

BAB VIII

PERENCANAAN STRUKTUR PORTAL BETON BERTULANG DENGAN DAKTILITAS TERBATAS

Pada bab ini merupakan kelanjutan dari bahasan analisa struktur sebelumnya. Untuk perencanaan daktilitas terbatas meliputi momen rencana balok, penulangan lentur balok, gaya geser rencana balok, penulangan geser balok, momen rencana kolom, penulangan lentur kolom, gaya geser rencana kolom, dan penulangan geser kolom. Struktur, pembebanan dan lain-lain diambil sama dengan perhitungan daktilitas penuh, sehingga gaya-gaya dalam yang dihasilkan analisa struktur tetap dapat dipakai. Khusus untuk gaya gempa diberi faktor pengali 2 ($K = 2,0$).

8.1 Desain Balok

8.1.1 Momen Rencana Balok

Momen rencana balok dihitung berdasarkan tipe-tipe pembebanan menurut SK SNI T-15-1991-03 adalah sebagai berikut.

$$M_{u1} = 1,2M_D + 1,6M_L$$

$$M_{u2} = 1,05 (M_D + 0,9M_L + M_{Gki})$$

$$M_{u3} = 1,05 (M_D + 0,9M_L + M_{Gka})$$

$$M_{u4} = 0,9 (M_D + M_{Gki})$$

$$M_{u5} = 0,9 (M_D + M_{Gka})$$

Contoh perhitungan diambil pada Balok lantai 1 tumpuan kiri:

Diketahui:

$$M_D = -130,9800 \text{ kN} ; M_L = -71,3500 \text{ kN}$$

$$M_{Gki} = 432,3000 \text{ kN} ; M_{Gka} = -428,8800 \text{ kN}$$

$$M_u = 1,05 (M_D + 0,9M_L + M_{Gka})$$

$$= 1,05 (-130,9800 + 0,9 \cdot (-71,3500) + (-428,8800)) = -655,2788 \text{ kN}$$

Hasil perhitungan momen rencana balok lainnya disajikan pada Tabel 8.1.

Tabel 8.1 Lanjutan

Por-tal	No. Elm Balok	Letak Momen	M mati	M hidup	M Gempa		Mu1	Mu2	Mu3	Mu4	Mu5	Balok
			MD	ML	MGki	MGka						
[1]	[2]	[3]	[4]	[5]	[6]	[7]						
As 2, As 5 (A-B)	18	Tump ki	-5,8900	-0,8800	39,3600	-39,4200	-8,4760	34,3119	-48,4071	30,1230	-40,7790	Balok
		Lap	5,6700	0,7900	39,3600	56,4800	8,0680	48,0281	66,0041	40,5270	55,9350	Atap
		Tump ka	-5,6400	-0,7800	-56,7000	56,4800	-8,0160	-66,1941	52,6449	-56,1060	45,7560	
As 2 dan As 5 (E-G)	19	Tump ki	-8,86	-0,5600	160,8600	-160,6200	-11,5280	159,0708	-178,4832	136,8000	-152,5320	Balok
		Lap	3,69	0,6100	160,8600	62,2400	5,4040	173,3540	69,8030	148,0950	59,3370	Sloof
		Tump ka	-2,89	0,6100	-62,3400	62,2400	-2,4920	-67,9151	62,8940	-58,7070	53,4150	
	20	Tump ki	-2,48	0,6900	46,6800	-46,8200	-1,8720	47,0621	-51,1130	39,7800	-44,3700	
		Lap	3,99	0,6900	46,6800	124,2400	5,8920	53,8556	135,2936	45,6030	115,4070	
		Tump ka	-8,73	-0,7600	-123,9200	124,2400	-11,6920	-140,0007	120,5673	-119,3850	103,9590	
	21	Tump ki	-22,39	-3,8800	251,2000	-250,7600	-33,0760	236,5839	-290,4741	205,9290	-245,8350	Balok
		Lap	10,23	1,8400	251,2000	86,7800	15,2200	276,2403	103,5993	235,2870	87,3090	Lantai 1
		Tump ka	-10,87	-2,2300	-86,9400	86,7800	-16,6120	-104,8079	77,5982	-88,0290	68,3190	
22	Tump ki	-10,2	-2,1200	61,4800	-61,7200	-15,6320	51,8406	-77,5194	46,1520	-64,7280		
	Lap	11,63	2,1100	61,4800	188,1400	17,3320	78,7595	211,7525	65,7990	179,7930		
	Tump ka	-20,11	-3,4200	-187,5400	188,1400	-29,6040	-221,2644	173,1996	-186,8850	151,2270		
23	Tump ki	-26,51	-4,5400	249,0000	-248,6600	-39,0760	229,3242	-293,2188	200,2410	-247,6530	Balok	
	Lap	11,17	1,9700	249,0000	87,0800	16,5560	275,0402	105,0242	234,1530	88,4250	Lantai 2	
	Tump ka	-6,19	-1,4900	-87,1800	87,0800	-9,8120	-99,4466	83,5265	-84,0330	72,8010		
24	Tump ki	-5,14	-1,3100	65,2600	-65,3800	-8,2640	61,8881	-75,2840	54,1080	-63,4680		
	Lap	12,43	2,1900	65,2600	190,1000	18,4200	83,6441	214,7261	69,9210	182,2770		
	Tump ka	-24,96	-4,2600	-189,7800	190,1000	-36,7680	-229,5027	169,3713	-193,2660	148,6260		
25	Tump ki	-29,22	-4,9200	197,3600	-197,0200	-42,9360	171,8976	-242,2014	151,3260	-203,6160	Balok	
	Lap	12,01	2,0700	197,3600	68,5000	17,7240	221,7947	86,4917	188,4330	72,4590	Lantai 3	
	Tump ka	-3,07	-1,0500	-68,6200	68,5000	-5,3640	-76,2668	67,7093	-64,5210	58,8870		
26	Tump ki	-1,72	-0,8500	54,3800	-54,5400	-3,4240	54,4898	-59,8763	47,3940	-50,6340		
	Lap	13,42	2,3000	54,3800	153,6600	19,7840	73,3635	177,6075	61,0200	150,3720		
	Tump ka	-27,72	-4,6400	-153,2000	153,6600	-40,6880	-194,3508	127,8522	-162,8280	113,3460		
27	Tump ki	-31,18	-5,0800	125,8800	-125,8800	-45,5440	94,6344	-169,7136	85,2300	-141,3540	Balok	
	Lap	12,82	2,1200	125,8800	43,2400	18,7760	147,6384	60,8664	124,8300	50,4540	Lantai 4	
	Tump ka	-0,67	-0,8500	-43,2000	43,2400	-2,1640	-46,8668	43,8953	-39,4830	38,3130		
28	Tump ki	1,17	-0,6200	39,1800	-39,1400	0,4120	41,7816	-40,4544	36,3150	-34,1730		
	Lap	13,91	2,3600	39,1800	103,3000	20,4680	57,9747	125,3007	47,7810	105,4890		
	Tump ka	-31,47	-4,8500	-103,3400	103,3000	-45,5240	-146,1338	70,8383	-121,3290	64,6470		
29	Tump ki	-26,36	-2,7900	70,1000	-70,4000	-36,0960	43,2905	-104,2346	39,3660	-87,0840	Balok	
	Lap	13,3	1,5000	70,1000	17,3800	18,3600	88,9875	33,6315	75,0600	27,6120	Atap	
	Tump ka	-2,76	1,2500	-17,2200	17,3800	-1,3120	-19,7978	16,5323	-17,9820	13,1580		
30	Tump ki	-1,78	1,3800	13,9800	-13,7800	0,0720	14,1141	-15,0339	10,9800	-14,0040		
	Lap	15,66	1,6600	13,9800	48,2800	21,4480	32,6907	68,7057	26,6760	57,5460		
	Tump ka	-21,92	-2,5200	-48,7000	48,2800	-30,3360	-76,5324	25,2966	-63,5580	23,7240		
As 3 dan As 4	41	Tump ki	-4,6300	-0,8500	107,8400	-106,5200	-6,9160	107,5673	-117,5108	92,8890	-100,0350	Balok
		Lap	5,1000	1,7900	107,8400	198,4600	8,9840	120,2786	215,4296	101,6460	183,2040	Sloof
		Tump ka	-3,8400	1,7900	-200,0400	198,4600	-1,7440	-212,3825	206,0426	-183,4920	175,1580	
	42	Tump ki	-26,7100	-0,8600	159,3000	-157,2400	-33,4280	138,4068	-193,9602	119,3310	-165,5550	
		Lap	12,2300	0,5500	159,3000	160,4800	15,5560	180,6263	181,8653	154,3770	155,4390	
		Tump ka	-23,5200	0,5500	-162,0600	160,4800	-27,3440	-194,3393	144,3278	-167,0220	123,2640	
	43	Tump ki	-24,8300	0,0200	164,5800	-164,0400	-29,7640	146,7564	-198,2946	125,7750	-169,9830	
		Lap	12,4000	0,0200	164,5800	164,2400	14,9120	185,8479	185,4909	159,2820	158,9760	
		Tump ka	-25,0300	-0,0500	-164,2800	164,2400	-30,1160	-198,8228	146,1233	-170,3790	125,2890	
	44	Tump ki	-23,2900	0,6300	160,6000	-161,6200	-26,9400	144,7709	-193,5602	123,5790	-166,4190	
		Lap	12,1800	0,6300	160,6000	158,9200	15,6240	182,0144	180,2504	155,5020	153,9900	
		Tump ka	-27,0500	-0,9700	-157,4200	158,9200	-34,0120	-194,6102	137,5469	-166,0230	118,6830	
	45	Tump ki	-7,1100	0,7800	191,7600	-193,0800	-7,2840	194,6196	-209,4624	166,1850	-180,1710	
		Lap	3,8400	0,7800	191,7600	85,3600	5,8560	206,1171	94,3971	176,0400	80,2800	
		Tump ka	-4,0100	0,2000	-85,0200	85,3600	-4,4920	-93,2925	85,6065	-80,1270	73,2150	
46	Tump ki	-3,6600	0,5700	35,1400	-36,9000	-3,4800	33,5927	-42,0494	28,3320	-36,5040		
	Lap	4,6600	0,5700	35,1400	81,4600	6,5040	42,3287	90,9647	35,8200	77,5080		
	Tump ka	-5,7500	-0,8400	-78,9400	81,4600	-8,2440	-89,7183	78,7017	-76,2210	68,1390		
47	Tump ki	-8,3400	-1,6900	121,9000	-120,7000	-12,7120	117,6410	-137,0891	102,2040	-116,1360	Balok	
	Lap	16,7100	3,1000	121,9000	225,3600	25,0120	148,4700	257,1030	124,7490	217,8630	Lantai 1	
	Tump ka	-44,3200	-9,6200	-225,5400	225,3600	-68,5760	-292,4439	181,0011	-242,8740	162,9360		
48-50	Tump ki	-163,9700	-43,1100	432,9200	-426,0600	-265,7400	241,6586	-660,2705	242,0550	-531,0270		
	Lap	95,0200	25,3400	432,9200	411,3600	154,5680	578,2833	555,6453	475,1460	455,7420		
	Tump ka	-183,6900	-48,7700	-416,4400	411,3600	-298,4600	-676,2242	192,9659	-540,1170	204,9030		
51-53	Tump ki	-178,9600	-47,4200	401,3600	-399,8000	-290,6240	188,7081	-652,5099	200,1600	-520,8840		
	Lap	89,2800	23,6600	401,3600	400,5200	144,9920	537,5307	536,6487	441,5760	440,8200		
	Tump ka	-179,8700	-47,6800	-400,6800	400,5200	-292,1320	-654,6351	186,6249	-522,4950	198,5850		
54-56	Tump ki	-182,9500	-48,5500	412,3600	-415,5800	-297,2200	195,0008	-674,3363	206,4690	-538,6770		
	Lap	94,9000	25,3000	412,3600	432,4800	154,3600	556,5315	577,6575	456,5340	474,6420		
	Tump ka	-164,9000	-43,3900	-427,5800	432,4800	-267,3040	-663,1076	239,9555	-533,2320	240,8220		

Tabel 8.1 Lanjutan

Por-tal	No. Elm Balok	Letak Momen	M mati	M hidup	M Gempa		Mu1	Mu2	Mu3	Mu4	Mu5	Balok	
			MD	ML	M Gki	M Gka							
[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]	[11]	[12]	[13]	
As B dan As E	82-83	Tump ki	-8,100	-30,580	17,4000	-17,4000	-58,6480	-19,1331	-55,6731	8,3700	-22,9500	18,6120	Balok Atap
		Lap	3,280	7,890	17,4000	17,4000	16,5600	29,1701	29,1701	18,6120	18,6120	18,6120	
		Tump ka	-8,100	-30,580	-17,4000	17,4000	-58,6480	-55,6731	-19,1331	-22,9500	8,3700	8,3700	
	84-85	Tump ki	-17,530	-68,070	77,2200	-77,3200	-129,9480	-1,6517	-163,9187	53,7210	-85,3650	79,1370	
		Lap	14,650	53,200	77,2200	73,2800	102,7000	146,7375	142,6005	82,6830	57,1230	57,1230	
		Tump ka	-9,810	-41,750	-73,1000	73,2800	-78,5720	-126,5093	27,1898	-74,6190	40,1580	40,1580	
86-87	Tump ki	-5,650	-25,460	46,2800	-46,0200	-47,5160	18,6018	-78,3132	36,5670	-46,5030	57,4740		
	Lap	9,540	27,470	46,2800	54,3200	55,4000	84,5702	93,0122	50,2380	57,4740	57,4740		
	Tump ka	-9,700	-40,330	-54,6400	54,3200	-76,1680	-105,6689	8,7392	-57,9060	40,1580	40,1580		
As C dan As D	21	Tump ki	-48,8800	-1,8800	169,5200	-168,0000	-61,6640	124,8954	-229,5006	108,5760	-195,1920	163,0080	Balok Sloof
		Lap	20,4400	0,1300	169,5200	160,6800	24,7360	199,5809	190,2989	170,9640	163,0080	163,0080	
Tump ka		-43,0200	0,1300	-161,5600	160,6800	-51,4160	-214,6862	123,6659	-184,1220	105,8940	105,8940		
22	Tump ki	0,4100	2,1900	440,4200	-440,1400	3,9960	464,9411	-459,6470	396,7470	-395,7570	396,7470		
	Lap	4,5600	2,1900	440,4200	440,4200	8,9760	469,2986	469,2986	400,4820	400,4820	400,4820		
	Tump ka	0,4100	2,1900	-440,1400	440,4200	3,9960	-459,6470	464,9411	-395,7570	396,7470	396,7470		
23	Tump ki	-43,0200	0,1300	160,6800	-161,5600	-51,4160	123,6659	-214,6862	105,8940	-184,1220	105,8940		
	Lap	20,4400	0,1300	160,6800	169,5200	24,7360	199,5809	199,5809	163,0080	170,9640	170,9640		
	Tump ka	-48,8800	-1,8800	-168,0000	169,5200	-61,6640	-229,5006	124,8954	-195,1920	108,5760	108,5760		
24-27	Tump ki	-441,4100	-129,4600	476,9800	-471,9200	-736,8280	-84,9912	-1081,3362	32,0130	-821,9970	663,4710	Balok Lantai 1	
	Lap	311,3300	95,3000	476,9800	425,8600	526,0760	917,7840	864,1080	709,4790	663,4710	663,4710		
	Tump ka	-460,1200	-135,3800	-428,5200	425,8600	-768,7520	-1061,0061	-163,9071	-799,7760	-30,8340	-30,8340		
28	Tump ki	-100,9000	-29,0400	822,4400	-821,9800	-167,5440	730,1742	-996,4668	649,3860	-830,5920	649,3860		
	Lap	-84,0600	-26,1600	822,4400	822,4400	-142,7280	750,5778	750,5778	664,5420	664,5420	664,5420		
	Tump ka	-100,9000	-29,0400	-821,9800	822,4400	-167,5440	-996,4668	730,1742	-830,5920	649,3860	649,3860		
29-32	Tump ki	-460,1200	-135,3800	425,8600	-428,5200	-768,7520	-163,9071	-1061,0061	-30,8340	-799,7760	709,4790		
	Lap	311,3300	95,3000	425,8600	476,9800	526,0760	864,1080	917,7840	663,4710	709,4790	709,4790		
	Tump ka	-441,4100	-129,4600	-471,9200	476,9800	-736,8280	-1081,3362	-84,9912	-821,9970	32,0130	32,0130		
33-36	Tump ki	-452,4800	-133,0100	445,9600	-442,2200	-755,7920	-132,5405	-1065,1295	-5,8680	-805,2300	644,3010	Balok Lantai 2	
	Lap	306,0300	93,5400	445,9600	409,8600	516,9000	877,9848	840,0798	676,7910	644,3010	644,3010		
	Tump ka	-459,6600	-135,3400	-411,8400	409,8600	-768,1360	-1042,9713	-180,1863	-784,3500	-44,8200	-44,8200		
37	Tump ki	-86,5900	-24,2600	669,1800	-668,7000	-142,7240	588,7938	-815,9802	524,3310	-679,7610	524,3310		
	Lap	-69,7400	-21,3800	669,1800	669,1800	-117,8930	609,2079	609,2079	539,4960	539,4960	539,4960		
	Tump ka	-86,5900	-24,2600	-668,7000	669,1800	-142,7240	-815,9802	588,7938	-679,7610	524,3310	524,3310		
38-41	Tump ki	-459,6600	-135,3400	409,8600	-411,8400	-768,1360	-180,1863	-1042,9713	-44,8200	-784,3500	676,7910		
	Lap	306,0300	93,5400	409,8600	445,9600	516,9000	840,0798	877,9848	644,3010	676,7910	676,7910		
	Tump ka	-452,4800	-133,0100	-442,2200	445,9600	-755,7920	-1065,1295	-132,5405	-805,2300	-5,8680	-5,8680		
42-45	Tump ki	-459,3900	-134,9800	347,6600	-343,7400	-767,2360	-244,8726	-970,8426	-100,5570	-722,8170	564,6600	Balok Lantai 3	
	Lap	302,0600	92,3900	347,6600	325,3400	510,2960	769,5146	746,0786	584,7480	521,6600	521,6600		
	Tump ka	-460,6800	-135,6700	-327,4000	325,3400	-769,8880	-955,6922	-270,3152	-709,2720	-121,8060	-121,8060		
46	Tump ki	-74,0700	-20,6500	388,3800	-387,9000	-121,9240	310,5113	-504,5828	282,8790	-415,7730	282,8790		
	Lap	-57,2200	-17,7700	388,3800	388,3800	-97,0960	330,9254	330,9254	298,0440	298,0440	298,0440		
	Tump ka	-74,0700	-20,6500	-387,9000	388,3800	-121,9240	-504,5828	310,5113	-415,7730	282,8790	282,8790		
47-50	Tump ki	-460,6800	-135,6700	325,3400	-327,4000	-769,8880	-270,3152	-955,6922	-121,8060	-709,2720	584,7480		
	Lap	302,0600	92,3900	325,3400	347,6600	510,2960	746,0786	769,5146	564,6600	521,6600	521,6600		
	Tump ka	-459,3900	-134,9800	-343,7400	347,6600	-767,2360	-970,8426	-244,8726	-722,8170	-100,5570	-100,5570		
51-54	Tump ki	-400,5800	-117,7300	225,4200	-222,2000	-669,0640	-295,1729	-765,1739	-157,6440	-560,5020	496,5480	Balok Lantai 4	
	Lap	332,8400	101,4700	225,4200	218,8800	561,7600	682,0622	675,1952	502,4340	496,5480	496,5480		
	Tump ka	-457,9400	-134,7700	-220,4600	218,8800	-765,1600	-839,6777	-378,3707	-610,5600	-215,1540	-215,1540		
55	Tump ki	-158,8000	-45,8000	89,1200	-89,0200	-263,8400	-116,4450	-303,4920	-62,7120	-223,0380	109,3050		
	Lap	-141,9500	-42,9200	89,1200	89,1200	-239,0120	-96,0309	-96,0309	-47,5470	-47,5470	-47,5470		
	Tump ka	-158,8000	-45,8000	-89,0200	89,1200	-263,8400	-303,4920	-116,4450	-223,0380	-62,7120	-62,7120		
56-59	Tump ki	-457,9400	-134,7700	218,8800	-220,4600	-765,1600	-378,3707	-839,6777	-215,1540	-610,5600	502,4340		
	Lap	332,8400	101,4700	218,8800	225,4200	561,7600	675,1952	682,0622	496,5480	502,4340	502,4340		
	Tump ka	-400,5800	-117,7300	-222,2000	225,4200	-669,0640	-765,1739	-295,1729	-560,5020	-157,6440	-157,6440		
As F	25	Tump ki	-12,3900	-0,9700	132,8200	-132,4200	-16,4200	125,5349	-152,9672	108,3870	-130,3290	110,8080	Balok Sloof
		Lap	5,9200	0,4400	132,8200	117,2000	7,8080	146,0928	129,6918	124,8660	110,8080	110,8080	
		Tump ka	-9,0200	0,4400	-117,4200	117,2000	-10,1200	-132,3462	114,0048	-113,7960	97,3620	97,3620	
	26	Tump ki	-1,9500	1,0600	145,7600	-145,7200	-0,6440	152,0022	-154,0518	129,4290	-132,9030	132,0750	
		Lap	0,9900	1,0600	145,7600	145,7600	2,8840	155,0892	155,0892	132,0750	132,0750	132,0750	
		Tump ka	-4,5600	-0,2800	-145,7200	145,7600	-5,9200	-158,0586	147,9954	-135,2520	127,0800	127,0800	
	27	Tump ki	-9,8800	-0,0100	117,2000	-117,4200	-11,8720	112,6766	-133,6745	96,5880	-114,5700	124,9110	
		Lap	5,9700	-0,0100	117,2000	132,8200	7,1480	129,3191	145,7201	110,8530	109,3050	109,3050	
		Tump ka	-11,3700	-0,4400	-132,4200	132,8200	-14,3480	-151,3953	127,1067	-129,4110	124,9110	124,9110	
	28	Tump ki	-43,4500	-13,1200	170,8200	-170,2400	-73,1320	121,3401	-236,7729	114,6330	-192,3210	162,6030	Balok Lantai 1
		Lap	26,6100	8,2200	170,8200	154,0600	45,0840	215,0694	197,4714	177,6870	162,6030	162,6030	
		Tump ka	-41,1700	-12,5600	-154,3600	154,0600	-69,5000	-217,1757	106,6653	-175,9770	101,6010	101,6010	
29	Tump ki	-12,8800	-3,0800	192,9600	-192,8800	-20,3840	186,1734	-218,9586	162,0720	-185,1840	173,2320		
	Lap	-0,4800	-0,5700	192,9600	192,9600	-1,4880	201,5654	201,5654	173,2320	173,2320	173,2320		
	Tump ka	-14,1900	-3,8400	-192,8800	192,9600	-23,1720	-221,0523	184,0797	-186,3630	160,8930	160,8930		

Tabel 8.1 Lanjutan

Por-tal	No. Elm Balok	Letak Momen	M mati		M hidup		M Gempa		Mu1	Mu2	Mu3	Mu4	Mu5	Balok
			MD	ML	M Gki	M Gka								
[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]	[11]	[12]	[13]		
As F	30-31	Tump ki	-33,4400	-8,8100	154,0600	-154,3600	-54,2240	118,3256	-205,5155	108,5580	-169,0200			Balok Lantai 1
		Lap	25,2500	8,1700	154,0600	170,8200	43,3720	195,9962	213,5942	161,3790	176,4630			
		Tump ka	-34,0600	-8,4600	-170,2400	170,8200	-54,4080	-222,5097	135,6033	-183,8700	123,0840			
	32	Tump ki	-46,0300	-13,9600	166,9600	-166,5800	-77,5720	113,7843	-236,4327	108,8370	-191,3490			Balok Lantai 2
		Lap	26,0500	8,0000	166,9600	152,7000	44,0600	210,2205	195,2475	173,7090	160,8750			
		Tump ka	-39,7700	-12,1800	-152,8800	152,7000	-67,2120	-213,7926	107,0664	-173,3850	101,6370			
	33	Tump ki	-10,6900	-2,1300	176,0800	-176,0200	-16,2360	171,6467	-198,0584	148,8510	-168,0390			
		Lap	0,6100	-0,1400	176,0800	176,0800	0,5080	185,3922	185,3922	159,0210	159,0210			
		Tump ka	-14,3200	-4,0700	-176,0200	176,0800	-23,6960	-203,7032	166,0019	-171,3060	145,5840			
	34-35	Tump ki	-32,7600	-8,8100	152,7000	-152,8800	-53,4080	117,6116	-203,2475	107,9460	-167,0760			
		Lap	24,7400	7,9800	152,7000	166,9600	42,4560	193,8531	208,8261	159,6960	172,5300			
		Tump ka	-35,7600	-8,8400	-166,5800	166,9600	-57,0560	-220,8108	129,4062	-182,1060	118,0800			
	36	Tump ki	-46,8100	-14,1800	133,6600	-133,2800	-78,8600	77,7924	-202,4946	78,1650	-162,0810			Balok Lantai 3
		Lap	26,2700	8,0500	133,6600	123,4200	44,4040	175,5338	164,7818	143,9370	134,7210			
		Tump ka	-38,6100	-11,8700	-123,6000	123,4200	-65,3240	-181,5377	77,8334	-145,9890	76,3290			
	37	Tump ki	-10,4400	-1,9600	125,8400	-125,7800	-15,6640	119,3178	-144,8832	103,8600	-122,5980			
		Lap	0,4900	-0,1300	125,8400	125,8400	0,3800	132,5237	132,5237	113,6970	113,6970			
		Tump ka	-14,8600	-4,3100	-125,7800	125,8400	-24,7280	-151,7450	112,4561	-126,5760	99,8820			
	38-39	Tump ki	-32,0300	-8,7200	123,4200	-123,6000	-52,3880	87,7191	-171,6519	82,2510	-140,0670			
		Lap	24,9000	8,0100	123,4200	133,6600	42,6960	163,3055	174,0575	133,4880	142,7040			
		Tump ka	-36,1800	-8,8700	-133,2800	133,6600	-57,6080	-186,3152	93,9719	-152,5140	87,7320			
	40	Tump ki	-48,1300	-14,3100	85,7000	-85,3200	-80,6520	25,9256	-153,6455	33,8130	-120,1050			Balok Lantai 4
		Lap	25,9000	8,0700	85,7000	80,4400	43,9920	124,8062	119,2832	100,4400	95,7060			
		Tump ka	-38,0900	-11,7100	-80,6400	80,4400	-64,4440	-135,7325	33,4016	-106,8570	38,1150			
41	Tump ki	-9,9800	-2,0500	60,9200	-60,8600	-15,2560	51,5498	-76,3193	45,8460	-63,7560				
	Lap	1,1900	-0,1300	60,9200	60,9200	1,2200	65,0927	65,0927	55,8990	55,8990				
	Tump ka	-13,8700	-4,1600	-60,8600	60,9200	-23,3000	-82,3977	45,4713	-67,2570	42,3450				
42-43	Tump ki	-31,6400	-8,6300	80,4400	-80,6400	-51,7760	43,0847	-126,0494	43,9200	-101,0520				
	Lap	24,3800	7,9700	80,4400	85,7000	42,0080	117,5927	123,1157	94,3380	99,0720				
	Tump ka	-37,6000	-9,0500	-85,3200	85,7000	-59,6000	-137,6183	41,9528	-110,6280	43,2900				
44-45	Tump ki	-33,2500	-7,3600	49,4200	-49,1000	-51,6760	10,0233	-93,4227	14,5530	-74,1150			Balok Atap	
	Lap	35,8100	7,3400	49,4200	51,3400	54,7160	96,4278	98,4438	76,7070	78,4350				
	Tump ka	-27,3500	-4,8400	-51,4600	51,3400	-40,5640	-87,3243	20,6157	-70,9290	21,5910				
46	Tump ki	-9,6500	-0,5300	0,9000	-0,8600	-12,4280	-9,6884	-11,5364	-7,8750	-9,4590				
	Lap	-6,0900	-0,4800	0,9000	0,9000	-8,0760	-5,9031	-5,9031	-4,6710	-4,6710				
	Tump ka	-16,6400	-4,1500	-0,8600	0,9000	-26,6080	-22,2968	-20,4488	-15,7500	-14,1660				
47-48	Tump ki	-31,0500	-6,7700	51,3400	-51,4600	-48,0920	14,9069	-93,0332	18,2610	-74,2590				
	Lap	35,3900	7,1200	51,3400	49,4200	53,8600	97,7949	95,7789	78,0570	76,3290				
	Tump ka	-30,3900	-5,8800	-49,1000	49,4200	-45,8760	-89,0211	14,4249	-71,5410	17,1270				

Keterangan Tabel 8.1:

- [1] Portal yang ditinjau
- [2] Nomor elemen balok
- [3] Letak momen: Tumpuan kiri, Tumpuan kanan, dan Lapangan
- [4] MD = Momen akibat beban mati
- [5] ML = Momen akibat beban hidup
- [6] M Gki = Momen akibat beban gempa kiri
- [7] M Gka = Momen akibat beban gempa kanan
- [8] Mu1 = 1,2MD + 1,6ML
- [9] Mu2 = 1,05 (MD + 0,9ML + M Gki)
- [10] Mu3 = 1,05 (MD + 0,9ML + M Gka)
- [11] Mu4 = 0,9 (MD + M Gki)
- [12] Mu5 = 0,9 (MD + M Gka)
- [13] Keterangan Balok: sloof, lantai 1 s/d 4, dan atap.

