**Example Problem for Similitude**

**SPEAKER**: In this section, I'm going to step through an example problem for similitude. We have a box culvert model that is one-tenth scale of the prototype, and we're told that we need to maintain Froude similarity. So in the model, we have determined through experimentation that the discharge, Q sub-m, is equal to one cubic foot per second. The velocity at the wing wall, V sub-m, is equal to 1.3 feet per second, and the time to move water through the culvert, T sub-m, is 1.6 seconds. For the prototype, they want us to compute the discharge, Q sub-p, the velocity at the wing wall, V sub-p, and the time to move the water through the culvert, T sub-p.

Well, in order to maintain Froude similarity, we need to set the Froude numbers in the model and the prototype equal to one another, which means we take the velocity in the model over the square root of G times the characteristic length in the model, and set it equal to the velocity and the prototype over the square root of G times the characteristic length in the prototype. Therefore, we can solve for the velocity in the prototype as a function of the velocity in the model. We can cancel out the square root of G that's in the upper and lower terms of the equation on the bottom of the screen. And you can see, as we work our way across, we can replace the L sub-p over L sub-m with the ratio of the model, ten over one. So we find out that the velocity in the prototype is equal to 3.16 times the velocity determined in the model. So the velocity at the wing wall of the prototype is 4.11 feet per second.

As will be shown in the next lecture, Lecture 4, we know that the discharge is equal to the velocity times the area through which the velocity flows, and therefore we can set up a relationship, a ratio of the prototype to model discharges, Q sub-p over Q sub-m, and that's equal to V sub-p, A sub-p over V sub-m times A sub-m. And changing the area into a characteristic length and squaring it, we then have V sub-p times L sub-p squared over V sub-m times L sub-m squared. We can then set up a ratio like we did in the previous slide where we have what the discharge in the prototype is, Q sub-p. That's equal to Q sub-m times the ratio of the velocities in the prototype in the model and the square of the ratio of the lengths in the prototype to the model. The ratio of the velocities was 3.16. The ratio of the lengths is ten over one. We square that,

which gives us that the ratio of the discharge and the prototype to the model is 316 times Q sub-m. So the discharge in the prototype then is 316 times the one cubic feet per second, or 316 cubic feet per second.

The time of travel is determined by T is equal to the distance traveled over the average velocity. So therefore we can set up a relationship of T sub-p, the time and the prototype, over the time in the model, T sub-m. That is a characteristic length over velocity in the prototype over the length in the model over the velocity in the model.

And flipping out that around a little bit, transposing it, we get L sub-p times V sub-m over L sub-m times V sub-p. So the time in the prototype is equal to the time in the model times the ratio of the model to prototype velocities times the length in the prototype over the length in the model. The prototype velocity--the ratio of the velocity is one over 313.16. The ratio of the lengths is ten over one, which just so happens to work out to be 3.16 when you multiply all that out. So the time of travel in the prototype, T sub-p is equal to 3.16 times 1.6 in the model for an answer of 5.06 seconds. And that ends this example problem for similitude.