Second Semester Examination
2018/2019 Academic Session

June 2019

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

Duration : 2 hours
(Masa : 2 jam)

Please check that this examination paper consists of **TWELVE (12)** pages of printed material including appendix before you begin the examination.

*[Sila pastikan bahawa kertas peperiksaan ini mengandungi **DUA BELAS (12)** muka surat yang bercetak termasuk lampiran sebelum anda memulakan peperiksaan ini.]*

Instructions : This paper consists of **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.]

...2/-

(1). (a). Explain why only high strength materials (concrete and steel) are required for prestressed concrete.

Terangkan mengapa hanya bahan berkekuatan tinggi (konkrit and keluli) yang diperlukan untuk konkrit prategasan.

[7 marks/*markah*]

(b). A concrete beam of 10 m span, 250 mm wide and 300 mm deep, is pre-stressed by 3 cables. The cross sectional area of each cable is 200 mm^2 and the initial stress in the cable is 1200 MPa for each cable. Cable 1 is parabolic with an eccentricity of 50 mm above the centroid at the ends and 50 mm below the centroid at the centre of the span. Cable 2 is also parabolic with zero eccentricity at the ends and 50 mm below the centroid at the centre of span. Cable 3 is straight with 50 mm uniform eccentricity below the centroid. Estimate the maximum live load that this beam can carry by considering only the allowable section stresses at the mid-span with no tension. Use $\gamma_{\text{con.}} = 25\,\text{kN/m}^3$, $f_{\text{ck}}(t) = 27\,\text{MPa}$ and concrete strength C40/50. Assume total losses are 20%.

Rasuk konkrit dengan rentang 10 m, lebar 250 mm dan kedalaman 300 mm, diprategaskan oleh 3 kabel. Keluasan keratan rentas setiap kabel adalah 200 mm^2 dan tegasan awal dalam kabel adalah 1200 MPa untuk setiap kabel. Kabel 1 adalah parabola dengan kesipian 50 mm di atas sentroid di hujung dan 50 mm di bawah sentroid di tengah rentang. Kabel 2 juga adalah parabola dengan kesipian sifar pada hujung dan 50 mm di bawah sentroid di tengah rentang. Kabel 3 adalah lurus dengan kesipian seragam 50 mm di bawah sentroid. Anggarkan beban hidup maksimum yang boleh ditanggung oleh rasuk ini dengan hanya mempertimbangkan tegasan keratan yang dibenarkan pada tengah rentang adalah sifar tegangan. Gunakan $\gamma_{\text{con.}} = 25\,\text{kN/m}^3$, $f_{\text{ck}}(t) = 27\,\text{MPa}$ *dan kekuatan konkrit C40/50. Anggapkan jumlah kehilangan ialah 20%.*

[18 marks/*markah*]

(2). (a). The cross-section of a post-tensioned beam at mid-span is shown in **Figure 1**. The beam is designed having double tendons with parabolic profile. Each tendon consists of 1056 mm^2 strand (f_{pk} = 1770 N/mm^2). If the initial stress applied to these strands is 1100 N/mm^2, design the ultimate moment of resistance for the beam. Verify that x = 368 mm can be used as the depth of the neutral axis from the top outermost fibre. Take the characteristic strength of concrete = 40 N/mm^2, E_p = 205 kN/mm^2, γ_m = 1.15, pre-stress loss = 30% and, γ_p = 0.9.

Keratan rentas di tengah rentang satu rasuk pasca-tegasan adalah seperti di ***Rajah 1****. Rasuk tersebut direkabentuk mempunyai tendon berganda dengan susuk parabola. Setiap tendon mempunyai 1056 mm^2 lembar (f_{pk} = 1770 N/mm^2). Jika tegasan awal yang dikenakan kepada setiap lembar adalah 1100 N/mm^2, sediakan rekabentuk momen rintangan muktamad untuk rasuk tersebut. Tentusahkan x = 368 mm boleh digunakan sebagai kedalaman paksi neutral dari gentian atas paling luar. Ambil kekuatan ciri konkrit = 40 N/mm^2, E_p = 205 kN/mm^2, γ_m = 1.15, kehilangan pra-tegasan = 30% dan γ_p = 0.9.*

