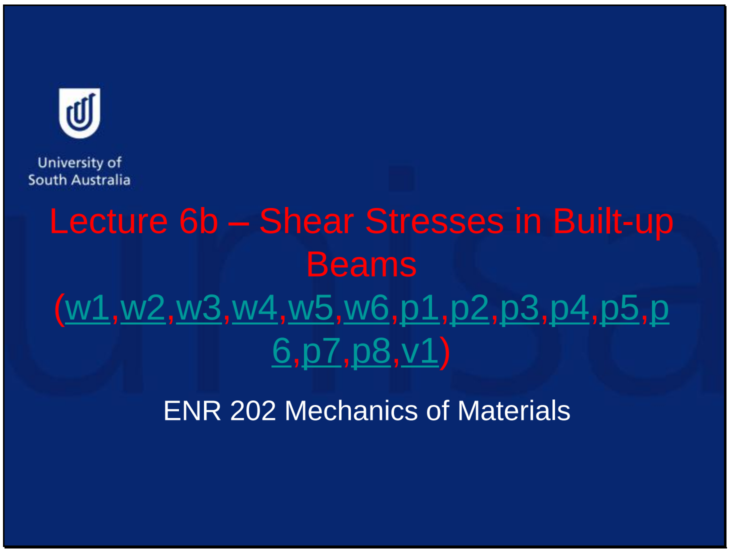
ENR202 Mechanics of Materials Lecture 6B Slides and Notes

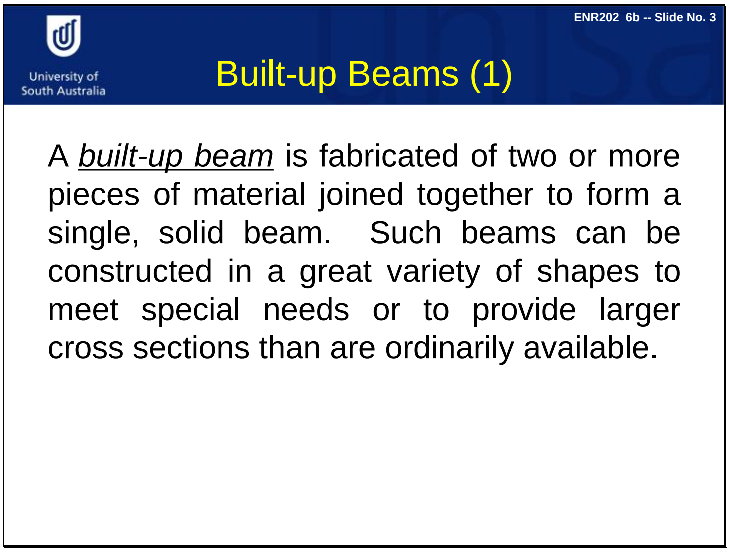
Slide 1

Slide 2



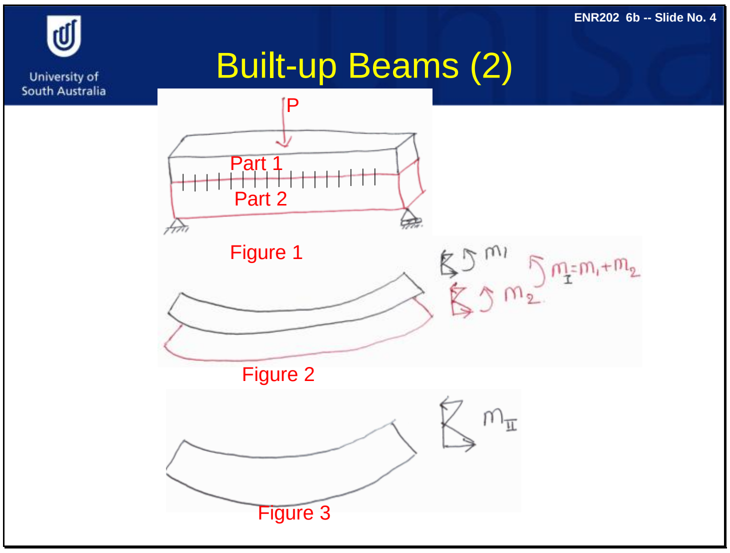
Welcome to lecture 6b. In this lecture, we will be continuing on the same topic: shear stresses in beams. However, in this lecture we will look at shear stresses in built up beams. Again, access the internet links for further information or if you have any problem understanding the lectures.