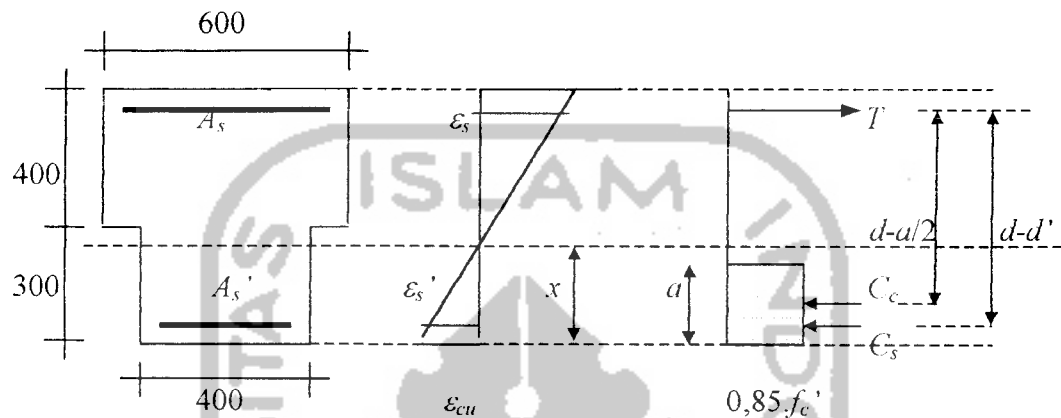
Angka yang dicetak tebal adalah Mu terbesar

8.1.2 Penulangan Lentur Balok

Sebagai contoh perhitungan penulangan lentur balok ditinjau pada Portal as 1 dan as 6, untuk balok lantai 1 adalah sebagai berikut (Dipohusodo,1996):

1. Tulangan tumpuan balok Lantai 1

- Untuk momen negatif ($M_u = - 655,2788$ kNm)



Gambar 8.1 Analisis balok bertulangan rangkap tumpuan untuk momen negatif

$$\rho_b = \frac{0,85 \cdot f_c'}{f_y} \beta_1 \left(\frac{600}{600 + f_y} \right) = \frac{0,85 \cdot 25}{400} \cdot 0,85 \left(\frac{600}{600 + 400} \right) = 0,02709$$

$$\rho_{min} = 1,4/f_y = 1,4/400 = 0,0035 ; \rho_{maks} = 0,75 \cdot \rho_b = 0,75 \cdot 0,02709 = 0,02032$$

$$\rho_{min} < \rho \leq \rho_{maks} \text{ diambil } \rho = (0,0035 + 0,02709)/4 = 0,007146$$

$$d' = p(\text{selimut beton}) + \varnothing_{\text{tul. sengkang}} + \frac{1}{2} \cdot \varnothing_{\text{tul. lentur}} = 50 + 10 + \frac{1}{2} \cdot 25 = 72,5 \text{ mm}$$

$$d = h - d' = 700 - 72,5 = 627,5 \text{ mm}$$

$$x = [600/(600 + f_y)] \cdot d = [600/(600 + 400)] \cdot 627,5 = 376,5 \text{ mm}$$

$$a = \beta_1 \cdot x = 0,85 \cdot 376,5 = 320,025 \text{ mm}$$

$$\text{Luas tulangan tarik : } A_{s1} = \rho \cdot b \cdot d = 0,007146 \cdot 400 \cdot 627,5 = 1793,646 \text{ mm}^2$$

$$T_1 = A_{s1} \cdot f_y = 1793,646 \cdot 400 = 717458,4 \text{ kN}$$

$$M_{n1} = T_1 \cdot (d - a/2) = 717458,4 \cdot (627,5 - 320,025/2)$$

$$= 335.4028 \text{ kNm} < M_n = M_u/0,8 = 819,0985 \text{ kNm}$$

$$M_{n2} = M_n - M_{n1} = 819,0985 - 335,4028 = 483,6957 \text{ kNm}$$

$$M_{n2} = C_s \cdot (d - d') \text{ atau } M_{n2} = T_2 \cdot (d - d')$$

$$T_2 = C_s = M_{n2} / (d - d') = 483,6957 / (627,5 - 72,5) = 871523,78 \text{ N}$$

Periksa regangan tulangan tekan:

$$\varepsilon_s' = [(x-d')/x] \cdot \varepsilon_{cu} = [(376,5 - 72,5)/376,5] \cdot 0,003 = 0,0024$$

$$\varepsilon_y = f_y/E_s = 400/200000 = 0,002$$

$$\varepsilon_s' > \varepsilon_y$$

dianggap baja tekan telah leleh saat beton tekan mencapai regangan hancur 0,003

dan $f_s' = f_y = 400$ MPa

$$\text{Luas tulangan tekan: } A_s' = C_c/f_s' = 871523,78/400 = 2178,81 \text{ mm}^2$$

$$\text{Tambahan luas tulangan tarik: } A_{s2} = T_2/f_y = 871523,78/400 = 2178,81 \text{ mm}^2$$

$$\text{Luas tulangan tarik: } A_s = A_{s1} + A_{s2} = 1793,646 + 2178,81 = 3872,46 \text{ mm}^2$$

$$\text{Dipakai tulangan: - tulangan tarik/atas: } \mathbf{8D25} = 3926,991 \text{ mm}^2 > A_s = 3872,46 \text{ mm}^2$$

$$\text{- tulangan tekan/bawah: } \mathbf{4D25} = 1963,50 \text{ mm}^2 > A_s' = 2178,81 \text{ mm}^2$$

Periksa kapasitas penampang (lihat Gambar 8.1)

Anggap tulangan tarik dan tulangan tekan telah leleh :

$$C_c = 0,85 \cdot f_c' \cdot b \cdot a = 0,85 \cdot 25 \cdot 400 \cdot a = 8500 \cdot a$$

$$C_s = A_s' \cdot (f_y - 0,85 \cdot f_c') = 1963,50 \cdot (400 - 0,85 \cdot 25) = 929592,64 \text{ N}$$

$$T = A_s \cdot f_y = 3926,991 \cdot 400 = 1570796,4 \text{ N}$$

Keseimbangan gaya-gaya dalam:

$$T = C_c + C_s$$

$$1570796,4 = 8500 \cdot a + 929592,64, \text{ didapat } a = 75,44 \text{ mm}$$

$$x = a/\beta_1 = 75,44/0,85 = 88,75 \text{ mm}$$

$$\varepsilon_s' = [(x-d')/x] \cdot \varepsilon_{cu} = [(88,75-72,5)/88,75]0,003 = 0,00055 < (\varepsilon_y = 0,002)$$

$$\varepsilon_s = [(d-x)/x] \cdot \varepsilon_{cu} = [(627,5-88,75)/88,75]0,003 = 0,0182 > (\varepsilon_y = 0,002)$$

Anggapan tidak benar, tulangan tekan belum leleh dicari garis netral terlebih dahulu:

untuk mendapatkan nilai x digunakan persamaan sebagai berikut:

$$(0,85 \cdot f_c' \cdot b \cdot \beta_1)x^2 + (600 \cdot A_s' - A_s \cdot f_y)x - 600 \cdot d' \cdot A_s' = 0$$

$$(0,85 \cdot 25 \cdot 400 \cdot 0,85)x^2 + (600 \cdot 1963,50 - 3926,991 \cdot 400)x - 600 \cdot 72,5 \cdot 2454,369 = 0$$

$$7225 \cdot x^2 - 98175 \cdot x - 106765051,5 = 0$$

dari persamaan diatas didapat $x = 139,25$ mm

$$f_s' = [(x-d')/x]600 = [(139,25-72,5)/139,25]600 = 287,61 \text{ MPa} < f_y = 400 \text{ MPa}$$

Periksa rasio tulangan

$$\rho = A_{s1}/(bd) = [A_s - (A_s' \cdot f_s')/f_y]/(b \cdot d)$$

$$= [3926,991 - (1963,50.261,60)/400]/(400.627,5) = 0,01$$

$\rho_{min} = 0,0035 < \rho = 0,01 < \rho_{maks} = 0,0203$, memenuhi syarat

$$a = 0,85 \cdot x = 0,85 \cdot 139,25 = 118,36 \text{ mm}$$

Hitung momen nominal aktual negatif tumpuan.

$$C_c = 0,85 \cdot f_c' \cdot b \cdot a = 0,85 \cdot 25 \cdot 400 \cdot 118,36 \cdot 10^{-3} = 1006,0749 \text{ kN}$$

$$C_s = A_s' \cdot f_s' = 1963,50 \cdot 287,61 = 564,7214 \text{ kN}$$

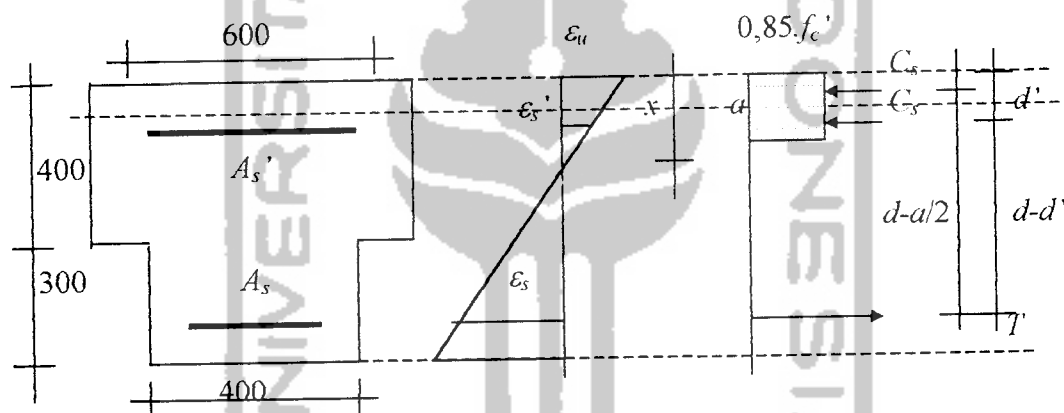
$$M_{nak} = C_c \cdot [d - (a/2)] + C_s \cdot (d - d')$$

$$= 1006,0749 \cdot [627,5 - (118,46/2)] + 654,7214 \cdot (627,5 - 72,5)$$

$$= 885,1920 \text{ kN.m} \quad \text{- aman -}$$

$$(0,8 \cdot M_{nak} = 0,8 \cdot 885,1920 = 708,1536 \text{ kNm}) > (M_u = 655,2788 \text{ kN}) \quad \text{- aman -}$$

- Untuk momen tumpuan positif ($M_u = 271,1880 \text{ kN.m}$)



Gambar 8.2 Analisis balok bertulangan rangkap tumpuan untuk momen positif

Periksa kapasitas penampang (lihat Gambar 8.2):

Anggap tulangan tarik dan tulangan tekan telah leleh :

$$C_c = 0,85 \cdot f_c' \cdot b \cdot a = 0,85 \cdot 25 \cdot 600 \cdot a = 12750 \cdot a$$

$$C_s = A_s' \cdot (f_y - 0,85 \cdot f_c') = 3926,991 \cdot (400 - 0,85 \cdot 25) = 1487347,84 \text{ N}$$

$$T = A_s \cdot f_y = 1963,50 \cdot 400 = 981747,6 \text{ N}$$

Keseimbangan gaya-gaya dalam:

$$T = C_c + C_s$$

$$981747,6 = 12750 \cdot a + 1487347,84, \text{ didapat } a = -39,65 \text{ mm}$$

$$x = a/\beta_1 = -39,65/0,85 = -46,65 \text{ mm}$$

$$\epsilon_s' = [(x-d')/x] \cdot \epsilon_{cu} = [(46,65-72,5)/46,65] \cdot 0,003 = -0,00166 < \epsilon_y = 0,002$$

$$\epsilon_s = [(d-x)/x] \cdot \epsilon_{cu} = [(627,5-46,65)/46,65] \cdot 0,003 = 0,0373 > \epsilon_y = 0,002$$

Anggapan tidak benar, tulangan tekan belum leleh dicari garis netral terlebih dahulu:
 untuk mendapatkan nilai x digunakan persamaan sebagai berikut:

$$(0,85 \cdot f_c' \cdot b \cdot \beta_1)x^2 + (600 \cdot A_s' - A_s \cdot f_y)x - 600 \cdot d' \cdot A_s' = 0$$

$$(0,85 \cdot 25 \cdot 600 \cdot 0,85) \cdot x^2 + (600 \cdot 3926,991 - 2454,369 \cdot 400)x - 600 \cdot 72,5 \cdot 3926,991 = 0$$

$$10837,5 \cdot x^2 + 1374447 \cdot x - 170824108,5 = 0$$

dari persamaan diatas didapat $x = 77,24$ mm

$$f_s' = [(x-d')/x]600 = [(77,25-72,5)/77,25]600 = 36,83 \text{ MPa} < f_y = 400 \text{ MPa}$$

Periksa rasio tulangan

$$\rho = A_{s1}/(bd) = [A_s - (A_s' \cdot f_s')/f_y]/(b \cdot d)$$

$$= [2454,369 - (3926,991 \cdot 36,83)/400]/(600 \cdot 627,5) = 0,0055$$

$$\rho_{min} = 0,0035 < \rho = 0,0055 < \rho_{maks} = 0,0203, \text{ memenuhi syarat}$$

$$a = 0,85 \cdot x = 0,85 \cdot 77,25 = 65,66 \text{ mm}$$

Hitung momen nominal aktual balok positif tumpuan.

$$C_c = 0,85 \cdot f_c' \cdot b \cdot a = 0,85 \cdot 25 \cdot 600 \cdot 65,66 \cdot 10^{-3} = 837,1067 \text{ kN}$$

$$C_s = A_s' \cdot f_s' = 3926,991 \cdot 36,83 \cdot 10^{-3} = 144,6410 \text{ kN}$$

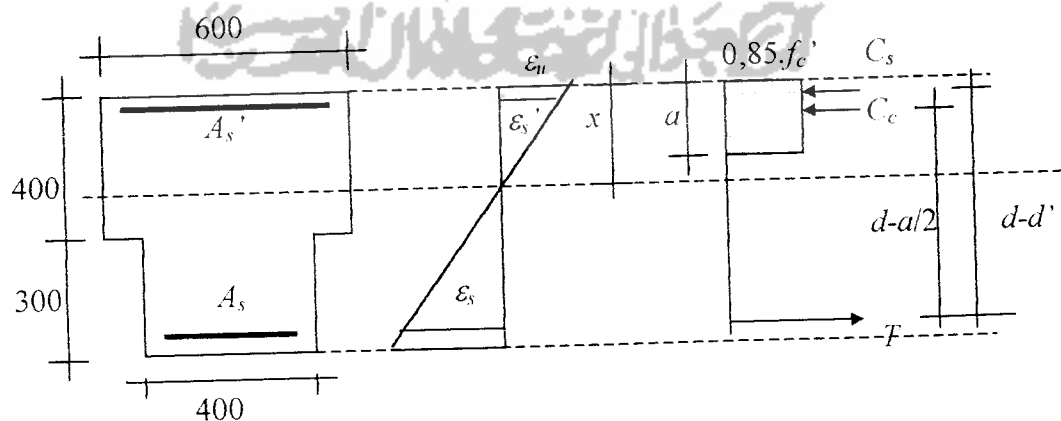
$$M_{nak} = C_c \cdot [d - (a/2)] + C_s \cdot (d - d')$$

$$= 837,1067 \cdot [627,5 - (65,66/2)] - 144,6410 \cdot (627,5 - 72,5)$$

$$= 578,0799 \text{ kNm}$$

$$(0,8 \cdot M_{nak} = 0,8 \cdot 578,0799 = 462,4639 \text{ kNm}) > (M_u = 271,1880 \text{ kNm}) - \text{aman}$$

2. Tulangan lapangan balok Lantai 1 ($M_u = 576,2222$ kNm)



Gambar 8.3 Analisis balok bertulangan rangkap untuk momen lapangan

$$\rho_b = \frac{0,85 \cdot f_c'}{f_y} \beta_1 \left(\frac{600}{600 + f_y} \right) = \frac{0,85 \cdot 25}{400} \cdot 0,85 \left(\frac{600}{600 + 400} \right) = 0,02709$$

$$\rho_{min} = 1,4/f_y = 1,4/400 = 0,0035 ; \rho_{maks} = 0,75 \cdot \rho_b = 0,75 \cdot 0,02709 = 0,02032$$

$$\rho_{min} < \rho \leq \rho_{maks} \text{ diambil } \rho = 0,004866$$

$$d' = p_{(selimut beton)} + \varnothing_{tul.sengkang} + \frac{1}{2} \cdot \varnothing_{tul.lentur} = 50 + 10 + \frac{1}{2} \cdot 25 = 72,5 \text{ mm}$$

$$d = h - d' = 700 - 72,5 = 627,5 \text{ mm}$$

$$x = \left[\frac{600}{(600 + f_y)} \right] \cdot d = \left[\frac{600}{(600 + 400)} \right] \cdot 627,5 = 376,5 \text{ mm}$$

$$a = \beta_1 \cdot x = 0,85 \cdot 376,5 = 320,025 \text{ mm}$$

$$\text{Luas tulangan tarik: } A_{s1} = \rho \cdot b \cdot d = 0,004866 \cdot 600 \cdot 627,5 = 1832,049 \text{ mm}^2$$

$$T_1 = A_{s1} \cdot f_y = 1832,049 \cdot 400 = 732819,6 \text{ N}$$

$$M_{n1} = T_1 \cdot (d - a/2) = 732819,6 \cdot (627,5 - 320,025/2)$$

$$= 342584002,755 \text{ Nmm}$$

$$= 342,5840 \text{ kNm} < M_n = M_u/0,8 = 720,2778 \text{ kNm}$$

$$M_{n2} = M_n - M_{n1} = 720,2778 - 342,5840 = 377,6938 \text{ kNm}$$

$$M_{n2} = C_s \cdot (d - d') \text{ atau } M_{n2} = T_2 \cdot (d - d')$$

$$T_2 = C_s = M_{n2}/(d - d') = 377,6938 \cdot 10^6 / (627,5 - 72,5) = 680529,37 \text{ N}$$

Periksa regangan tulangan tekan:

$$\varepsilon_s' = [(x - d')/x] \cdot \varepsilon_{cu} = [(376,5 - 72,5)/376,5] \cdot 0,003 = 0,0024$$

$$\varepsilon_y = f_y/E_s = 400/200000 = 0,002$$

$$\varepsilon_s' > \varepsilon_y$$

dianggap baja tekan telah leleh saat beton tekan mencapai regangan hancur 0,003

dan $f_s' = f_y = 400 \text{ MPa}$

$$\text{Luas tulangan tekan: } A_{s2}' = C_s/f_s' = 680529,37/400 = 1701,32 \text{ mm}^2$$

$$\text{Tambahan luas tulangan tarik: } A_{s2} = T_2/f_y = 680529,37/400 = 1701,32 \text{ mm}^2$$

$$\text{Luas tulangan tarik: } A_s = A_{s1} + A_{s2} = 1832,049 + 1701,32 = 3433,36 \text{ mm}^2$$

$$\text{Dipakai tulangan: - tulangan tarik/bawah: } \mathbf{7D25} = 3436,117 \text{ mm}^2 > A_s = 3433,36 \text{ mm}^2$$

$$\text{- tulangan tekan/atas: } \mathbf{4D25} = 1963,50 \text{ mm}^2 > A_{s2}' = 1701,31 \text{ mm}^2$$

Periksa kapasitas penampang:

Anggap tulangan tarik dan tulangan tekan telah leleh :

$$C_c = 0,85 \cdot f_c' \cdot b \cdot a = 0,85 \cdot 25 \cdot 600 \cdot a = 12750 \cdot a$$

$$C_s = A_s' \cdot (f_y - 0,85 \cdot f_c') = 1963,50 \cdot (400 - 0,85 \cdot 25) = 929592,26 \text{ N}$$

$$T = A_s \cdot f_y = 3436,117 \cdot 400 = 1374446,8 \text{ N}$$

Keseimbangan gaya-gaya dalam:

$$T = C_c + C_s$$

$$1374446,8 = 12750 \cdot a + 929592,26, \text{ didapat } a = 34,89 \text{ mm}$$

$$x = a/\beta_1 = 34,89/0,85 = 41,05 \text{ mm}$$

$$\varepsilon_s' = [(x-d')/x] \cdot \varepsilon_{cu} = [(41,05-72,5)/41,05]0,003 = -0,0022 < \varepsilon_y = 0,002$$

$$\varepsilon_s = [(d-x)/x] \cdot \varepsilon_{cu} = [(627,5-41,05)/41,05]0,003 = 0,043 > \varepsilon_y = 0,002$$

Anggapan tidak benar, berarti tulangan tekan belum leleh diperlukan mencari garis netral terlebih dahulu:

untuk mendapatkan nilai x digunakan persamaan sebagai berikut:

$$(0,85 \cdot f_c' \cdot b \cdot \beta_1) x^2 + (600 \cdot A_s' - A_s \cdot f_y) x - 600 \cdot d' \cdot A_s' = 0$$

$$(0,85 \cdot 25 \cdot 600 \cdot 0,85) x^2 + (600 \cdot 2454,369 - 4346,117 \cdot 400) x - 600 \cdot 72,5 \cdot 2454,369 = 0$$

$$10837,5 \cdot x^2 - 265825,4 \cdot x - 106765051,5 = 0$$

dari persamaan diatas didapat $x = 98,30 \text{ mm}$

$$f_s' = [(x-d')/x]600 = [(98,30-72,5)/98,30]600 = 157,46 \text{ MPa} < f_y = 400 \text{ MPa}$$

Periksa rasio tulangan

$$\rho = A_s/(bd) = [A_s - (A_s' \cdot f_s')/f_y]/(b \cdot d)$$

$$= [3436,117 - (1963,50 \cdot 157,46)/400]/(600 \cdot 627,5) = 0,0066$$

$$\rho_{min} = 0,0035 < \rho = 0,0066 < \rho_{maks} = 0,0203$$

$$a = 0,85 \cdot x = 0,85 \cdot 98,30 = 83,55 \text{ mm} - \text{memenuhi syarat}$$

Hitung momen nominal aktual balok lapangan

$$C_c = 0,85 \cdot f_c' \cdot b \cdot a = 0,85 \cdot 25 \cdot 600 \cdot 80,60 \cdot 10^{-3} = 1065,2794 \text{ kN}$$

$$C_s = A_s' \cdot f_s' = 1963,50 \cdot (157,46) \cdot 10^{-3} = 564,7214 \text{ kN}$$

$$M_{nak} = C_c \cdot [d - (a/2)] + C_s \cdot (d - d')$$

$$= 1065,2794 \cdot [627,5 - (83,55/2)] + 564,7214 \cdot (627,5 - 72,5)$$

$$= 795,5480 \text{ kNm}$$

$$(0,8 \cdot M_{nak} = 0,8 \cdot 795,5480 = 636,4384 \text{ kNm}) > (M_u = 576,2222 \text{ kNm}) - \text{aman}$$

Dengan cara yang sama didapat penulangan lentur semua balok, disajikan dalam lampiran Tabel 8.2.

Tabel 8.2 Penulangan Lentur Balok Daktilitas Terbatas

Por-tal	Balok	Ukuran [mm]	l [m]	Letak Tulangan	Tulangan terpakai	As (mm ²)	ρ	Analisis	Mu (kNm)	b (mm)	d' (mm)	d (mm)	x (mm)	a (mm)	fs' (MPa)	Cc (kN)	Cs (kN)	Mnek (kN.m)	$\phi Mnek$ (kN.m)
[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]	[11]	[12]	[13]	[14]	[15]	[16]	[17]	[18]	[19]	[20]
As 1	Sloof	b = 400 h = 600	7,2	Tump.	Atas	1134,11	0,0056	M.tump. -	200,3579	400	69,5	530,5	66,25	56,31	-29,42	478,6684	-25,0225	233,4988	186,7990
					Bawah	850,59	0,0052	M.tump. +	143,9939	400	69,5	530,5	60,72	51,61	-86,80	438,6757	-98,4412	181,2968	145,0374
dan					Atas	850,59	0,0056	M.lap.	184,9649	400	69,5	530,5	66,25	56,31	-29,42	478,6684	-25,0225	233,4988	186,7990
As 6				Lap.	Bawah	1134,11													
					Atas	3926,99	0,0100	M.tump. -	655,2788	400	72,5	627,5	139,25	118,36	287,61	1006,0749	564,7214	885,1920	708,1536
	Lantai 1	bf = 600 bw = 400 hf = 400 h = 700	7,2	Tump.	Bawah	1963,50	0,0052	M.tump. +	271,1880	600	72,5	627,5	72,49	61,62	-0,06	785,6386	-0,2404	468,6498	374,9198
					Atas	1963,50	0,0071	M.lap.	576,2222	600	72,5	627,5	98,30	83,55	157,46	1065,2794	309,1674	795,5480	636,4384
	Lantai 2	bf = 600 bw = 400 hf = 400 h = 700	7,2	Tump.	Bawah	3436,12	0,0100	M.tump. -	636,8985	400	72,5	627,5	139,25	118,36	287,61	1006,0749	564,7214	885,1920	708,1536
					Atas	1963,50	0,0052	M.tump. +	235,9440	600	72,5	627,5	72,49	61,62	-0,06	785,6386	-0,2404	468,6498	374,9198
	Lantai 3	bf = 600 bw = 400 hf = 400 h = 700	7,2	Tump.	Bawah	1472,62	0,0066	M.lap.	541,3727	600	72,5	627,5	98,30	83,55	157,46	1065,2794	309,1674	795,5480	636,4384
					Atas	2945,24	0,0089	M.tump. -	555,5193	400	72,5	627,5	123,16	104,69	246,81	889,8441	484,6027	780,7539	624,6031
	Lantai 4	bf = 600 bw = 400 hf = 400 h = 700	7,2	Tump.	Bawah	1963,50	0,0052	M.tump. +	158,7150	600	72,5	627,5	72,49	61,62	-0,07	785,6303	-0,2321	468,6497	374,9197
					Atas	1472,62	0,0066	M.lap.	454,5576	600	72,5	627,5	91,66	77,91	125,43	993,3862	184,7110	687,1658	549,7326
	Lantai 5	bf = 600 bw = 400 hf = 400 h = 700	7,2	Tump.	Bawah	3436,12	0,0089	M.tump. -	443,7017	400	72,5	627,5	123,16	104,69	246,81	889,8441	484,6027	780,7539	624,6031
					Atas	1963,50	0,0052	M.tump. +	74,5380	600	72,5	627,5	72,49	61,62	-0,07	785,6303	-0,2321	468,6497	374,9197
	Ring	b = 500 h = 600		Lap.	Bawah	1472,62	0,0066	M.lap.	355,9563	600	72,5	627,5	91,66	77,91	125,43	993,3862	184,7110	687,1658	549,7326
					Atas	2945,24	0,0056	M.tump. -	150,8598	500	69,5	530,5	65,89	56,00	-32,90	595,0427	-27,9852	286,1066	228,8853
					Bawah	1417,64	0,0049	M.tump. +	20,4840	500	69,5	530,5	57,44	48,83	-125,94	518,7775	-178,5430	180,2382	144,1905
	As 2	b = 400 h = 600	3,6	Tump.	Bawah	850,59	0,0051	M.lap.	150,1269	500	69,5	530,5	59,61	50,67	-99,57	538,3369	-84,6909	232,9072	186,3258
					Atas	1134,11	0,0050	M.tump. -	-141,6051	400	69,5	530,5	59,28	50,38	-103,49	428,2656	-88,0311	198,6807	158,9446
	As 5	b = 400 h = 600	3,6	Tump.	Bawah	850,59	0,0050	M.tump. +	130,3659	400	69,5	530,5	59,28	50,38	-103,49	428,2656	-88,0311	198,6807	158,9446
					Atas	850,59	0,0050	M.lap.	140,0784	400	69,5	530,5	59,28	50,38	-103,49	428,2656	-88,0311	198,6807	158,9446
	Lantai 1	b = 200 h = 700	3,6	Tump.	Bawah	1472,62	0,0071	M.tump. -	-226,9428	200	72,5	627,5	98,50	83,72	158,37	355,8277	233,2209	337,8238	270,2590
					Atas	1472,62	0,0071	M.tump. +	189,9702	200	72,5	627,5	98,50	83,72	158,37	355,8277	233,2209	337,8238	270,2590
	Lantai 2	b = 200 h = 700	3,6	Tump.	Bawah	1472,62	0,0071	M.tump. -	-225,7269	200	72,5	627,5	98,50	83,72	158,37	355,8277	233,2209	337,8238	270,2590
					Atas	1472,62	0,0071	M.tump. +	190,1991	200	72,5	627,5	98,50	83,72	158,37	355,8277	233,2209	337,8238	270,2590
	Lantai 3	b = 200 h = 700	3,6	Tump.	Bawah	1472,62	0,0071	M.tump. -	-185,2190	200	72,5	627,5	98,50	83,72	158,37	355,8277	233,2209	337,8238	270,2590
					Atas	1472,62	0,0071	M.tump. +	149,8361	200	72,5	627,5	98,50	83,72	158,37	355,8277	233,2209	337,8238	270,2590
	Lantai 4	b = 200 h = 700	3,6	Tump.	Bawah	1472,62	0,0071	M.tump. -	-128,6300	200	72,5	627,5	98,50	83,72	158,37	355,8277	233,2209	337,8238	270,2590
					Atas	1472,62	0,0071	M.tump. +	92,9400	200	72,5	627,5	98,50	83,72	158,37	355,8277	233,2209	337,8238	270,2590
					Lap.	1472,62	0,0071	M.lap.	124,1100	200	72,5	627,5	98,50	83,72	158,37	355,8277	233,2209	337,8238	270,2590

