ENGINEERING SCIENCE H1

OUTCOME 1 - TUTORIAL 2

SHEAR FORCE IN BEAMS

EDEXCEL HNC/D ENGINEERING SCIENCE LEVEL 4 – H1
FORMERLY UNIT 21718P

This material is duplicated in the Mechanical Principles module H2 and those studying the Mechanical Engineering course will find this a good introduction to that module.

You should judge your progress by completing the self assessment exercises.

These may be sent for marking or you may request copies of the solutions at a cost (see home page).

On completion of this tutorial you should be able to do the following.

- Define and calculate SHEAR FORCE in a beam.
- Draw basic SHEAR FORCE Diagrams.
- Determine where the maximum shear force occurs in a beam.
- Determine the mean shear stress on a beam section.

You may have already covered this material at national level in which case you may skip to the next tutorial. It is assumed that students doing this tutorial already understand the basic principles of moments, shear force and how to calculate the reaction forces for simply supported beams. This information is contained in the preliminary level tutorials.

1. SHEAR FORCE

1.1 SHEAR

The forces on a beam produce shearing at all sections along the length. The sign convention for shear force is such that if the total force on the left section is up then the shear is positive. If it is down, the shear is negative. Positive shear tends to make the section slide up on the left.

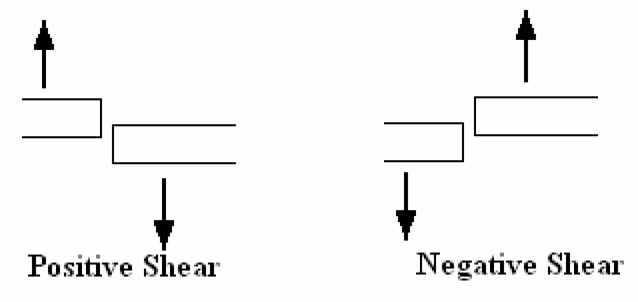

Figure 1

DEFINITION ***The shear force is the sum of all the force acting to the left of the section.***

Since the beam is in equilibrium, it must also be the sum of all the forces acting to the right

1.2 SHEAR FORCE DIAGRAMS

A shear force diagram is simply a graph of shear force plotted against distance x from the left end. This is best demonstrated with several worked examples. Note that in this module you are only required to study simply supported beams so cantilevers have been omitted.

WORKED EXAMPLE No.1

Draw the shear force diagram for the simply supported beam shown and determine the maximum shear force.

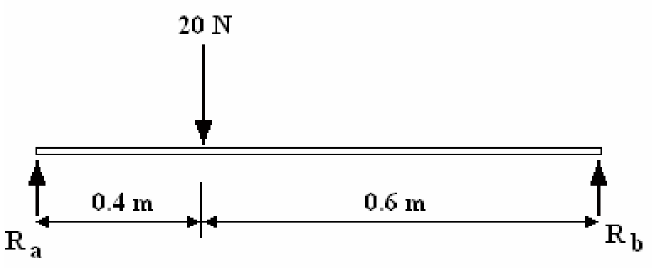

Figure 2

SOLUTION

First calculate the reaction forces by balancing the moments about the left end.
$R_b \times 1.0 = 20 \times 0.4$ $R_b = 8$ N

Repeat the process about the right end.
$R_a \times 1.0 = 20 \times 0.6$ $R_b = 12$ N

Check $R_a + R_b = 20$ N so the upwards and downwards forces are the same.

Consider the balance of forces on a section x metres from the left end. If the section is detached as shown but held in equilibrium, then a force F must placed on the end to keep it in balance.

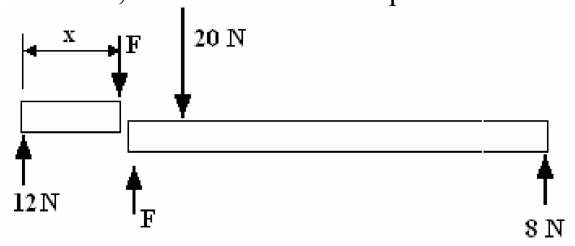

Figure 3

Balancing vertical forces for the left section we get the following.