Slide 3



What is a built-up beam? It means different pieces of materials connected together to form a single beam. These beams can be constructed in a great variety of shapes to meet special needs or to provide larger cross sections than are ordinarily available.

Slide 4

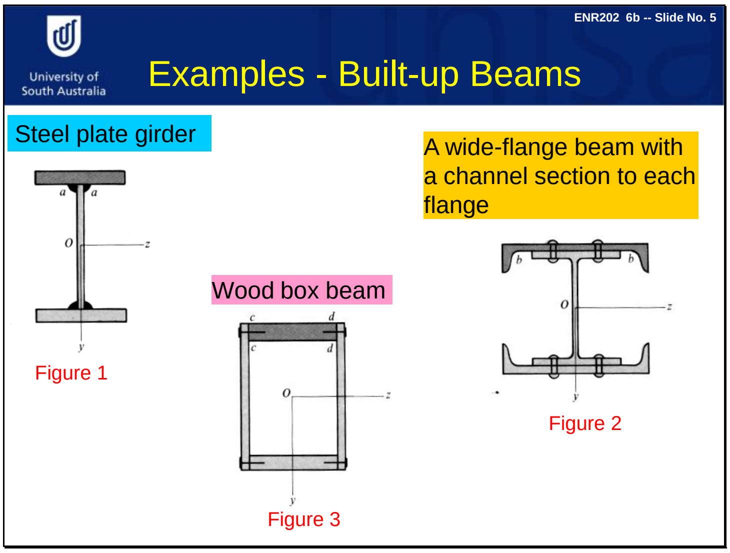


Suppose we have a beam with two parts. Part one in figure 1 is a rectangular cross section. We have another beam (part 2) on the bottom which has the same cross section. These two beams are free of each other; there is no bonding between them. We can use this beam as a simply supported beam. What will happen if we apply a lateral load 'P' acting on the beam as shown in figure 1?

The beam will deform as shown in figure 2, with bending of the top beam and bottom beam, as shown in figure 2. We will also get slip at the interface of the two beams. That means that if we don't have any bond between two beams, we don't have shear to transfer between the beams.
If we have bending moment, then we have normal stress distribution as shown in figure 2. The bending moment acting on the top beam is M1, and the bending moment acting on the bottom beam is M2. M1+M2=MI. That means total moment is distributed into these two beams.

But what if we use glue to connect these two beams and they work together as a single beam? That means the beam will deform as you see in figure 3. This is called the interface. We don't have any slip at the interface. The normal stress distribution is something like figure 3. This normal stress distribution carries all the moment MII. The strength and stiffness of the combined beam is much better than for the two beams. That is why we use built up beams.

Slide 5



We have different type of built-up beams. For example if we have an I beam, we have a top flange, a bottom flange and a web. We weld between the top flange and the web, and between the bottom flange and the web to transfer shear between the web and flanges. If we use the I beam together with the channel section, we bolt or weld them together as shown in figure 2. In another example (a wood box beam), we can use screws to join pieces of beams as shown in figure 3.

This is the concept of the built up beam. To design a built up beam, we need to give careful consideration to designing the bolt.

Slide 6

University of South Australia

Shear Flow (1)

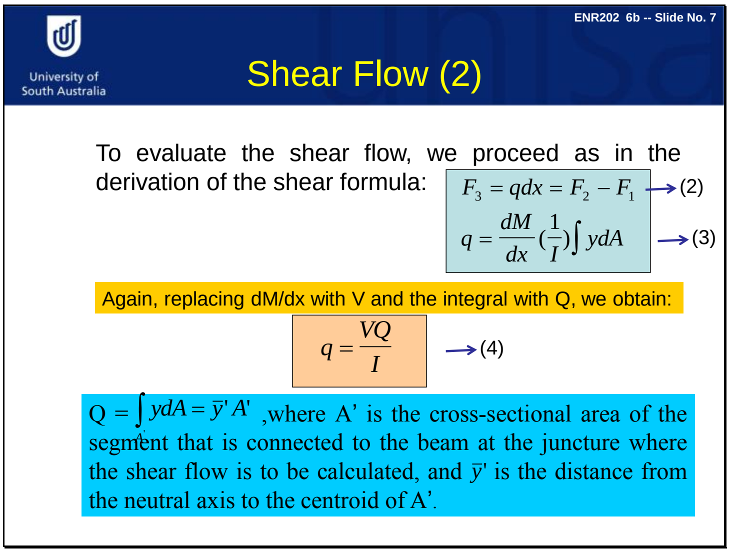
In the derivation of shear formula, we assumed that the shear stress was uniformly distributed across the width of the beam. However, in a more general case, this assumption may not be valid. Therefore, instead of calculating the shear stresses, we calculate the total horizontal force F_3:

$$\boxed{F_3 = qdx} \longrightarrow (1)$$

in which q is the shear force per unit distance along the axis of the beam (when the shear stress is uniformly distributed across the width of the beam, as we assumed for a beam of rectangular cross section, then $q = \tau b$). The quantity q, called the *shear flow*, has units of force per unit distance.

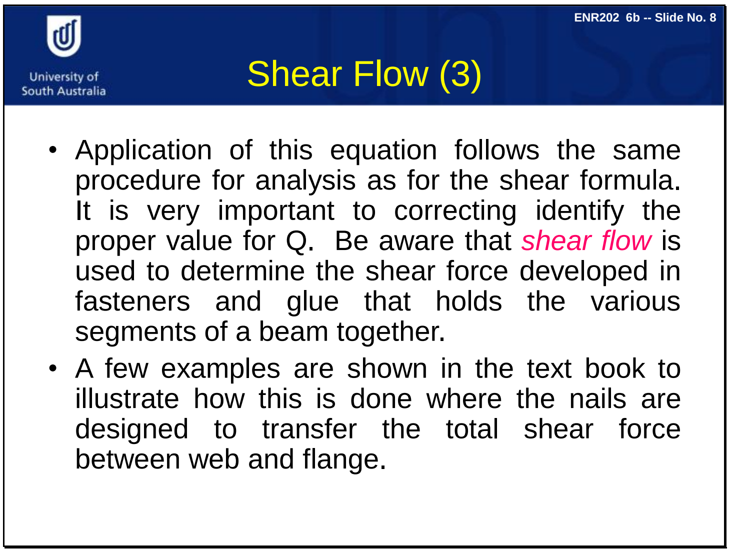
In the derivation of the shear formula in lecture 6a, we assumed that the shear stress was uniformly distributed across the width of the beam. However, in a more general case, this assumption may not be valid. Therefore, instead of calculating the shear stresses, we calculate the total horizontal force F_3 (slide 10 in lecture 6a). What is ‘q’ in this equation? ‘q’ is the shear force per unit distance along the axis of the beam; that is, when the shear stress is uniformly distributed across the width of the beam as we assumed for a beam with rectangular cross section. We can derive the q from that. We calculate shear stress by the shear formula which states that tou equals V times Q divided by Ib. However, ‘q’ is the product of shear stress and the width of the beam. The quantity q is called shear flow, which equals V times Q divided by I. The unit for shear flow ‘q’ is force per unit distance, just like a uniformly distributed load unit.

Slide 7



To evaluate the shear flow, we proceed as in the derivation of the shear formula that we covered in slide 11 of lecture 6a (equation 7). Here, the shear flow concept is the product of q and dx, which equals F2 minus F1, as we discussed in an earlier lecture. You will get the shear flow as per equation 3 in this slide. Replace dM divided by dx with V and the integral with Q. We then obtain equation 4 for shear flow, which is V times Q divided by I. The 'Q' is integration y times dA which is equal to y bar dash times A dash. A dash is the cross sectional area of the segment that is connected to the beam at the junction where the shear flow is to be calculated. y bar dash is the distance from the neutral axis to the centroid of A dash.