[20 marks/*markah*]

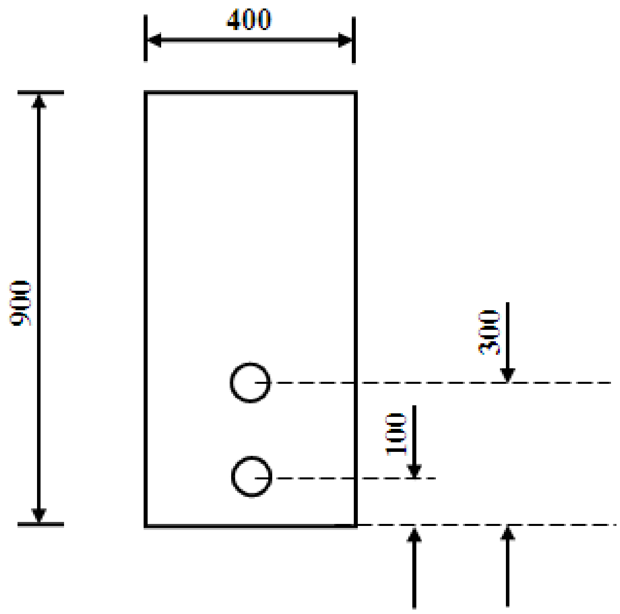


Figure 1 (all dimensions in mm)/*Rajah 1 (semua ukuran dalam mm)*

...4/-

(b). In some cases, the calculated ultimate moment of resistance may be lower than the design moment. This phenomenon is particularly true when there is a change to the floor usage. Generally, apart from adjusting the tendon profile within the safe tendon zone, design engineers will provide additional steel reinforcement. Explain the design concept of adding reinforcement (untensioned). Justify the advantage of using this approach compared to adjusting the tendon profile.

Dalam beberapa kes, momen rintangan muktamad yang telah dikira boleh menjadi lebih rendah daripada momen rekabentuk. Fenomena ini adalah benar apabila terdapat perubahan kepada penggunaan lantai. Secara amnya, selain daripada melaraskan susuk tendon di antara zon selamat tendon, jurutera rekabentuk akan menyediakan tetulang tambahan. Terangkan konsep rekabentuk menggunakan tetulang tambahan (tanpa tegangan). Buat penilaian terhadap kelebihan menggunakan pendekatan ini berbanding melaraskan susuk tendon.

[5 marks/*markah*]

(3). (a). A rectangular concrete beam with 300 mm deep and 250 mm wide was pre-tensioned by means of 12 nos. of wires with diameter of 7 mm located 50 mm from the soffit of the beam, and 3 nos. of wires with diameter of 5 mm located 45 mm from the top (**Figure 2**). The wires were initially stressed to 1200 N/mm^2. Estimate the total percentage loss of stresses due to elastic shortening, creep and shrinkage of the concrete.

*Satu rasuk konkrit segi empat tepat dengan kedalaman 300 mm dan kelebaran 250 mm diprategaskan menggunakan 12 bilangan wayar bergarispusat 7 mm terletak 50 mm dari datum rasuk dan 3 bilangan wayar bergarispusat 5 mm terletak 45 mm dari atas rasuk (**Rajah 2**). Tegasan awal wayar adalah 1200 N/mm^2. Anggarkan jumlah peratusan kehilangan prategasan yang disebabkan oleh pemendekan elastik, rayapan dan pengecutan konkrit.*

...5/-

Given:

Diberi:

$\gamma_{\text{con.}}$ = 25 kN/m^3
E_p = 210 GPa
$E_{cm,0}$ (transfer) = 32,000 MPa
$\varphi(\infty, t_0)$ = 1.6
ε_{cs} = 330×10^{-6}

