UNIVERSITI SAINS MALAYSIA

Second Semester Examination
2016/2017 Academic Session

June 2017

EAS453 – Pre-Stressed Concrete Design
[Reka Bentuk Konkrit Pra- Tegasan]

Duration : 2 hours
[Masa : 2 jam]

Please check that this examination paper consists of **TWELVE (12)** pages of printed material including **ONE (1)** appendix before you begin the examination.
*[Sila pastikan bahawa kertas peperiksaan ini mengandungi **DUA BELAS (12)** muka surat yang bercetak termasuk **SATU (1)** 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.]*

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 precast pre-tensioned simply supported beam of rectangular cross section carries the load as shown in **Figure 1**. The member is to be designed with a concrete strength class C40/50. The prestress force is transferred to the member at 32 N/mm^2 cylinder strength.

Satu rasuk pratuang pra-tegangan yang disokong mudah dengan keratan rentas segi empat tepat menanggung beban seperti yang ditunjukkan di dalam Rajah 1. Anggota itu direkabentuk dengan kelas kekuatan konkrit C40/50. Daya prategasan dipindahkan kepada anggota pada kekuatan silinder 32 N/mm^2.

[a] Taking the loses to be 20%, determine an appropriate rectangular section for the member by taking the density of prestressed concrete to be 25 kN/m^3. Maintain the breadth of the beam as 300 mm.

Dengan mengambil kehilangan sebanyak 20%, tentukan keratan segi empat tepat yang sesuai dengan mengambil ketumpatan konkrit prategasan ialah 25 kN/m^3. *Kekalkan lebar rasuk sebagai 300 mm.*

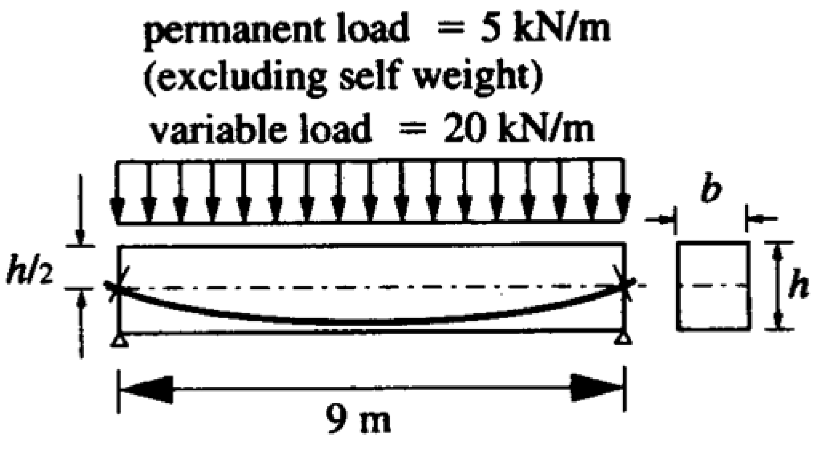


Figure 1/*Rajah 1*

[12 marks/*markah*]

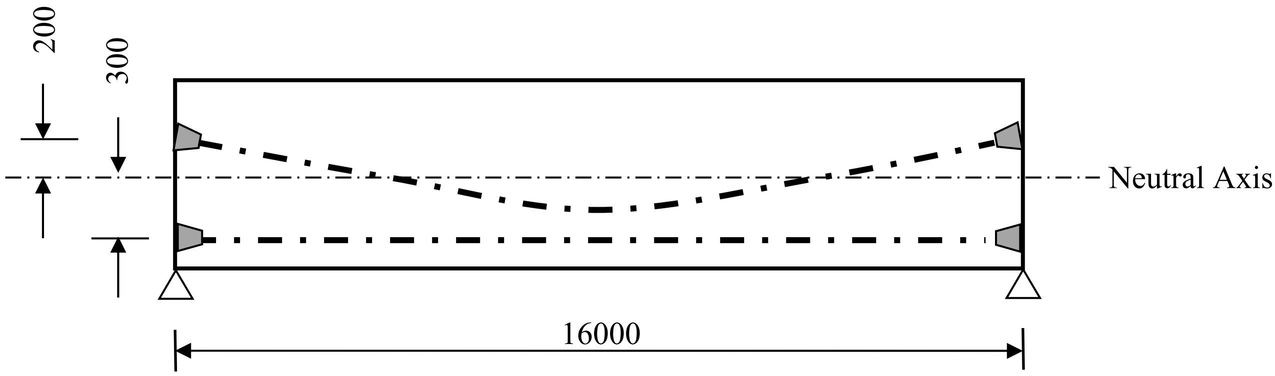
[b] Draw the upper and lower limit eccentricities of the beam for a prestress force of 2500 kN.

