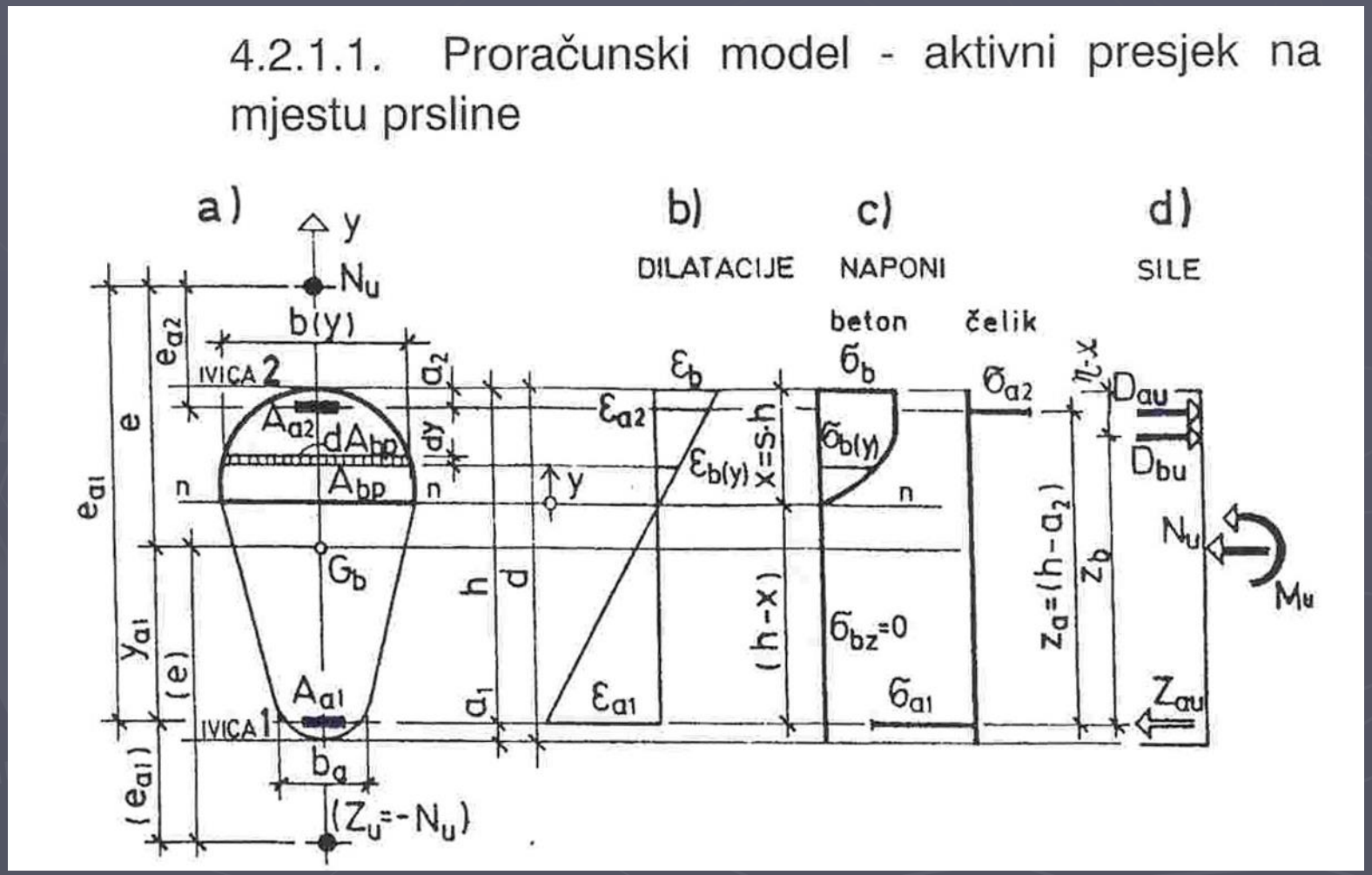
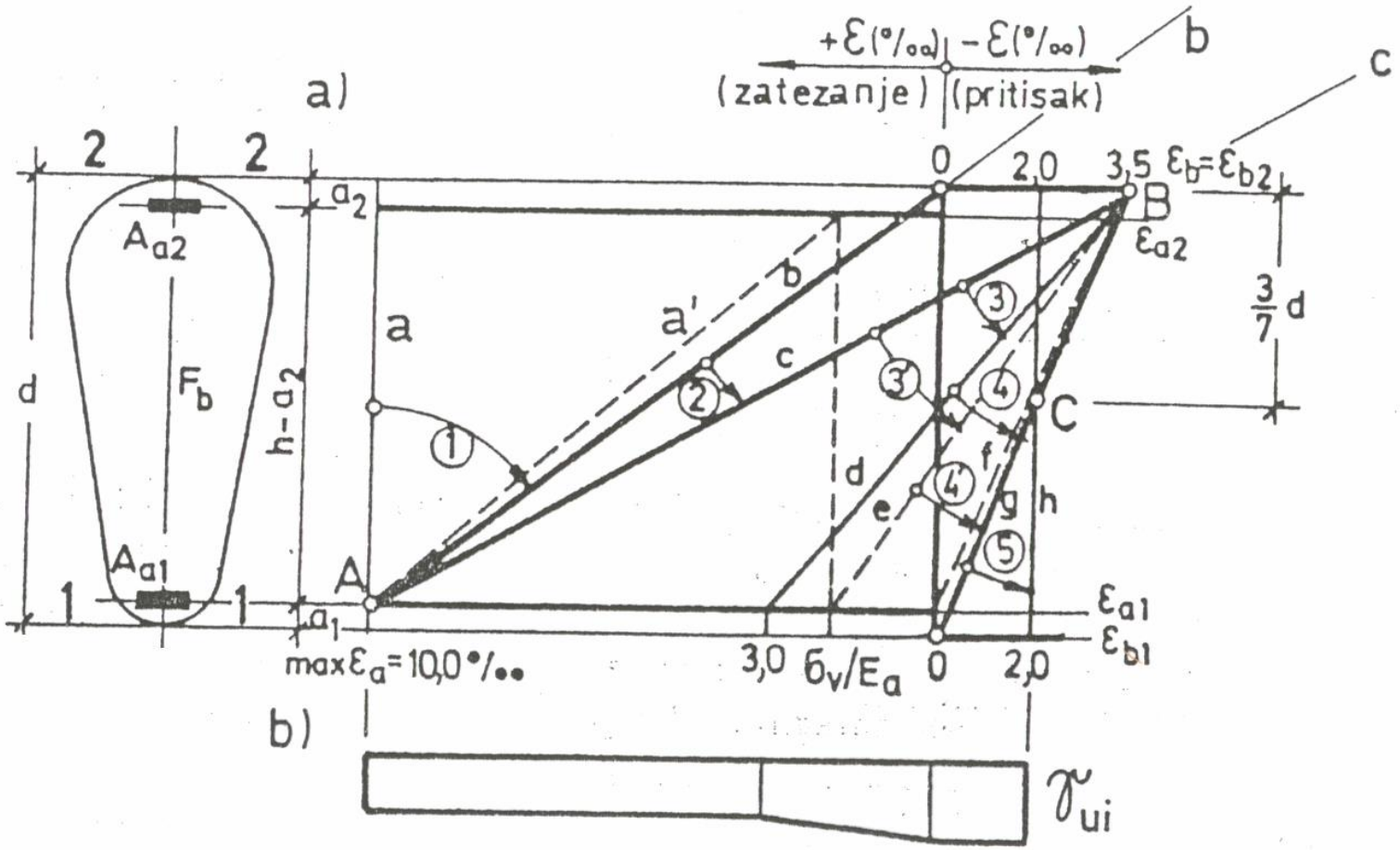
Pravo složeno savijanje sa normalnom silom – veliki ekcentricitet



Naponsko deformacijske obalsti



Slika 84/1 Oblast mogućih raspodela dilatacija u armiranobetonskom preseku kod dostizanja granične nosivosti

α_b - koeficijent punoće naponskog dijagrama

h- statička visina presjeka, udaljenost težišta zategnute armature od pritisnute ivice

x = s x h - udaljenost neutralne ose od pritisnute ivice
s- koeficijent udaljenosti neutralne ose od pritisnute ivice
z_b - krak unutrašnjih sila $z_b = h-\eta x = h-\eta sh = h(1-\eta s) = h\,\zeta_b$

η- koeficijent udaljenosti sile pritiska u betonu D_b od pritisnute ivice

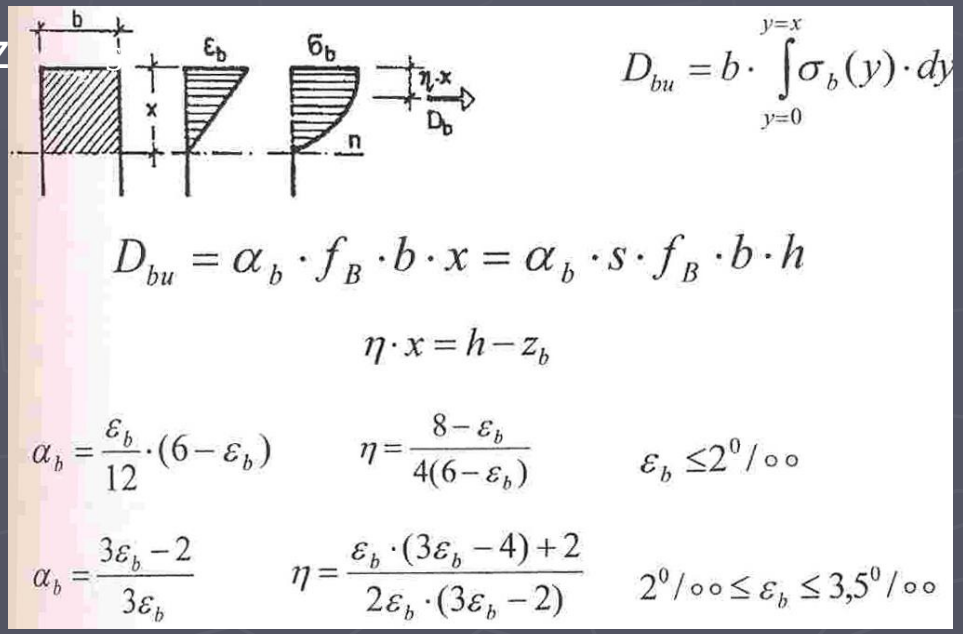
ζ_b – koeficijent kraka unutrašnjih sila

ε_b – deformacija betona na pritisnutoj ivici presjeka

ε_{a1} – deformacija armature u težištu z

A_{a1} – površina zategnute armature
A_{a2} – površina pritisnute armature
Z_{au} – sila u zategnutoj armaturi

