Preliminary design of concrete structures

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1 Content

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2 Preliminary design

2.1 Reinforced concrete slab

First of all it is necessary to design a slab thickness. The slab thickness is derived in accordance with span to effective depth ratio (simplified method). If the slab thickness is designed using this method, the slab is considered to be adequate for avoiding deflection problems in normal circumstances. The most critical slab (with the biggest span or with the worst static scheme) is used for the calculation.

$$d_s \geq \frac{l}{\kappa_{c1} \, . \, \kappa_{c2} \, . \, \kappa_{c3} . \, \lambda_{d,tab}}$$

d_s *effective depth of cross-section*

l *element span (in case of two-way slab use the smaller span)*

κ_{c1} *coefficient of cross-section (rectangular cross-section 1; T-shape cross-section 0.8)*

κ_{c2} *coefficient of span (for $l \leq 7$ m $\kappa_{c2} = 1.0$, other cases $\kappa_{c2} = 7/l$)*

κ_{c3} *coefficient of stress in tensile reinforcement (assumed $\kappa_{c3} = 1.1 - 1.3$)*

$\lambda_{d,tab}$ *design span to depth ratio obtained from the attached table (in case of a slab, use the reinfor. ratio 0.5 %)*

$\lambda_{d,tab}$ design span to depth ratio								
Structural system	Reinforcement ratio	Strength class						
		C12/15	C16/20	C20/25	C25/30	C30/37	C40/50	C50/60
Simply supported beam, one-way or two-way spanning simply supported slab	0,5%	16,6	15,8	17,0	18,5	20,5	25,8	32,0
	1,5%	12,2	12,6	13,0	13,5	14,0	15,0	16,0
Cantilever	0,5%	5,8	6,3	6,8	7,4	8,0	10,3	12,8
	1,5%	4,9	5,0	5,2	5,4	5,6	6,0	6,4
Slab supported on columns without beams (flat slab, locally supported slab)	0,5%	17,5	19,0	20,4	22,2	24,0	30,9	38,4
	1,5%	14,6	15,1	15,6	16,2	16,8	18,0	19,2
End span of continuous beam or one-way continuous slab or two-way spanning slab continuous over one long side	0,5%	19,0	20,5	22,1	24,1	26,0	33,5	41,5
	1,5%	15,9	16,4	16,9	17,6	18,0	19,5	20,8
Interior span of continuous beam or one-way or two-way spanning continuous slab	0,5%	21,9	23,7	25,5	27,8	30,8	38,6	48,0
	1,5%	18,3	18,9	19,5	20,3	21,0	22,5	24,0

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$$h_s = d_s + c + \frac{\emptyset}{2}$$

h_s *slab thickness (cross-section depth) - roundup to nearest tens mm*

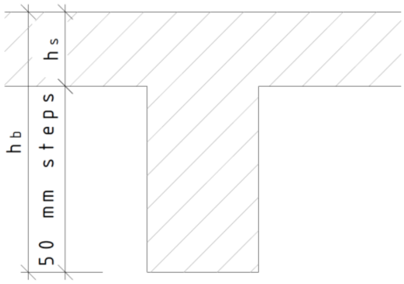
c *concrete cover (depends on the exposure classes, service life etc., use 20,25,30,35 mm)*

$\emptyset$ *assumed bar diameter (for slab 8,10 or 12 mm bar)*

Using this method, the value of the slab thickness obtained from the calculation is relatively conservative (on safe side). It is not a mistake to use the obtained value for other calculation within the preliminary design. But if you want to be more precise, you should consider the size of uniform loading the slab is subject to and adjust the obtained value by your engineering opinion. That means to design a thinner slab or a thicker slab if the uniform load is expected to be lower or higher, respectively, in comparison with a common size.

2.2 Reinforced concrete beam

First, the dimensions of a cross-section have to be determined using the following formula. The formula was derived based on the experience with designing concrete structures and should give you only an idea about the cross-section size. As consequence, it is not necessary to fulfil the condition and select the dimensions in the proposed range.



$$h_b = \left(\frac{1}{12} \div \frac{1}{8}\right).l_b$$

$$w_b = \left(\frac{1}{3} \div \frac{1}{2}\right).h_b$$

l_b *beam span*
h_b *cross-section depth - use such h_b to get (h_b - h_s) in 50 mm steps (for instance: h_s = 170 mm, h_b = 420 mm)*
w_b *cross-section width - roundup to nearest fifties mm*

Subsequently, the beam of the selected cross-section has to be validated that it is able to withstand assumed loading. First, determine line load acting on the proposed beam and then the maximum bending moment and shear force.

