UNIVERSITI SAINS MALAYSIA

Second Semester Examination
2015/2016 Academic Session

June 2016

EAS453 – 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 **TWO (2)** appendices before you begin the examination.

[*Sila pastikan bahawa kertas peperiksaan ini mengandungi **DUABELAS (12)** muka surat yang bercetak termasuk **DUA (2)** 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.*]

All questions **MUST BE** answered on a new page.

[*Semua soalan **MESTILAH** dijawab pada muka surat baru.*]

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

[*Sekiranya terdapat percanggahan pada soalan peperiksaan, versi Bahasa Inggeris hendaklah diguna pakai.*]

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1. A Class 1 post-tensioned concrete beam is simply supported over a 10 m span. The characteristic imposed load consists of a single 100 kN force at mid-span. The characteristic strength of concrete is 50 N/mm^2 and the unit weight of concrete is 24 kN/m^3. The beam is of uniform section having the following properties: area of 120 000 mm^2, $Z_b = 19.0 \times 10^6$ mm^3, and $Z_t = 21.7 \times 10^6$ mm^3.

Satu rasuk konkrit pasca-tegangan Kelas 1 disokong sepanjang 10 m. Beban ciri yang dikenakan adalah terdiri daripada beban tunggal 100 kN yang dikenakan di tengah rentang. Kekuatan ciri bagi konkrit adalah 50 N/mm^2 *dan berat unit konkrit ialah 24* kN/m^3*. Rasuk adalah keratan seragam mempunyai sifat-sifat berikut: keluasan 120 000* mm^2, $Z_b = 19.0 \times 10^6$ mm^3*, and* $Z_t = 21.7 \times 10^6$ mm^3.

[a] Determine the followings under service condition:

[i] the minimum effective pre-stressing force required (P_{emin}) and the corresponding mid-span tendon eccentricity (e_s);

[ii] the maximum effective pre-stressing force required (P_{emax}) and the corresponding mid-span tendon eccentricity (e_s).

Tentukan yang berikut di bawah keadaan kebolehkhidmatan:

[i] daya minimum pra-tegasan berkesan yang diperlukan (P_{emin}*) dan kesipian tendon yang sepadan di tengah rentang (*e_s*);*

[ii] daya maksimum pra-tegasan berkesan yang diperlukan (P_{emax}*) dan kesipian tendon yang sepadan di tengah rentang (*e_s*).*

[10 marks/markah]

[b] If the effective pre-stressing force adopted in the design is the mean of the minimum required force and the maximum permissible force, plot the permissible tendon zone.

Jika daya pra-tegasan berkesan yang digunapakai dalam rekabentuk ialah purata daya minimum yang diperlukan dan daya maksimum yang dibenarkan, plotkan zon tendon yang dibenarkan.

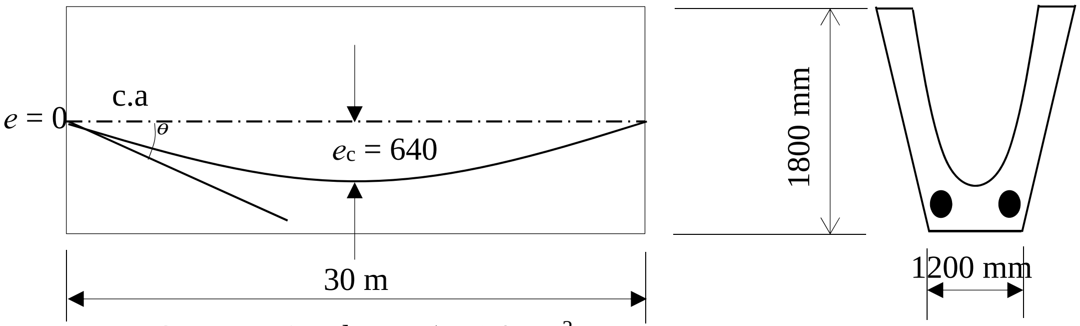
[15 marks/markah]

2. [a] A post-tensioned beam shown in **Figure 1** is stressed by two tendons with a parabolic profile and having a total cross-sectional area, A_{st} = 7500 mm^2. The total initial pre-stress force, P_o = 10500 kN and the total characteristics strength of the tendons is 14000 kN. Evaluate the pre-stress loss at mid-span due to shrinkage and creep of concrete. Assume the following data:

- Coefficient of friction, $\mu = 0.20$;
- Elastic modulus, E_c (transfer) = 32 kN/mm^2;
- Specific creep = 48 x 10^{-6}/ N/mm^2;
- Shrinkage/unit length, $\varepsilon_{sh} = 30 \times 10^{-6}$;
- Parabolic equation, $y = Cx^2$;
- Radius of curvature, $r_{ps} = \frac{1}{d^2y/dx^2}$.

