UNIVERSITI SAINS MALAYSIA

Second Semester Examination
2013/2014 Academic Session

June 2014

EAS 453/2 – Pre-Stressed Concrete Design
[*Rekabentuk Konkrit Pra-Tegasan*]

Duration : 2 hours
[*Masa : 2 jam*]

Please check that this examination paper consists of **TEN (10)** pages of printed material including **TWO (2)** appendices before you begin the examination.

[*Sila pastikan bahawa kertas peperiksaan ini mengandungi* ***SEPULUH (10)*** *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.*]

1. (a) In structural design, the quality of concrete is usually controlled by the specification of a minimum concrete compressive strength at 28 days. In practice, the concrete used in pre-stressed concrete construction usually has better quality and higher strength compared to ordinary reinforced concrete. Describe, **FIVE (5)** reasons why high strength concrete are needed in Pre-stressed Concrete.

Dalam rekabentuk struktur, kualiti konkrit lazimnya dikawal oleh spesifikasi minimum kekuatan konkrit pada 28 hari. Secara pratikal, konkrit yang digunakan dalam konkrit pra-tegasan mempunyai kualiti yang lebih baik berbanding konkrit tetulang yang normal. Jelaskan, ***LIMA (5)*** *alasan mengapa konkrit berkekuatan tinggi diperlukan dalam konkrit pra-tegasan.*

[5 marks/*markah*]

(b) Determining the minimum sectional properties is among the earliest step in designing a pre-stressed member. Discuss its importance by referring to any of the basic equations in pre-stressed concrete design.

Penentuan keratan minimum adalah langkah yang terawal dalam merekabentuk konkrit pra-tegasan. Bincangkan kepentingannya dengan merujuk kepada salah satu persamaan asas yang digunakan dalam merekabentuk konkrit pra-tegasan.

[10 marks/*markah*]

(c) The 10 m span rectangular section post-tensioned beam is to carry in addition to its self-weight, a uniformly distributed load of 3 kN/m over a simply supported span of 10 m. Cross section of the beam is given as 200 mm x 350 mm (Z_b=Z_t= 4.08 x 10^6 mm^3). Calculate the minimum initial pre-stress force required for an assumed maximum eccentricity of 75 mm (below neutral axis). The beam is post-tensioned beam class 1 and the concrete strength at service is 40 N/mm^2. Assumed losses as 20% (K=0.8).

Rasuk segiempat tepat pasca tegangan yang berukuran rentang 10 m yang disokong mudah dan menanggung beban teragih seragam 3 kN/m dan juga berat diri sendiri. Keratan rentas rasuk diberikan sebagai 200 mm x 350 mm (Z_b=Z_t= 4.08x10^6 mm^3). Hitungkan daya mula pra-tegasan yang diperlukan dengan mengandaikan kesipian adalah 75 mm (dibawah paksi neutral). Rasuk adalah pascategangan kelas 1 dan kekuatan konkrit semasa khidmat adalah 40 N/mm^2. Andaikan kehilangan adalah 20% (K=0.8).

[10 marks/*markah*]

2. A 15 meter simply supported Class 1 post-tensioned beam is subjected to a combined dead and live load of 30 kN/m, apart from its own self weight. Determine a suitable pre-stress force, Po and associated eccentricity at critical section, e if the maximum pre-stress loss is assumed to be 20%. The concrete grade at 28 days is 40 N/mm^2 and at transfer is 28 N/mm^2. The typical cross sectional area of the beam is 410 x 10^3 mm^2 with z_t = 100.4 x 10^6 mm^3 and z_b = 96.1 x 10^6 mm^3.

   Rasuk Kelas 1 pascategangan disokong mudah adalah tertakluk kepada beban gabungan mati dan hidup sebanyak 30 kN/m, selain daripada berat diri sendiri dengan rentang 15 meter. Tentukan daya pra-tekanan yang sesuai, Po dan kesipian bersekutu pada seksyen kritikal, e jika kehilangan pra-tegasan maksimum dianggap sebagai 20%. Gred konkrit pada umur 28 hari ialah 40 N/mm^2 dan pada masa pemindahan ialah 28 N/mm^2. Kawasan tipikal keratan rentas rasuk adalah 410 x 103 mm^2 dengan gentian atas, z_t ialah 100.4 x 10^6 mm^3 dan gentian bawah, z_b ialah 96.1 x 10^6 mm^3.