D_{bu} – sila u pritisnutom betonu
M_u – spoljašnji granični moment
N_u – spoljašnja granična sila



$$D_{bu} = b \cdot \int_{y=0}^{y=x} \sigma_b(y) \cdot dy$$

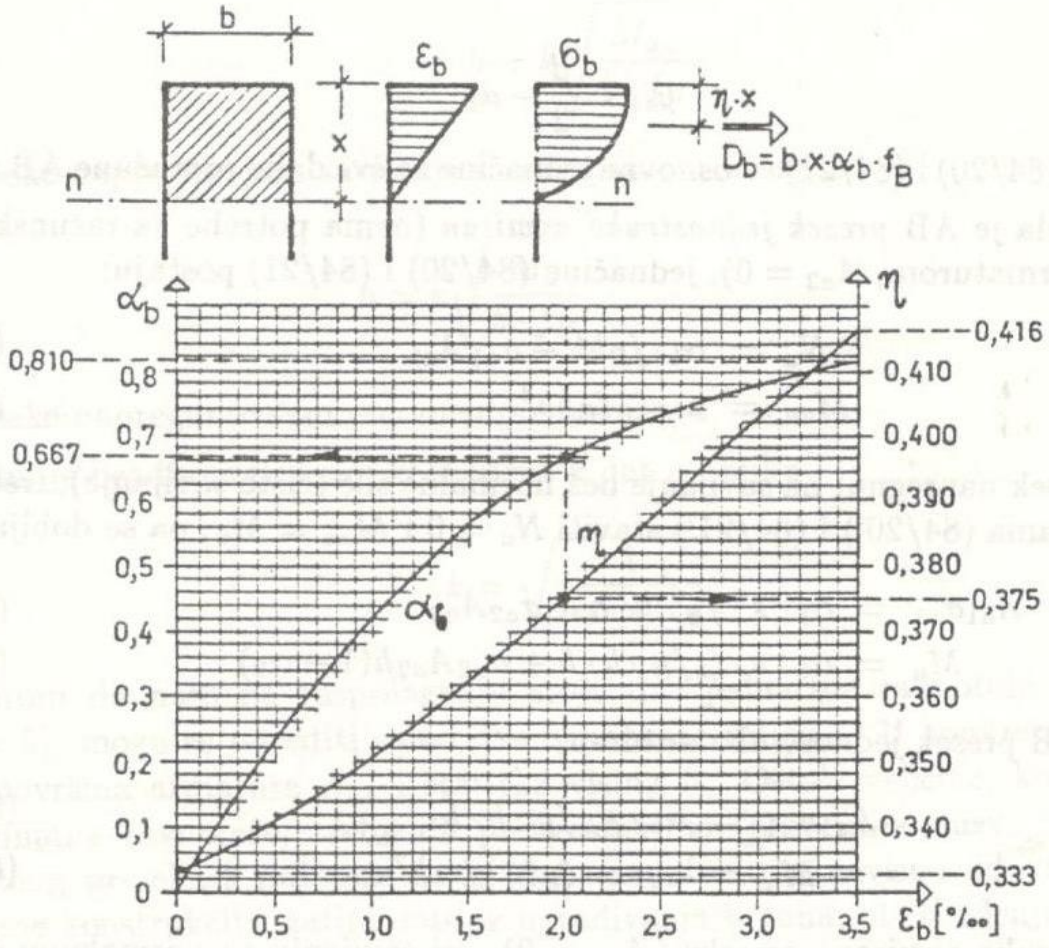
$$D_{bu} = \alpha_b \cdot f_B \cdot b \cdot x = \alpha_b \cdot s \cdot f_B \cdot b \cdot h$$

$$\eta \cdot x = h - z_b$$

$$\alpha_b = \frac{\varepsilon_b}{12} \cdot (6 - \varepsilon_b) \qquad \eta = \frac{8 - \varepsilon_b}{4(6 - \varepsilon_b)} \qquad \varepsilon_b \le 2^0/_{00}$$

$$\alpha_b = \frac{3\varepsilon_b - 2}{3\varepsilon_b} \qquad \eta = \frac{\varepsilon_b \cdot (3\varepsilon_b - 4) + 2}{2\varepsilon_b \cdot (3\varepsilon_b - 2)} \qquad 2^0/_{00} \le \varepsilon_b \le 3{,}5^0/_{00}$$

Izraz za potrebnu armaturu zatezanja dobijaju se iz uslova ravnoteže unutrašnjih sila u presjeku i spoljašnjih sila i momenata.



Slika 84/3 Koeficijenti α_b i η (dijagram $\sigma_b - \varepsilon_b$; kvadratna parabola + prava) za pravougaoni oblik pritisnutog poprečnog preseka, u funkciji $\varepsilon_b \ldots (x < d)$, prema jedn. (84/13) - (84/16)

Jednostruko armirani presjek, sa normalnom silom pritiska

Presjek je jednostruko armiran kada nema potrebe za računskom pritisnutom armaturom $A_{a2,}$ U jednačinama ravnoteže uzima se da je $A_{a2}=0$.

4.2.1.3.1. Jednostruko armirani presjeci

$$A_{a2} = 0 \Rightarrow \qquad N_u = \alpha_b \cdot s \cdot f_B \cdot b \cdot h - \sigma_{a1} \cdot A_{a1}$$

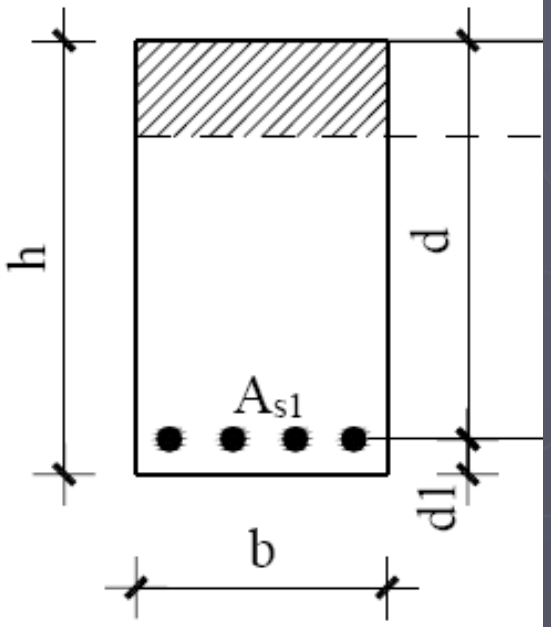
$$M_{au} = \alpha_b \cdot s \cdot \varsigma_b \cdot f_B \cdot b \cdot h^2$$

$$h = k \cdot \sqrt{\frac{M_{au}}{b \cdot f_B}} \qquad k = \sqrt{\frac{1}{\alpha_b \cdot s \cdot \varsigma_b}}$$

$$\frac{Z_{au}}{\sigma_{a1}} = potr.A_{a1} = \frac{D_{bu} - N_u}{\sigma_{a1}} = \frac{1}{\sigma_{a1}} \cdot \left(\frac{M_{au}}{z_b} - N_u \right) = \frac{M_{au}}{\sigma_{a1} \cdot z_b} - \frac{N_u}{\sigma_{a1}}$$

$$potr.A_{a1} = \mu_{1M} \cdot b \cdot h - \frac{N_u}{\sigma_{a1}} \qquad \mu_{1M} = \alpha_b \cdot s \cdot \frac{f_B}{\sigma_{a1}}$$

$$\varepsilon_{a1} \geq \frac{\sigma_v}{E_a} \quad \Rightarrow \quad \sigma_{a1} = \sigma_v$$



Jednostruko armirani presjek, sa normalnom silom zatezanja

Svi izrazi izvedeni kod ekcentrično pritisnutih elemenata važe i kod ekcentrično zategnutih elemenata. Sila zatezanja usvaja se da ima negativni znak pa se u zvim izrazima gdje figuriše normalna sila znak mijenja, a izrazi se pišu u sledećem obliku:

$$M_{au} = M_u - Z_u\left(\frac{d}{2} - a_1\right)$$

$$h = k\sqrt{\frac{M_{au}}{b f_B}}$$

$$A_{a1} = \bar{\mu}_1 b h \frac{f_B}{\sigma_v} + \frac{Z_u}{\sigma_v}$$

Na ovaj način, bezdimenzione veličine s, α_b, η, ζ_b, $\overline{\mu}$, k, koje zavise isključivo od dilatacija u betonu i armaturi, lako se tabulišu u cilju pojednostavljenja svakodnevnih proračuna.

Problem dimenzionisanja jednostruko armiranih pravougaonih preseka prema graničnoj nosivosti, za poznati granični moment savijanja, svodi se na dva slučaja:

- *slobodno dimenzionisanje*, koje podrazumeva proračun dimenzija betonskog poprečnog preseka i potrebne površine armature,
- *vezano dimenzionisanje*, koje podrazumeva proračun potrebne površine zategnute armature u elementu poznatih dimenzija poprečnog preseka.

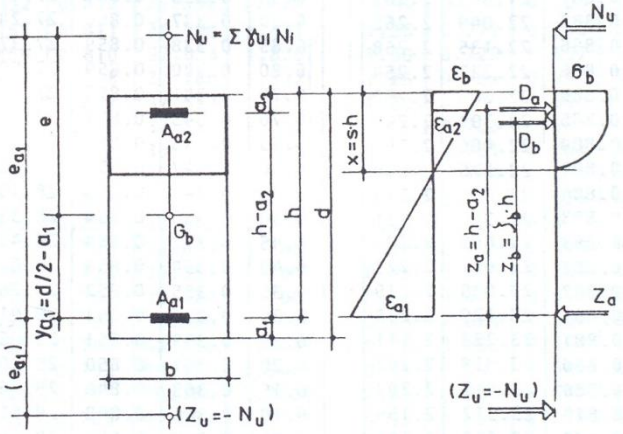
Koeficijenti za proračun pravougaonih preseka sa prslinom - veliki ekscentricitet i čisto savijanje

