Chapter Four

Analysis and Design of One-way Slabs for Flexure

One-way slabs are concrete structural floor panels for which the ratio of the long span to the short span equals or exceeds a value of two. When this ratio is less than 2, the floor panel becomes a two-way slab or plate, which will be covered in chapter six.

4.1 One-Way Solid Slab

A one-way slab is designed as a singly reinforced 1-meter wide beam strip using the same design and analysis procedures discussed earlier for singly reinforced beams. Fig. shows a one-way slab floor system.

Loading for slabs is normally in KN per square meter (KN/m^2). One has to distribute the reinforcement over the 1-meter strip and specify the center to center spacing of the reinforcing bars.

Transverse reinforcement has to be provided perpendicular to the direction of bending in order to resist shrinkage and temperature stresses.

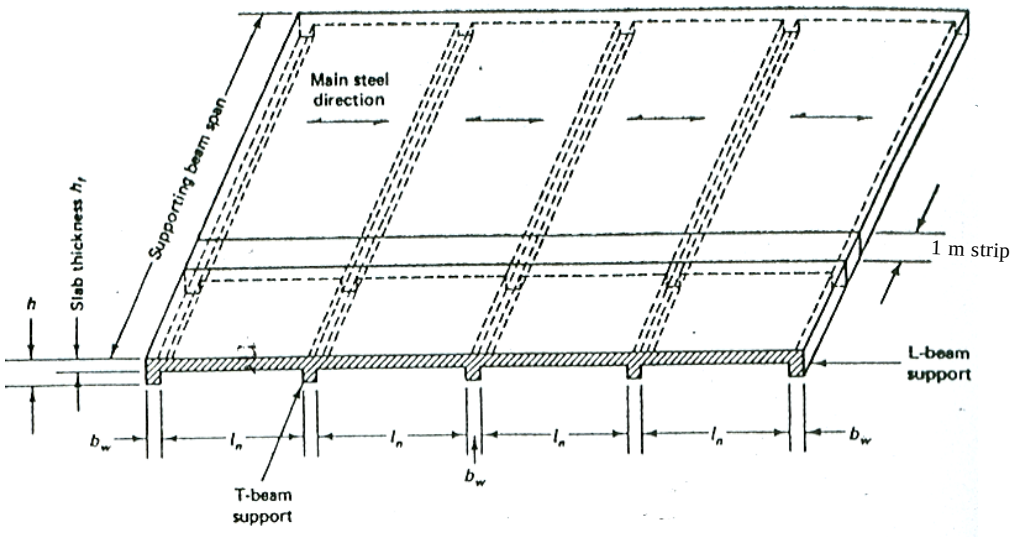


Fig.4.1 Isometric view of four-span continuous one-way-slab floor system

Flexural Reinforcement for Slabs as per EBCS 2:

- The geometrical main reinforcement ratio in a slab shall not be less than:

$$\rho_{\min} = \frac{0.5}{f_{yk}} \qquad \text{where } f_{yk} \text{ is in MPA}$$

- The ratio of the secondary reinforcement to the main reinforcement shall be at least equal to 0.2.
- The spacing between main bars for slabs shall not exceed the smaller of 2h or 350mm. where h is the thickness of the slab.
- The spacing between secondary bars shall not exceed 400mm.

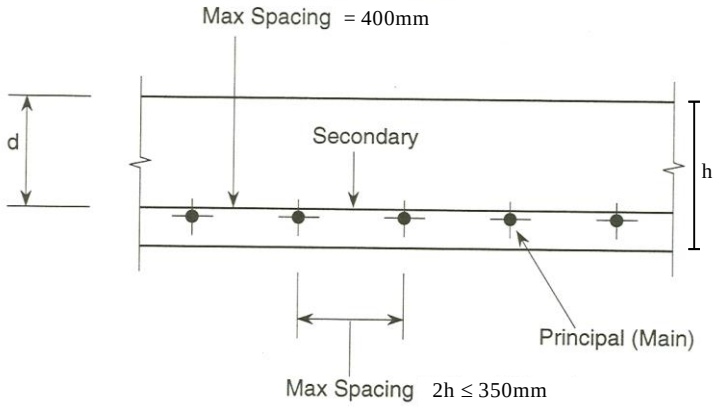


Fig. 4.2 Bar spacing in slabs

4.2 Ribbed Slabs

Ribbed slabs comprise closely spaced concrete joists which are monolithically built with thin concrete slabs (See Fig). These are economical for buildings where there are long spans and light and moderate live loads such as in hospitals or apartment buildings.

