

## Beam response analysis of moving vehicle with half car modeling

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**Abstract.** There were several tragedies concerning damages of bridge which seem to be sooner than the predicted period. One of hypothesis in this situation is an addition of vibration caused by long vehicle such as super long truck which has huge force transferred into the bridge and its long body causes more vibration due to phase difference of front and rear tire. The selected method which is used in this problem is using a simulation for modeling a bridge-vehicle system using half car vehicle model. The simulation is done using ANSYS Workbench 15.0 with some variation such as the thickness of beam and its supports. There are 3 kind of variation used in the thickness variety which are 2 m, 1 m, and 0.5 m. While in supports variation, we have fixed support, knife-edge support, and slider support. The results show that there is addition of vibration caused by long vehicle. It is proved by an oscillation which is showed in every response of beam's total deformation. Highest total deformation is achieved in slider support beam of 0.5 thicknesses, 1.08 mm in 1.12 second. First ripple seen in responses is at 0.84 second. Meanwhile, response of knife-edge and fixed support beam show a similarity. The ripple in this situation is caused by beat modulation from the front and rear tire.

### 1. Introduction

There are two crucial parts of a bridge, truss and beam. Beam is planar transverse vibrations of one-dimensional elastic continua [1]. In bridges structure, beam is a deck part which accept direct contact with force and vibration from vehicle above it. From elementary theory of elasticity, it is known that when the beam is deflected, certain hypothetical longitudinal lines or fibres are elongated, while others are compressed [2]. From the previous researches, it only used a static mass to see the beam responses. But in reality, vehicles are moving and it can have more or less responses than the static vehicle. Even though there is a suspension system in each vehicle, there are still some vibrations left which is continued into the bridge. This will be discussed in this research as a force that transfer from vehicle's weight or weight force. The differences of mass in order to build a force is directly influence beam responses while in this chapter, the selected vehicle is long truck with huge mass and force. It is a control variable. Variation of beam's thickness and support are done in total 9 models and simulation. Modeling is done by computational simulation based on Finite Element Method which can calculate beam's responses with an output of deformation in time domain. Moving vehicle is the main problem in this research. Beam responses of moving vehicle in bridge-vehicle system are going to be analysed in the further explanation considering each varieties of model.

In previous papers, discussion about beam's deformation is rarely done. Almost all research is talking about beam's natural frequency or modal analysis in bridge's system. So, in this research, I would like



to enhance more about beam's responses in different perspective such as deformation in total direction using analysis method in order to know better about beam's characteristics when there is addition vibration applied at top of the bridge.

## 2. Modeling Techniques

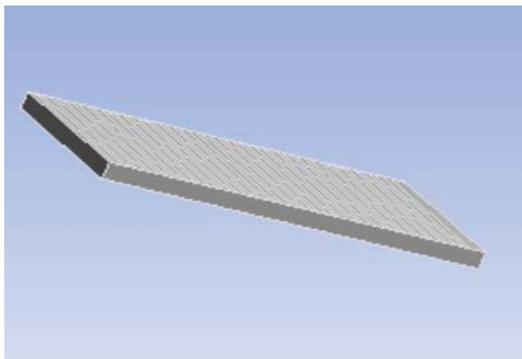
The general characteristics of the FE modeling techniques used in this research are discussed in this section. Specific information includes geometry of beam for each variation and force setting in simulation.

### A. General Specification

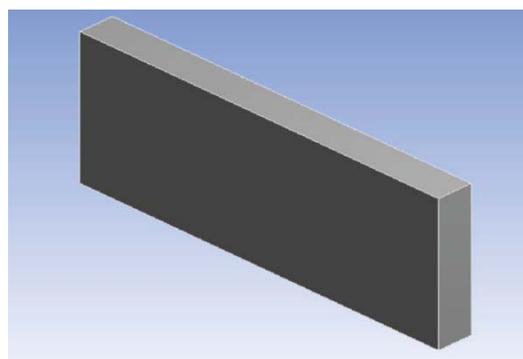
The focus of this paper is to discuss beam responses using simulation. Simulation of all models are done by refining 3D finite element modeling that has been performed using package ANSYS [3]. In this particular bridge, modeling was running by half car type as a vehicle because full car analysis can be more complicated and need more consideration from simulation step. Structural behavior is modeled by considering the structure as a whole, with actual boundary and loading conditions included in the finite element [3].

### B. Physical Model

Physical model from bridge's beam will be shown below.

