ENR202 Mechanics of Materials Lecture 1A Slides and Notes

Slide 1

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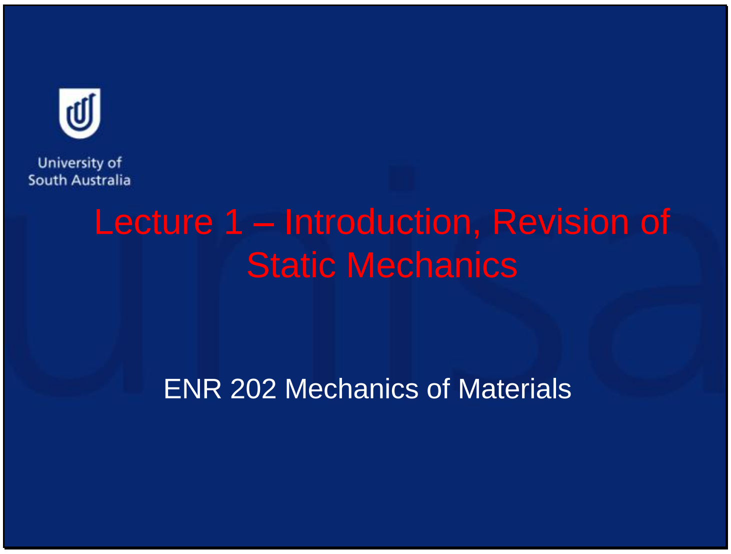
Slide 2



Welcome to this first lecture summary for Mechanics of Materials. We hope you enjoy your studies in this unit. In this lecture summary, we'll cover a brief introduction to the unit, and also review static mechanics.

Note that throughout all the lecture summaries for Mechanics of Materials, you will see live links, denoted by the letters W, P and V. These links point to web pages, presentations and videos which will enhance your understanding of the content. You can pause the presentation at any time to access these links, and then go back to the presentation when you have finished looking at them.

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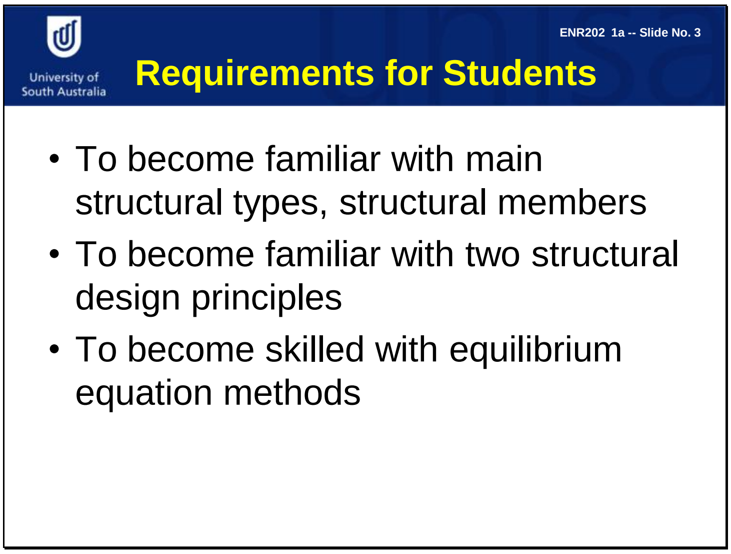

In this unit, you are required to become familiar with main structural types, structural members. You will learn two structural design principles, and develop the ability to work with equilibrium equation methods.

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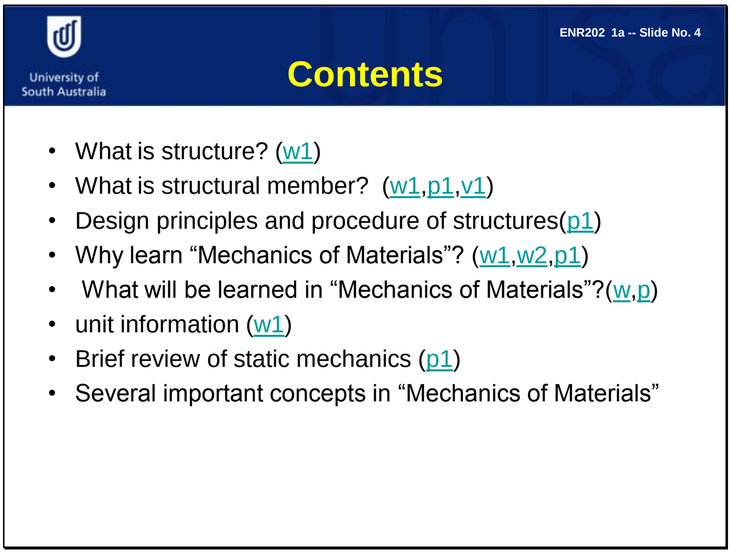

These lecture summaries will begin by introducing the basic concepts of structures and what a structural member is, the design principles and procedures of structure design. We will also cover why we learn Mechanics of Materials. Click on the live links (the letters w, p and v) to access more detailed resources for each of these concepts.

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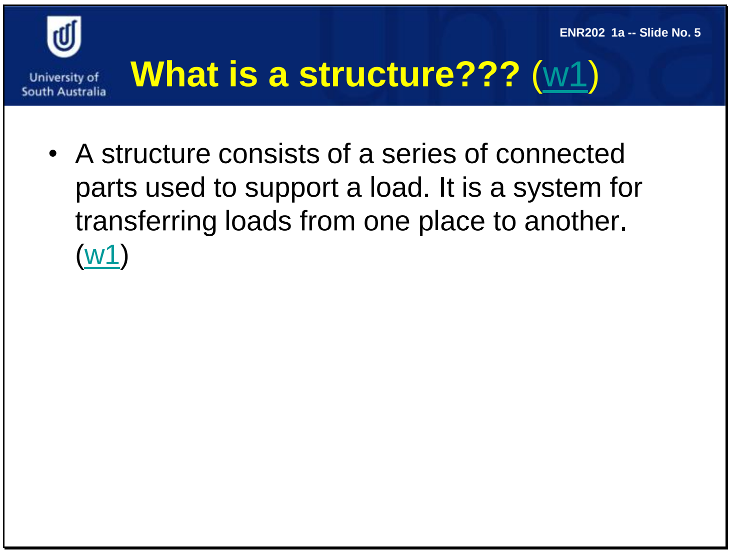

Firstly, what is structure? A structure consists of a series of connected parts used to support a load. Structure means a system to transfer loadings from one place to another. In case this is a little bit complicated, we will look at some examples of loading transfer systems.

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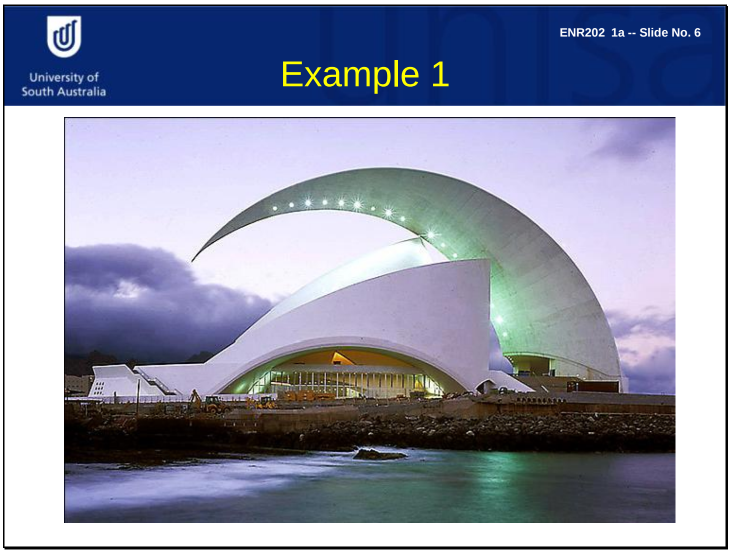

This is a long span building, with a large span roof. In fact, the roof is the kind of structure in which we might have acting loads : for example, wind load and snow load acting in the middle. So the loads on the roof have to be transferred to the foundation.

