AC 2009-557: MULTIDISCIPLINARY PROJECT AND COLLABORATIVE TEAMS

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Multi-disciplinary Project and Collaborative Teams

Abstract

Multi-disciplinary Project and Collaborative Teams (MPACT) is a collaborative effort between faculty and undergraduate students of Civil and Electrical Engineering Technology programs. This project is part of an undergraduate research project supported by the Minority Access to Graduate Education and Careers in Science, Technology, Engineering and Mathematics (MAGEC-STEM) program at Savannah State University (SSU) and sponsored by the National Science Foundation (NSF). The goal of MPACT is to support multi-disciplinary design and application experiences for Civil and Electrical Engineering Technology students. The collaborative team is to develop a simulation model to study the effects of movable loads on the abutments; and, shear and moment at specified points on simply-supported and a single over-hanging bridge beams using the LabView software. The results of the simulation model are then compared with the results obtained from the physical model. The physical model, called Support Reactions was developed by PASCO Engineering in cooperation with Professor Matt Ohland at Clemson University. The model consists of a steel beam that acts as a bridge beam and three interfacing sensors: two force sensors and one rotating motion sensor. The sensors record the time and the weight of the load at the given location on the beam. The movable load is simulated by a K'NEX model truck that is carrying a 4 inch diameter ball. As a result of the simulation model, a plot is generated to show the influence of the movable load on the beam supports, the shear, and the moment at specified points. The influence diagram for the support reactions is compared to the physical model plot while the influence line of the shear and moment are compared to a manual solution. This data is compared with the simulation model using LabView to confirm the accuracy of the simulation model.

Introduction

It has been documented in literature that involving engineering undergraduates in research may help the student become more passionate about the engineering subject under study, create interest and appreciation for research practice, improve the critical thinking process in problem-solving and could serve as motivation for further education in graduate school[1]. Minority Access to Graduate Education and Careers in Science, Technology, Engineering and Mathematics (MAGEC-STEM) program at Savannah State University (SSU) and sponsored by the National Science Foundation (NSF) provide minority students with undergraduate research experience at the freshmen level and continues through their bachelor degree in STEM field. The main goal of the MAGEC-STEM at SSU is to significantly increase the number of ethnic minority students that graduate in STEM and continue to graduate school. Pursuant to this goal, one of the main activities is the involvement of undergraduate STEM students in research.

This paper describes the work produced by a team of two sophomore students. One student is majoring in electronics engineering technology and the other in civil engineering technology. The reason for multi-disciplinary is the fact that the real society in which we live and practice the profession is a multi-disciplinary, multi-cultural and interdisciplinary environment. "Interdisciplinary cooperation broadens the students' knowledge and increases the students' ability to undertake complex practical projects."

The main goal is to have the students work as a team for a hands-on learning experience in civil/electronics engineering. Their task is to develop a simulation model to study the effects of movable loads on the support reactions (abutments), shear and moment at specified points on two types of beams: simply-supported and a single over-hanging bridge beams. The simulation model is to be developed using the LabVIEW software and the results are to be compared with a physical model developed by PASCO Engineering in cooperation with Professor Matt Ohland at Clemson University. The rationale for hands-on learning in an undergraduate research is chosen because literature shows that the ability of students to solve practical problems related to the real engineering world has significantly enhanced with hands-on equipment compared to others[3, 4].

Innovation In Structure Analysis Education

Analysis of statically determinate, statically indeterminate structures, and influence lines by classical methods (slope-deflection and moment distribution) and stiffness method, using computing technologies such as EXCEL, MATLAB, MathCAD, and web-base learning have been covered in several articles[5,6,7,8,9]. However, such supplementary packages lack the coverage of the simulation of the topic of influence lines for beams under moving loads.