Lukiskan kesipian had atas dan had bawah bagi rasuk untuk daya prategasan 2500 kN.

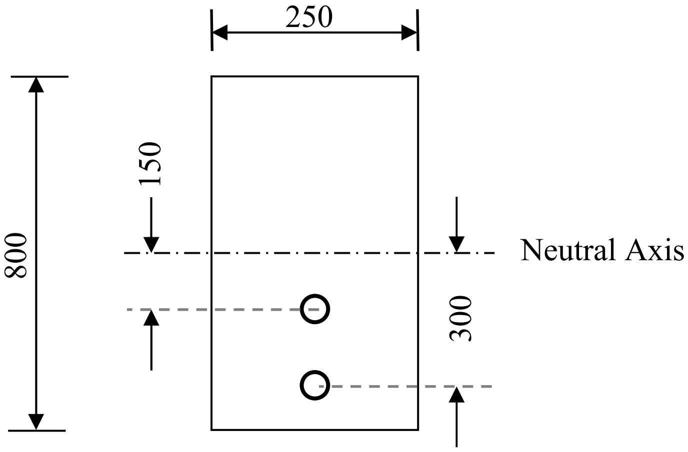
[13 marks/*markah*]

2. [a] **Figure 2** shows the tendon profile and cross section of a simply supported 16 m post-tensioned beam. It can be seen that the beam is designed using two circular tendons. The initial pre-stressing force for the parabolic tendon and straight tendon is 1000 kN and 800 kN, respectively. Previous calculation estimated that the total pre-stress loss will be 20%. If the beam is supporting 8 kN/m finishes and 1 kN/m variable load, evaluate the maximum deflection of the beam the at **ALL** stages. It is anticipated that only 30% of the variable load contributes to the quasi-permanent action. Take E_{cm} = 32 kN/mm^2 and creep factor = 2.0. Standard equations for deflection are given in **Appendix A**.

Rajah 2 *menunjukkan susuk tendon dan keratan rentas satu rasuk pasca-tegasan dengan rentangan 16 m. Adalah dapat dilihat rasuk tersebut direkabentuk menggunakan dua tendon bulat. Daya tujahan awal untuk tendon parabolik dan lelurus masing-masing adalah 1000 kN dan 800 kN. Pengiraan terdahulu menganggarkan jumlah kehilangan pra-tegasan adalah sebanyak 20%. Jika rasuk tersebut menanggung 8 kN/m beban kemasan dan 1 kN/m beban boleh ubah, buat penilaian terhadap pesongan maksima rasuk tersebut pada* ***SEMUA*** *peringkat. Adalah dijangkakan hanya 30% dari beban boleh ubah menyumbang kepada kelakuan kuasi-kekal. Ambil E_{cm} = 32 kN/mm^2 dan faktor rayapan = 2.0. Persamaan piawai untuk pesongan diberikan di* ***Lampiran A****.*



(a) longitudinal section/*keratan membujur*



(b) section at midspan/*keratan pada tengah rentang*

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

[13 marks/*markah*]

[b] From the time that the prestressing force is applied to the concrete member, losses of this force will take place because of a few factors. Explain the mechanism of loss due to elastic shortening of the pre-tensioned and post-tensioned concrete member as well as how it is quantified.

Dari masa daya prategasan diaplikasikan kepada anggota konkrit, kehilangan tenaga ini akan berlaku disebabkan beberapa faktor. Terangkan mekanisme kehilangan akibat pemendekan anjal konkrit untuk anggota konkrit pra-tegangan dan pasca-tegangan serta bagaimana ia dinilai.

[12 marks/*markah*]

3 [a] The cross section of a 15 m post-tensioned beam at midspan is shown in **Figure 3**. The beam is equipped with two tendons marked **T1** and **T2.** Tendon **T1** and **T2** consists of 10 and 15 strands, respectively. This design used 9.5 mm diameter strands with A_{ps} = 55 mm^2. Each strand is initially stressed to 985 N/mm^2 and 25% pre-stress losses are anticipated. If the beam is supporting a total uniformly distributed factored dead load = 20 kN/m and variable load = 10 kN/m, evaluate the ultimate moment capacity of the beam. Verify that x = 367 mm can be used to balance F_c and F_s. Take f_{ck} = *C35/45*, E_p = 195 kN/mm^2 γ_p = 0.9 and f_{pd} = 1450 N/mm^2.