Tabel 8.2 Lanjutan

Por-tal	Baok	Ukuran	/	Letak	Tulangan	Tulangan	As	ρ	Analisis	M_u	b	d'	d	x	a	f_s'	C_c	C_s	M_{nek}	ϕM_{nek}
[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]	[11]	[12]	[13]	[14]	[15]	[16]	[17]	[18]	[19]	[20]	[21]
As 2	Atap	b = 200 h = 700	3,6	Tump.	Atas	3 D 19	850,59	0,0056	M.tump.	-66,1900	200	69,5	630,5	78,30	66,56	67,45	282,8657	57,3687	201,1174	160,8939
As 5	Bawah	b = 200 h = 700	3,6	Tump.	Bawah	3 D 19	850,59	0,0056	M.tump. +	52,6400	200	69,5	630,5	78,30	66,56	67,45	282,8657	57,3687	201,1174	160,8939
(A-B)	Atas	b = 200 h = 700	3,6	Lap	Atas	3 D 19	850,59	0,0056	M.lap.	66,0000	200	69,5	630,5	78,30	66,56	67,45	282,8657	57,3687	201,1174	160,8939
As 2	Sloof	b = 400 h = 600	3,6	Tump.	Atas	4 D 19	1134,11	0,0056	M.tump.	-178,4800	400	69,5	530,5	66,25	56,31	-29,42	478,6684	-25,0225	258,6800	206,9440
dan	Bawah	b = 400 h = 600	3,6	Tump.	Bawah	3 D 19	850,59	0,0062	M.tump. +	159,0700	400	69,5	530,5	60,72	51,61	-86,80	438,6757	-98,4412	198,8984	159,1187
As 5	Atas	b = 400 h = 600	3,6	Lap	Atas	3 D 19	850,59	0,0056	M.lap.	173,3500	400	69,5	530,5	66,25	56,31	-29,42	478,6684	-25,0225	258,6800	206,9440
(E-G)	Bawah	b = 400 h = 600	3,6	Lap	Bawah	4 D 19	1134,11	0,0087	M.tump.	-290,4700	200	72,5	627,5	120,27	102,23	238,31	434,4649	350,9332	445,1876	356,1501
Lantai 1	Atas	b = 200 h = 700	3,6	Tump.	Atas	4 D 25	1963,50	0,0087	M.tump.	-293,2200	200	72,5	627,5	120,27	102,23	238,31	434,4649	350,9332	445,1876	356,1501
Lantai 2	Atas	b = 200 h = 700	3,6	Tump.	Atas	4 D 25	1963,50	0,0087	M.tump.	-293,2200	200	72,5	627,5	120,27	102,23	238,31	434,4649	350,9332	445,1876	356,1501
Lantai 3	Atas	b = 200 h = 700	3,6	Tump.	Atas	3 D 25	1472,62	0,0071	M.tump. +	171,9000	200	72,5	627,5	98,50	83,72	158,37	355,8277	233,2209	337,8238	270,2590
Lantai 4	Atas	b = 200 h = 700	3,6	Lap	Atas	3 D 25	1472,62	0,0071	M.lap.	221,7900	200	72,5	627,5	98,50	83,72	158,37	355,8277	233,2209	337,8238	270,2590
Lantai 3	Bawah	b = 200 h = 700	3,6	Tump.	Bawah	3 D 25	1472,62	0,0071	M.tump.	-242,2000	200	72,5	627,5	98,50	83,72	158,37	355,8277	233,2209	337,8238	270,2590
Lantai 4	Bawah	b = 200 h = 700	3,6	Lap	Bawah	3 D 25	1472,62	0,0071	M.lap.	147,6400	200	72,5	627,5	98,50	83,72	158,37	355,8277	233,2209	337,8238	270,2590
Atap	Atas	b = 200 h = 700	3,6	Tump.	Atas	3 D 25	1472,62	0,0071	M.tump.	-169,7100	200	72,5	627,5	98,50	83,72	158,37	355,8277	233,2209	337,8238	270,2590
Atap	Bawah	b = 200 h = 700	3,6	Lap	Bawah	3 D 25	1472,62	0,0071	M.lap.	94,6300	200	72,5	627,5	98,50	83,72	158,37	355,8277	233,2209	337,8238	270,2590
Atap	Atas	b = 200 h = 700	3,6	Tump.	Atas	3 D 25	1472,62	0,0071	M.tump.	-104,2300	200	69,5	630,5	78,30	66,56	67,45	282,8657	57,3687	201,1174	160,8939
Atap	Bawah	b = 200 h = 700	3,6	Lap	Bawah	3 D 25	1472,62	0,0056	M.lap.	88,9900	200	69,5	630,5	78,30	66,56	67,45	282,8657	57,3687	201,1174	160,8939
Atap	Atas	b = 200 h = 700	3,6	Tump.	Atas	3 D 25	1472,62	0,0071	M.tump.	-198,9200	400	69,5	530,5	74,10	62,99	37,25	535,3742	-106,1778	183,1972	146,5578
Atap	Bawah	b = 200 h = 700	3,6	Lap	Bawah	3 D 25	1472,62	0,0063	M.lap.	146,1200	400	69,5	530,5	61,79	52,52	-74,90	446,4123	-106,1778	183,1972	146,5578
Sloof	Atas	b = 400 h = 600	7,2	Tump.	Atas	3 D 19	850,59	0,0063	M.tump.	-185,8500	400	69,5	530,5	74,10	62,99	37,25	535,3742	-106,1778	183,1972	146,5578
dan	Bawah	b = 400 h = 600	7,2	Tump.	Bawah	3 D 19	850,59	0,0063	M.tump.	146,1200	400	69,5	530,5	61,79	52,52	-74,90	446,4123	-106,1778	183,1972	146,5578
As 4	Atas	b = 400 h = 600	3,6	Lap	Atas	3 D 19	850,59	0,0056	M.lap.	172,3436	400	69,5	530,5	66,25	56,31	-29,42	478,6684	-25,0225	233,4988	186,7990
As 4	Bawah	b = 400 h = 600	3,6	Lap	Bawah	4 D 19	1134,11	0,0056	M.lap.	169,9060	400	69,5	530,5	66,25	56,31	-29,42	478,6684	-25,0225	233,4988	186,7990
Lantai 1	Atas	bf = 600 bw = 400 hf = 400 h = 700	7,2	Tump.	Atas	8 D 25	3926,99	0,0093	M.tump.	-676,2200	400	72,5	627,5	128,55	109,26	261,60	928,7391	642,0572	888,3869	710,7095
Lantai 1	Bawah	bf = 600 bw = 400 hf = 400 h = 700	7,2	Tump.	Bawah	5 D 25	2454,37	0,0056	M.tump. +	242,0600	600	72,5	627,5	77,24	65,66	36,83	837,1067	144,6410	578,0799	462,4639
Lantai 1	Atas	bf = 600 bw = 400 hf = 400 h = 700	3,6	Lap	Atas	5 D 25	2454,37	0,0068	M.lap.	578,2800	600	72,5	627,5	94,83	80,60	141,28	1027,7023	346,7445	795,9079	636,7263
Lantai 1	Bawah	bf = 600 bw = 400 hf = 400 h = 700	3,6	Lap	Bawah	7 D 25	3436,12	0,0063	M.tump.	-292,4400	400	72,5	627,5	87,61	74,47	103,49	632,9948	152,4033	458,2185	366,5748
Lantai 1	Atas	bf = 600 bw = 400 hf = 400 h = 700	3,6	Lap	Atas	3 D 25	1472,62	0,0047	M.tump. +	181,0000	600	72,5	627,5	65,67	55,82	-62,44	711,6554	-122,6068	358,6561	286,9249
Lantai 1	Bawah	bf = 600 bw = 400 hf = 400 h = 700	3,6	Lap	Bawah	3 D 25	1472,62	0,0052	M.lap.	257,1000	600	72,5	627,5	72,49	61,61	-0,12	785,5679	-0,1697	468,6490	374,9192

Tabel 8.2 Lanjutan

Por- tal	Balok	Ukuran [mm]	l [m]	Letak Tulangan	Tulangan terpakai	As (mm ²)	ρ	Analisis	Mu (kNm)	b (mm)	d' (mm)	d (mm)	x (mm)	a (mm)	f's' (MPa)	Cc (kN)	Cs (kN)	M _{nak} (kN.m)	ϕ M _{nak} (kNm)	
[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]	[11]	[12]	[13]	[14]	[15]	[16]	[17]	[18]	[19]	[20]	
As 3 dan As 4	Lantai 2	bf = 600 bw = 400 hf = 400 h = 700	7,2	Tump	Atas	8 D 25	3926,99	0,0093	M.tump. -	-634,5200	400	72,5	627,5	128,55	109,26	261,60	928,7391	642,0572	888,3869	710,7095
				Lap	Bawah	5 D 25	2454,37	0,0056	M.tump. +	202,3200	600	72,5	627,5	77,24	65,66	36,83	837,1067	144,6410	578,0799	462,4639
				Lap	Atas	5 D 25	2454,37	0,0056	M.lap.	535,6500	600	72,5	627,5	94,83	80,60	141,28	1027,7023	346,7445	795,9079	636,7263
				Lap	Bawah	7 D 25	3436,12	0,0063	M.tump. -	-285,3900	400	72,5	627,5	87,61	74,47	103,49	632,9948	152,4033	458,2185	366,5748
	Lantai 3	bf = 600 bw = 400 hf = 400 h = 700	7,2	Tump	Atas	7 D 25	3436,12	0,0089	M.tump. -	-535,9600	400	72,5	627,5	123,16	104,69	246,81	889,8441	484,6027	780,7539	624,6031
				Lap	Bawah	4 D 25	1963,50	0,0052	M.tump. +	111,5800	600	72,5	627,5	72,49	61,62	-0,07	785,6303	-0,2321	468,6497	374,9197
				Lap	Atas	4 D 25	1963,50	0,0064	M.lap.	430,6000	600	72,5	627,5	88,78	75,46	110,00	982,1087	215,9886	687,2967	549,8374
				Lap	Bawah	6 D 25	2945,24	0,0063	M.tump. -	-206,7000	400	72,5	627,5	87,61	74,47	103,49	632,9948	152,4033	458,2185	366,5748
	Lantai 4	bf = 600 bw = 400 hf = 400 h = 700	7,2	Tump	Atas	7 D 25	3436,12	0,0089	M.tump. -	-444,2800	400	72,5	627,5	123,16	104,69	246,81	889,8441	484,6027	780,7539	624,6031
				Lap	Bawah	4 D 25	1963,50	0,0052	M.tump. +	84,0900	600	72,5	627,5	72,49	61,62	-0,07	785,6303	-0,2321	468,6497	374,9197
				Lap	Atas	4 D 25	1963,50	0,0064	M.lap.	389,7800	600	72,5	627,5	88,78	75,46	110,00	982,1087	215,9886	687,2967	549,8374
				Lap	Bawah	6 D 25	2945,24	0,0063	M.tump. -	-205,7100	400	72,5	627,5	87,61	74,47	103,49	632,9948	152,4033	458,2185	366,5748
Atap	b = 200 h = 700	3,6	Tump	Atas	4 D 19	1134,11	0,0066	M.tump. -	-199,6900	200	69,5	630,5	91,55	77,82	144,51	330,7255	122,9205	264,6127	211,6901	
			Lap	Bawah	3 D 19	850,59	0,0055	M.tump. +	49,2900	200	69,5	630,5	76,64	65,14	55,88	276,8552	63,3793	201,0955	160,8764	
			Lap	Atas	3 D 19	850,59	0,0066	M.lap.	69,5400	200	69,5	630,5	91,55	77,82	144,51	330,7255	122,9205	264,6127	211,6901	
			Lap	Bawah	4 D 19	1134,11	0,0050	M.tump. -	-153,7600	400	69,5	630,5	59,28	50,38	-103,49	428,2656	-88,0311	198,6807	158,9446	
Lantai 1	b = 200 h = 700	4,8	Tump	Atas	3 D 19	850,59	0,0050	M.tump. -	-147,6400	400	69,5	630,5	59,28	50,38	-103,49	428,2656	-88,0311	198,6807	158,9446	
			Lap	Bawah	3 D 19	850,59	0,0050	M.lap.	151,8600	400	69,5	630,5	59,28	50,38	-103,49	428,2656	-88,0311	198,6807	158,9446	
			Lap	Atas	3 D 19	850,59	0,0071	M.tump. -	-219,3200	200	72,5	627,5	98,50	83,72	158,37	355,8277	233,2209	337,8238	270,2590	
			Lap	Bawah	3 D 25	1472,62	0,0071	M.tump. +	183,4300	200	72,5	627,5	98,50	83,72	158,37	355,8277	233,2209	337,8238	270,2590	
Lantai 2	b = 200 h = 700	4,8	Tump	Atas	3 D 25	1472,62	0,0071	M.tump. -	-215,3000	200	72,5	627,5	98,50	83,72	158,37	355,8277	233,2209	337,8238	270,2590	
			Lap	Bawah	3 D 25	1472,62	0,0071	M.tump. +	158,5100	200	72,5	627,5	98,50	83,72	158,37	355,8277	233,2209	337,8238	270,2590	
			Lap	Atas	3 D 25	1472,62	0,0071	M.lap.	208,5100	200	72,5	627,5	98,50	83,72	158,37	355,8277	233,2209	337,8238	270,2590	
			Lap	Bawah	3 D 25	1472,62	0,0071	M.tump. -	-183,8800	200	72,5	627,5	98,50	83,72	158,37	355,8277	233,2209	337,8238	270,2590	
Lantai 3	b = 200 h = 700	4,8	Tump	Atas	3 D 25	1472,62	0,0071	M.tump. -	-107,3800	200	72,5	627,5	98,50	83,72	158,37	355,8277	233,2209	337,8238	270,2590	
			Lap	Bawah	3 D 25	1472,62	0,0071	M.tump. +	176,0500	200	72,5	627,5	98,50	83,72	158,37	355,8277	233,2209	337,8238	270,2590	
			Lap	Atas	3 D 25	1472,62	0,0071	M.lap.	176,0500	200	72,5	627,5	98,50	83,72	158,37	355,8277	233,2209	337,8238	270,2590	
			Lap	Bawah	3 D 25	1472,62	0,0071	M.tump. -	-183,8800	200	72,5	627,5	98,50	83,72	158,37	355,8277	233,2209	337,8238	270,2590	

Tabel 8.2 Lanjutan

Por-tal	Balok	Ukuran [mm]	l [m]	Letak Tulangan	Tulangan terpakai	As (mm ²)	ρ	Analisis	Mu (kNm)	b (mm)	d' (mm)	d (mm)	x (mm)	a (mm)	f's (MPa)	Cc (kN)	Cs (kN)	M nak (kN.m)	φ M nak (kNm)																																																																					
[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]	[11]	[12]	[13]	[14]	[15]	[16]	[17]	[18]	[19]	[20]																																																																					
As C dan As D	Lantai 4	bf = 600 bw = 400 hf = 400 h = 700	9,6	Tump	Atas	12 D 25	5890,49	0,0119	M.tump. -	-839,6800	400	72,5	627,5	165,65	140,80	337,40	1196,8405	1159,3539	1310,1984	1048,1587																																																																				
				Lap	Bawah	7 D 25	3436,12	0,0060	M.tump. +	0,0000	600	72,5	627,5	83,58	71,05	79,56	905,8247	468,6221	796,3131	637,0504																																																																				
				Lap	Atas	6 D 25	2945,24	0,0078	M.lap.	682,0600	600	72,5	627,5	108,73	92,42	199,92	1178,3377	588,8082	1011,7452	809,3662																																																																				
				Lap	Bawah	9 D 25	4417,86																																																																																	
				Lap	Atas	7 D 25	3436,12	0,0083	M.tump. -	-303,4900	400	72,5	627,5	114,96	97,71	221,60	830,5643	543,8824	782,4552	625,9642																																																																				
				Lap	Bawah	5 D 25	2454,37	0,0056	M.tump. +	0,0000	600	72,5	627,5	77,75	66,09	40,50	842,5911	139,1566	578,1163	462,4930																																																																				
	AS F	Lantai 1	b = 400 h = 600	4,8	Tump	Atas	3 D 19	850,59	0,0050	M.tump. -	-158,0600	400	69,5	530,5	59,28	50,38	-103,49	428,2656	-88,0311	198,6807	158,9446																																																																			
					Lap	Bawah	3 D 19	850,59	0,0050	M.tump. +	148,0000	400	69,5	530,5	59,28	50,38	-103,49	428,2656	-88,0311	198,6807	158,9446																																																																			
					Lap	Atas	3 D 19	850,59	0,0050	M.lap.	155,0900	400	69,5	530,5	59,28	50,38	-103,49	428,2656	-88,0311	198,6807	158,9446																																																																			
					Lap	Bawah	3 D 19	850,59																																																																																
					Lap	Atas	3 D 25	1472,62	0,0071	M.tump. -	-236,7700	200	72,5	627,5	98,50	83,72	158,37	355,8277	233,2209	337,8238	270,2590																																																																			
					Lap	Bawah	3 D 25	1472,62	0,0071	M.tump. +	186,1700	200	72,5	627,5	98,50	83,72	158,37	355,8277	233,2209	337,8238	270,2590																																																																			
Lantai 2		b = 200 h = 700	4,8	Lap	Atas	3 D 25	1472,62	0,0071	M.lap.	215,0700	200	72,5	627,5	98,50	83,72	158,37	355,8277	233,2209	337,8238	270,2590																																																																				
																					Lap	Bawah	3 D 25	1472,62	0,0071	M.tump. -	-236,4300	200	72,5	627,5	98,50	83,72	158,37	355,8277	233,2209	337,8238	270,2590																																																			
																																						Lap	Atas	3 D 25	1472,62	0,0071	M.tump. +	166,0000	200	72,5	627,5	98,50	83,72	158,37	355,8277	233,2209	337,8238	270,2590																																		
																																																							Lap	Bawah	3 D 25	1472,62	0,0071	M.lap.	210,2200	200	72,5	627,5	98,50	83,72	158,37	355,8277	233,2209	337,8238	270,2590																	
																																																																								Lap	Atas	3 D 25	1472,62	0,0071	M.tump. -	-202,4946	200	72,5	627,5	98,50	83,72	158,37	355,8277	233,2209	337,8238	270,2590

Keterangan Tabel 8.2.

- [1] Portal yang ditinjau
- [2] Balok: Sloof, Lantai 1 s/d 4, dan Atap
- [3] Ukuran Balok: bf = lebar sayap, bw = lebar badan, hf = tinggi sayap, h = tinggi balok
- [4] l = bentang balok
- [5] Letak tulangan: Tumpuan & lapangan, Atas & bawah
- [6] Tulangan yang dipakai
- [7] Luas tulangan
- [8] $\rho = (A_s - A_s') / f_s' / f_c' / (b \cdot d)$ (rasio penulangan)
- [9] Analisis: Momen tumpuan: -, negatif; positif dan lapangan
- [10] Mu = momen rencana balok (dari Tabel 8.1)
- [11] b = lebar balok daerah desak
- [12] d' = D/2 + 10 + 50
- [13] d = h - d' (tinggi efektif)
- [14] x: didapat dari persamaan $(0,85 \cdot f_c' \cdot b \cdot 0,85) x^2 + (600 A_s - A_s') x - 600 d' A_s = 0$
- [15] a = x · 0,85
- [16] fs' = (x - d') / x · 600
- [17] Cc = 0,85 · fc' · b · a
- [18] Cs = As · fs'
- [19] Mnak = Cc(d - a/2) + Cs(d - d')
- [20] 0,8 · Mnak ≥ Mu

8.1.3 Gaya Geser Rencana Balok

Gaya geser rencana balok dapat dihitung dengan rumus (Kusuma dan Andriono, 1993):

$$V_{u,b} = 1,05.(V_{D,b} + V_{L,b} + 4/k . V_{E,b})$$

Sebagai contoh perhitungan adalah gaya geser rencana balok Portal as 1 dan as 6, lantai 1, sebagai berikut ini.

Diketahui:

$$V_{D,b} = 100,9757 \text{ kN}$$

$$V_{L,b} = 57,3986 \text{ kN}$$

$$V_{E,b} = 58,0100 \text{ kN}$$

$$k = 2$$

$$V_{u,b} = 1,05.(100,9757 + 57,3986 + 4/2.58,0100) = 288,1140 \text{ kN}$$

Dengan cara yang sama didapat gaya geser rencana dari semua balok, disajikan pada Tabel 8.3.



Tabel 8.3 Gaya Geser Rencana Balok Daktilitas Terbatas

Port- tal	Balok	ln (m)	U- jung	V_D (kN)	V_L (kN)	V_E (kN)	$V_{u,b}$ (kN)
[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]
As 1- dan As 6	Sloof	6.5	1	19.3104	0.5146	22.3400	67.7303
			2	19.3104	0.5146	22.3400	-26.0978
	Lantai 1	6.5	1	100.9757	57.3986	58.0100	288.1140
			2	100.9757	57.3986	58.0100	44.4720
	Lantai 2	6.5	1	99.2063	56.3604	54.0700	276.8920
			2	99.2063	56.3604	54.0700	49.7980
	Lantai 3	6.5	1	100.0819	56.4688	42.9000	254.4682
			2	100.0819	56.4688	42.9000	74.2882
	Lantai 4	6.5	1	99.7750	56.1347	29.8900	226.4742
			2	99.7750	56.1347	29.8900	100.9362
	Ring	6.5	1	44.0736	8.8021	10.5100	77.5905
			2	44.0736	8.8021	10.5100	33.4485
As 2 dan As 5 (A-B)	Sloof	3.1	1	8.9642	0.0861	32.8900	78.5718
			2	8.9642	0.0861	32.8900	-59.5662
	Lantai 1	3.1	1	24.7742	4.0817	49.6500	134.5636
			2	24.7742	4.0817	49.6500	-73.9664
	Lantai 2	3.1	1	24.3781	3.9956	49.7800	134.3303
			2	24.3781	3.9956	49.7800	-74.7457
	Lantai 3	3.1	1	24.3522	3.9869	40.1000	113.9661
			2	24.3522	3.9869	40.1000	-54.4539
	Lantai 4	3.1	1	24.4642	4.0128	26.7400	86.0548
			2	24.4642	4.0128	26.7400	-26.2532
	Ring	3.1	1	11.0050	1.5758	13.3200	41.1819
			2	11.0050	1.5758	13.3200	-14.7621
As 2 dan As 5 (E-G)	Sloof	3.1	1	10.4281	0.3444	31.0000	76.4111
			2	10.4281	0.3444	31.0000	-53.7889
	Lantai 1	3.1	1	28.1583	5.0461	46.9600	133.4807
			2	28.1583	5.0461	46.9600	-63.7513
	Lantai 2	3.1	1	30.2681	5.3819	46.6900	135.4815
			2	30.2681	5.3819	46.6900	-60.6165
	Lantai 3	3.1	1	31.6631	5.5714	36.9400	116.6702
			2	31.6631	5.5714	36.9400	-38.4778
	Lantai 4	3.1	1	33.2131	5.6661	23.4900	90.1521
			2	33.2131	5.6661	23.4900	-8.5059
	Ring	3.1	1	30.2250	2.5144	12.1900	59.9754
			2	30.2250	2.5144	12.1900	8.7774
As 3 dan As 4	Sloof	6.5	1	19.6444	0.1986	22.8400	68.7992
			2	19.6444	0.1986	22.8400	-27.1288
		3.1	1	9.7483	0.6337	42.7600	100.6970
			2	9.7483	0.6337	42.7600	-78.8950
	Lantai 1	6.5	1	122.5521	30.7486	58.8900	284.6347
			2	122.5521	30.7486	58.8900	37.2967
		3.1	1	47.4826	10.1563	48.0600	161.4468
			2	47.4826	10.1563	48.0600	-40.4052
	Lantai 2	6.5	1	119.8708	29.9813	53.5100	269.7157
			2	119.8708	29.9813	53.5100	44.9737
		3.1	1	48.7413	10.2170	42.3800	150.9043
			2	48.7413	10.2170	42.3800	-27.0918
Lantai 3	6.5	1	121.3333	30.3333	40.6200	244.5520	
		2	121.3333	30.3333	40.6200	73.9480	
	3.1	1	50.0174	10.3559	30.4500	127.3369	
		2	50.0174	10.3559	11.9300	38.3389	
Lantai 4	6.5	1	124.3396	31.0917	30.7100	227.6938	
		2	124.3396	31.0917	30.7100	98.7118	

Tabel 8.3 Lanjutan

Portai	Balok	ln (m)	U-jung	V _D (kN)	V _L (kN)	V _E (kN)	V _{u,b} (kN)
[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]
As 3 dan As 4	Lantai 4	3.1	1	53.8628	11.3976	28.0000	127.3234
			2	53.8628	11.3976	28.0000	9.7234
As 4	Atap	3.1	1	31.3628	4.5747	29.9600	100.6504
			2	31.3628	4.5747	29.9600	-25.1816
As A dan As G	Sloof	4.1	1	12.2915	0.1879	23.5500	62.5583
			2	12.2915	0.1879	23.5500	-36.3517
		1.7	1	4.9725	0.0354	39.8133	88.8663
			2	4.9725	0.0354	39.8133	-78.3497
	Lantai 1	4.1	1	38.3777	8.1658	34.2900	120.8797
			2	38.3777	8.1658	34.2900	-23.1383
		1.7	1	12.6083	1.7921	52.7067	125.8044
			2	12.6083	1.7921	52.7067	-95.5636
	Lantai 2	4.1	1	39.2660	8.1231	32.7800	118.5966
			2	39.2660	8.1231	32.7800	-19.0794
		1.7	1	12.7783	1.8700	45.4733	110.8748
			2	12.7783	1.8700	45.4733	-80.1133
	Lantai 3	4.1	1	39.8981	8.2256	26.5400	106.2639
			2	39.8981	8.2256	26.5400	-5.2041
		1.7	1	12.9200	1.9408	31.8667	82.5239
			2	12.9200	1.9408	31.8667	-51.3161
	Lantai 4	4.1	1	40.8377	8.3708	17.6200	88.6710
			2	40.8377	8.3708	17.6200	14.6670
		1.7	1	13.6708	2.2950	14.8733	47.9981
			2	13.6708	2.2950	14.8733	-14.4699
	Atap	4.1	1	45.9883	7.2775	8.7700	74.3461
			2	45.9883	7.2775	8.7700	37.5121
		1.7	1	13.4938	1.1900	0.5600	16.5939
			2	13.4938	1.1900	0.5600	14.2419
As B dan As E	Sloof	4.1	1	12.4367	0.2221	29.3200	59.8910
			2	12.4367	0.2221	29.3100	-38.6075
		1.7	1	4.8946	0.0000	33.7560	60.8215
			2	4.8946	0.0000	33.7560	-52.5986
	Lantai 1	4.1	1	75.4138	19.5433	67.3000	193.6680
			2	76.4138	19.5433	67.3000	-32.4601
		1.7	1	19.9183	3.4000	59.8160	120.0783
			2	19.9183	3.4000	59.8160	-80.9035
	Lantai 2	4.1	1	78.8908	20.2523	59.8800	183.8786
			2	78.8908	20.2523	59.8800	-17.3182
		1.7	1	19.9183	3.4000	50.0440	103.6613
			2	19.9183	3.4000	50.0440	-64.4865
	Lantai 3	4.1	1	80.1977	20.6367	49.1500	167.2729
			2	80.1977	20.6367	49.1500	2.1289
		1.7	1	19.9183	3.4000	34.6520	77.8028
			2	19.9183	3.4000	34.6520	-38.6280
	Lantai 4	4.1	1	80.9750	20.8758	34.7900	144.0019
			2	80.9750	20.8758	34.7900	27.1075
		1.7	1	19.9183	3.4000	16.6680	47.5896
			2	19.9183	3.4000	16.6680	-8.4148
	Ring	4.1	1	53.6160	12.2744	15.6900	81.7072
			2	53.6160	12.2744	15.6900	28.9888
		1.7	1	27.0442	3.4000	2.9000	30.4451
			2	27.0442	3.4000	2.9000	20.7011
As C dan As D	Sloof	8.9	1	26.1994	0.1947	17.2400	51.1342
			2	26.1994	0.1947	17.2400	-6.7922
		1.7	1	4.8946	0.0000	52.4143	92.1675
			2	4.8946	0.0000	52.4143	-83.9446

Tabel 8.3 Lanjutan

Por-tal	Balok	ln (m)	U-ujung	V_D (kN)	V_L (kN)	V_E (kN)	$V_{u,b}$ (kN)
[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]
As C dan As D	Lantai 1	8.9	1	240.3185	67.9367	46.7600	337.4912
			2	240.3185	67.9367	46.7600	180.3776
		1.7	1	19.8900	3.4000	97.8829	184.0068
			2	19.8900	3.4000	97.8829	-144.8796
	Lantai 2	8.9	1	239.2060	67.5844	44.6800	332.7664
			2	239.2060	67.5844	44.6800	182.6416
		1.7	1	19.8900	3.4000	79.6371	153.3540
			2	19.8900	3.4000	79.6371	-114.2268
	Lantai 3	8.9	1	238.6405	67.4268	34.8500	315.6445
			2	238.6405	67.4268	34.8500	198.5485
		1.7	1	19.8900	3.4000	46.2057	97.1892
			2	19.8900	3.4000	46.2057	-58.0620
	Lantai 4	8.9	1	244.0547	69.0121	23.2200	301.9857
			2	244.0547	69.0121	23.2200	223.9665
		1.7	1	19.8900	3.4000	24.7400	61.1268
			2	19.8900	3.4000	24.7400	-21.9996
As F	Sloof	4.1	1	12.4110	0.2477	26.0700	68.0387
			2	12.4110	0.2477	26.0700	-41.4553
		1.7	1	5.6667	0.3967	40.4800	91.3745
			2	5.6667	0.3967	40.4800	-78.6415
	Lantai 1	4.1	1	49.4563	15.0931	33.8700	138.9038
			2	49.4563	15.0931	33.8700	-3.3502
		1.7	1	15.7888	3.6267	53.5867	132.9182
			2	15.7888	3.6267	53.5867	-92.1458
	Lantai 2	4.1	1	50.1652	15.3067	33.3200	138.7175
			2	50.1652	15.3067	33.3200	-1.2265
		1.7	1	16.4688	12.6933	48.9000	133.3102
			2	16.4688	12.6933	48.9000	-72.0698
	Lantai 3	4.1	1	50.5154	15.4006	26.8000	125.4918
			2	50.5154	15.4006	26.8000	12.9318
		1.7	1	16.7025	4.0942	34.9467	95.2245
			2	16.7025	4.0942	34.9467	-51.5515
	Lantai 4	4.1	1	50.8400	15.4519	17.3300	105.9995
			2	51.1817	15.4519	17.3300	33.5722
		1.7	1	16.5538	4.0233	16.9133	57.1239
			2	16.5538	4.0233	16.9133	-13.9121
	Atap	4.1	1	33.9617	6.8760	10.5100	64.9506
			2	33.9617	6.8760	10.5100	20.8086
		1.7	1	9.8388	2.4296	0.4867	13.9038
			2	9.8388	2.4296	0.4867	11.8598

Keterangan Tabel 8.3:

- [1] Portal yang ditinjau
 [2] Balok yang ditinjau
 [3] ln = bentang bersih balok
 [4] Ujung: 1 = ujung balok, 2 = ujung balok yang lain
 [5] V_D = gaya geser balok akibat beban mati
 [6] V_L = gaya geser balok akibat beban hidup
 [7] V_E = gaya geser balok akibat beban gempa
 [8] Untuk ujung 1. $V_{u,b} = 1.05(V_D + V_L + 2.V_E)$
 Untuk ujung 2. $V_{u,b} = 1.05(V_D + V_L - 2.V_E)$

8.1.4 Penulangan Geser Balok

Sebagai contoh perhitungan adalah penulangan geser balok ditinjau pada portal as 1 dan as 6, lantai 1, sebagai berikut ini. (Kusuma, dan Andriano, 1993)

a. Sepanjang dalam daerah d

Tulangan geser dalam daerah $d = 0,6275 \text{ m} \approx 0,6 \text{ m}$ dari muka kolom ke tengah bentang.

$$V_{u,b1} = 288,1140 \text{ kN (pada ujung komponen)}$$

$$V_{u,b2} = 44,4720 \text{ kN (pada ujung komponen yang lain)}$$

$$d = 0,6275 \text{ m}$$

$$\begin{aligned} V_{u,b \text{ terpakai}} &= [(V_{u,b1} + V_{u,b2})/(l_n - d)/l_n] - V_{u,b2} \quad (\text{lihat Gambar 8.4}) \\ &= [(288,1140 + 44,4720) \cdot (6,5 - 0,6275)/6,5] - 44,4720 \\ &= 256,0067 \text{ kN} \end{aligned}$$

$$\frac{1}{2} \cdot V_c = \frac{1}{2} \cdot (1/6 \cdot \sqrt{f_c} \cdot b_w \cdot d) = \frac{1}{2} \cdot (1/6 \cdot \sqrt{24.400} \cdot 627,5) \cdot 10^{-3} = 104,5833 \text{ kN}$$

$$V_s = V_{u,b}/\phi - \frac{1}{2} \cdot V_c = 256,0067/0,6 - 104,5833 = 322,0944 \text{ kN}$$

dipakai sengkang diameter 10 mm, mutu baja $f_y = 240 \text{ MPa}$

$$A_v = \frac{1}{4} \cdot \pi \cdot d^2 = \frac{1}{4} \cdot 3,14 \cdot 10^2 = 78,54 \text{ mm}^2$$

$$S = A_v \cdot f_y \cdot d / V_s$$

$$S = (3 \cdot 78,54 \cdot 240 \cdot 627,5) / (322,0944 \cdot 10^3) = 110,17 \text{ mm}$$

$$S_{\text{terpakai}} = 110 \text{ mm} \leq S_{\text{maks}} \quad d/4 = 156,88 \text{ mm} \quad (\text{SK-SNI,1991})$$

digunakan sengkang **3P-110**

kontrol kuat geser

$$V_{u,b} \leq 0,6 \cdot (1/2 \cdot V_c + V_s)$$

$$256,0067 \text{ kN} \leq 0,6 \cdot (104,5833 + (3 \cdot 78,54 \cdot 240 \cdot 627,5) / 110 \cdot 10^3) = 256,2025 \text{ kN} \text{ --aman--}$$

b. Di luar jarak d

Untuk menghemat tulangan sengkang pada jarak di luar d , dibagi menjadi dua daerah tulangan geser.

