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SHM Report

INTRODUCTION

The SHM Unit was implemented in two courses at UNF. The courses are: CES3100 Analysis of Structures and CES4702c Design of Reinforced Concrete. The fundamentals modules (FEMs) were introduced in the first course and the application modules (SEMs and SAMs) were introduced in the second course. Overall, the experience of the students was positive and the delivery of the content went smoothly. In this report, I will address the two items requested by the project's PIs.

a. SUMMARY OF STUDENTS' EXPERIENCES AND OBSERVATIONS RELATIVE TO THE IMPLEMENTATION OF THE SHM UNIT:

The following comments were taken from the students' feedback after introducing the relevant modules. They are divided into three groups for clarity; namely comments on FEMs, SEMs and SAMs.

I. Students' Feedback Comments on FEMs

- These sections helped to explain the data collection process and define common words that were used in the preceding sections. The biggest takeaway from this section was the schematic of how the sensors send the data to a processor for engineers to be able to retrieve it and analyze the data from the sensors. These sections also explained the importance of SHM, and why implementing the sensors onto structures will help better understand how structures react to certain environmental impacts or damages.
- The FEMs described the Structural Health Monitoring (SHM) system and the responsibilities behind the software as well as the benefits of having a system implemented within structures.
- This section provided a list of professional responsibilities of a structural engineer using SHM and reasons for the installation in bridges with "high consequences" of failure. SHM would be useful on dated bridges and bridges which contain cracks and heavy loads.
- The FEMs were an excellent way to learn what Structural Health Monitoring means. This section introduced different SHM methodology, testing categories/classifications and

specific applications of SHM. Information in sensor technology, data, and systems was covered. How to choose which sensor or devise to apply was also included. Finally, it discussed ways to minimize error in SHM. The FEMs truly gave a fundamental understanding.

- The first of the three sections. It was started last year in the spring semester and became a small part of our analyses of structures class. It was not hard but strange the way it all happened so fast. I believe this will not be an issue in future years as it will most likely start at the begging of the semester with the class. Over all the experience was straight forward and simple. A good way to get people to start thinking of structural health.
- We learned about the devices used for SHM. We were able to see how devices like tiltmeters, LVDT, and others are used in the field and what data they record for the structures. It was very useful to use this information in the application stages of the SHM project.

Instructor's Feedback Comments on FEMs

The FEMs were adequate to make students learn about the Structural Health Monitoring, the different SHM methodology, sensor technology, data, and systems, testing, and applications of SHM.

II. Students' Feedback Comments on SEMs

- These two sections explain the different type of sensors, and how sensors are chosen for a structure. The methodology of the SHM system is to detection any damage before the structure fails due to the damage. This was tested in class with a PVC board. The board had holes drilled into it near midspan to simulate a damage girder. The sensors measured the PVC board before the damage was applied, and once the damage was initiated.
- The SEMs described how the sensors in a structure are like human skin. There are millions of sensors and many more data points to analyze. Although the monitors provide the data to analyze a structure, they also cause many data points and could be difficult to understand where the damage or failure may occur.
- The cost of the monitors is also another reason why the monitors are not wide spread. Not only are the monitors expensive to buy and install, the maintenance over years can be costly.

- The SEM section covered how to implement the goals of a specific project to sensors. It discussed the installation of critical sensor and alternative SHM systems. This section also taught, ways to summarize a specific system, and outline expected outcomes of the plan. Personally, I found this the most interesting section because it went over real world projects.
- The second part of the SHM program was done in sequence with the SAMs, third part. We were told about this section half way through the semester again which, as before, made for a strange way of going about it. Over all the experience was very similar to FEMs. Not too hard or time consuming but got people thinking about structural health in a critical way.
- We learned about the process of applying SHM to a structure and the steps involved with those projects. We were also shown examples of how SHM devices are used on projects in Austria and other locations.