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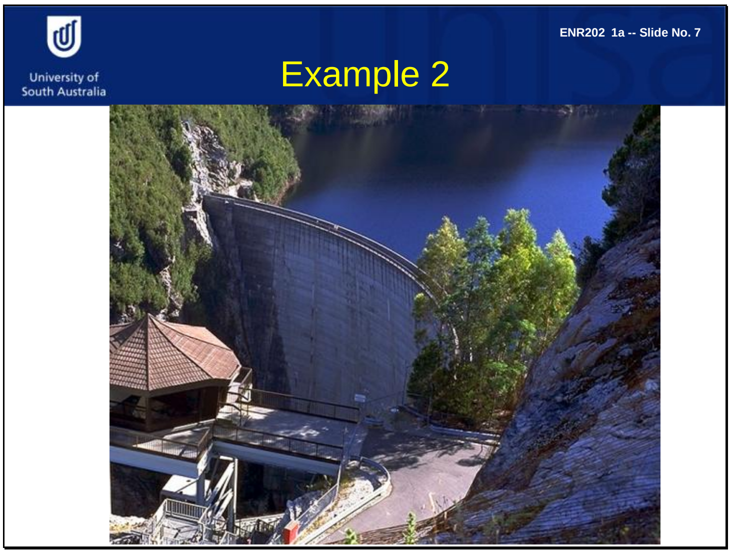

This structure is a small bridge, another kind of structure. The self-weight of the small building need to be transferred to the deck of the bridge, then to the foundation of the bridge.

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This is a long, cable-stayed bridge. We can have cars and pedestrians on the bridge. The self weight of the cars need to be transferred to the deck of the bridge and then to the ties of the bridge cables. The cables transfer the loads to the tower of the bridge and to the supports of the bridge. Finally, the structure of the bridge transfers loads to the foundation.

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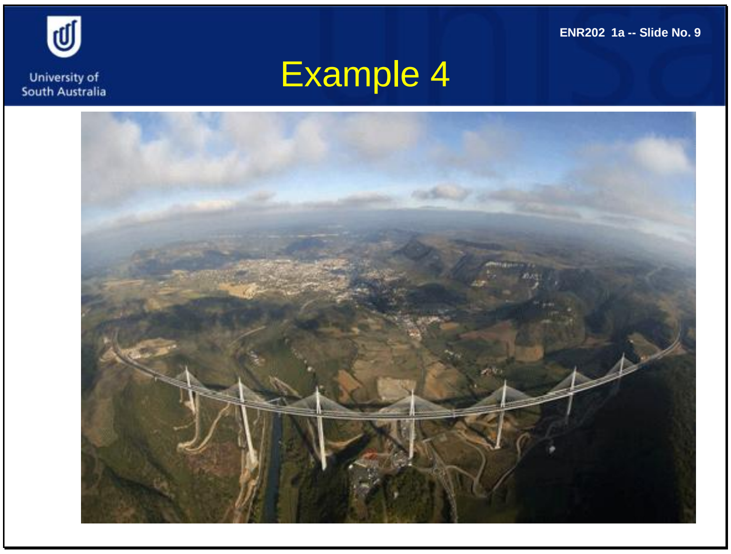

This is a multi-span bridge.

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In aircraft, we have the self weight of the passengers inside the airplane, and have air pressure outside the airplane. Aircraft transfer loadings to the frame of the structure.

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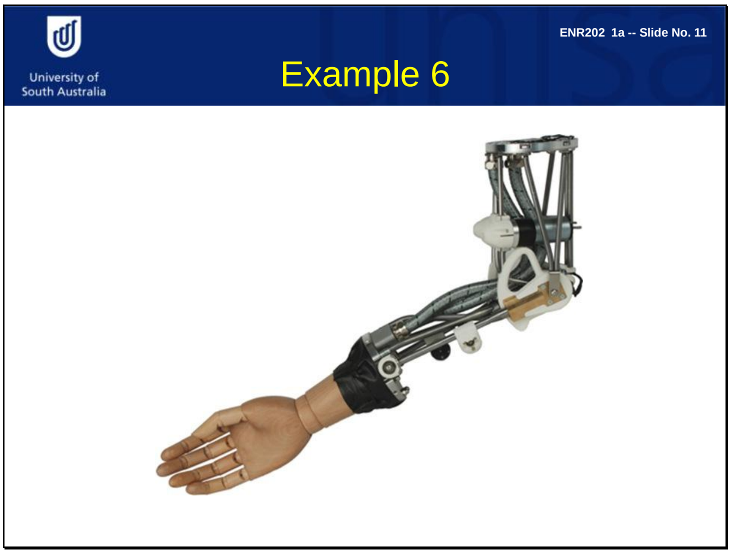

In this mechanical hand, loadings are transferred to the support.

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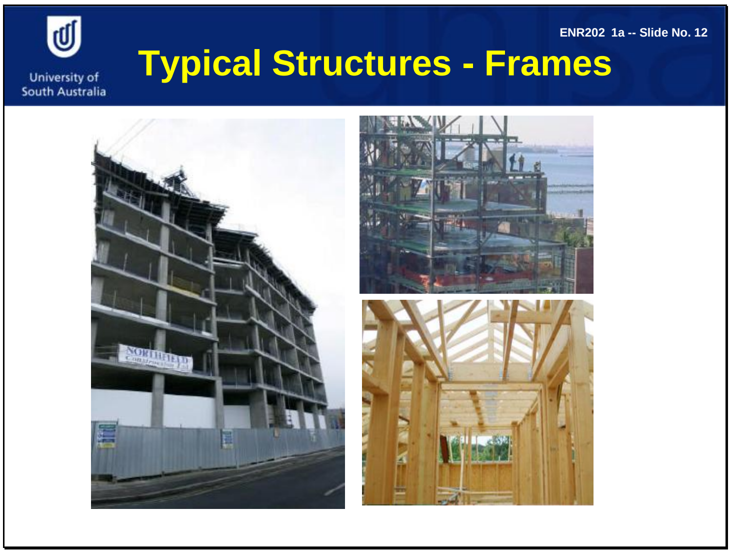

In this image, you can see different kind of structural frame types. A frame means a system of beams, columns and fixed joints between them. After put together, the frame structure may transfer forces and bending moments. We can have concrete framed structures (as in the image on the left), or steel framed structures (top right) or timber framed structures (bottom right).

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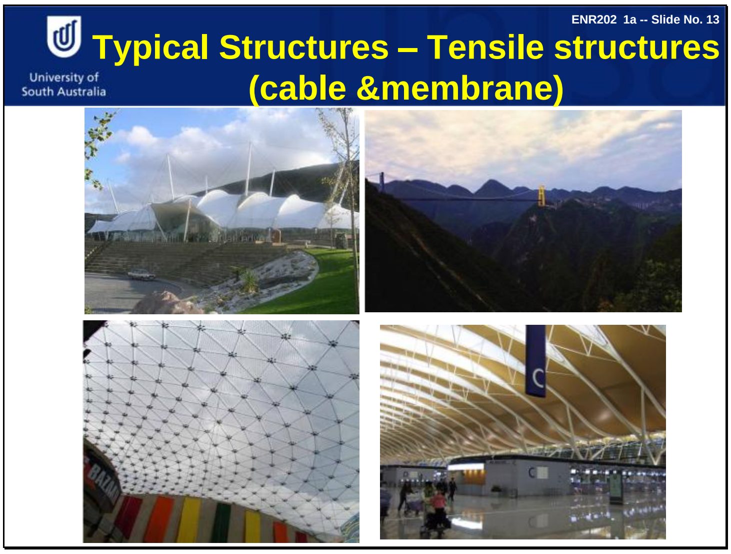

Here we see a tensile structural type. Here we have a membrane and cable structure: membrane and cable (top left), and membrane with cable in two directions (bottom left.) The membrane and cable system may transfer wind load to the foundations. We also have a cable stayed bridge (top right), and a cable truss structure (bottom right), where the cable will only carry tension, and the truss will carry both compression and tension – we will talk more about these terms in later lectures.