In a typical civil engineering and civil engineering technology undergraduate program, students are required to take statics and strength of materials as prerequisites to structural analysis course. In these courses, extensive examples and topics are covered concerning the determination of reactions and internal forces such as shear and moment in beams and frames that are subjected to static loadings. In these types of problems, a constant reaction and a static shear and moment diagrams are constructed. However, when the beam is subjected to movable loads as in the case of bridge structures, the reaction which is the response of the abutment to the location and magnitude of the movable vehicles is continuously changing as the location of the load changes. In a similar way, the shear and moment values at a specified point are no longer constant values. The students taking structure analysis course are having a hard time in visualizing these changes. This has created the need for the development of a physical model. A physical model was developed by PASCO Engineering in cooperation with Professor Matt Ohland at Clemson University. However, this model only shows the response of the support to the movable loads. It does not illustrate the influence of the movable load on the shear and moment at a specified point. The purpose of this paper is to present the simulation model that is developed by the undergraduate research students that addresses this shortfall and

compare the results of the abutment response of the simulation model to those obtained from the physical model.

Influence Lines

An influence line is a graph that shows the variation of the function such as reaction, axial force, shear force, or bending moment, at any given point on a structure due to the application of a unit load at any point on the structure. An influence line for a function differs from a shear, axial or bending moment diagram. Influence lines can be generated by independently applying a unit load at several points on a structure and determining the value of the function due to this load, i.e. shear, axial, and moment at the desired location. The calculated values for each function are then plotted where the load was applied and then connected together to generate the influence line for the function.

There are two methods that are used to plot an influence line for any function. The first method is to write an equation for the function being determined, for example, the equation for the shear, moment, or axial force induced at a point due to the application of a unit load at any other location on the structure. The second method uses the Müller Breslau Principle, to draw qualitative influence lines, which are directly proportional to the actual influence line[10]. For the purpose of the development of the simulation model the first method that requires the writing of an equation for the function being determined is used.

LabVIEW

LabVIEW is based on graphical programming language C. The development of a virtual instrument (VI) with LabVIEW consists of a front panel and a block diagram. The front panel is the graphical user interface (GUI) of the VI which may contain switches, knobs, meters, and other type of devices. Drag-and-drop method is used to select controls and indicators to build user interface on the front panel. From the front panel, the user can interact with the applications using controls to change values on switches, knobs, sliders, gauges, and etc. Data can also be displayed on the front panel using graphs, charts, LEDs, etc. The block diagram contains the source code for the virtual instrument. The user can select functions such as file I/O, instrument I/O, or data acquisition, and place them on the block diagram of your VI. The user can connect these functions together with wires like a schematic or a flow chart to define execution of the VI[11].

In order to facilitate the organization of front panel and block diagram, LabVIEW has graphical floating-point palettes to create virtual instruments. The three main palettes include the tools, control, and function palettes. Tools palette is used for creating, modifying, and debugging virtual instruments. The tools palette consists of operating, labeling, positioning, wiring, color copy tool, and etc. The control palette is used to add controls and indicators to the front panel. Each option in the palette displays a sub palette of available controls and indicators for that selection. The control palette consists of numeric, string, Boolean, list, graph sub-palettes and etc. Function palette is used to build block diagram. Each option in the palette displays a subpalette of top-level icons. If the

functions palette is not visible, you can open the palette by selecting Show Functions Palette from the windows menu. Functions palette may consist of structures, Boolean, numeric, string, file I/O, instrument drivers, select a VI, and etc[11].

Physical and Simulation Models

The physical model that is used in the summer undergraduate research project is the model that is developed by PASCO Engineering in cooperation with Professor Matt Ohland at Clemson University. The model consists of:

1. Beam (1m long) with attachment screws for the force sensors. The beam will act as the bridge deck and the force sensors will act as the abutments.
2. Three interfacing sensors: two force sensors, and one rotating motion sensor
3. Ball (10 cm diameter, 810 g mass). The ball is mounted on the truck and its motion will be detected by the rotating motion sensor
4. 90 cm and 120 cm long rods
5. Two multi-clamps
6. K'NEX built truck to act as a movable load
7. DataStudio software to graph the force vs. position of the ball for each support force.