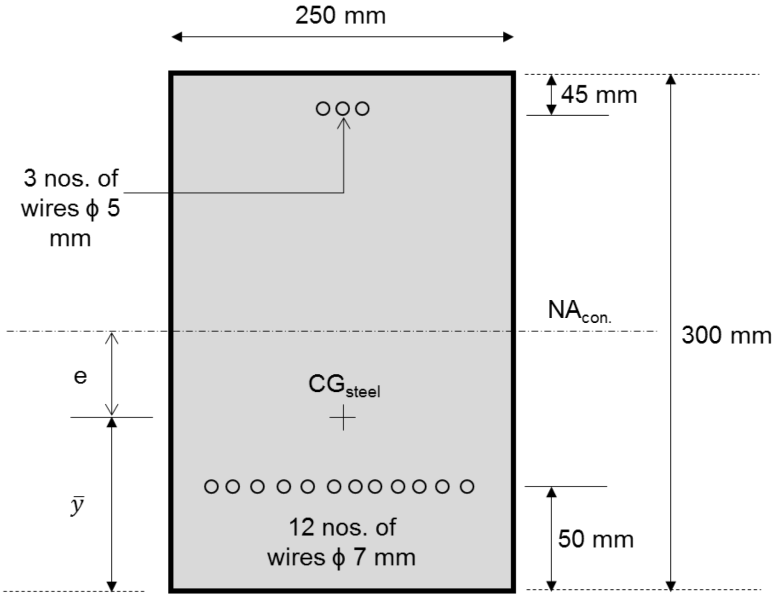


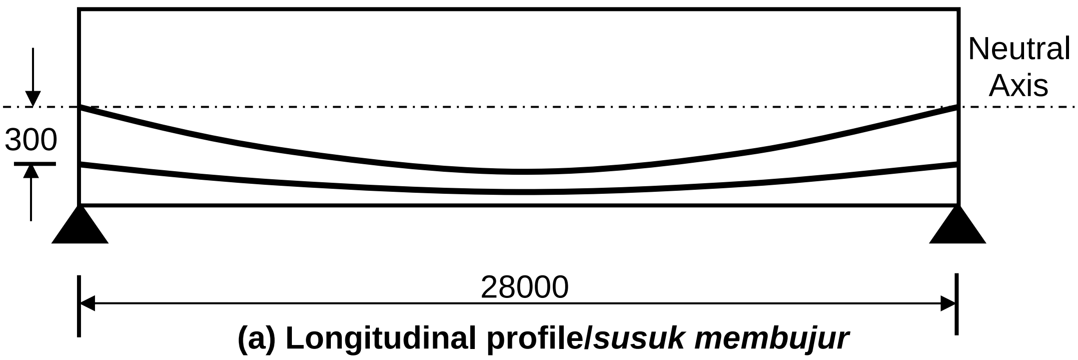
Figure2/*Rajah 2*

[12 marks/*markah*]

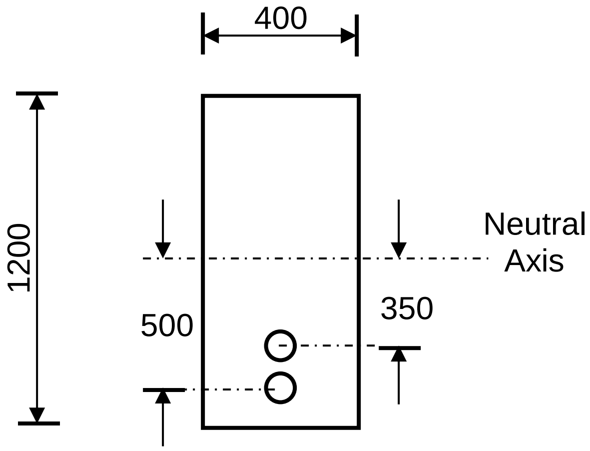
(b). The tendon profile and the mid-span cross section of a simply supported 28 meter post-tension beam are shown in **Figure 3**. The beam is designed with 2 parabolic tendons. In order to reduce the upward deflection, the centroid anchorage for the upper tendon is placed to coincide with the centroid of the beam. The initial pre-stressing force for the parabolic tendons is set at 1200 kN. If the beam is supporting permanent load 4 kN/m, finishes load 1 kN/m and variable load 2 kN/m, evaluate the maximum long term deflection. 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, creep coefficient = 1.5 and total pre-stress loss = 28%.

