So I hope you had fun building tensegrity structures. I know they can be a little frustrating. But they're rewarding once you get the whole structure put together. So I like to start with tensegrity structures because they're visual. And they give you a physical and visual representation of tension versus compression, so the rubber bands versus the wooden dowels. So the rubber bands in the case of the structures we had you build are the tension elements. And they make a net that holds those compression elements in position.

There aren't too many structures in the world it used tensegrity. One example is the Kurilpa Pedestrian Bridge in Brisbane, Australia. It's an example of a hybrid tensegrity structure. There are also some dome structures that use tensegrity for the roofing system. So tensegrity structures are a nice example of tension and compression in separate elements.

Another example of a structure that has tension and compression in separate elements is a truss. A truss is a little bit more common of a structure, not quite as visual because we use the same types of members for the tension elements and the compression elements. But you've probably seen trusses. So I'm guessing you've all seen a truss either in the roof of your house or you've walked or driven across a bridge that's a truss.

So what is a truss? According to Hibbeler, "a truss is a structure composed of slender members joined together at their end point." And the joint at those end points is kind of the key to a truss.

So truss members are pinned together. So every joint in a trust will be pinned. And this is a model of the pin joint. So I have two members. And I have a dowel through the two members connecting them. And that creates a pin joint. It's one of the more simple pin joints. But it allows these two members to rotate. So they can rotate independently of each other. They will move together. So if this structure somehow moves horizontally or vertically they'll move together. But they'll rotate independently. And that's the definition of a pin joint.

Another key, with trusses is all the loads will be applied to the joints, assuming it's designed properly. As an introduction to trusses I want us to consider two separate pin jointed structures. So this is a triangulated system. So it's got three members all with these dowel or pinned connections.

And what I want you to consider is if I apply a horizontal force to this is this going to be stronger or weaker than a rectangular system. So if I were to take four members and also pin connect them and again push on this one laterally is the rectangular or square system going to be stronger or weaker than this triangulated system?

So let's go ahead and try it. So I'm supporting the base of this rectangular system. I'm going to push on the side. Uh oh, and that one topples right over.

So let's see what happens with the triangulated system. This one if I support at the base and push on it I can push really hard on this one. And it's both stiff and strong. So strength is going to be a measure of when it's going to fail. And stiffness is how much it deflects. And this one is not really deflecting all.

So why does that happen? Why is this so much stronger than the rectangular system? It has to do with the joints. So a truss is all pin connected joins. If we have pin connected joints we really need some of the members to be off at angles. So most trusses that you see will be composed of a series of triangles. So if I take this triangle and keep adding on triangles I'll generate a larger truss system. It does a great job resisting loads. It's a very stiff and strong system. The rectangular system, not so good. OK, it's just going to collapse. Now we do use rectangular systems. We use them all the time. But we need different joints. So these pinned or dowelled connections aren't going to work. We need different joints. We'll talk about that eventually.

So we're going to truss number. And my goal here is to try to figure out the relationship between all these forces. We often call a truss number two-force member. And I'm hopefully going to show you why we call it a two-force member.

So I've pulled out this blue line is meant to represent a truss member. It's off at an angle. A truss member is always pinned at the ends, or we model it with pins at the ends. And if we have a pin, a pin allows rotation. So think of a dowel through the joint. You have rotation allowable here. But it's restrained in two orthogonal directions. So it can translate perpendicular to the member or parallel in both directions. I've represented that with A1 and A2 at join A and B1 and B2 and joint B.

OK, so I can just look at this and use equilibrium like we've been using. And I'm going to do equilibrium. First I'll start with the forces in the one direction, so along the axis of the member. And we see I have A1 acting along the member and B1. So that would just be A1 plus B1 equals 0. We find a relationship between A1 and B1, that they have to be equal and opposite. And that makes sense for truss.

So let's now look at the two direction, summing force is in this direction perpendicular to the member. We get A2 plus B2. And that all has to equal 0. So we get a similar relationship that those two have to be equal and opposite.

So that's the starting point. But we still haven't really solved for all of it. So I can use one more equilibrium, and that's rotation. We sum moments. But really it's again just saying I don't want any rotation. I'm going to sum my moments or have my pivot point be this joint B. If we look at these two forces that are going right through that point so they're not going to cause any rotation. This A1 is going right through that joint. So it's not going to cause any rotation either.

