Second Semester Examination
2017/2018 Academic Session

May/June 2018

EAS458 – Pre-Stressed Concrete Design
(Rekabentuk Konkrit Pra-Tegasan)

Duration : 2 hours
(Masa : 2 jam)

Please check that this examination paper consists of **FORTEEN (14)** pages of printed material including appendix before you begin the examination.

[Sila pastikan bahawa kertas peperiksaan ini mengandungi ***EMPAT BELAS (14)*** *muka surat yang bercetak termasuk lampiran sebelum anda memulakan peperiksaan ini.]*

Instructions : This paper contains **FIVE (5)** questions. Answer **FOUR (4)** questions.

*[**Arahan** : Kertas ini mengandungi **LIMA (5)** soalan. Jawab **EMPAT (4)** soalan.]*

In the event of any discrepancies, the English version shall be used.

[Sekiranya terdapat sebarang percanggahan pada soalan peperiksaan, versi Bahasa Inggeris hendaklah digunapakai.]

1. A post-tensioned prestressed beam of a rectangular section of 300 mm wide is to be designed for an imposed load of 6.6 kN/m uniformly distributed on a span of 15 m. The member is to be designed with a concrete strength class C40/50.

Satu rasuk prategasan pasca-tegangan segiempat tepat dengan kelebaran 300 mm perlu direkabentuk untuk menanggung beban kenaan teragih seragam 6.6 kN/m pada rentang 15 m. Struktur itu direka bentuk dengan kelas kekuatan konkrit C40/50.

(a). Given the density of prestressed concrete, 25 kN/m^3 and the characteristic compressive strength of the concrete at transfer is 27 MPa, propose a minimum possible depth of the post-tensioned prestressed beam if the loses is 15%.

Diberikan ketumpatan konkrit prategasan, 25 kN/m^3 dan kekuatan mampatan ciri konkrit ketika pemindahan ialah 27 MPa, cadangkan kedalaman minimum rasuk prategasan pasca-tegangan jika kehilangan adalah 15%.

[7 marks/*markah*]

(b). For the section proposed in (a), determine the minimum prestressing force required and its corresponding eccentricity at the mid-span.

Bagi keratan yang dicadangkan di (a), tentukan daya prategasan minimum yang diperlukan dan kesipian yang sepadan untuk tengah rentang.

[12 marks/*markah*]

(c). If the economic value of prestressing force is to be considered in the design of this section, determine the range of possible eccentricity at the mid-span for cable zone limit.

Sekiranya nilai ekonomi daya prategasan diambilkira dalam rekabentuk ini, tentukan julat kesipian yang mungkin pada tengah rentang bagi had zon kabel.

[6 marks/*markah*]

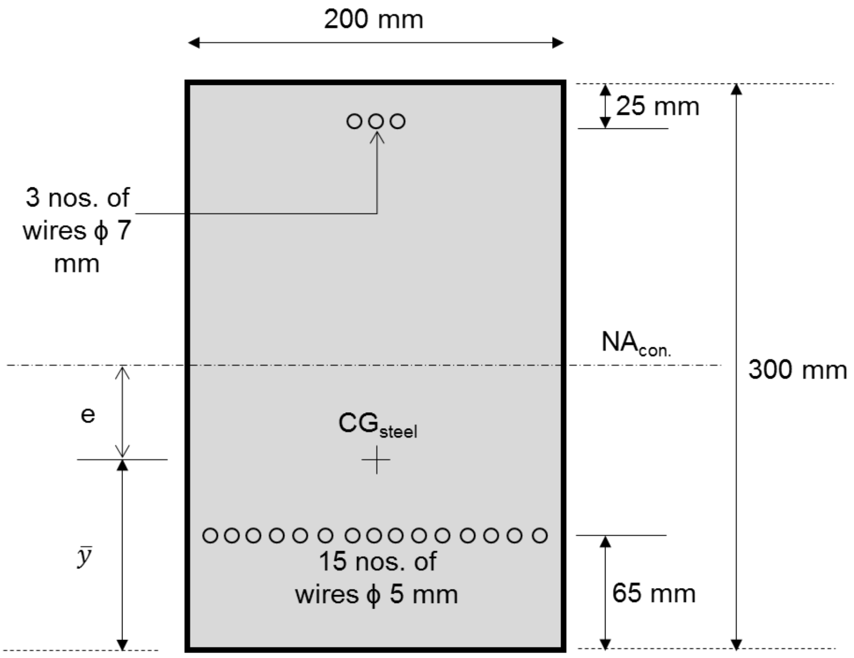
2. (a). A rectangular prestressed concrete beam with a cross-section of 300 mm depth and 200 mm width as shown in **Figure 1** is pre-tensioned by means of 15 nos. of wires of 5 mm diameter located 65 mm from the bottom of the beam and 3 nos. of wires with diameter of 7 mm, 25 mm from the top. The member is to be designed with a concrete strength of C50/60. Assuming the prestress in the steel as 840 N/mm^2, estimate the percentage of stress losses due to elastic shortening, creep and shrinkage of concrete.