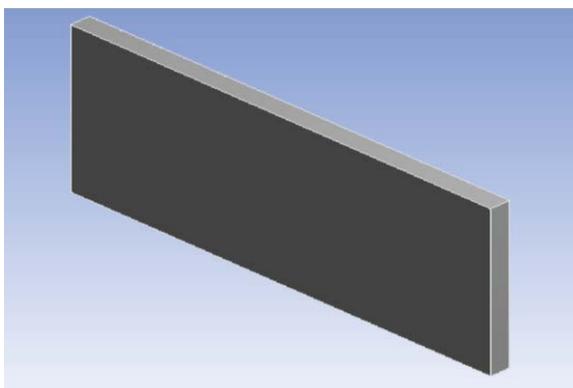


**Figure 1.** Beam modeling

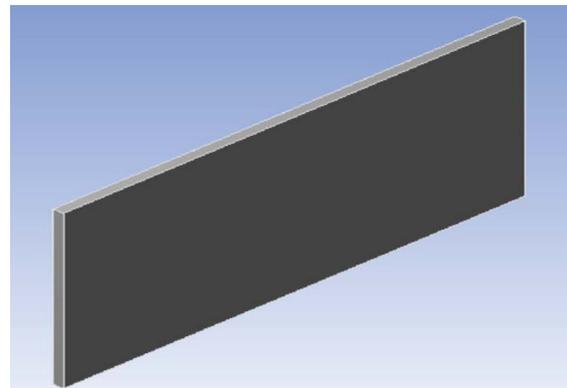


**Figure 2.** Two meters thickness of beam

The geometry of beam in this research is decided as 22 meters long and 10 meters' width. While thickness of beam will be the variation that is made in order to understand its influence to the response. There are three kinds of thickness which are used, 2 meters, 1 meter, and 0.5 meter.



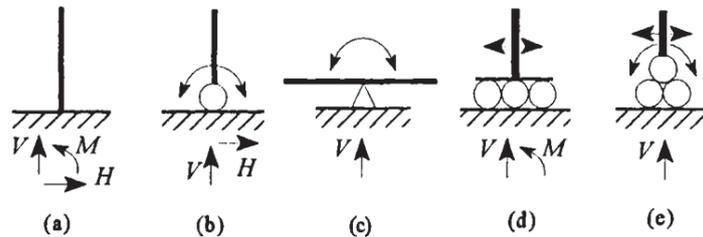
**Figure 3.** One meter thickness of beam



**Figure 4.** 0.5 meter thickness of beam

Another variation that will be discussed in this paper is beam support. Initially, there are five kinds of support in beam [4], but when we look up to the reality, there will be mostly three kinds of beam support that is used, fixed support, knife-edge support, and slider support. In this research, there three support

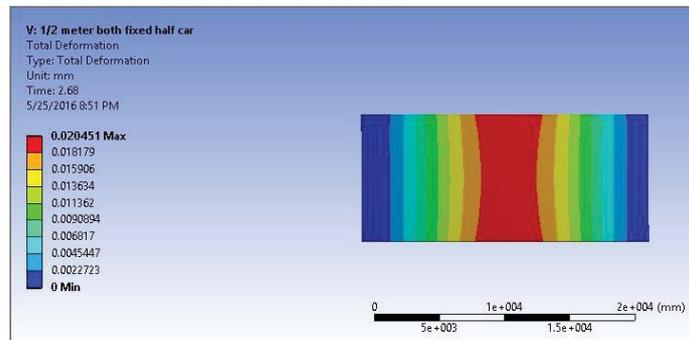
will not stand alone by itself but there will be a combination in one of the model, slider support. For the slider support beam, the slider support will not be set in both edge of beam, but only in one edge. That one is the end of the bridge, the edge when the vehicle is leaving the bridge.



**Figure 5.** (a) Simple-supported beam (b) pin support beam (c) knife-edge support beam (d) slider support beam (e) pinned slider support beam [4]

**3. Results and Discussion**

The result in this system analysis will be presented by both graph and contour. Deformation in contour result is shown by different color choices as we see below.

