UNIVERSITI SAINS MALAYSIA

First Semester Examination
2011/2012 Academic Session

January 2012

EMM 213/3 – Strength of Materials
[Kekuatan Bahan]

Duration : 3 hours
Masa : 3 jam

INSTRUCTIONS TO CANDIDATE:
ARAHAN KEPADA CALON:

Please check that this paper contains **NINE (9)** printed pages, **THREE (3)** pages appendix and **SEVEN (7)** questions before you begin the examination.
*Sila pastikan bahawa kertas soalan ini mengandungi **SEMBILAN (9)** mukasurat bercetak, **TIGA (3)** mukasurat lampiran dan **TUJUH (7)** soalan sebelum anda memulakan peperiksaan.*

Answer **FIVE (5)** questions.
*Jawab **LIMA (5)** soalan.*

Appendix/*Lampiran*:

1. Table of Average Mechanical Properties of Typical Engineering Materials (SI Units) [1 page/*mukasurat*]
2. Beam Deflection Formulae [1 page/*mukasurat*]
3. Table Q4[a]: Result of bending test [1 page/*mukasurat*]

You may answer all questions in **English** OR **Bahasa Malaysia** OR a combination of both.
*Calon boleh menjawab semua soalan dalam **Bahasa Malaysia** ATAU **Bahasa Inggeris** ATAU kombinasi kedua-duanya.*

Answer to each question must begin from a new page.
Jawapan untuk setiap soalan mestilah dimulakan pada mukasurat yang baru.

In the event of any discrepancies, the English version shall be used.
Sekiranya terdapat sebarang percanggahan pada soalan peperiksaan, versi Bahasa Inggeris hendaklah diguna pakai.

Q1. [a] For the beam and loadings shown in Figure Q1[a], determine the shear force and bending moment as the functions of *x*, then draw the shear force diagram and bending moment diagram.

Bagi rasuk dan beban-beban yang ditunjukkan dalam Rajah S1[a], tentukan daya ricih dan momen lentur sebagai fungsi x, seterusnya lukis rajah daya ricih dan rajah momen lentur.

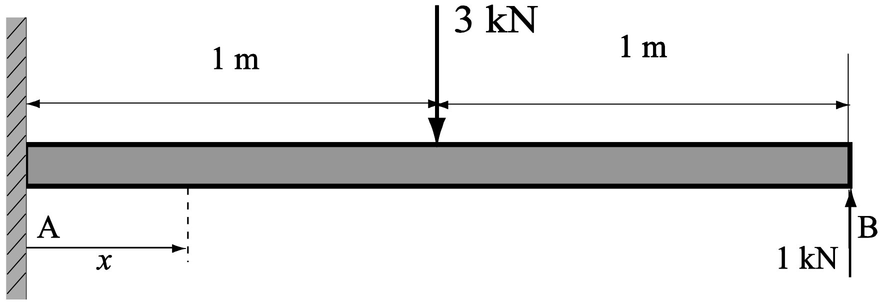


Figure Q1[a]
Rajah S1[a]

(30 marks/*markah*)

[b] A schematic diagram of a turbine dam is shown in Figure Q1[b]. If the wall of dam can be assumed as i) cantilever beam and ii) simply supported beam, determine the maximum bending moment on the wall for both assumptions and compare your result.

Rajah skema empangan turbin ditunjukkan dalam Rajah S1[b]. Jika dinding empangan boleh dianggap sebagai i) rasuk tetap dan ii) rasuk sokongan mudah, tentukan momen lentur maksimum bagi kedua-dua anggapan dan bandingkan keputusan anda.