Satu rasuk konkrit segiempat tepat prategasan dengan keratan rentas kedalaman 300 mm dan kelebaran 200 mm ditunjukkan dalam ***Rajah 1*** *ditegang menggunakan 15 bil. wayar berdiameter 5 mm terletak pada 65 mm dari bawah rasuk dan 3 bil. wayar berdiameter 7 mm terletak pada 25 mm dari atas rasuk. Rasuk direkabentuk dengan kekuatan konkrit C50/60. Dengan mengandaikan prategasan dalam keluli sebagai 840 N/mm^2, anggarkan peratusan kehilangan tegasan disebabkan oleh pemendekan elastik, rayapan dan pengecutan konkrit.*

Given:

Diberi:

$\gamma_{\text{con.}}$	=	25 kN/m^3
E_p	=	195 GPa
$E_{cm,0}$ (transfer)	=	32,000 MPa
$\varphi(\infty, t_0)$	=	1.6
ε_{cs}	=	330×10^{-6}



Note: $\bar{y}$ = centroid of the prestressing force

Figure 1/*Rajah 1*

[12 marks/*markah*]

(b). Precast beams using pre-stressing strands are commonly known as pre-stressed beams. Unlike the normal precast concrete beams that can be stored for several years, pre-stressed beams need to be installed within a short period of time upon completion. Discuss this phenomenon.

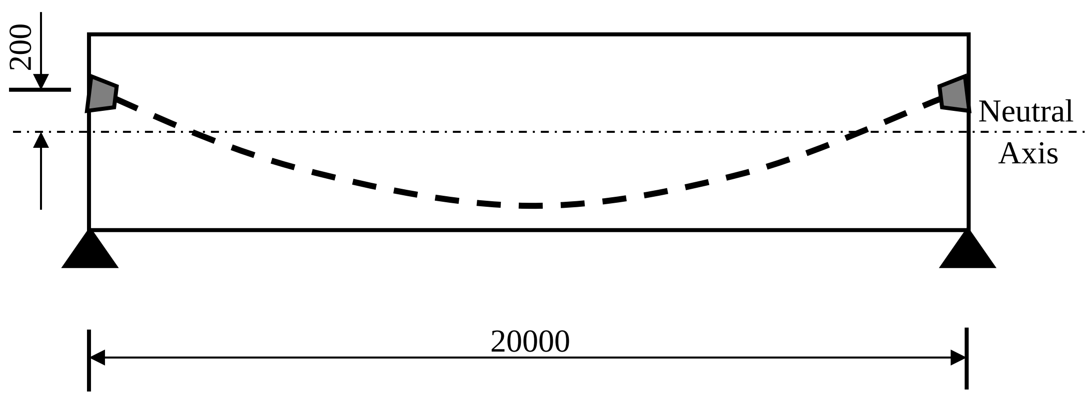
Rasuk pra-tuang yang menggunakan lembar pra-tegasan lazimnya dikenali sebagai rasuk pra-tegasan. Tidak seperti rasuk konkrit pra-tuang biasa yang boleh disimpan selama beberapa tahun, rasuk pra-tegasan perlu dipasang dalam jangka masa yang pendek selepas disiapkan. Bincangkan fenomena ini.