The physical model, shown in Figure 1, is interchangeable so that one can assemble various types of bridge beams by simply moving the location of one sensor. Figure 2 shows the assembly that resembles the simply supported bridge beam, while Figure 3 shows the assembly for a single overhanging bridge beam. The truck shows a realistic representation of a movable vehicle is able to hold the weight of the ball and move freely down the beam, allowing for the sensor to record the data.
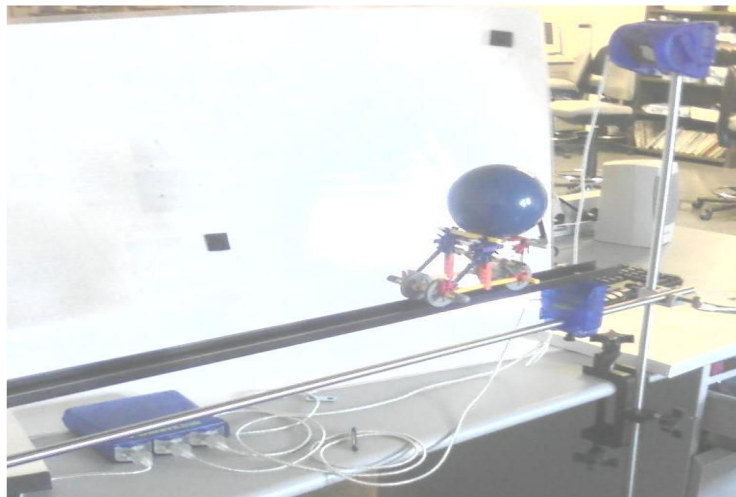

Figure 1 Physical Model

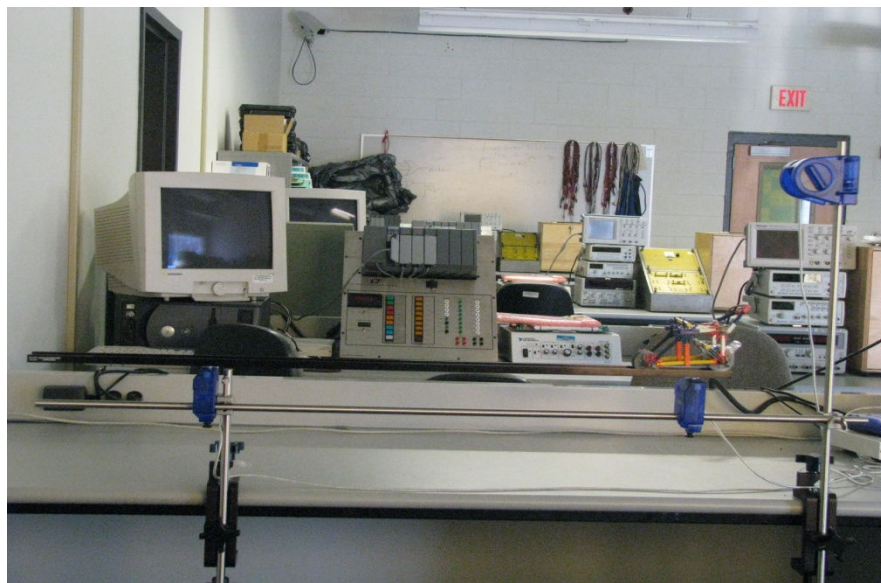Figure 2 Physical Model as a simply supported bridge beam

Figure 3 Physical Model as a single overhanging bridge beam

The data is being transmitted automatically to DataStudio software to generate real-time graph of the force versus position of load. Figure 4 shows the force versus the position of the truck for each support of the single overhanging bridge beam. This figure illustrates the influence of the movable load on the supports. The right support, represented by the orange color line in figure 4, will be fully responsible for resisting the weight of the truck when the location of the truck is directly over the force sensor. However, as the truck moves, the left support that is presented by the magenta color in figure 4 will start sharing