The validation of the beam size in terms of flexural behaviour:

$$M_{Ed,max} = ???$$

$$d_b = h_b - c - \emptyset_{sw} - \frac{\emptyset}{2}$$

$$\mu = \frac{M_{Ed,max}}{w_b.d_b^2.f_{cd}} \quad \rightarrow \quad use\ the\ table\ below\ to\ determine\ the\ coefficient\ \xi$$

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$\emptyset$	*assumed flexural reinforcement diameter (16, 18, 20, 22, 25, 28 mm)*
$\emptyset_{sw}$	*assumed stirrups diameter (8 or 10 mm)*
f_{cd}	*design value of compressive concrete strength (depends on concrete strength class)*

The coefficient ξ should be less than 0,45 in accordance with CSN EN 1992-1-1. Moreover, to design a cost-effective and material-efficient beam, the coefficient ξ should be in a range 0,15 - 0,4; otherwise change the dimensions of the beam cross-section.

The validation of the beam size in terms of shear behaviour:

$$V_{Ed,max} = ???$$

$$V_{Rd,max} = \nu \, f_{cd} \, w_b \, \zeta \, d_b \frac{\cot\theta}{1+\cot^2\theta}$$

$$\nu = 0.6\left(1-\frac{f_{ck}}{250}\right)$$

$V_{Ed,max} \leq V_{Rd,max}$; otherwise change the cross-section dimensions

$V_{Rd,max}$	*the design value of the maximum shear force which can be sustained by the member, limited by crushing of the compression struts.*
ζ	*general coefficient, use the table below*
$\cot\theta$	*cotangens of the angle between the concrete compression strut and the beam axis perpendicular to the shear force, use 1.2 ÷ 1.5*
f_{ck}	*characteristic value of compressive concrete strength (depends on concrete strength class)*

2.3 Reinforced concrete column

Once you validate the beam cross-section and slab thickness you are capable to calculate point load on a selected column (the most critical column in terms of load size). To determine the size of a column cross-section, use the following formula for a centrally loaded column.

$$N_{Ed} \leq N_{Rd} = 0{,}8.A_c.f_{cd} + A_s.\sigma_s$$

$$N_{Ed} \leq 0{,}8.A_c.f_{cd} + \rho.A_c.\sigma_s$$

$$N_{Ed} \leq A_c.(0{,}8.f_{cd} + \rho.\sigma_s)$$

$$\frac{N_{Ed}}{(0{,}8.f_{cd}+\rho.\sigma_s)} \leq A_c \rightarrow determine\ cross-section\ width\ w_c\ and\ depth\ d_c\ (rounup\ to\ 50\ mm)$$

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N_{Ed}	*maximum point load acting on a selected column*
A_c	*cross-section area*
A_s	*reinforcement area*
ρ	*reinforcement ratio (use 1%-3%)*
σ_s	*stress in reinforcement (use 400 MPa)*

One of the cross-section dimensions is strongly recommended to be the same as the beam width due to manufacturing technology .