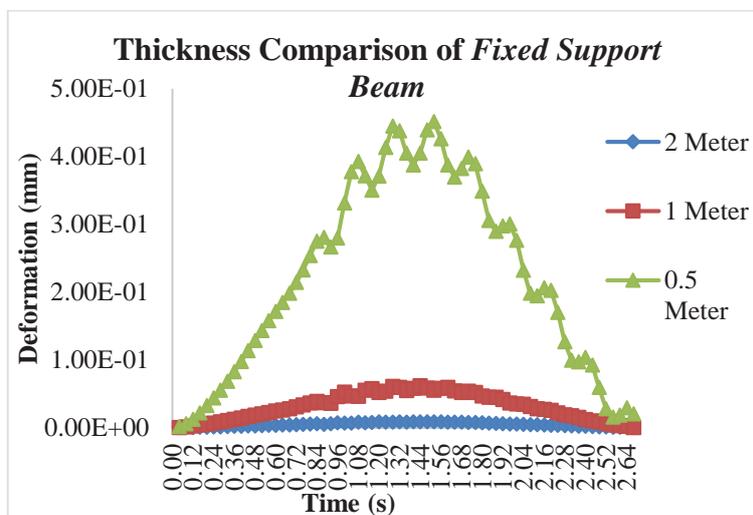


**Figure 6.** Deformation contour of beam

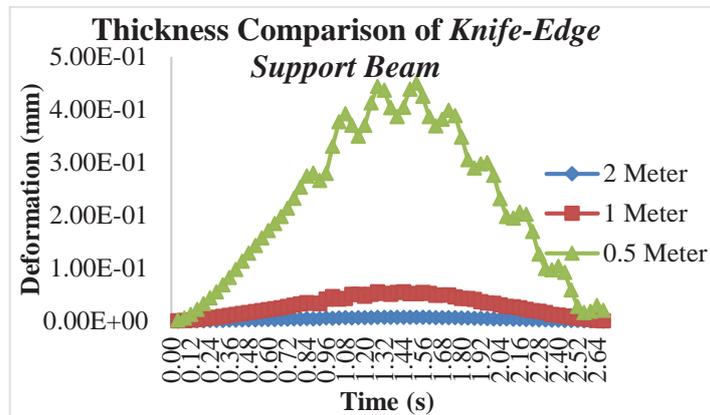
In order to see the differences from all the models, beam responses will be shown in one graph per variation. So, there are three graphs from thickness variation and another three graphs from support variation.

**A. Beam responses of thickness variation**

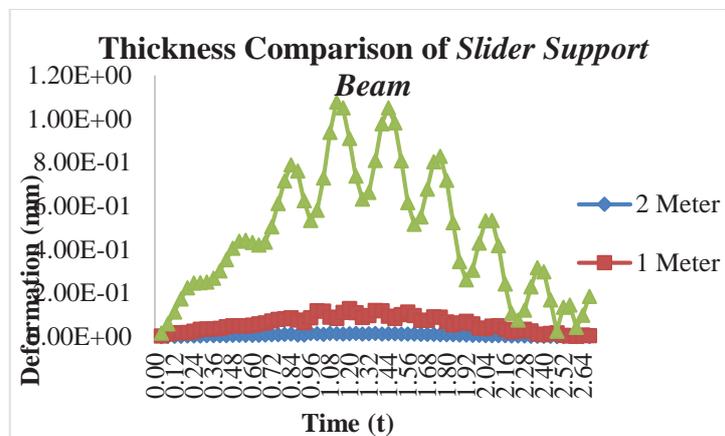
The differences of deformation from each support shown by all kinds of thickness will be shown in graphs below.



**Figure 7.** Fixed support beam responses of thickness variation



**Figure 8.** Knife-edge support beam responses of thickness variation

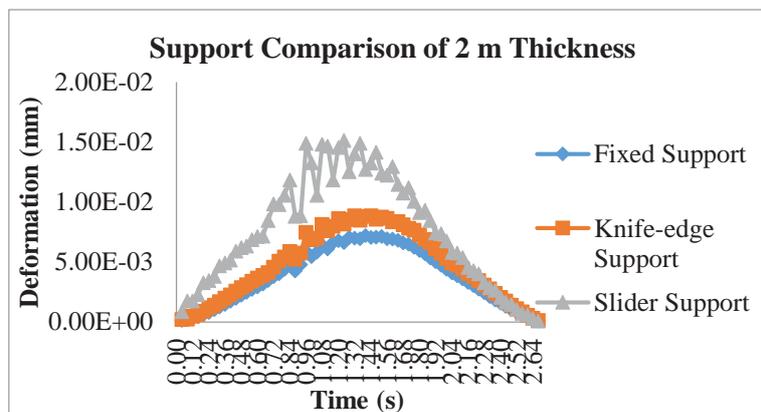


**Figure 9.** Slider support beam responses of thickness variation

There are significant difference in all three kinds of thickness in each support of beam. The similarity of all graph is shown in 0.5 thickness. It is the model that has the biggest deformation in all thickness variation. Nevertheless, there are different deformation too in 2 meters and 1 meter thickness, but the value is not that significant. There are correlation between thickness of beam and deformation. Increasing of beam thickness caused decreasing of beam deformation by the same condition and force.

**B. Beam responses of support variation**

The differences of deformation from each thickness shown by all kinds of support will be shown in graphs below.