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Another structure type is the truss structure. It is very common in engineering applications. For example, here we have a TV tower, a three dimensional truss structure (on the left), and a transmission tower (also a three dimensional truss structure, on the top right), and a truss roof structure carrying vertical loadings (bottom right). A truss structure is a little bit different from a frame structure. It has structural members connected together, but the joints do not transfer any rotational movements. They do transfer forces into three directions, but do not transfer bending moments.

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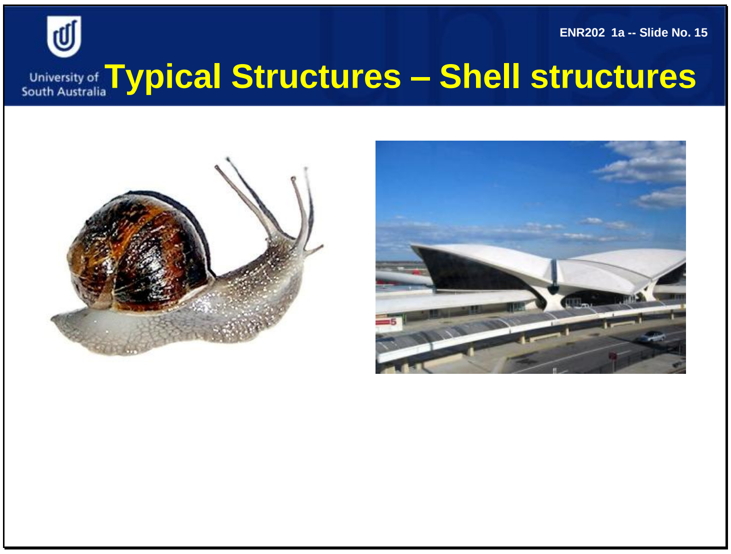

On the left you can see a natural shell structure. We use the theory behind this natural structure to build long span structures, particularly roof structures, in this kind of shell structure.

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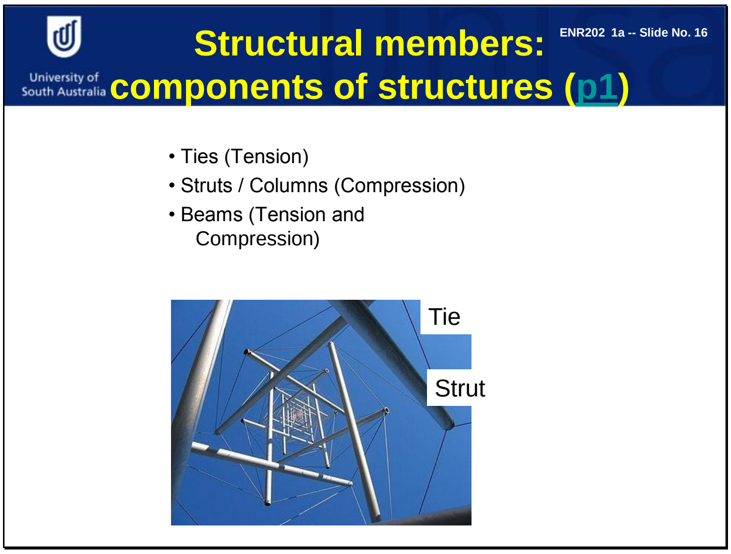

Although we have many structural types, in fact we only have a few structural members. ‘Structural member’ means a component of the structural parts. For all these structural members, we can have ‘tie’ structural members (for example, the cable in this structure). These structural members only carry tension, not compression, because if we have compression on a cable, it may become loose. We can also have struts or columns, and these kind of members can carry compression. For example, the strut here can only carry compression. We also have beams. Beams, in fact, carry tension, compression and bending moments. Click on the live link (p1 in the title) for more detailed information on these concepts.

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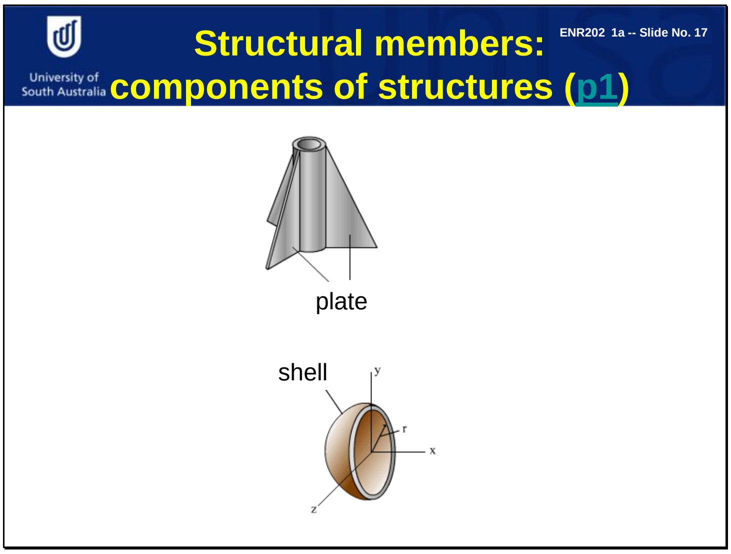

We also have shells and plate elements. A plate element is in one plane. The plate element has s straight surface. We can also have curved surfaces, which are a type of shell element. When we consider structural members, everything is three dimensional in reality. However, in a solid structural member, one side might be smaller than the other two sides. For example, the plate element thickness is very small, the plate element can be considered as two dimensional. In other words, we call this plate element a two dimensional element because we don't consider the direction in thickness. If bar (ties) width and depth are very small compared with length, we only consider the dimension in the length of the bar, so that a bar is a one dimensional element. Ties, struts, columns and beams, are all one dimensional elements. In this unit, we only study one dimensional elements. If you are interested, you can later study advanced mechanics units which introduce plate theory or solid theory.

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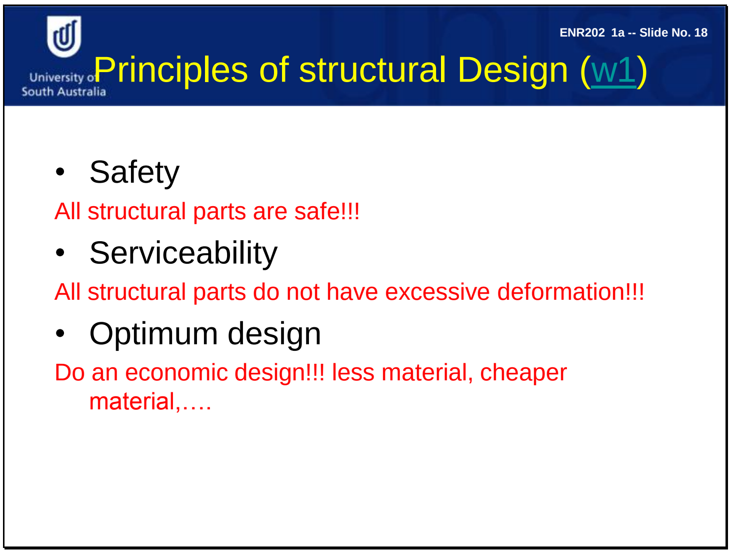

When discussing the principles of structural design, the first principle should be safety, because if we design a building or machine, we must make sure it is safe. So, what do we mean by safety? If a structure is safe, it means all the structural parts are safe. That means that when we design the structure, we must analyse all parts of structure, and design all parts of the structure to be safe. For example, when you design a building, you have to consider the floor, beams, columns, foundations ... But that is not enough! You also have to consider the joints between the beams and columns, between the floors and beams, and between columns and footings.
Another principle is serviceability. Serviceability means that if you design a machine or building, this building or this machine has to work well. Excessive deformation will mean that tge parts do not perform properly.
Another thing to consider in structural design is optimum design or economic design (that is, using less material and cheaper materials to make the cost economic).

