DEPARTMENT OF CIVIL ENGINEERING

CE-221 SOLID MECHANICS

Quiz-2 16/10/15 PAPER CODE: A

Note: Write your name, roll no., and paper code on answerbook and on summary answer sheet provided on the reverse.

You must submit the question-paper-cum-summary-answer-sheet along with the answerbook otherwise your paper will not be graded.

Closed book, closed notes test. No formula sheet allowed. No mobile phones allowed in the exam hall.
Both questions carry equal marks. Assume suitable data if required and state the same clearly

Problem 1

A steel beam (cross-section **16mm x 46mm**) is covered with **2-mm** thick aluminium cladding to provide corrosion resistance as shown in **Fig. 1**. The bending moment is **500 N.m** in the direction shown. Take E_{steel} **= 210 GPa,** $E_{aluminium}$ **= 70 GPa**.

Find the maximum normal stress due to bending in (a) steel ($\sigma_{st,max}$) (b) aluminium ($\sigma_{al,max}$).

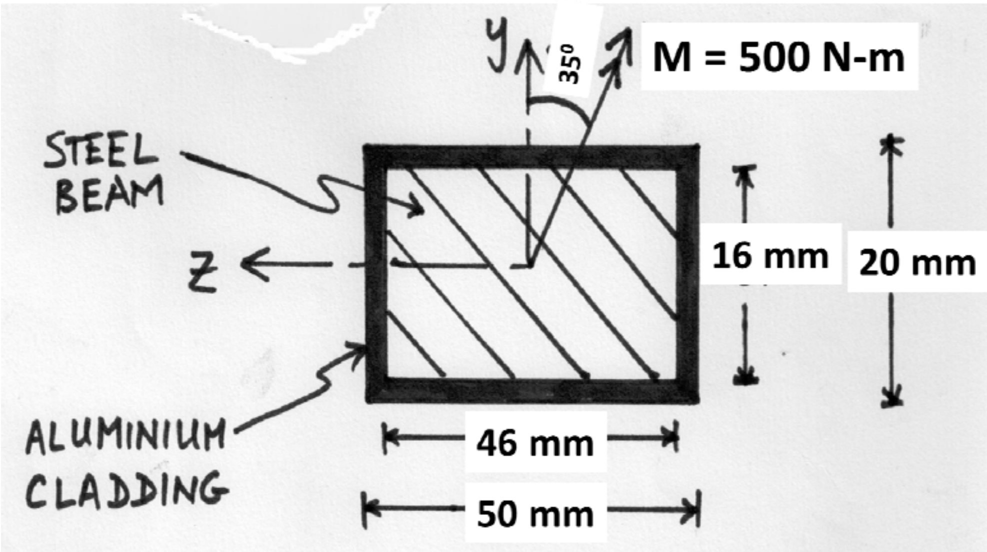

Fig. 1

Problem 2

A cantilevered beam has a thin-walled slit rectangular section as shown in **Fig. 2**. The slit is very small as shown in **Fig. 2**. The wall thickness is uniform and it is very small compared to the width and height of the section, so you must neglect higher order terms in the wall thickness. The dimensions shown in **Fig. 2** are centerline dimensions.

Determine, the distance *e* <u>with respect to the slit</u>, as to where a vertical load should be applied to prevent twisting of the beam.

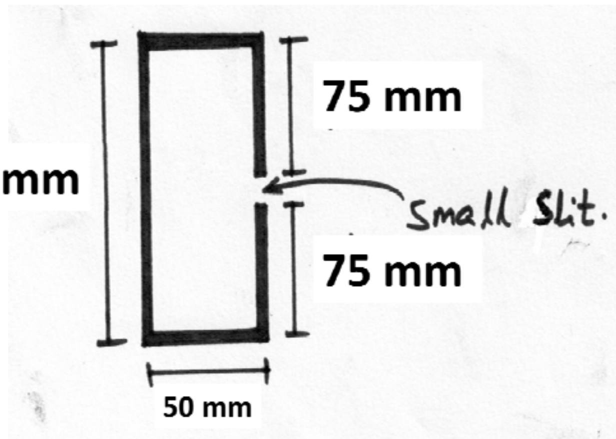

Fig. 2

DEPARTMENT OF CIVIL ENGINEERING

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Problem 1

A steel beam (cross-section **21mm x 41mm**) is covered with **2-mm** thick aluminium cladding to provide corrosion resistance as shown in **Fig. 1**. The bending moment is **400 N.m** in the direction shown. Take E_{steel} **= 200 GPa,** $E_{aluminium}$ **= 50 GPa**.