An advantage of such constriction systems is either effectiveness in spanning longer openings and in reducing the dead loads by essentially eliminating concrete in tension in the space between the ribs below the neutral axis. Near the supports the full depth is retained **(the slab is made soild)** to achieve greater shear strength.

They can be formed in one of the following ways: (**The topping is considered to contribute to structural strength)**

a) As a series of in situ concrete ribs cast between hollow or solid block formers which remain part of the completed slab (See Fig.). **Floors having hollow blocks are generally constructed with blocks made of clay type or with concrete containing a light weight aggregate.**

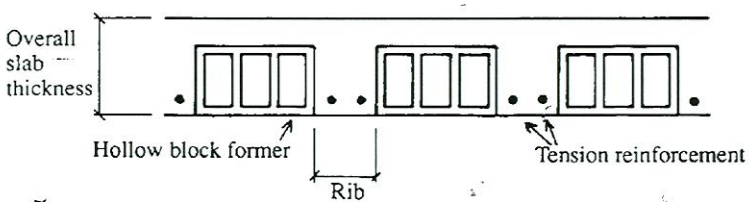


Fig. 4.3 Cross section of a ribbed slab cast with integral hollow block

b) As a series of in situ concrete ribs cast monolithically with the concrete topping on removable forms (see Fig).

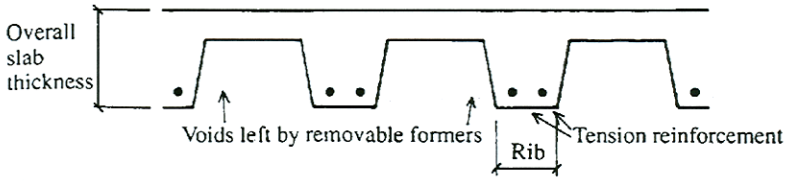


Fig. 4.4 Cross section of a ribbed slab cast on removable formers

c) As an apparently solid slab but containing permanent forms to create voids within the cross section (See Fig.)

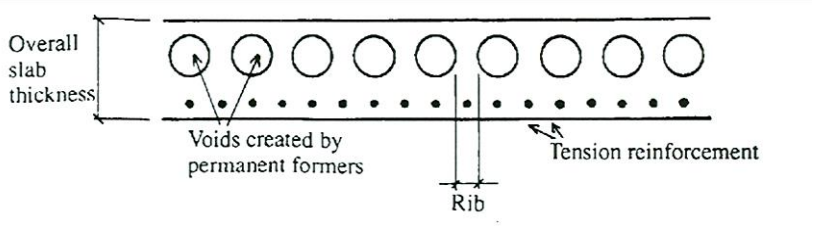


Fig. 4.5 Cross section of a ribbed slab cast with permanent void formers

The design of ribs can follow the design principles of T-beams except that the closeness of the joist ribs in a floor system resulting into a good redistribution of local over loads to adjacent members

Design of ribbed Slab, as per EBCS 2 (general requirement)

Sizes:

1) Ribs shall not be less than 70mm in width; and shall have a depth, excluding any toping, of not more than 4 times the minimum width of the rib. The rib spacing shall not exceed 1.0m (must not exceed 1.5m).
2) thickness of topping shall not be less than 40mm, nor less than 1/10 the clear distance between ribs

Minimum Reinforcement

1) The topping shall be provided with a reinforcement mesh providing in each direction a cross sectional area not less than 0.001 of the section of the slab.
2) If the rib spacing exceeds 1.0m, the toping shall be designed as a slab resting on ribs, considering load concentrations, if any.

Transverse ribs

1) transverse ribs shall be provided if the span of the ribbed slab exceeds 6.0m

2) when transverse ribs are provided, the centre to center distance shall not exceed 20 times the overall depth of the ribbed slab
3) The transverse ribs shall be designed for at least half the values of maximum moments and shear force in the longitudinal ribs.