μ	ω	ξ	ζ	ε_{s1}	ε_c	ε_{s2} pro d_2/d			
						0,05	0,1	0,15	0,2
0,010	0,0101	0,013	0,995	275,093	-3,500	10,430	24,359	38,289	52,219
0,020	0,0202	0,025	0,990	135,086	-3,500	3,429	10,359	17,288	24,217
0,030	0,0305	0,038	0,985	88,412	-3,500	1,096	5,691	10,287	14,882
0,040	0,0408	0,051	0,980	65,071	-3,500	-0,071	3,357	6,786	10,214
0,050	0,0513	0,064	0,974	51,063	-3,500	-0,772	1,956	4,684	7,413
0,060	0,0619	0,077	0,969	41,722	-3,500	-1,239	1,022	3,283	5,544
0,070	0,0726	0,091	0,964	35,047	-3,500	-1,573	0,355	2,282	4,209
0,080	0,0835	0,104	0,958	30,039	-3,500	-1,823	-0,146	1,531	3,208
0,090	0,0945	0,118	0,953	26,142	-3,500	-2,018	-0,536	0,946	2,428
0,100	0,1056	0,132	0,947	23,022	-3,500	-2,174	-0,848	0,478	1,804
0,110	0,117	0,146	0,942	20,468	-3,500	-2,302	-1,103	0,095	1,294
0,120	0,128	0,160	0,936	18,337	-3,500	-2,408	-1,316	-0,224	0,867
0,130	0,140	0,175	0,930	16,533	-3,500	-2,498	-1,497	-0,495	0,507
0,140	0,151	0,189	0,924	14,985	-3,500	-2,576	-1,651	-0,727	0,197
0,150	0,163	0,204	0,918	13,642	-3,500	-2,643	-1,786	-0,929	-0,072
0,160	0,175	0,219	0,912	12,465	-3,500	-2,702	-1,903	-1,105	-0,307
0,170	0,188	0,234	0,906	11,426	-3,500	-2,754	-2,007	-1,261	-0,515
0,180	0,200	0,250	0,900	10,500	-3,500	-2,800	-2,100	-1,400	-0,700
0,190	0,213	0,266	0,894	9,670	-3,500	-2,841	-2,183	-1,524	-0,866
0,200	0,225	0,282	0,887	8,922	-3,500	-2,879	-2,258	-1,637	-1,016
0,210	0,238	0,298	0,881	8,244	-3,500	-2,913	-2,326	-1,738	-1,151
0,220	0,252	0,315	0,874	7,626	-3,500	-2,944	-2,387	-1,831	-1,275
0,230	0,265	0,331	0,867	7,060	-3,500	-2,972	-2,444	-1,916	-1,388
0,240	0,279	0,349	0,861	6,540	-3,500	-2,998	-2,496	-1,994	-1,492
0,250	0,293	0,366	0,854	6,060	-3,500	-3,022	-2,544	-2,066	-1,588
0,260	0,307	0,384	0,846	5,615	-3,500	-3,044	-2,588	-2,133	-1,677
0,270	0,322	0,402	0,839	5,202	-3,500	-3,065	-2,630	-2,195	-1,760
0,280	0,337	0,421	0,832	4,817	-3,500	-3,084	-2,668	-2,253	-1,837
0,290	0,352	0,440	0,824	4,456	-3,500	-3,102	-2,704	-2,307	-1,909
0,300	0,368	0,459	0,816	4,118	-3,500	-3,119	-2,738	-2,357	-1,976
0,310	0,384	0,479	0,808	3,800	-3,500	-3,135	-2,770	-2,405	-2,040
0,320	0,400	0,500	0,800	3,500	-3,500	-3,150	-2,800	-2,450	-2,100
0,330	0,417	0,521	0,792	3,216	-3,500	-3,164	-2,828	-2,493	-2,157
0,340	0,434	0,543	0,783	2,947	-3,500	-3,178	-2,855	-2,533	-2,211
0,350	0,452	0,565	0,774	2,691	-3,500	-3,190	-2,881	-2,571	-2,262
0,360	0,471	0,589	0,765	2,447	-3,500	-3,203	-2,905	-2,608	-2,311
0,370	0,490	0,613	0,755	2,213	-3,500	-3,214	-2,929	-2,643	-2,357
0,380	0,510	0,638	0,745	1,989	-3,500	-3,226	-2,951	-2,677	-2,402
0,390	0,531	0,664	0,735	1,773	-3,500	-3,236	-2,973	-2,709	-2,445
0,400	0,553	0,691	0,724	1,565	-3,500	-3,247	-2,993	-2,740	-2,487
0,410	0,576	0,720	0,712	1,363	-3,500	-3,257	-3,014	-2,770	-2,527
0,420	0,600	0,750	0,700	1,167	-3,500	-3,267	-3,033	-2,800	-2,567
0,430	0,626	0,782	0,687	0,974	-3,500	-3,276	-3,053	-2,829	-2,605
0,440	0,654	0,817	0,673	0,784	-3,500	-3,286	-3,072	-2,857	-2,643
0,450	0,684	0,855	0,658	0,595	-3,500	-3,295	-3,091	-2,886	-2,681
0,460	0,717	0,896	0,641	0,404	-3,500	-3,305	-3,110	-2,914	-2,719
0,470	0,755	0,944	0,622	0,208	-3,500	-3,315	-3,129	-2,944	-2,758
0,480	0,800	1,000	0,600	0,000	-3,500	-3,325	-3,150	-2,975	-2,800
0,490	0,859	1,073	0,571	-0,239	-3,500	-3,337	-3,174	-3,011	-2,848

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