

Analysis of Power Generating Speed Bumps Made of Concrete Foam Composite

B Syam^{1*}, M Muttaqin², D Hastrino³, A Sebayang², Basuki W S⁴, M Sabri¹, and S Abda⁵

¹Impact and Fracture Research Center, Dept. of Mechanical Engineering, Faculty of Engineering, University of Sumatera Utara (USU)

²Graduate Student, MechEngr Study Program, USU

³Undergraduate Student, Dept of MechEngr Study, USU

⁴Dept. of Chemistry, Faculty of Science, University of Sumatera Utara

⁵Graduate student, Dept. of Mech. Engr, Faculty of Engineering, University of Sumatera Utara

*bstsyam@gmail.com

Abstract. This paper discusses the analysis of speed bump made of concrete foam composite which is used to generate electrical power. Speed bumps are designed to decelerate the speed of vehicles before passing through toll gates, public areas, or any other safety purposes. In Indonesia a speed bump should be designed in the accordance with KM Menhub 3 year 1994. In this research, the speed bump was manufactured with dimensions and geometry comply to the regulation mentioned above. Concrete foam composite speed bumps were used due to its light weight and relatively strong to receive vertical forces from the tyres of vehicles passing over the bumps. The reinforcement materials are processed from empty fruit bunch of oil palm. The materials were subjected to various tests to obtain its physical and mechanical properties. To analyze the structure stability of the speed bumps some models were analyzed using a FEM-based numerical softwares. It was obtained that the speed bumps coupled with polymeric composite bar (3 inches in diameter) are significantly reduce the radial stresses. In addition, the speed bumps equipped with polymeric composite casing or steel casing are also suitable for use as part of system components in producing electrical energy.

1. Introduction

In search of energy harvesting originated from waste materials in oil palm industry, empty fruit bunches (EFB) were used to produce EFB concrete composite. As you are aware that that the EFBs were left behind after being stripped of their fruits used for oil production. The processed EFB fibers were used to strengthen concrete mixture. A new material produce from EFB fibers and concrete is called concrete foam composite (confoam). It is physically light in weight compared to conventional concrete mixtures.



Syam, et al [1-3] has used the so called confoam for several light structure products, such as tiles, parking bumper, and speed bumps [4].

In this paper, confoam is used as speed bumps for generating electrical power. As shown in Figure 1, The structure of the speed bumps is equipped with casing and attached on top of the apparatus top plate. With this connection, the speed bump is able to function well when they are subjected to both static (speed up to 10 km/hr) and impact load (speed more than 10 km/hr) resulted from vehicles passing on them.

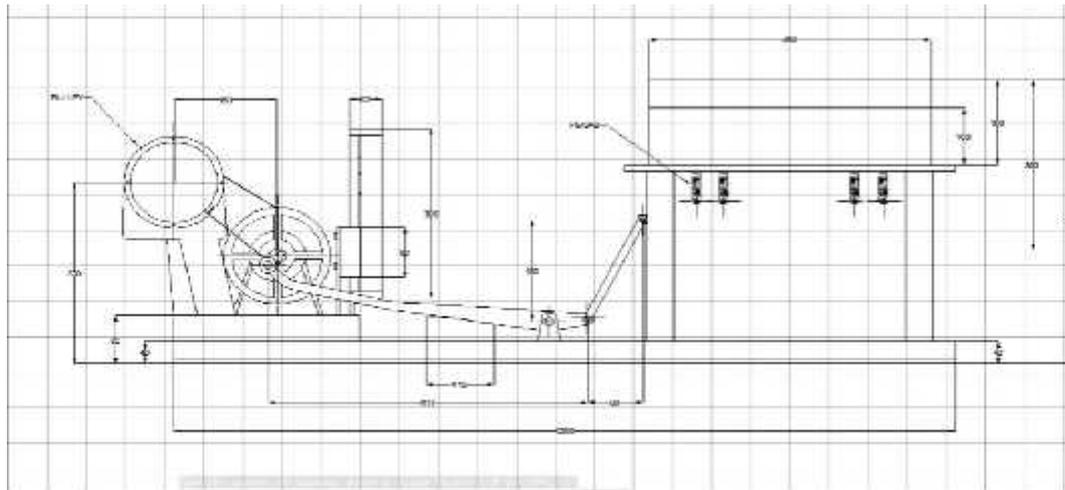


Figure 1. Energy harvesting (power generation) using speed bump

2. Materials and Method

2.1. Material

As shown in Figure 1, the speed bump is placed on a bed equipped with steel casing attached to the top plate of the power generation set (genset). The speed bump receives load from wheel cars passing through the street. To withstand both static and impact loads the speed bumps have to be designed and manufactured so that they meet engineering characteristics and other requirements. For this, we select a newly developed materials in our research center which are light in weight and strong enough to withstand both the static and impact loading (not reported in this paper).