Instructor's Feedback Comments on SEMs

The SEMs section was properly introduced in a very clear way for the students to learn about sensors and the process of applying SHM and devices used

III. Students' Feedback Comments on SAMs

- The SAMs section provided specific cases of the use of SHM. To offset costs, engineers can determine if a bridge need monitors the whole life of the bridge or short term. The determination of short term versus long term monitoring can depend on what type of data needs to be analyzed.
- The part of the SAMs section discussed the impact of damage on deformation and whether the damage is localized of distributed over a large section of the structural member. Sometimes, when the damaged is localized, the structure can be fixed easily and require a section fix. With a distributed damage, the whole bridge would need to be repaired in some way.
- These two sections explained testing of the PVC, and how the test would be run.
- The in-class beam experiment analyzed the stresses and strains in a damaged and undamaged beam. The damaged area was local causing the beam to deform heavily in one area but did not fail.

- The SAMs were the most in depth sections. They covered ways to sketch a SHM plan, organize a set of specifications and defend the suitability of the developed plan for a specific project. It explained how to produce a template for recording SHM data, conduct a SHM test for a beam, compare/critique data, and report results.
- The third, and final, part of the SHM program included a group project in which we implemented real SHM sensors into a beam and measured the forces and deformation on the beam. This part was by far the most engaging and enjoyable. The hands-on section at the end was a very nice way to wrap up everything we had thought and discussed about over the two semesters.
- This consisted of the implementation of everything we learned in prior modules in order to perform the experiment on the beam with our groups. It was useful to see how the devices were applied in real time and how the software would obtain the data.

Instructor's Feedback Comments on SAMs

The SAMs section was the most interesting part that captured the students' enthusiasm and their best level of engagement.

b. SPECIFIC RECOMMENDATIONS FOR ENHANCEMENT/IMPROVEMENT OF THE EDUCATION/ASSIGNMENT MODULES AND THE EDUCATION PEDAGOGY.

In this section, recommendations to enhance the developed modules are provided for the benefit of the project PIs in future implementations. First, suggestions by students on how the modules could be provided are summarized. Then, additional comments based on the instructor's experience are provided.

STUDENTS' SUGGESTED RECOMMENDATIONS FOR IMPROVEMENT:

- I do not have any recommendations. I think the PowerPoint slides give a thorough overview of SHM. Testing the PVC boards allows the students to get hands on experience with the sensors, and hands on experience is crucial in the learning process.
- I would suggest a separate class, summer or online class, for the SHM information and experiment. I believe this information is important and would benefit all engineers to know and use this technology in the future. I enjoyed learning the material, especially from a well-educated Professor, Dr. ElSafty, and will continue to take what I learned from the above sections into my career.
- I would recommend giving these modules to students at the beginning of the semester instead. Beginning is a less busy time and students will be more engaged in these topics. For some sections, no PDF presentations were available. Some prefer the PDF rather than PowerPoint. In addition, videos may give a better visual and fuller experience of these sensors. Ultimately, this project was a wonderful idea. Structural health monitoring is an interesting topic and extremely important. Understanding this can save lives. In addition, it was a privilege to get the opportunity to work on a project rather than exams only. Learning beyond the scope of exams is what makes education more meaningful.
- Overall my thoughts on the SHM program were relatively positive. It was a good way to get students to start thinking about the importance and practicality of SHM. The group project was a very nice finish to the entire program. My one suggestion to make this program better would be to not start it in the middle of a semester. Start it form the beginning and left the discussions happen throughout the entire semester. Maybe make

some SHM elective if that is possible for students who are very eager to learn more about this topic.

- The modules would be much better learned/retained if there were a more interactive feature in the class to review them. If the modules were a focus throughout the semester instead of towards the end of the semester, the students would have more time to focus on the modules and fully understand the concepts. Its a great topic of discussion and is something that many of us may need to use in our career, which is why a more dedicated approach would have been beneficial for us.
- The SHM learning units were very interesting and provided a lot of information on a totally new subject for me. I'm not sure what changes there should be, but I have a couple of observations and ideas. This is just my honest opinion in hopes to better UNF in quality of learning.

  I did not like the idea of letting students discuss information of which they are not familiar. No student in this class can add any new information to the subject of which we all read about for the first time. It is a completely new subject for us and I feel that better learning would come from recorded lectures with the reading/powerpoint.