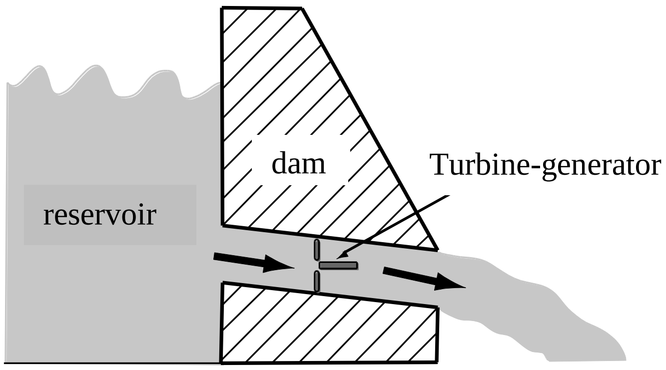


Figure Q1[b]
Rajah S1[b]

(70 marks/*markah*)

Q2. [a] The copper pipe has an outer diameter of 40 mm and an inner diameter of 37 mm. If it is tightly secured to the wall at *A* and three torques are applied to it as shown in Figure Q2[a], determine the absolute maximum shear stress developed in the pipe.

Paip tembaga berdiameter luar 40 mm dan garis pusat dalaman 37 mm. Jika ia diketatkan pada dinding di A dan dikenakan tiga kilasan seperti yang ditunjukkan dalam Rajah S2[a], tentukan tegasan ricih maksimum mutlak yang terhasil di dalam paip.

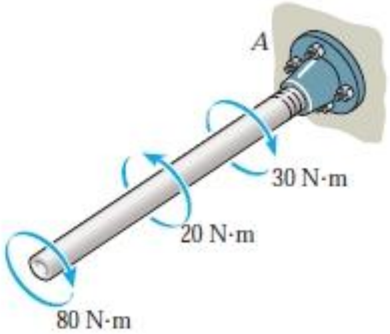


Figure Q2[a]
Rajah S2[a]

(30 marks/*markah*)

[b] In Figure Q2[b], the motor delivers 12 kW to the pulley at *A* while turning at a constant rate of 1800 rpm. Determine to the nearest multiples of 5 mm the smallest diameter of shaft *BC* if the allowable shear stress is τ_{allow} = 84 MPa. The belt does not slip on the pulley.

Dalam Rajah S2[b],motor menghantar 12 kW ke kapi semasa A berpusing pada kadar malar 1800 rpm. Tentukan diameter terkecil aci BC kepada gandaan terdekat 5 mm, jika tegasan ricih yang dibenarkan adalah τ_{allow} *= 84 MPa. Tali pinggang tidak tergelincir pada takal.*

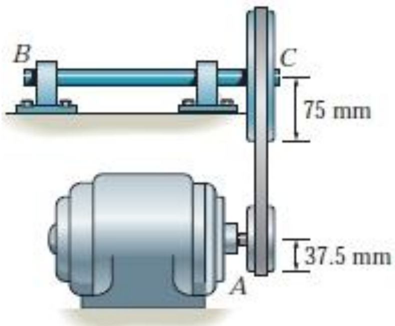


Figure Q2[b]
Rajah S2[b]

(30 marks/*markah*)

[c] **The A-36 steel shaft is made from two segments: *AC* has a diameter of 10 mm and *CB* has a diameter of 20mm as shown in Figure Q2[c]. If the shaft is fixed at its ends *A* and *B* and subjected to a uniform distributed torque of 300 N.m/m along segment *CB*, determine the absolute maximum shear stress in the shaft.**

Aci keluli A-36 dibuat dari dua segmen: AC berdiameter 10 mm dan CB berdiameter 20 mm seperti yang ditunjukkan dalam Rajah S2[c]. Jika aci ditetapkan pada hujung A dan B, dan tertakluk kepada daya kilas agihan seragam 300 N.m/m di sepanjang segmen CB, tentukan tegasan ricih maksimum mutlak dalam aci.