*Satu rasuk pasca-tegangan seperti di **Rajah 1** ditegaskan oleh dua tendon dengan profil parabola dan mempunyai keratan rentas A_{st} = 7500 mm^2. Jumlah permulaan daya prategasan P_o = 10.500 kN dan jumlah kekuatan ciri tendon adalah 14.000 kN. Nilaikan kehilangan prategasan di tengah rentang yang diakibatkan pengecutan dan rayapan konkrit. Andaikan data berikut:*

- *Pekali geseran, $\mu = 0.20$;*
- *Modulus kekenyalan, E_c (pemindahan) = 32 kN/mm^2;*
- *Rayapan spesifik = 48 x 10^{-6}/N/mm^2;*
- *Pengecutan/unit panjang, $\varepsilon_{sh} = 30 \times 10^{-6}$;*
- *Persamaan parabola, $y = Cx^2$;*
- *Jejari kelengkungan, $r_{ps} = \frac{1}{d^2y/dx^2}$.*



Cross-sectional area $A = 1.05$ m^2
Second moment of area $I = 0.36$ m^4

Cross-section at mid-span

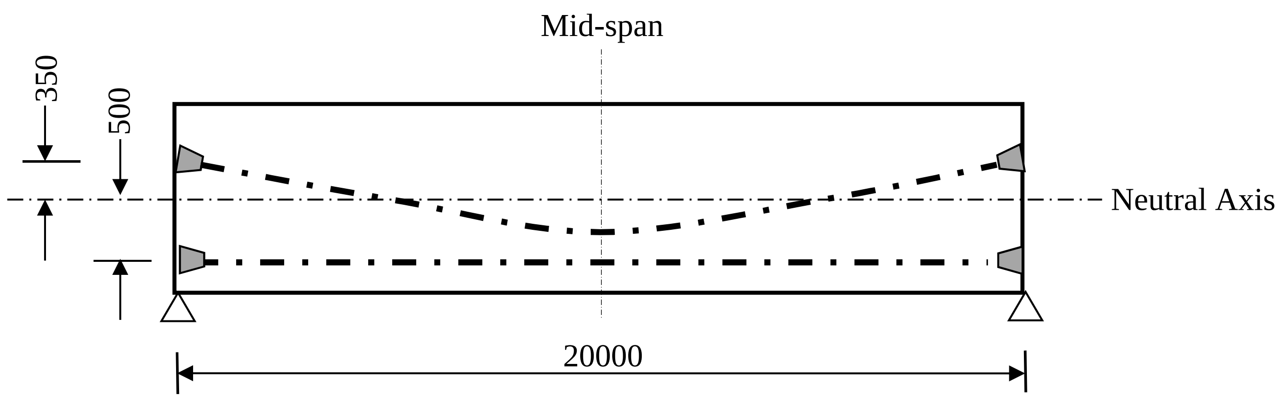
Figure 1 / *Rajah 1*

[12 marks/markah]

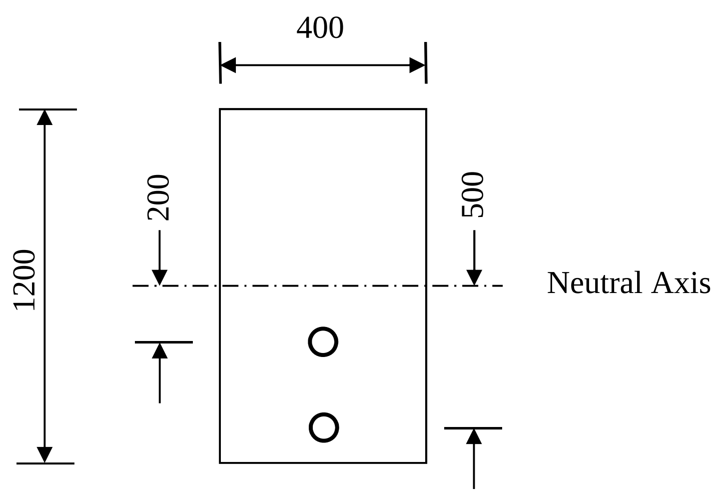
[b] A 20 m span post-tensioned beam was designed using two tendons as shown in **Figure 2**. If the initial pre-stressing force applied at each tendon is 1600 kN, determine the long term deflection of the beam taking into account dead load (excluding self-weight of the beam) = 6 kN/m and live load = 5 kN/m. Assume concrete density = 24 kN/m^3, modulus of elasticity (E_c) = 28 kN/mm^2, pre-stress loss = 30% and creep factor = 1.5. The standard formulae for beam deflection are given in **Appendix 1**.