So we're just left with A2. And a moment requires that we also have a distance. So let's give this truss member a length. Let's call it l. And that's all we have causing a rotation. So A2 is the only force trying to cause a rotation. So A2 times l has to be equal to 0. If we don't want the length to be 0 then that force, A2, to be 0. If A2 is 0 then B2 is also 0. So these two both end up being 0. And I'm left with just two forces that are equal and opposite. And that's how for a truss member we get that the truss member is either both of them pushing on the bar, which would be compression, or both of them pulling, which would be tension.

So I want to talk a little bit about supports. So supports are what engineers use to prevent motion in a structure. They're typically some type of connection to the ground or a different part of the structure. But it's what holds it in place. So I want us to think a little bit about how much support we need, how much is too little, and is it possible to put in too much support.

So I brought in this little truss, this simple truss. And I want us to consider the supports that we need to use for the truss.

So if I just set it on the table like it is right now it's being supported vertically. So it's self weight, we're getting a reaction force along the whole bottom in this case, a vertical reaction force that supports the load. And if I press down on it vertically I also get vertical support. Now I'm supporting it on the whole table. It would typically be supported on two sides, maybe spanning across an open space of some type. So It would typically be represented by supports on the two sides.

And vertically if I just set it on there that's sufficient for a vertical load. But horizontally if I push on it horizontally that's not sufficient. It's going to start slide across the ground. And that's fine for skateboards but not for buildings. So I don't like my buildings to slide across the ground. I'd like them to be stationary. So I need more than just setting it on the ground. I need a physical support, at least at one end. So I'm going to represent that with my hand. I'm just going to hold on to this side. What that would be usually is a physical connection between this end of the truss and the table, or a beam, or other substructure below. But something over here would have a solid connection. And that's what's going to provide both lateral and vertical support. So now I can push on it horizontally. And I can push on a vertically and it's supported.

Now typically I will represent this pin connection with a triangle, so in my drawings I would represent it with the triangle. What that's representing is it's telling me that I can replace that join with both the vertical and horizontal resistive force. So when I'm starting to do calculations to make sure the supports are OK it'll signify to me that I'm designing that as a pin support, so both vertical and horizontal resistance.

And then the other side doesn't have to have that horizontal supports. So I'll often represent that with a circle. And I'll put that piece of dowel underneath, which is actually often used for bridges. They'll actually put a roller connection like this. So this type of connection I'll represent it with a circle in my drawings. And I refer to it as a roller. So one side will typically have a roller support that I show as a circle. And the other side will be a pin support. And that's one of the most typical.

Now I sometimes get questions from my students, so you need vertical and horizontal support. Why don't you just use one connection? So why don't you just use this pin connection? So what happens when I try to just use that pin connection? I don't have any resistance to rotation. So if I just have a vertical and horizontal support or a pin support on one end it's going be free to rotate. And I typically don't like my structures to rotate either. So providing that additional vertical support on one side is going to prevent rotation, in this case for vertical downward loads.

So that would be sufficient support. So the bottom line is for a truss like this-- a simple truss-- I need a minimum of three external support forces. I'm getting that with two supports, a pin on one side and a roller. But that represents three actual forces resisting the motion. So a vertical force at the roller and a horizontal and vertical force at the pin.

So we've talked a little bit about too few supports. So when I just pinned one end that was too few. If I just use two rollers that was too few, because it would roll. So we need at least three. But how about too many? Is it possible to have too many supports?

So what if in addition to pinning this side instead of a roller on the other side I pin that side as well? I could even go in and support the top with a pin connection or hold it more firmly so it doesn't move anywhere. Is that a good thing? It can be. It's referred to as a redundancy. So it means I have extra supports. So the nice thing about that is if one of these supports fails, the other supports will still hold the structure stable. And it won't collapse. And that can be a good thing.

It also tends to make it stiffer, and stiffer system, so less likely to deflect. It can be stronger.

It can also be a bad thing though. So especially in longer span bridges if we connect everything really strongly and then one of those supports moves a little bit you can induce stresses in the members. And that can be a bad thing.

So it's just something to think about. You need a minimum of three supports. You can have too few supports. And you can actually have too many supports.