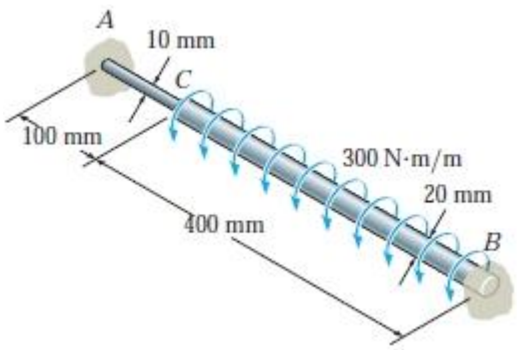


Figure Q2[c]
Rajah S2[c]

(40 marks/*markah*)

Q3. [a] **The wood beam in Figure Q3[a] has an allowable shear stress of $\tau_{allow} = 7MPa$. Determine the maximum shear force *V* that can be applied to the cross section.**

Rasuk kayu dalam Rajah S3[a] mempunyai tegasan ricih yang dibenarkan $\tau_{allow} = 7MPa$. Tentukan daya ricih V maksimum yang boleh dikenakan pada keratan rentas tersebut.

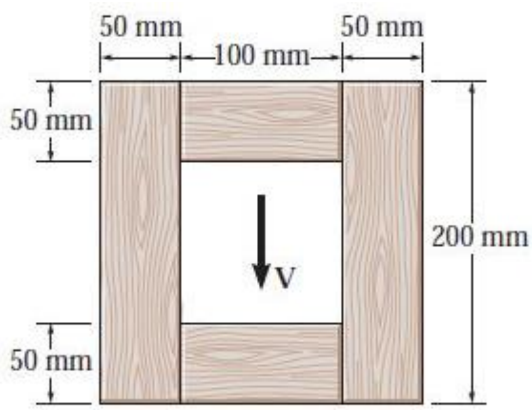


Figure Q3[a]
Rajah S3[a]

(15 marks/*markah*)

[b] **The beam in Figure Q3[b] is fabricated from two equivalent structural tees and two plates. Each plate has a height of 150 mm and a thickness of 12 mm. If the bolts are spaced at *s*=200 mm determine the maximum shear force *V* that can be applied to the cross section. Each bolt can resist a shear force of 75 kN.**

Rasuk dalam Rajah S3[b] dipasang daripada dua struktur T dan dua plat. Setiap plat mempunyai ketinggian 150 mm dan ketebalan 12 mm. Jika jarak antara bolt, s = 200 mm, tentukan daya ricih V maksimum yang boleh dikenakan pada keratan rentas. Setiap bolt boleh merintangi daya ricih sebanyak 75 kN.

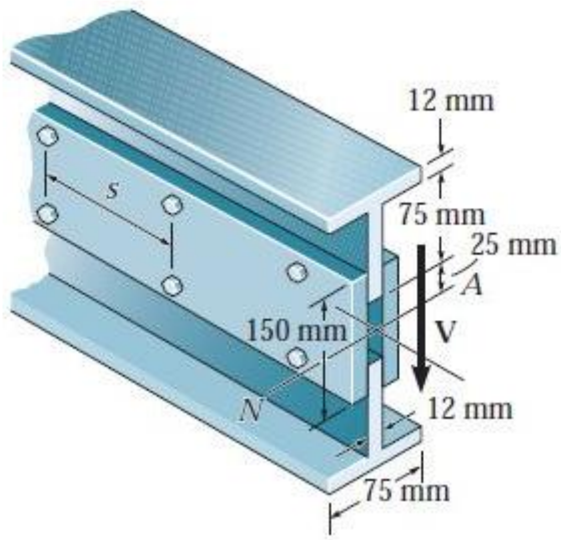


Figure Q3[b]
Rajah S3[b]

(25 marks/*markah*)

[c] **In Figure Q3[c], the aluminum strut is 10 mm thick and has the cross section shown. If it is subjected to a shear of *V*= 150 N , determine the maximum shear flow in the strut.**

Dalam Rajah S3[c], tupang aluminium adalah 10 mm tebal dan mempunyai keratan rentas yang ditunjukkan. Jika ia dikenakan daya ricih V = 150 N, tentukan aliran maksimum ricih dalam tupang.