the responsibility of resisting the weight and eventually will be fully responsible for resisting the total weight when the truck reaches the location of the left force sensor.
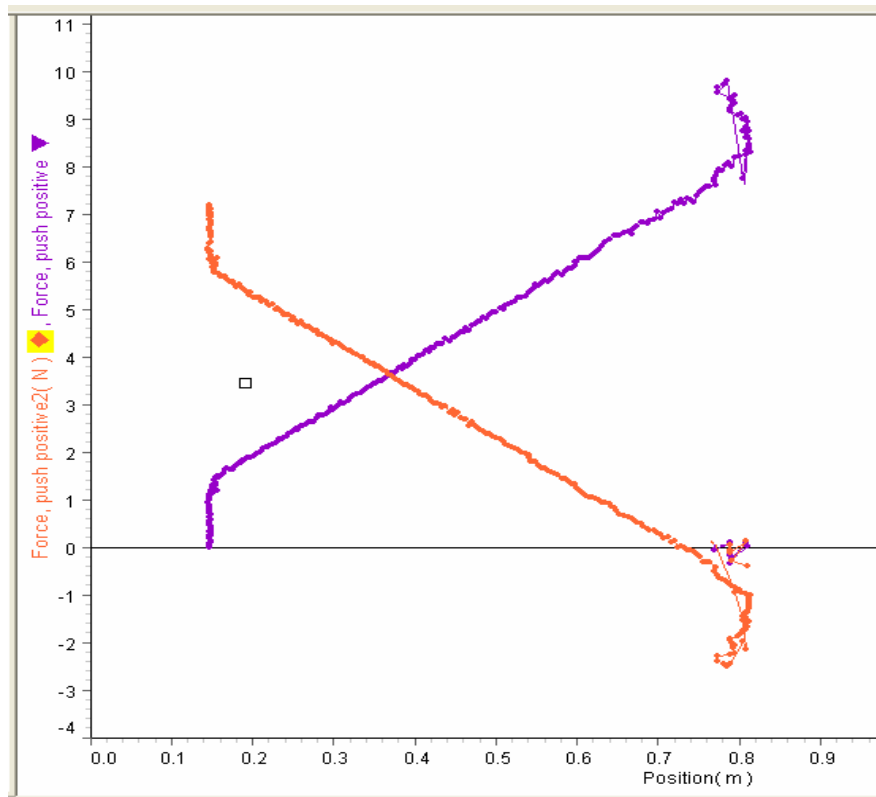

Figure 4 Force vs. Position of the truck for each support of the single overhanging bridge beam

The real time graphing of the reaction function is a great visualizing tool for the students to understand the concept of movable loads and their influence on the support reactions. The physical model did not have the capability to generate the influence lines for shear and moment at specific points of interest. This created the need for the development of a simulation model that addresses this point.

LabVIEW software is used in this project to develop the simulation model. To achieve this goal, several tasks are identified and developed: First task is to create all objects and controls in the Front Panel. In this project the following objects are used:
- Numeric Indicators (used to display numeric values)
- Waveform Graph
- Array control
- Numeric Control (used to enter numeric values)
- Cluster (data structure that groups data)
- Decoration controls (circle, triangle, arrows)
- Stop button control

Second task is to create new Programming functions in the Block Diagram. The following functions are used:

- Formula node
- For Loop
- While Loop
- Timer Control
- Build Array functions
- Add and Increment function

Final task is to create variables needed for the above programming functions to achieve the desire goal. The Block diagram is where all programming functions need to be connected by correctly wiring the functions before running the simulation. The most important function in this project is the Formula Node because all formulas needed are placed in it. Formulas to find A_y, B_y, V_c and M_c. The formulas for A_y and B_y represents the amount of load that is supported by each support as the object moves across the bridge. V_c and M_c represent the shear and moment at any point c on the beam. In our project point c represents the half way distance between the two supports.

The influence line equations for A_y, B_y, V_c and M_c using simply supported and single overhanging beams as well as the block diagrams and front panels for individual case are shown in Figures 5 through 10.

