Executive Summary

The Virginia Transportation Research Council completed the attached report entitled "Giles County, VA Pedestrian Bridge Collapse and Failure Analysis" which investigates the failure of the pedestrian bridge over Walker Creek in Giles County located near Route 749. Researchers from Virginia Tech contributed to the report.

As a typical suspension bridge, this structure was constructed with two parallel cables that run across the top of the bridge and connect on each side of the stream. These cables support the pedestrian walkway on the bridge. Anchor bolts connect each cable end to heavy concrete blocks (called dead-men) buried on both sides of the creek. The anchor bolts are embedded in the concrete and have a hooked end that connects to a tensioning device. The tensioning device, called a turnbuckle, joins to the looped end of the cable. One of the four anchor bolts broke causing the bridge to collapse.

The investigation of the bridge's collapse consisted of four components.

The first part of the investigation was an analysis of the bridge's design. Engineers examined how weight was distributed on the bridge and its components. The goal was to determine how the bridge functions to support the weight of its own components and to support the weight of any load that would travel on it. Of particular interest was how load was distributed into and to be carried by the cable and the anchor bolts. To analyze the design, engineers took measurements of the bridge and created a diagram. Then, using mathematical and structural engineering formulas, they calculated how load was distributed and determined the total amount of tension that would have been exerted on the anchor bolt at the time of its breaking.

The second component of the investigation was an analysis of the broken bolt. Several tests were performed on the galvanized steel bolt to determine if the properties of the metal could have contributed to its breaking. Materials tests were performed to examine the metal's type, strength, and susceptibility to straining, bending or cracking. In addition, researchers looked for any defects in the metal and to see if any corrosion was present. When examining the bolt, engineers detected a small defect on its surface located on the inside of the hook. The defect is believed to have contributed to the bolt's sudden break.

As part of the materials testing, engineers found that the metal on the outside of the bolt was stronger than the metal in its core. Engineers calculated the yield strength and the ultimate strength of the inside of the bolt and the outside. Yield strength is the measure of how much tension the metal can hold before it begins to stretch. Ultimate strength is the amount of tension the metal can hold before it breaks. The yield strength of the metal in the center of the bolt was 55,000 pounds per square inch, and the yield strength of the outside of the bolt was 79,000 pounds per square inch. The ultimate strength of the metal in the center of the bolt was 88,000 pounds per square inch and the outside was 128,000. Materials testing suggests that the strain associated with the bend of the hook had caused the metal on the outside to be stronger than the metal in the bolt's core.

The third component of investigation was to test the unbroken remaining bolt that attached the same cable to the concrete block on the opposite side of the creek. A laboratory test was performed on the unbroken bolt to determine what load it could carry. The test took into account the tension in the cable and an increase in loading because of the hook starting to open. As the hook opened, it changed how the cable and the bolt aligned. This change in alignment is called eccentricity and increases the load on the anchor bolt. Testing shows that with a load of 7,000 pounds the hook began to open and was close to the point of breaking at 11,900 pounds. Data from this test helped researchers to confirm the yield and ultimate strength measures that were calculated during the materials testing.

The fourth part of the investigation involved comparing the strength of the bolt to the amount of tension present at the time when it broke. The strength of the bolt was determined from the materials testing, and the amount of tension expected to be on the bolt at the time of its breaking was concluded from the design analysis. This comparison shows that the anchor bolt would have supported the load and tension present at the time of its breaking if there had not been a defect in the metal.

In addition, the remaining cable and its two anchor bolts are supporting a larger load than each cable carried when they were working together. Even though the metal hooks of the anchor bolts on the remaining cable are stretching open, the bridge remains standing. This remaining load of just the bridge and all its components on this single cable exceeds the load that was present on it when people were walking on the bridge. This also supports that the anchor bolts would have held except for the defect.

Investigators concluded that three factors contributed to the bridge's partial collapse: (1) a small defect in the material of one of the bridge's four anchor bolts, (2) an unusual pedestrian load (3) the configuration of the anchor bolts which allowed the hook to open.