Virginia Tech Experience with Structural Health Monitoring Unit

EXPERIENCES AND OBSERVATIONS

At Virginia Tech, the Structural Health Monitoring teaching modules developed by LSU were presented in the class CEE3954 – Bridges, Builders and Society. This is a class that presents a general introduction to a variety of bridge types, the engineers that made significant contributions to bridge design, significant bridges of various types, and also the impacts of bridges on communities. The class is team taught by nine professors and the basic units are:

- History of Bridges
- Bridge Aesthetics
- Masonry and Concrete Arch Bridges
- Prestressed Concrete Bridges
- Steel and Composite Bridges
- Cable Supported Structures
- Societal Impacts and Failures
- Bridge Design Specifications
- Future Developments in Bridge Engineering
- Structural Health Monitoring

This class also includes an 11-day capstone study abroad trip to Europe to view many of the famous bridges that are presented in the class. One of the highlights of the trip this year was to visit two bridges in Italy that are equipped with structural health monitoring systems. A recently graduated PhD student from the University of Trento, who had worked on the bridge for his dissertation, was our guide.

The Structural Health Monitoring (SHM) unit in the class was added in the spring of 2018 and used the teaching modules prepared by LSU. The SHM unit was limited to two one-hour and 15-minute class periods, so the approach taken was as follows:

Student Preparation for Class 1

Students were required to view the first three presentations (FEM0, FEM1 and FEM2) prior to class and take the quizzes. They were also told to print out and respond to the discussion questions, and then bring their sheets to class.

Class Period 1

In the class, we first discussed their responses to the discussion questions. The students were very engaged and all fully participated in the conversation. I was very pleased with their level of interest in the topic. We then viewed FEM3 and FEM4 together during class. FEM3 started out well, with the overview of types of sensors, but got into too much detail about each type of sensor toward the end. I felt I lost the student's attention at this point in the presentation. We were not able to get all the way through FEM4, so I told the students to complete viewing the presentation outside of class.

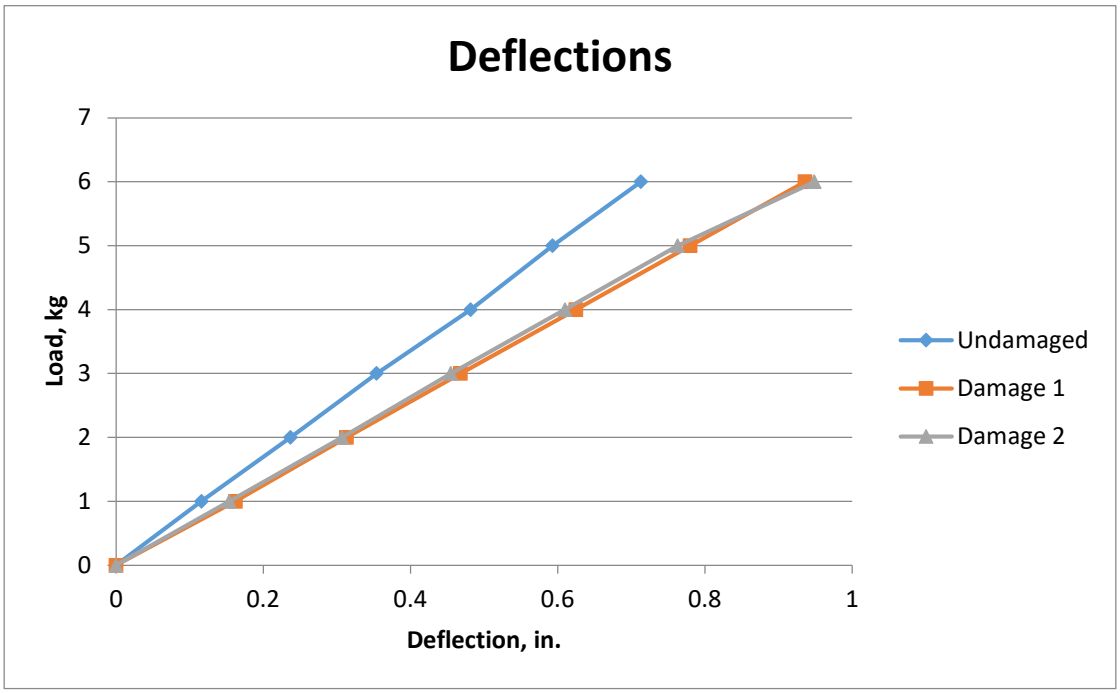
Student Preparation for Class 2

Students were required to view the next four presentations (SEM1, SEM2, SAM1 and SAM2) prior to class and take the quizzes. They were also told to print out and respond to the discussion questions, and then bring their sheets to class.