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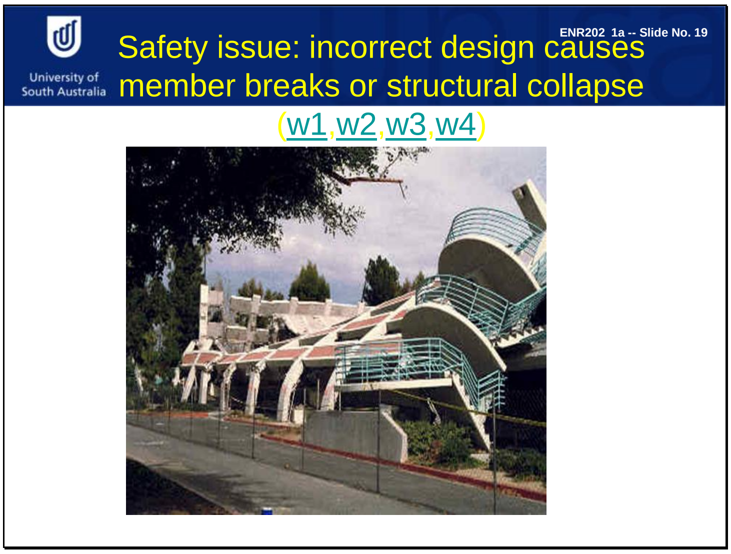

This is an example of where incorrect design has caused member breaks or structural collapse.

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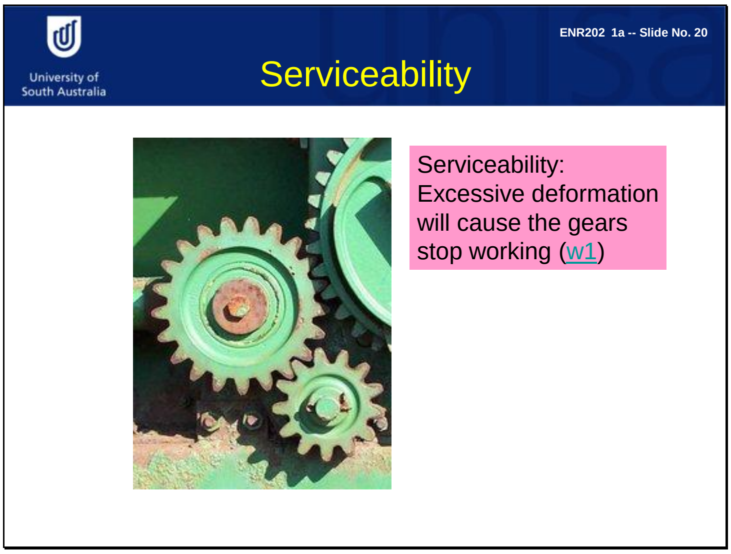

In this machine, large deformation has stopped the gears from working properly.

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In design, you have to consider cost. For example, this is an example of beam design. We are using the same material for both designs. In the top image, the beam can carry only one coin. However, if you use the same material, but change the cross section and the shape of the beam, it can carry several coins. As we can see, the bottom design is more economic than the top design. This is an example of using mechanics theory to produce economic design.

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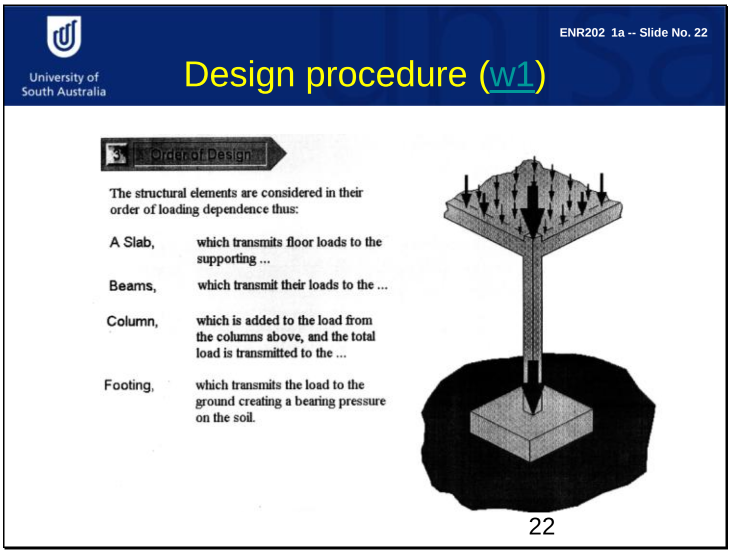

Design procedure includes consideration of a number of different elements. For example, in this building design, we must consider different loadings or different forces acting on the building, and the slab. When we design the slab, we have to consider how the loadings are transferred from the slab to the beam. And the beam also transfers loadings to the column. When we design the column, we have to consider how the column transfers loadings to the footings. Finally, the footings transfers loadings to the earth, so we have to consider the geotechnical problem of the soil. As we do the design, we follow these kind of steps and design procedure.

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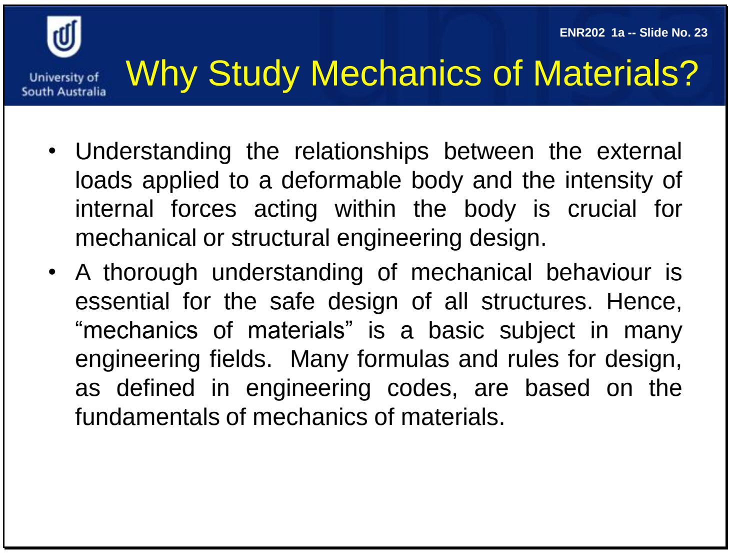

In this unit, we want you to understand the relationships between the external loadings on a structure, and the intensity of the internal forces acting on a structure. You need to understand its mechanical behaviour, and how this mechanical behaviour affects safe design of the structure. Mechanics of Materials is a basic subject for many engineering fields (civil engineering, mechanical engineering, aerospace engineering, etc). All engineering fields need the background of mechanics of materials.

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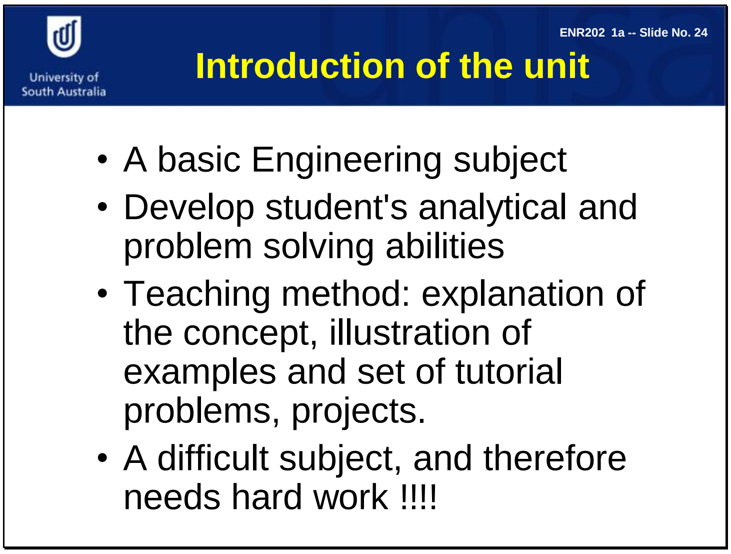

This unit is a basic engineering subject, to develop your analytical and problem solving abilities. The teaching methods include the introduction of concepts with examples, and problems. The unit information is all on the website, and in the Unit Outline. The most important thing is to prepare solutions for the problems, so you can perform well in final exam.