Tulangan geser dalam daerah (0,6 m - 2 m) dari muka kolom ke tengah bentang.

$$V_{u,b \text{ terpakai}} = 256,0067 \text{ kN}$$

$$V_c = 1/6 \cdot \sqrt{f_c} \cdot b_w \cdot d = 1/6 \cdot \sqrt{24.400} \cdot 627,5 = 209,1667 \text{ kN}$$

$$V_s = V_{u,b}/\phi - V_c = 256,0067/0,6 - 209,1667 = 217,5111 \text{ kN}$$

$$S = (2 \cdot 78,54 \cdot 240 \cdot 627,5) / (217,5111 \cdot 10^3) = 108,76 \text{ mm}$$

$$S_{\text{terpakai}} = 100 \text{ mm} \leq S_{\text{maks}} = d/2 = 313,75 \text{ mm} \quad (\text{SK-SNI,1991})$$

dipakai sengkang **2P-100**

kontrol kuat geser

$$V_{u,b} \leq 0,6 \cdot (V_c + V_s)$$

$$256,0067 \text{ kN} \leq 0,6 \cdot (209,1667 + (2,78,54 \cdot 240 \cdot 627,5) / 100 \cdot 10^{-3}) = 267,3652 \text{ kN} \text{ -- aman}$$

Tulangan geser dalam daerah (2 m - tengah bentang)/sisa

$$V_{u,b \text{ terpakai}} = [(V_{u,b1} + V_{u,b2}) / (l_n - 2) / l_n] - V_{u,b2} \quad (\text{lihat Gambar 8.4})$$

$$= [(288,1140 + 44,4720) \cdot (6,5 - 2) / 6,5] - 44,4720$$

$$= 185,7798 \text{ kN}$$

$$V_c = 1/6 \cdot \sqrt{f_c} \cdot b_w \cdot d = 1/6 \cdot \sqrt{25} \cdot 400 \cdot 627,5 = 209,1667 \text{ kN}$$

$$V_s = V_{u,b} / \phi - V_c = 185,7798 / 0,6 - 209,1667 = 100,4664 \text{ kN}$$

$$S = (2,78,54 \cdot 240 \cdot 627,5) / (100,4664 \cdot 10^3) = 235,46 \text{ mm}$$

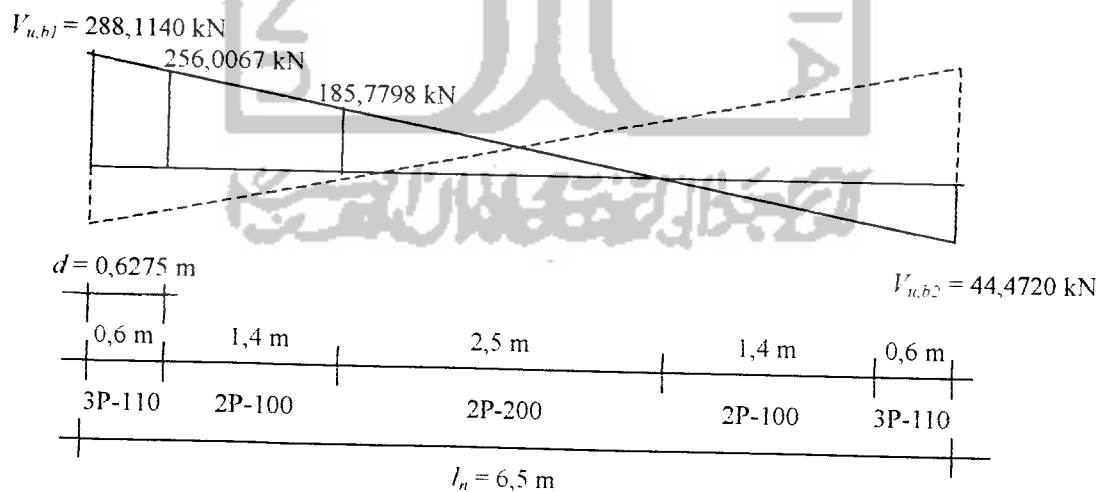
$$S_{\text{terpakai}} = 200 \leq S_{\text{maks}} = d/2 = 313,75 \text{ mm} \quad (\text{SK-SNI,1991})$$

dipakai sengkang **2P-200**

kontrol kuat geser

$$V_{u,b} \leq 0,6 \cdot (V_c + V_s)$$

$$185,7798 \text{ kN} \leq 0,6 \cdot (209,1667 + (2,78,54 \cdot 240 \cdot 627,5) / 200 \cdot 10^{-3}) = 196,4326 \text{ kN} \text{ -- aman}$$



Gambar 8.4 Distribusi gaya dan tulangan geser balok

Dengan cara yang sama didapat penulangan geser balok dari semua balok, disajikan pada Tabel 8.4.

Tabel 8.4.Lanjutan

Por-tal	Ba-lok	l/n	U-jung	V _{u,b}	Lokasi	Jarak	V _{u,b'}	d	b _w	V _c	V _s	S	S _{max}	Tul.ges terpakai	0.6(V _s +V _c) ≥ V _{u,b'}
[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]	[11]	[12]	[13]	[14]	[15]	[16]
As 3 dan As 4	Lt.4	3,1	1	127,3234	Dalam d	0-0,6	90,1114	627,5	400	104,5833	45,6023	518,49	156,88	2P10- 150	157,3268
			2	9,7234	Luar d	sisa	90,1114	627,5	400	209,1667	-58,9810	-400,88	313,75	2P10- 200	196,4326
As 4	A.	3,4	1	100,6504	Dalam d	0-0,6	85,3741	627,5	200	52,2917	89,9984	262,72	156,88	2P10- 150	125,9518
			2	-25,1816	Luar d	sisa	85,3741	627,5	200	104,5833	37,7068	627,05	313,75	2P10- 200	133,6826
As A dan As G	S.	4,1	1	62,5583	Dalam d	0-0,6	59,1674	530,5	400	88,4167	10,1957	1960,56	132,63	2P10- 130	145,3080
			2	-36,3517	Luar d	Sisa	59,1674	530,5	400	176,8333	-78,2210	-255,55	265,25	2P10- 250	139,6819
	1,7	1	88,8663	Dalam d	0-0,6	85,5845	530,5	400	88,4167	54,2242	368,64	132,63	2P10- 130	145,3080	
		2	-78,3497	Luar d	sisa	85,5845	530,5	400	176,8333	-34,1925	-584,61	265,25	2P10- 250	139,6819	
	Lt.1	4,1	1	120,8797	Dalam d	0-0,6	105,9205	627,5	200	52,2917	124,2425	190,31	156,88	2P10- 150	125,9518
			2	-23,1383	Luar d	Sisa	105,9205	627,5	200	104,5833	71,9508	328,62	313,75	2P10- 200	112,4028
	1,7	1	125,8044	Dalam d	0-0,6	114,6420	627,5	200	52,2917	138,7783	170,37	156,88	2P10- 150	125,9518	
		2	-95,5636	Luar d	sisa	114,6420	627,5	200	104,5833	86,4866	273,39	313,75	2P10- 200	112,4028	
	Lt.2	4,1	1	118,5966	Dalam d	0-0,6	103,3656	627,5	200	52,2917	119,9844	197,06	156,88	2P10- 150	125,9518
			2	-19,0794	Luar d	Sisa	103,3656	627,5	200	104,5833	67,6927	349,29	313,75	2P10- 200	112,4028
	1,7	1	110,8748	Dalam d	0-0,6	99,5202	627,5	200	52,2917	113,5753	208,18	156,88	2P10- 150	125,9518	
		2	-80,1133	Luar d	sisa	99,5202	627,5	200	104,5833	61,2836	385,82	313,75	2P10- 200	112,4028	
	Lt.3	4,1	1	106,2639	Dalam d	0-0,6	90,7968	627,5	200	52,2917	99,0364	238,74	156,88	2P10- 150	125,9518
			2	-5,2041	Luar d	Sisa	90,7968	627,5	200	104,5833	46,7447	505,82	313,75	2P10- 200	112,4028
	1,7	1	82,5239	Dalam d	0-0,6	71,0046	627,5	200	52,2917	66,0493	357,98	156,88	2P10- 150	125,9518	
		2	-51,3161	Luar d	sisa	71,0046	627,5	200	104,5833	13,7576	1718,63	313,75	2P10- 200	112,4028	
	Lt.4	4,1	1	88,6710	Dalam d	0-0,6	72,8552	627,5	200	52,2917	69,1337	342,01	156,88	2P10- 150	125,9518
			2	14,6670	Luar d	Sisa	72,8552	627,5	200	104,5833	16,8421	1403,88	313,75	2P10- 200	112,4028
	1,7	1	47,9981	Dalam d	0-0,6	35,6222	627,5	200	52,2917	7,0787	3340,17	156,88	2P10- 150	125,9518	
		2	-14,4699	Luar d	sisa	35,6222	627,5	200	104,5833	-45,2129	-522,95	313,75	2P10- 200	112,4028	
A.	4,1	1	74,3461	Dalam d	0-0,6	57,1445	630,5	200	52,5417	42,6992	556,39	157,63	2P10- 150	126,5540	
		2	37,5121	Luar d	Sisa	57,1445	630,5	200	105,0833	-9,8425	-1689,62	315,25	2P10- 200	134,3217	
1,7	1	16,5939	Dalam d	0-0,6	5,1574	630,5	200	52,5417	-43,9459	-540,60	157,63	2P10- 150	126,5540		
	2	14,2419	Luar d	sisa	5,1574	630,5	200	105,0833	-96,4876	-172,35	315,25	2P10- 200	134,3217		
As B dan As E	S.	4,1	1	59,8910	Dalam d	0-1,2	57,1371	530,5	500	110,5208	-15,2923	-1307,14	132,63	2P10- 130	158,5705
			2	-38,6075	Luar d	sisa	57,1371	530,5	500	221,0417	-125,8131	-158,88	265,25	2P10- 250	180,5992
	1,7	1	60,8215	Dalam d	0-1	58,2555	530,5	500	110,5208	-13,4284	-1488,58	132,63	2P10- 130	158,5705	
		2	-52,5986	Luar d	sisa	58,2555	530,5	500	221,0417	-123,9492	-161,27	265,25	2P10- 250	180,5992	
	Lt.1	4,1	1	193,6680	Dalam d	0-0,6	168,9953	627,5	400	104,5833	177,0755	150,02	156,88	2P10- 150	157,3268
			2	-32,4601	Luar d	Sisa	168,9953	627,5	400	209,1667	72,4922	326,16	313,75	2P10- 200	196,4326
	1,7	1	120,0783	Dalam d	0-0,6	105,6182	627,5	400	104,5833	71,4470	330,93	156,88	2P10- 150	157,3268	
		2	-80,9035	Luar d	sisa	105,6182	627,5	400	209,1667	-33,1364	-713,54	313,75	2P10- 200	196,4326	
	Lt.2	4,1	1	183,8786	Dalam d	0-0,6	158,3867	627,5	400	104,5833	159,3946	155,75	156,88	2P10- 150	157,3268
			2	-17,3182	Luar d	Sisa	158,3867	627,5	400	209,1667	54,8112	431,38	313,75	2P10- 200	196,4326
	1,7	1	103,6613	Dalam d	0-0,6	89,2012	627,5	400	104,5833	44,0853	536,33	156,88	2P10- 150	157,3268	
		2	-64,4865	Luar d	sisa	89,2012	627,5	400	209,1667	-60,4980	-390,83	313,75	2P10- 200	196,4326	
	Lt.3	4,1	1	167,2729	Dalam d	0-0,6	141,3462	627,5	400	104,5833	130,9936	180,50	156,88	2P10- 150	157,3268
			2	2,1289	Luar d	Sisa	141,3462	627,5	400	209,1667	26,4103	895,27	313,75	2P10- 200	196,4326
	1,7	1	77,8028	Dalam d	0-0,6	63,3427	627,5	400	104,5833	0,9878	23935,82	156,88	2P10- 150	157,3268	
		2	-38,6280	Luar d	sisa	63,3427	627,5	400	209,1667	-103,5955	-228,24	313,75	2P10- 200	196,4326	
	Lt.4	4,1	1	144,0019	Dalam d	0-0,6	117,8138	627,5	400	104,5833	91,7730	257,64	156,88	2P10- 150	157,3268
			2	27,1075	Luar d	Sisa	117,8138	627,5	400	209,1667	-12,8103	-1845,72	313,75	2P10- 200	196,4326
	1,7	1	47,5896	Dalam d	0-0,6	33,1295	627,5	400	104,5833	-49,3675	-478,94	156,88	2P10- 150	157,3268	
		2	-8,4148	Luar d	sisa	33,1295	627,5	400	209,1667	-153,9509	-153,58	313,75	2P10- 200	196,4326	
R.	4,1	1	81,7072	Dalam d	0-0,6	64,7653	530,5	500	110,5208	-2,5786	-7751,83	132,63	2P10- 150	146,2695	
		2	28,9888	Luar d	Sisa	64,7653	530,5	500	221,0417	-113,0995	-176,74	265,25	2P10- 250	180,5992	
1,7	1	30,4451	Dalam d	0-0,6	11,5661	530,5	500	110,5208	-91,2439	-219,07	132,63	2P10- 130	158,5705		
	2	20,7011	Luar d	sisa	11,5661	530,5	500	221,0417	-201,7648	-99,07	265,25	2P10- 200	192,5927		
As C dan As D	S.	8,9	1	51,1342	Dalam d	0-0,6	48,0078	530,5	400	88,4167	-8,4036	-2378,65	132,63	2P10- 130	145,3080
			2	-6,7922	Luar d	Sisa	48,0078	530,5	400	176,8333	-96,8203	-206,46	265,25	2P10- 250	154,0742
1,7	1	92,1675	Dalam d	0-0,6	89,1323	530,5	400	88,4167	60,1371	332,39	132,63	2P10- 130	145,3080		
	2	-83,9446	Luar d	Sisa	89,1323	530,5	400	176,8333	-28,2795	-706,84	265,25	2P10- 250	154,0742		
Lt.1	8,9	1	337,4912	Dalam d	0-0,6	300,9785	627,5	400	104,5833	397,0476	119,10	156,88	4P10- 110	320,6867	
		2	180,3776	Luar d	Sisa	300,9785	627,5	400	209,1667	292,4642	121,27	313,75	3P10- 120	302,8315	
1,7	1	184,0068	Dalam d	0-0,6	166,9659	627,5	400	104,5833	173,6931	153,14	156,88	2P10- 150	169,1489		
	2	-144,8796	Luar d	Sisa	166,9659	627,5	400	209,1667	73,4404	321,95	313,75	2P10- 200	196,4326		

Tabel 8.4.Lanjutan

Por-tal	Ba-lok	l_n	U-jung	$V_{u,b}$	Lokasi	Jarak	$V_{u,b}'$	d	bw	V_c	V_s	S	S_{max}	Tul.ges terpakai	$0,6(V_s+V_c)$ $\geq V_{u,b}'$ (kN)	
[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]	[11]	[12]	[13]	[14]	[15]	[16]	
As C dan As D	Lt.2	8,9	1	332,7664	Dalam d	0-0,6	296,4272	627,5	400	104,5833	389,4621	121,42	156,88	4P10- 110	320,6867	
			2	182,6416	Luar d	0,6-2,7	296,4272	627,5	400	209,1667	284,8787	124,50	313,75	3P10- 120	302,8315	
		1,7	1	153,3540	Dalam d	0-0,6	136,3131	627,5	400	104,5833	122,6051	216,95	156,88	2P10- 150	169,1489	
			2	-114,2268	Luar d	Sisa	138,9115	627,5	400	209,1667	22,3524	1057,79	313,75	2P10- 200	196,4326	
		Lt.3	8,9	1	315,6445	Dalam d	0-0,6	279,3910	627,5	400	104,5833	361,0683	130,97	156,88	4P10- 130	281,0042
				2	198,5485	Luar d	0,6-2,7	279,3910	627,5	400	209,1667	256,4850	138,28	313,75	3P10- 130	289,1906
	1,7	1	97,1892	Dalam d	0-0,6	80,1483	627,5	400	104,5833	28,9971	917,32	156,88	2P10- 150	169,1489		
		2	-58,0620	Luar d	Sisa	82,7467	627,5	400	209,1667	-71,2556	-331,82	313,75	2P10- 200	196,4326		
	Lt.4	8,9	1	Dalam d	0-0,6	264,9058	627,5	400	104,5833	336,9263	140,35	156,88	4P10- 130	281,0042		
				Luar d	0,6-2,7	264,9058	627,5	400	209,1667	232,3429	152,65	313,75	3P10- 130	289,1906		
		1,7	1	61,1268	Dalam d	0-0,6	44,0859	627,5	400	104,5833	-31,1069	-855,11	156,88	2P10- 150	169,1489	
			2	-21,9996	Luar d	Sisa	46,6843	627,5	400	209,1667	-131,3596	-180,00	313,75	2P10- 200	196,4326	
As F	S	4,1	1	68,0387	Dalam d	0-0,6	51,2808	530,5	200	44,2083	41,2596	484,47	132,63	2P10- 130	118,7830	
			2	-41,4553	Luar d	sisa	51,2808	530,5	200	88,4167	-2,9487	-6778,99	265,25	2P10- 250	101,0242	
		1,7	1	91,3745	Dalam d	0-0,6	28,6186	530,5	200	44,2083	3,4893	5728,69	132,63	2P10- 130	118,7830	
			2	-78,6415	Luar d	sisa	28,6186	530,5	200	88,4167	-40,7190	-490,91	265,25	2P10- 250	101,0242	
		Lt.1	4,1	1	138,9038	Dalam d	0-0,6	117,1320	627,5	200	52,2917	142,9283	165,43	156,88	2P10- 150	125,9518
				2	-3,3502	Luar d	sisa	117,1320	627,5	200	104,5833	90,6367	260,87	313,75	2P10- 200	133,6826
	1,7	1	132,9182	Dalam d	0-0,6	49,8431	627,5	200	52,2917	30,7802	768,16	156,88	2P10- 150	125,9518		
		2	-92,1458	Luar d	sisa	49,8431	627,5	200	104,5833	-21,5115	-1099,14	313,75	2P10- 200	133,6826		
	Lt.2	4,1	1	Dalam d	0-0,6	117,2992	627,5	200	52,2917	143,2071	165,10	156,88	2P10- 150	125,9518		
				Luar d	sisa	117,2992	627,5	200	104,5833	90,9154	260,07	313,75	2P10- 200	133,6826		
		1,7	1	133,3102	Dalam d	0-0,6	57,5008	627,5	200	52,2917	43,5430	543,01	156,88	2P10- 150	125,9518	
			2	-72,0698	Luar d	sisa	57,5008	627,5	200	104,5833	-8,7486	-2702,62	313,75	2P10- 200	133,6826	
	Lt.3	4,1	1	Dalam d	0-0,6	108,2646	627,5	200	52,2917	128,1494	184,50	156,88	2P10- 150	125,9518		
				Luar d	sisa	108,2646	627,5	200	104,5833	75,8577	311,69	313,75	2P10- 200	133,6826		
		1,7	1	95,2245	Dalam d	0-0,6	41,0469	627,5	200	52,2917	16,1198	1466,78	156,88	2P10- 150	125,9518	
			2	-51,5515	Luar d	sisa	41,0469	627,5	200	104,5833	-36,1719	-653,66	313,75	2P10- 200	133,6826	
	Lt.4	4,1	1	Dalam d	0-0,6	94,9146	627,5	200	52,2917	105,8993	223,27	156,88	2P10- 150	125,9518		
				Luar d	sisa	94,9146	627,5	200	104,5833	53,6077	441,06	313,75	2P10- 200	133,6826		
		1,7	1	57,1239	Dalam d	0-0,6	30,9033	627,5	200	52,2917	-0,7862	-30073	156,88	2P10- 150	125,9518	
			2	-13,9121	Luar d	sisa	30,9033	627,5	200	104,5833	-53,0779	-445,46	313,75	2P10- 200	133,6826	
	A	4,1	1	Dalam d	0-0,6	58,1947	627,5	200	52,2917	44,6995	528,96	156,88	2P10- 150	125,9518		
				Luar d	sisa	58,1947	627,5	200	104,5833	-7,5921	-3114,30	313,75	2P10- 200	133,6826		
		1,7	1	13,9038	Dalam d	0-0,6	13,1493	627,5	200	52,2917	-30,3761	-778,38	156,88	2P10- 150	125,9518	
			2	11,8598	Luar d	sisa	13,1493	627,5	200	104,5833	-82,6678	-286,01	313,75	2P10- 200	133,6826	

Keterangan Tabel 8.4:

- [1] Portal yang ditinjau
 [2] Balok: Sloof, Lantai 1 s/d 4, dan Atap/Ring
 [3] l_n = jarak bentang bersih balok
 [4] Ujung: 1 = ujung balok, 2 = ujung balok yang lain
 [5] $V_{u,b}$ = gaya geser rencana balok dari Tabel 8.3
 [6] Lokasi tulangan geser: Dalam d atau Luar d
 [7] Jarak penulangan dari ujung ke tengah bentang balok
 [8] $V_{u,b}'$ = gaya geser terpakai disesuaikan lokasi tulangan
 [9] d = tinggi efektif balok
 [10] bw = lebar badan balok
 [11] $V_c = 1/2(1/6 \cdot f_c^{0,5} \cdot d \cdot bw)$ (untuk dalam d)
 $V_c = 1/6 \cdot f_c^{0,5} \cdot d \cdot bw$ (untuk luar d)
 [12] $V_s = V_{u,b}'/0,6 - V_c$
 [13] $S = (A_v \cdot f_y \cdot d)/V_s$, diameter: 10 mm (P10)
 jika $S > S_{max}$ dipakai S_{max}
 [14] $S_{max} = d/4$ (pada dalam d)
 $= d/2$ (luar d)
 [15] Tulangan geser terpakai
 [16] $0,6(V_c+V_s) \geq V_{u,b}$
 $V_s = (A_v \cdot f_y \cdot d)/S_{terpakai}$
 $f_y = 240 \text{ MPa}$, $f_c' = 25 \text{ MPa}$

8.2 Desain Kolom

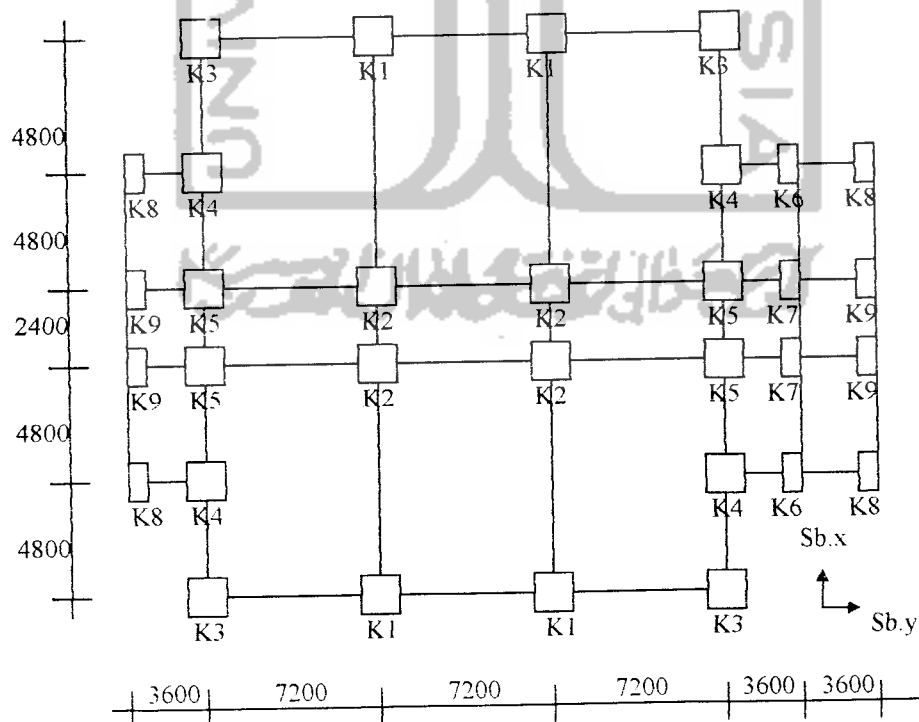
Kolom yang akan didesain telah ditentukan terlebih dahulu letak pada denah portal dan ukuran dimensinya. Kolom-kolom yang didesain adalah sebagai berikut ini:

- K1, K2, K3, K4, K5, dan, K6 dengan dimensi 700 mm x 700 mm
- K7, K8, dan K9 dengan dimensi 250 mm x 700 mm

Letak kolom-kolom yang dimaksud diatas dapat dilihat pada Gambar 8.5

Desain kolom pada pembahasan ini meliputi.

1. Momen rencana kolom
2. Gaya aksial rencana kolom
3. Perhitungan diagram interaksi kolom
4. Cek kelangsingan kolom dan faktor pembesaran momen
5. Penulangan lentur dan aksial kolom
6. Gaya geser rencana kolom
7. Penulangan geser kolom



Gambar 8.5 Denah rencana kolom lantai 1 s/d lantai 5 (Skala 1 : 280)

8.2.1 Momen Rencana Kolom

Momen rencana kolom dengan daktilitas terbatas yang ditentukan dengan rumus sebagai berikut (Kusuma dan Andriono, 1993):

$$M_{u,k \max} = 1,05 \cdot [M_{D,k,x} + M_{L,x} + \omega_d \cdot K \cdot (M_{E,k,x} + 0,3M_{E,k,y})]$$

Sebagai contoh perhitungan ditinjau pada momen kolom atas K2 lantai 1 (sejajar sumbu x)

diketahui:

$\omega_d = 1$ untuk kolom lantai 1 dan lantai paling atas

$\omega_d = 1,3$ untuk kolom lantai 2,3,4

$M_{D,k-x \text{ atas}} = 111,7600 \text{ kNm}$

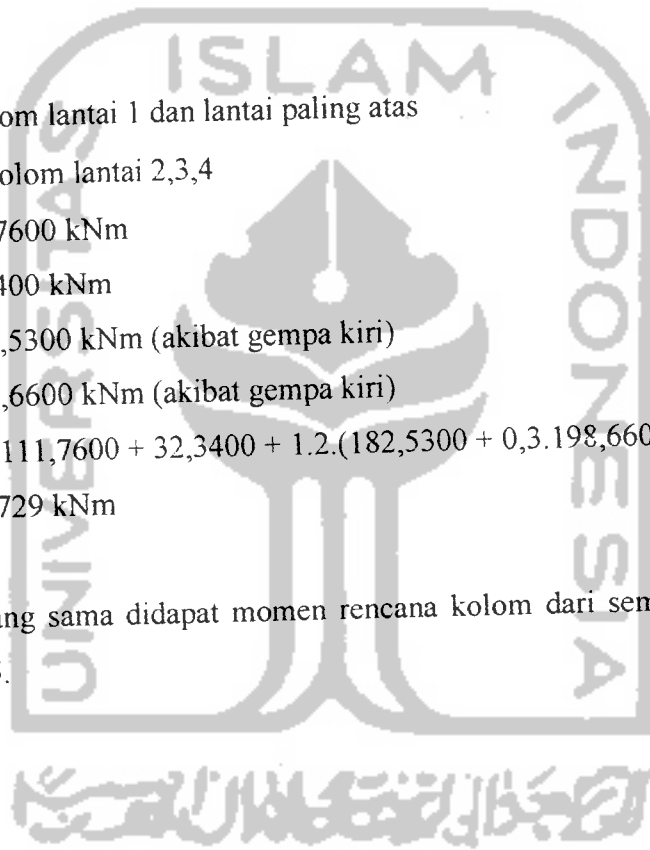
$M_{L,k-x \text{ atas}} = 32,3400 \text{ kNm}$

$M_{Eki,k-x \text{ atas}} = 182,5300 \text{ kNm}$ (akibat gempa kiri)

$M_{Eki,k-y \text{ atas}} = 198,6600 \text{ kNm}$ (akibat gempa kiri)

$M_{u,k \text{ atas}} = 1,05 [111,7600 + 32,3400 + 1,2 \cdot (182,5300 + 0,3 \cdot 198,6600)]$
 $= 593,6729 \text{ kNm}$

Dengan cara yang sama didapat momen rencana kolom dari semua kolom disajikan pada Tabel .8.5.



