UNIVERSITY OF JOHANNESBURG
SPECIAL EXAMINATION

January 2015

COURSE: ENGINEERING | ***TIME:*** 3 HOURS
SUBJECT: *STRENGTH OF MATERIALS 2B (SLR2B21)* | ***MARKS:*** **100**
Examiner : Prof E. T. Akinlabi
Moderator : Mr D. M. Madyira

Instructions:

- **Answer all questions.**
- **Show your workings clearly in the answer booklet provided.**
- **Do not use Tipp-Ex or any correction fluid on your answer booklet.**

Question 1 **(25 marks)**

(a) With the aid of sketches, give the four types of support or connection in engineering structures.

(b) The pin support A and roller support B of the bridge truss are supported on concrete abutments as shown in Figure 1. The load applied at pin support A is 750 kN and at roller support B is 500 kN. If the bearing failure stress of the concrete is $(\sigma_{fail})_b = 25$ MPa. Determine the required minimum dimension of the square bearing plates at C and D to the nearest millimetre. Apply a factor of safety of 2 against failure.

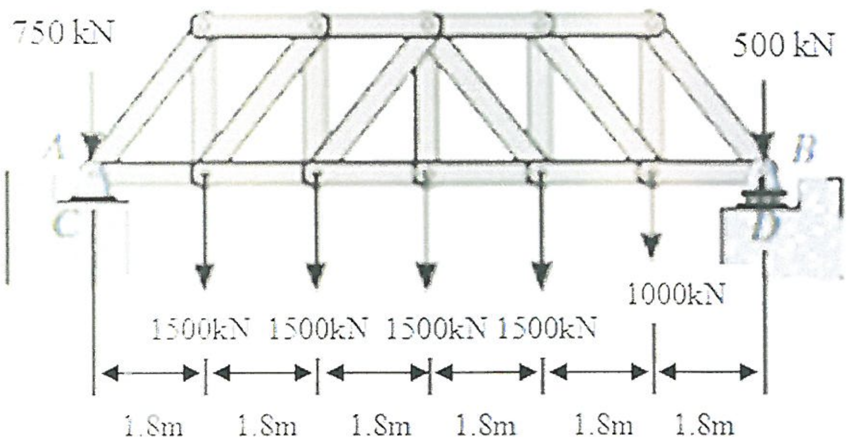

Figure1: A bridge truss

Question 2 **(15 marks)**

Figure 2 shows the motor M connected to the speed reducer C by the tubular shaft and coupling. If the motor supplies 15 kW and rotates the shaft at a rate of 600 rpm, determine the minimum inner and outer diameters d_i and d_o of the shaft if $\frac{d_i}{d_o} = 0.75$. Note that the shaft is made from a material having an allowable shear stress of $\tau_{allow} = 84$ MPa.

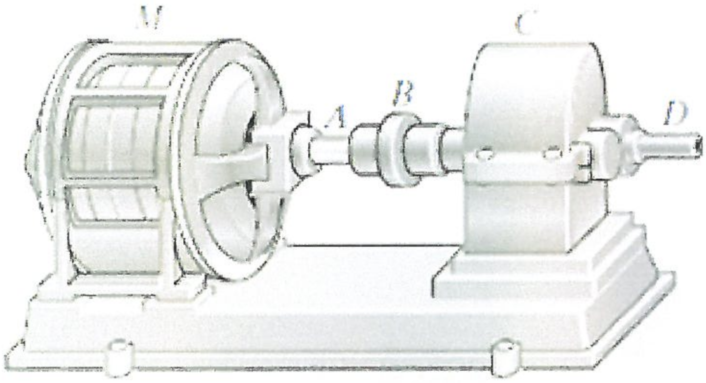

Figure 2: A Motor

Question 3 **(15 marks)**

The T-beam is subjected to an unknown bending moment M as shown in Figure 3. Determine:

(i) The location $\bar{y}$ of the centroid from the bottom edge at D.
(ii) The second moment of area of the beam section.
(iii) The moment M that will produce a maximum stress of 70 MPa on the cross section.

