DartmouthX-SP | C2_ExampleSuspensionBridge

So now I wanted to look at a suspension bridge. And I kind of want to compare this to the cable stay bridge, which is why I used the same span and I use the same distributed load.

So the cable stay bridge tends to have more cables. I has these vertical cables we often refer to as suspenders or suspender cables. Their job is really just to take the load up to this main cable. And that upper cable is the main cable that's draping over. That main cable gets connected back to abutments and goes over and over the towers.

So the suspenders, they're important. But their main job is really just to take this load from the deck and take it up to the main cables. So analyzing them is fairly straightforward. It's somewhat like what we've done previously, summing forces in the y direction. We don't even have an angle that we have to deal with.

So online we've posted all the steps to go through that. But the bottom line for those suspenders is that we have a certain diameter that's required. And I use the same allowable stress that I used for the cable stayed bridge.

But the diameter of the suspenders ends up being 3.03 millimeters. And that's kind of the story I wanted to tell with that. The diameter is quite a bit smaller.

So the diameter, just for comparison, of the cable stay bridge. We used the same size cable for all those cables. So for the cable stayed cables that was 6.4 millimeters.

So significantly less for the suspenders, but that makes sense. There were only eight cables for the cable stay bridge. Now, there's 18 cables in this main span for the suspenders, so we can use a smaller diameter. Again, I was using the same strength.

But now the main thing I want to look at is this main cable. So I need to calculate the tension force in the main cable. That'll be my first goal. And then, I also want to calculate the diameter of a steel cable that I would use for that main cable.

So to do that, I'm going to look at a free body diagram focusing on that main cable. So I'll put that down here.

Here's my main cable. I am going to look at half of the span. So let's let that 9 meters equal L. That's the full span. And so this would be L over 2, or 4.5 meters.

Since this is a distributed load, this will still carry that distributed load. And that distributed load is w, 4.48 kilonewtons per meter, distributed over that length.

And then, I'm going to look at the forces. So I have a force. I'm going to call that T mid. So that's a tension force at the middle. And then, I'll have a tension force at the support. I can resolve that into a Tx and a Ty. And my goal is to calculate the tension force in the support.

There will be suspenders in here carrying that force up to that main cable. But I'm really focusing on this main cable. And these forces T support and T mid are the tension force in that cable.

So to figure out what those values are, we can still use equilibrium. We have horizontal and vertical equilibrium. But because we're looking at a piece of this bridge, we also have rotational equilibrium. And that is where I'm going to actually start. So I'm going to start with rotation. And I want no rotation, if I want to make this work. I'm going to use the support as my rotation point. So I will do something called summing the moments. and we'll talk about moments more when we look at arches and even more when we look at beams. Again, it's a fancy way of saying, I don't want any rotation. So I'll assume clockwise positive.

So I'm going to look at these forces and see what's happening. This distributed force is going to try to pull it clockwise around my support point. Instead of looking at a distributed load, I'm going to make the total load.

So the total load will be W times L over 2. Because this is a rectangular load, it's evenly distributed. And it's acting at the point here that'll be L over 4. So if this is half the span, it'll act right in the middle. And that'll be my total force.

The reason I needed to do that, or it's helpful to do that, is causing this rotation will be the total load and the distance makes a difference. So rotation is going to be affected by how far away it is. So when I sum my moments, I will have WL over two. That's my total force acting at a distance that is L over 4.

Again, we'll talk more about moments later in the course. And that's balanced out by this T mid, which is just the tension force at the middle.

And I left off the distance. But that distance is a sag and is 2 meters. And that's important because that's the distance that this tension force is acting from my support. So that will be 2 meters, which I often refer to as d.

It's just a sag in my suspension bridge. And that's something we would play with as a designer, how far should the span be and how much sag should we use.

Setting that equal to zero, I can solve for this tension force. So this tension force will end up being WL squared over 8d. And that's going to allow me to solve for this tension force at the mid. We know all these values. So we know the distributed load, 4.48 kilonewtons per meter. We know the length. And again, I'm using 9 meters as the length. And that's squared over 8. And then, this d is the sag. And that is 2 meters.

I can calculate this T tension force at the middle. And tension force at the middle ends up being 22.7 kilonewtons. So that's the tension force maximum at the middle. It turns out that the tension force at the support is higher.

But if we use horizontal and vertical equilibrium, we can solve for that. I'm not going to write the equations. We've done horizontal and vertical equilibrium quite a bit.

But if we look at horizontally T mid and T x are the only two things happening. So Tx is going to equal T mid if we don't want this to move horizontally. And that is also then 22.7 kilonewtons.

And vertically, we have just Ty and the total load acting downward, which is WL over 2. That value ends up being 20.2 kilonewtons. That's the vertical and horizontal component of the tension force at the support.

If I want the actual tension force at the support, I would take Tx squared plus Ty squared square root. And that value ends up being 30.4 kilonewtons. This is the maximum tension force in the main cable. So that's what I would design for. I'd design for the 30.4.

If I wanted to calculate the diameter, I would again use my equation. I'll use a different color so we can see it in the middle.

I can calculate the stress in the cable. We've done this one before. But it is force over area. And keep that less than the allowable stress. I use the same allowable stress that I use for the cable stay bridge.

We can solve for the cross-sectional area, putting in this 30.4 for T. And my allowable stress was 310,850 kilonewtons per meter squared. I can solve for area.

And then, I can solve for diameter. The diameter of these main cables, if you do that, the main cables of the suspension bridge ends up being 11.2 millimeters. So quite a bit higher than the cables of the cable stay bridge. But the suspenders are quite a bit lighter.

In the end, these are the values for the suspension bridge. The total amount of steel for a suspension bridge tends to be greater-- and I'm sure that would be the scenario here-- than a cable stay bridge. Because we're using all these suspenders and larger main cables, we tend to be able to make our suspension bridges span a lot further.

So there's pros and cons to using a cable stay bridge versus a suspension bridge. But this was to give you a little bit of background on how you would analyze a suspension bridge.