  It would be cool to visit a site that has SHM devices and monitors and collects the data locally to see that SHM is actually being used where we are. It makes it worth it to put the time and effort into learning and understanding. It appeared to me that the uses of SHM are sporadic and few. Maybe instead of just visiting the site, you could partner with a company that deals with SHM and have them show what they do. The best way to get more students involved, in my opinion, would be to show that learning SHM can lead to an even better or lucrative career as a civil engineer. We are already getting that without the SHM. This is the whole reason we are at UNF in the first place. It just seems to me that, as it is currently represented, SHM does not seem worth it to learn while other jobs and careers seem more viable and are currently available that we can see ourselves. I guess this would be a way to get more students involved and excited about SHM rather than improving the actual learning module.

- Throughout the education we have received and taken on ourselves, we have learned the basics of structures – how to calculate forces, what makes them stand, what forces they can

hold – and we have also learned how to design structures and foundations including the use of LRFD. As an engineer in training there are many concerns – What if I did everything I thought was right and my structure fails due to unforeseen circumstances? Failure, especially when people's lives are at state, is a huge concern for everybody. SHM brings a new light to the use of technology to monitor a structure remotely.

The FEM, SEM, and SAM modules were brought to us help to teach us about the problems structures have and to give us a solution to fix it. Since we are new to most things engineering, there are more things we don't know than there is that we do know. Many of the issues that were brought to us are things that learning engineers are not aware of such as where a bridge is most likely to fail. I think overall we were able to learn from the PowerPoints, but I do think there are improvements to be made.

With the intensive curriculum we have, I know it is hard to fit extra topics in, such as the SHM modules that we learned. The use of PowerPoints is a good way to get some extra lessons without having to take from the rest of the class, however, I, like some other students, have a hard time learning from PowerPoints and I think that actual lessons could stick with us a little bit more. I do think the discussions are a big help, and we are able to get a lot out of our other classmates. I think another big help was the project at the end of the semester. We were able to actually see how the SHM sensors work which will maybe bring us to put them in our structures when we get the paygrade to make decisions like that. Overall, I think the SHM is a great addition to our curriculum that should be brought to the classes after us.

PROFESSOR'S RECOMMENDATIONS FOR IMPROVEMENT:

1- Introduce more critical thinking in the discussion questions

   Instead of having the discussion questions an exercise of recollection, questions that promotes critical thinking by the student. Not all discussion questions should be changed, but a few modules can benefit from such a change, especially advanced ones.

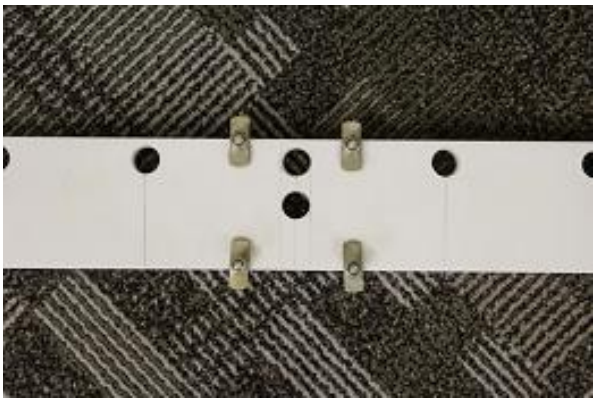
2- Introduce some applications in the FEMs

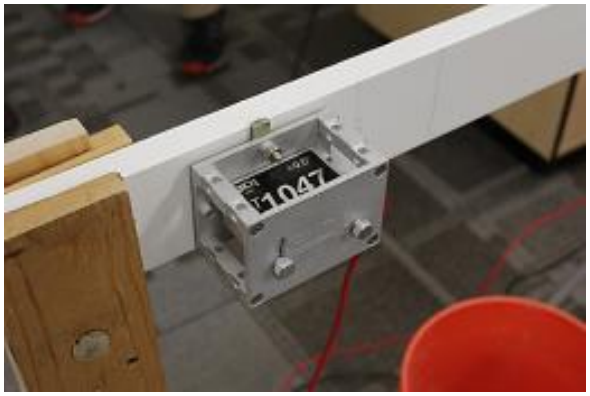
   The fact that the FEMs are introduced in one course and the SEMs/SAMs are introduced in a following semester makes student wait a long time before they can

have their hand-on experience with the SHM equipment. Introducing a hands-on activity with the sensors in the FEMs would help in that regard.