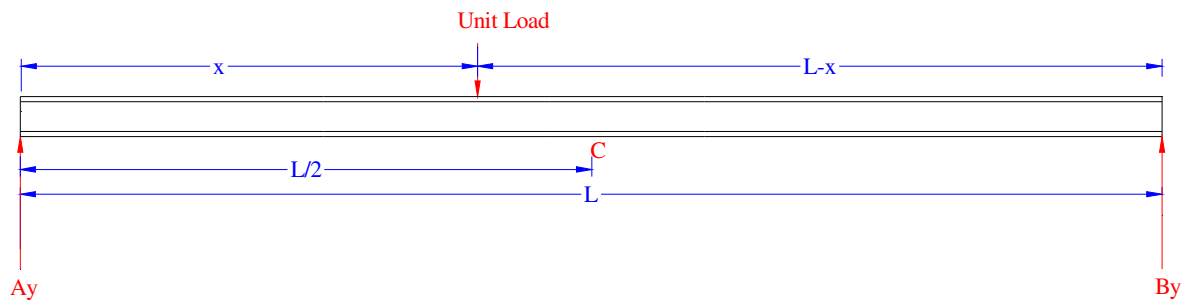*For simply supported beam:*

Figure 5 Simply supported bridge beam subjected to a unit movable load

Influence line equations for the support reactions,

$$A_y = \frac{(L - x)}{L} \text{ and } B_y = \frac{x}{L}$$

Influence line equations for the shear at point c,

$$V_c = \begin{cases} -\dfrac{x}{L} & for\ 0 \leq x \leq \dfrac{L}{2} \\[2ex] \dfrac{(L-x)}{L} & for\ \dfrac{L}{2} \leq x \leq L \end{cases}$$

Influence line equations for the moment at point c,

$$M_c = \begin{cases} \dfrac{x}{2} & for\ 0 \leq x \leq \dfrac{L}{2} \\[2ex] \dfrac{(L-x)}{2} & for\ \dfrac{L}{2} \leq x \leq L \end{cases}$$
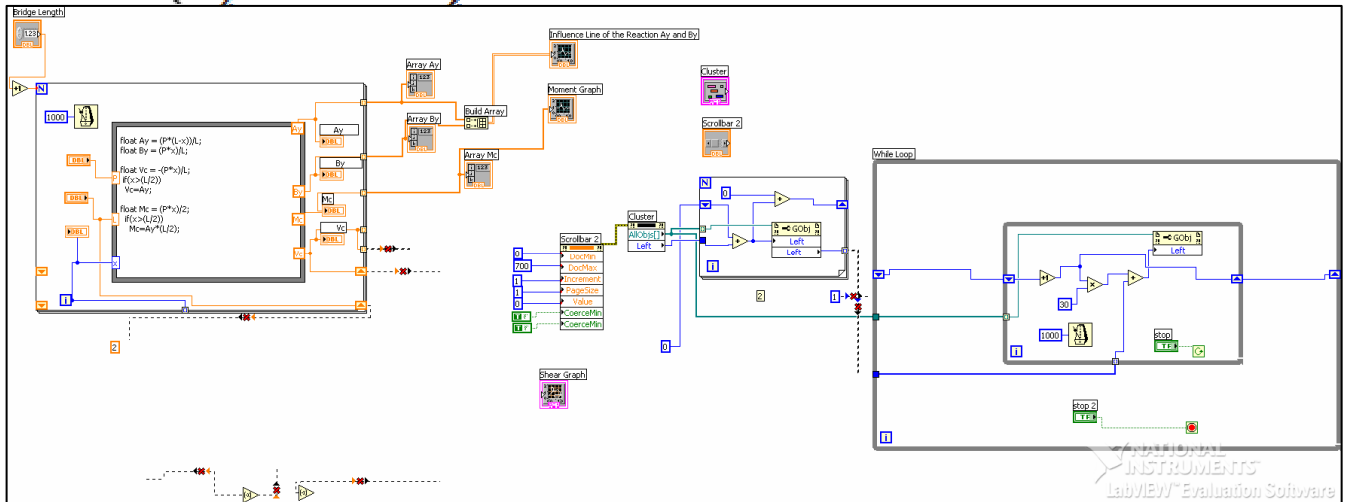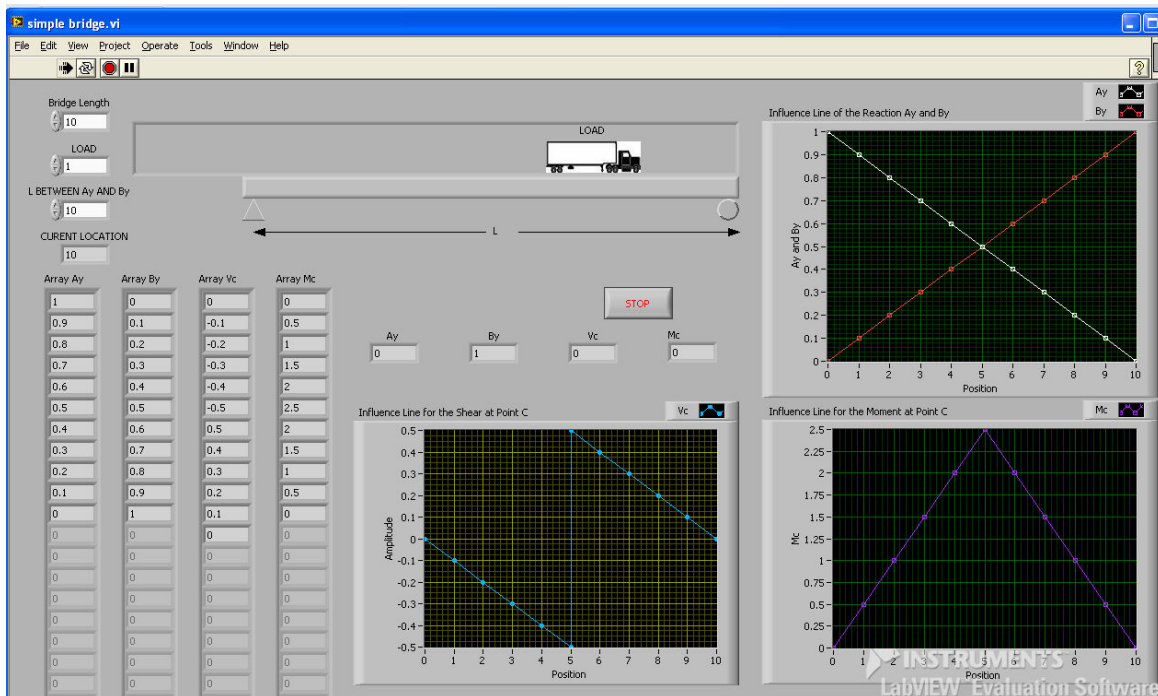