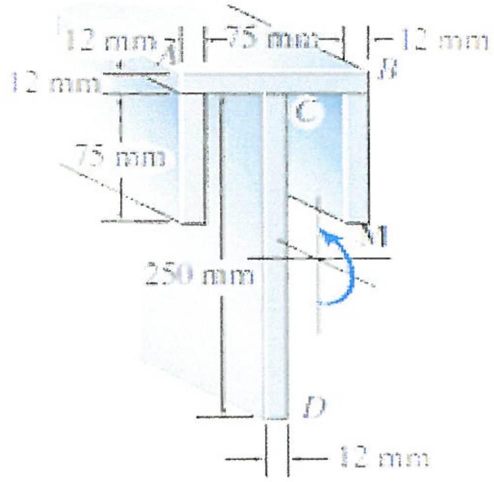

Figure 3: T-beam

Question 4 **(20 Marks)**

(a) A steel water pipe has an inner diameter of 300 mm and wall thickness of 6 mm. If the valve is closed and the water pressure is 2.5 MPa, determine the longitudinal and the hoop stress developed in the wall of the pipe.

(b) A pressure-vessel head is fabricated by gluing the circular plate to the end of the vessel as shown in Figure 4. If the vessel sustains an internal pressure of 450 kPa.

Determine:

(i) The average shear stress in the glue.
(ii) The state of the stress in the wall of the vessel.

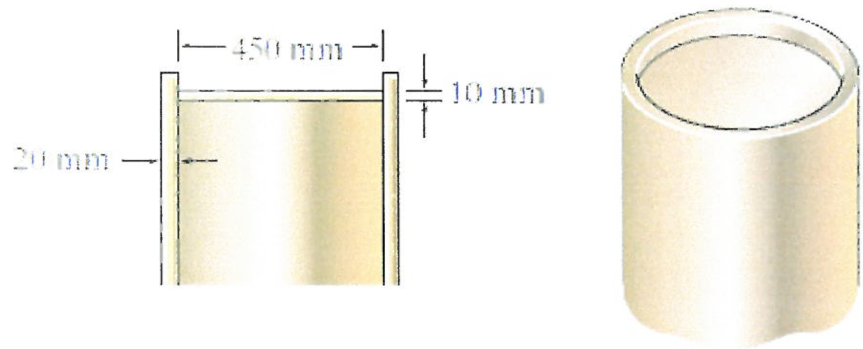

Figure 4: A pressure-vessel head

Question 5 **(25 Marks)**

The state of stress at a point is shown on the element in Figure 5.

Determine:

(i) The principal stress in the element.
(ii) The orientation of the principal stresses.
(iii) The maximum in-plane shear stress
(iv) The average normal stress at the point.
(v) In each case, specify the orientation of the element.
(vi) Show how the stresses deform the element within x-y plane.

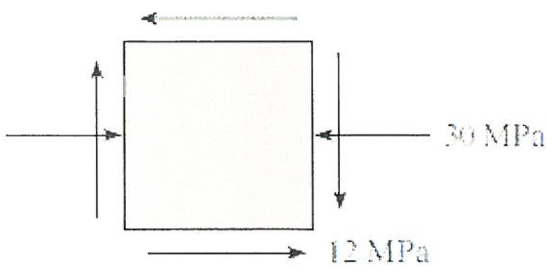

Figure 5: An Element

FORMULA SHEET

$$\sigma = \frac{P}{A} \quad ; \quad \tau_{avg} = \frac{V}{A} \quad ; \quad \sigma = E\varepsilon \quad ; \quad \tau = G\gamma$$

$$\nu = \frac{-\varepsilon_{lat}}{\varepsilon_{long}} \quad ; \quad G = \frac{E}{2(1+\upsilon)} \quad ; \quad \tau = \frac{VQ}{It} \quad ; \quad \delta = \sum \frac{PL}{AE}$$

$$q = \frac{VQ}{I} \quad ; \quad \phi = \sum \frac{TL}{JG} \quad ; \quad -w = \frac{dV}{dx} \quad ; \quad V = \frac{dM}{dx} ;$$