3- Provide a more realistic and significant damage in the demonstration beam. The level of damage introduced by the drilled holes and the ability of the wood plugs to bring the beam to an undamaged state may not be the best way to demonstrate damage to the students and may raise more questions than answers.

INSTRUMENTATION FOR THE TESTED BEAM:



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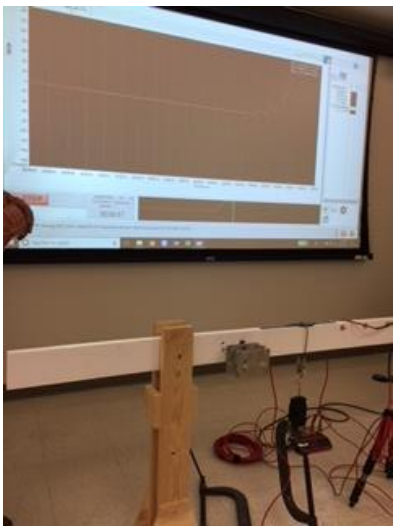

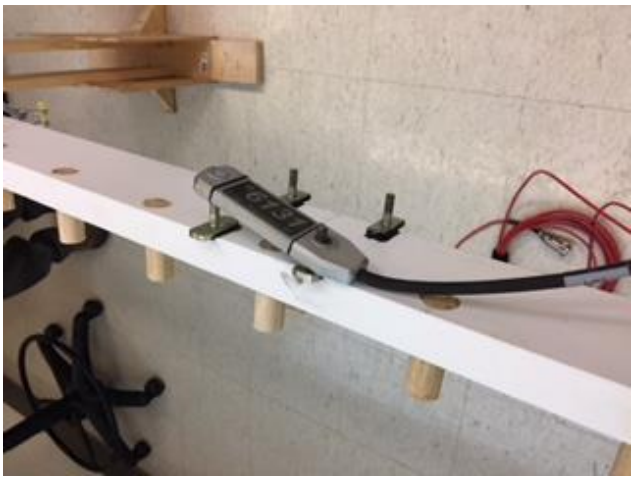


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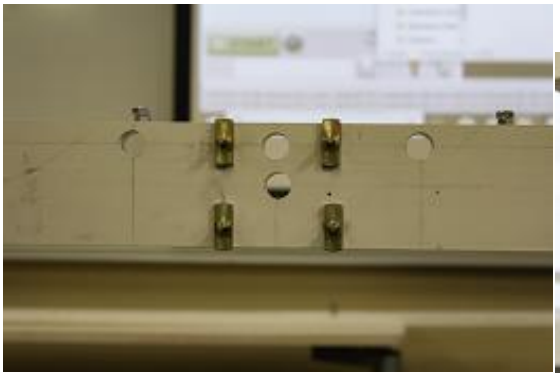