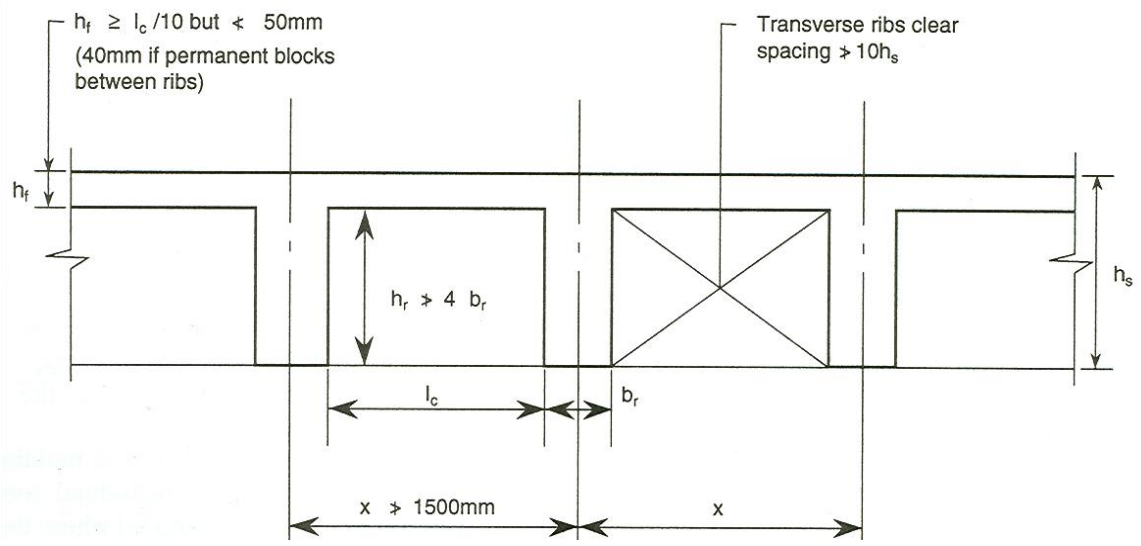
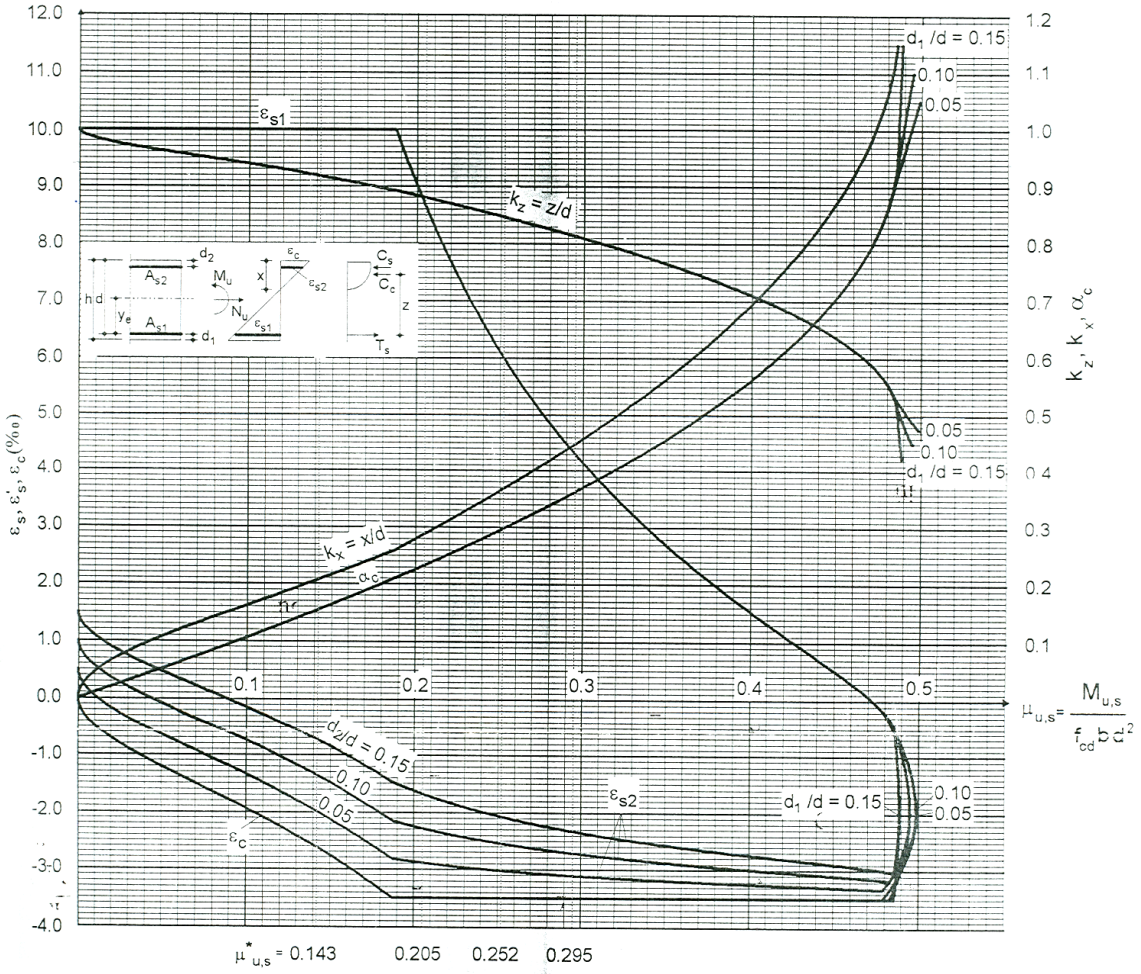