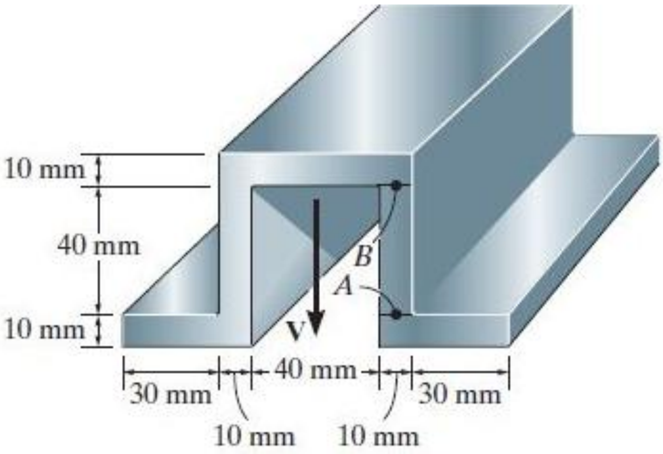


Figure Q3[c]
Rajah S3[c]

(60 marks/*markah*)

Q4. A three point bending test experiment for 2 beams specimen A and B was conducted and the result of beam's deflection is shown in Appendix 3. In this experiment, a point load P is being applied at the middle between the two supports. Based on the result given and the equation below, answer in detail the following questions. In the below equation: deflection (δ), point load (*P*), distance between supports (*l*), modulus of elasticity (E) and moment of inertia (I).

$$\delta = \frac{Pl^3}{48EI}$$

(i) If steel and aluminum have been used, determine the material for specimen A and B.

(20 marks)

(ii) If the own weight of the beam must be considered, determine the maximum deflection of specimen A for Case 2.

(40 marks)

(iii) Discuss whether the weight of hanger and beam's own weight have affected the result in Appendix 3. The mass of the hanger is 175 g.

(40 marks)

Ujikaji 3 titik lenturan rasuk untuk spesimen A dan B telah dilakukan, dan keputusan ditunjukkan dalam Lampiran 3. Dalam ujikaji tersebut, beban titik P dikenakan di tengah-tengah antara 2 penyokong. Berdasarkan keputusan yang diberikan dan persamaan di bawah, jawab dengan lengkap perkara-perkara berikut. Dalam persamaan di bawah: pesongan (δ), beban titik (P), jarak antara sokongan (l), modulus keanjalan (E) dan momen inersia (I).

$$\delta = \frac{Pl^3}{48\mathrm{EI}}$$

(i) Jika besi dan aluminium telah digunakan, tentukan bahan bagi spesimen A dan B.

(20 markah)

(ii) Jika berat sendiri rasuk perlu diambilkira, tentukan pesongan maksimum spesimen A bagi kes 2.

(40 markah)

(iii) Bincangkan sama ada jisim penyangkut dan berat sendiri rasuk memberi kesan kepada keputusan dalam Lampiran 3. Jisim penyangkut adalah 175 g.

(40 markah)

Q5. [a] Determine the minimum thickness of a pipe with internal diameter of 20 mm used to convey hydraulic fluid at a pressure of 250 bar if the yield stress of the material is 800 MPa and the safety factor used is 4.

Tentukan ketebalan minimum paip dengan diameter dalaman 20 mm yang digunakan untuk menghantar cecair hidraulik pada tekanan 250 bar jika tegasan alahan bahan adalah 800 MPa dan faktor keselamatan ialah 4.

(30 marks/*markah*)

[b] One of the method to determine the tensile strength of a circular pipe is by applying hydraulic pressure until it bursts. In one of the burst test, a pipe of an internal diameter of 20 mm with thickness of 4 mm is pressurized until it burst at the pressure of 1200 bar. Determine the ultimate tensile strength of the material used for the pipe.

Satu kaedah yang boleh digunakan untuk menentukan kekuatan tegangan bagi paip bulat ialah dengan mengenakan tekanan hidraulik sehingga paip itu pecah. Di dalam satu ujian yang serupa, paip dengan diameter dalaman 20 mm dan ketebalan 4 mm dikenakan tekanan sehingga ia pecah pada 1200 bar. Tentukan tegasan tegangan puncak bagi bahan paip tersebut.