Tabel 8.5 Momen Rencana Kolom Daktilitas Terbatas (Satuan: kNm)

Ko- lom	Letak Momen	Sejajar Sumbu x					Sejajar Sumbu y					Akibat Gempa kiri			Akibat Gempa kanan		
		MD,k-x	ML,k-x	MEki,k-x	MEta,k-x	MD,k-y	ML,k-y	MEki,k-y	MEta,k-y	Mu,k-x1	[12]	[13]	Mu,k-x2	[14]	[15]		
K1	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]	[11]	[12]	[13]	[14]	[15]			
	1	Atas	-139,8500	-40,1100	72,9200	-71,1800	-0,5200	-0,4800	187,0200	-186,1700	81,9966	437,6316	-455,7231	-436,8504			
		Bawah	42,6500	8,5700	-139,9100	136,9500	0,4700	0,3900	-225,8100	224,8200	-382,2903	-533,3241	493,7434	531,3835			
	2	Atas	-172,0400	-50,6500	88,2100	-87,7300	-0,4800	-0,0300	213,9600	-213,4000	86,2113	554,8416	-536,5658	-503,9454			
		Bawah	191,2100	56,9900	-70,1700	70,4000	1,0100	0,8300	-205,8900	205,4400	-16,4577	-474,6441	537,8772	477,7080			
K2	3	Atas	-154,2200	-45,3100	87,3400	-86,8000	-4,3400	-1,9100	191,0300	-190,6300	94,2564	495,2434	-527,0022	-461,5695			
		Bawah	167,3300	49,1200	-45,5800	44,9400	3,2300	1,7400	-157,6300	157,2400	32,2476	-354,5199	420,7077	363,7347			
	4	Atas	-300,4400	-88,3000	67,6300	-66,6600	-1,1800	-1,3900	146,8800	-147,6300	-173,6196	348,3564	-547,9727	-381,1187			
		Bawah	190,3200	55,9300	-16,9600	16,3100	1,1100	1,3000	-105,9600	105,6400	156,1917	-230,6703	359,3667	234,6498			
	5	Atas	-300,4400	-88,3000	-67,6300	-66,6600	-7,8700	-2,5700	73,0800	-70,2700	-504,1596	99,8991	-555,5819	-210,0029			
	Bawah	190,3200	55,9300	-16,9600	16,6600	5,7800	1,2200	-60,1100	55,9400	185,0772	-129,5658	328,7907	135,3198				
K3	1	Atas	111,7600	32,3400	182,5300	-181,9900	1,4100	0,4200	198,6600	-197,1400	593,6729	355,3600	-291,7751	-460,6452			
		Bawah	-44,6700	-10,4000	-212,4700	211,9600	-1,0900	-0,3400	-239,8800	237,9200	-580,4710	-503,4646	462,8064	552,5195			
	2	Atas	147,8900	44,1500	195,1300	-194,7400	2,1900	0,6200	225,2400	-222,3600	584,6278	524,3944	-278,7687	-512,9864			
		Bawah	-157,6500	-47,4200	-192,7600	192,3700	-3,3200	-0,9300	-210,2300	208,4400	-587,3415	-497,0191	253,0589	484,5900			
	3	Atas	123,3800	36,7000	155,4800	-155,4800	1,6400	0,5900	188,2700	-193,3000	557,5623	329,8369	-224,1671	-438,5556			
	Bawah	-131,9100	-39,1600	-128,8300	128,8300	-0,1400	-0,1000	-150,4000	150,9000	-499,2566	-347,6295	140,2853	348,0443				
4	Atas	224,3600	66,7300	-92,3600	-92,3600	7,1500	1,8800	169,8200	-149,6800	229,5463	205,6653	53,4219	-316,4690				
	Bawah	-166,5800	-49,5800	58,4900	58,4900	-4,6300	-1,1700	-100,5600	89,8000	-174,9263	-158,6264	-69,9904	191,1601				
K4	1	Atas	-28,2900	-6,0400	91,0200	-88,5300	-57,4300	-29,8200	107,7700	-106,1100	211,8411	182,4447	-274,3684	-351,7065			
		Bawah	11,9200	1,8000	-124,3000	120,8600	22,5100	6,9100	-179,0600	176,4700	-341,4602	-402,2718	360,4187	453,7388			
	2	Atas	-38,0500	-8,7200	90,5600	-89,4300	-70,9800	-38,6300	108,3800	-123,0400	272,5393	242,2078	-374,3211	-465,5453			
		Bawah	38,5700	8,7700	-78,7500	78,1700	76,3500	42,4900	-123,6200	108,3300	-253,1990	-263,3370	334,2417	460,3169			
	3	Atas	-41,4000	-9,7900	81,8400	-80,7400	-71,5500	-38,9100	116,8800	-115,7800	252,1285	256,6200	-350,5438	-442,4165			
	Bawah	40,3500	9,4600	-60,0100	58,8000	71,1300	38,7000	-77,0100	76,3600	-165,8681	-136,8608	261,5952	353,3444				
4	Atas	-45,5400	-10,7600	65,8100	-63,4600	-77,7400	-44,3000	88,2700	-92,9900	183,1975	158,3968	-293,0936	-412,2795				
	Bawah	43,3500	10,2400	-35,0500	33,7400	73,5300	-39,9700	-42,3900	42,6400	-70,4277	-103,7330	174,1368	170,3143				
5	Atas	-40,3300	-9,7000	27,1600	-27,3200	-70,2400	-18,7000	39,2300	-35,6000	27,7584	5,8015	-125,7149	-176,0907				
	Bawah	41,3000	9,8800	-6,5300	7,7800	66,8400	32,4700	-23,2400	14,1000	24,1156	48,7897	75,0120	131,8476				
K4	1	Atas	-7,3600	-3,3600	151,9400	-149,8500	-11,9500	-2,0100	41,0600	-40,8600	333,6648	167,2902	-351,7038	-194,8695			
		Bawah	2,2800	1,0300	-162,7800	160,5300	2,8400	0,1700	-173,1700	172,7000	-447,4596	-463,0479	449,3895	466,9644			
	2	Atas	-10,2200	-4,6700	158,9800	-157,5600	-14,1000	-2,4000	82,7800	-82,6900	447,5768	338,8690	-475,1993	-372,1103			
		Bawah	10,1100	4,7700	-152,2200	150,9200	10,4400	1,8700	-84,5400	84,5200	-431,8826	-342,5369	459,8395	367,2686			
	3	Atas	-12,1500	-5,1300	139,7700	-138,3900	-15,4200	-2,5400	88,2200	-88,1200	400,7707	336,4542	-433,5055	-327,7670			
	Bawah	11,6900	5,0000	-121,8100	120,4500	12,4200	2,1400	-41,7200	41,6400	-320,9770	-198,3700	352,5383	372,6138				
4	Atas	-12,6900	-5,6400	106,8500	-105,0800	-15,7700	-2,6300	77,3300	-76,9300	308,4770	279,3011	-342,2072	-315,3994				
	Bawah	12,4100	5,3300	-83,5900	82,2200	13,8000	2,3800	-10,4600	10,3900	-199,9276	-80,0270	233,6762	112,6919				
5	Atas	-16,2900	-4,1600	59,6400	-59,6400	-26,3600	-2,7900	35,0500	-35,2000	125,8530	80,5707	-124,6455	5,7078				
	Bawah	12,7300	4,7300	-40,9600	41,4000	15,4100	2,4500	-14,4000	13,9800	-76,7550	-37,2918	114,0804	74,1930				

Tabel 8.5 Lanjutan

Ko- lom	Lan- tai	Letak Momen	Sejajar Sumbu x					Sejajar Sumbu y					Akibat Gempa kiri			Akibat Gempa kanan		
			MD,k-x	ML,k-x	MEk,k-x	MEk,k-y	MEk,k-x	MD,k-y	ML,k-y	MEk,k-y	MEk,k-x	Mu,k-x1	Mu,k-y1	Mu,k-x2	Mu,k-y2	[14]	[15]	
[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]	[11]	[12]	[13]	[14]	[15]				
K5	1	Atas	23,8700	6,8100	165,0600	-164,5500	-51,3400	-13,9700	169,6900	-166,6200	437,1702	352,5852	-376,4804	-469,9296				
		Bawah	-10,5800	-2,3900	-176,1000	175,5900	19,4600	3,8400	-241,4700	236,7900	-481,9991	-534,2085	453,8684	569,1111				
	2	Atas	32,9900	9,7700	166,7100	-166,3100	-64,6500	-19,5300	179,4300	-178,9100	498,9088	397,4619	-416,9365	-524,3853				
		Bawah	-33,8800	-10,1200	-162,3700	161,9800	68,3200	18,3100	-159,5400	159,0900	-478,6523	-351,0885	394,4009	513,6404				
	3	Atas	33,7700	9,9000	141,0600	-140,6700	-64,0800	-18,1200	165,1400	-157,9200	461,8369	353,6262	-349,6795	-510,1882				
K6	1	Atas	-18,6200	-5,3300	37,6500	-37,3200	-0,0600	-0,0300	33,5800	-33,5800	75,0729	75,3144	-124,6749	-75,2993				
		Bawah	9,7400	1,9800	-77,7600	77,2200	0,2100	0,0600	-32,9200	32,9200	-171,7296	-94,2698	187,3993	92,0900				
	2	Atas	-22,9800	-6,9800	49,6100	-49,6100	-0,1800	-0,0700	40,3700	-40,3700	98,3031	92,6503	-161,0721	-93,0350				
		Bawah	24,8300	7,8000	-47,7600	47,8000	0,3500	0,0800	-40,6400	40,6400	-91,6377	-91,9850	160,2447	92,7276				
	3	Atas	-23,3700	-6,9700	47,4200	-47,3200	-0,4100	-0,0900	35,4700	-35,4700	90,0711	83,0893	-153,5751	-83,8569				
K7	1	Atas	12,4000	4,0300	79,8700	-79,7400	-1,0300	-0,1800	34,3300	-35,1800	196,2761	84,7984	-172,3659	-94,0385				
		Bawah	-5,8300	-1,3100	-111,3700	111,2100	0,4600	0,0300	-34,3700	35,2700	-189,3795	-99,2779	248,2641	98,3578				
	2	Atas	15,1800	5,2900	93,1000	-93,0400	-1,5000	-0,2800	34,8300	-35,3000	172,0414	90,9489	-196,1295	-94,2299				
		Bawah	-15,8900	-5,4600	-93,8000	93,7400	1,6000	0,3300	-34,9600	35,4600	-176,2383	-91,3385	196,7763	97,5951				
	3	Atas	14,4200	4,9800	80,5900	-80,5300	-1,0200	-0,1100	28,7100	-28,5500	166,1570	76,9133	-166,7295	-87,2628				
K8	1	Atas	-14,6300	-3,1000	41,2400	-40,8100	-8,1900	-1,3200	40,2600	-40,5300	93,3513	65,3521	-129,8514	-72,4853				
		Bawah	8,1900	1,1700	-54,4100	53,8300	6,0700	0,7800	-59,9800	60,3100	-142,2204	-99,4785	160,8663	95,6211				
	2	Atas	-18,5600	-4,1700	45,0800	-44,9100	-11,7000	-2,0300	52,8500	-52,9200	104,0970	81,2298	-151,5171	-92,3051				
		Bawah	19,0300	4,3800	-43,3200	43,2300	11,9200	2,1000	-53,5100	53,5400	-100,1028	-81,2120	149,0937	92,6339				
	3	Atas	-19,2500	-4,1400	40,3900	-40,2400	-13,3700	-2,2400	49,0800	-49,1500	91,1799	72,8801	-140,0280	-94,2219				
K8	4	Atas	18,6800	4,0500	-35,1100	34,9200	13,2600	2,2300	-42,0400	42,1300	-76,3497	-61,1902	123,7404	82,3791				
		Bawah	-18,5000	-4,3400	31,5200	-31,0600	-13,6600	-2,3900	37,3700	-37,6400	65,7531	52,9634	-112,9212	-75,0518				
	4	Atas	19,1900	4,2200	-24,1100	23,8500	14,3500	2,4000	-27,5100	27,6800	-43,3818	-35,9923	92,1039	58,9817				
		Bawah	-19,1900	-4,2200	24,1100	-23,8500	-14,3500	-2,4000	27,5100	-27,6800	43,3818	35,9923	-92,1039	-58,9817				

Tabel 8.5 Lanjutan

Ko- lom	Lan- tai	Sejajar Sumbu x			Sejajar Sumbu y			Akibat Gempa kiri		Akibat Gempa kanan			
		MD,k-x	MEki,k-x	MEka,k-x	MD,k-y	MEki,k-y	MEka,k-y	Mu,k-x1	Mu,k-y1	Mu,k-x2	Mu,k-y2		
[1]	[2]	[4]	[5]	[6]	[7]	[8]	[9]	[10]	[11]	[12]	[13]	[14]	[15]
K8	5 Atas	-28,8000	-3,4200	19,1100	-19,4400	-21,9200	-2,5200	24,3500	-24,1400	21,6405	31,8855	-89,8632	-70,8826
	Bawah	22,4100	3,9300	-10,7600	11,2400	17,8100	2,4600	-14,3000	14,0100	-3,9480	-16,3016	63,0917	60,6750
K9	1 Atas	-9,5600	-2,4300	85,7100	-85,7100	5,5900	1,1100	23,7500	-24,9700	140,4203	75,4170	-160,3999	-67,5915
	Bawah	4,7800	0,7700	-106,4900	106,4900	-3,3800	-0,5600	-25,1300	26,4000	-179,8977	-84,3191	189,4881	80,5064
	2 Atas	-11,0700	-3,1400	89,9300	-89,9300	7,8000	1,6100	24,2100	-25,0800	145,6723	79,8166	-169,0719	-67,6215
	Bawah	12,1800	3,4200	-89,2400	89,2400	-7,5800	-1,5800	-23,8300	24,6300	-143,2484	-78,7999	168,8617	66,8618
	3 Atas	-10,2100	-2,9500	76,0500	-76,0500	8,8300	1,8300	20,3800	-21,1200	122,2193	69,2937	-143,8580	-55,1279
	Bawah	10,0100	2,8600	-69,1200	69,1200	-8,5900	1,7900	-19,5100	20,2000	-110,8259	-62,3265	131,9715	53,6014
	4 Atas	-7,5500	-2,6400	54,6700	-54,6700	9,2600	1,9200	14,1500	-14,6800	113,0220	56,9221	-134,7549	-40,1483
	Bawah	8,9100	2,7800	-44,2500	44,2500	-8,9200	-1,8200	-12,8300	14,3000	-88,7334	-52,2170	114,2085	36,8381
	5 Atas	-20,3000	-4,6000	23,4900	-23,4900	7,4800	0,9200	4,5100	-17,6000	32,5316	49,6346	-103,8744	-42,9387
	Bawah	12,9700	3,5200	-14,3600	14,3600	-7,7100	-1,1100	-3,4900	16,8500	-21,0563	-38,4552	81,3204	38,6879

Keterangan Tabel 8.5:

- [1] Kolom yang ditinjau
- [2] Tingkat lantai tiap kolom yang ditinjau
- [3] Letak momen pada bagian atas dan bawah kolom
- [4] $M_{D,k-x}$ = Momen kolom akibat beban mati sejajar sb-x
- [5] $M_{L,k-x}$ = Momen kolom akibat beban hidup sejajar sb-x
- [6] $M_{Eki,k-x}$ = Momen kolom akibat beban gempa kiri sejajar sb-x
- [7] $M_{Eka,k-x}$ = Momen kolom akibat beban gempa kanan sejajar sb-x
- [8] $M_{D,k-y}$ = Momen kolom akibat beban mati sejajar sb-y
- [9] $M_{L,k-y}$ = Momen kolom akibat beban hidup sejajar sb-y
- [10] $M_{Eki,k-y}$ = Momen kolom akibat beban gempa kiri sejajar sb-y
- [11] $M_{Eka,k-y}$ = Momen kolom akibat beban gempa kanan sejajar sb-y
- [12] $M_{u,k-x1} = 1,05(M_{D,k-x} + M_{L,k-x} + \omega_d \cdot k)(M_{Eki,k-x} - 0,3M_{Eka,k-x})$
(Momen maksimum kolom sejar sb-x, akibat gempa kiri) dengan $k = 1$
- [13] $M_{u,k-y1} = 1,05(M_{D,k-y} + M_{L,k-y} + \omega_d \cdot k)(M_{Eki,k-y} - 0,3M_{Eka,k-y})$
(Momen maksimum kolom sejar sb-y, akibat gempa kiri) dengan $k = 1$
- [14] $M_{u,k-x2} = 1,05(M_{D,k-x} + M_{L,k-x} + \omega_d \cdot k)(M_{Eka,k-x} - 0,3M_{Eki,k-x})$
(Momen maksimum kolom sejar sb-x, akibat gempa kanan) dengan $k = 1$
- [15] $M_{u,k-y2} = 1,05(M_{D,k-y} + M_{L,k-y} + \omega_d \cdot k)(M_{Eka,k-y} - 0,3M_{Eki,k-y})$
(Momen maksimum kolom sejar sb-y, akibat gempa kanan) dengan $k = 1$
dengan $k = 2, \omega_d = 1$ (untuk lantai 1 dan 5), $\omega_d = 1,3$ (untuk lantai 2,3, dan 4)

8.2.2. Gaya Aksial Rencana Kolom

Gaya aksial rencana $N_{u,k}$ yang bekerja pada kolom portal dengan daktilitas penuh dihitung dengan rumus sebagai berikut, untuk gaya gravitasi dijumlah dengan arah tegak lurus nya, namun untuk gaya gempa arah tegak lurus nya hanya diambil 30 % saja. (Kusuma dan Andriono, 1993)

$$N_{u,k,max} = 1,05 (N_{g,k,x} + N_{g,k,y} + \omega_d K.(N_{E,k,x} + N_{E,k,y})$$

dengan:

$$N_{g,k} = N_{D,k} + N_{L,k} \text{ (sesuai arah } x \text{ dan arah } y)$$

Sebagai contoh perhitungan ditinjau pada kolom K2 lantai 1

diketahui:

$\omega_d = 1$ untuk kolom lantai 1 dan lantai paling atas

$\omega_d = 1,3$ untuk kolom lantai 2,3,4

Gaya aksial

Berat kolom = 197,57 kN

$$N_{D,k,x} = 1150,2200 \text{ kN}, N_{L,k,x} = 312,5500 \text{ kN}$$

$$N_{g,k,x} = 1150,2200 + 312,5500 = 1462,7700 \text{ kN}$$

$$N_{D,k,y} = 1072,9700 \text{ kN}, N_{L,k,y} = 268,5900 \text{ kN}$$

$$N_{g,k,y} = 1072,9700 + 268,5900 = 1341,5600 \text{ kN}$$

$$N_{Eka,k,x} = 671,1900 \text{ kN}$$

$$N_{Eka,k,y} = 5,8100 \text{ kN}$$

$$\begin{aligned} N_{u,k,x} &= 1,05.(Berat kolom + N_{g,k,x} + N_{g,k,y} + \omega_d K.(N_{E,k,x} + 0,3.N_{E,k,y})) \\ &= 1,05.[1462,7700 + 1341,5600 + 1,2.(671,1900 + 0,3.5,8100)] \\ &= 4557,8337 \text{ kN} \end{aligned}$$

Dengan cara yang sama didapat gaya aksial rencana kolom dari semua kolom, yang disajikan pada Tabel 8.6.

Tabel 8.6 Gaya Aksial Rencana Kolom Daktilitas Terbatas (Satuan kN)

Ko- lom	Lantai	Berat Kolom	Sejajar Sumbu x					Sejajar Sumbu y					Akibat Gempa Kiri			Akibat Gempa Kanan		
			N _{D,k-x}	N _{L,k-x}	N _{Eki,k-x}	N _{Eka,k-x}	N _{D,k-y}	N _{L,k-y}	N _{Eki,k-y}	N _{Eka,k-y}	N _{u,k-x1}	N _{u,k-y1}	N _{u,k-x2}	N _{u,k-y2}				
[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]	[11]	[12]	[13]	[14]	[15]				
K1	1	-242,2600	-1020,3000	-287,9400	150,2200	-148,9600	-1028,4300	-534,7300	-11,8300	9,1200	-2961,3339	-3199,5474	-3576,4134	-3344,0358				
	2	-178,7500	-764,9700	-215,8900	103,0600	-102,2000	-806,8000	-408,8700	-6,9500	4,6300	-2218,3823	-2428,6114	-2769,2580	-2565,1059				
	3	-143,0600	-508,4400	-143,4700	58,3800	-57,8200	-587,1600	-284,1600	-3,6800	1,6400	-1593,2410	-1711,8377	-1906,1099	-1792,4819				
	4	-89,3800	-251,3000	-70,8900	23,2200	-22,9700	-368,5400	-159,8900	-1,6800	-0,1600	-924,9853	-972,5692	-1049,8391	-1006,2492				
	5	-44,6900	-251,3000	-70,8900	23,2200	-22,9700	-149,7800	-35,2500	-0,4100	-0,4200	-531,0018	-565,7379	-628,0071	-594,8586				
K2	1	-197,5700	-1150,2200	-312,5500	669,9300	-671,1900	-1072,9700	-268,5900	-16,6200	5,8100	-1755,6128	-2764,8411	-4557,8337	-3562,6437				
	2	-134,0600	-862,9200	-234,4700	374,5000	-375,3600	-804,3300	-201,3000	-13,3300	3,2300	-1337,4663	-2078,6094	-3371,0214	-2647,5359				
	3	-89,3800	-576,8200	-156,7700	140,4500	-141,0100	-536,8900	-134,3900	-11,0400	1,5100	-1194,5758	-1484,0732	-1952,6831	-1680,3274				
	4	-44,6900	-291,3300	-79,2400	13,8900	-14,1400	-269,9200	-67,6400	-10,0700	0,6900	-760,7888	-806,5762	-828,4981	-800,1580				
K3	1	-242,2600	-352,9900	-69,2400	212,4900	-209,3600	-501,6400	-261,5600	195,3800	-192,6800	-929,7561	-954,9078	-2060,1189	-2035,5993				
	2	-178,7500	-281,4300	-55,7900	145,1900	-143,1700	-393,9100	-200,6000	137,3700	-135,0600	-657,1293	-672,0733	-1667,4722	-1651,9740				
	3	-143,0600	-205,1300	-40,9300	85,3200	-84,1300	-284,2200	-138,4800	83,3100	-81,2700	-551,2565	-555,0976	-1148,6460	-1143,1806				
	4	-89,3800	-126,1200	-25,2700	39,0300	-38,7100	-173,7400	-75,9300	40,4000	-38,5600	-375,3225	-372,7044	-652,2209	-651,9343				
	5	-44,6900	-46,0200	-9,3400	10,4500	-10,5100	-63,0500	-13,7500	10,5100	-9,6800	-157,1262	-157,0380	-213,8619	-212,6418				
K4	1	-242,2600	-912,4900	-234,6000	9,0200	-10,8300	-178,6500	-28,1200	166,2100	-166,0700	-1552,2717	-1321,2024	-1803,2931	-2031,4959				
	2	-178,7500	-701,0800	-179,4600	14,0700	-15,1800	-145,9500	-22,2600	119,2400	-119,1900	-1152,8063	-951,8265	-1427,9330	-1626,6961				
	3	-143,0600	-497,2900	-126,5700	14,3100	-14,9300	-110,8000	-16,0100	72,5500	-72,5600	-839,9318	-728,6351	-1038,6020	-1148,7330				
	4	-89,3800	-297,7600	-74,9100	11,4500	-11,5500	-74,0400	-9,5400	35,6100	-35,6800	-512,4884	-466,3187	-633,6649	-679,7774				
	5	-44,6900	-100,2300	-23,8100	5,2300	-5,1500	-36,0600	-2,9600	12,1300	-12,1900	-199,5126	-189,3696	-236,6322	-246,9810				
K5	1	-242,2600	-583,9300	-138,7100	188,6900	-190,0000	-775,7400	-179,7600	7,6600	-33,2800	-1615,3452	-1881,4593	-2436,3864	-2206,0080				
	2	-178,7500	-466,3500	-111,0300	101,4000	-102,3200	-589,8500	-135,8800	-3,0700	-23,1900	-1281,6453	-1481,2875	-1854,2792	-1703,0618				
	3	-143,0600	-345,8800	-82,5200	35,9100	-36,4800	-404,7600	-92,2200	-15,1700	-12,5100	-1036,2519	-1133,8658	-1231,6981	-1185,8914				
	4	-89,3800	-223,8700	-53,5700	-1,5600	1,3400	-219,9800	-48,6700	-27,2500	-2,8500	-693,8201	-742,9136	-665,9195	-673,9265				
	5	-44,6900	-100,9500	-24,3300	-8,4300	8,4100	-33,9300	-4,6700	-29,9600	4,3500	-255,5763	-287,2254	-198,5970	-204,5652				
K6	1	-86,5200	-289,5800	-80,0500	147,8900	-147,5100	-251,0700	-37,7100	46,1700	45,7600	-500,6946	-785,9628	-1063,1187	-779,0118				
	2	-63,8400	-217,1500	-62,0900	87,9500	-87,7300	-180,6800	-27,7300	26,4900	26,3900	-360,6563	-579,3512	-796,9540	-578,8707				
	3	-47,8800	-158,4200	-44,1700	54,6300	-54,4700	-132,8300	-18,5900	15,2200	15,2400	-285,3098	-418,7931	-558,2060	-424,9902				
	4	-31,9200	-99,2800	-26,1400	27,8400	-27,7300	-88,3200	-9,9200	-7,1100	7,2800	-198,1789	-264,9683	-338,0396	-271,1955				
	5	-15,9600	-39,7600	-8,0500	10,5100	-10,4600	-46,8500	-1,4700	-3,4200	3,5700	-97,7781	-118,2552	-137,4114	-116,7873				

Tabel 8.6. Lanjutan

Ko- lom	Lantai	Berat Kolom	Sejajar Sumbu x			Sejajar Sumbu y			Akibat Gempa Kiri		Akibat Gempa Kanan			
			$N_{D,k-x}$	$N_{L,k-x}$	$N_{Eka,k-x}$	$N_{D,k-y}$	$N_{L,k-y}$	$N_{Eki,k-y}$	$N_{u,k-x1}$	$N_{u,k-y1}$	$N_{u,k-x2}$	$N_{u,k-y2}$		
[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]	[11]	[12]	[13]	[14]	[15]
K7	1	-86,5200	-350,9500	-92,3100	110,0700	-110,3900	-385,7900	-78,2300	-67,3700	84,4700	-854,7861	-1115,6229	-1222,0929	-935,6487
	2	-63,8400	-272,8000	-70,3900	63,5600	-63,7900	-296,7100	-59,2800	-42,6000	60,7800	-662,5416	-865,4134	-925,5389	-687,4856
	3	-47,8800	-196,4500	-49,2200	23,5200	-23,6900	-211,0700	-40,7700	-21,4800	41,3800	-526,0420	-612,0370	-603,4430	-479,0942
	4	-31,9200	-120,8200	-28,3400	-2,1000	2,0000	-128,0700	-22,6200	-6,3100	30,1900	-359,2594	-367,3047	-318,1729	-264,3018
	5	-15,9600	-45,3700	-7,4100	-10,1400	10,0900	-49,9900	-5,5800	-1,1800	20,8000	-152,5629	-139,3917	-96,2325	-80,4888
K8	1	-86,5200	-226,9100	-41,3900	119,9000	-119,5900	-177,6600	-27,9300	-127,3400	127,5100	-416,8647	-780,3075	-759,2382	-396,0012
	2	-63,8400	-182,3900	-32,2100	85,6100	-85,4700	-145,4000	-22,1700	-92,7500	92,8000	-310,5575	-651,4034	-625,6404	-284,9664
	3	-47,8800	-136,6600	-22,8300	52,8200	-52,8000	-110,3900	-15,9500	-57,3300	57,3200	-253,1502	-463,6468	-447,5944	-237,1551
	4	-31,9200	-90,3200	-13,3700	26,2800	-26,3900	-73,6600	-9,5000	-28,5000	28,4000	-181,3056	-285,9902	-278,4936	-173,7899
	5	-15,9600	-43,2600	-3,9300	8,6700	-8,7700	-35,1000	-2,9200	-8,7100	8,6200	-93,5088	-119,0574	-119,2149	-93,6516
K9	1	-86,5200	-333,0500	-55,3100	134,5000	-134,9000	-226,3800	-43,3000	-77,0300	91,2600	-547,8669	-858,8160	-1007,5842	-675,1290
	2	-63,8400	-250,7800	-43,4700	53,5600	-53,6900	-215,4300	-33,3500	-41,9700	54,5800	-525,3681	-707,9260	-739,0862	-532,1822
	3	-47,8800	-190,1400	-32,0100	18,1300	-18,1500	-124,8200	-23,6200	-23,9600	35,6100	-409,5218	-489,9558	-459,7784	-357,0431
	4	-31,9200	-130,4300	-20,7600	-3,1300	3,2400	-77,3500	-13,7000	-10,1300	20,0900	-304,7094	-318,0864	-262,5691	-230,3687
	5	-15,9600	-72,8900	-10,1900	-7,8300	7,9300	-29,3800	-3,8700	-2,2600	5,9500	-156,7713	-148,5834	-118,5030	-121,4136

Keterangan Tabel 8.6:

- [1] Kolom yang ditinjau
- [2] Tingkat lantai pada kolom yang ditinjau
- [3] Berat sendiri kolom
- [4] $N_{D,k-x}$ = Gaya aksial kolom akibat beban mati sejajar sb-x
- [5] $N_{L,k-x}$ = Gaya aksial kolom akibat beban hidup sejajar sb-x
- [6] $N_{Eka,k-x}$ = Gaya aksial kolom akibat beban gempa kiri sejajar sb-x
- [7] $N_{Eki,k-x}$ = Gaya aksial kolom akibat beban gempa kanan sejajar sb-x
- [8] $N_{D,k-y}$ = Gaya aksial kolom akibat beban mati sejajar sb-y
- [9] $N_{L,k-y}$ = Gaya aksial kolom akibat beban hidup sejajar sb-y
- [10] $N_{Eki,k-y}$ = Gaya aksial kolom akibat beban gempa kiri sejajar sb-y
- [11] $N_{Eka,k-y}$ = Gaya aksial kolom akibat beban gempa kanan sejajar sb-y
- [12] $N_{u,k-x1} = 1,05(N_{D,k-x} + N_{L,k-x} + N_{D,k-y} + N_{L,k-y} + \omega d.k.(N_{Eki,k-x} + 0,3.N_{Eki,k-y}))$ dengan $k=1$
(Gaya aksial rencana kolom akibat gempa kiri sejajar sb-x)
- [13] $N_{u,k-x1} = 1,05(N_{D,k-x} + N_{L,k-x} + N_{D,k-y} + N_{L,k-y} + \omega d.k.(N_{Eki,k-y} + 0,3.N_{Eki,k-x}))$ dengan $k=1$
(Gaya aksial rencana kolom akibat gempa kiri sejajar sb-y)
- [14] $N_{u,k-x1} = 1,05(N_{D,k-x} + N_{L,k-x} + N_{D,k-y} + N_{L,k-y} + \omega d.k.(N_{Eka,k-x} + 0,3.N_{Eka,k-y}))$
(Gaya aksial rencana kolom akibat gempa kanan sejajar sb-x)
- [15] $N_{u,k-x1} = 1,05(N_{D,k-x} + N_{L,k-x} + N_{D,k-y} + N_{L,k-y} + \omega d.k.(N_{Eka,k-y} + 0,3.N_{Eka,k-x}))$
(Gaya aksial rencana kolom akibat gempa kanan sejajar sb-y)
dengan $k = 2$, $\omega d = 1$ (untuk lantai 1 dan 5), $\omega d = 1,3$ (untuk lantai 2,3, dan 4)

8.2.3 Perhitungan Kelangsingan Kolom dan Pembesaran Momen

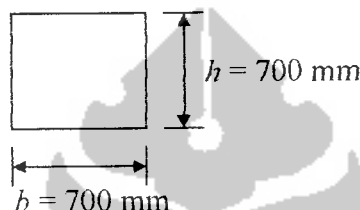
Sebagai contoh perhitungan kelangsingan kolom dan pembesaran momen ditinjau pada kolom K2 lantai 1 sejajar sumbu x .