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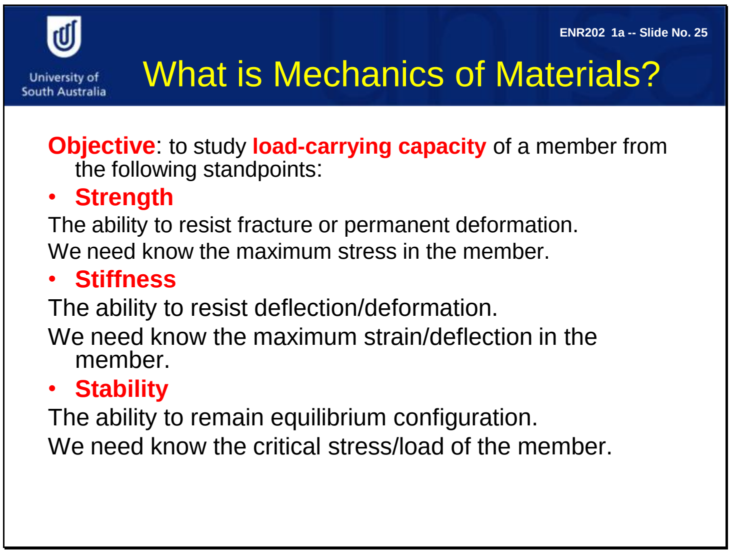

Lets come back to the introduction of the unit: What is mechanics of Materials? The objective of this unit is to study load-carrying capacity of a structural member from following three standpoints: Strength, stiffness, and stability.

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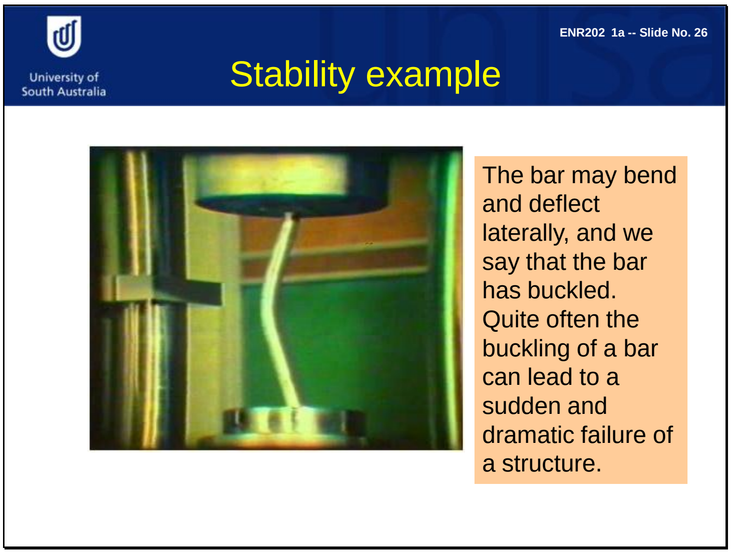

In this example, we have a column, and if we apply loadings on the column (apply compression on the column), it will become shorter and shorter. But if the column is very thin and you apply the compression, it will suddenly buckle, so the straight column will change its shape to a curved column. We call this phenomenon buckling. You have to use stability analysis to stop buckling in the column.

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University of South Australia

Difference between Statics and Mechanics of Materials???

Statics/Dynamics deal primarily with the forces and motions associated with particles and rigid bodies.

In the Mechanics of Materials, we go one step further by **examining** the stresses and strains that occur inside real bodies that deform under loads.

We need to understand the difference between static mechanics, and the mechanics of materials or mechanics of structures. If you have an object, and you apply load to the object, it will move. Some forces may make it rotate – this is static mechanics (forces related to motions of the object). But if you apply forces on the object, it will have an internal effect. The object may become deformed. For example, if you have a spring, just press the spring and it will shorten. This is a kind of deformation. This is a kind of internal effect. We may also have internal forces inside of the object because you put a load on the object. We need to learn what internal effects will be on the structure of a structural member. This is the difference between static mechanics and mechanics of structures.

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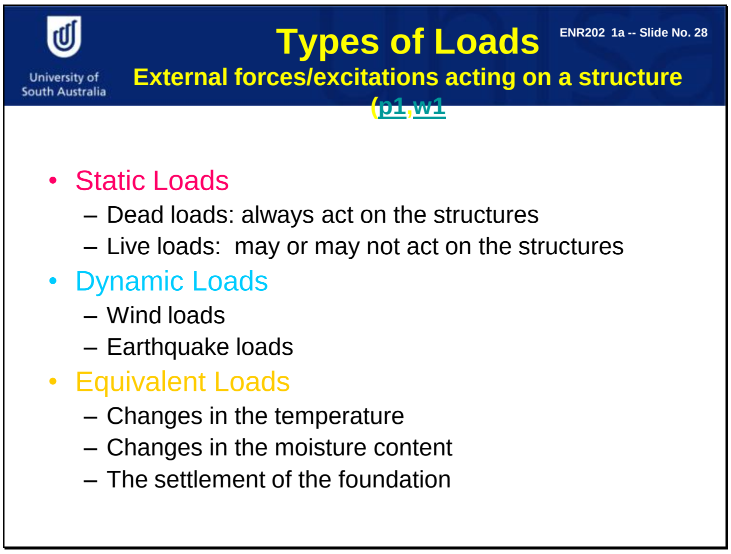

So what are loadings? Load means external forces or external excitations acting on the structure, so loadings are just external forces. For example, you can have a self weight which is always acting on the structure. Self weight is a kind of dead load. You can also have a live load, which may or may not act on the structure, so you have to consider the most dangerous case. You can also have a dynamic load (for example, wind load). Wind load can cause vibration of a building. You can also have earthquake loading. Temperature differences or changes cause other extra loadings, as do moisture changes and the settlement of the foundation. (Many buildings have cracks on the walls. This is due to settlement of foundation.)

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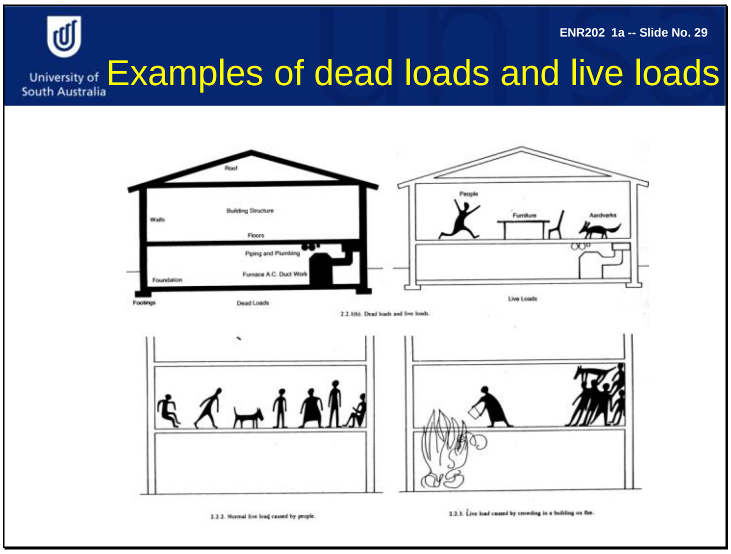

These are the some examples of dead load (self weight of the structure), and live load (people or furniture or fire).