Find the maximum normal stress due to bending in (a) steel ($\sigma_{st,max}$) (b) aluminium ($\sigma_{al,max}$).

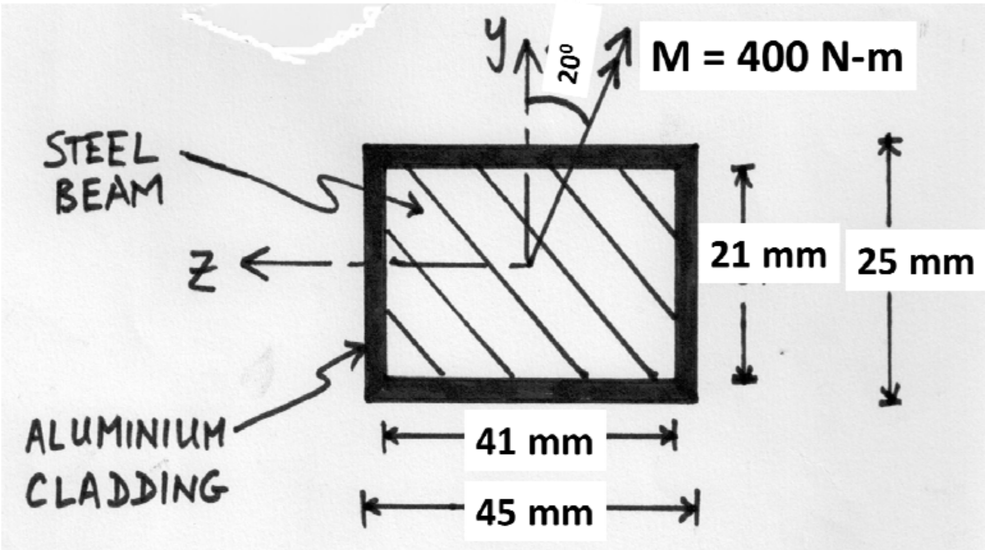

Fig. 1

Problem 2

A cantilevered beam has a thin-walled slit rectangular section as shown in **Fig. 2**. The slit is very small as shown in **Fig. 2**. The wall thickness is uniform and it is very small compared to the width and height of the section, so you must neglect higher order terms in the wall thickness. The dimensions shown in **Fig. 2** are centerline dimensions.

Determine, the distance *e* <u>with respect to the slit</u>, as to where a vertical load should be applied to prevent twisting of the beam.

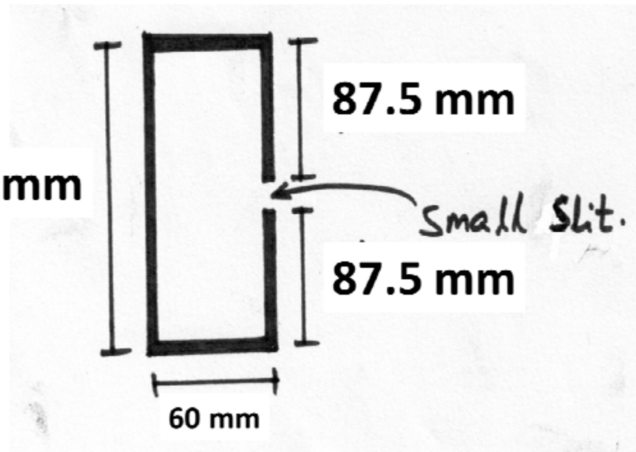

Fig. 2

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CE-221 SOLID MECHANICS

Quiz-2 16/10/15 PAPER CODE: C

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Problem 1

A steel beam (cross-section **31mm x 51mm**) is covered with **2-mm** thick aluminium cladding to provide corrosion resistance as shown in **Fig. 1**. The bending moment is **600 N.m** in the direction shown. Take E_{steel} **= 240 GPa,** $E_{aluminium}$ **= 80 GPa**.