Fig. 4.6 General requirement for ribbed slabs, EC2

The ribbed slabs are formed using temporary or permanent shuttering. the forms which remain part of the completed structure may contribute to the structural strength of the slab. If not they can be regarded as non-removable formers. It should be remembered that we are talking about in situ concrete slabs, not slabs consisting of pre-cast concrete ribs with in fill blocks between them, on top of which is cast a concrete topping. Where the block do contribute to the structural strength they will be referred as structural-type blocks which comply with requirements of EBCS. Although these blocks may contribute to flexural strength, their main contribution is regarding shear and deflection.

(Analysis and design example)

General Design Chart No. 1



(1) If $\mu_{Sd,s} \leq \mu^*_{u,s}$ compression reinforcement is not required:

$$A_{s1} = \frac{M_{Sd,s}}{z f_{yd}} + \frac{N_{Sd}}{f_{yd}}$$

(2) If $\mu_{Sd,s} > \mu^*_{u,s}$ compression reinforcement is required:

$$A_{s2} = \frac{M_{Sd,s} - M^*_{u,s}}{(d - d_2)\sigma_{s2}}$$

$$A_{s1} = \frac{M_{Sd,s}}{z f_{yd}} + \frac{M_{Sd,s} - M^*_{u,s}}{(d - d_2) f_{yd}} + \frac{N_{Sd}}{f_{yd}}$$

Bending with or without Normal Load, with or without Compression Reinforcement

General Design Table No. 1a
(no moment redistribution)