Satu rasuk pasca - tegasan dengan rentangan 20 m telah direkabentuk menggunakan dua tendon seperti di ***Rajah 2****. Sekiranya daya tujahan awal yang dikenakan pada setiap tendon adalah 1600 kN, tentukan pesongan jangka panjang maksima rasuk tersebut dengan mengambilkira beban mati (tidak termasuk swa-berat rasuk)= 6 kN/m dan beban hidup = 5 kN/m. Anggap ketumpatan konkrit = 24 kN/m*^{3}*, modulus kekenyalan (*E_c*) = 28 kN/mm*^{2}*, kehilangan pra-tegasan = 30% dan faktor rayapan = 1.5. Persamaan piawai untuk pesongan rasuk diberikan di* ***Lampiran 1****.*

[13 marks/*markah*]



(a) longitudinal profile (all dimensions in mm)



(b) section at mid-span (all dimensions in mm)

Figure 2 / *Rajah 2*

3. [a] Pre-stressed members are designed by considering load at transfer and at service. However, the moment capacity of that member is checked at ultimate loading condition. Explain why such approach is used for designing pre-stressed members.

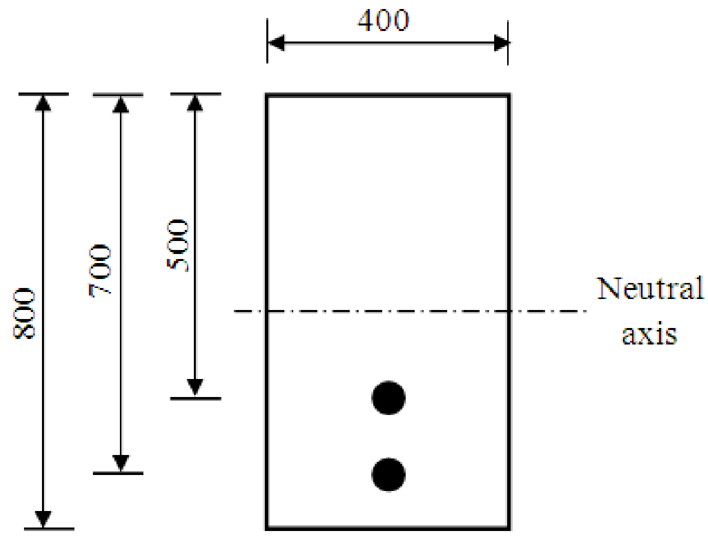
Anggota pra-tegasan direkabentuk dengan mengambilkira beban masa pindah dan kebolehkhidmatan. Namun demikian, keupayaan momen anggota tersebut disemak pada keadaan beban muktamad. Bincangkan mengapa pendekatan ini digunakan untuk merekabentuk anggota pra-tegasan.

[5 marks/*markah*]

[b] The section with the dimension 400 mm x 800 mm for a pre-stressed beam is shown in **Figure 3**. The beam has been designed using double grouted tendon and each tendon consists of 1695 mm^2 pre-stressing strand area (characteristic strength = 1770 N/mm^2). If the effective pre-stress applied to each tendon is 885 N/mm^2, determine the ultimate moment of resistance for the section using Table 4.4 BS 8110. Take the concrete strength and modulus of elasticity as 50 N/mm^2 and 32 kN/mm^2, respectively.

*Keratan rentas berdimensi 400 mm × 800 mm untuk satu rasuk pra-tegasan ditunjukkan di **Rajah 3**. Rasuk tersebut telah direkabentuk menggunakan dua tendon berturap dan setiap tendon mempunyai keluasan lembar pra-tegasan 1695* mm^2 *(kekuatan ciri = 1770* N/mm^2*). Sekiranya pra-tegasan efektif yang dikenakan pada setiap tendon adalah 885* N/mm^2*, tentukan momen rintangan muktamad keratan tersebut dengan menggunakan Jadual 4.4 BS 8110. Ambil kekuatan konkrit dan modulus keanjalan masing-masing sebagai 50* N/mm^2 *dan 32* kN/mm^2.