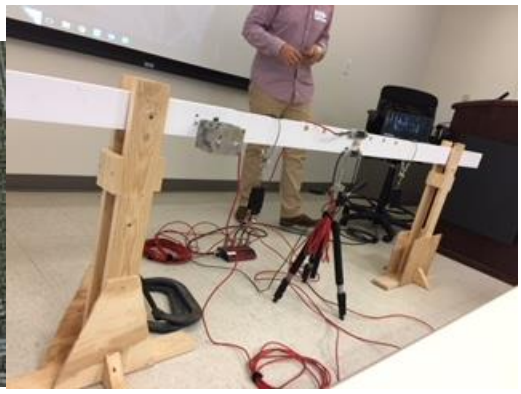

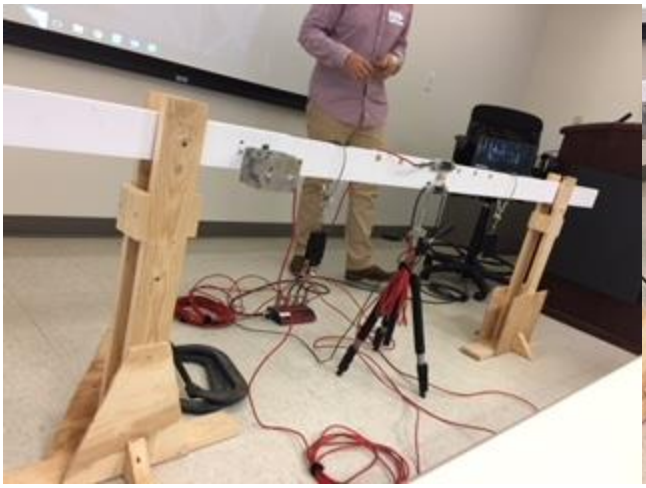

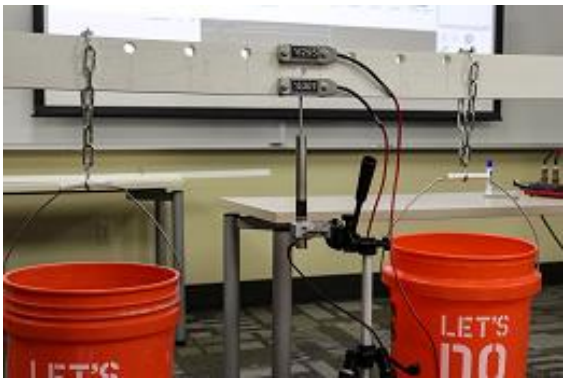
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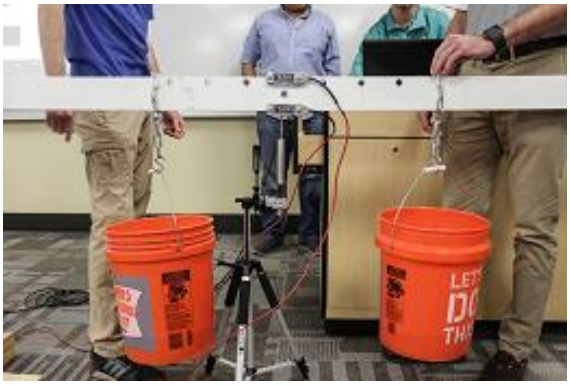

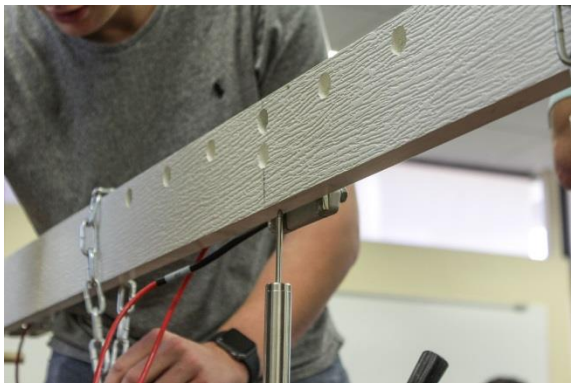

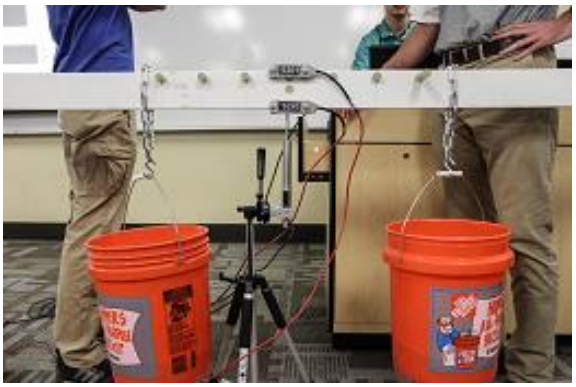


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