Find the maximum normal stress due to bending in (a) steel ($\sigma_{st,max}$) (b) aluminium ($\sigma_{al,max}$).

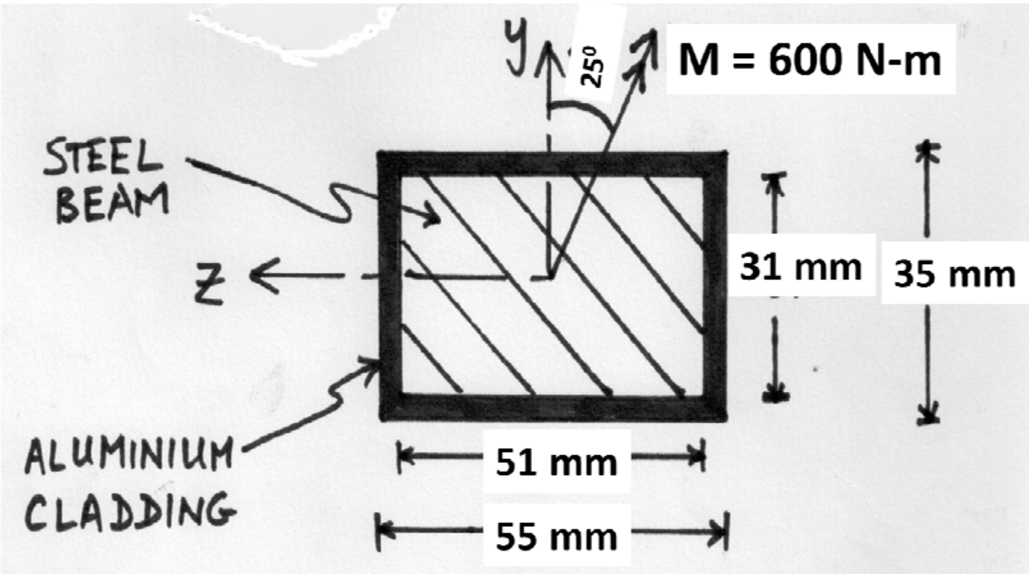

Fig. 1

Problem 2

A cantilevered beam has a thin-walled slit rectangular section as shown in **Fig. 2**. The slit is very small as shown in **Fig. 2**. The wall thickness is uniform and it is very small compared to the width and height of the section, so you must neglect higher order terms in the wall thickness. The dimensions shown in **Fig. 2** are centerline dimensions.

Determine, the distance *e* <u>with respect to the slit</u>, as to where a vertical load should be applied to prevent twisting of the beam.

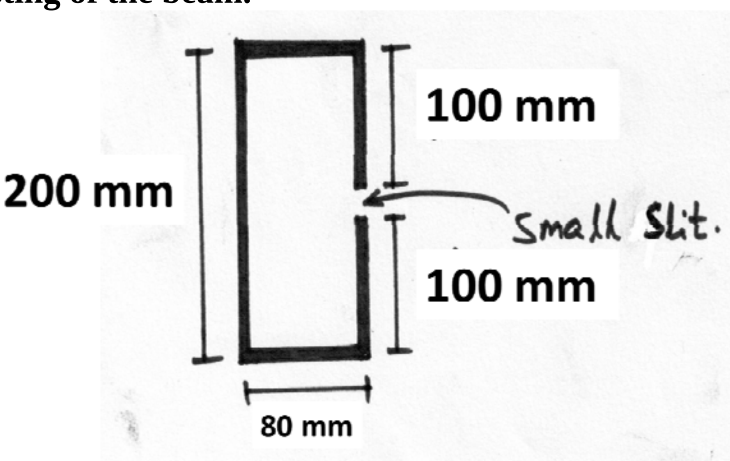

Fig. 2

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CE-221 SOLID MECHANICS

Quiz-2 16/10/15 PAPER CODE: D

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Both questions carry equal marks. Assume suitable data if required and state the same clearly

Problem 1

A steel beam (cross-section **26mm x 36mm**) is covered with **2-mm** thick aluminium cladding to provide corrosion resistance as shown in **Fig. 1**. The bending moment is **500 N.m** in the direction shown. Take E_{steel} = **240 GPa**, $E_{aluminium}$ = **60 GPa**.