[20 marks/*markah*]



(all dimensions in mm)

Figure 3 / *Rajah 3*

4. For a pre-stressed beam, the maximum shear force is 800 kN and the bending moment is 4000 kNm. The characteristics of the section are :

Width (b) = 650 mm

Overall depth (h) = 1300 mm

Effective depth (d) = 1150 mm

Area of pre-stressing tendon (A_{ps}) = 4750 mm^2

f_{pu} = 1800 N/mm^2

f_{cu} = 40 N/mm^2

f_{yv} = 460 N/mm^2

e_s = 560 N/mm^2

β = 3.5°at section considered

φ_{duct} = 125 mm^2

Using BS8110-1:1997 Section 4.3.8; calculate the shear reinforcement required.

Untuk sebuah rasuk pra-tegasan, daya ricih maksima adalah 800kN dan momen lentur ialah 4000 kNm. Ciri-ciri keratan tersebut adalah :

Lebar (b) = 650 mm
Kedalaman keseluruhan (h) = 1300 mm
Kedalaman efektif (d) = 1150 mm

Luas kawasan tendon pra tegasan (A_{ps}) *= 4750* mm^2
f_{pu} = 1800 N/mm^2
f_{cu} = 40 N/mm^2
f_{yv} = 460 N/mm^2
e_s = 560 N/mm^2
β = 3.5° *di keratan tersebut*
φ_{duct} = 125mm^2

Dengan menggunakan BS8110-1:1997 Seksyen 4.3.8, kirakan tetulang ricih yang diperlukan.

[25 marks/*markah*]

5. [a] Describe **TWO (2)** effects of pre-stressing force at the anchorage plates in post-tensioned beams.

Terangkan ***DUA (2)*** *kesan daya pra-tegasan di plat tambatan untuk rasuk pasca-tegangan.*

[4 marks/*markah*]

[b] Explain with the help of sketches the stress distribution at the anchorage zones.

Terangkan dengan bantuan lakaran agihan tegasan di zon tambatan.

[6 marks/*markah*]

[c] The end beam cross section is shown in **Figure 4** with the following parameters,

P_o = 5,500 kN

Bar size = R20

Using Guyon's Method and BS8110-1:1997 Section 4.11, calculate the reinforcement required for lateral section of the end block.

Keratan rentas hujung rasuk ditunjukkan dalam ***Rajah 4*** *dengan parameter-parameter rekabentuk berikut;*

P_o = 5,500 kN

Saiz bar tetulang = R20

Dengan menggunakan Kaedah Guyon dan BS8110-1:1997 Seksyen 4.11, kirakan tetulang yang diperlukan untuk bahagian mendatar blok hujung tersebut.

[15 marks/*markah*]

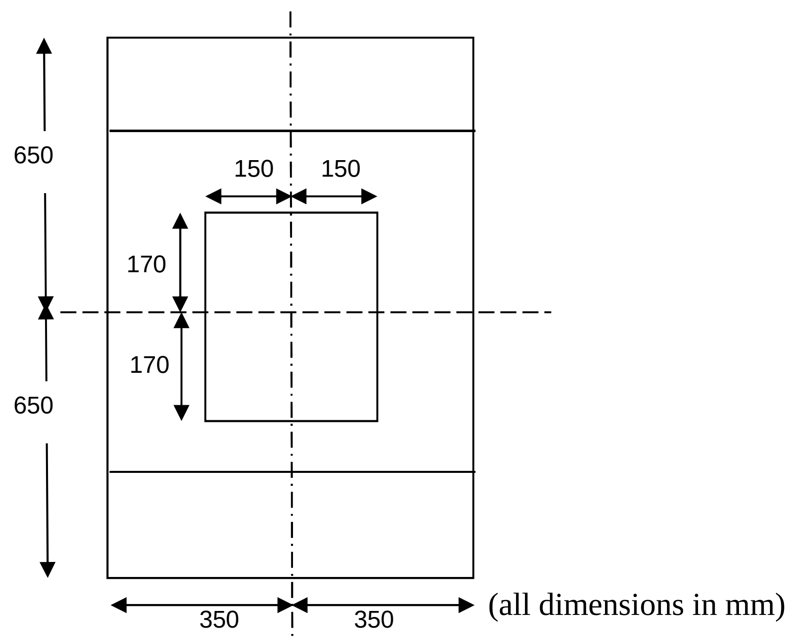
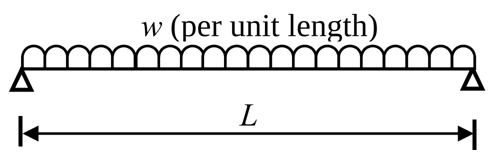
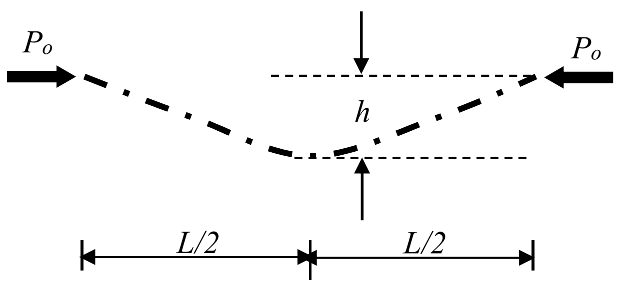
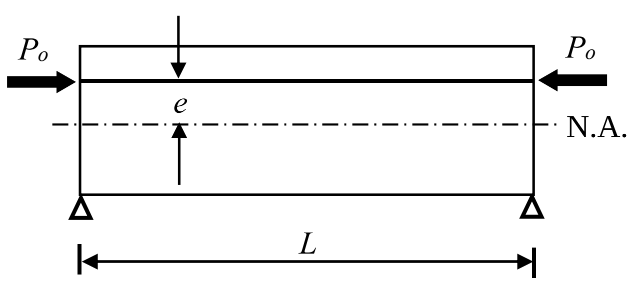