k_m					k_s							Redist-ribution
C15	C20	C25	C30	C40	S300	S400	S460	ε_c	ε_{s1}	k_x	k_z	
15	17	19	21	24	3.95	2.96	2.58	0.94	10	0.09	0.97	
19	22	25	27	31	3.99	2.99	2.60	1.27	10	0.11	0.96	
23	26	29	32	37	4.04	3.03	2.63	1.59	10	0.14	0.95	
26	30	33	37	42	4.08	3.06	2.66	1.92	10	0.16	0.94	
29	33	37	40	47	4.12	3.09	2.69	2.24	10	0.18	0.93	
31	35	40	43	50	4.17	3.13	2.72	2.56	10	0.20	0.92	
31.12	35.94	40.18	44.02	50.83	4.18	3.13	2.72	2.63	10	0.208	0.918	30%
33	38	42	46	53	4.21	3.16	2.75	2.89	10	0.22	0.91	
34	40	44	49	56	4.26	3.19	2.78	3.22	10	0.24	0.90	
36	42	46	51	59	4.31	3.23	2.81	3.50	9.7	0.26	0.89	
37.36	43.13	48.23	52.83	61	4.36	3.27	2.84	3.50	8.7	0.288	0.880	20%
37	43	48	53	61	4.36	3.27	2.84	3.50	8.6	0.29	0.88	
39	45	50	55	63	4.41	3.30	2.87	3.50	7.7	0.31	0.87	
40	46	52	56	65	4.46	3.34	2.91	3.50	6.9	0.34	0.86	
41	47	53	58	67	4.51	3.38	2.94	3.50	6.2	0.36	0.85	
41.42	47.83	53.47	58.58	67.64	4.53	3.39	2.95	3.50	6.0	0.368	0.847	10%
42	49	54	60	69	4.56	3.42	2.98	3.50	5.6	0.38	0.84	
43	50	56	61	71	4.62	3.46	3.01	3.50	5.1	0.41	0.83	
44	51	57	63	72	4.67	3.51	3.05	3.50	4.6	0.43	0.82	
44.79	51.72	57.83	63.35	73.15	4.71	3.53	3.07	3.50	4.3	0.448	0.814	

No redistribution ($k_x = 0.448$)

k_m/k^*_m	k_m					k_s		
	C15	C20	C25	C30	C40	S300	S400	S460
	44.79	51.72	57.83	63.35	73.15	4.71	3.53	3.07
1.03	46	53	59	65	75	4.68	3.51	3.05
1.05	47	54	61	67	77	4.65	3.49	3.04
1.08	48	56	63	69	79	4.63	3.47	3.02
1.11	50	58	64	71	81	4.60	3.45	3.00
1.15	51	59	66	73	84	4.57	3.43	2.98
1.19	53	61	69	75	87	4.54	3.40	2.96
1.23	55	64	71	78	90	4.51	3.38	2.94
1.28	57	66	74	81	94	4.48	3.36	2.92
1.33	60	69	77	84	97	4.45	3.34	2.90
1.39	62	72	81	88	102	4.43	3.32	2.89
1.46	66	76	85	93	107	4.40	3.30	2.87

Notes:

1 See Table 1b for Design Equations

2 Initial values for 0%, 10%, 20% & 30% Moment Redistribution are shown shaded in Tables No.1a & 1b

Factors ρ and k_s' are applicable to all values of moment redistribution

Correction factor ρ

k_m/k^*_m	d_2/d						
	0.07	0.08	0.1	0.12	0.14	0.16	0.18
1	1	1	1	1	1	1	1
1.03	1	1.00	1.00	1.00	1.00	1.00	1.01
1.05	1	1.00	1.00	1.00	1.01	1.01	1.01
1.08	1	1.00	1.00	1.01	1.01	1.01	1.02
1.11	1	1.00	1.01	1.01	1.01	1.02	1.02
1.15	1	1.00	1.01	1.01	1.02	1.02	1.03
1.19	1	1.00	1.01	1.02	1.02	1.03	1.04
1.23	1	1.00	1.01	1.02	1.03	1.03	1.04
1.28	1	1.00	1.01	1.02	1.03	1.04	1.05
1.33	1	1.00	1.01	1.02	1.03	1.04	1.05
1.39	1	1.00	1.02	1.03	1.04	1.05	1.06
1.46	1	1.01	1.02	1.03	1.04	1.05	1.07

k_m/k^*_m	k_s'		
	S300	S400	S460
1	0	0	0
1.03	0.20	0.15	0.13
1.05	0.40	0.30	0.26
1.08	0.60	0.45	0.39
1.11	0.80	0.60	0.52
1.15	1.00	0.75	0.65
1.19	1.20	0.90	0.78
1.23	1.40	1.05	0.91
1.28	1.60	1.20	1.04
1.33	1.80	1.35	1.17
1.39	2.00	1.50	1.30
1.46	2.20	1.65	1.43

Correction factor ρ'

All K_m/K^*_m	1	1.01	1.03	1.06	1.08	1.11	1.13

Rectangular Section ... Moment with or without Axial Load, with or without Compression Reinforcement