- Cek kelangsingan kolom

$$\beta_d = \frac{1,05 \cdot M_{D,k}}{1,05(M_{D,k} + M_{L,k} + k \cdot M_{E,k})}$$

$$= \frac{1,05 \cdot 111,7600}{1,05 \cdot (111,7600 + 32,3400 - 2.182,5300)} = 0,19$$

- Ukuran kolom: $b = 700$ mm, $h = 700$ mm



Gambar 8.6 Penampang melintang kolom ukuran 700 mm x 700 mm

$$E_c = 4700 \cdot \sqrt{f_c} = 4700 \cdot \sqrt{25} = 23500 \text{ MPa}$$

$$I_k = 1/12 \cdot b \cdot h^3 = 1/12 \cdot 700 \cdot 700^3 = 2 \cdot E10 \text{ mm}^4$$

$$EI_k = \frac{\left(\frac{E_c \cdot I_k}{2,5} \right)}{1 + \beta_d} = \frac{\left(\frac{23500 \cdot 2 \cdot E10}{2,5} \right)}{1 + 0,19} = 1,59 \cdot E14 \text{ Nmm}^2$$

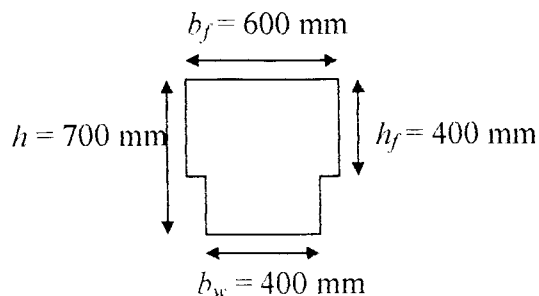
$$l_k = 5400 \text{ mm (panjang kolom lantai 1)}$$

$$l_{u,k} = 5400 - 700 - 600 = 4100 \text{ mm (panjang bersih kolom lantai 1)}$$

$$l_k = 3800 \text{ mm (panjang kolom lantai 2)}$$

$$l_{u,k} = 3800 - 700 = 3100 \text{ mm (panjang bersih kolom lantai 2)}$$

- Ukuran balok lantai 1: $b_f = 600$ mm, $h_f = 400$ mm, $b_w = 400$ mm, $h = 700$ mm



Gambar 8.7 Penampang melintang balok T

$$E_c = 4700 \cdot \sqrt{f_c'} = 4700 \cdot \sqrt{25} = 23500 \text{ MPa}$$

$$I_b = 1/12 \cdot b \cdot h^3 = 1/12 \cdot 600 \cdot 400^3 + 1/12 \cdot 400 \cdot 300^3 = 4,1 \cdot 10^9 \text{ mm}^4$$

$$EI_{b,a} = \frac{\left(\frac{E_c \cdot I_b}{5} \right)}{1 + \beta_d} = \frac{\left(\frac{23500 \cdot 4,1 \cdot 10^9}{5} \right)}{1 + 0,19} = 1,62 \cdot 10^{13} \text{ Nmm}^2$$

$l_b = 9600 \text{ mm}$ (panjang balok sebelah kiri kolom)

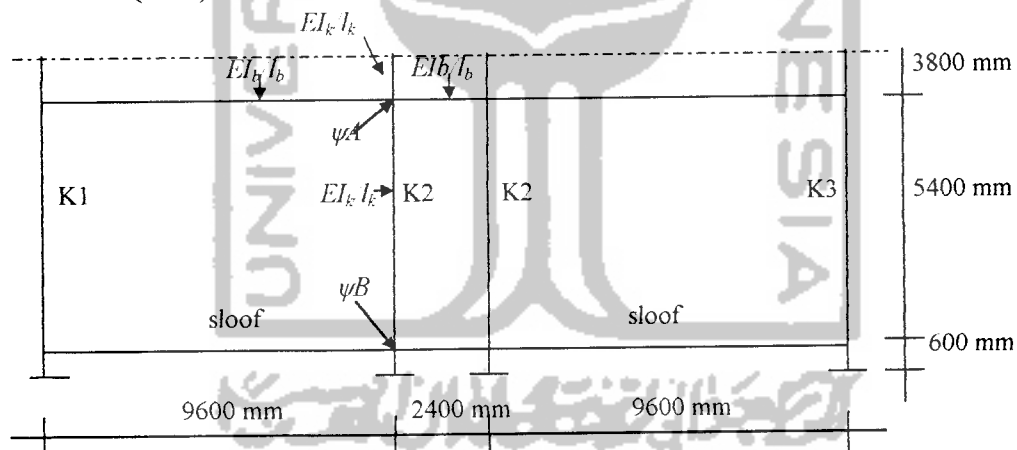
$l_{n,b} = 9600 - 700 = 8900 \text{ mm}$ (panjang bersih balok sebelah kiri kolom)

$l_b = 2400 \text{ mm}$ (panjang balok sebelah kanan kolom)

$l_{n,b} = 2400 - 700 = 1700 \text{ mm}$ (panjang balok bersih sebelah kanan kolom)

Kekakuan relatif kolom bagian atas

$$\varphi_A = \frac{\sum \left(\frac{EI_k}{l_{n,k}} \right)}{\sum \left(\frac{EI_b}{l_{n,b}} \right)} = \frac{\frac{1,59 \cdot 10^{14}}{3700} + \frac{1,59 \cdot 10^{14}}{5400}}{\frac{1,62 \cdot 10^{13}}{8900} + \frac{1,62 \cdot 10^{13}}{1700}} = 6,31$$



Gambar 8.8 Kekakuan relatif kolom K2 sejajar sumbu x (portal as C dan D)

Kekakuan relatif kolom bagian bawah

$\psi_B = 0$ (dianggap dukungan jepit)

$$\psi_m = (\psi_A + \psi_B)/2 = (6,31 + 0)/2 = 3,155$$

Nilai k diambil dengan rumus Furlong (Wang dan Salmon, 1987):

$$\psi_m > 2,0$$

$$k = 0,9 \cdot (1 + \psi_m)^{1/2} = 0,9 \cdot (1 + 3,155)^{1/2} = 1,835$$

Cek kelangsingan kolom K2 portal bergoyang

$$A = 700 \times 700 = 4,9E5 \text{ mm}^2$$

$$r = \sqrt{(I/A)} = \sqrt{(2E10/4,9E5)} = 202,03$$

$$L = 4100 \text{ mm (panjang bersih kolom lantai 1)}$$

$$(k.L)/r = (1,835.4100)/202,03 = 37 > 22 \text{ (kolom langsing)}$$

$$P_{c,K2} = \frac{\pi^2 EI_k}{(kL)^2} = \frac{3,14^2 1,59E14.10^{-3}}{(1,835.4100)^2} = 27640,5546 \text{ kN}$$

$$P_{u,K2} = N_{u,k,K2} = 4557,8337 \text{ kN}$$

Dengan cara yang sama dapat dihitung kelangsingan dan gaya tekuk Euler untuk kolom K1 dalam satu tingkat yang sama dan dalam satu portal arah x yang sama (disajikan pada Tabel 8.7)

$$P_{u,K1} = N_{u,k,K1} = 3576,4134 \text{ kN}$$

$$P_{c,K1} = 7369,2149 \text{ kN}$$

$$\Sigma P_u = 2.3576,4134 + 2.4557,8337 = 16268,4942 \text{ kN}$$

$$\Sigma P_c = 2.7369,2149 + 2.27640,5546 = 70019,5390 \text{ kN}$$

Faktor pembesaran momen

$$\delta_s = \frac{1}{1 - \frac{\Sigma P_u}{\phi \Sigma P_c}} = \frac{1}{1 - \frac{16268,4942}{0,65 \cdot 70019,5390}} = 1,4474 > 1$$

Dengan cara yang sama didapat perhitungan kolom dan faktor kelangsingan kolom-kolom yang lain, disajikan pada Tabel 8.7.

Tabel 8.7 Perhitungan Kelangsingan dan Faktor Pembesaran Momen Kolom Daktililitas Terbatas

Ko- lom	Arah	lb,a (mm ⁴)	lb,b (mm ⁴)	Ik (mm ⁴)	β/d	E/ba (N/mm ²)	E/bb (N/mm ²)	E/ik (N/mm ²)	ψA	ψB	k	kL/r	Pu (kN)	Pu (kN)	ΔPu (kN)	ΔPc (kN)	δ's	
[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]	[11]	[12]	[13]	[14]	[15]	[16]	[17]	[18]	[19]
K1	1	Sb-x	4,10E+09	7,20E+09	2,00E+10	0,39	1,39E+13	0,00E+00	1,35E+14	24,60	0,00	3,28	66,6	3576,4134	7369,2149	16268,4942	70019,5390	1,4629
		Sb-y	4,10E+09	7,20E+09	2,00E+10	0,001	1,92E+13	0,00E+00	1,88E+14	17,97	0,00	2,84	57,7	3576,4134	13634,9834	11273,0646	39330,7315	1,6027
	2	Sb-x	4,10E+09	4,10E+09	2,00E+10	0,45	1,33E+13	1,33E+13	1,30E+14	21,02	21,02	4,22	64,78	2769,2580	7466,1538	12280,5588	64973,4495	1,3818
		Sb-y	4,10E+09	4,10E+09	2,00E+10	0,002	1,92E+13	1,92E+13	1,88E+14	15,35	15,35	3,64	55,83	2769,2580	14550,8784	8873,4604	39109,1440	1,4902
	3	Sb-x	4,10E+09	4,10E+09	2,00E+10	0,51	1,28E+13	1,28E+13	1,25E+14	21,02	21,02	4,22	64,78	1906,1099	7178,4771	7717,5860	60316,9679	1,2451
K2	4	Sb-x	4,10E+09	4,10E+09	2,00E+10	0,11	1,91E+13	1,91E+13	1,86E+14	15,35	15,35	3,64	55,83	1906,1099	14424,8553	6109,6900	38256,4838	1,3257
		Sb-y	4,10E+09	4,10E+09	2,00E+10	0,54	1,25E+13	1,25E+13	1,22E+14	21,02	21,02	4,22	64,78	1049,8391	7029,2015	3756,6744	66275,6898	1,0955
	5	Sb-x	4,10E+09	4,10E+09	2,00E+10	0,004	1,92E+13	1,92E+13	1,87E+14	15,35	15,35	3,64	55,83	1049,8391	14528,8463	3404,1200	38140,0780	1,1592
		Sb-y	9,00E+09	9,00E+09	2,00E+10	0,54	1,25E+13	1,25E+13	1,22E+14	11,21	22,42	3,8	58,27	628,0071	8687,8473	1256,0142	17375,6947	1,1251
	1	Sb-x	4,10E+09	7,20E+09	2,00E+10	0,052	4,02E+13	4,02E+13	1,79E+14	3,73	7,46	2,31	35,45	628,0071	34374,0977	1683,7380	91420,2520	1,0292
K3	2	Sb-x	4,10E+09	7,20E+09	2,00E+10	0,19	1,62E+13	0,00E+00	1,59E+14	6,31	0,00	1,83	37	4557,8337	27640,5546	16268,4942	70019,5390	1,4474
		Sb-y	4,10E+09	7,20E+09	2,00E+10	0,004	1,92E+13	0,00E+00	1,87E+14	14,38	0,00	2,58	51,93	4557,8337	16591,8453	17225,7015	113681,1444	1,3040
	3	Sb-x	4,10E+09	4,10E+09	2,00E+10	0,23	1,57E+13	1,57E+13	1,53E+14	7,19	6,31	2,51	38,44	3371,0214	25020,5710	12280,5588	64973,4495	1,4100
		Sb-y	4,10E+09	4,10E+09	2,00E+10	0,008	1,91E+13	1,91E+13	1,87E+14	16,37	14,38	3,64	55,87	3371,0214	14451,2099	12854,3125	110598,8225	1,2177
	4	Sb-x	4,10E+09	4,10E+09	2,00E+10	0,27	1,52E+13	1,52E+13	1,48E+14	7,19	7,19	2,58	39,51	1952,6831	22980,0088	7717,5860	60316,9679	1,2451
K4		Sb-y	4,10E+09	4,10E+09	2,00E+10	0,43	1,35E+13	1,35E+13	1,32E+14	3,60	7,19	2,28	34,91	828,4981	26108,6434	3756,6744	68275,6898	1,1353
	1	Sb-x	4,10E+09	4,10E+09	2,00E+10	0,021	1,89E+13	1,89E+13	1,84E+14	8,19	16,37	3,28	50,31	828,4981	17597,5321	4146,3009	107706,6173	1,0630
		Sb-y	4,10E+09	7,20E+09	2,00E+10	0,13	1,70E+13	0,00E+00	1,66E+14	22,67	0,00	3,16	64,13	2060,1189	9748,1233	13056,0024	118613,4313	1,2039
	2	Sb-x	4,10E+09	4,10E+09	2,00E+10	0,192	1,62E+13	0,00E+00	1,58E+14	35,94	0,00	3,92	79,53	2060,1189	6030,3824	11273,0646	39330,7315	1,6099
		Sb-y	4,10E+09	4,10E+09	2,00E+10	0,17	1,65E+13	1,65E+13	1,61E+14	25,82	22,67	4,52	69,37	1667,4722	8070,7377	10296,8950	105285,9449	1,1771
K5	3	Sb-x	4,10E+09	4,10E+09	2,00E+10	0,209	1,59E+13	1,59E+13	1,56E+14	40,93	35,94	5,65	86,7	1667,4722	5003,6936	8873,4604	39109,1440	1,4594
		Sb-y	4,10E+09	4,10E+09	2,00E+10	0,19	1,62E+13	1,62E+13	1,58E+14	25,82	25,82	4,86	71,5	1148,6460	7455,8064	7058,1542	98283,6961	1,1242
	4	Sb-x	4,10E+09	4,10E+09	2,00E+10	0,209	1,59E+13	1,59E+13	1,56E+14	40,93	40,93	5,63	89,4	1148,6460	4703,3866	6109,6900	38256,4838	1,3257
		Sb-y	4,10E+09	4,10E+09	2,00E+10	0,25	1,54E+13	1,54E+13	1,51E+14	25,82	25,82	4,86	71,5	652,2209	7122,1218	4149,8238	95604,3195	1,0716
	5	Sb-x	9,00E+09	9,00E+09	2,00E+10	0,62	2,61E+13	2,61E+13	1,16E+14	5,88	11,76	2,82	43,27	213,8619	14999,6599	1496,1366	214265,8324	1,0192
K6		Sb-y	9,00E+09	9,00E+09	2,00E+10	0,404	3,01E+13	3,01E+13	1,34E+14	9,32	18,65	3,48	53,45	213,8619	11336,0283	1683,7380	91420,2520	1,0292
	1	Sb-x	4,10E+09	7,20E+09	2,00E+10	0,02	1,88E+13	0,00E+00	1,84E+14	11,33	0,00	2,32	47,15	2031,4959	19974,0740	13056,0024	118613,4313	1,2039
		Sb-y	5,72E+09	7,20E+09	2,00E+10	0,125	2,39E+13	0,00E+00	1,67E+14	12,39	0,00	2,41	48,98	2031,4959	16841,7789	3874,9221	45182,6451	1,1520
	2	Sb-x	4,10E+09	4,10E+09	2,00E+10	0,03	1,87E+13	1,87E+13	1,82E+14	12,91	11,33	3,26	50,01	1626,6961	17628,0927	10296,8950	105285,9449	1,1771
		Sb-y	5,72E+09	5,72E+09	2,00E+10	0,078	2,49E+13	2,49E+13	1,75E+14	14,11	12,39	3,4	52,12	1626,6961	15528,0351	3075,0535	49921,7666	1,1047
K7	3	Sb-x	4,10E+09	4,10E+09	2,00E+10	0,04	1,85E+13	1,85E+13	1,81E+14	12,91	12,91	3,36	51,49	1148,7330	16465,0557	7058,1542	98283,6961	1,1242
		Sb-y	5,72E+09	5,72E+09	2,00E+10	0,079	2,49E+13	2,49E+13	1,74E+14	14,11	14,11	3,5	53,67	1148,7330	14618,3621	2170,5858	47385,2469	1,0758
	4	Sb-x	4,10E+09	4,10E+09	2,00E+10	0,06	1,83E+13	1,83E+13	1,78E+14	12,91	12,91	3,36	51,49	679,7774	16243,2350	4149,8238	95604,3195	1,0716
		Sb-y	5,72E+09	5,72E+09	2,00E+10	0,092	2,46E+13	2,46E+13	1,72E+14	14,11	14,11	3,5	53,67	679,7774	14455,7125	1296,3706	46397,4071	1,0449

Tabel 8.7 Lanjutan

Ko- lom	Arah	lb, a (mm ⁴)	lb, b (mm ⁴)	Ik (mm ⁴)	β/d	Eiba (Nmm ²)	Eibb (Nmm ²)	Elk (Nmm ²)	ψA	ψB	k	kL/r	Pu (kN)	Pu (kN)	ΣPu (kN)	ΣPc (kN)	$\delta's$
[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]	[11]	[12]	[13]	[14]	[15]	[17]	[18]	[19]
K5	Sb-x	9,00E+09	9,00E+09	2,00E+10	0,12	3,79E+13	3,79E+13	1,69E+14	2,94	5,88	2,09	32,12	246,9810	39493,2999	1496,1366	214265,8324	1,0109
	Sb-y	5,72E+09	5,72E+09	2,00E+10	0,265	2,12E+13	2,12E+13	1,49E+14	7,06	14,11	3,06	46,99	246,9810	16275,2325	503,6073	53136,3762	1,0148
	Sb-x	4,10E+09	7,20E+09	2,00E+10	0,07	1,81E+13	0,00E+00	1,76E+14	6,64	0,00	1,87	37,96	2436,3864	29584,5183	13056,0024	118613,4313	1,2039
	Sb-y	5,72E+09	7,20E+09	2,00E+10	0,129	2,38E+13	0,00E+00	1,67E+14	8,37	0,00	2,05	41,58	2436,3864	23295,7294	17225,7015	113681,1444	1,3040
	Sb-x	4,10E+09	4,10E+09	2,00E+10	0,09	1,76E+13	1,76E+13	1,72E+14	7,57	6,64	2,56	39,31	1854,2792	26944,1421	10296,8950	105285,9449	1,1771
K6	Sb-y	5,72E+09	5,72E+09	2,00E+10	0,168	2,30E+13	2,30E+13	1,61E+14	9,53	8,37	2,84	43,55	1854,2792	20515,4807	12854,3125	110598,8225	1,2177
	Sb-x	4,10E+09	4,10E+09	2,00E+10	0,10	1,75E+13	1,75E+13	1,70E+14	7,57	7,57	2,63	40,41	1231,6981	25220,9859	7058,1542	98283,6961	1,1242
	Sb-y	5,72E+09	5,72E+09	2,00E+10	0,208	2,22E+13	2,22E+13	1,56E+14	9,53	9,53	2,92	44,81	1231,6981	18738,2753	7960,7110	102753,9011	1,1353
	Sb-x	4,10E+09	4,10E+09	2,00E+10	0,14	1,69E+13	1,69E+13	1,65E+14	7,57	7,57	2,63	40,41	742,9136	24436,8029	4149,8238	95604,3195	1,0716
	Sb-y	5,72E+09	5,72E+09	2,00E+10	0,243	2,16E+13	2,16E+13	1,51E+14	9,53	9,53	2,92	44,81	742,9136	18214,2567	4146,3009	107706,6173	1,0630
K7	Sb-x	9,00E+09	9,00E+09	2,00E+10	0,26	3,35E+13	3,35E+13	1,49E+14	1,72	3,45	1,7	26,14	287,2254	52639,9564	1496,1366	214265,8324	1,0109
	Sb-y	5,72E+09	5,72E+09	2,00E+10	0,108	2,43E+13	2,43E+13	1,70E+14	4,77	9,53	2,57	39,41	287,2254	26415,1852	1040,5563	92300,8544	1,0177
	Sb-x	5,72E+09	7,20E+09	9,11E+08	0,19	2,26E+13	0,00E+00	7,21E+12	0,74	0,00	1,15	65,27	1063,1187	4808,0681	4570,4232	22473,5308	1,2370
	Sb-y	5,72E+09	7,20E+09	7,15E+09	0,003	2,68E+13	0,00E+00	6,70E+13	2,29	0,00	1,38	28,01	1063,1187	20622,2989	3874,9221	45182,6451	1,1520
	Sb-x	5,72E+09	5,72E+09	9,11E+08	0,19	2,25E+13	2,25E+13	7,18E+12	0,84	0,74	1,29	55,29	796,9540	4459,8132	3444,9858	22499,9311	1,3081
K8	Sb-y	5,72E+09	5,72E+09	7,15E+09	0,002	2,68E+13	2,68E+13	6,70E+13	2,61	2,29	1,67	25,64	796,9540	24640,6169	3075,0535	49921,7666	1,1047
	Sb-x	5,72E+09	5,72E+09	9,11E+08	0,19	2,26E+13	2,26E+13	7,22E+12	0,84	0,84	1,3	55,86	588,2060	4384,2081	2340,4860	22164,0791	1,1940
	Sb-y	5,72E+09	5,72E+09	7,15E+09	0,007	2,67E+13	2,67E+13	6,67E+13	2,61	2,61	1,71	26,22	588,2060	23444,8664	2170,5858	47385,2469	1,0758
	Sb-x	5,72E+09	5,72E+09	9,11E+08	0,22	2,21E+13	2,21E+13	7,05E+12	0,84	0,84	1,3	55,86	338,0996	4279,3171	1410,8086	21376,4186	1,1130
	Sb-y	5,72E+09	5,72E+09	7,15E+09	0,015	2,65E+13	2,65E+13	6,62E+13	2,61	2,61	1,71	26,22	338,0996	23259,8558	1296,3706	46397,4071	1,0449
K9	Sb-x	5,72E+09	5,72E+09	9,11E+08	0,37	1,96E+13	1,96E+13	6,26E+12	0,42	0,84	1,24	53,15	137,4114	4197,3054	579,9486	20622,8002	1,0452
	Sb-y	5,72E+09	5,72E+09	7,15E+09	0,033	2,60E+13	2,60E+13	6,50E+13	1,30	2,61	1,55	23,8	137,4114	27756,4906	503,6073	53136,3762	1,0148
	Sb-x	5,72E+09	7,20E+09	9,11E+08	0,07	2,51E+13	0,00E+00	8,00E+12	0,22	0,00	1,05	59,49	1222,0929	6428,6973	4570,4232	22473,5308	1,2370
	Sb-y	5,72E+09	7,20E+09	7,15E+09	0,103	2,44E+13	0,00E+00	6,09E+13	2,32	0,00	1,38	28,1	1222,0929	18639,1216	17225,7015	113681,1444	1,3040
	Sb-x	5,72E+09	5,72E+09	9,11E+08	0,08	2,50E+13	2,50E+13	7,98E+12	0,25	0,22	1,1	47,13	925,5389	6790,1524	3444,9858	22499,9311	1,3081
K10	Sb-y	5,72E+09	5,72E+09	7,15E+09	0,135	2,37E+13	2,37E+13	5,92E+13	2,61	2,29	1,67	25,64	925,5389	21760,2629	12854,3125	110598,8225	1,2177
	Sb-x	5,72E+09	5,72E+09	9,11E+08	0,08	2,49E+13	2,49E+13	7,93E+12	0,25	0,25	1,1	47,38	612,0370	6697,8314	2340,4860	22164,0791	1,1940
	Sb-y	5,72E+09	5,72E+09	7,15E+09	0,172	2,29E+13	2,29E+13	5,73E+13	2,61	2,61	1,71	26,22	612,0370	20147,0995	7960,7110	102753,9011	1,1353
	Sb-x	5,72E+09	5,72E+09	9,11E+08	0,13	2,38E+13	2,38E+13	7,59E+12	0,25	0,25	1,1	47,38	367,3047	6408,8922	1410,8086	21376,4186	1,1130
	Sb-y	5,72E+09	5,72E+09	7,15E+09	0,235	2,18E+13	2,18E+13	5,44E+13	2,61	2,61	1,71	26,22	367,3047	19121,8158	4146,3009	107706,6173	1,0630
K11	Sb-x	5,72E+09	5,72E+09	9,11E+08	0,24	2,17E+13	2,17E+13	6,93E+12	0,12	0,25	1,08	46,33	152,5629	6114,0947	579,9486	20622,8002	1,0452
	Sb-y	5,72E+09	5,72E+09	7,15E+09	0,488	1,81E+13	1,81E+13	4,51E+13	1,30	2,61	1,55	23,8	152,5629	19259,5313	1040,5563	92300,8544	1,0177
	Sb-x	5,72E+09	7,20E+09	7,15E+09	0,15	2,34E+13	0,00E+00	5,85E+13	5,81	0,00	1,78	36,08	780,3075	10872,8474	3575,7834	49463,7393	1,1251
	Sb-y	5,72E+09	7,20E+09	2,60E+09	0,091	2,48E+13	0,00E+00	2,24E+13	1,73	0,00	1,31	37,11	780,3075	7718,5673	3874,9221	45182,6451	1,1520
	Sb-x	5,72E+09	5,72E+09	7,15E+09	0,17	2,29E+13	2,29E+13	5,73E+13	6,61	5,81	2,42	37,07	651,4034	10068,9098	2780,9792	76971,6256	1,0589
K12	Sb-y	5,72E+09	5,72E+09	2,60E+09	0,098	2,45E+13	2,45E+13	2,23E+13	1,97	1,73	1,53	32,9	651,4034	9753,1146	3075,0535	49921,7666	1,1047