Slide 8

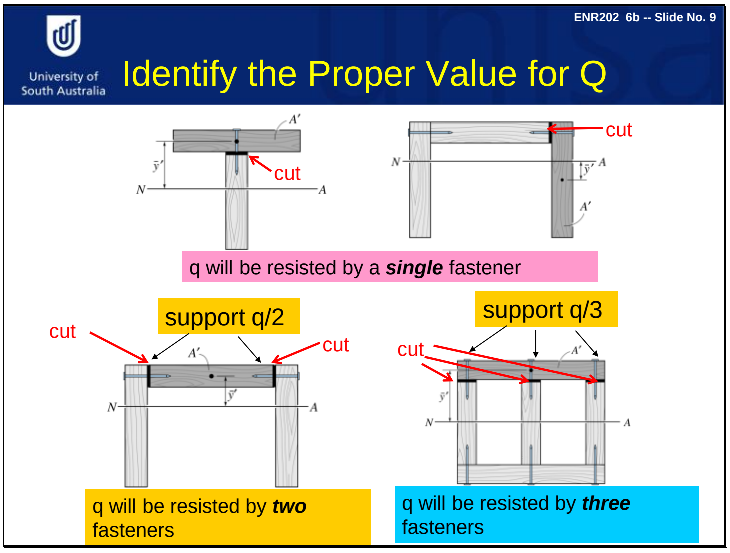


Apply this equation in the same way as for the shear formula. It is very important to correctly identify the proper value for Q.

Be aware that *shear flow* is used to determine the shear force developed in fasteners and glue that holds the various segments of a beam together.

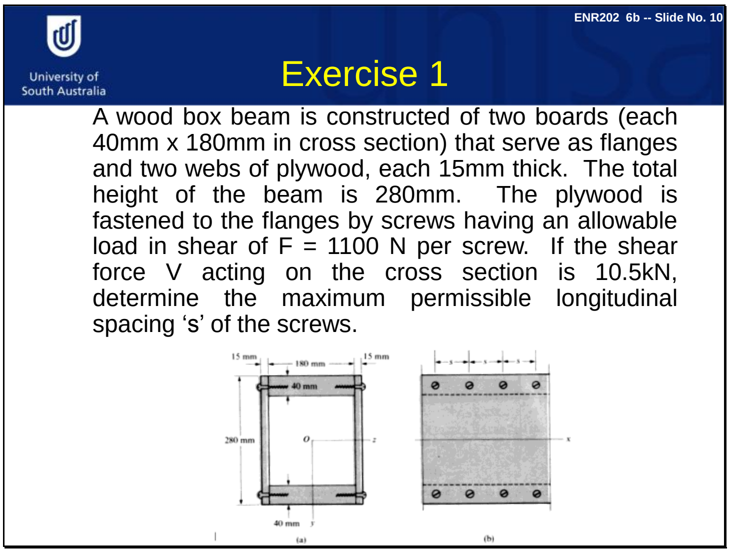
The next slide shows a few examples to illustrate how to identify the proper value for Q.

Slide 9



In a bulit-up beam, you need to make sure that the bolt, screw or weld is safe. Consider a T shape cross section as shown in top left figure. Suppose that a screw is to be designed transferring the shear force from top board (flange) to the bottom board (web). So, you have to cut the screw cross section and draw a free body diagram of the flange. You need to calculate 'Q' for the shaded area of the T shaped cross section as shown in the top left figure. You can see in the top two figures that the shear flow will be resisted by a single fastener. In the bottom left figure, the shear flow will be resisted by two fasteners. In the bottom right figure, the shear flow will be resisted by three fasteners. Observe the shaded area in all figures; you need to calculate 'Q' for this shaded area, and for that you need to identify the proper value to calculate 'Q' in the shear formula. You need to understand how many cutting surfaces there are in the cross section. Based on cutting surfaces, you can find the shaded portion and value of the shear flow 'q' as shown in the figures. For example, in the top figures the shear flow is 'q'. In the bottom left figure, the shear flow is q divided by 2. In the bottom right side figure, the shear flow is q divided by 3. Therefore, you can calculate the proper 'Q' value based on the shaded area to use in the shear formula. We will look at this in the next exercise.