2.1.1 KOEFICIJENTI ZA PRORAČUN PRAVOUGAONIH PRE SEKA SA PRSLINOM - LOM PO BETONU

2.1.2 KOEFICIJENTI ZA PRORAČUN PRAVOUGAONIH PRE SEKA SA PRSLINOM - LOM PO ARMATURI

$$\sigma_b = \frac{f_B}{4}(4-\varepsilon_b)\varepsilon_b \ \ldots\ 0 \le \varepsilon_b \le 2^o/_{oo}$$

$$\sigma_b = f_B \ \ldots\ 2^o/_{oo} \le \varepsilon_b \le 3{,}5^o/_{oo}$$



$$N_u = \Sigma\gamma_{ui}N_i;\ M_u = \Sigma\gamma_{ui}M_i;\ \Delta M_{au} = M_{au} - M_{abu}$$

$$M_{au} = N_u \cdot e_{a1} = N_u[e + (0{,}5d - a_1)] = M_u + N_u(0{,}5d - a_1)$$

$$\mu_{1M} = \overline{\mu}_{1M} \cdot \frac{f_B}{\sigma_{a1}};\ h = k\sqrt{\frac{M_{au}}{f_B b}}$$

$$A_{a1} = \mu_{1M} b \cdot h - \frac{N_u}{\sigma_{a1}} + \frac{\Delta M_{au}}{(h-a_2)\sigma_{a1}}$$

$$A_{a2} = \frac{\Delta M_{au}}{(h-a_2)\sigma_{a2}};\ \sigma_{a1} = \sigma_v \text{ za } \varepsilon_{a1} \ge \frac{\sigma_v}{E_a}$$

*) Sila pritiska $N_u > 0$. Sila zatezanja $N_u < 0$

2.1.1 KOEFICIJENTI ZA PRORACUN PRAVOUGAONIH PRE-
SEKA SA PRSLINOM - LOM PO BETONU

$\varepsilon_b = 3.5\,^o/_{oo}$ $\quad \alpha = 0{,}8095$ $\quad \eta = 0{,}416$

ε_{a1} (‰)	s	ξ_b	$\overline{\mu}_{1M}$ (%)	k
10.00	0.259	0.892	20.987	2.311
9.95	0.260	0.892	21.065	2.307
9.90	0.261	0.891	21.144	2.303
9.85	0.262	0.891	21.223	2.300
9.80	0.263	0.891	21.303	2.296
9.75	0.264	0.890	21.383	2.292
9.70	0.265	0.890	21.464	2.288
9.65	0.266	0.889	21.546	2.285
9.60	0.267	0.889	21.628	2.281
9.55	0.268	0.888	21.711	2.277
9.50	0.269	0.888	21.794	2.273
9.45	0.270	0.888	21.878	2.269
9.40	0.271	0.887	21.963	2.265
9.35	0.272	0.887	22.049	2.262
9.30	0.273	0.886	22.135	2.258
9.25	0.275	0.886	22.222	2.254
9.20	0.276	0.885	22.309	2.250
9.15	0.277	0.885	22.397	2.246
9.10	0.278	0.884	22.486	2.242
9.05	0.279	0.884	22.576	2.239
9.00	0.280	0.884	22.666	2.235
8.95	0.281	0.883	22.757	2.231
8.90	0.282	0.883	22.849	2.227
8.85	0.283	0.882	22.941	2.223
8.80	0.285	0.882	23.035	2.219
8.75	0.286	0.881	23.129	2.215
8.70	0.287	0.881	23.223	2.211
8.65	0.288	0.880	23.319	2.207
8.60	0.289	0.880	23.415	2.203
8.55	0.290	0.879	23.512	2.199
8.50	0.292	0.879	23.610	2.196
8.45	0.293	0.878	23.709	2.192
8.40	0.294	0.878	23.809	2.188
8.35	0.295	0.877	23.909	2.184
8.30	0.297	0.877	24.011	2.180
8.25	0.298	0.876	24.113	2.176
8.20	0.299	0.876	24.216	2.172
8.15	0.300	0.875	24.320	2.168
8.10	0.302	0.874	24.425	2.164
8.05	0.303	0.874	24.530	2.160
8.00	0.304	0.873	24.637	2.156
7.95	0.306	0.873	24.745	2.152
7.90	0.307	0.872	24.853	2.148
7.85	0.308	0.872	24.963	2.144
7.80	0.310	0.871	25.073	2.140
7.75	0.311	0.871	25.184	2.136
7.70	0.313	0.870	25.297	2.132
7.65	0.314	0.869	25.410	2.128
7.60	0.315	0.869	25.525	2.123

ε_{a1} (‰)	s	ξ_b	$\overline{\mu}_{1M}$ (%)	k
7.55	0.317	0.868	26.640	2.119
7.50	0.318	0.868	25.757	2.115
7.45	0.320	0.867	25.874	2.111
7.40	0.321	0.866	25.993	2.107
7.35	0.323	0.866	26.113	2.103
7.30	0.324	0.865	26.234	2.099
7.25	0.326	0.865	26.356	2.095
7.20	0.327	0.864	26.479	2.091
7.15	0.329	0.863	26.603	2.087
7.10	0.330	0.863	26.729	2.083
7.05	0.332	0.862	26.855	2.078
7.00	0.333	0.861	26.983	2.074
6.95	0.335	0.861	27.112	2.070
6.90	0.337	0.860	27.243	2.066
6.85	0.338	0.859	27.374	2.062
6.80	0.340	0.859	27.507	2.058
6.75	0.341	0.858	27.641	2.053
6.70	0.343	0.857	27.777	2.049
6.65	0.345	0.857	27.914	2.045
6.60	0.347	0.856	28.052	2.041
6.55	0.348	0.855	28.192	2.037
6.50	0.350	0.854	28.333	2.032
6.45	0.352	0.854	28.475	2.028
6.40	0.354	0.853	28.619	2.024
6.35	0.355	0.852	28.764	2.020
6.30	0.357	0.851	28.911	2.016
6.25	0.359	0.851	29.059	2.011
6.20	0.361	0.850	29.209	2.007
6.15	0.363	0.849	29.360	2.003
6.10	0.365	0.848	29.513	1.999
6.05	0.366	0.848	29.668	1.994
6.00	0.368	0.847	29.824	1.990
5.95	0.370	0.846	29.982	1.986
5.90	0.372	0.845	30.141	1.981
5.85	0.374	0.844	30.302	1.977
5.80	0.376	0.843	30.465	1.973
5.75	0.378	0.843	30.630	1.968
5.70	0.380	0.842	30.796	1.964
5.65	0.383	0.841	30.965	1.960
5.60	0.385	0.840	31.135	1.955
5.55	0.387	0.839	31.307	1.951
5.50	0.389	0.838	31.481	1.947
5.45	0.391	0.837	31.656	1.942
5.40	0.393	0.836	31.834	1.938
5.35	0.395	0.835	32.014	1.934
5.30	0.398	0.835	32.196	1.929
5.25	0.400	0.834	32.380	1.925
5.20	0.402	0.833	32.566	1.920
5.15	0.405	0.832	32.754	1.916

ε_{a1}(‰)	s	ξ_b	$\bar{\mu}_{1M}$(%)	k
5.10	0.407	0.831	32.945	1.912
5.05	0.409	0.830	33.138	1.907
5.00	0.412	0.829	33.332	1.903
4.95	0.414	0.828	33.530	1.898
4.90	0.417	0.827	33.729	1.894
4.85	0.419	0.826	33.931	1.889
4.80	0.422	0.825	34.136	1.885
4.75	0.424	0.824	34.343	1.880
4.70	0.427	0.822	34.552	1.876
4.65	0.429	0.821	34.764	1.871
4.60	0.432	0.820	34.978	1.867
4.55	0.435	0.819	35.196	1.862
4.50	0.438	0.818	35.416	1.858
4.45	0.440	0.817	35.638	1.853
4.40	0.443	0.816	35.864	1.849
4.35	0.446	0.815	36.092	1.844
4.30	0.449	0.813	36.324	1.840
4.25	0.452	0.812	36.558	1.835
4.20	0.455	0.811	36.796	1.831
4.15	0.458	0.810	37.036	1.826
4.10	0.461	0.808	37.280	1.822
4.05	0.464	0.807	37.527	1.817
4.00	0.467	0.806	37.777	1.812
3.95	0.470	0.805	38.030	1.808
3.90	0.473	0.803	38.287	1.803
3.85	0.476	0.802	38.548	1.799
3.80	0.479	0.801	38.812	1.794
3.75	0.483	0.799	39.079	1.789
3.70	0.486	0.798	39.351	1.785
3.65	0.490	0.796	39.626	1.780
3.60	0.493	0.795	39.905	1.776
3.55	0.496	0.793	40.188	1.771
3.50	0.500	0.792	40.475	1.766
3.45	0.504	0.791	40.766	1.762
3.40	0.507	0.789	41.062	1.757
3.35	0.511	0.787	41.361	1.752
3.30	0.515	0.786	41.666	1.748
3.25	0.519	0.784	41.974	1.743
3.20	0.522	0.783	42.287	1.738
3.15	0.526	0.781	42.605	1.734
3.10	0.530	0.779	42.928	1.729
3.05	0.534	0.778	43.256	1.724
3.00	0.538	0.776	43.589	1.719
2.95	0.543	0.774	43.927	1.715
2.90	0.547	0.772	44.270	1.710
2.85	0.551	0.771	44.618	1.705
2.80	0.556	0.769	44.972	1.701
2.75	0.560	0.767	45.332	1.696
2.70	0.565	0.765	45.698	1.691
2.65	0.569	0.763	46.069	1.686
2.60	0.574	0.761	46.447	1.682
2.55	0.579	0.759	46.831	1.677
2.50	0.583	0.757	47.221	1.672
2.45	0.588	0.755	47.618	1.667
2.40	0.593	0.753	48.021	1.663
2.35	0.598	0.751	48.432	1.658
2.30	0.603	0.749	48.849	1.653

