcement for Rectangular Beams and f_y = 460 N/mm^2:

Action	Percentage	Minimum	Maximum
Tension	$100\,A_s / bd$	0.13	4
Compression	$100\,A_s' / bd$	0.2	4

Spacing Requirements (to control cracking):

1. Minimum requirements, between bundles of bars (h_{agg} = max. aggregate size):
   - Vertically: $\geq 2\, h_{agg} / 3$ mm
   - Horizontally: $\geq h_{agg} + 5$ mm
2. Maximum requirements:
   - Horizontally (f_y = 460 N/mm^2): $s_1 \leq 160$ mm
   - Diagonally (from corner of beam): $s_2 \leq s_1 / 2$ mm
   - Vertically ($d \geq 750$ mm only): $s_3 \leq 250$ mm (sides of beam only)

RC Beam Design Procedure – Section Design for Shear

Initial Design:
Mostly determined by deflection/ durability considerations, however, make sure that the maximum shear stress ($v_{max} = V/b_v d$) at the support does not exceed $0.8\sqrt{f_{cu}}$ or 5 N/mm^2. If these values are exceeded alter the section so as to meet these comfortably.

Analysis:
Establish the shear force diagram using usual techniques.

Design Procedure:

1. At the given section calculate the shear stress, v:

$$v = V / b_v d$$

Check $v \le 0.8\sqrt{f_{cu}}$ or 5 N/mm^2

2. Calculate the design concrete shear stress, v_c, from:

$$v_c = 0.79(f_{cu}/25)^{1/3}\,(100A_s/b_v d)^{1/3}(400/d)^{1/4}/\gamma_m$$

Where:

$100A_s/b_v d \le 3$
$400/d \ge 1$
$f_{cu}/25 \ge 1$ and $f_{cu} \le 40$ N/mm^2

3. Enhance the design concrete shear capacity for sections $\le 2d$ to the support:

$$\text{enhanced } v_c = 2v_c d/a_v$$

4. Calculate the required area of vertical shear links A_{sv}, from:

$$A_{sv} = b_v s_v(v - v_c)/0.95f_y$$

Or calculate the maximum spacing for a given bar size (or A_{sv}) from:

$$s_v = 0.95f_y A_{sv} / b_v(v - v_c)$$

Choosing Reinforcement:
T or R bars may be used. Usual bar sizes are 8, 10, 12ϕ. Link spacing, s_v, should be a multiple of 25 mm. Use the same bar size in a beam, just alter the spacing to accommodate differing strength requirements. Links can be provided across the full width of the beam, they do not have to be concentrated in the perimeter.

Specific Detailing Requirements:
Minimum area of shear links to be provided anywhere in a beam: $A_{sv} = 0.4b_v s_v / 0.95f_y$. Spacing of links ≤ 0.75d. Spacing of links should not be less than 100 mm, or 75 mm in exceptional circumstances for poker access to the concrete.