Find the maximum normal stress due to bending in (a) steel ($\sigma_{st,max}$) (b) aluminium ($\sigma_{al,max}$).

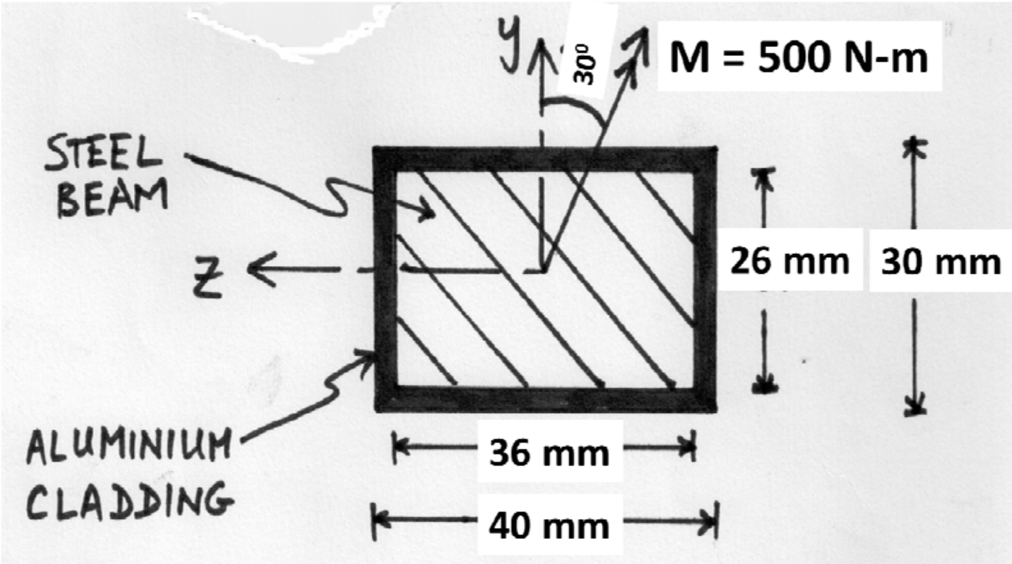

Fig. 1

Problem 2

A cantilevered beam has a thin-walled slit rectangular section as shown in **Fig. 2**. The slit is very small as shown in **Fig. 2**. The wall thickness is uniform and it is very small compared to the width and height of the section, so you must neglect higher order terms in the wall thickness. The dimensions shown in **Fig. 2** are centerline dimensions.

Determine, the distance *e* <u>with respect to the slit</u>, as to where a vertical load should be applied to prevent twisting of the beam.