$R_a + F = 0$ $\quad$ $12 + F = 0$ $\quad$ F = -12 N (Down as shown)

Balancing forces for the right section we get the following.

$R_b + F – 20 = 0$ $\quad$ $8 + F – 20 = 0$ $\quad$ F = 12 N (Up as shown)

These are the internal forces on the beam that balance the external force. However the external force is 12 N up to the left so the shear Force is positive.

Now consider the section on the right side of the force.

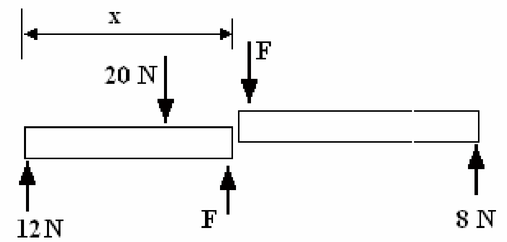

Figure 4

Balancing vertical forces for the left section we get the following.
Ra –20 + F = 0 $\quad$ 12 – 20 + F = 0 $\quad$ F = 8 N (Up as shown)
Balancing forces for the right section we get the following.
Rb + F = 0 $\quad$ 8+ F = 0 $\quad$ F = -8 N (Down as shown)

The total external force to the left is 8N down so the shear force is negative.

It is clear that the shear force is constant for any value of x between the point loads. A shear force diagram is simply a graph of shear force plotted against x. For the above case the SF diagram would look like this. The maximum shear force is 12 N

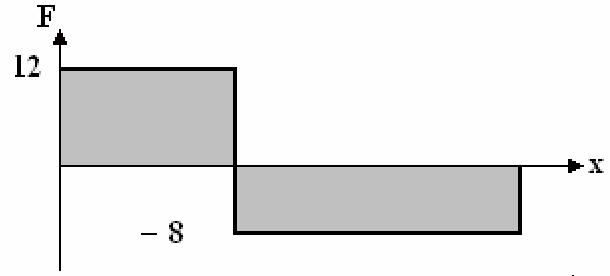

Figure 5

WORKED EXAMPLE No.2

Draw the shear force diagram for the simply supported beam shown.

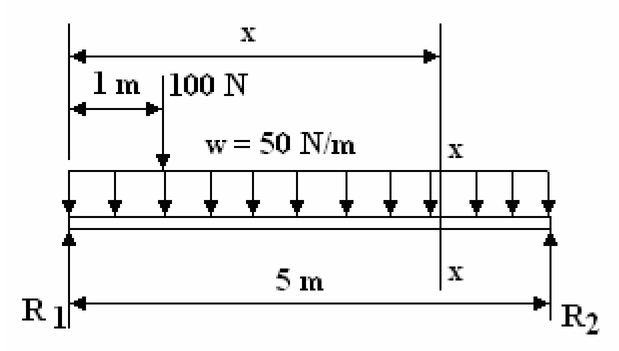

Figure 6

SOLUTION

It is necessary to first calculate the beam reactions.
Total downwards load due the u.d.l.= w x length = (50 x 5) = 250 N This will act at the middle 2.5m from the end.
Total load down = 250 + 100 = 350 N.

Balance moments about left end.
$(R_2)(5) - (50)(5)(5/2) - (100)(1) = 0$

$R_2 = 145$ N $\qquad$ $R_1 = 350 - 145 = 205$ N

Now calculate the shear force at 1 m intervals.
At x = 0, the shear force suddenly changes from zero to 205 N up F = 205 N

At x = 1, F = 205 – wx = 205 – 50 x 1 = 155 N

At this point the shear force suddenly changes as the 100 N acts down so there is a sudden change from 155 to 55 N.

At x = 2, F = 205 – 100 – wx = 105 – 50 x 2 = 105 – 100 = 5 N

At x = 3, F = 205 – 100 – wx = 105 – 50 x 3 = 105 – 150 = -45 N

At x = 4, F = 205 – 100 – wx = 105 – 50 x 4 = 105 – 200 = -95 N

At x = 5, F = 205 – 100 – wx = 105 – 50 x 5 = 105 – 250 = -145 N

At the left end, the reaction force is 145 N up to balance the shear force of 1455 N down. The diagram looks like this.