[3 marks/*markah*]

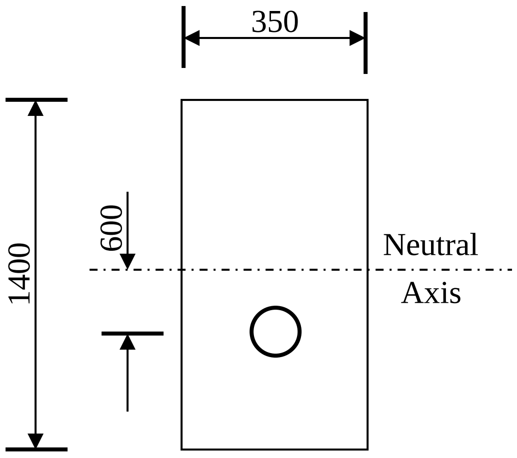
(c). The tendon profile of a simply supported post-tensioned beam is shown in **Figure 2**. The beam has been designed using concrete strength of C40/50 and a single parabolic tendon with 600 mm mid-span eccentricity. The initial pre-stressing force is 1800 kN and the anticipated total pre-stress loss is 28%. If the beam is supporting finishes load 4 kN/m and variable load 3 kN/m, evaluate the maximum long term deflection of the post-tensioned beam. Assume only 30% of the variable load contributes to the quasi-permanent action. Take the concrete density, 25 kN/m^3, Modulus of Elasticity, 32 kN/mm^2 and creep coefficient, 1.5.

Susuk tendon satu rasuk pasca-tegasan ditunjukkan di ***Rajah 2****. Rasuk tersebut telah direkabentuk menggunakan kekuatan konkrit gred C40/50 dan tendon parabolik tunggal dengan 600 mm kesipian di tengah rentang. Daya pra-tegasan awal adalah 1800 kN dan jumlah kehilangan pra-tegasan dijangkakan sebanyak 28%. Jika rasuk tersebut menanggung beban kemasan sebanyak 4 kN/m dan beban boleh ubah 3 kN/m, nilaikan pesongan jangka panjang maksima rasuk pasca-tegasan. Anggap hanya 30% dari beban boleh ubah menyumbang kepada kelakuan kuasi-kekal. Ambil ketumpatan konkrit, 25 kN/m*^{3}*, Modulus Keanjalan, 32 kN/mm*^{2} *dan pekali rayapan, 1.5.*

[10 marks/*markah*]



(a) longitudinal profile



(b) cross section at mid-span

Figure 2 (all dimensions in mm)/*Rajah 2 (semua ukuran dalam mm)*

3. (a). **Figure 3** shows the cross section at mid-span for a simply supported post-tensioned beam. The beam is designed using double parabolic tendons and each tendon consists of 15 strands (A_p = 1500 mm^2). The initial pre-stressing and total pre-stress loss are 1200 N/mm^2 and 30%, respectively. Verify that the depth from the top fibre to the neutral axis, x = 475 mm can be used to determine the depth of neutral axis. If the maximum design moment due to ultimate load is 1800 kNm, evaluate the design adequacy based on the ultimate moment of resistance. Take E_p = 195 kN/mm^2, f_{ck} = C40/50, f_{pd} = 1400 N/mm^2 and γ_p = 0.9.

***Rajah 3** menunjukkan keratan rentas di tengah rentang rasuk pasca-tegasan tersangga mudah. Rasuk tersebut direkabentuk menggunakan tendon parabolik berkembar dan setiap tendon mempunyai 15 lembar (A_p = 1500 mm^2). Pra-tegasan awal dan jumlah kehilangan pra-tegasan masing-masing adalah 1200* N/mm^2 *dan 30%. Tentusahkan x = 475 mm boleh digunakan untuk menentukan kedalaman paksi neutral. Jika momen rekabentuk maksima disebabkan beban muktamad adalah 1800 kN, buat penilaian terhadap kecukupan rekabentuk berdasarkan momen rintangan muktamad rasuk. Ambil E_p = 195 kN/mm^2, f_{ck} = C40/50, f_{pd} = 1400 N/mm^2 dan γ_p = 0.9*

[20 marks/*markah*]