Tabel 8.7 Lanjutan

Ko- lom	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]	[11]	[12]	[13]	[14]	[15]	[16]	[17]	[18]	[19]
Arah	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]	[11]	[12]	[13]	[14]	[15]	[16]	[17]	[18]	[19]	
Lt	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]	[11]	[12]	[13]	[14]	[15]	[16]	[17]	[18]	[19]	
3	Sb-x	5,72E+09	5,72E+09	5,72E+09	7,15E+09	0,19	2,27E+13	2,27E+13	5,67E+13	6,61	6,61	2,48	38,1	463,6468	9438,0721	1907,2052	73474,0544	1,0416	
	Sb-y	5,72E+09	5,72E+09	5,72E+09	2,60E+09	0,118	2,40E+13	2,40E+13	2,19E+13	1,97	1,97	1,55	33,36	463,6468	9322,1985	2170,5858	47385,2469	1,0758	
4	Sb-x	5,72E+09	5,72E+09	5,72E+09	7,15E+09	0,27	2,12E+13	2,12E+13	5,30E+13	6,61	6,61	2,48	38,1	278,4936	8826,5040	1193,1600	70889,6646	1,0266	
	Sb-y	5,72E+09	5,72E+09	5,72E+09	2,60E+09	0,200	2,24E+13	2,24E+13	2,04E+13	1,97	1,97	1,55	33,36	278,4936	8681,8388	1296,3706	46397,4071	1,0449	
5	Sb-x	5,72E+09	5,72E+09	5,72E+09	7,15E+09	0,40	1,92E+13	1,92E+13	4,78E+13	3,31	6,61	2,2	33,71	119,2149	10191,6859	551,9724	74515,1418	1,0115	
	Sb-y	5,72E+09	5,72E+09	5,72E+09	2,60E+09	0,300	2,07E+13	2,07E+13	1,88E+13	0,98	1,97	1,46	31,31	119,2149	9104,6531	503,6073	53136,3762	1,0148	
K9	Sb-x	5,72E+09	7,20E+09	7,20E+09	7,15E+09	0,05	2,55E+13	0,00E+00	6,38E+13	4,68	0,00	1,64	33,37	1007,5842	13859,0223	3575,7834	49463,7393	1,1251	
	Sb-y	5,72E+09	7,20E+09	7,20E+09	2,60E+09	0,103	2,44E+13	0,00E+00	2,22E+13	1,73	0,00	1,31	37,11	1007,5842	7633,4367	17225,7015	113681,1444	1,3040	
2	Sb-x	5,72E+09	5,72E+09	5,72E+09	7,15E+09	0,06	2,58E+13	2,53E+13	6,32E+13	1,94	1,70	1,51	23,19	739,0862	28416,9030	2780,9792	76971,6256	1,0589	
	Sb-y	5,72E+09	5,72E+09	5,72E+09	2,60E+09	0,133	2,37E+13	2,37E+13	2,18E+13	1,97	1,73	1,53	32,9	739,0862	9452,5892	12854,3125	110598,8225	1,2177	
3	Sb-x	5,72E+09	5,72E+09	5,72E+09	7,15E+09	0,06	2,53E+13	2,53E+13	6,33E+13	1,94	1,94	1,54	23,67	489,9558	27298,9551	1907,2052	73474,0544	1,0416	
	Sb-y	5,72E+09	5,72E+09	5,72E+09	2,60E+09	0,172	2,29E+13	2,29E+13	2,09E+13	1,97	1,97	1,55	33,36	489,9558	8890,9428	7960,7110	102753,9011	1,1353	
4	Sb-x	5,72E+09	5,72E+09	5,72E+09	7,15E+09	0,09	2,47E+13	2,47E+13	6,17E+13	1,94	1,94	1,54	23,67	318,0864	26618,3283	1193,1600	70889,6646	1,0266	
	Sb-y	5,72E+09	5,72E+09	5,72E+09	2,60E+09	0,228	2,19E+13	2,19E+13	1,99E+13	1,97	1,97	1,55	33,36	318,0864	8480,6120	4146,3009	107706,6173	1,0630	
5	Sb-x	5,72E+09	5,72E+09	5,72E+09	7,15E+09	0,28	2,10E+13	2,10E+13	5,24E+13	0,97	1,94	1,41	21,63	156,7713	27065,8850	551,9724	74515,1418	1,0115	
	Sb-y	5,72E+09	5,72E+09	5,72E+09	2,60E+09	0,172	2,29E+13	2,29E+13	2,09E+13	0,98	1,97	1,46	31,31	156,7713	10100,4763	5160,7941	104361,6191	1,0823	

Keterangan Tabel 8.7:

- [1] Kolom yang ditinjau
- [2] Lantai kolom yang ditinjau
- [3] Arah bekerjanya momen sejajar sb-x dan sb-y
- [4] l_b, a = Inersia balok atas; $l = 1/12 \cdot b \cdot h^3$
- [5] l_b, b = Inersia balok bawah
- [6] l_k = Inersia kolom
- [7] $\beta d = 1,05MD / (1,05(MD + ML + 2ME))$
- [8] $EI_b, a = [(Ec \cdot l_b, a) / 2,5] / [1 + \beta d]$
- [9] $EI_b, b = [(Ec \cdot l_b, b) / 2,5] / [1 + \beta d]$
- [10] $EIk = [(Ec \cdot k) / 5] / [1 + \beta d]$
- [11] $\psi A = \sum [EI / Ik] / \sum [EI / l_b, a]$
- [12] $\psi B = \sum [EI / Ik] / \sum [EI / l_b, b]$
- [13] $k = 0,9 \cdot (1 + \psi m)^{0,5}$ untuk $\psi m = (yA + yB) / 2 > 2,0$
 $k = (20 - \psi m) / 20 \cdot (1 + \psi m)^{0,5}$ untuk $\psi m < 2,0$
- [14] $kL / r > 22$ kolom langsing $r = (I/A)^{0,5}$
- [15] $P_u = Nu, k =$ Gaya aksial rencana tercapai kolom
- [16] $P_c = [3,14 \cdot 2 \cdot EIk] / [(k \cdot l)^2]$
- [17] $\Sigma P_u =$ jumlah gaya-gaya aksial dalam lantai dan portal yang sama
- [18] $\Sigma P_c =$ jumlah gaya-gaya tekuk Euler dalam lantai dan portal yang sama
- [19] $\delta s = 1 / [1 - (\Sigma P_u / 0,65 \Sigma P_c)] > 1$ (faktor pembesaran momen)

8.2.4 Penulangan Kombinasi Lentur dan Aksial Kolom

Sebagai contoh perhitungan penulangan kombinasi lentur dan aksial kolom adalah Kolom K2 Lantai 1.

Diketahui dari perhitungan sebelumnya:

$$P_u = N_{u,k} = 4557,8337 \text{ kN}$$

$$M_{u,k,x} = 593,6729 \text{ kNm} ; \delta_{s,x} = 1,4474$$

$$M_{c,x} = \delta_{s,x} \cdot M_{u,k,x} = 1,4474 \cdot 593,6729 = 859,2822 \text{ kNm}$$

$$M_{u,k,y} = 503,4646 \text{ kNm} ; \delta_{s,y} = 1,3040$$

$$M_{c,y} = \delta_{s,y} \cdot M_{u,k,y} = 1,3040 \cdot 503,4646 = 656,5178 \text{ kNm}$$

Eksentrisitasnya adalah:

$$e_x = M_{c,x}/P_u = 859,2822/4557,8337 = 0,189 \text{ m} = 189 \text{ mm}$$

$$e_y = M_{c,y}/P_u = 656,5178/4557,8337 = 0,144 \text{ m} = 144 \text{ mm}$$

Untuk menentukan harga-harga dari P_x dan P_y diperlukan Gambar 7.7 Diagram Interaksi Kolom Ukuran 700 mm x 700 mm, dalam lentur uniaksial masing-masing terhadap sumbu x dan sumbu y , oleh karena sifat simetris dalam hal ini, hanya diperlukan diagram tunggal yang telah dibuat sebelumnya. Dari Diagram Interaksi Kolom 700 mm x 700 mm, diambil penulangan 32D25 dengan $A_{st} = 15707,96 \text{ mm}^2$, jadi $\rho_g = A_{st}/A_g = 15707,96/490000 = 0,032$, ditentukan P_x dan P_y (cara penentuan P_x dan P_y lihat Gambar 8.9)

untuk $e_x = 189 \text{ mm}$ didapat $\phi P_{n,x} = 5800,0000 \text{ kN}$

untuk $e_y = 144 \text{ mm}$ didapat $\phi P_{n,y} = 6700,0000 \text{ kN}$

dan $\phi P_o = 10850,1300 \text{ kN}$

Kemudian dengan menggunakan persamaan *Bresler* didapat ϕP_n (Wang dan Salmon, 1993):

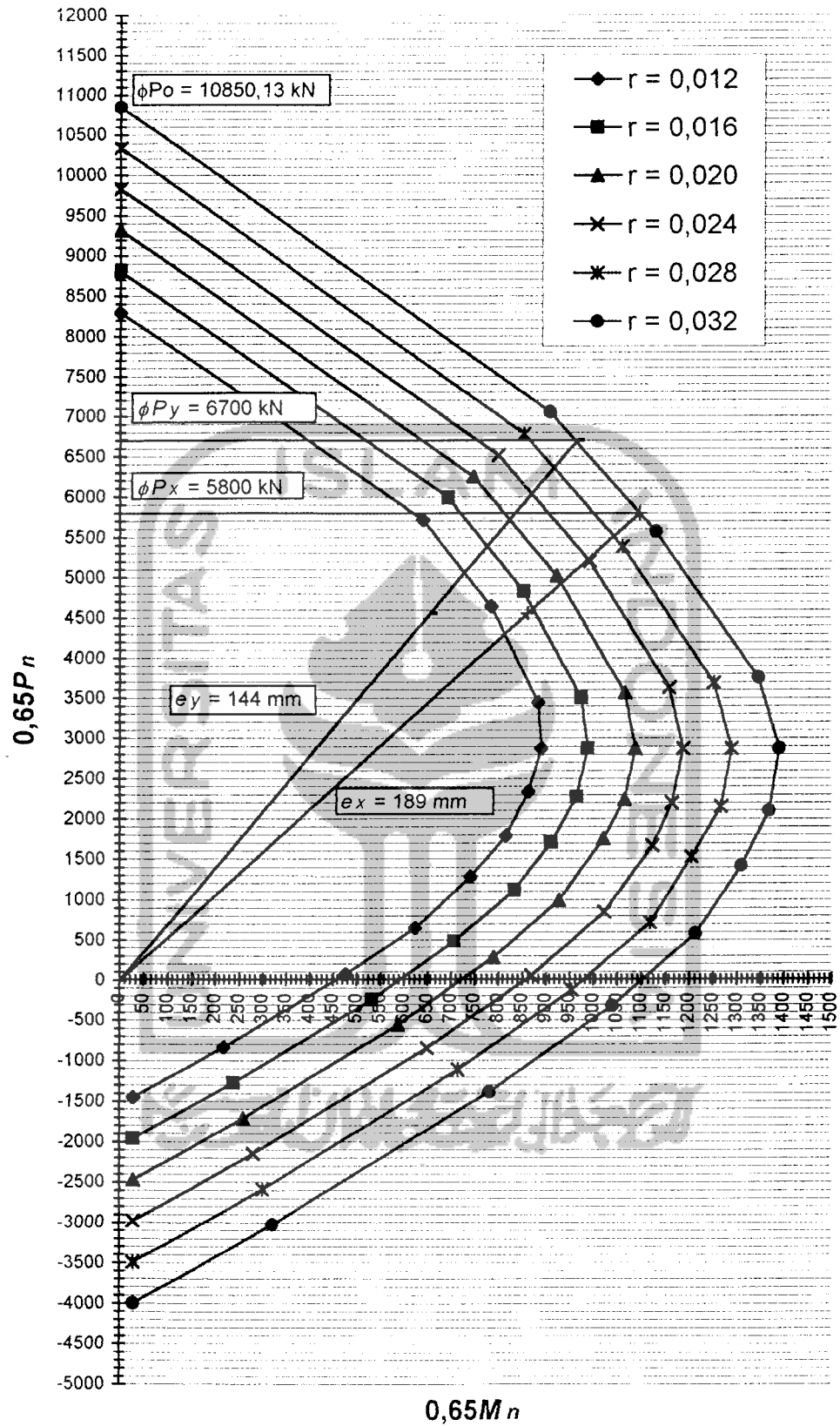
$$1/\phi P_n = (1/\phi P_{n,x}) + (1/\phi P_{n,y}) - (1/\phi P_o)$$

$$1/\phi P_n = (1/5800,0000) + (1/6700,0000) - (1/10850,1300)$$

didapat, $\phi P_n = 4562,0732 \text{ kN} \geq (P_u = 4557,8337 \text{ kN})$ - aman -

Jadi tulangan kolom 32D25, dengan penempatan tulangan 9D25 pada masing-masing sisi dapat dipergunakan pada kolom K2 Lantai 1.

Dengan cara yang sama dapat dihitung penulangan lentur dan aksial kolom-kolom yang lain, disajikan pada Tabel 8.8.



Gambar 8.9 Menentukan harga-harga ϕP_o , ϕP_x , dan ϕP_y pada Kolom K2 Lantai 1

Tabel 8.8 Penulangan Kombinasi Lentur dan Aksial Kolom Daktilitas Terbatas

Ko- lom	Lt.	Arah	Ukuran b x h (mm)	δ_s	$M_{u,k}$ (kNm)	M_c (kNm)	$P_u/N_{u,k}$ (kN)	e (mm)	Tul. total	Tul. tiap sisi	ρ total	Diagram Interaksi Kolom			
												ϕP (kN)	ϕP_o (kN)	$\phi P_n \geq P_u$ (kN)	ϕM_n (kNm)
[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]	[11]	[12]	[13]	[14]	[15]	[16]
K1	1	Sb-x	700x700	1,4629	493,7434	722,2972	3576,4134	202	32D25	9D25	0,032	5600,0000	10850,1300	3631,2008	733,3622
		Sb-y	700x700	1,6027	533,3241	854,7585		239		9D25			5000,0000		867,8527
	2	Sb-x	700x700	1,3818	537,8772	743,2387	2769,2580	268	32D25	9D25	0,032	4500,0000	10850,1300	2781,0471	746,4028
		Sb-y	700x700	1,4902	554,8416	826,8250		299		9D25			4100,0000		830,3449
	3	Sb-x	700x700	1,2451	527,0022	656,1704	1906,1099	344	32D25	9D25	0,032	3500,0000	10850,1300	2169,9950	747,0118
		Sb-y	700x700	1,3257	495,2434	656,5442		344		9D25			3500,0000		747,4373
	4	Sb-x	700x700	1,0955	547,9727	600,3041	1049,8391	572	32D25	9D25	0,032	2700,0000	10850,1300	1533,4583	876,8404
		Sb-y	700x700	1,1592	381,1187	441,7928		421		9D25			2500,0000		645,3092
	5	Sb-x	700x700	1,1251	555,5819	625,0852	628,0071	995	32D25	9D25	0,032	2000,0000	10850,1300	712,1011	708,7879
		Sb-y	700x700	1,0292	210,0029	210,0029		344		9D25			950,0000		245,0768
K2	1	Sb-x	700x700	1,4474	593,6729	859,2822	4557,8337	189	32D25	9D25	0,032	5800,0000	10850,1300	4562,0372	860,0746
		Sb-y	700x700	1,3040	503,4646	656,5178		144		9D25			6700,0000		657,1233
	2	Sb-x	700x700	1,4100	587,3415	828,1515	3371,0214	246	32D25	9D25	0,032	4800,0000	10850,1300	3411,1102	838,0000
		Sb-y	700x700	1,2177	524,3944	638,5551		189		9D25			5650,0000		646,1489
	3	Sb-x	700x700	1,2451	557,5623	694,2208	1952,6831	356	32D25	9D25	0,032	3050,0000	10850,1300	2135,5557	759,2360
		Sb-y	700x700	1,1353	438,5556	497,8922		255		9D25			4300,0000		544,5207
	4	Sb-x	700x700	1,0955	229,5463	251,4680	828,4981	304	32D25	9D25	0,032	1500,0000	10850,1300	860,0396	261,0415
		Sb-y	700x700	1,0630	316,4690	336,4065		406		9D25			1700,0000		349,2138
K3	1	Sb-x	700x700	1,2039	360,4187	433,9081	2060,1189	211	16D25	5D25	0,016	4300,0000	8809,1250	2071,7838	436,3650
		Sb-y	700x700	1,6099	453,7388	730,4741		355		5D25			2750,0000		734,6102
	2	Sb-x	700x700	1,1771	374,3211	440,6134	1667,4722	264	16D25	5D25	0,016	3600,0000	8809,1250	1669,3328	441,1050
		Sb-y	700x700	1,4594	465,5453	679,4168		407		5D25			2300,0000		680,1749
	3	Sb-x	700x700	1,1242	350,5438	394,0813	1148,6460	343	16D25	5D25	0,016	2400,0000	8809,1250	1245,1005	427,1733
		Sb-y	700x700	1,3257	442,4165	586,5116		511		5D25			2000,0000		635,7623
	4	Sb-x	700x700	1,0716	293,0936	314,0791	652,2209	482	16D25	5D25	0,016	1500,0000	8809,1250	683,8828	329,3260
		Sb-y	700x700	1,1592	412,2795	477,9144		733		5D25			1100,0000		501,1146
	5	Sb-x	700x700	1,0109	125,7149	127,0852	213,8619	594	16D25	5D25	0,016	1000,0000	8809,1250	468,0593	278,1393
		Sb-y	700x700	1,0292	176,0907	181,2325		847		5D25			800,0000		396,6465
K4	1	Sb-x	700x700	1,2039	449,3895	541,0200	2031,4959	266	16D25	5D25	0,016	3500,0000	8809,1250	2183,8356	581,5905
		Sb-y	700x700	1,1520	466,9644	537,9430		265		5D25			3500,0000		578,2828
	2	Sb-x	700x700	1,1771	475,1993	559,3571	1626,6961	344	16D25	5D25	0,016	2800,0000	8809,1250	1945,9248	669,1273
		Sb-y	700x700	1,1047	372,1103	411,0702		253		5D25			3700,0000		491,7402
	3	Sb-x	700x700	1,1242	433,5055	487,3469	1148,7330	424	16D25	5D25	0,016	2000,0000	8809,1250	1333,1241	565,5743
		Sb-y	700x700	1,0758	372,7670	401,0227		349		5D25			2750,0000		465,3937
	4	Sb-x	700x700	1,0716	342,2072	366,7092	679,7774	539	16D25	5D25	0,016	1200,0000	8809,1250	866,1028	467,2234
		Sb-y	700x700	1,0449	315,3994	329,5608		485		5D25			2300,0000		419,8927
	5	Sb-x	700x700	1,0109	125,8530	127,2248	246,9810	515	16D25	5D25	0,016	500,0000	8809,1250	281,4406	144,9756
		Sb-y	700x700	1,0148	80,5707	81,7631		331		5D25			600,0000		93,1710
K5	1	Sb-x	700x700	1,2039	481,9991	580,2787	2436,3864	238	16D25	5D25	0,016	3900,0000	8298,8800	2461,9485	586,3669
		Sb-y	700x700	1,3040	569,1111	742,1209		305		5D25			3700,0000		749,9071
	2	Sb-x	700x700	1,1771	498,9088	587,2655	1854,2792	317	16D25	5D25	0,016	3100,0000	8298,8800	1867,7073	591,5183
		Sb-y	700x700	1,2177	524,3853	638,5440		344		5D25			3000,0000		643,1681
	3	Sb-x	700x700	1,1242	461,8369	519,1970	1231,6981	422	16D25	5D25	0,016	2400,0000	8298,8800	1256,0156	529,4476
		Sb-y	700x700	1,1353	510,1882	579,2167		470		5D25			2000,0000		590,6522
	4	Sb-x	700x700	1,0716	297,4443	318,7413	742,9136	429	16D25	5D25	0,016	1000,0000	8298,8800	749,5986	321,6095
		Sb-y	700x700	1,0630	439,2691	466,9431		629		5D25			2200,0000		471,1448
	5	Sb-x	700x700	1,0109	206,6904	208,9433	287,2254	727	16D25	5D25	0,016	750,0000	8298,8800	347,2823	252,6320
		Sb-y	700x700	1,0177	300,9090	306,2351		1066		5D25			600,0000		370,2668
K6	1	Sb-x	250x700	1,2370	187,3993	231,8129	1063,1187	218	20D22	8D22	0,043	2100,0000	4392,8800	1092,6382	238,2497
		Sb-y	700x250	1,1520	92,0900	106,0877		100		6D22			1500,0000		109,0334
	2	Sb-x	250x700	1,3081	161,0721	210,6984	796,9540	264	20D22	8D22	0,043	2000,0000	4392,8800	932,5236	246,5403
		Sb-y	700x250	1,1047	93,0350	102,7758		129		6D22			1250,0000		120,2589
	3	Sb-x	250x700	1,1940	153,5751	183,3687	558,2060	328	20D22	8D22	0,043	1500,0000	4392,8800	645,1044	211,9145
		Sb-y	700x250	1,0758	83,8589	90,2154		162		6D22			900,0000		104,2596
	4	Sb-x	250x700	1,1130	128,6607	143,1994	338,0996	424	20D22	8D22	0,043	1200,0000	4392,8800	515,7230	218,4303
		Sb-y	700x250	1,0449	63,3360	66,1798		196		6D22			750,0000		100,9479
	5	Sb-x	250x700	1,0452	104,0298	108,7319	137,4114	791	20D22	8D22	0,043	950,0000	4392,8800	353,9835	280,1028
		Sb-y	700x250	1,0148	39,5304	40,1154		292		6D22			500,0000		103,3408

Tabel 8.8. Lanjutan

Ko- lom	Lt	Arah	Ukuran b x h (mm)	δ_s	Mu,k (kNm)	Mc (kNm)	$Pu/Nu,k$ (kN)	e (mm)	Tul total	Tul tiap sisi	ρ total	Diagram Interaksi Kolom			ϕMn (kNm)
												ϕP (kN)	ϕPo (kN)	$\phi Pn > Pu$ (kN)	
[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]	[11]	[12]	[13]	[14]	[15]	[16]
K7	1	Sb-x	250x700	1,2370	189,3795	234,2624	1222,0929	192	20D22	8D22	0,043	2500,0000	4392,8800	1223,2114	234,4768
		Sb-y	700x250	1,3040	98,3578	128,2586		105		6D22			1550,0000		128,3760
	2	Sb-x	250x700	1,3081	176,2383	230,5373	925,5389	249	20D22	8D22	0,043	2050,0000	4392,8800	943,2505	234,9490
		Sb-y	700x250	1,2177	97,5951	118,8416		128		6D22			1250,0000		121,1158
	3	Sb-x	250x700	1,1940	166,1570	198,3915	612,0370	324	20D22	8D22	0,043	1550,0000	4392,8800	599,6929	194,3901
		Sb-y	700x250	1,1353	87,2628	99,0695		162		6D22			800,0000		97,0713
	4	Sb-x	250x700	1,1130	153,2958	170,6182	367,3047	465	20D22	8D22	0,043	1000,0000	4392,8800	386,0198	179,3117
		Sb-y	700x250	1,0630	72,1371	76,6817		209		6D22			550,0000		80,5889
5	Sb-x	250x700	1,0452	93,9652	98,2124	152,5629	644	20D22	8D22	0,043	700,0000	4392,8800	220,5430	141,9746	
	Sb-y	700x250	1,0177	64,5152	65,6571		430		6D22			300,0000		94,9131	
K8	1	Sb-x	250x700	1,1251	160,8663	180,9907	780,3075	232	20D22	8D22	0,043	2100,0000	4392,8800	924,3146	214,3928
		Sb-y	700x250	1,1520	95,6211	110,1555		141		6D22			1200,0000		130,4849
	2	Sb-x	250x700	1,0589	151,5171	160,4415	651,4034	246	20D22	8D22	0,043	2000,0000	4392,8800	656,8753	161,7892
		Sb-y	700x250	1,1047	92,6339	102,3327		157		6D22			800,0000		103,1923
	3	Sb-x	250x700	1,0416	140,0280	145,8532	463,6468	315	20D22	8D22	0,043	1900,0000	4392,8800	472,3986	148,6063
		Sb-y	700x250	1,0758	94,2219	101,3639		219		6D22			550,0000		103,2773
	4	Sb-x	250x700	1,0266	112,9212	115,9249	278,4936	416	20D22	8D22	0,043	1100,0000	4392,8800	282,5982	117,6335
		Sb-y	700x250	1,0449	75,0518	78,4216		282		6D22			350,0000		79,5775
	5	Sb-x	250x700	1,0115	89,8632	90,8966	119,2149	762	20D22	8D22	0,043	700,0000	4392,8800	192,2733	146,6007
		Sb-y	700x250	1,0148	70,8826	71,9317		603		6D22			250,0000		116,0135
K9	1	Sb-x	250x700	1,1251	189,4881	213,1931	1007,5842	212	20D22	8D22	0,043	2100,0000	4392,8800	1038,5994	219,7555
		Sb-y	700x250	1,3040	84,3191	109,9521		109		6D22			1400,0000		113,3366
	2	Sb-x	250x700	1,0589	169,0719	179,0302	739,0862	242	20D22	8D22	0,043	1900,0000	4392,8800	883,3860	213,9842
		Sb-y	700x250	1,2177	79,8166	97,1927		132		6D22			1200,0000		116,1686
	3	Sb-x	250x700	1,0416	143,8580	149,8425	489,9558	306	20D22	8D22	0,043	1400,0000	4392,8800	625,8779	191,4114
		Sb-y	700x250	1,1353	69,2937	78,6691		161		6D22			900,0000		100,4933
K9	4	Sb-x	250x700	1,0266	134,7549	138,3394	318,0864	435	20D22	8D22	0,043	1200,0000	4392,8800	561,1160	244,0357
		Sb-y	700x250	1,0630	56,9221	60,5082		190		6D22			850,0000		106,7386
	5	Sb-x	250x700	1,0115	103,8744	105,0690	156,7713	670	20D22	8D22	0,043	600,0000	4392,8800	209,5400	140,4348
		Sb-y	700x250	1,0823	42,9387	46,4726		296		6D22			300,0000		62,1151

Keterangan Tabel 8.8.

- [1] Kolom yang ditinjau
- [2] Lantai kolom yang ditinjau
- [3] Arah momen yang bekerja sejajar sb-x dan sb-y
- [4] Ukuran kolom
- [5] δ_s = faktor pembesaran momen (Tabel 8.7)
- [6] Mu,k = momen rencana kolom terpakai
- [7] $Mc = \delta_s \cdot Mu,k$ (Momen rencana yang telah diperbesar)
- [8] $Pu = Nu,k$ = gaya aksial rencana kolom terpakai
- [9] $e = Mc/Pu$ (eksentrisitas)
- [10] Tulangan terpasang
- [11] Tulangan terpasang pada tiap-tiap sisi
- [12] ρ = rasio tulangan terpasang
- [13] ϕPx dan ϕPy (dilihat pada diagram interaksi kolom)
- [14] ϕPo (dilihat pada diagram interaksi kolom)
- [15] ϕPn = hasil dari persamaan Bresler $1/\phi Pn = 1/\phi Px + 1/\phi Py - 1/\phi Po$
- [16] $\phi Pn \geq Pu$ (tulangan terpasang aman digunakan)
- [16] $\phi Mn = \phi Pn \cdot e$ (Momen nominal kolom) dengan $\phi = 0,65$

8.2.5 Gaya Geser Rencana Kolom

Gaya geser rencana kolom diperoleh dengan persamaan berikut (Andriono dan Takim, 1993)

$$V_{u,k} = 1,05.(V_{D,k,x} + V_{L,k,x} + \omega_d K.(V_{E,k,x} + 0,3.V_{E,k,y}))$$

dengan:

$$\omega_d = 1 \text{ (untuk lantai 1 dan 5)}$$

$$\omega_d = 1,3 \text{ (untuk lantai 2,3, dan 4)}$$

$$K = 2$$

Sebagai contoh perhitungan ditinjau pada kolom K2 lantai 1.

Diketahui:

$$V_{D,k,x} = 56,3700 \text{ kN}$$

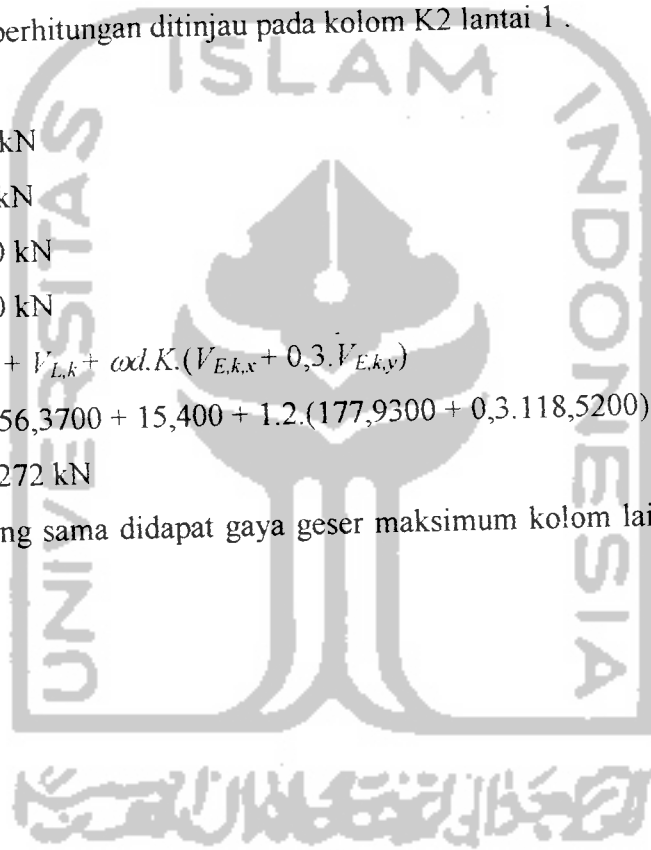
$$V_{L,k,x} = 15,4000 \text{ kN}$$

$$V_{E,k,x} = 177,9300 \text{ kN}$$

$$V_{E,k,y} = 118,5200 \text{ kN}$$

$$\begin{aligned} V_{u,k} &= 1,05.(V_{D,k} + V_{L,k} + \omega_d K.(V_{E,k,x} + 0,3.V_{E,k,y})) \\ &= 1,05.(56,3700 + 15,400 + 1,2.(177,9300 + 0,3.118,5200)) \\ &= 445,1272 \text{ kN} \end{aligned}$$

Dengan cara yang sama didapat gaya geser maksimum kolom lainnya disajikan pada Tabel 8.9.