*Keratan rentas dipertengahan rentang untuk satu rasuk pasca-tegasan 15 m panjang ditunjukkan di **Rajah 3**. Rasuk tersebut dilengkapkan dengan dua tendon bertanda **T1** dan **T2**. Tendon **T1** dan **T2** masing-masing terdiri daripada 10 dan 15 lembar. Rekabentuk ini menggunakan lembar bergarispusat 9.5 mm dengan A_{ps} = 55 mm^2. Tegasan awal untuk setiap lembar adalah 985 N/mm^2 dan kehilangan pra-tegasan dijangkakan sebanyak 25%. Jika rasuk tersebut menanggung sejumlah beban mati teragih seragam terfaktor beban mati = 20 kN/m dan beban boleh ubah = 10 kN/m, buat penilaian terhadap keupayaan momen muktamad rasuk. Tentusahkan x = 367 mm boleh digunakan untuk mengimbangi F_c dan F_s. Ambil f_{ck} = C35/45, E_p = 195 kN/mm^2, γ_p = 0.9 dan f_{pd} =* 1450 N/mm^2.

[20 marks/*markah*]

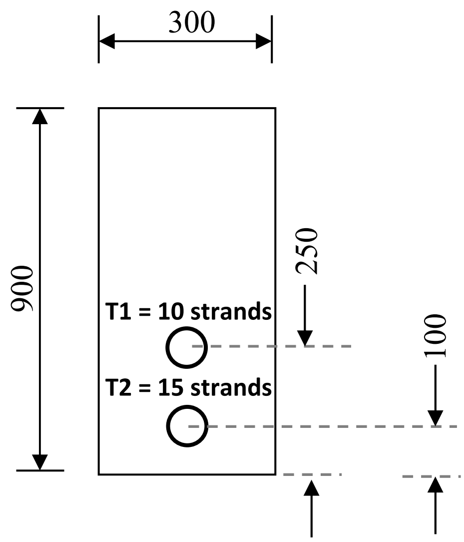


Figure 3 (all dimensions in mm)/*Rajah 3 (semua ukuran dalam mm)*

[b] Upon approval, the detailing of the post-tensioned beam was immediately sent to a factory for fabrication. However, due to unforeseen matters, the design engineer realized that the beam actually must be able to withstand a new ultimate moment of 1100 kNm. Unfortunately, the factory had fabricated the moulds and purchased the strands within a short period of time. Based on the existing condition, propose (with technical justifications) the most efficient approach to overcome this problem.

Setelah diluluskan, perincian rasuk pra-tegasan telah dihantar ke kilang dengan segera untuk pembuatan. Namun demikian, disebabkan oleh perkara luar jangka, jurutera rekabentuk telah menyedari bahawa rasuk tersebut sebenarnya perlu menanggung momen muktamad baru sebanyak 1100 kNm. Malangnya, pihak kilang telahpun membuat acuan dan membeli lembar dalam tempoh masa yang singkat. Berdasarkan kepada keadaan sedia ada, cadangkan (dengan justifikasi teknikal) kaedah yang paling berkesan untuk mengatasi masalah ini.

[5 marks/*markah*]

4. For a pre-stressed beam of dimensions 650 mm x 1300 mm, the maximum shear force is 750 kN and the prestress force after losses (P_o) is 2353 kN. The effective depth at that section is given as 1200 mm and the height of centroidal axis from the base is 700 mm.

Untuk sebuah rasuk pra-tegasan dengan dimensi 650 mm x *1300 mm, daya ricih maksima adalah 750 kN dan daya prategasan selepas kehilangan ialah (P_o) 2353 kN. Kedalaman efektif di keratan tersebut ialah 1200 mm dan ketinggian paksi sentroid daripada asas ialah 700 mm.*

The characteristics of the section are

Ciri-ciri keratan tersebut adalah

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

Luas kawasan tendon pra tegasan (A_{ps}) = 4750 mm^2

Characteristic strength of concrete (f_{ck}) = 50 N/mm^2

Ciri kekuatan konkrit (f_{ck}) =50 N/mm^2

Characteristic strength of steel reinforcements (f_{yk}) = 500 N/mm^2

Ciri kekuatan tetulang besi (f_{yk}) = 500 N/mm^2

Prestress force after losses factor (K) = 0.9

Faktor daya prategasan selepas kehilangan (K) = 0.9

Partial safety factor (γ_p) = 0.9

Faktor keselamatan separa (γ_p) = 0.9

Angle of tendon (β) = 3.5°at section considered

Sudut tendon (β) = 3.5° di keratan tersebut

Using MS EN1992:2010 design and sketch the shear reinforcements required for the section.