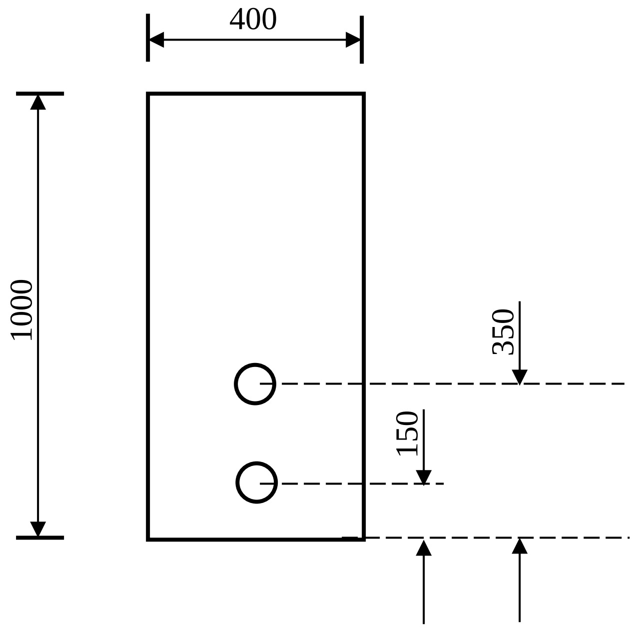


Figure 3 (all dimensions in mm)/*Rajah 3 (semua ukuran dalam mm)*

(b). Prior to submitting the engineering drawing of this post-tensioned beam to the factory, the design engineer realized that the design ultimate moment was actually 15% higher than 1800 kNm. Without performing any calculation, suggest (with technical justifications) one economical approach to increase the ultimate moment of resistance for this beam.

Sebelum menghantar lukisan kejuruteraan rasuk pasca-tegangan ini ke kilang, jurutera struktur menyedari bahawa momen rekabentuk muktamad sebenarnya adalah 15% lebih tinggi dari 1800 kNm. Tanpa melakukan sebarang pengiraan, cadangkan (dengan justifikasi teknikal) satu pendekatan yang ekonomikal untuk meningkatkan momen rintangan muktamad.

[5 marks/*markah*]

4. (a). **Figure 4** shows the forces acting on the end block of a rectangular prestressed concrete beam. The cross-section of the beam is 125 mm wide and 225 mm deep supporting an eccentric prestressing force of 100 kN, the line of action coincides with the bottom kern of the section. The depth of the anchor plate is 50 mm. Calculate the magnitude and position of the principal tensile stress on a horizontal plane passing through the centre of the anchorage plate.

***Rajah 4** menunjukkan daya-daya yang bertindak ke atas blok hujung sebuah rasuk segiempat tepat konkrit prategasan. Keratan rentas rasuk adalah 125 mm lebar dan 225 mm dalam menyokong daya prategasan sipi 100 kN, garis tindak adalah berbetulan dengan bawah teras keratan. Kedalaman plat penambat adalah 50 mm. Kirakan magnitud dan kedudukan tegasan tegangan utama ke atas satah ufuk yang melepasi pusat plat penambat.*

[17 marks/*markah*]