ε_{a1}(‰)	s	ξ_b	$\bar{\mu}_{1M}$(%)	k
2.25	0.609	0.747	49.274	1.649
2.20	0.614	0.745	49.706	1.644
2.15	0.619	0.742	50.146	1.639
2.10	0.625	0.740	50.954	1.634
2.05	0.631	0.738	51.050	1.630
2.00	0.636	0.735	51.514	1.625
1.95	0.642	0.733	51.986	1.620
1.90	0.648	0.730	52.468	1.615
1.85	0.654	0.728	52.958	1.611
1.80	0.660	0.725	53.458	1.606
1.75	0.667	0.723	53.967	1.601
1.70	0.673	0.720	54.486	1.597
1.65	0.680	0.717	55.015	1.592
1.60	0.686	0.715	55.554	1.587
1.55	0.693	0.712	56.104	1.583
1.50	0.700	0.709	56.665	1.578
1.45	0.707	0.706	57.238	1.573
1.40	0.714	0.703	57.822	1.569
1.35	0.722	0.700	58.418	1.564
1.30	0.729	0.697	59.026	1.559
1.25	0.737	0.693	59.648	1.555
1.20	0.745	0.690	60.282	1.550
1.15	0.753	0.687	60.930	1.546
1.10	0.761	0.683	61.593	1.541
1.05	0.769	0.680	62.270	1.537
1.00	0.778	0.676	62.961	1.532
0.95	0.787	0.673	63.669	1.528
0.90	0.795	0.669	64.392	1.523
0.85	0.805	0.665	65.132	1.519
0.80	0.814	0.661	65.890	1.515
0.75	0.824	0.657	66.665	1.511
0.70	0.833	0.653	67.459	1.506
0.65	0.843	0.649	68.271	1.502
0.60	0.854	0.645	69.104	1.498
0.55	0.864	0.640	69.957	1.494
0.50	0.875	0.636	70.832	1.490
0.45	0.886	0.631	71.728	1.486
0.40	0.897	0.627	72.648	1.482
0.35	0.909	0.622	73.591	1.478
0.30	0.921	0.617	74.560	1.475
0.25	0.933	0.612	75.554	1.471
0.20	0.946	0.606	76.575	1.467
0.15	0.959	0.601	77.624	1.464
0.10	0.972	0.596	78.702	1.461
0.05	0.986	0.590	79.810	1.457
0.00	1.000	0.584	80.590	1.454
-0.05	1.014	0.578	82.124	1.451
-0.10	1.029	0.572	83.331	1.449
-0.15	1.045	0.565	84.575	1.446
-0.20	1.061	0.559	85.857	1.444
-0.25	1.077	0.552	87.177	1.442
-0.30	1.094	0.545	88.540	1.440
-0.35	1.111	0.538	89.945	1.438
-0.40	1.129	0.530	91.396	1.436
-0.45	1.148	0.523	92.894	1.435
-0.50	1.167	0.515	94.442	1.434

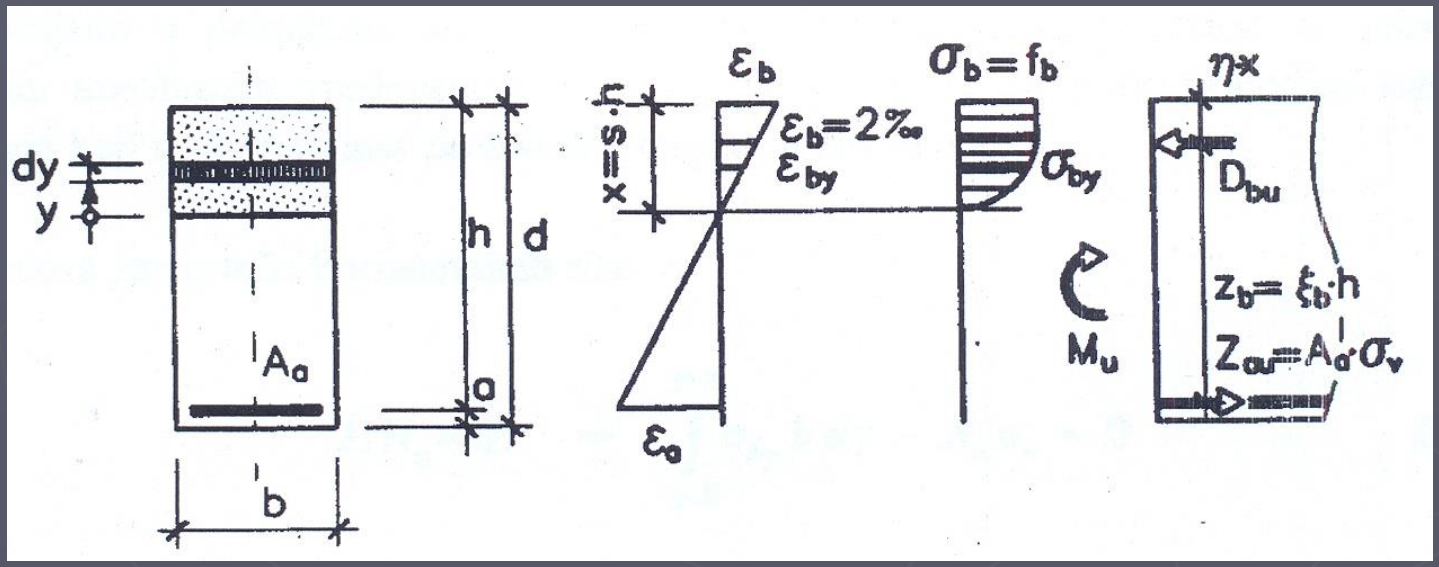
ε_{a1}=10‰

ε_b(‰)	s	α_b	η	ξ_b	$\bar{\mu}_{1M}$(%)	k
3.500	0.259	0.810	0.416	0.892	20.988	2.311
3.475	0.258	0.808	0.415	0.893	20.841	2.318
3.450	0.257	0.807	0.415	0.894	20.694	2.325
3.425	0.255	0.805	0.414	0.894	20.546	2.333
3.400	0.254	0.804	0.414	0.895	20.398	2.340
3.375	0.252	0.802	0.413	0.896	20.249	2.348
3.350	0.251	0.801	0.413	0.896	20.100	2.356
3.325	0.250	0.799	0.412	0.897	19.950	2.364
3.300	0.248	0.798	0.412	0.898	19.799	2.372
3.275	0.247	0.796	0.411	0.899	19.648	2.380
3.250	0.245	0.795	0.411	0.899	19.497	2.388
3.225	0.244	0.793	0.410	0.900	19.345	2.397
3.200	0.242	0.792	0.410	0.901	19.192	2.405
3.175	0.241	0.790	0.409	0.901	19.039	2.414
3.150	0.240	0.788	0.408	0.902	18.885	2.423
3,125	0.238	0.787	0.408	0.903	18.730	2.432
3.100	0.237	0.785	0.407	0.904	18.575	2.441
3.075	0.235	0.783	0.407	0.904	18.419	2.450
3.050	0.234	0.781	0.406	0.905	18.263	2.460
3.025	0.232	0.780	0.405	0.906	18.106	2.469
3.000	0.231	0.778	0.405	0.907	17.949	2.479
2.975	0.229	0.776	0.404	0.907	17.791	2.489
2.950	0.228	0.774	0.404	0.908	17.632	2.499
2.925	0.226	0.772	0.403	0.909	17.473	2.509
2.900	0.225	0.770	0.402	0.910	17.313	2.520
2.875	0.223	0.768	0.402	0.910	17.152	2.531
2.850	0.222	0.766	0.401	0.911	16.991	2.542
2.825	0.220	0.764	0.400	0.912	16.829	2.553
2.800	0.219	0.762	0.400	0.913	16.667	2.564
2.775	0.217	0.760	0.399	0.913	16.504	2.576
2.750	0.216	0.758	0.398	0.914	16.340	2.587
2.725	0.214	0,755	0.397	0.915	16.175	2.599
2.700	0.213	0.753	0.397	0.916	16.010	2.612
2.675	0.211	0.751	0.396	0.916	15.845	2.624
2.650	0.209	0.748	0.395	0.917	15.679	2.637
2.625	0.208	0.746	0.395	0.918	15.512	2.650
2.600	0.206	0.744	0.394	0.919	15.344	2.663
2.575	0.205	0.741	0.393	0.919	15.176	2.677
2.550	0.203	0.739	0.392	0.920	15.007	2.691
2.525	0.202	0.736	0.392	0.921	14.837	2.705
2.500	0.200	0.733	0.391	0.922	14.667	2.720
2.475	0.198	0.731	0.390	0.923	14.496	2.734
2.450	0.197	0.728	0.389	0.923	14.324	2.750
2.425	0.195	0.725	0.389	0.924	14.152	2.765
2.400	0.194	0.722	0.388	0.925	13.978	2.781
2.375	0.192	0.719	0.387	0.926	13.805	2.797
2.350	0.190	0.716	0.386	0.927	13.630	2.814
2.325	0.189	0.713	0.385	0.927	13.455	2.831

ε_b(‰)	s	α_b	η	ζ_b	$\bar{\mu}_{1M}$(%)	k
2.300	0.187	0.710	0.385	0.928	13.279	2.849
2.275	0.185	0.707	0.384	0.929	13.102	2.866
2.250	0.184	0.704	0.383	0.930	12.925	2.885
2.225	0.182	0.700	0.382	0.930	12.747	2.904
2.200	0.180	0.697	0.381	0.931	12.568	2.923
2.175	0.179	0.693	0.381	0.932	12.389	2.943
2.150	0.177	0.690	0.380	0.933	12.208	2.963
2.125	0.175	0.686	0.379	0.934	12.027	2.984
2.100	0.174	0.683	0.378	0.934	11.846	3.006
2.075	0.172	0.679	0.377	0.935	11.663	3.028
2.050	0.170	0.675	0.377	0.936	11.480	3.051
2.025	0.168	0.671	0.376	0.937	11.296	3.074
2.000	0.167	0.667	0.375	0.938	11.111	3.098
2.000	0.167	0.667	0.375	0.938	11.111	3.098
1.975	0.165	0.662	0.374	0.938	10.926	3.123
1.950	0.163	0.658	0.373	0.939	10.739	3.149
1.925	0.161	0.654	0.373	0.940	10.552	3.175
1.900	0.160	0.649	0.372	0.941	10.365	3.203
1.875	0.158	0.645	0.371	0.941	10.177	3.231
1.850	0.156	0.640	0.370	0.942	9.988	3.260
1.825	0.154	0.635	0.370	0.943	9.799	3.290
1.800	0.153	0.630	0.369	0.944	9.610	3.321
1.775	0.151	0.625	0.368	0.944	9.421	3.352
1.750	0.149	0.620	0.368	0.945	9.231	3.385
1.725	0.147	0.615	0.367	0.946	9.041	3.419
1.700	0.145	0.609	0.366	0.947	8.851	3.454
1.675	0.143	0.604	0.366	0.948	8.661	3.491
1.650	0.142	0.598	0.365	0.948	8.471	3.528
1.625	0.140	0.592	0.364	0.949	8.282	3.567
1.600	0.138	0.587	0.364	0.950	8.092	3.607
1.575	0.136	0.581	0.363	0.951	7.903	3.648
1.550	0.134	0.575	0.362	0.951	7.714	3.691
1.525	0.132	0.569	0.362	0.952	7.525	3.736
1.500	0.130	0.563	0.361	0.953	7.337	3.782
1.475	0.129	0.556	0.360	0.954	7.149	3.830
1.450	0.127	0.550	0.360	0.954	6.962	3.879
1.425	0.125	0.543	0.359	0.955	6.776	3.931
1.400	0.123	0.537	0.359	0.956	6.591	3.984
1.375	0.121	0.530	0.358	0.957	6.406	4.039
1.350	0.119	0.523	0.358	0.957	6.222	4.097
1.325	0.117	0.516	0.357	0.958	6.039	4.157
1.300	0.115	0.509	0.356	0.959	5.858	4.219
1.275	0.113	0.502	0.356	0.960	5.677	4.284
1.250	0.111	0.495	0.355	0.961	5.498	4.352
1.225	0.109	0.487	0.355	0.961	5.320	4.422
1.200	0.107	0.480	0.354	0.962	5.143	4.496
1.175	0.105	0.472	0.354	0.963	4.968	4.573
1.150	0.103	0.465	0.353	0.964	4.794	4.653
1.125	0.101	0.457	0.353	0.964	4.622	4.737
1.100	0.099	0.449	0.352	0.965	4.451	4.825
1.075	0.097	0.441	0.352	0.966	4.283	4.917
1.050	0.095	0.433	0.351	0.967	4.116	5.014
1.025	0.093	0.425	0.351	0.967	3.951	5.115
1.000	0.091	0.417	0.350	0.968	3.788	5.222