Figure 6 Block diagram for simply supported bridge beam

Figure 7 Front panel for simply supported bridge beam
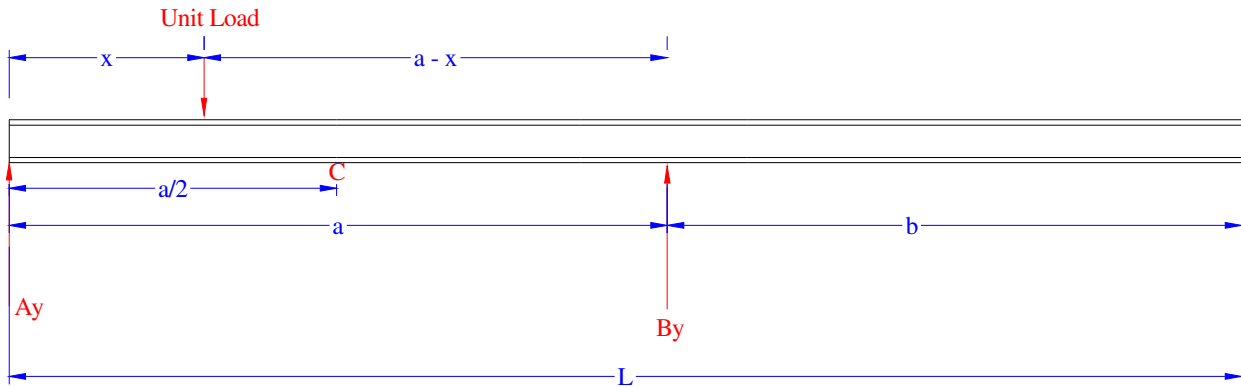
For single overhanging beam:

Figure 8 Single overhanging bridge beam subjected to a unit movable load

Influence line equations for the support reactions,

$$A_y = \frac{(a-x)}{a} \; and \; B_y = \frac{x}{a}$$

Influence line equations for the shear at point c,

$$V_c = \begin{cases} \dfrac{(a-x)}{a} - 1 & for \; 0 \le x \le \dfrac{a}{2} \\ \dfrac{(a-x)}{a} & for \; \dfrac{a}{2} \le x \le L \end{cases}$$

Influence line equations for the moment at point c,

$$M_c = \begin{cases} \dfrac{(a-x)}{2} - \left(\dfrac{a}{2} - x\right) & for \; 0 \le x \le \dfrac{a}{2} \\ \dfrac{(a-x)}{2} & for \; \dfrac{a}{2} \le x \le L \end{cases}$$
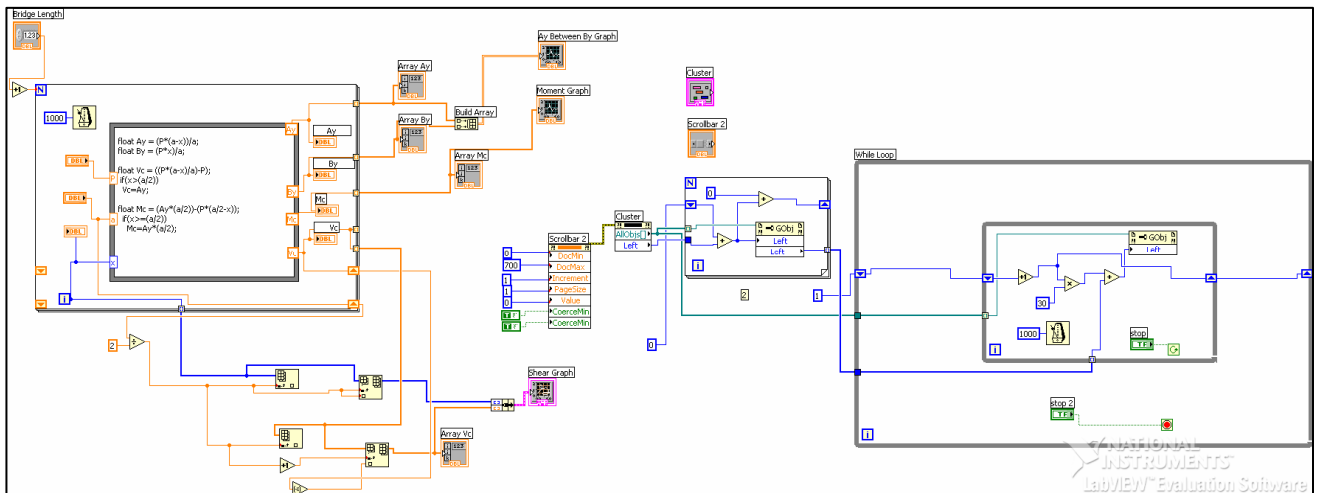
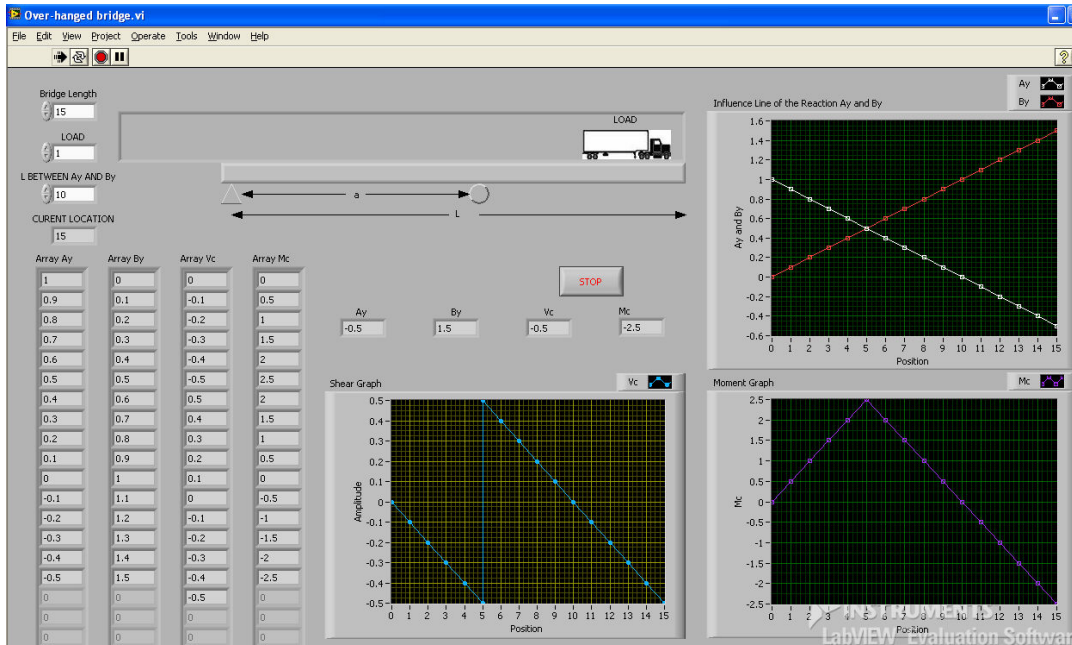Figure 9 Block diagram for single overhanging bridge beam