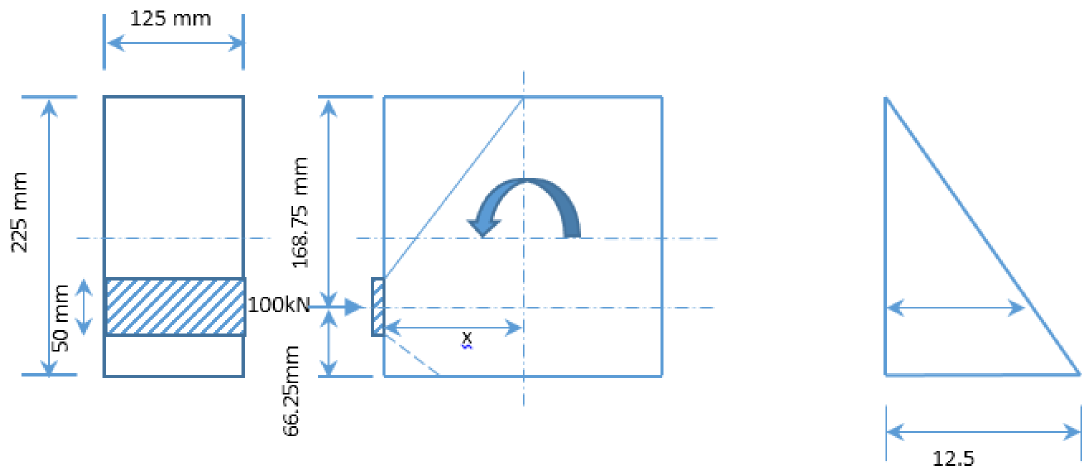


Figure 4 Forces acting on the end block
Rajah 4 Daya-daya bertindak ke atas blok hujung

(b). Sketch the typical arrangement of reinforcements in end blocks of post-tensioned prestressed concrete beams with single and multiple anchorages.

Lakarkan susunan tetulang tipikal di blok hujung bagi rasuk prategasan pasca-tegangan untuk tambatan tunggal dan berbilang.

[8 marks/*markah*]

5. (a). Prestressed concrete beam carries a uniformly distributed load over a span of 24 m. It has an effective prestressing force of 3.3 MN. Determine the ultimate shear strength at the left quarter point at which the beam has the cross-section shown in **Figure 5**. The cable line is parabolic with eccentricities equal to zero at both ends and 0.45 m at midspan. Concrete grade is 35 with the ultimate stress of prestressing steel, f_{pu}, 1600 MPa and yield stress of stirrups, f_y, 250 MPa.

Rasuk konkrit prategasan membawa beban teragih seragam di sepanjang rentang 24 m. Rasuk dikenakan daya prategasan efektif sebesar 3.3 MN. Tentukan kekuatan ricih muktamad pada titik suku kiri rasuk yang ditunjukkan dalam ***Rajah 5****. Garisan kabel adalah parabolik dengan kesipian adalah sifar di kedua-dua hujung dan 0.45 m pada pertengahan rentang. Gred konkrit adalah 35 dengan tegasan muktamad keluli prategasan, f_{pu}, 1600 MPa dan tegasan alah rakap, f_y, 250 MPa.*

[17 marks/*markah*]

(b). Outline the factors influencing the ultimate shear resistance of prestressed concrete sections with flexural-shear cracks.

Nyatakan faktor-faktor yang mempengaruhi rintangan ricih muktamad bagi keratan konkrit prategasan yang mengalami keretakan ricih-lentur.

[8 marks/*markah*]