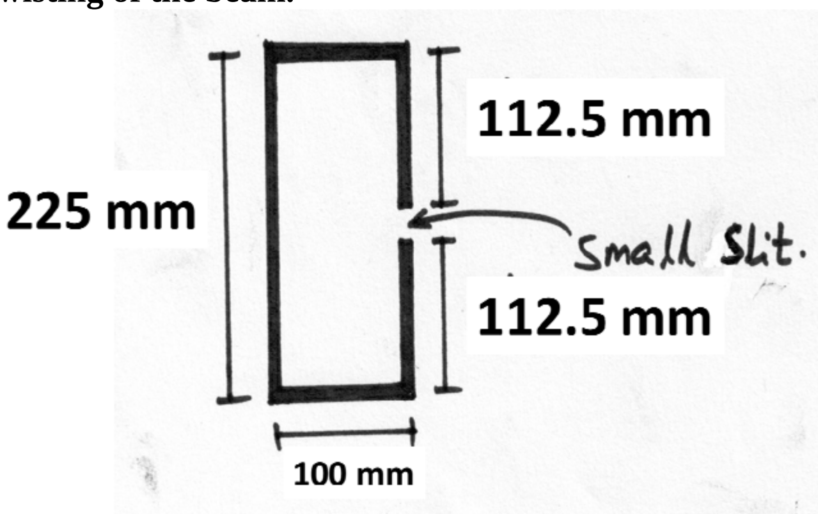

Fig. 2

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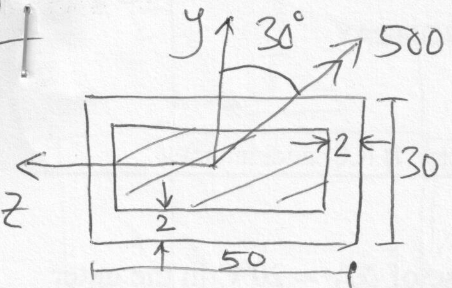
P1



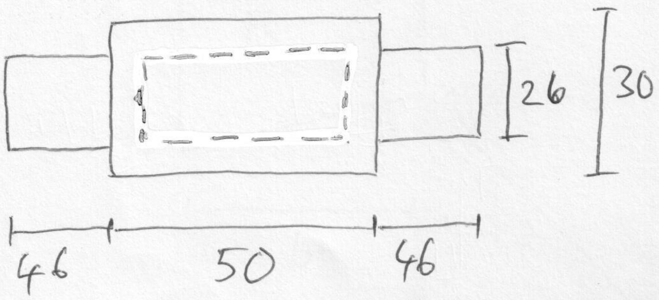
$n = \frac{210}{70} = 3$ (ie transform to full AL sections).

$M_y = M\cos\theta$, $M_z = -M\sin\theta$

Transformed sections:

For xy-plane bending due to M_z:

46 mm dimension of steel $\equiv 3*46$ (ie $n*46$) of AL.

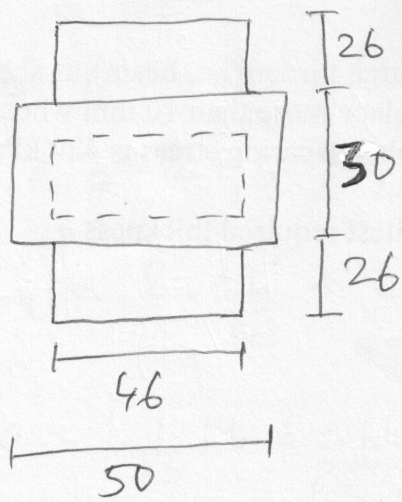


$$I_z = \frac{(50)(30^3)}{12} + 2*\frac{(46)(26^3)}{12}$$

$$= 247249.33\ mm^4$$

For xz-plane bending due to M_y:

26 mm dimension of steel $\equiv n*26 = 3*26$ of AL.



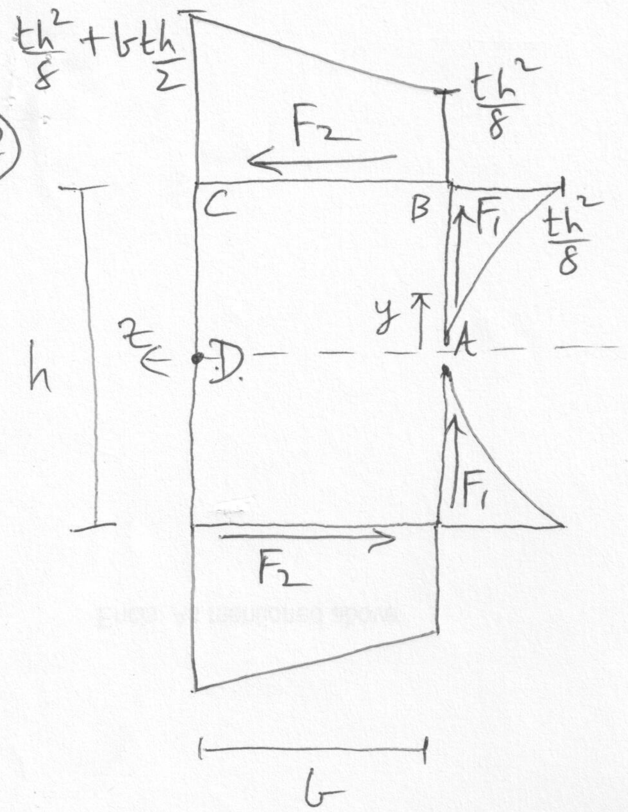
$$I_y = \frac{(30)(50^3)}{12} + \frac{2*(26)(46^3)}{12}$$