[25 marks/*markah*]

3. (a) A rectangular concrete beam, 300 mm deep and 200 mm wide is pre-stressed by means of fifteen 5 mm diameter wires located 65 mm from the bottom of the beam and three 5 mm wires, located 25 mm from the top of the beam. If the wire was initially tensioned to a stress of 840 N/mm^2, calculate the percentage loss of stress in steel immediately after transfer,

allowing for the loss of stress due to elastic deformation of concrete only. Given elastic modulus of steel, E_s is 210 kN/mm^3 dan elastic modulus of concrete, E_c is 31.5 kN/mm^2

Satu rasuk konkrit segiempat berdimensi 300 mm dalam dan 200 mm lebar dikenakan pra-tegasan dengan lima belas wayar 5 mm diameter terletak 65 mm dari bahagian bawah rasuk dan tiga wayar 5 mm, terletak 25 mm dari atas rasuk. Jika wayar pada mulanya ditegangkan kepada tekanan 840 N/mm^2, kirakan peratusan kehilangan tegasan dalam keluli serta-merta selepas pemindahan, membenarkan untuk kehilangan tegasan disebabkan oleh ubah bentuk anjal konkrit sahaja. Diberi modulus elastik keluli, E_s ialah 210 kN/mm^2 dan modulus keanjalan konkrit, E_c ialah 31.5 kN/mm^2.

[12 marks/*markah*]

(b) Discuss the influential effect of tendon profile towards deflections in prestressed concrete beams.

Bincang kesan pengaruh profil tendon terhadap lenturan untuk rasuk konkrit prategasan.

[3 marks/*markah*]

(c) A concrete beam of cross section 125 mm x 275 mm and span of 8.0 m is prestressed by a parabolic cable carrying an initial prestressed force of 300 kN. The cable has an eccentricity of 55 mm at the centre of span and is concentric at supports. The live load is 2.5 kN/m. The weight of reinforced concrete is assumed at 24 kN/m^3, Young's Modulus is 38 kN/mm^2 and creep coefficient is 2.5. The loss of prestress is 25 percent of the initial stress after 6 months. Using BS8110-1:1997;

i. Estimate the short term deflection of the beam at the centre of the span.

ii. Estimate the long term deflection of the beam at the centre of the span after 6 months, assuming that the dead and live loads are simultaneously applied after release of prestress.

You can use the equations in **Appendix 1** for this question.

Sebuah rasuk konkrit berukuran 125 mm x 275 mm dan rentang 8.0 m di prategang dengan kabel parabolik yang membawa daya prategangan awal sebanyak 300 kN. Kabel mempunyai kesipian 55 mm di tengah rentangan dan bertumpu di penyokong. Beban hidup ialah 2.5 kN/m. Berat konkrit bertetulang boleh diandaikan 24 kN/m^3, Modulus Young ialah 38 kN/mm^2 dan pekali rayapan ialah 2.5. Kehilangan prategangan ialah 25 peratus tegasan awal selepas 6 bulan. Dengan menggunakan BS8110-1:1997

i. Anggarkan lenturan jangka pendek rasuk di tengah rentang.

ii. Anggarkan lenturan jangka panjang di tengah rentang selepas 6 bulan, dengan mengandaikan beban mati dan hidup digunakan serentak selepas pelepasan prategang.

*Anda boleh menggunakan persamaan di **Lampiran 1** untuk soalan ini.*

[10 marks/*markah*]

4. (a) For a prestressed beam, describe the common method of determination of mode of failure and its **FOUR (4)** categories.

*Untuk sebuah rasuk prategasan, bincangkan kaedah lazim untuk penentuan mod gagal dan **EMPAT (4)** kategorinya*

[10 marks/*markah*]

(b) A prestressed concrete T beam shown in **Figure 1** is being designed as a simply supported beam. It spans 20 m and carries its own weight, characteristic dead load of 5 kN/m and characteristic imposed loads of 10 kN/m. The beam is pretensioned using 16 numbers of 15.7 mm diameter 7 wire strands (A_{ps} = 150 mm^2). Due to debonding, only 8 strands are active at a section 2.5 m from support. The effective prestressing force for the 8 strands is 1200 kN. The properties of the section are: A = 5.2 x 10^5 mm^2, I_{xx} = 134 x 10^8 mm^4, f_{pu} = 1780 N/mm^2.
Design the section for shear using BS8110-1: 1997. The characteristics strength for reinforcement is f_{yv} = 250 N/mm^2