Susuk tendon dan keratan rentas di tengah rentang satu rasuk tersangga mudah pasca-tegasan 28 meter panjang ditunjukkan di ***Rajah 3****. Rasuk tersebut direkabentuk menggunakan 2 tendon parabola. Untuk mengurangkan pesongan ke atas, sentroid penambat tendon atas diletakkan bertepatan dengan sentroid rasuk. Daya tujuhan awal untuk kedua-dua tendon adalah ditetapkan pada 1200 kN. Jika rasuk tersebut menanggung beban kekal 4 kN/m, beban kemasan 1 kN/m dan beban boleh ubah 2 kN/m, buat penilaian terhadap pesongan maksimum jangka panjang. 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}*, pekali rayapan = 1.5 dan jumlah kehilangan pra-tegasan = 28%.*

[13 marks/*markah*]



(a) Longitudinal profile/*susuk membujur*



(b) Cross-section at mid-span/*keratan rentas di tengah rentang*

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

(4). (a). Explain the mechanism by which prestressing force is transferred to concrete in pre-tensioned beams.

Jelaskan mekanisma yang mana daya pra-tegasan dipindahkan ke konkrit bagi rasuk pra-tegasan.

[5 marks/*markah*]

(b). Explain with sketches, the typical tensile and compressive stresses distribution in an end block of a post-tensioned concrete beam with a single anchorage.

Jelaskan bersama lakaran, taburan tipikal tegasan tegangan dan mampatan di blok hujung bagi rasuk konkrit pasca-tegasan dengan tambatan tunggal.

[8 marks/*markah*]

(c). The end block of a prestressed concrete beam, rectangular in section, is 100 mm wide and 200 mm deep. A concentric prestressing force of 100 kN is transmitted to concrete by a bearing plate, 100 mm wide and 50 mm deep located at the ends.

Blok hujung bagi rasuk konkrit prategasan, dengan keratan segiempat tepat, adalah 100 mm lebar dan 200 mm dalam. Daya prategasan sepusat 100 kN dipindahkan kepada konkrit oleh plat galas 100 mm lebar dan 50 mm kedalaman, pada hujungnya.

(i). Using Guyon's method, compute the position and magnitude of maximum tensile stress and bursting tension for the end block on the horizontal section through the centre and edge of the bearing plate.

Menggunakan kaedah Guyon, hitung kedudukan dan magnitud tegasan tegangan maksimum dan tegangan letusan untuk blok hujung pada keratan mendatar melalui pusat dan hujung plat galas.

(ii). Determine the reinforcement required (in accordance with EC2) to contain the bursting forces if $f_{yk} = 250\ \mathrm{N/mm^2}$.

Tentukan tetulang yang diperlukan (mengikut EC2) bagi menanggung daya letusan jika $f_{yk} = 250\ N/mm^2$.

[12 marks/*markah*]

(5). (a). A 10 m long post-tensioned beam of rectangular cross section, 200 mm wide and 400 mm deep, carries a uniformly distributed load of 8 kN/m. The effective prestressing force in a cable is 500 kN. The cable is parabolic with zero eccentricity at the supports and a maximum eccentricity of 140 mm at the centre of the span.

Satu rasuk pasca-tegasan 10 m panjang berkeratan rentas segi empat, 200 mm lebar dan 400 mm kedalaman, menanggung beban teragih seragam sebanyak 8 kN/m. Daya prategasan berkesan di dalam kabel adalah 500 kN. Kabel adalah parabola dengan kesipian kosong di penyokong dan kesipian maksimum 140 mm di tengah rentang.

(i). Calculate the principal stresses at the supports.
Kira tegasan utama di penyokong.

(ii). Determine the magnitude of the principal stresses at the supports in the absence of prestress.
Tentukan magnitud tegasan utama di penyokong apabila ketiadaan prategasan.