ε_b(‰)	s	α_b	η	ζ_b	$\bar{\mu}_{1M}$(%)	k
0.975	0.089	0.408	0.350	0.969	3.627	5.334
0.950	0.087	0.400	0.349	0.970	3.469	5.453
0.925	0.085	0.391	0.349	0.970	3.312	5.578
0.900	0.083	0.383	0.348	0.971	3.158	5.710
0.875	0.080	0.374	0.348	0.972	3.007	5.849
0.850	0.078	0.365	0.347	0.973	2.858	5.997
0.825	0.076	0.356	0.347	0.974	2.712	6.155
0.800	0.074	0.347	0.346	0.974	2.568	6.322
0.775	0.072	0.337	0.346	0.975	2.427	6.500
0.750	0.070	0.328	0.345	0.976	2.289	6.690
0.725	0.068	0.319	0.345	0.977	2.154	6.894
0.700	0.065	0.309	0.344	0.977	2.023	7.112
0.675	0.063	0.300	0.344	0.978	1.894	7.347
0.650	0.061	0.290	0.343	0.979	1.769	7.599
0.625	0.059	0.280	0.343	0.980	1.647	8.782
0.600	0.057	0.270	0.343	0.981	1.528	8.169
0.575	0.054	0.260	0.342	0.981	1.413	8.491
0.550	0.052	0.250	0.342	0.982	1.302	8.842
0.525	0.050	0.240	0.341	0.983	1.195	9.227
0.500	0.048	0.229	0.341	0.984	1.091	9.651
0.475	0.045	0.219	0.340	0.985	0.992	10.120
0.450	0.043	0.208	0.340	0.985	0.896	10.641
0.425	0.041	0.197	0.340	0.986	0.805	11.224
0.400	0.038	0.187	0.339	0.987	0.718	11.880
0.375	0.036	0.176	0.339	0.988	0.635	12.623
0.350	0.034	0.165	0.338	0.989	0.557	13.473
0.325	0.031	0.154	0.338	0.989	0.484	14.454
0.300	0.029	0.143	0.338	0.990	0.415	15.599
0.275	0.027	0.131	0.337	0.991	0.351	16.952
0.250	0.024	0.120	0.337	0.992	0.292	18.577
0.225	0.022	0.108	0.337	0.993	0.238	20.562
0.200	0.020	0.097	0.336	0.993	0.190	23.045
0.175	0.017	0.085	0.336	0.994	0.146	26.238
0.150	0.015	0.073	0.335	0.995	0.108	30.395
0.125	0.012	0.061	0.335	0.996	0.076	36.456
0.100	0.010	0.049	0.335	0.997	0.049	45.398
0.075	0.007	0.037	0.334	0.998	0.028	60.303
0.050	0.005	0.025	0.334	0.998	0.012	90.115
0.025	0.002	0.012	0.344	0.999	0.003	179.548

Elementi napregnuti na čisto savijanje



Pravougaoni presjek opterećen na čisto savijanje – proračunski model

Iz uslova ravnoteže horizontalnih sila

$$\Sigma N_x = 0: \quad \rightarrow \quad \int_{y=0}^{y=x} \sigma_{by}\, b\, dy - A_a \sigma_v = 0$$

i uslova ravnoteže momenata oko težišta zategnute armature

$$\Sigma M_{au} = 0: \quad \rightarrow \quad \int_{y=0}^{y=x} \sigma_{by}\, b\, (h - x + y)\, dy = M_u$$

odredićemo nepoznatu statičku visinu preseka i količinu zategnute armature. Pri tome je položaj neutralne linije određen iz veličine dilatacija:

$$x = \frac{\varepsilon_b}{\varepsilon_b + \varepsilon_a} h \quad \Rightarrow \quad s = \frac{x}{h} = \frac{\varepsilon_b}{\varepsilon_b + \varepsilon_a} \tag{7.17}$$

Ukoliko izraz (7.10) uvrstimo u uslov ravnoteže (7.11), dobijamo:

$$\int_0^x \frac{f_B}{4}\left(4\varepsilon_{by} - \varepsilon_{by}^2\right) b\, dy - A_a \sigma_v = 0 \tag{7.18}$$

Rešavanjem integrala konačno se dobija:

$$f_B\, b\, x\, \alpha_b - A_a \sigma_v = 0 \tag{7.18}$$

gde prvi član u jednačini (7.18) predstavlja silu pritiska u betonu u trenutku loma D_{bu}. Pri tome je α_b koeficijent punoće naponskog dijagrama i zavisi od veličine dilatacije pritisnute ivice betona:

$$\alpha_b = \frac{\varepsilon_b}{12}(6 - \varepsilon_b) \qquad 0.0 \le \varepsilon_b \le 2.0\,‰$$

$$\alpha_b = \frac{3\,\varepsilon_b - 2}{3\,\varepsilon_b} \qquad 2.0 \le \varepsilon_b \le 3.5\,‰$$

Ovaj koeficijent dostiže maksimalnu vrednost za $\varepsilon_b = 3.5\,‰$ i iznosi $\alpha_b = 0.8095$, dok je za $\varepsilon_b = 2\,‰$ njegova vrednost $\alpha_b = 0.667$.

Ako se jednačina (7.18) podeli sa $b\,h\,f_B$, dobija se:

$$\alpha_b s - \frac{A_a}{b\,h}\,\frac{\sigma_v}{f_B} = 0 \qquad (7.19)$$

Ukoliko se odnos površine zategnute armature i površine betonskog preseka, dimenzija $b \times h$, izrazi preko *koeficijenta armiranja* μ, i ako se uvede oznaka $\bar{\mu}$ za *mehanički koeficijent armiranja*:

$$\mu = \frac{A_a}{b\,h} \quad ; \quad \bar{\mu} = \frac{A_a}{b\,h}\,\frac{\sigma_v}{f_B} = \mu\,\frac{\sigma_v}{f_B} \qquad (7.19a)$$

$$\alpha_b s\,(1 - \eta s) = \frac{M_u}{b\,h^2 f_B} \qquad (7.23)$$

gde je η bezdimenzioni koeficijent položaja sile pritiska u betonu u odnosu na gornju ivicu preseka, koji ima vrednosti:

$$\eta = \frac{8 - \varepsilon_b}{4\,(6 - \varepsilon_b)} \qquad 0.0 \le \varepsilon_b \le 2.0\,‰$$

$$\eta = \frac{\varepsilon_b\,(3\,\varepsilon_b - 4) + 2}{2\,\varepsilon_b\,(3\,\varepsilon_b - 2)} \qquad 2.0 \le \varepsilon_b \le 3.5\,‰$$

Veličina z_b, slika 7.9, predstavlja *krak unutrašnjih sila* i može se izraziti u obliku:

$$z_b = h - \eta x = h - \eta s h = h\,(1 - \eta s) \qquad (7.24)$$

Uvodeći oznaku ζ_b za bezdimenzioni koeficijent kraka unutrašnjih sila:

$$\zeta_b = 1 - \eta s$$

izraz (7.24) može se napisati u obliku:

$$z_b = \zeta_b h \tag{7.25}$$

Statička visina se određuje iz jednačine (7.23):

$$h = \sqrt{\frac{M_u}{b f_B}} \sqrt{\frac{1}{\alpha_b s (1 - \eta s)}} = \sqrt{\frac{M_u}{b f_B}} \sqrt{\frac{1}{\alpha_b s \zeta_b}} \tag{7.26}$$

Uvođenjem bezdimenzionog koeficijenta k, poslednji izraz pišemo u konačnom obliku:

$$h = k \sqrt{\frac{M_u}{b f_B}} \tag{7.27}$$

Potrebnu površinu armature određujemo iz izraza (7.19a):

$$A_a = \mu b h = \overline{\mu} b h \frac{f_B}{\sigma_v} \tag{7.28}$$

Primjeri dimenzionisanja jednostruko armiranih presjeka

Zadatak 1.

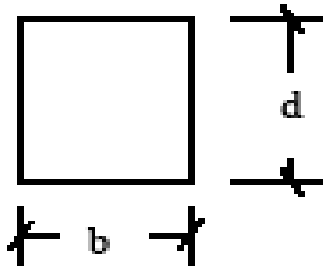
Dimenzionisati pravougaoni poprečni presjek za zadate podatke i za slučaj dostizanja granične nosivosti po :

a) betonu;
b) armaturi;
c) armaturi i betonu simultano.