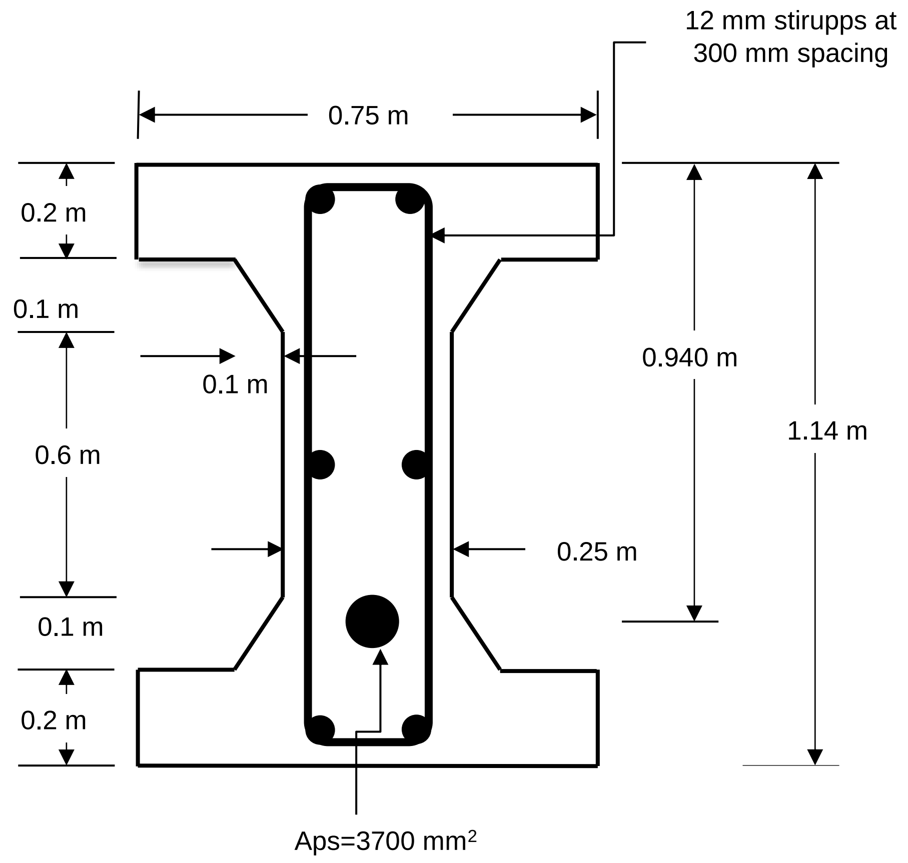


Figure 5 Cross-section of prestressed concrete beam
Rajah 5 Keratan rentas rasuk konkrit pra-tegasan

APPENDIX/*LAMPIRAN*

Governing inequalities:

At transfer:

$$\frac{P_{\mathrm{m0}}}{A_{\mathrm{c}}}-\frac{P_{\mathrm{m0}}e}{Z_{\mathrm{t}}}+\frac{M_0}{Z_{\mathrm{t}}}\geq f_{\mathrm{ct,0}}\ ---\ \text{top fibre}$$

$$\frac{P_{\mathrm{m0}}}{A_{\mathrm{c}}}+\frac{P_{\mathrm{m0}}e}{Z_{\mathrm{b}}}-\frac{M_0}{Z_{\mathrm{b}}}\leq f_{\mathrm{cc,0}}\ ---\ \text{bottom fibre}$$

At service:

$$\frac{P_{\mathrm{m,t}}}{A_{\mathrm{c}}}-\frac{P_{\mathrm{m,t}}e}{Z_{\mathrm{t}}}+\frac{M_{\mathrm{T}}}{Z_{\mathrm{t}}}\leq f_{\mathrm{cc,t}}\ ---\ \text{top fibre}$$

$$\frac{P_{\mathrm{m,t}}}{A_{\mathrm{c}}}+\frac{P_{\mathrm{m,t}}e}{Z_{\mathrm{b}}}-\frac{M_{\mathrm{T}}}{Z_{\mathrm{b}}}\geq f_{\mathrm{ct,t}}\ ---\ \text{bottom fibre}$$

Minimum section moduli:

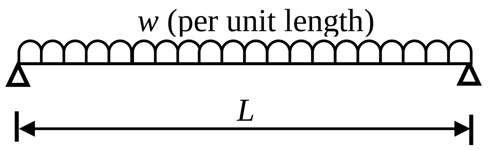
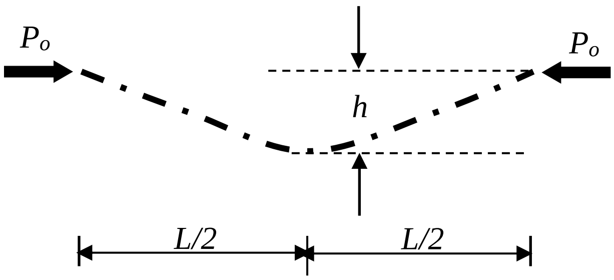
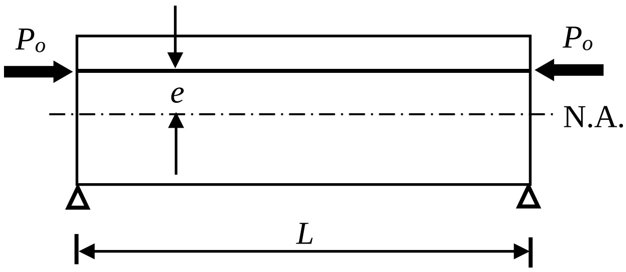
$$(M_T-\Omega M_0)\leq\left(f_{cc,t}-\Omega f_{ct,0}\right)Z_t$$
$$(M_T-\Omega M_0)\leq\left(\Omega f_{cc,0}-f_{ct,t}\right)Z_b$$