**Figure 10.** Two meters thickness beam response of support variation

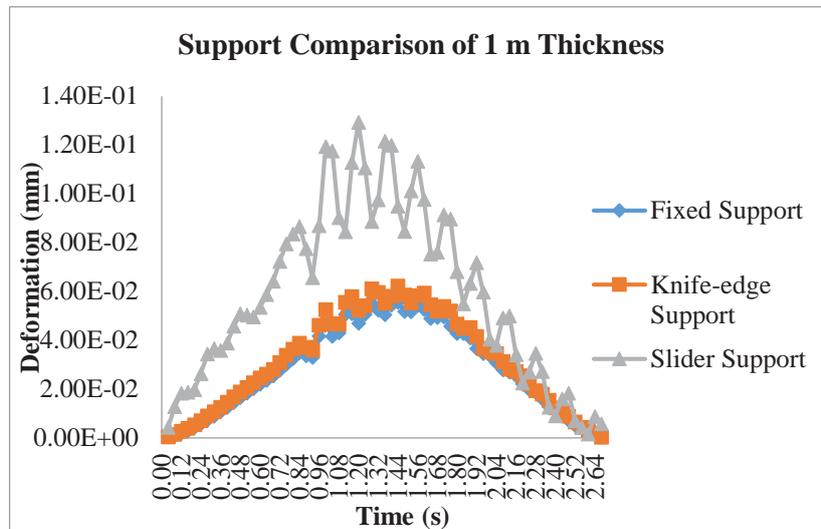


Figure 11. One meters thickness beam response of support variation

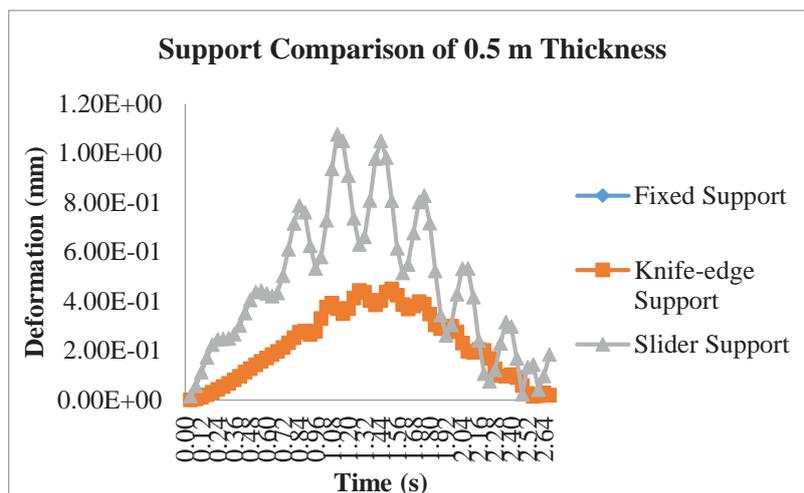
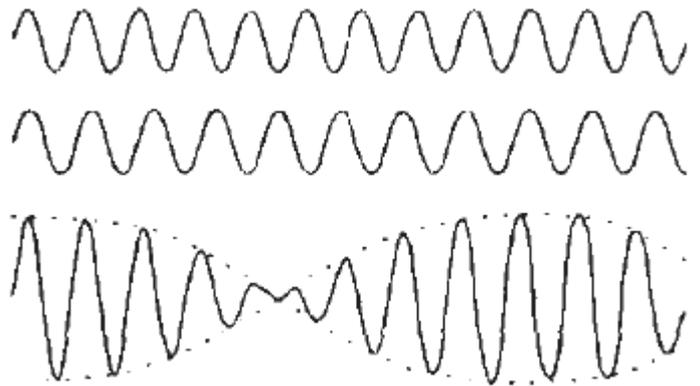


Figure 12. 0.5 meters thickness beam response of support variation

The similarity of responses is found in two kinds of support, fixed and knife-edge. These two beam deformation are almost having the same value in all kinds of thickness. Even in the 0.5-meter thickness beam response, knife-edge and fixed support have exactly the same deformation value so the graph seems to be overlapped. Meanwhile, maximum deformation is shown by slider support beam.

### C. Discussion

There is one specific characteristic of beam responses which are analyzed before, oscillation. Oscillation is another name for vibration [1]. This phenomenon has been proved the initial hypothesis about addition of vibration in bridge's beam caused by half car modeling (front and rear tire). Oscillation in this responses is caused by the effect of new waves from rear tire of vehicle which build a new exactly same as the wave from front tire, but has different phase or velocity. This is called beat modulation [4]. Beat modulation is changing first and second wave to a new wave, so it is adding new vibration to the beam.



**Figure 13.** Beat modulation [4]

We can conclude that there are several advantages after I run this research in simulation method. First, we know that there is addition vibration when a half car model going through a beam bridge. It's different with a quarter can responses that has no ripple in it. This phenomenon has added more vibration in beam and influence its total deformation. Second, there is a connection between deflection or deformation in bridges and thickness of beam. When the beam's thickness is increasing, response of beam, which is its total deformation decrease. And when beam's thickness is decreasing, its total deformation will increase. Also we get another conclusion according to the variety of beam's support. Different kind of support determines different responses of beam, in term of total deformation.

## References

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