Class Period 2

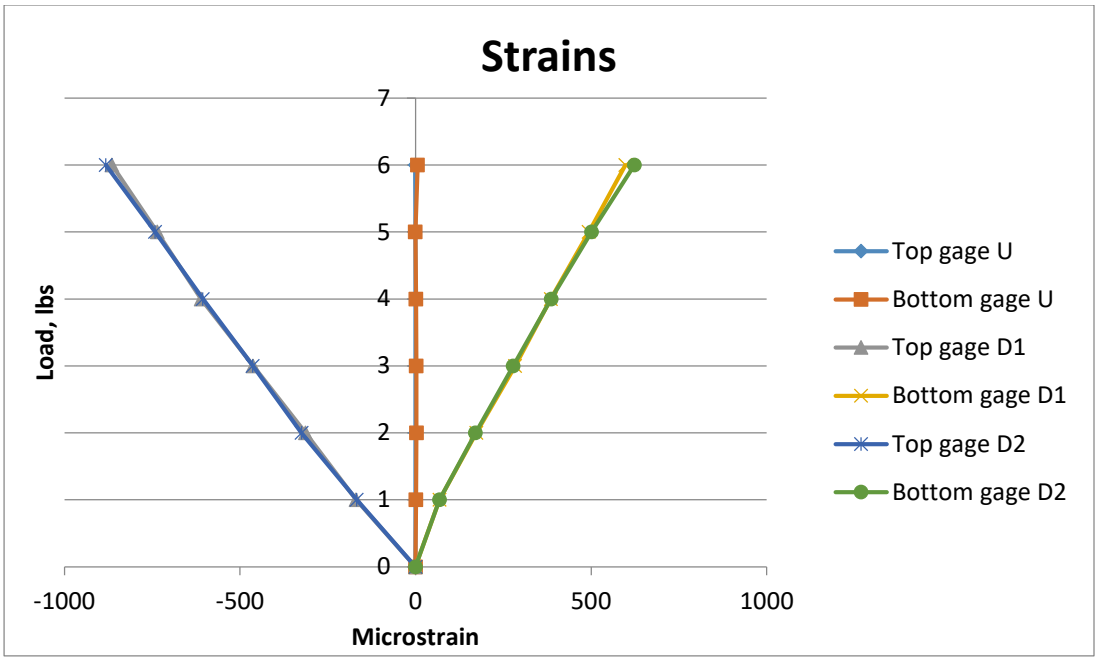
In the class, we first discussed the responses to the discussion questions. As with the first class, the students seemed very interested and engaged and had very good responses and participated fully in the discussions.

We then performed the class demonstration. We used a slightly different loading method, using 1 kg weights that we could place on a hook suspended at mid-span. We incrementally loaded a completely undamaged beam, then a damaged beam with all of the wooden plugs in place (Damage 1), and then the damaged beam with the two midspan plugs removed (Damage 2). We used an EXCEL spreadsheet to record and plot the readings as they were made. The following figure is the load vs displacement plot.



Graphing the increase in deflection with load showed the students that even with the damage, the behavior is still linear. They also saw a significant change between the undamaged beam and the damaged beam with the plugs in place (Damage 1). Then we saw very little change in deflection with two of the plugs removed (Damage 2). This could indicate that our plugs were not fitting tightly enough into their respective holes.

We also measured and graphed strains under the same load regime, and the responses are shown in the graph below.



Unfortunately, there seems to have been errors in the strain measurements on the undamaged beam (U). We had placed the feet for the gages on both beams so we could use the gages first on the undamaged beam, and then move them to the damaged beam. Somehow, when the gages were on the undamaged beam they did not register correctly, but when we moved them to the damaged beam they seemed to perform fine. We were not able to discover what the problem was.

In comparing the strains measured on the damaged beam with the plugs in place (D1), or removed (D2), there was only a slight change in response. This also indicates that the plugs were probably not snug enough to transfer the compression across the hole.

Generally during this demonstration the students were very engaged. I had a graduate assistant who monitored the computer connected to the data acquisition system, and students were invited to look over her shoulder to see what the program looked like. I asked one student to load the beam for me. I input the data into the EXCEL spreadsheet so we could watch the plots take shape on the overhead screen.

After the demonstration we only had a brief time for discussions, but the students were very animated and seemed pleased to have been able to see first-hand sensors and a data acquisition system like those that had been described in the powerpoint presentations.

RECOMMENDATIONS FOR IMPROVEMENTS

I will again present the structural health monitoring modules in the same class in the spring semester of 2019. We have a new professor in our group who specializes in structural health monitoring, so I intend to get him involved in the module as well.

I intend to revisit the powerpoint presentations and remove some of the material that I view as too detailed for this class. I would like to keep the topic a little more general, especially with respect to the finer points of sensor selection.

I also will revisit the class presentation. In general it went smoothly, and I think incrementally loading the beam so the students could see the linear behavior was good. I need to make sure to double check the sensors prior to loading, so I don't have the problem with the gages not reading correctly. I also will work with the hole plugs to see if I can get the response of the beam with the plugs to be more similar to the beam with no damage at all.