Pascal's law, $p = \gamma_w Z$, $\sigma_1 = \frac{pr}{t}$; $\sigma_2 = \frac{pr}{2t}$;

$$\sigma_b = \frac{Mc}{I} \quad ; \quad I = \frac{1}{12} bD^3 \quad ; \quad \sigma_{x^1} = \frac{\sigma_x + \sigma_y}{2} + \frac{\sigma_x - \sigma_y}{2}\cos 2\theta + \tau_{xy}\sin 2\theta$$

$$\tau_{x^1y^1} = -\frac{\sigma_x - \sigma_y}{2}\sin 2\theta + \tau_{xy}\cos 2\theta \quad ; \quad \sigma_{1,2} = \frac{\sigma_x + \sigma_y}{2} \pm \sqrt{(\frac{\sigma_x - \sigma_y}{2})^2 + \tau_{xy}{}^2}$$

$$\tau_{\max\_in\_plane} = \sqrt{(\frac{\sigma_x - \sigma_y}{2})^2 + \tau_{xy}{}^2} \quad ; \quad \sigma_{avg} = \frac{\sigma_x + \sigma_y}{2}; \quad \delta_t = \alpha \Delta T L$$

$$\varepsilon_{x^1} = \frac{\varepsilon_x + \varepsilon_y}{2} + \frac{\varepsilon_x - \varepsilon_y}{2}\cos 2\theta + \frac{1}{2}\gamma_{xy}\sin 2\theta \; ; \quad \varepsilon_{1,2} = \frac{\varepsilon_x + \varepsilon_y}{2} \pm \sqrt{(\frac{\varepsilon_x - \varepsilon_y}{2})^2 + \frac{\gamma_{xy}^2}{4}}$$

$$\varepsilon_{y^1} = \frac{\varepsilon_x + \varepsilon_y}{2} - \frac{\varepsilon_x - \varepsilon_y}{2}\cos 2\theta - \frac{1}{2}\gamma_{xy}\sin 2\theta \; ; \quad \frac{\gamma_{x^1y^1}}{2} = -(\frac{\varepsilon_x - \varepsilon_y}{2})\sin 2\theta + \frac{\gamma_{xy}}{2}\cos 2\theta$$

$$\gamma_{\max\_in\_plane} = 2\sqrt{(\frac{\varepsilon_x - \varepsilon_y}{2})^2 + \frac{\gamma_{xy}{}^2}{4}} \quad ; \quad \varepsilon_{avg} = \frac{\varepsilon_x + \varepsilon_y}{2}; \quad P = T\omega, \qquad \sigma = -\frac{M_z y}{I_z} + \frac{M_y z}{I_y}$$

$$\varepsilon_x = \frac{1}{E}(\sigma_x - \nu(\sigma_y + \sigma_z)) \; ; \quad \varepsilon_y = \frac{1}{E}(\sigma_y - \nu(\sigma_x + \sigma_z)) \; ; \quad \varepsilon_z = \frac{1}{E}(\sigma_z - \nu(\sigma_x + \sigma_y))$$

$$\tan 2\theta_p = \frac{2\tau_{xy}}{(\sigma_x - \sigma_y)}; \quad \tan 2\theta_s = -(\frac{\varepsilon_x - \varepsilon_y}{\gamma_{xy}}); \quad F.S. = \frac{\sigma_y}{\sigma_{calculated}}$$

$$\sigma_1 = \frac{\Pr}{t} \quad ; \quad \sigma_2 = \frac{\Pr}{2t}; \quad EI\frac{d^2y}{dx^2} = M \; ; \quad EI\frac{d^3y}{dx^3} = V; \quad EI\frac{d^4y}{dx^4} = -w$$

$$J = \frac{\pi}{32}\left[D^4 - d^4\right]; \qquad \tau_{allow} = \frac{Tc}{J}$$

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