[12 marks/*markah*]

(b). The beam cross-section of 200 mm wide and 600 mm deep is constant over a 10 m simply supported span with a parabolic tendon profile. Eccentricity of the tendon profile varies between zero at the ends and 100 mm at the mid-span, measured below the neutral axis in both cases. The beam supports an ultimate uniformly distributed load of 4 kN/m and f_{ck} = 35 N/mm^2. Check if shear reinforcement is required.

Satu rasuk berkeratan rentas 200 mm lebar dan 600 mm kedalaman adalah seragam sepanjang 10 m rentang tersokong mudah dengan susuk tendon parabola. Kesipian bagi susuk tendon adalah berubah-ubah di antara kosong di hujung rasuk dan 100 mm di tengah rentang, kedua-duanya diukur di bawah paksi neutral. Rasuk tersebut menanggung beban teragih seragam muktamad 4 kN/m dan f_{ck} = 35 N/mm^2. Semak jika tetulang ricih diperlukan.

Given data:
Diberi data:

Prestress force after losses = 2590 kN
D*aya prategasan selepas kehilangan = 2590 kN*
A_p = 3450 mm^2 (= A_{sl})
f_{yk} = 500 N/mm^2 for the shear reinforcement/*untuk tetulang ricih*
f_{ctk} = 2.2 N/mm^2.

[13 marks/*markah*]

APPENDIX

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:

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

Losses:

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

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

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

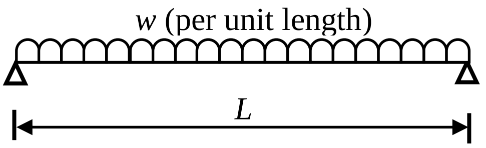
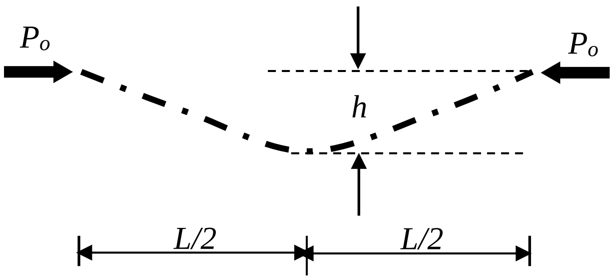
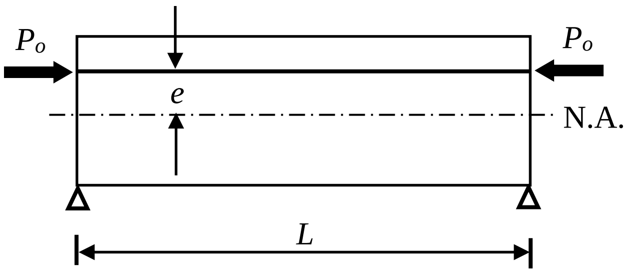
Vertical stresses along axis at ends of prestressed beams (Guyon)

Distribution ratio y_{po}/y_o	Position of zero stress $x/2y_o$	Position of max. stress $x/2y_o$	Ratio of max. tensile stress to average stress
0.00	0.00	0.17	0.50
0.10	0.09	0.24	0.43
0.20	0.14	0.30	0.36
0.30	0.16	0.36	0.33
0.40	0.18	0.39	0.27
0.50	0.20	0.43	0.23
0.60	0.22	0.44	0.18
0.70	0.23	0.45	0.13
0.80	0.24	0.46	0.09

Bar areas

Sectional areas of groups of bars (mm^2)

Bar size (mm)	Number of bars									
	1	2	3	4	5	6	7	8	9	10
6	28.3	56.6	84.8	113	141	170	198	226	255	283
8	50.3	101	151	201	251	302	352	402	452	503
10	78.6	157	236	314	393	471	550	628	707	786
12	113	226	339	452	566	679	792	905	1018	1131
16	201	402	603	804	1005	1207	1408	1609	1810	2011
20	314	628	943	1257	1571	1885	2199	2514	2828	3142
25	491	982	1473	1964	2455	2946	3437	3928	4418	4909
32	804	1609	2413	3217	4022	4826	5630	6435	7239	8044
40	1257	2514	3770	5027	6284	7541	8798	10054	11311	12568

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

-oooOooo-