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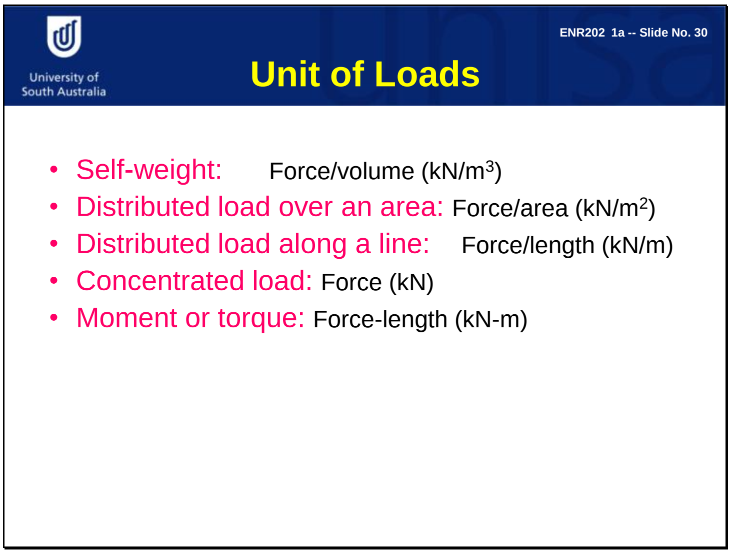

When we consider loads (forces), we can have different kind of loadings. For example, the self weight of the structure is measured as kilo Newtons per cubic meter, or force per volume. If the load is distributed over an area, we have force per area, which is measured as kilo Newtons per square meter. In fact, it is similar to pressure. We also have distributed loadings along a line, called line load. Line load is force divided by length. This is also measured as kilo Newtons per meter. And we can also have concentrated loading, just the force – this is measured as kilo Newtons. We may also have moment or torque acting on the structure, which is measured as kilo Newton metres. When we design, we have to consider the units of the loading.

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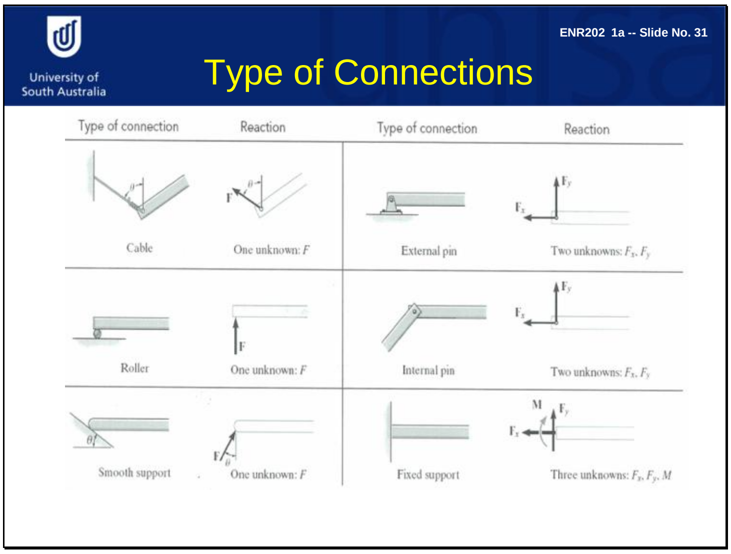

We need to consider the type of connections. We can have different kind of connections. For example, a cable connection can only carry tension. The reaction force will be on tension in the cable direction. We can have a roller connection, and the roller and support only carry vertical loading. We can have a smooth support without any friction, and so we have only contact force. We can have a pinned joint, either external or internal. A pinned joint can have two forces, because the pinned joint restrains in two directions. We can have a fixed support, in which we don’t have rotation at the support point, so we have reaction forces (two forces and one moment in the support).

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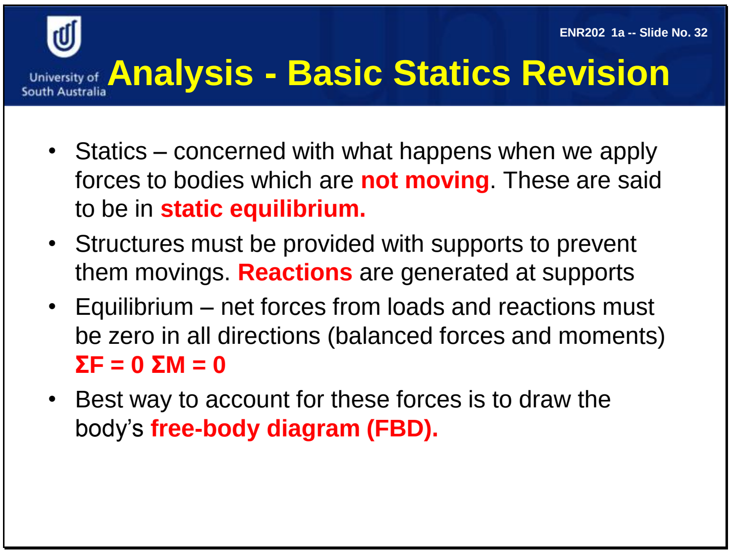

Static mechanics are concerned with what happens when we apply loadings to bodies which are not moving. If we have known forces on the body, but the body is not moving, we say the body is in static equilibrium. We have applied balanced forces on the body. Equilibrium means that the forces are balanced, that the forces and reactions together are zero or a balanced force system. Forces in three directions are zero and moments in three directions are zero. In this unit we will only consider everything in static equilibrium, which means the structure is not moving. We may have to support to prevent it from moving, so we have reaction generated at the support.

The best way to analyse the forces is to draw free body diagrams.

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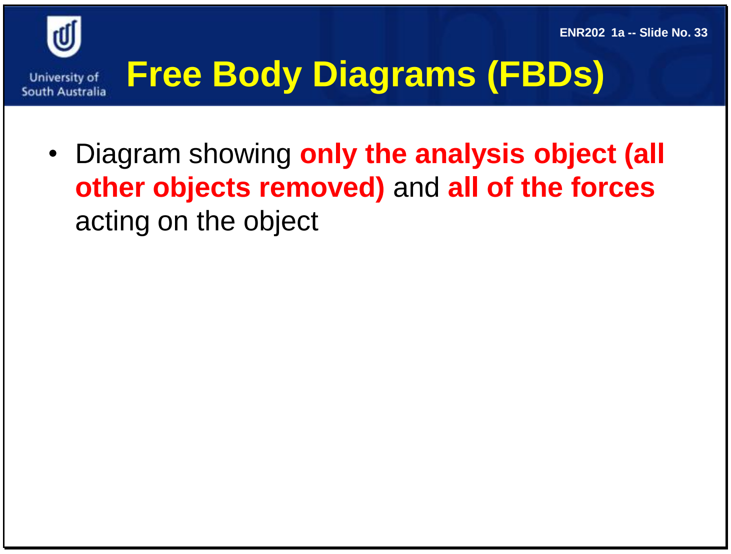

Now we will look at some examples of free body diagrams, showing only the analysis object (all other objects removed) and the forces acting on the object.

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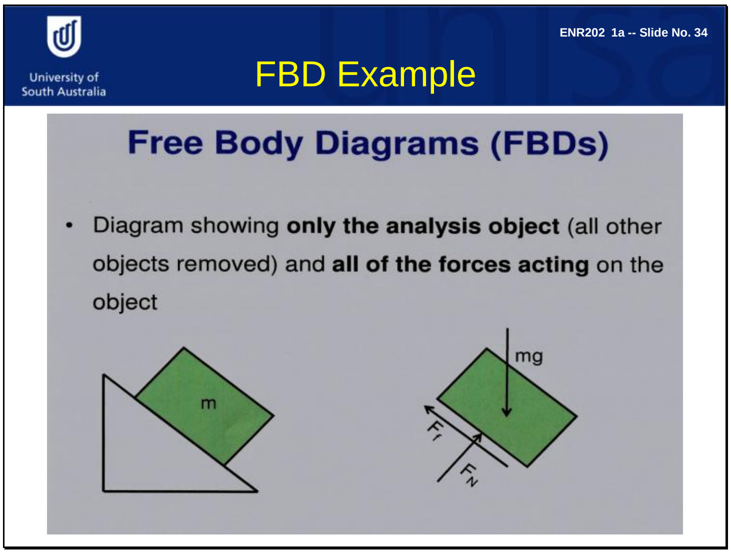

Here we have an object on the surface, and this object is in equilibrium and not moving. We can say that self weight is acting on the object, and we have the reaction force from the surface of the supporting object. This reaction force may be a contact force (normal force, denoted by Fn) and a friction force (denoted by Ff). The three forces together balance the object, so the three forces together form a balanced force system. We can see the equilibrium of this force system. We have to consider the forces in two directions. The force in x- direction together is zero and force in y-direction together is zero. We call these equilibrium equations.