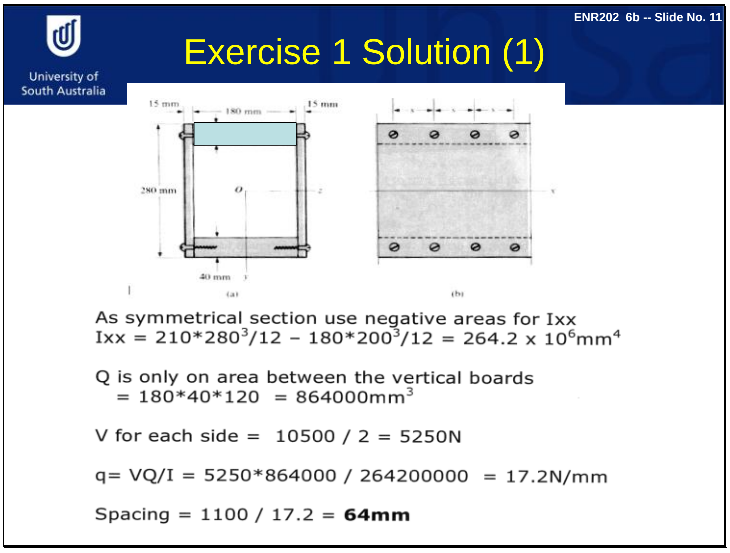
Slide 10



Look at this example of a wood box beam. This wood box beam has a top flange 180 mm wide and 40 mm thick, and a bottom flange with the same dimensions (180 mm wide and 40 mm thick). The total height of the beam is 280 mm and the web thickness is 15 mm, as shown in the left figure. We need to know how many screws are required to transfer the shear force.
We already know that the shear strength of the screw is 1100 Newtons, and we know that the shear force acting on the cross section is 10.5 Kilo Newtons. So we need to calculate the spacing ‘s’ between the two screws, as shown in the right side figure.

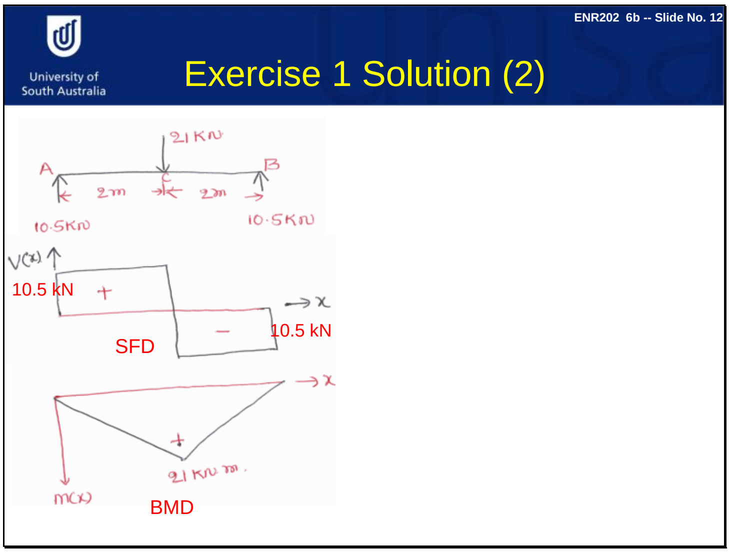
Now pause this presentation and try to calculate the shear stress at the top flange.
The answers are on the next four slides.

Slide 11



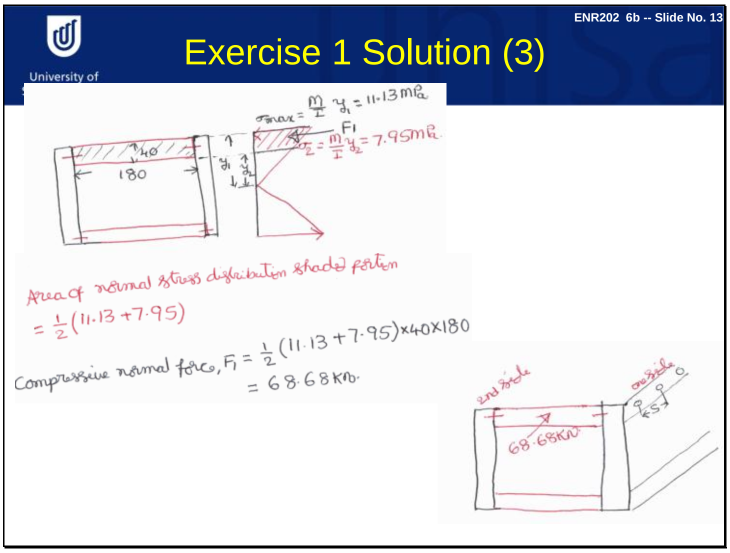
First we need to calculate shear stress at junction of webs and top flange. Therefore, you need to calculate the second moment of inertia I value of whole cross section. So the I value equals 264.2 times 10 to the power of 6 mm to the power of 4.
Next, you need to calculate Q for the cross section. That means you need to calculate Q for the shaded area. The area of shaded portion is 180 mm times 40 mm. The Y bar dash is equal to the distance from the neutral axis to the centroid of the shaded area, which is equal to 140 mm minus 20 mm, which is 120 mm. You know the shear formula to calculate shear stress is tou is equal to V times Q divided by Ib. For b, we need to consider double 40; that is, two places of cutting width equal to 2 times 40, which is 80 mm. We know the shear force and the moment of inertia for the whole cross section, Q and b for the shaded area.
Now, screws may resist this shear stress. Each screw will resist a shear force of 1100N. The strength of the screw is 1100 Newtons which is equal to shear stress tou times the cutting width (flange thickness of 40 mm times spacing ‘s’). Because screws are spacing with s, that means one screw carries shear at the cutting area which is 40 mm times ‘s’. We already have tou at the cutting surface, so we can work out spacing s, which is 64 mm.