Tabel 8.9 Gaya Geser Rencana Kolom Daktililitas Terbatas (Satuan kN)

Kolom	Lantai	Sejajar Sumbu x					Sejajar Sumbu y					Akibat Gempa Kiri		Akibat Gempa Kanan	
		$V_{D,k-x}$	$V_{L,k-x}$	$V_{Eki,k-x}$	$V_{Eka,k-x}$	$V_{D,k-y}$	$V_{L,k-y}$	$V_{Eki,k-y}$	$V_{Eka,k-y}$	$V_{u,k-x1}$	$V_{u,k-y1}$	$V_{u,k-x2}$	$V_{u,k-y2}$		
K1	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]	[11]	[12]	[13]	[14]		
	1	-65,7600	-17,5400	95,8700	-93,7500	0,2700	0,2300	111,5800	-111,0800	184,1574	295,2411	-304,7155	-291,8055		
	2	-127,4600	-37,7700	69,4600	-69,3500	0,1400	0,2300	110,4900	-110,2200	106,6256	358,9139	-362,4697	-357,3098		
	3	-112,8200	-33,1300	58,3000	-57,7800	-1,9900	-0,9600	91,7500	-91,5500	81,0548	295,1277	-308,7731	-300,3508		
	4	-172,1900	-50,6000	37,1000	-36,3900	-0,6400	-0,7100	66,5400	-66,6500	-78,1502	210,6216	-310,2884	-213,1754		
K2	5	-172,1900	-50,6000	37,1000	-36,3900	-3,4000	-0,9900	35,0500	-33,2100	-133,9380	92,3685	-265,0166	-97,2762		
	1	56,3700	15,4000	177,9300	-177,4500	0,6800	0,2100	118,5200	-117,5800	445,1272	361,9224	-371,3619	-357,7770		
	2	107,2100	32,1300	170,1200	-169,7800	1,4500	0,4100	114,6000	-113,3700	457,9848	454,1393	-410,0424	-446,5969		
	3	89,5700	26,6200	125,0100	-124,7000	-0,4000	-1,1800	89,1200	-90,5800	429,0129	344,0218	-292,6165	-351,0717		
	4	137,1700	40,8100	66,5700	-66,1600	3,1000	0,8000	71,1500	-63,0200	334,3505	195,4491	8,2404	-169,9278		
K3	1	-10,8700	-2,1200	58,2000	-56,5900	-21,6000	-9,9300	77,5200	-76,3700	157,4181	166,3515	-180,5916	-229,1352		
	2	-20,1600	-4,6000	44,5600	-44,1100	-38,7700	-21,3500	61,0500	-60,8900	145,6508	140,0351	-196,2872	-246,8981		
	3	-21,5100	-5,0700	37,3300	-36,7200	-37,5500	-20,4200	51,0200	-50,5600	115,7873	108,9894	-169,5632	-228,9710		
	4	-23,3900	-5,5300	26,5400	-25,5800	-43,4700	-22,1800	34,3800	-35,6900	70,2454	46,6612	-129,4295	-187,3162		
	5	-21,4800	-5,1500	8,8700	-9,2400	-33,2700	-13,4700	16,4400	-13,0800	1,0227	-8,9649	-55,6059	-82,3662		
K4	1	-2,6000	-1,1900	85,0600	-83,8900	-4,0000	-0,5900	57,9000	-57,7200	211,1235	170,3583	-216,5121	-178,8822		
	2	-5,3500	-2,4800	81,9000	-81,1800	-6,4600	-1,1200	44,0300	-44,0000	251,4261	179,3190	-247,2674	-194,5654		
	3	-6,2700	-2,6700	68,8400	-68,1100	-7,3200	-1,2300	34,1900	-34,1500	206,5478	140,7412	-223,2962	-157,9891		
	4	-6,6000	-2,8900	50,1100	-49,2900	-7,7800	-1,3200	23,1100	-22,9800	145,7629	94,5754	-163,3468	-112,6589		
	5	-7,6400	-2,3400	26,4700	-26,6000	-10,9900	-1,3800	5,4400	-5,5800	48,5352	15,1116	-69,8544	-41,4645		
K5	1	9,3100	2,4900	92,2100	-91,9300	-19,1300	-4,8100	111,1300	-109,0300	276,0429	266,3283	-249,3519	-312,0159		
	2	17,6000	5,2300	86,6000	-86,3900	-34,9900	-9,9500	89,2000	-88,9500	300,0999	267,2544	-284,7233	-360,7739		
	3	17,5500	5,1500	70,2200	-70,0100	-33,8500	-9,5900	73,5200	-71,4000	275,7485	212,6078	-225,7689	-297,8722		
	4	18,1700	5,4500	48,0300	-47,8100	-41,7800	-12,0800	24,0900	-49,3200	175,6526	48,5493	-146,1134	-230,3530		
	5	19,3300	5,1300	20,9900	-20,9800	1,1800	0,0000	59,6300	2,2000	107,3289	139,6857	-16,9890	-7,3584		
K6	1	-7,6700	-1,9800	31,1900	-30,9600	-0,1600	0,0300	17,9700	-17,9900	66,6876	57,2502	-86,4822	-57,4203		
	2	-12,5800	-3,8900	25,6400	-25,6300	-0,1400	0,0200	21,3200	-21,3200	70,1648	79,0768	-104,7245	-79,3206		
	3	-12,2200	-3,6700	21,3700	-21,3200	-0,2400	0,0400	18,7700	-18,7700	57,0282	68,5341	-90,2607	-68,9132		
	4	-12,0200	-3,7800	15,3700	-15,3200	-0,3200	0,0500	13,5800	-13,6000	36,4921	49,3779	-69,5520	-49,9586		
	5	-15,5700	-3,8200	7,5200	-7,4500	-0,4100	0,0600	8,2100	-8,2000	0,6048	21,6111	-41,1705	-22,2810		

Tabel 8.9. lanjutan

Kolom	Lantai	Sejajar Sumbu x				Sejajar Sumbu y				Akibat Gempa Kiri		Akibat Gempa Kanan	
		$V_{D,k-x}$	$V_{L,k-x}$	$V_{Eki,k-x}$	$V_{Eka,k-x}$	$V_{D,k-y}$	$V_{L,k-y}$	$V_{Eki,k-y}$	$V_{Eka,k-y}$	$V_{u,k-x1}$	$V_{u,k-y1}$	$V_{u,k-x2}$	$V_{u,k-y2}$
[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]	[11]	[12]	[13]	[14]
K7	1	4,9300	1,4400	51,6900	-51,6100	-0,4000	-0,0600	18,5700	-19,0400	126,9366	71,0787	-113,6877	-72,9813
	2	8,1800	2,8300	49,1800	-49,1500	-0,8200	-0,1600	18,3700	-18,6200	160,8669	89,3995	-137,8688	-92,1155
	3	7,4500	2,5600	39,9900	-39,9600	-0,5400	-0,0600	15,1200	-15,0700	132,0665	73,3994	-110,9226	-74,4983
	4	7,1000	2,6200	26,9400	-26,9100	-0,9100	-0,1600	9,8800	-10,6000	91,8439	47,9128	-71,9397	-52,1008
	5	8,5800	2,3500	10,1800	-10,1400	-1,5600	-0,4800	3,0100	-12,6400	34,7508	10,5924	-17,7807	-35,0742
K8	1	-6,1700	-1,1500	25,8500	-25,5800	-2,5600	-0,3300	21,0700	-21,0300	59,8731	57,4980	-74,6529	-63,3129
	2	-9,8900	-2,2500	23,2600	-23,1900	-3,8300	-0,6400	23,1800	-23,1800	69,7372	77,6378	-95,0401	-86,9675
	3	-9,9800	-2,1600	19,8700	-19,7800	-3,6800	-0,6000	20,0200	-20,0100	57,8945	66,4341	-83,1346	-75,3211
	4	-9,9200	-2,2500	14,6400	-14,4500	-3,7800	-0,6200	14,3700	-14,3500	38,9577	46,6003	-63,9797	-55,6301
	5	-13,4800	-1,9400	7,8600	-8,0700	-3,2800	-0,5000	9,0500	-9,0700	6,0165	19,9878	-38,8521	-28,1001
K9	1	3,8300	0,8400	51,9500	-51,8200	2,4300	0,4500	13,2100	-13,8900	122,3208	63,4935	-112,6692	-58,7916
	2	6,0200	1,6800	47,1500	-47,0900	4,0500	0,8400	12,6400	-13,0800	147,1567	78,2576	-131,1832	-69,1406
	3	5,1100	1,4300	38,2000	-38,1400	4,5800	0,9500	10,5000	-10,8700	119,7525	65,7573	-106,1577	-55,1053
	4	4,3500	1,4400	26,0300	-25,9500	4,7800	0,9800	7,1000	-7,6200	82,9563	46,7496	-71,0048	-36,0077
	5	6,3300	0,9900	9,9600	-10,0600	4,0000	0,5300	2,1000	-9,0700	29,9250	15,4413	-19,1541	-20,6283

Keterangan Tabel 8.9:

- [1] Kolom yang ditinjau
 [2] Tingkat lantai pada kolom yang ditinjau
 [3] $V_{D,k-x}$ = Gaya geser kolom akibat beban mati sejajar sb-x
 [4] $V_{L,k-x}$ = Gaya geser kolom akibat beban hidup sejajar sb-x
 [5] $V_{Eki,k-x}$ = Gaya geser kolom akibat beban gempa kiri sejajar sb-x
 [6] $V_{Eka,k-x}$ = Gaya geser kolom akibat beban gempa kanan sejajar sb-x
 [7] $V_{D,k-y}$ = Gaya geser kolom akibat beban mati sejajar sb-y
 [8] $V_{L,k-y}$ = Gaya geser kolom akibat beban hidup sejajar sb-y
 [9] $V_{Eki,k-y}$ = Gaya geser kolom akibat beban gempa kiri sejajar sb-y
 [10] $V_{Eka,k-y}$ = Gaya geser kolom akibat beban gempa kanan sejajar sb-y
 [11] $V_{u,k-x1} = 1,05(N_{D,k-x} + N_{L,k-x} + \omega d \cdot k(N_{Eka,k-x} + 0,3N_{Eki,k-x}))$
 (Gaya geser rencana kolom akibat gempa kiri sejajar sb-x)
 [12] $V_{u,k-y1} = 1,05(N_{D,k-y} + N_{L,k-y} + \omega d \cdot k(N_{Eka,k-y} + 0,3N_{Eki,k-y}))$
 (Gaya geser rencana kolom akibat gempa kiri sejajar sb-y)
 [13] $V_{u,k-x2} = 1,05(N_{D,k-x} + N_{L,k-x} + \omega d \cdot k(N_{Eka,k-x} + 0,3N_{Eki,k-x}))$
 (Gaya geser rencana kolom akibat gempa kanan sejajar sb-x)
 [14] $V_{u,k-y2} = 1,05(N_{D,k-y} + N_{L,k-y} + \omega d \cdot k(N_{Eka,k-y} + 0,3N_{Eki,k-y}))$
 (Gaya geser rencana kolom akibat gempa kanan sejajar sb-y)
 dengan: $k = 2,$
 $\omega d = 1$ (untuk lantai 1 dan 5)
 $\omega d = 1,3$ (untuk lantai 2,3, dan 4)

8.2.6 Penulangan Geser Kolom

Sebagai contoh perhitungan penulangan geser kolom ditinjau pada kolom K2 lantai 1, adalah sebagai berikut ini. (Kusuma, dan Andriono, 1993)

- Penulangan geser sepanjang l_o

Syarat panjang l_o dari muka balok (SK-SNI T-15-1991-03):

$$l_o \geq h = 700 \text{ mm, bila } N_{u,k} \leq 0,3 \cdot A_g \cdot f_c'$$

$$l_o \geq 1,5 h = 1,5 \cdot 700 = 1050 \text{ mm, bila } N_{u,k} > 0,3 \cdot A_g \cdot f_c'$$

$$(N_{u,k} = 4557,8337 \text{ kN}) > (0,3 \cdot 700 \cdot 700 \cdot 25 = 3675 \text{ kN}), \text{ dipakai } l_o = 1050 \text{ mm}$$

$$0,5 \cdot V_c = 0,5 \cdot \left[1 + \frac{N_{u,k}}{14 \cdot A_g} \right] \cdot \frac{1}{6} \sqrt{f_c'} \cdot b \cdot d = 0,5 \cdot \left[1 + \frac{4557,8337}{14 \cdot 700 \cdot 700} \right] \cdot \frac{1}{6} \sqrt{25} \cdot 700 \cdot 635,5 = 313,7962 \text{ kN}$$

$$V_{s,k} = V_{u,k} / 0,6 - 0,5 \cdot V_c = 445,1272 / 0,6 - 313,7962 = 428,0824 \text{ kN}$$

$$S = (A_v \cdot f_y \cdot d) / V_{s,k} = 3 \cdot 0,25 \cdot \pi \cdot 12^2 \cdot 240 \cdot 635,5 / 4280824 = 127,83 \text{ mm}$$

Jarak maksimum tulangan geser pada daerah l_o (SK-SNI T-15-1991-03):

$$- 1/2 \cdot b = 1/2 \cdot 700 = 350 \text{ mm}$$

$$- 10 \text{ kali diameter tulangan longitudinal} = 10 \cdot 25 = 250 \text{ mm}$$

$$- 200 \text{ mm}$$

dipakai **3P12-120**

Cek tulangan geser,

$$V_{s,k} = (A_v \cdot f_y \cdot d) / S = (3 \cdot 0,25 \cdot \pi \cdot 12^2 \cdot 240 \cdot 635,5 / 120) \cdot 10^{-3} = 331,7313 \text{ kN}$$

$$0,6(V_{s,k} + V_c) = 461,8893 \text{ kN} \geq V_{u,k} = 445,1272 \text{ kN} \quad \text{- aman -}$$

- Penulangan geser daerah diluar l_o

$$V_c = \left[1 + \frac{N_{u,k}}{14 \cdot A_g} \right] \cdot \frac{1}{6} \sqrt{f_c'} \cdot b \cdot d = \left[1 + \frac{4557,8337}{14 \cdot 700 \cdot 700} \right] \cdot \frac{1}{6} \sqrt{25} \cdot 700 \cdot 635,5 = 627,5925 \text{ kN}$$

$$V_{s,k} = V_{u,k} / 0,6 - V_c = 445,1272 / 0,6 - 627,5925 = 114,2862 \text{ kN}$$

$$S = (A_v \cdot f_y \cdot d) / V_{s,k} = 2 \cdot 0,25 \cdot \pi \cdot 12^2 \cdot 240 \cdot 635,5 / 1142862 = 319,2019 \text{ mm}$$

dipakai **2P12-250**

Cek tulangan geser kolom,

$$V_{s,k} = (A_v \cdot f_y \cdot d) / S = (2 \cdot 0,25 \cdot \pi \cdot 12^2 \cdot 240 \cdot 635,5 / 250) \cdot 10^{-3} = 145,9323 \text{ kN}$$

$$0,6(V_{s,k} + V_c) = 464,1112 \text{ kN} \geq V_{u,k} = 445,1272 \text{ kN} \quad \text{- aman -}$$

Dengan cara yang sama didapat dimensi dan jarak sengkang geser kolom lainnya yang disajikan pada Tabel 8.10.

Tabel 8.10 Penulangan Geser Kolom Daktilitas Terbatas

Ko- lom	Lan- tai	<i>l</i>	<i>l_n</i>	<i>b</i>	<i>h</i>	<i>N_{u,k}</i>	0,3 <i>A_gf_c</i>	Lokasi	Jarak	<i>V_{u,k}</i>	<i>V_c</i>	<i>V_s</i>	<i>S</i>	<i>S_{max}</i>	Tul.ges terpakai	<i>V_{u,k} ≤</i> 0,6(<i>V_s+V_c</i>)
[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]	[11]	[12]	[13]	[14]	[15]	[16]	[17]
K1	1	5,4	4,1	700	700	3576,4134	3675,0000	Pada lo	0-700	304,7155	283,9840	325,4470	112,10	200	2P12- 100	389,2796
								Luar lo	sisa	304,7155	567,9681	-60,1089	-606,92	400	2P12- 300	413,7439
	2	3,8	3,1	700	700	2769,2580	3675,0000	Pada lo	0-700	362,4697	262,0206	342,0955	106,64	200	2P12- 100	376,1016
								Luar lo	sisa	362,4697	524,0413	80,0749	455,59	400	2P12- 300	387,3878
	3	3,8	3,1	700	700	1906,1099	3675,0000	Pada lo	0-700	308,7731	238,5336	276,0882	132,14	200	2P12- 100	362,0094
								Luar lo	sisa	308,7731	477,0672	37,5546	971,43	400	2P12- 300	359,2034
	4	3,8	3,1	700	700	1049,8391	3675,0000	Pada lo	0-700	310,2884	215,2337	301,9136	120,83	200	2P12- 100	348,0294
								Luar lo	sisa	310,2884	430,4674	86,6799	420,88	400	2P12- 300	331,2435
	5	3,8	3,1	700	700	628,0071	3675,0000	Pada lo	0-700	265,0166	203,7553	326,2779	111,81	200	2P12- 100	341,1424
								Luar lo	sisa	265,0166	407,5106	34,1837	1067,22	400	2P12- 300	317,4694
K2	1	5,4	4,1	700	700	4557,8337	3675,0000	Pada lo	0-1050	445,1272	313,7962	428,0824	127,83	200	3P12- 100	500,9766
								Luar lo	sisa	445,1272	627,5925	114,2862	319,21	400	2P12- 250	464,1112
	2	3,8	3,1	700	700	3371,0214	3675,0000	Pada lo	0-700	457,9848	300,6668	462,6412	118,28	200	3P12- 100	508,7339
								Luar lo	sisa	457,9848	601,3335	147,2495	259,55	400	2P12- 250	465,0331
	3	3,8	3,1	700	700	1952,6831	3675,0000	Pada lo	0-700	429,0129	271,4546	443,5689	123,38	200	3P12- 100	491,2066
								Luar lo	sisa	429,0129	542,9092	152,5818	250,48	400	2P12- 250	429,9785
	4	3,8	3,1	700	700	828,4981	3675,0000	Pada lo	0-700	334,3505	209,2108	348,0400	154,73	200	3P12- 100	344,4157
								Luar lo	sisa	334,3505	418,4217	138,8292	262,78	400	2P12- 250	338,6087
K3	1	5,4	4,1	700	700	2060,1189	3675,0000	Pada lo	0-700	229,1352	242,7243	139,1677	262,14	200	2P12- 200	255,0792
								Luar lo	sisa	229,1352	485,4486	-103,5566	-352,29	400	2P12- 300	364,2323
	2	3,8	3,1	700	700	1667,4722	3675,0000	Pada lo	0-700	246,8981	232,0401	179,4568	203,29	200	2P12- 200	248,6686
								Luar lo	sisa	246,8981	464,0801	-52,5833	-693,79	400	2P12- 300	351,4111
	3	3,8	3,1	700	700	1148,6460	3675,0000	Pada lo	0-700	228,9710	217,9223	163,6960	222,86	200	2P12- 200	240,1980
								Luar lo	sisa	228,9710	435,8447	-54,2263	-672,76	400	2P12- 300	334,4699
	4	3,8	3,1	700	700	652,2209	3675,0000	Pada lo	0-700	187,3162	204,4142	107,7795	338,48	200	2P12- 200	232,0931
								Luar lo	sisa	187,3162	408,8283	-96,6347	-377,52	400	2P12- 300	318,2601
	5	3,8	3,1	700	700	213,8619	3675,0000	Pada lo	0-700	82,3662	192,4860	-55,2090	-660,79	200	2P12- 200	224,9362
								Luar lo	sisa	82,3662	384,9721	-247,6951	-147,28	400	2P12- 300	303,9463
K4	1	5,4	4,1	700	700	2031,4959	3675,0000	Pada lo	0-700	216,5121	241,9455	118,9080	306,80	200	2P12- 200	254,6119
								Luar lo	sisa	216,5121	483,8909	-123,0374	-296,51	400	2P12- 300	363,2976
	2	3,8	3,1	700	700	1626,6961	3675,0000	Pada lo	0-700	247,2674	230,9305	181,1818	201,35	200	2P12- 200	248,0029
								Luar lo	sisa	247,2674	461,8610	-49,7487	-733,32	400	2P12- 300	350,0797
	3	3,8	3,1	700	700	1148,7330	3675,0000	Pada lo	0-700	223,2962	217,9247	154,2356	236,53	200	2P12- 200	240,1994
								Luar lo	sisa	223,2962	435,8494	-63,6891	-572,81	400	2P12- 300	334,4727
	4	3,8	3,1	700	700	679,7774	3675,0000	Pada lo	0-700	163,3468	205,1640	67,0807	543,85	200	2P12- 200	232,5430
								Luar lo	sisa	163,3468	410,3280	-138,0834	-264,20	400	2P12- 300	319,1599
	5	3,8	3,1	700	700	246,3810	3675,0000	Pada lo	0-700	69,8544	193,3872	-75,9632	-474,01	200	2P12- 200	225,4770
								Luar lo	sisa	69,8544	386,7745	-270,3505	-134,94	400	2P12- 300	305,0278
K5	1	5,4	4,1	700	700	2436,3864	3675,0000	Pada lo	0-700	276,0429	278,2592	181,8123	200,65	200	2P12- 200	276,4001
								Luar lo	sisa	276,0429	556,5184	-96,4469	-378,26	400	2P12- 300	406,8741
	2	3,8	3,1	700	700	1854,2792	3675,0000	Pada lo	0-700	300,0999	260,8356	177,2822	205,78	200	2P12- 200	307,6391
								Luar lo	sisa	300,0999	521,6711	-21,5046	-1696,45	400	2P12- 300	385,9658
	3	3,8	3,1	700	700	1231,6981	3675,0000	Pada lo	0-700	275,7485	220,1823	177,3323	205,72	200	2P12- 200	283,2471
								Luar lo	sisa	275,7485	440,3645	19,2163	1898,47	400	2P12- 300	337,1818
	4	3,8	3,1	700	700	742,9136	3675,0000	Pada lo	0-700	175,6526	206,8820	85,8723	424,83	200	2P12- 200	233,5738
								Luar lo	sisa	175,6526	413,7640	-121,0097	-301,48	400	2P12- 300	321,2215
	5	3,8	3,1	700	700	287,2254	3675,0000	Pada lo	0-700	139,6857	194,4823	38,3272	951,85	200	2P12- 200	226,1340
								Luar lo	sisa	139,6857	388,9646	-156,1551	-233,62	400	2P12- 300	306,3419
K6	1	5,4	4,1	250	700	1063,1187	1312,5000	Pada lo	0-700	86,4822	95,5951	48,5419	497,04	200	2P10- 150	153,8670
								Luar lo	sisa	86,4822	191,1901	-47,0531	-512,77	400	2P10- 250	172,6201
	2	3,8	3,1	250	700	796,9540	1312,5000	Pada lo	0-700	104,7245	88,3525	86,1883	279,94	200	2P10- 150	149,5214
								Luar lo	sisa	104,7245	176,7050	-2,1641	-11148,7	400	2P10- 250	163,9290
	3	3,8	3,1	250	700	558,2060	1312,5000	Pada lo	0-700	90,2607	81,8559	68,5786	351,82	200	2P10- 150	145,6235
								Luar lo	sisa	90,2607	163,7119	-13,2774	-1817,19	400	2P10- 250	156,1331
	4	3,8	3,1	250	700	338,0996	1312,5000	Pada lo	0-700	69,5520	75,8667	40,0533	602,38	200	2P10- 150	142,0299
								Luar lo	sisa	69,5520	151,7333	-35,8133	-673,70	400	2P10- 250	148,9460
	5	3,8	3,1	250	700	137,4114	1312,5000	Pada lo	0-700	41,1705	70,4058	-1,7883	-13492,2	200	2P10- 150	138,7534
								Luar lo	sisa	41,1705	140,8115	-72,1940	-334,20	400	2P10- 250	142,3929

Tabel 8.10.lanjutan

Ko- lom	Lan- tai	<i>l</i>	<i>l_n</i>	<i>b</i>	<i>h</i>	<i>N_{u,k}</i>	0,3 <i>A_g f_c</i>	Lokasi	Jarak	<i>V_{u,k}</i>	<i>V_c</i>	<i>V_s</i>	<i>S</i>	<i>S_{max}</i>	Tul.ges terpakai	<i>V_{u,k} ≤</i> 0,6(<i>V_s+V_c</i>)
[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]	[11]	[12]	[13]	[14]	[15]	[16]	[17]
K7	1	5,4	4,1	250	700	1222,0929	1312,5000	Pada lo	0-700	126,9366	119,9051	91,6559	263,24	200	2P10- 150	168,4530
								Luar lo	0-700	126,9366	239,8101	-28,2491	-854,10	400	2P10- 250	201,7921
	2	3,8	3,1	250	700	925,5389	1312,5000	Pada lo	0-700	160,8669	110,2217	157,8898	152,81	200	2P10- 150	162,6430
								Luar lo	0-700	160,8669	220,4434	47,6681	506,16	400	2P10- 250	190,1720
	3	3,8	3,1	250	700	612,0370	1312,5000	Pada lo	0-700	132,0665	83,3207	136,7901	176,38	200	2P10- 150	146,5024
							Luar lo	0-700	132,0665	166,6415	53,4694	451,24	400	2P10- 250	157,8909	
	4	3,8	3,1	250	700	367,3047	1312,5000	Pada lo	0-700	91,8439	76,6614	76,4118	315,76	200	2P10- 150	142,5068
							Luar lo	0-700	91,8439	153,3227	-0,2495	-96688,60	400	2P10- 250	149,8996	
	5	3,8	3,1	250	700	152,5629	1312,5000	Pada lo	0-700	35,0742	70,8180	-12,3610	-1951,90	200	2P10- 150	139,0008
							Luar lo	0-700	35,0742	141,6361	-83,1791	-290,07	400	2P10- 250	142,8876	
K8	1	5,4	4,1	250	700	780,3075	1312,5000	Pada lo	0-700	74,6529	87,8995	36,5220	660,63	200	2P10- 150	149,2497
								Luar lo	0-700	74,6529	175,7990	-51,3775	-469,61	400	2P10- 250	163,3854
	2	3,8	3,1	250	700	651,4034	1312,5000	Pada lo	0-700	95,0401	84,3919	74,0082	326,01	200	2P10- 150	147,1451
								Luar lo	0-700	95,0401	168,7839	-10,3837	-2323,59	400	2P10- 250	159,1763
	3	3,8	3,1	250	700	463,6468	1312,5000	Pada lo	0-700	83,1346	79,2829	59,2748	407,04	200	2P10- 150	144,0797
							Luar lo	0-700	83,1346	158,5658	-20,0081	-1205,88	400	2P10- 250	153,0455	
	4	3,8	3,1	250	700	278,4936	1312,5000	Pada lo	0-700	63,9797	74,2447	32,3881	744,95	200	2P10- 150	141,0568
							Luar lo	0-700	63,9797	148,4894	-41,8566	-576,43	400	2P10- 250	146,9996	
	5	3,8	3,1	250	700	119,2149	1312,5000	Pada lo	0-700	38,8521	69,9106	-5,1571	-4678,49	200	2P10- 150	138,4563
							Luar lo	0-700	38,8521	139,8212	-75,0677	-321,41	400	2P10- 250	141,7987	
K9	1	5,4	4,1	250	700	1007,5842	1312,5000	Pada lo	0-700	122,3208	94,0839	109,7841	219,77	200	2P10- 150	152,9603
								Luar lo	0-700	122,3208	188,1678	15,7002	1536,77	400	2P10- 250	170,8067
	2	3,8	3,1	250	700	739,0862	1312,5000	Pada lo	0-700	147,1567	86,7779	158,4833	152,24	200	2P10- 150	148,5767
								Luar lo	0-700	147,1567	173,5557	71,7055	336,48	400	2P10- 250	162,0394
	3	3,8	3,1	250	700	489,9558	1312,5000	Pada lo	0-700	119,7525	79,9988	119,5987	201,75	200	2P10- 150	144,5092
							Luar lo	0-700	119,7525	159,9976	39,5899	609,44	400	2P10- 250	153,9045	
	4	3,8	3,1	250	700	318,0864	1312,5000	Pada lo	0-700	82,9563	75,3221	62,9384	383,35	200	2P10- 150	141,7032
							Luar lo	0-700	82,9563	150,6442	-12,3837	-1948,33	400	2P10- 250	146,2925	
	5	3,8	3,1	250	700	156,7713	1312,5000	Pada lo	0-700	29,9250	70,9326	-21,0576	-1145,79	200	2P10- 150	139,0695
							Luar lo	0-700	29,9250	141,8651	-91,9901	-262,28	400	2P10- 250	143,0250	

Keterangan Tabel 8.10:

- [1] Kolom yang ditinjau
- [2] Lantai kolom yang ditinjau
- [3] *l* = panjang kolom
- [4] *l_n* = panjang bersih kolom
- [5] *b* = lebar penampang kolom
- [6] *h* = tinggi penampang kolom
- [7] *N_{u,k}* = gaya aksial terpakai kolom (Tabel 8.6)
- [8] 0,3 *A_g f_c* dengan *A_g = b · h* , *f_c' = 25 MPa*
- [9] Daerah penulangan geser
- [10] Jarak penulangan geser dari muka kolom
l_o = h = 700 mm untuk *N_{u,k} < 0,3 A_g f_c'*
l_o = 1,5h = 1050 mm untuk *N_{u,k} > 0,3 A_g f_c'*
l_o = 1,5h = 1050 mm untuk *N_{u,k} > 0,3 A_g f_c'*
- [11] *V_{u,k}* = gaya geser rencana kolom (Tabel 8.9)
- [12] *V_c = [1 + N_{u,k} / (14 A_g)] · (1/6) · (f_c' · 0,5 · b · d)*
(gaya geser beton)
- [13] *V_s = V_{u,k} / 0,6 - V_c*
- [14] *S = (A_v · f_y · d) / V_s* dengan:
diameter sengkang = 12 mm (untuk kolom K1 s/d K5),
diameter sengkang = 10 mm (untuk kolom K6 s.d K9)
f_y = 240 MPa d = 640 mm
- [15] *S_{maks} = 8 · d* tul. pokok
- [16] Tulangan geser kolom terpasang
- [17] *V_{u,k} ≤ 0,6 (V_s + V_c)* tulangan geser aman