Dengan menggunakan MS EN1992:2010 rekabentuk dan lakar tetulang ricih yang diperlukan untuk keratan tersebut.

[25 marks/*markah*]

5. [a] Sketch the differences of stress distribution between a flat plate anchorage and a conical plate anchorage for end blocks.

Lakar perbezaan agihan tegasan antara plat tambatan rata dengan plat tambatan kon untuk blok hujung.

[5 marks/*markah*]

[b] For post-tensioned members with end bearing plates, describe in brief the differences between the local zone and general zone at the end zone.

Untuk anggota pasca-tegangan dengan plat galas hujung, terangkan dengan ringkas perbezaan antara zon tempatan dan zon keseluruhan di zon hujung.

[5 marks/*markah*]

[c] The beam shown in **Figure 4** is stressed by four identical 80 mm diameter conical anchorages with a jacking force of 200 kN applied to each anchorage. Design the reinforcement required around the anchorages when f_{yk} = 500 N/mm^2 and f_{ck} = 50 N/mm^2. Assume that the stress in the steel reinforcement is limited to 300 Nmm^{-2}.

*Rasuk yang ditunjukkan di **Rajah 4** ditegangkan oleh tambatan kon bergarispusat 80 mm dengan daya bicu 200 kN yang dikenakan pada setiap tambatan. Rekabentuk tetulang yang diperlukan di sekeliling tambatan bila f_{yk} = 500 N/mm^2 dan f_{ck} = 50 N/mm^2. Andaikan tegasan dalam tetulang besi dihadkan pada 300 Nmm^{-2}.*

The cross section of the beam is shown below;

Keratan rentas rasuk adalah seperti di bawah ini;

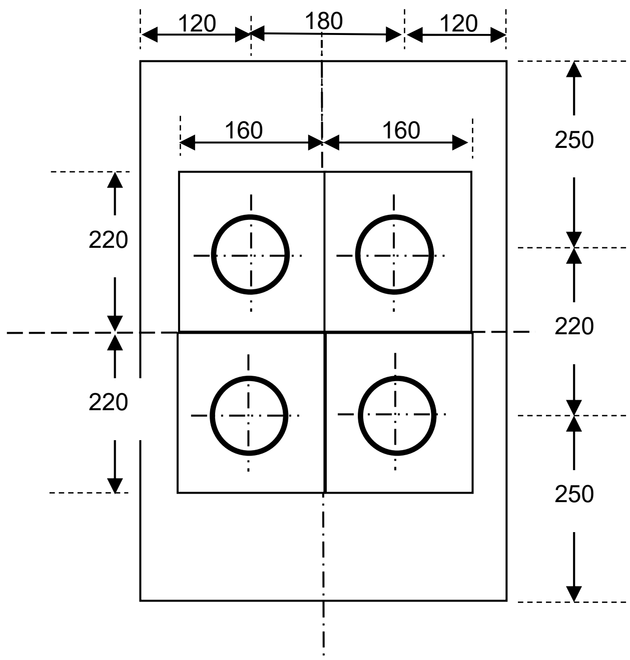
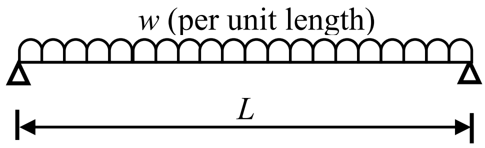
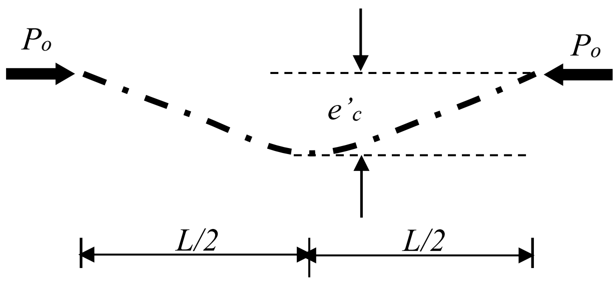
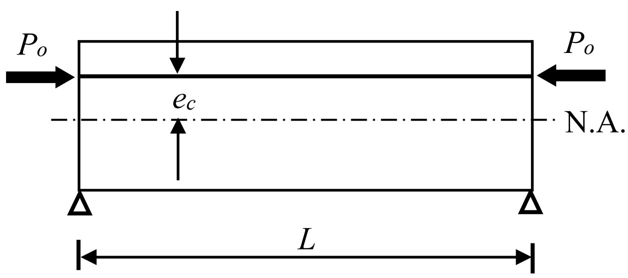