Figure 4 / *Rajah 4*

APPENDIX 1 / *LAMPIRAN 1*

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

APPENDIX 2 / *LAMPIRAN 2*

Table 1 BS8110, Table 4.7

Table 4.7 — Design bursting tensile forces in end blocks

y_{po}/y_o	0.2	0.3	0.4	0.5	0.6	0.7
F_{bst}/P_o	0.23	0.23	0.20	0.17	0.14	0.11

NOTE Intermediate values may be interpolated.

Table 2 Guyon's method Distributed axial force

Distribution ratio (y_{po}/y_o)	Position of zero stress ($x/2y_o$)	Position of maximum stress ($x/2y_o$)	Ratio of maximum 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

Table 3 Tables of steel reinforcement details (from Bungey & Mosely, 1990)

Bar Areas and Perimeters

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	84.9	113	142	170	198	226	255	283
8	50.3	101	151	201	252	302	352	402	453	503
10	78.5	157	236	314	393	471	550	628	707	785
12	113	226	339	452	566	679	792	905	1020	1130
16	201	402	603	804	1010	1210	1410	1610	1810	2010
20	314	628	943	1260	1570	1890	2200	2510	2830	3140
25	491	982	1470	1960	2450	2950	3440	3930	4420	4910
32	804	1610	2410	3220	4020	4830	5630	6430	7240	8040
40	1260	2510	3770	5030	6280	7540	8800	10100	11300	12600

Sectional areas per metre width for various bar spacings (mm^2)

Bar size (mm)	Spacing of bars								
	50	75	100	125	150	175	200	250	300
6	566	377	283	226	189	162	142	113	94.3
8	1010	671	503	402	335	287	252	201	168
10	1570	1050	785	628	523	449	393	314	262
12	2260	1510	1130	905	754	646	566	452	377
16	4020	2680	2010	1610	1340	1150	1010	804	670
20	6280	4190	3140	2510	2090	1800	1570	1260	1050
25	9820	6550	4910	3930	3270	2810	2450	1960	1640
32	16100	10700	8040	6430	5360	4600	4020	3220	2680
40	25100	16800	12600	10100	8380	7180	6280	5030	4190

Shear Reinforcement

A_{sv}/s_v for varying stirrup diameter and spacing

Stirrup diameter (mm)	Stirrup spacing (mm)										
	85	90	100	125	150	175	200	225	250	275	300
8	1.183	1.118	1.006	0.805	0.671	0.575	0.503	0.447	0.402	0.366	0.335
10	1.847	1.744	1.57	1.256	1.047	0.897	0.785	0.698	0.628	0.571	0.523
12	2.659	2.511	2.26	1.808	1.507	1.291	1.13	1.004	0.904	0.822	0.753
16	4.729	4.467	4.02	3.216	2.68	2.297	2.01	1.787	1.608	1.462	1.34

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