Losses:

The remaining force after elastic shortening, P'(pretensioned) $=\dfrac{P_{m0}}{1+m\dfrac{A_{\mathrm{p}}}{A_{\mathrm{c}}}\left(1+\dfrac{e^2A_{\mathrm{c}}}{I}\right)}$

Loss of prestressing force due to creep $= E_{\mathrm{p}}P'\dfrac{A_{\mathrm{p}}}{A_{\mathrm{c}}}\left(1+\dfrac{e^2A_{\mathrm{c}}}{I}\right)\left(\dfrac{\varphi(\infty,t_0)}{1.05E_{\mathrm{cm,0}}}\right)$

Loss in prestressing force due to shrinkage $=\varepsilon_{\mathrm{cs}}E_{\mathrm{p}}A_{\mathrm{p}}$

	$\delta_{max} = \dfrac{-5\ wL^4}{384\ EI}$
	$\delta_{max} = \dfrac{5\ P_o h L^2}{48\ EI}$
	$\delta_{max} = \dfrac{-P_o\ eL^2}{8\ EI}$

$$f_v = K_1\left(\frac{M}{bh^2}\right) + K_2\left(\frac{H}{bh}\right)$$

$$\tau = K_3\left(\frac{V}{bh}\right)$$

$$f_h = \frac{P}{bh}\left(1 + 12\frac{e'^2}{h'^2}\right)$$

$$f_{max}\ or\ f_{min} = \left(\frac{f_v + f_h}{2}\right) \pm \frac{1}{2}\sqrt{(f_h - f_v) + 4\tau^2}$$

$$Tan\ 2\theta = \left(\frac{2\tau}{f_v - f_h}\right)$$

$$F_{bst} = \left(\frac{2}{3}x\ distributing\ point\ between\ compression\ and\ tensionx\ f_{min}\right)100$$

$$e_p = \frac{4S(l - x)}{l^2}$$

$$\frac{100A_p}{b_w d_p}$$

$$V_{co} = bD(0.67f_t)\sqrt{\left(1 + \frac{0.8p}{f_t}\right)} + PSin\theta$$

$$f_t = 0.24\sqrt{f_{ck}}$$

$$V_{cr} = \left(1 + \frac{0.55f_{pe}}{f_{pu}}\right)bd_p v_c + \frac{M_o}{\left({}^{M}/_{V}\right)}$$

$$M_o = \left(0.8f_{pe}\right)\frac{I}{\left(d_p - y_T\right)}$$

$$f_{pe} = \frac{P}{A} + \frac{Pe_p^2}{I}$$

$$\frac{A_v}{S_v} = \frac{V - V_c}{\left(0.87f_{sy}\right)d_v}$$

Value of v_c, the design concrete shear stress, in MPa								
$\frac{100\,(A_p + A_s)}{bd}$	Effective depth in mm							
	125	150	175	200	225	250	300	400
≤ 0.15	0.45	0.43	0.41	0.40	0.39	0.38	0.36	0.34
0.25	0.53	0.51	0.49	0.47	0.46	0.45	0.43	0.40
0.50	0.67	0.64	0.62	0.60	0.58	0.56	0.54	0.50
0.75	0.77	0.73	0.71	0.68	0.66	0.65	0.62	0.57
1.00	0.84	0.81	0.78	0.75	0.73	0.71	0.68	0.63
1.50	0.97	0.92	0.89	0.86	0.83	0.81	0.78	0.72
2.00	1.06	1.02	0.98	0.95	0.92	0.89	0.86	0.80
3.00	1.22	1.16	1.12	1.08	1.05	1.02	0.98	0.91

Coefficients for Stresses in End Blocks (Magnel)			
Distance from far end, x/h	K_1	K_2	K_3
0	20.00	-2.000	0.000
0.10	9.720	0.000	1.458
0.20	2.560	1.280	2.048
0.30	-1.960	1.960	2.058
0.40	-4.320	2.160	1.728
0.50	-5.000	2.000	1.250
0.60	-4.480	1.600	0.768
0.70	-3.240	1.080	0.378
0.80	-1.760	0.560	0.128
0.90	-0.520	0.160	0.018
1.00	0	0	0

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