Figure 10 Front panel for single overhanging bridge beam

Summary

In the presented paper the development of a simulation model of the influence lines for abutment reactions, shear, and moment at specified points using LabVIEW were presented and discussed. By comparing the influence lines, Figure 11, for the reactions at supports A and B of the single overhanging beam generated using the physical model to the ones generated from the simulated model; one can see that these figures are identical in behavior and shape.
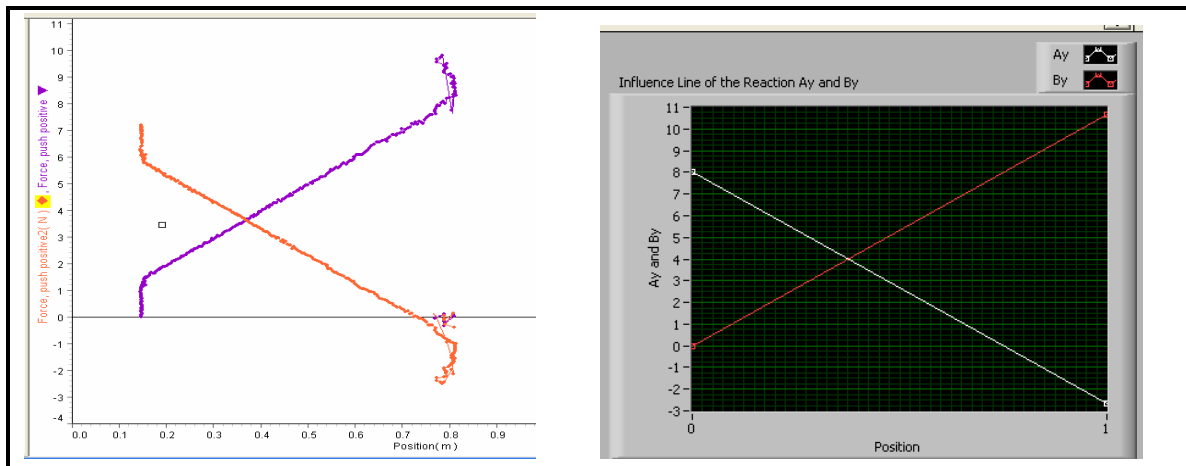
Figure 11 Influence lines for the reactions using physical model vs. the simulation model

The influence lines for the shear and moment at the half point between supports was checked versus hand calculation. The LabVIEW simulation model was developed by two undergraduate sophomore students. Both students were required to work as a team and develop the mathematical equations for the influence lines under the supervision of a civil engineering technology faculty. The development of the LabVIEW simulation model was also developed by the two students under the mentoring of an electronic engineering technology faculty. The entire duration of the project was three months as part of the MAGEC-STEM summer undergraduate research requirements.

The simulation model was used to illustrate the concept of the influence lines in structure analysis course and test results were compared with previous years where the simulation model was not used. It was observed that there was an improvement of 14% on the assessment evaluation of the outcome of the influence line subject.

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