MB 30
RA 400/500
M_u= 300 kNm
b= 30 cm

Rješenje:

Ulazni podaci



MB 30 ⇨ f_b= 2,05 kN/cm^2

RA 400/500 ⇨ σ_v= 40 kN/cm^2

M_u= 300 kNm

b= 30 cm

a) Lom po betonu (ε_b= 3.5‰ i ε_a < 10‰)

$\varepsilon_a/\varepsilon_b$= 7.5/3.5 ⇨ k=2.115; $\bar{\mu}$=25.757%; s = 0.318; ξ_b=0.868

$$_{potr}h = kx\sqrt{\frac{M_u}{bxf_b}} = 2.115x\sqrt{\frac{300}{0.3x2.05}} = 46.71 \text{ cm}$$

$$A_a = \bar{\mu}xbxhx\frac{f_b}{\sigma_v} = \frac{25.757}{100}x30x46.7x\frac{2.05}{40} =$$

A_a=18.5 cm^2

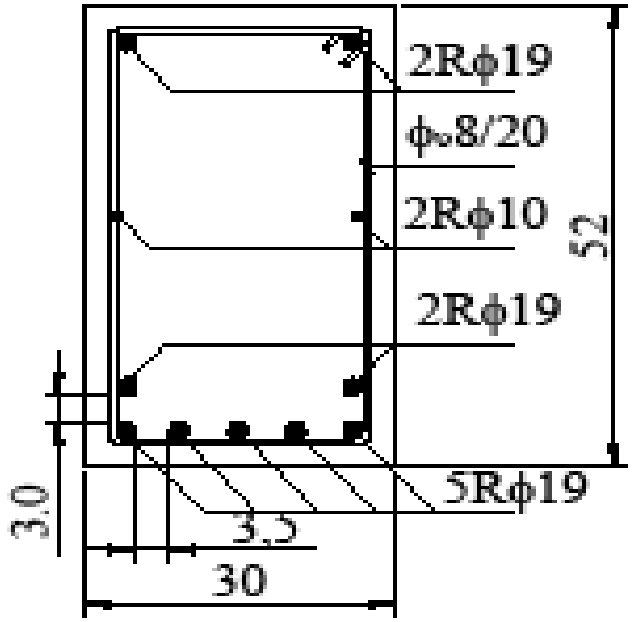
$_{potr}d = h+a_a$

usvojeno: 7Rϕ19 (19.9 cm^2)

$$a_g = \frac{\left(5 x a_\phi x \left(a_0 + \phi_w + \frac{\phi}{2}\right) + 2 x a_\phi x \left(a_0 + \phi_w + \phi + 3 + \frac{\phi}{2}\right)\right)}{7 x a_\phi}$$

$$a_g = \frac{5}{7} x \left(2.5 + 0.8 + \frac{1.9}{2}\right) + \frac{2}{7} x \left(2.5 + 0.8 + 3.0 + \frac{3}{2} x 1.9\right) = 5.65 \text{ cm}$$

$$\text{potr } d = h + a_g = 46.7 + 5.65 = 52.35 \approx 52 \text{ cm}$$



$$a_h = \frac{(30 - 2.5x2 - 2x0.8 - 5x1.9)}{4} = 3.47 > 3 \text{ cm}$$

b) Lom po armaturi ($\varepsilon_a > 10‰$)

npr. $\varepsilon_a/\varepsilon_b = 10/2.5$ { $k=2.720$, $\bar{\mu}=14.667\%$

$_{potr}h = 2.72x\sqrt{\frac{300}{0.3x2.05}} = 60.1$ cm

$A_a = \frac{14.667}{100} x30x60.1x\frac{2.05}{40} = 13.55\,cm^2$ usvojeno: 5Rϕ19 (14.2 cm^2)

$_{potr}d = h + a_0 + \phi_u + \frac{\phi}{2} = 60.1 + 2.5 + 0.8 + \frac{1.9}{2} = 64.35$ cm usvojeno: 30/65

c) Simultani lom ($\varepsilon_b/\varepsilon_a = 3.5/10‰$)

$\varepsilon_a/\varepsilon_b = 10/3.5$ { $k=2.311$, $\bar{\mu}=20.987\%$

$_{potr}h = 2.311x\sqrt{\frac{300}{0.3x2.05}} = 51.04$ cm

$A_a = \frac{20.987}{100} x30x51.04x\frac{2.05}{40} = 16.45\,cm^2$ usvojeno: 6Rϕ19 (17.04 cm^2)

$a_a = \frac{4}{6} x\left(2.5+0.8+\frac{1.9}{2}\right) + \frac{2}{6} x\left(2.5+0.8+1.9+3.0+\frac{1.9}{2}\right) = 5.88\,cm$

$_{potr}d = h + a_a = 51.04 + 5.88 = 56.92$ cm usvojeno: 30/57

$a_h = (30 - 4x1.9 - 2x2.5 - 2x0.8)/3 = 5.27$ cm

- Da li se može usvojiti 30/55 i 6Rϕ19 ?

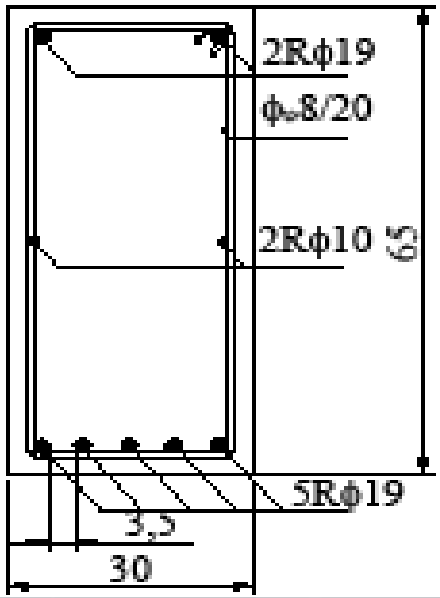
h= 55-5.88= 49.12 cm

$$k_b=\frac{49.12}{\sqrt{\frac{300}{0.3x2.05}}}=2.224 \Rightarrow \mu=22.945\ \%$$

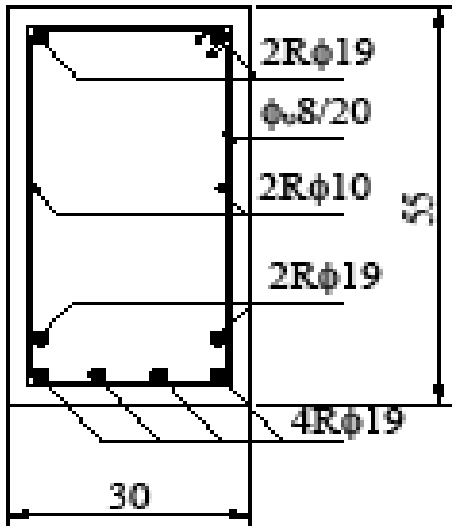
$$A_a=\frac{22.945}{100}x30x49.12x\frac{2.05}{40}=17.33\ cm^2 > 17.04\ cm^2$$

$$\Delta=\frac{17.33-17.04}{17.04}x100=1.69\% < 5\%$$ Usvojena armatura 6Rϕ19 je zadovoljavajuća

b)



c)



Zadatak 2.

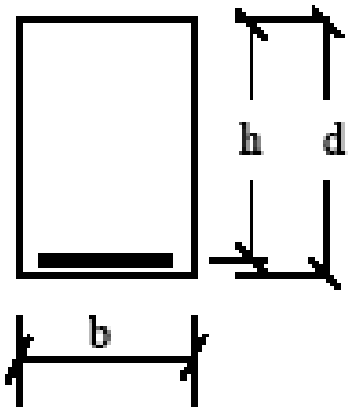
Za pravougaoni poprečni presjek utvrđenih dimenzija i datog momenta savijanja odrediti potrebnu količinu armature.

MB 30
GA 240/360
M_u= 250 kNm
b= 30 cm d= 60 cm

Nacrtati raspored armature u poprečnom presjeku u razmjeri 1:10.

Rješenje:

<u>Ulazi podaci</u>



MB 30 f_b= 2,05 kN/cm^2

GA 240/360 σ_v= 24 kN/cm^2

M_u= 250 kNm

b= 30 cm d= 60 cm h= 0.9x60= 54 cm

$$k_b = \frac{h}{\sqrt{\frac{M_u}{f_b x b}}} = \frac{54}{\sqrt{\frac{250}{2.05x0.3}}} = 2,678 \quad \begin{cases} \pi = 15.170\% \\ \varepsilon_b / \varepsilon_a = 2,575/10‰ \text{ lom po armaturi} \end{cases}$$

$$_{potr}A_a = \frac{15.17}{100} x30x54x\frac{2.05}{24} = 20,99 \text{ cm}^2$$ usvojeno: 7Rϕ20 (21.98 cm^2)

$$a_a = \frac{5}{7}x\left(2.5+0.8+\frac{2.0}{2}\right)+\frac{2}{7}x\left(2.5+0.8+3.0+\frac{3}{2}x2.0\right) = 5,73 \text{ cm}$$

h_{stv}=60-5,73=54,27 > 54 cm

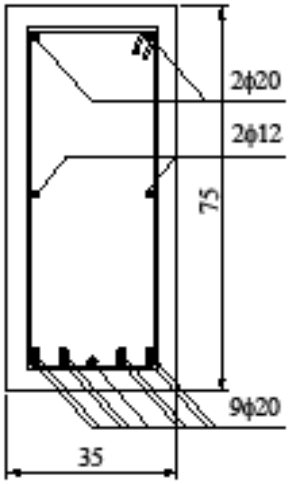
Jednostavniji (približan) način dimenzionisanja

$$_{potr}A_a = \frac{M_u}{zx\sigma_v} = \frac{250x100}{0.9x54x24} = 21,43 \text{ cm}^2$$

Postupak je dovoljno tačan za slučaj loma po armaturi.

Zadatak 3.

Za pravougaoni poprečni presjek AB elementa izloženog čistom savijanju, prikazanog na slici, odrediti vrijednost granične nosivosti presjeka.



MB 30

Rješenje:

Ulazi podaci

MB 30 $f_b = 2{,}05\ kN/cm^2$

GA 240/360 $\sigma_v = 24\ kN/cm^2$

b= 35 cm d= 75 cm $A_a = 9\phi20 = 9x3.14 = 28.26\ cm^2$

$$a_s = \frac{5}{9}x\left(2.5+0.8+\frac{2.0}{2}\right)+\frac{4}{9}x\left(2.5+0.8+\frac{3}{2}x2.0\right) = 5.19\ cm$$

h= 75-5.19 = 69.8 cm

$$\mu_1 = \frac{A_a}{bxh}x100 = \frac{28.26}{35x69.8}x100 = 1.157\%$$

$$\overline{\mu_1} = \mu_1 x\frac{\sigma_v}{f_b} = 1.157x\frac{24}{2.05} = 13.545\% < 20.987\ \%$$

$\zeta_b = 0.927$

$\alpha_b = 0.715$

s=0.1895

$$M_u = \alpha_b xsx\zeta_b xf_b xbxh^2 = \frac{0.715x0.1895x0.927x2.05x35x68.9^2}{100} = 428\ kNm$$

