Flume Demo Force on a Pier

SPEAKER Rick Huizinga: In this flume demonstration, we're going to switch things around a little bit from the example problem that we had before. In our example problem, we showed how you can compute the upstream depth given the drag force from a pier. However, in this case, we've inserted the pier and you can see the effect of that pier on the flow and how the upstream depth is higher than the downstream depth. We are going to now determine what the drag force from this pier is based on the upstream depth and the downstream depth. If I am now the black box and you can no longer see that there's a pier here, we are simply going to use the depths on the upstream and downstream sides to compute what the drag force is from this pier.

So taking a look at the upstream measurement, we can see that the depth is flowing at about 59 millimeters, and that tells us what the upstream depth is. Again, this is a metric scale and it makes it easier for our computations. Now, if we take a look at the downstream side, we can see what the depth is on that side with that scale, and we see that although the depth is fluctuating a little bit, it is approximately 51 millimeters. We are going to take these two depths, 59 millimeters on the upstream side and 51 millimeters on the downstream side, and we're going to now compute what the drag force is given these two depths.

Now that we've seen what the pier looks like and we've taken some measurements in the flume, we're now going to do the computations and, of course, we're going to use the momentum principle to calculate the drag force on the pier. Our knowns are that the flume is 100 millimeters wide, we've converted that to feet and that is 0.328 feet wide. We've measure the flow in the flume volumetrically using a bucket and a stopwatch and we've determined that the discharge is 0.057 cubic feet per second. The upstream depth that we measured, 59 millimeters, we convert to feet, 0.194 feet. And the downstream depth, we measured at 51 millimeters and convert that to feet, 0.167 feet. Now, our control volume, when we look at the forces that are acting on it, we have the water pressure force that's acting upward on the bottom which balances the weight force that's acting downward and we're going choose to ignore that. And we also have the bed shear acting along the bottom and we're going to chose to ignore that. Along the upstream and downstream faces, we have the hydrostatic forces. Along the top, of course, we have no force and internal to the black box or the control volume, we have the drag force of the pier. So let's

determine the forces. The drag force, of course, is our unknown. The two hydrostatic forces, we learned in Lesson 2 to use the equation F is equal to gamma, WD squared over 2. So F1, the force on the upstream side, gamma 62.4, the width is 0.328 feet, the depth is 0.194 and we're gonna square that, we take all of that over 2 for a value of 0.384 pounds, that's the upstream hydrostatic force. The downstream hydrostatic force, F2, 62.4 times the width, 0.328, times the depth squared, 0.167, all over 2, gives us a force of 0.287 pounds. We determine the velocities from the continuity equation. We know that Q is equal to V times A or V, the velocity, is equal to Q over A. So our Q is 0.057, our area is the width times the depth so 0.328 times 0.194 gives us a velocity at the upstream side of 0.90 feet per second. The downstream velocity, again, using Q and the width, our new depth is 0.167 and that gives us a velocity of 1.04 feet per second.

Well, now, we can apply the momentum equation and remember that that's the sum of the forces is equal to rho times Q times V2 minus V1. Our three forces are the hydrostatic force on the upstream side, F1, the drag force of the pier, F sub-d, and the downstream hydrostatic force, F2 and we set that equal to rho, Q times V2 minus V1. And all of the forces are acting to the right in the direction flow are positive. Well, substituting the various values that we have determined, we know that F1 is 0.384, Fd is the unknown, F2 is 0.287, rho is 1.94, Q is 0.057, V2 is 1.04 and V1 is 0.90. So when we put all those into the equation and solve for our only unknown, we find that the drag force on the pier, F sub-d is equal to 0.082 pounds. This is a fairly small value but you would still be able to feel it. If you were holding that pier in the flume, you would be able to feel that resistance as the velocity change and the flow causes it to move downstream. And this concludes the pier flume demonstration for the momentum principle.