General Design Table No. 1b
(with moment redistribution)

10% redistribution ($k_x = 0.368$)

k_m/k^*_m	k_m					k_s		
	C15	C20	C25	C30	C40	S300	S400	S460
1	41.42	47.83	53.47	58.58	67.64	4.53	3.39	2.95
1.03	42	49	55	60	69	4.52	3.39	2.95
1.05	44	50	56	62	71	4.52	3.39	2.95
1.08	45	52	58	63	73	4.52	3.39	2.95
1.11	46	53	60	65	76	4.51	3.38	2.94
1.15	48	55	61	67	78	4.51	3.38	2.94
1.19	49	57	63	70	80	4.51	3.38	2.94
1.23	51	59	66	72	83	4.50	3.38	2.94
1.28	53	61	68	75	86	4.50	3.37	2.93
1.33	55	64	71	78	90	4.50	3.37	2.93
1.39	58	67	74	82	94	4.49	3.37	2.93
1.46	61	70	78	86	99	4.49	3.37	2.93

Notes:

1 k^*_m is k_m value corresponding to $\mu^*_{u,s}$ (shown shaded in Tables No.1a &1b)

2. Units:

M (kNm)
b,d (m)
A_s (mm^2)

Correction factor ρ'

	d_2/d						
All	0.07	0.08	0.1	0.12	0.14	0.16	0.18
K_m/K^*_m	1	1.01	1.03	1.06	1.08	1.11	1.13

20% redistribution ($k_x = 0.288$)

k_m/k^*_m	k_m					k_s		
	C15	C20	C25	C30	C40	S300	S400	S460
1	37.36	43.13	48.23	52.83	61	4.36	3.27	2.84
1.03	38	44	49	54	63	4.34	3.26	2.83
1.05	39	45	51	56	64	4.33	3.25	2.83
1.08	40	47	52	57	66	4.32	3.24	2.82
1.11	42	48	54	59	68	4.31	3.23	2.81
1.15	43	50	55	61	70	4.30	3.22	2.80
1.19	44	51	57	63	72	4.29	3.22	2.80
1.23	46	53	59	65	75	4.28	3.21	2.79
1.28	48	55	62	68	78	4.26	3.20	2.78
1.33	50	57	64	70	81	4.25	3.19	2.77
1.39	52	60	67	74	85	4.24	3.18	2.77
1.46	55	63	71	77	89	4.23	3.17	2.76

Correction factor ρ'

	d_2/d			
All	0.07	0.08	0.1	0.12
K_m/K^*_m	1	1.01	1.03	1.06

30% redistribution ($k_x = 0.208$)

k_m/k^*_m	k_m					k_s		
	C15	C20	C25	C30	C40	S300	S400	S460
1	31.07	35.88	40.12	43.95	50.74	4.18	3.13	2.72
1.03	32	37	41	45	52	4.17	3.13	2.72
1.05	33	38	42	46	53	4.17	3.13	2.72
1.08	34	39	43	48	55	4.17	3.13	2.72
1.11	35	40	45	49	57	4.17	3.12	2.72
1.15	36	41	46	50	58	4.16	3.12	2.71
1.19	37	43	48	52	60	4.16	3.12	2.71
1.23	38	44	49	54	62	4.16	3.12	2.71
1.28	40	46	51	56	65	4.16	3.12	2.71
1.33	41	48	53	59	68	4.15	3.11	2.71
1.39	43	50	56	61	71	4.15	3.11	2.71
1.46	46	53	59	64	74	4.15	3.11	2.70

Correction factor $\rho' = 1$ for $d_2/d \leq 0.07$
(higher values of d_2/d not recommended)

$$k_m = \frac{\sqrt{M_{Sd,s}\,/\,b}}{d}$$

$$M_{Sd,s} = M_{Sd} - N_{Sd}\,\gamma_e$$

$$A_{s1} = \frac{M_{Sd,s}}{d} k_s \rho + \frac{N_{Sd}}{f_{yd}}$$

$$A_{s2} = \frac{M_{Sd,s}}{d} k'_s \cdot \rho'$$

Rectangular Section ... Moment with or without Axial load, with or without Compression Reinforcement