GEOMETRIJSKE KARAKTERISTIKE GLATKE ARMATURE GA 240/360

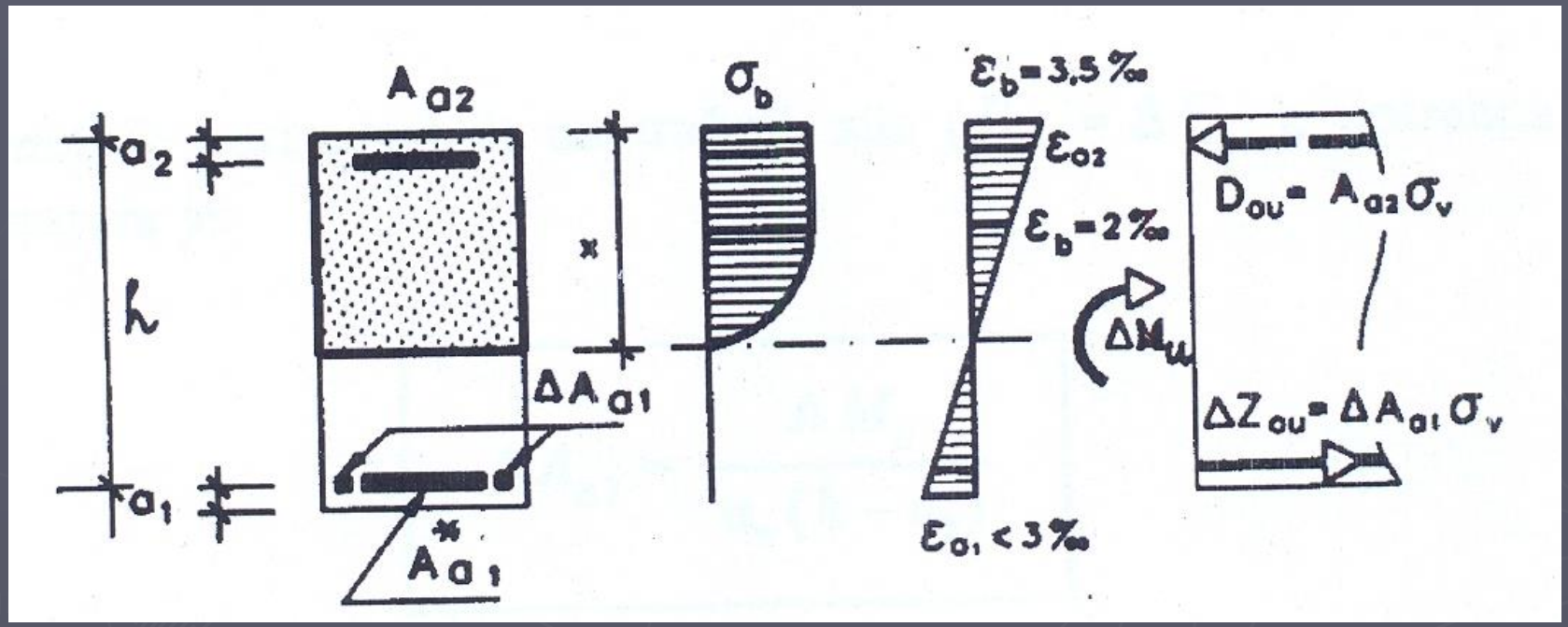
Ø	POVRŠINA POPREČNOG PRESEKA ZA KOMADA															Težina	Obim
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15		
mm	cm^2															kg/m	cm
5	0,20	0,39	0,59	0,79	0,98	1,18	1,37	1,57	1,77	1,96	2,16	2,36	2,55	2,75	2,95	0,154	1,57
6	0,28	0,57	0,85	1,13	1,41	1,70	1,98	2,26	2,55	2,83	3,11	3,39	3,68	3,96	4,24	0,222	1,89
8	0,50	1,01	1,51	2,01	2,51	3,02	3,52	4,02	4,52	5,03	5,53	6,03	6,54	7,04	7,54	0,395	2,51
10	0,79	1,57	2,36	3,14	3,93	4,71	5,50	6,28	7,07	7,85	8,64	9,43	10,21	11,00	11,78	0,617	3,14
12	1,13	2,26	3,39	4,52	5,66	6,79	7,92	9,05	10,18	11,31	12,44	13,57	14,70	15,83	16,97	0,888	3,77
14	1,54	3,08	4,62	6,16	7,70	9,24	10,78	12,32	13,86	15,39	16,93	18,47	20,01	21,55	23,09	1,208	4,40
16	2,01	4,02	6,03	8,04	10,05	12,06	14,07	16,09	18,10	20,11	22,12	24,13	26,14	28,15	30,16	1,578	5,03
18	2,54	5,09	7,63	10,18	12,72	15,27	17,81	20,36	22,90	25,45	27,99	30,54	33,08	35,63	38,17	1,998	5,65
20	3,14	6,28	9,43	12,57	15,71	18,85	21,99	25,13	28,27	31,42	34,56	37,70	40,84	43,98	47,12	2,466	6,28
22	3,80	7,60	11,40	15,21	19,01	22,81	26,64	30,41	34,21	38,01	41,81	45,62	49,42	53,22	57,02	2,984	6,91
25	4,91	9,82	14,73	19,64	24,54	29,45	34,36	39,27	44,18	49,09	54,00	58,90	63,81	68,72	73,63	3,853	7,85
28	6,16	12,32	18,47	24,63	30,79	36,95	43,10	49,26	55,42	61,58	67,73	73,89	80,05	86,21	92,36	4,834	8,80
32	8,04	16,09	24,13	32,17	40,21	48,26	56,30	64,34	72,38	80,42	88,47	96,51	104,55	112,60	120,64	6,313	10,05
36	10,18	20,36	30,54	40,72	50,89	61,07	71,25	81,43	91,61	101,79	111,97	122,15	132,32	142,50	152,68	7,990	11,31

GEOMETRIJSKE KARAKTERISTIKE REBRASTE ARMATURE RA 400/500[1)]

RØ	POVRŠINA POPREČNOG PRESEKA ZA KOMADA															Težina		Obim
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	RA 400/500-1	RA 400/500-2	
mm	cm^2															kg/m		cm
6	0,28	0,57	0,85	1,13	1,41	1,70	1,98	2,26	2,55	2,83	3,11	3,39	3,68	3,96	4,24	0,230	0,228	1,89
8	0,50	1,01	2,51	2,01	2,51	3,02	3,52	4,02	4,52	5,03	5,53	6,03	6,54	7,04	7,54	0,409	0,405	2,51
10	0,79	1,57	2,36	3,14	3,93	4,71	5,50	6,28	7,07	7,85	8,64	9,43	10,21	11,00	11,78	0,649	0,633	3,14
12	1,13	2,26	3,39	4,52	5,66	6,79	7,92	9,05	10,18	11,31	12,44	13,57	14,70	15,83	16,97	0,920	0,911	3,77
14	1,54	3,08	4,62	6,16	7,70	9,24	10,78	12,32	13,86	15,39	16,93	18,47	20,01	21,55	23,09	1,252	1,242	4,40
16	2,01	4,02	6,03	8,04	10,05	12,06	14,07	16,09	18,10	20,11	22,12	24,13	26,14	28,15	30,16	-	1,621	5,03
19	2,84	5,67	8,51	11,34	14,18	17,01	19,85	22,68	25,52	28,35	31,19	34,02	36,86	39,69	42,53	-	2,288	5,97
22	3,80	7,60	11,40	15,21	19,01	22,81	26,64	30,41	34,21	38,01	41,81	45,62	49,42	53,22	57,02	-	3,058	6,91
25	4,91	9,82	14,73	19,64	24,54	29,45	34,36	39,27	44,18	49,09	54,00	58,90	63,81	68,72	73,63	-	3,951	7,85
28	6,16	12,32	18,47	24,63	30,79	36,95	43,10	49,26	55,42	61,58	67,73	73,89	80,05	86,21	92,36	-	4,956	8,80
32	8,04	16,09	24,13	32,17	40,21	48,26	56,30	64,34	72,38	80,42	88,47	96,51	104,55	112,60	120,64	-	6,474	10,05
36	10,18	20,36	30,54	40,72	50,89	61,07	71,25	81,43	91,61	101,79	111,97	122,15	132,32	142,50	152,68	-	8,200	11,31

1) RA 400/500-1 se proizvodi od RØ6 do RØ14, a RA 400/500-2 od RØ6 do RØ36.

Dvostruko armirani presjek



Kada jednostruko armiran presjek, sa punim korišćenjem pritisnutog betona, ε_b=3.5 ‰, nije u stanju da primi spoljašni moment M_{au} tada se projektuje dvojno armiran presjek. Ovo se često dešava kada su ograničene dimenzije poprečnog presjeka.

Dvojno armiranim presjecima se pritisnuta zona betona ojačava pomoću pritisnute armature A_{a2}, koja se određuje proračunom. Dodavanje armature A_{a2} u pritisnutoj armaturi presjeka zahtijeva i dodatnu armaturu ΔA_{a1} u zategnutoj zoni. U protivnom uslovi ravnoteže sila u presjeku ne bi bili zadovoljeni.

Ako sa M_{bu} označavamo graničnu vrijednost momenta savijanja koju može da prihvati jednostruko armiran presjek, pri punom iskorišćenju betona, pri dilatacijama ε_b=3.5‰ i ε_{a1}=3.5‰ tada je:

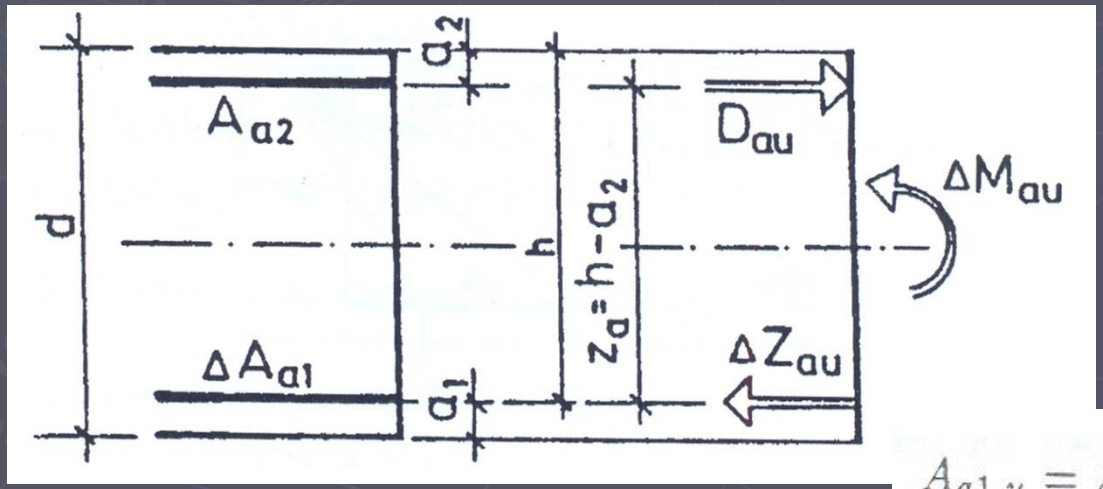
$$\Delta M_u = M_u - M_{bu}$$

gde je:

$$M_{bu} = \left(\frac{h}{k^*}\right)^2 b f_B$$

Vrednosti k^* i $\bar{\mu}_1^*$ se određuju iz tabela za dilatacije $\varepsilon_b = 3.5‰$, $\varepsilon_{a1} = 3‰$.