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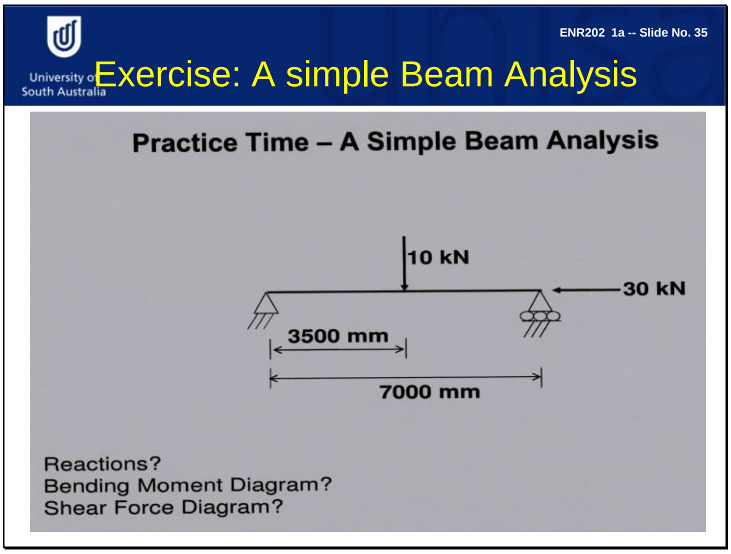

Now we'll look at an example of how to work out the reaction forces on a beam.

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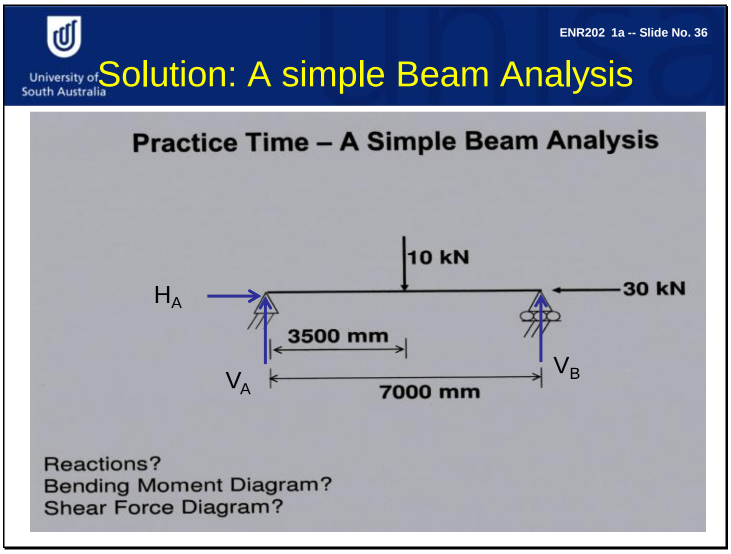

We have three equilibrium equations, two in forces and one in moment, for one object. All forces in a vertical direction are zero. That means sigma V equals zero, because we have a symmetric structure and symmetric loading. VA equals VB equals 5Kilo Newtons. All forces in a horizontal direction are zero. That means sigma H equals zero, HA equals 30Kilo Newtons. Take moments about the A point. All moments together are zero, which means that these calculations are correct.

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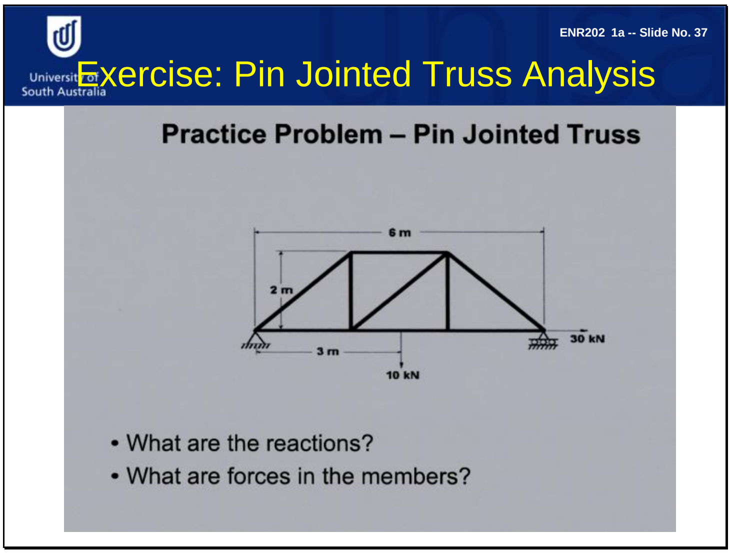

Here is another example. This is a truss problem with pinned supports on the left side and a roller support on right side. For the truss member or for truss structure, you have to calculate reaction forces, and also forces inside the truss members. Pause the presentation and try to work these out now. The solution is on the next six slides.

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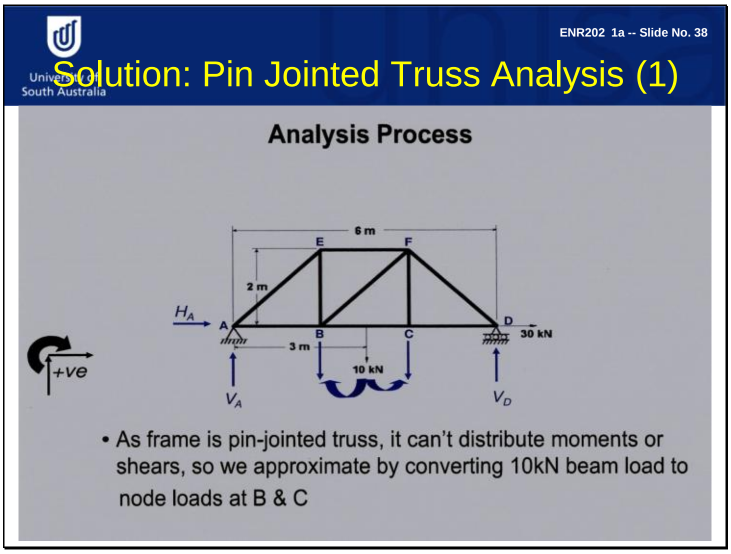

What are the reaction forces here? Just separate the 10 kilo Newtons into two parts, with the first 5 kilo Newtons on point B, and the other 5 kilo Newtons on point C. Try to work out the vertical reaction force at point A (VA), the horizontal reaction force at point A (HA), and the vertical reaction force at point D (VD).

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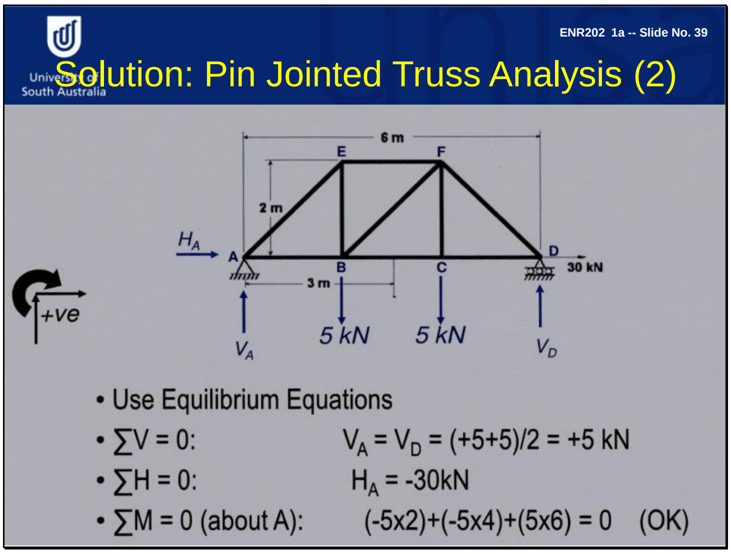

To consider the equilibrium equations, you should have one object. We have three equations, two in forces and one in moment, for one object. All forces in a vertical direction are zero. That means sigma V equals zero, because we have a symmetric structure and symmetric loading. VA equals VD equals 5Kilo Newtons. All forces in a horizontal direction are zero. That means sigma H equals zero, HA equals negative 30Kilo Newtons (in the opposite direction). Take moments about the A point. All moments together are zero, which means that these calculations are correct.