(30 marks/*markah*)

[c] **In the assembly process of fitting a shaft to a sleeve, the axial force supplied by a hydraulic cylinder is required to push a solid shaft of 20.005 mm diameter through a sleeve of internal diameter of 20.000 mm and 25.000 mm external diameter. Both the shaft and sleeve are made of steel (E = 200 GPa, ν=0.3) and the friction coefficient is 0.1. How much axial force is needed for this process?**

Di dalam proses pemasangan sebatang syaf kepada sebuah kelongsong, daya paksi yang dibekalkan oleh silinder hidraulik diperlukan untuk menekan masuk sebatang syaf padu berdiameter 20.005 mm menerusi sebuah kelongsong setebal 10 mm dengan diameter dalaman 20.000 mm dan diameter luaran 25.000 mm. Kedua-dua syaf dan jurnal di perbuat daripada keluli (E = 200 GPa, ν=0.3) dan pekali geseran ialah 0.1. Berapakah daya paksi yang diperlukan untuk proses ini?

(40 marks/*markah*)

Q6. [a] **Determine the principal stresses of a circular 10 mm diameter solid shaft subjected to a bending moment of 200 Nm and a torque of 10 Nm.**

Tentukan tegasan-tegasan utama bagi sebatang syaf bulat yang dikenakan momen lentur 200 Nm dan kilas 10 Nm.

(25 marks/*markah*)

[b] **A differential element is subjected to a stress condition as shown in the Figure Q5[b] below. Determine the maximum value of the normal stress in the y-axis if the principal stress is limited to 100 MPa.**

Satu elemen pembeza dikenakan keadaan tegasan seperti yang ditunjukkan di dalam Rajah S5[b] di bawah. Tentukan nilai tegasan normal maksimum di dalam paksi-y jika tegasan utama dihadkan kepada 100 MPa.

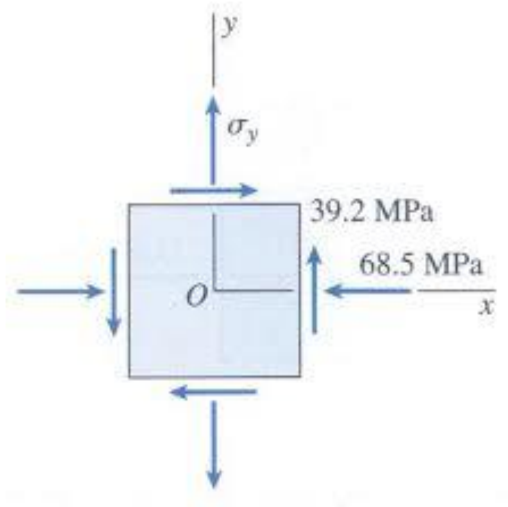


Figure Q5[b]
Rajah S5[b]

(25 marks/*markah*)

[c] Figure Q5[c] shows a pipe of an internal diameter of 50 mm (2R=50 mm) subjected to the force applied through the pipe wrench of P=500 N with the distance d=250 mm. The distance of L=400 mm determine the principal stresses at point A and point B. If the ultimate tensile strength of the pipe is 400 MPa, will the pipe be damaged from this work?

Rajah S5[c] menunjukkan sebatang paip dengan diameter dalaman 50 mm (2R=50 mm) dikenakan daya menerusi sebatang sepana dengan P=500 N pada jarak d=250 mm. Bagi jarak L=400 mm, tentukan tegasan-tegasan utama pada titik A dan B. Jika tegasan tegangan puncak bagi bahan paip ini ialah 400 MPa adakah paip ini akan mengalami kerosakan?