Slide 12



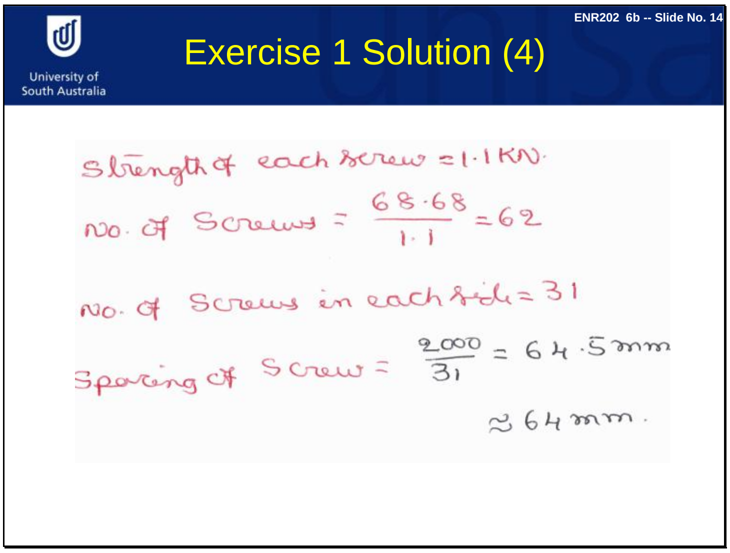
We have another method to calculate the spacing of the screws. Lets have a look. We have a simply supported beam subjected to a concentrated load of 21KN acting at the center. The length of the simply supported beam is 4 meters. If we have the shear force diagram in the figure, the maximum shear force in this beam is 10.5 Kilo Newtons. The bending moment diagram is shown in the figure. Based on the Bending Moment Diagram, the maximum bending moment is 21 Kilo Newton meters. So we know we have to deal with a shear force of 10.5 Kilo Newton.

Slide 13



If we consider the mid span cross section as shown in the top figure and we have a positive bending moment of 21 Kilo Newton meters, it is easy for us to calculate the normal stress distribution based on the flexure formula. The maximum normal stress distribution is 11.13 Mega Pascals at the top, and 7.95 Mega Pascals at the bottom, so we have normal stress distribution acting on the top flange as shown in the figure. Based on the normal stress distribution we have compression force acting on the top flange, which we can work out from the area of normal stress distribution and the width of the flange. The total compression force acting on the top flange is 68.68 KN. Now we can analyze the top flange. We can analyze the left half span of the beam.

Slide 14



We have a shear force carried by screws to balance 68.68 Kilo Newtons. We need to calculate how many screws are required for a span of 2 meters. We need 62 screws, which means 68.68 kilo Newtons divided by the strength of each screw. 1 kilo Newton equals 62 screws for the half the span, which means 31 screws on each side. The spacing should be 2 meters divided by 31, which is 64.5 mm, rounded up to 64 mm. Therefore, the screws should be spaced 64 mm apart.

Slide 15

Thank you for your attention. In the next lecture, we will study the deflection of beams.