$$= 734289.33\ mm^4$$

Put $M = 500*10^3$ N.mm, $\theta = 30°$

$$(\sigma_{AL})_{max} = \frac{M\sin\theta(15)}{I_z} + \frac{M\cos\theta(25)}{I_y} = 29.9\,MPa$$ ◄

$$(\sigma_{steel})_{max} = \frac{M\sin\theta(13)}{I_z} + \frac{M\cos\theta(23)}{I_y} = 80.1\,MPa$$ ◄



Assume wall thickness t

$$Q = y\,t\,\frac{y}{2} = \frac{ty^2}{2} \quad \text{in } AB$$

$$Q = t\left(\frac{h}{2}\right)^2\frac{1}{2} + s\,t\,\frac{h}{2} \quad \text{in } BC$$

Take $V=1$, $\tau = \frac{1\,Q}{I_z t}$

$$F_1 = \int \tau\, dA = \frac{1}{I_z t}\int_0^{h/2} \frac{ty^2}{2}\, t\, dy$$

$$= \frac{t}{I_z}\,\frac{1}{6}\,\frac{h^3}{8}$$

$$F_2 = \frac{1}{I_z t} \times \text{area under trapezium} \times t$$

$$= \frac{1}{I_z t}\left[\frac{th^2}{8}b + \frac{1}{2}\,b\,\frac{th}{2}\,b\right].t$$

Take moments about D:

$$1\,e = 2F_2 b + F_1 h = \frac{t}{I_z}\left[\frac{1}{24}h^3 b + \frac{h^3}{8}b + \frac{h^2b^2}{4}\right]$$

$$I_z = 2.\frac{th^3}{12} + 2bt\frac{h^2}{4} = t\left[\frac{h^3}{6} + \frac{bh^2}{2}\right]$$

$$e = \frac{\left[\frac{1}{24}hb + \frac{1}{8}hb + \frac{b^2}{4}\right]h^2}{\left[\frac{h}{6} + \frac{b}{2}\right]h^2} = \frac{(2h+3b)b}{(2h+6b)} \quad \text{wrt D}$$

$$= \frac{(4h+9b)b}{2h+6b} \quad \text{wrt A (slit)}$$

ANSWERS

Paper Code A

P1 $\sigma_{st,max} = 166.7$ $\quad$ $\left(M=500,\ \theta=35^\circ,\ b_0=50,\ h_0=20,\ t=2,\ E_S=210,\ E_a=70\right)$

$\sigma_{AL,max} = 66.2$

P2 $e = 87.5$ $\quad (h=150,\ b=50)$

Paper Code B

P1 $\sigma_{st,max} = 93.3$ $\quad$ $\left(M=400,\ \theta=20^\circ,\ b_0=45,\ h_0=25,\ t=2,\ E_S=200,\ E_A=50\right)$

$\sigma_{AL,max} = 26.5$

P2 $e = 104.79$, $\quad (h=175,\ b=60)$

Paper Code C

P1 $\sigma_{st,max} = 61.8$ $\quad$ $\left(M=600,\ \theta=25^\circ,\ b_0=55,\ h_0=35,\ t=2,\ E_S=240,\ E_A=80\right)$

$\sigma_{AL,max} = 22.6$

P2 $e = 138.18$ $\quad (h=200,\ b=80)$

Paper Code D

P1 $\sigma_{st,max} = 119.7$ $\quad$ $\left(M=500,\ \theta=30^\circ,\ b_0=40,\ h_0=30,\ t=2,\ E_S=240,\ E_A=60\right)$

$\sigma_{AL,max} = 33.8$

P2 $e = 171.43$ $\quad (h=225,\ b=100)$.