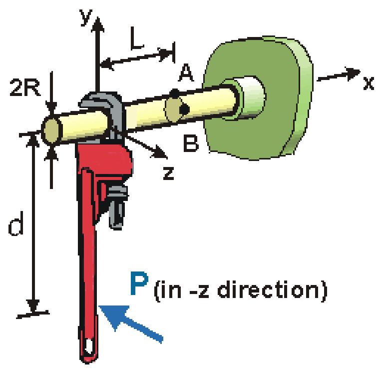


Figure Q5[c]
Rajah S5[c]

(50 marks/*markah*)

Q7. [a] Based on the first principle, derive the equation for the circumferential and radial stress (σ_Θ and σ_r) of an axially symmetrical structure of a thick cylinder with an internal diameter of d_i and thickness t, subjected to internal pressure of p_i as per the following steps. State clearly your assumptions.

Berdasarkan prinsip pertama, terbitkan persamaan untuk tegasan lingkaran dan tegasan jejari stress (σ_Θ dan σ_r) bagi struktur bersimetri paksi silinder berdinding tebal yang mempunyai diameter dalam d_i dan ketebalan t yang dikenakan tekanan dalaman p_i menurut langkah-langkah berikut. Nyatakan dengan jelas anggapan yang dibuat.

(80 marks/*markah*)

[b] What is the percentage of error when the ratio of diameter to thickness is 10 if the circumferential stress of a cylinder is calculated based on thin cylinder assumption

Berapakah peratus ralat apabila nisbah diameter kepada ketebalan adalah 10 jika tegasan lingkaran sebuah silinder dikira menggunakan anggapan silinder nipis.

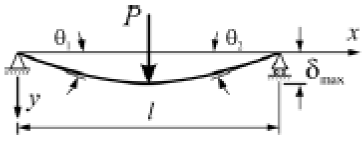
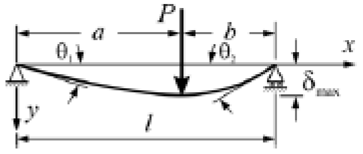
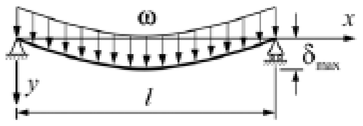
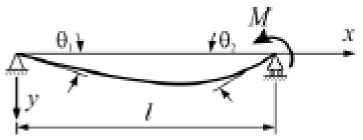
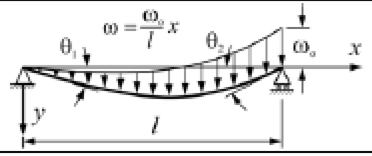
(20 marks/*markah*)

-oooOOooo-

APPENDIX 2/*LAMPIRAN 2*

Beam Deflection Formulae

(*Formula pesongan rasuk*)