*Sebuah rasuk konkrit prategasan ditunjukkan dalam **Rajah 1** sedang direbentuk sebagai rasuk disokong mudah. Rentangannya ialah 20 m dan membawa beban sendiri, ciri beban mati 5 kN/m dan ciri beban hidup 10 kN/m. Rasuk di prategang dengan menggunakan 16 bilangan ikatan bebenang 7 wayar 15.7 mm garispusat (A_{ps} = 150 mm^2). Oleh kerana nyah ikatan, hanya 8 ikatan bebenang aktif di bahagian 2.5 m dari penyokong. Daya efektif prategasan untuk 8 ikatan bebenang adalah 1200 kN. Ciri-ciri keratan rentas tersebut ialah: A = 5.2 x 10^5 mm^2, I_{xx} = 134 x 10^8 mm^4 , f_{pu} = 1780 N/mm^2.*
Rekabentuk keratan tersebut untuk ricih dengan menggunakan BS8110-1: 1997. Ciri kekuatan tetulang ialah f_{yv} = 250 N/mm^2.

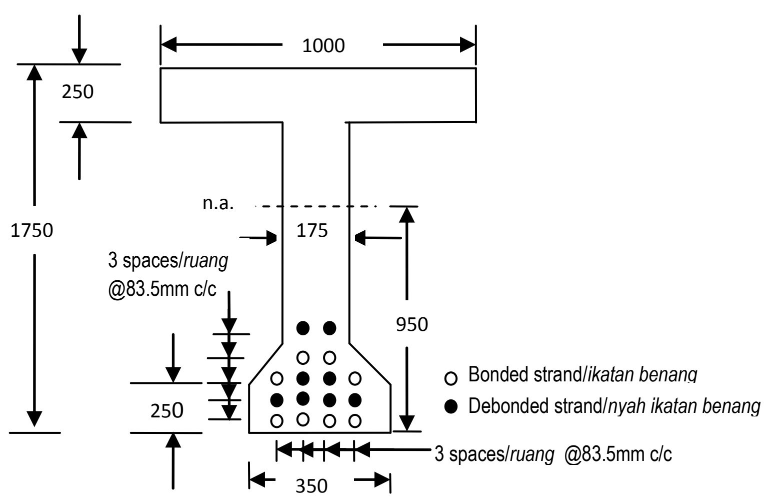


Figure 1 Prestressed Beam Section
Rajah 1 Keratan rentas Rasuk Pra-Tegasan

[15 marks/*markah*]

5. (a) Describe **FOUR (4)** effects of prestressing force at the anchorage plates in post-tensioned structural beams.

*Terangkan **EMPAT (4)** kesan daya pra tegasan di plat tambatan untuk rasuk struktur pasca-teganagan.*

[4 marks/*markah*]

(b) Describe with the aid of sketches the stress distribution at the anchorage zones.

Terangkan dengan bantuan lakaran agihan tegasan di zon tambatan.

[6 marks/*markah*]

(c) Design the end block reinforcement using BS8110-1; 1997 for the bonded post tensioned beam when a prestressing force of 1400 kN is applied by a single tendon shown in **Figure 2** . The bearing plate size is 210 mm x 320 mm and at support, e = 0. The 12 mm diameter steel reinforcement is proposed where the characteristic strength $f_y = 460 \text{ N/mm}^2$

*Rekabentuk tetulang blok hujung dengan menggunakan BS8110-1; 1997 untuk rasuk pasca tegang ikatan bebenang apabila daya prategasan ialah dikenakan untuk satu tendon seperti di **Rajah 2**. Saiz pelat galas ialah 210 mm x 320 mm dan di sokongan, e = 0. Dicadangan tetulang keluli 12 mm garispusat dan ciri kekuatannya ialah $f_y = 460 \text{ N/mm}^2$.*

[15 marks/*markah*]