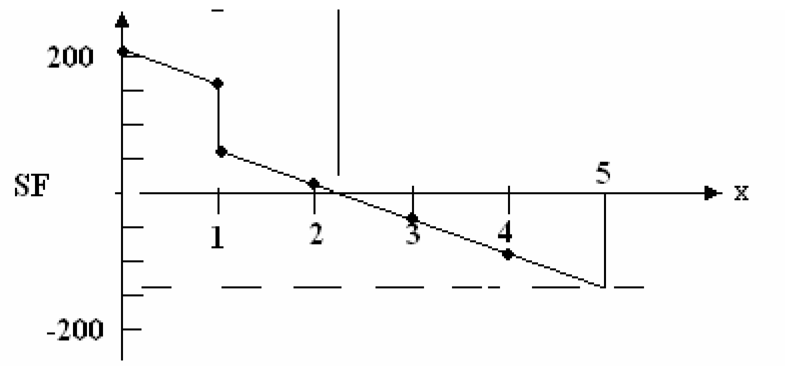

Figure 7

SELF ASSESSMENT EXERCISE No.2

1. A beam is loaded as shown below. Calculate the reactions and draw the shear force diagram. **(Answers 310 N and 210 N)**

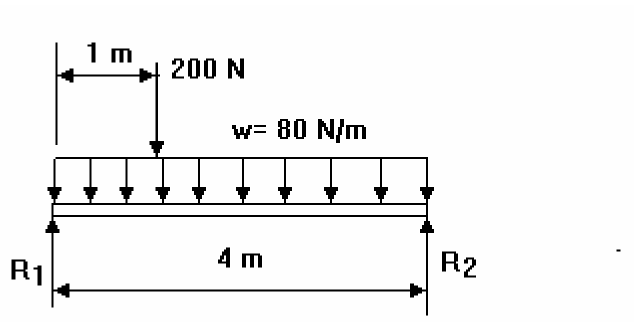

Figure 8

2. A beam is loaded as shown below. Calculate the reactions and draw the shear force diagram. (Answers 600 N and 600 N)

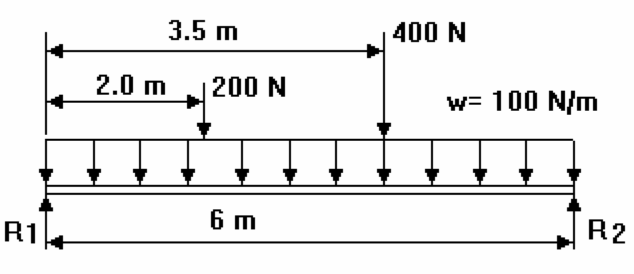

Figure 9

2. SHEAR STRESS

A shear force at any section on the beam will produce a mean shear stress on that section of F/A. It must be stressed that this is a mean shear stress and that further studies will show that the shear stress varies from zero at the surface to a maximum somewhere around the neutral axis.

$$\tau_{mean} = F/A$$

WORKED EXAMPLE No.3

If the mean shear stress in a beam must not exceed 60 MPa. The maximum shear force is 210 kN. Determine the cross sectional area required and select a suitable 'I' section beam from the table for universal columns to(BS4). (Found in tutorial 1)

SOLUTION

$F = 210000\text{N} \quad \tau = 60 \times 10^6 \text{ N/m}^2$

$\tau_{mean} = F/A \quad A = F/\tau_{mean} = 210000/(60 \times 10^6) = 3.5\ 10^{-3} \text{ m}^2$ or 35 cm^2

From the table, a suitable beam would be 254 x 102 x 28 which has a cross sectional area of 36.1 cm^2

SELF ASSESSMENT EXERCISE No.3

1. An 'I' section universal beam (BS4) size 152 x 89 x 16 must withstand a shear force of 12 kN. Determine the mean shear stress. **(Answers 5.9 MPa)**

2. An 'I' section universal beam (BS4) must withstand a shear force of 280 kN and the mean shear stress must not exceed 60 MPa. What would be a suitable size?
(Answers A = 4.67×10^{-3} m^2 so a suitable size would be 305 x 127 x 37)