Figure 4 (all dimensions in mm) / *Rajah 4 (semua ukuran dalam mm)*

[15 marks/*markah*]

APPENDIX A/*LAMPIRAN A*

	$\delta_{max} = \dfrac{5\,wL^4}{384\,E_{cm}I}$
	$\delta_{max} = \dfrac{-5\,P_o e'_c L^2}{48\,E_{cm}I}$
	$\delta_{max} = \dfrac{P_o\,e_c L^2}{8\,E_{cm}I}$

APPENDIX B/*LAMPIRAN B*

Diameter of link bars (mm)		Spacing of bars (s_v) (mm)									
		75	100	125	150	175	200	225	250	275	300
	8	1.34	1.005	0.804	0.67	0.574	0.503	0.447	0.402	0.366	0.335
	10	2.094	1.571	1.257	1.047	0.898	0.785	0.698	0.628	0.571	0.524
	12	3.016	2.262	1.81	1.508	1.293	1.131	1.005	0.905	0.823	0.754
	16	5.362	4.021	3.217	2.681	2.298	2.011	1.787	1.608	1.462	1.34

Table 1 Area of Shear links and spacing of links

No of bars		Bar Diameter (mm)							
		6	8	10	12	16	20	25	32
	1	28	50	79	113	201	314	491	804
	2	57	101	157	226	402	628	982	1608
	3	85	151	236	339	603	942	1473	2413
	4	113	201	314	452	804	1257	1963	3217
	5	141	251	393	565	1005	1571	2454	4021
	6	170	302	471	679	1206	1885	2945	4825
	7	198	352	550	792	1407	2199	3436	5630
	8	226	402	628	905	1608	2513	3927	6434
	9	254	452	707	1018	1810	2827	4418	7238
	10	283	503	785	1131	2011	3142	4909	8042

Table 2 Area of reinforcement bars

GOVERNING INEQUALITIES

At transfer

Top:

$$\frac{P_o}{A} - \frac{P_o e}{Z_t} + \frac{M_{min}}{Z_t} = f_{1t} \geq f_{tt}$$

Bottom:

$$\frac{P_o}{A} + \frac{P_o e}{Z_b} + \frac{M_{min}}{Z_b} = f_{2t} \leq f_{ct}$$

At Service

Top:

$$\frac{\alpha P_o}{A} - \frac{\alpha P_o e}{Z_t} + \frac{M_{max}}{Z_t} = f_{1s} \leq f_{cs}$$

Bottom:

$$\frac{\alpha P_o}{A} + \frac{\alpha P_o e}{Z_b} - \frac{M_{max}}{Z_b} = f_{2s} \geq f_{ts}$$

MINIMUM SECTION MODULI

$$Z_t \geq \frac{M_v}{(f_{cs} - \alpha f_{tt})}$$

$$Z_b \geq \frac{M_v}{(\alpha f_{ct} - f_{ts})}$$

THE RANGE OF ECCENTRICITIES

At transfer

Top:

$$e \leq \left[\frac{Z_t}{A} - \frac{f_{tt} Z_t}{P_o}\right] + \frac{M_{min}}{P_o}$$

Bottom:

$$e \leq \left[-\frac{Z_b}{A} + \frac{f_{ct} Z_b}{P_o}\right] + \frac{M_{min}}{P_o}$$

At Service

Top:

$$e \geq \left[\frac{Z_t}{A} - \frac{f_{cs} Z_t}{\alpha P_o}\right] + \frac{M_{max}}{\alpha P_o}$$

Bottom:

$$e \geq \left[-\frac{Z_b}{A} + \frac{f_{ts} Z_b}{\alpha P_o}\right] + \frac{M_{max}}{\alpha P_o}$$

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