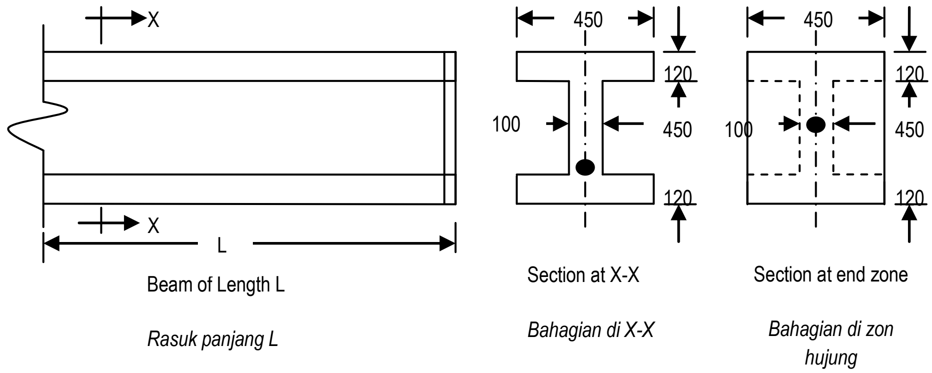
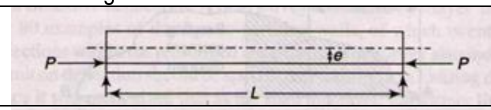
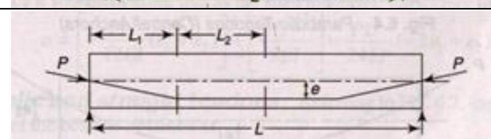
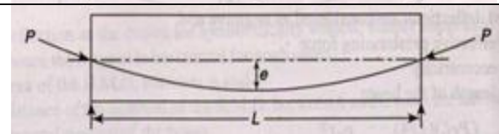
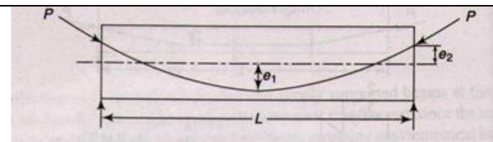
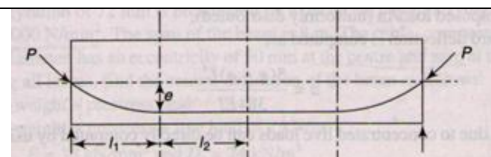
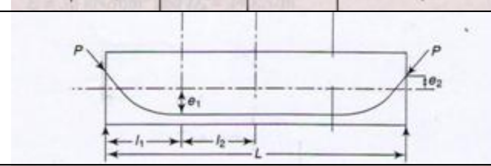
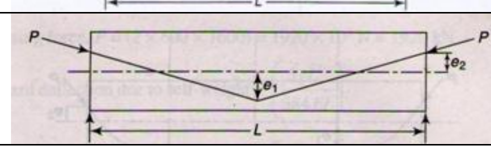


Figure 2 End Block of a Post Tensioned Beam

Rajah 2 Blok Hujung Rasuk Pasca Tegang

Appendix 1/ *Lampiran 1*

Deflection of Prestressed Beams (from Raju N K, 2008, *"Prestressed Concrete",* 4th . Edition, Tata McGraw Hill)

	Tendon type	Beam diagram	Equation
1	Straight tendons		$a = \frac{P_i e L^2}{8EI}$
2	Trapezoidal Tendons		$a = \frac{P_i e}{6EI}[2(l_1)^2 + 6l_1 l_2 + 3(l_2)^2]$
3	Parabolic tendons (central anchors)		$a = \frac{5P_i e L^2}{48EI}$
4	Parabolic tendons (eccentric anchors)		$a = \frac{P_i L^2}{48EI}(-5e_1 + e_2)$
5	Parabolic and straight tendons		$a = \frac{P_i e}{EI}[5(l_1)^2 + 12l_1 l_2 + 6(l_2)^2]$
6	Parabolic and Straight tendons (eccentric anchors)		$a = \frac{P_i(e_1 + e_2)}{12EI}[5(l_1)^2 + 12l_1 l_2 + 6(l_2)^2] + \left(\frac{P_i e_2 L^2}{8EI}\right)$
8	Sloping tendons (eccentric anchors)		$a = \frac{P_i L^2}{24EI}(-2e_1 + e_2)$
9	Deflections Due To Self-Weight And Imposed Loads		$a = \frac{5(g+q)L^4}{384EI}$
10	Long term deflection		$a_f = a_{i1}(1+\emptyset) - a_{ip}\left[\left(1-\frac{L_p}{P_i}\right)+\left(1-\frac{L_p}{2P_i}\right)\emptyset\right]$

Appendix 2/ *Lampiran 2*

Steel Reinforcement Data

Data Tetulang Keluli

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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