Razlika momenata se prihvata spregom unutrašnjih sila D_{au} i ΔZ_{au} , odnosno pritisnutom i dodatnom zategnutom armaturom.



$$A_{a2} = \frac{\Delta M_{au}}{\sigma_{a2}(h - a_2)}$$

$$\Delta A_{a1} = \frac{\Delta M_{au}}{\sigma_{a1}(h - a_2)}$$

$$A_{a1,u} = A_{a1} + \Delta A_{a1} = \mu_{1M} bh + \frac{\Delta M_{au}}{(h - a_2)\sigma_{a1}}$$

Primjeri dimenzionisanja dvostruko armiranih presjeka

Zadatak 1.

Za pravougaoni presjek utvrđenih dimenzija i datog momenta savijanja odrediti potrebnu količinu armature:

MB 35 RA 400/500 b= 30 cm d= 50 cm

M_g= 120 kNm M_p= 200 kNm

a) za slučaj unaprijed utvrženih dilatacija $\varepsilon_a / \varepsilon_b = 3.0/3.5$;
b) za slučaj unaprijed utvrženog odnosa pritisnute i zategnute armature k=

Nacrtati raspored armature u poprečnim presjecima u razmjeri R 1:10.

Rješenje:

<u>Ulazni podaci</u>

MB 35 ⇨ f_b= 2,3 kN/cm^2

RA 400/500 σ_v= 40 kN/cm^2

M_g= 120 kNm M_p= 200 kNm b/d= 30/50 cm

a) Slučaj unaprijed utvrđenih dilatacija (ε_b= 3.5‰ i ε_a=3.0‰)

Ako je $\varepsilon_a/\varepsilon_b$= 3.0/3.5 ‰ ⟹ k_b^*=1.719, μ_1 = 43.589%

M_u=1.6xM_g+1.8xM_p=1.6x120+1.8x200= 552 kN

h=0.9x50=45 cm

$$k_b=\frac{45}{\sqrt{\frac{552}{0.3x2.3}}}=1.591 < k_b^*$$

$$M_u^*=\left(\frac{h}{k^*}\right)^2 xbxf_b=\left(\frac{45}{1.719}\right)^2 x0.3x2.3=472.85 \text{ kNm}$$

$\Delta M_u=M_u-M_u^*$=552-472.85=79.15 kNm

$$A_{a1}=\frac{\mu_1^*}{100}xbxhx\frac{f_b}{\sigma_v}+\frac{\Delta M}{\sigma_v(h-a_a)}=\frac{43.589}{100}x30x45x\frac{2.3}{40}+\frac{79.15x100}{40x(45-5)}=$$

A_{a1}=33.84+4.95=38.79 cm^2

$$A_{a2}=\frac{\Delta M}{\sigma_v(h-a_a)}=4.95 \text{ cm}^2$$ ⟹ usvaja se: 8Rϕ25 (39.28 cm^2)

2Rϕ25 (9.82 cm^2)

b) Slučaj unaprijed određenog odnosa pritisnute i zategnute armature k

k=0.25 n_u=0, jer je N_u=0

$k=\frac{A_{a2}}{A_{a1}}=0.25$ $m_u=\frac{M_u}{bxd^2xf_b}=\frac{552x100}{30x50^2x2.3}=0.32$ $\frac{a}{d}=\frac{5.3}{50}=0.106$

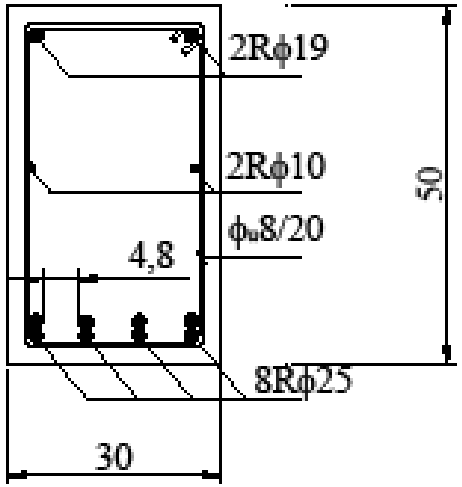
Interakcioni dijagrami 2.5.3.6 (str.176) $\Rightarrow$ $\bar{\mu}_1$=0.427

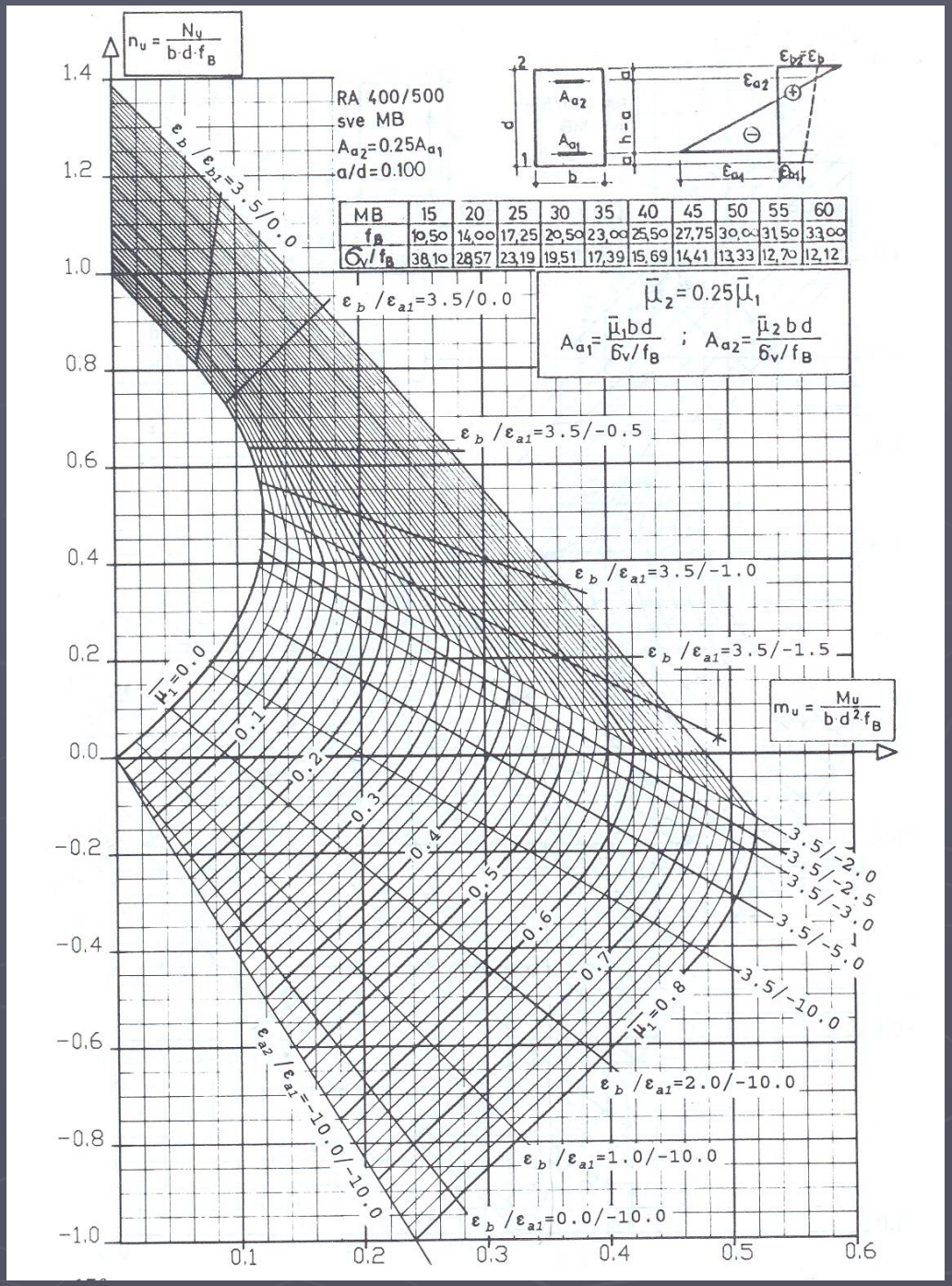
$A_{a1}=0.427x\frac{30x50}{\frac{40}{2.3}}=36.83\ cm^2$ usvojeno: 8Rϕ25 (39.28)

$A_{a2}=0.25x36.83=9.21\ cm^2$ usvojeno: 2Rϕ25 (9.82)

$a_a=\frac{4}{8}x\left(2.0+0.8+\frac{2.5}{2}\right)+\frac{4}{8}x\left(2.0+0.8+\frac{3}{2}x2.5\right)=5.3\ cm$

a_h=4.8 cm > $\sqrt{2}x2.5=3.5cm$




$n_u = \frac{N_u}{b \cdot d \cdot f_B}$
$m_u = \frac{M_u}{b \cdot d^2 \cdot f_B}$
RA 400/500
sve MB
$A_{a2} = 0.25 A_{a1}$
a/d = 0.100
$\bar{\mu}_2 = 0.25 \bar{\mu}_1$
$A_{a1} = \frac{\bar{\mu}_1 b d}{\sigma_v / f_B}$; $A_{a2} = \frac{\bar{\mu}_2 b d}{\sigma_v / f_B}$
MB | 15 | 20 | 25 | 30 | 35 | 40 | 45 | 50 | 55 | 60
f_B | 10,50 | 14,00 | 17,25 | 20,50 | 23,00 | 25,50 | 27,75 | 30,00 | 31,50 | 33,00
σ_v / f_B | 38,10 | 28,57 | 23,19 | 19,51 | 17,39 | 15,69 | 14,41 | 13,33 | 12,70 | 12,12
$\varepsilon_b / \varepsilon_{a1} = 3.5/0.0$
$\varepsilon_b / \varepsilon_{a1} = 3.5/-0.5$
$\varepsilon_b / \varepsilon_{a1} = 3.5/-1.0$
$\varepsilon_b / \varepsilon_{a1} = 3.5/-1.5$
$\bar{\mu}_1 = 0.0$
0.1
0.2
0.3
0.4
0.5
0.6
0.7
$\bar{\mu}_1 = 0.8$
3.5/-2.0
3.5/-2.5
3.5/-3.0
3.5/-5.0
3.5/-10.0
$\varepsilon_{a2} / \varepsilon_{a1} = -10.0/-10.0$
$\varepsilon_b / \varepsilon_{a1} = 2.0/-10.0$
$\varepsilon_b / \varepsilon_{a1} = 1.0/-10.0$
$\varepsilon_b / \varepsilon_{a1} = 0.0/-10.0$
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
-0.2
-0.4
-0.6
-0.8
-1.0
0.1
0.2
0.3
0.4
0.5
0.6
A_{a2}
A_{a1}
d
h-a
a
b
ε_{a2}
ε_{a1}
ε_b