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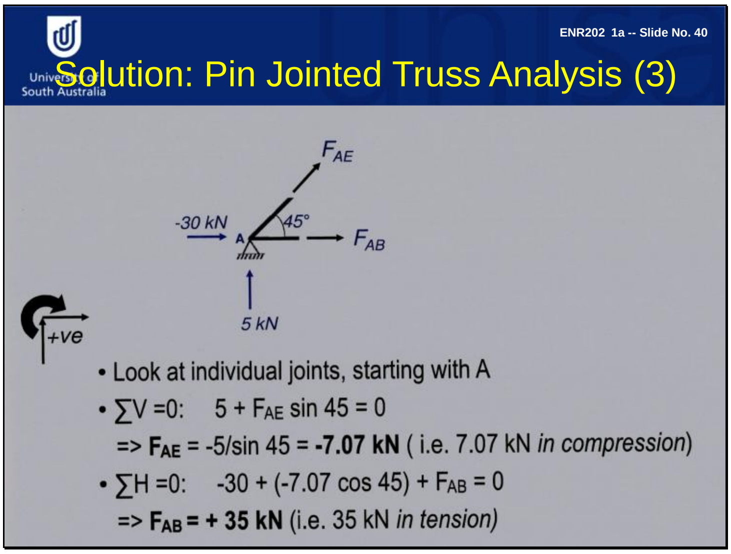

After working out the reaction forces, we have to calculate the forces in the truss members. For example, consider the A joint, with horizontal forces 30Kilo Newtons, and vertical reaction forces 5Kilo Newtons. We don't know the forces in the AE and AB members, so we need to consider equilibrium equations of the A joint. We have two equilibrium equations, that means all forces in the horizontal direction and vertical direction are zero. In a vertical direction, the member force in AE is negative 7.07Kilo Newtons. This means compression. In a horizontal direction, the member force in AB is 35Kilo Newtons, which means tension.

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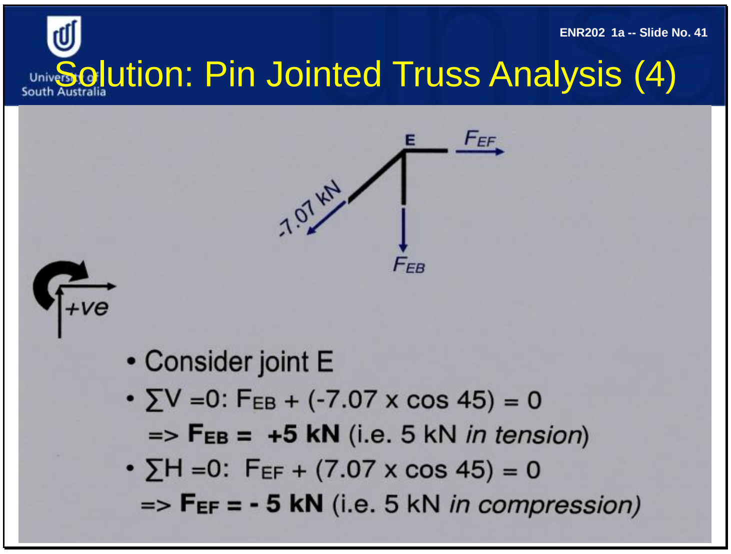

Now we come to the E joint, with one known force and 2 unknown forces, and we consider equilibrium equations of that joint. We have 2 equilibrium equations, that means all forces in the horizontal direction and vertical direction are zero, so we have member force in EB is 5KN means tension, and remember horizontal forces, so force in member in EF is negative 5KN, which means compression.

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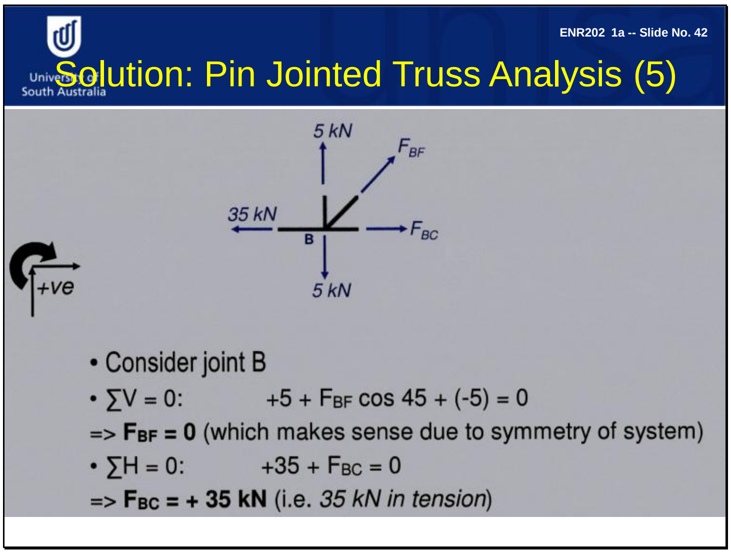

Now we come to the B joint with one known force and 2 unknown forces. We now consider equilibrium equations of the joint. For this joint, we have 2 equilibrium equations, which means all forces in horizontal direction and vertical direction are zero, so we have member force in BF is 0KN means no force, and remember horizontal forces, so force in member in BC is 35KN means tension.

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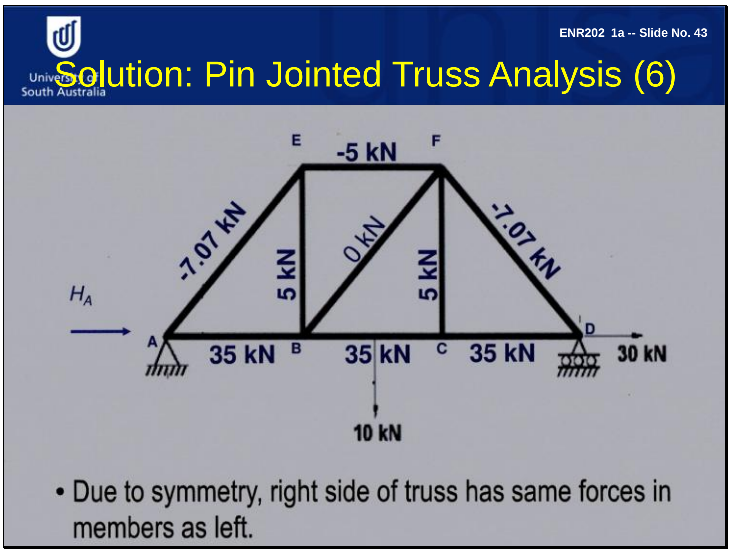

Due to symmetry, the right side of the truss has the same forces in members as the left. Finally, we work out that the truss members forces altogether look something like this.

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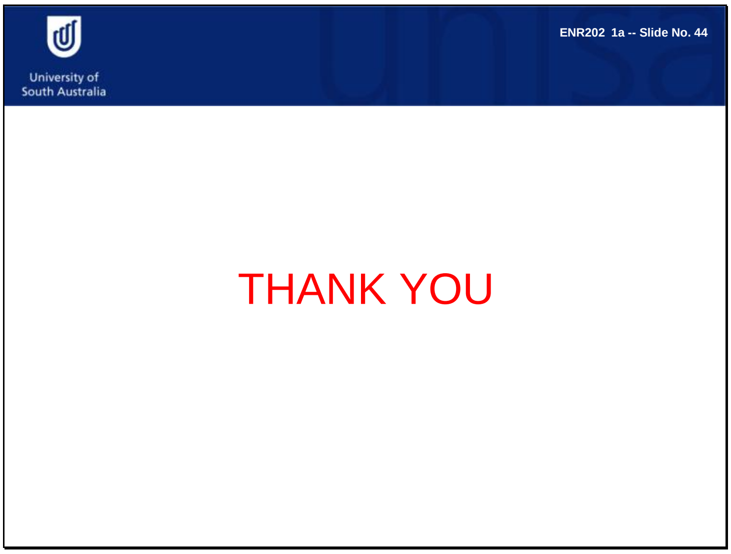

Thank you.