BEAM TYPE	SLOPE AT ENDS	DEFLECTION AT ANY SECTION IN TERMS OF x	MAXIMUM AND CENTER DEFLECTION
6. Beam Simply Supported at Ends – Concentrated load P at the center			
	$\theta_1 = \theta_2 = \frac{Pl^2}{16EI}$	$y = \frac{Px}{12EI}\left(\frac{3l^2}{4} - x^2\right)$ for $0 < x < \frac{l}{2}$	$\delta_{max} = \frac{Pl^3}{48EI}$
7. Beam Simply Supported at Ends – Concentrated load P at any point			
	$\theta_1 = \frac{Pb(l^2-b^2)}{6lEI}$ $\theta_2 = \frac{Pab(2l-b)}{6lEI}$	$y = \frac{Pbx}{6lEI}\left(l^2 - x^2 - b^2\right)$ for $0 < x < a$ $y = \frac{Pb}{6lEI}\left[\frac{l}{b}(x-a)^3 + (l^2-b^2)x - x^3\right]$ for $a < x < l$	$\delta_{max} = \frac{Pb\left(l^2-b^2\right)^{3/2}}{9\sqrt{3}\,lEI}$ at $x = \sqrt{\left(l^2-b^2\right)/3}$ $\delta = \frac{Pb}{48EI}\left(3l^2 - 4b^2\right)$ at the center, if $a > b$
8. Beam Simply Supported at Ends – Uniformly distributed load ω (N/m)			
	$\theta_1 = \theta_2 = \frac{\omega l^3}{24EI}$	$y = \frac{\omega x}{24EI}\left(l^3 - 2lx^2 + x^3\right)$	$\delta_{max} = \frac{5\omega l^4}{384EI}$
9. Beam Simply Supported at Ends – Couple moment M at the right end			
	$\theta_1 = \frac{Ml}{6EI}$ $\theta_2 = \frac{Ml}{3EI}$	$y = \frac{Mlx}{6EI}\left(1 - \frac{x^2}{l^2}\right)$	$\delta_{max} = \frac{Ml^2}{9\sqrt{3}\,EI}$ at $x = \frac{l}{\sqrt{3}}$ $\delta = \frac{Ml^2}{16EI}$ at the center
10. Beam Simply Supported at Ends – Uniformly varying load: Maximum intensity ω_o (N/m)			
	$\theta_1 = \frac{7\omega_o l^3}{360EI}$ $\theta_2 = \frac{\omega_o l^3}{45EI}$	$y = \frac{\omega_o x}{360lEI}\left(7l^4 - 10l^2x^2 + 3x^4\right)$	$\delta_{max} = 0.00652\frac{\omega_o l^4}{EI}$ at $x = 0.519l$ $\delta = 0.00651\frac{\omega_o l^4}{EI}$ at the center

APPENDIX 1/*LAMPIRAN 1*

Table of Average Mechanical Properties of Typical Engineering Materials (SI Units)

(Jadual ciri-ciri mekanik beberapa bahan kejuruteraan)

Materials		Density ρ (Mg/m^3)	Modulus of Elasticity E (GPa)	Modulus of Rigidity G (GPa)	Yield Strength (MPa)	Coef. of Therm. Expansion α (10^{-6})/°C
Metallic						
Aluminum Wrought Alloys	2014-T6	2.79	73.1	27	414	23
	6061-T6	2.71	68.9	26	255	24
Cost Iron Alloys	Gray ASTM 20	7.19	67.0	27		12
	Malleable ASTM A-197	7.28	1.72	68		12
Copper Alloys	Red Brass C83400	8.74	101	37	70.0	18
	Bronze C86100	8.83	103	38	345	17
Magnesium Alloy	[Am 1004-T61]	1.83	44.7	18	152	26
Steel Alloys	Structural A36	7.85	200	75	400	12
	Stainless 304	7.86	193	75	517	17
	Tool L2	8.16	200	75	800	12
Titanium Alloy	[Ti-6A 1-4V]	4.43	120	44	1000	9.4
Nonmetallic						
Concrete	Low Strength	2.38	22.1	-	-	11
	High Strength	2.38	29.0	-	-	11
Plastic Reinforced	Kevlar 49	1.45	131	-	-	-
	30% Glass	1.45	72.4	-	-	-

APPENDIX 3/*LAMPIRAN 3*

Table Q4[a]: Result of bending test

Jadual S4(a) Keputusan ujian lenturan

		Specimen A (4.9x19.1)*		Specimen B (6.5x19.1)*	
	Load (N)	δ_{exp}	δ_{cal}	δ_{exp}	δ_{cal}
Case 1 (1200 mm)	5	5.4	5.6	2.3	2.1
	10	10.8	11.1	4.5	4.1
	15	16.3	16.9	6.7	6.2
	20	22.0	22.6	8.9	8.3
Case 2 (900 mm)	5	2.3	2.4	1.0	0.9
	10	4.7	4.8	2.0	1.7
	15	7.0	7.1	2.9	2.6
	20	9.5	9.5	3.8	3.5
Case 3 (600 mm)	5	0.8	0.7	0.3	0.3
	10	1.4	1.4	0.6	0.5
	15	2.2	2.1	0.9	0.8
	20	2.9	2.8	1.2	1.0

*Specimen dimension (height x width)
**All units in mm unless indicated