There are several class of the confoam materials [3]. In this research, we choose type A5 in which its physical and mechanical properties of the material are shown in Table 1.

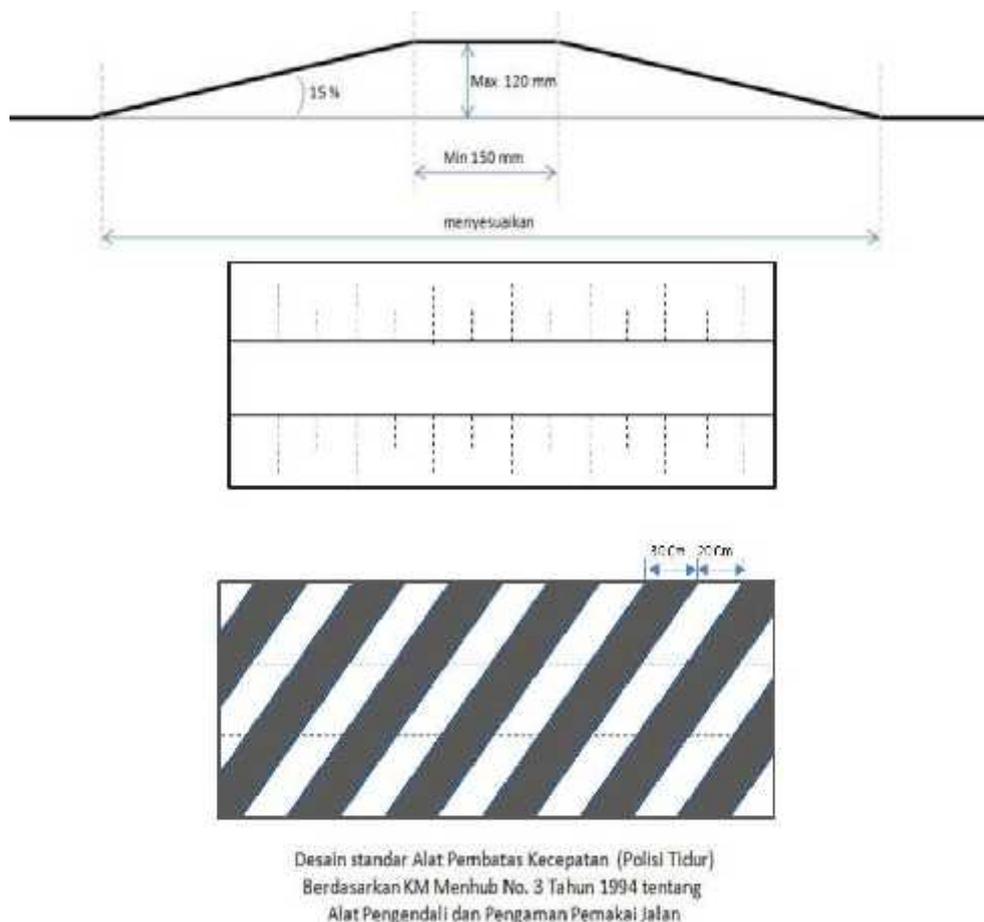
Table 1. Confoam mechanical properties (Laporan penelitian MP3EI)

| Type spesimen | S_{uc} (MPa) | S_{ut} , (MPa) | E (MPa) | |
|---------------|----------------|------------------|---------|------|
| A5 | 2.1 | 0.18 | 0.2 | 10.1 |

2.2. Geometry and Dimension of speed bump

The geometry of speed bumps used in this research has met the requirements stated in Kemenhub (Ministry of Transportation regulation), number 3, 1994, as shown in Figure 2. Some parts of the geometry of speed bumps has been revised to meet the structure integrity of speed bumps when they are subjected to vehicle loadings passing over, i.e. top surface configuration and speed bump base. In this paper, we propose the geometry and dimensions as shown in Figure 3 and 4. Main dimensions of the speed bumps are as follow: (1) length, $L=400\text{mm}$, (2) width, $w=200\text{mm}$, and (height, $t=50\text{mm}$).

As shown in Figures 3 and 4, there are three models proposed in this study. One is strengthened with a single solid polymeric composite bar with various diameters ($d=1$ inch, $d=2$ inches, and $d=3$ inches). The second model used two solid polymeric composite bars with various diameters ($d=1$ inch, $d=2$ inches, and $d=3$ inches). The third one (not shown) is the solid speed bump (without strengthened bar) enclosed with steel plate.

**Figure 2.** Kemenhub number 3 1994 (Transportation Ministry Regulation)

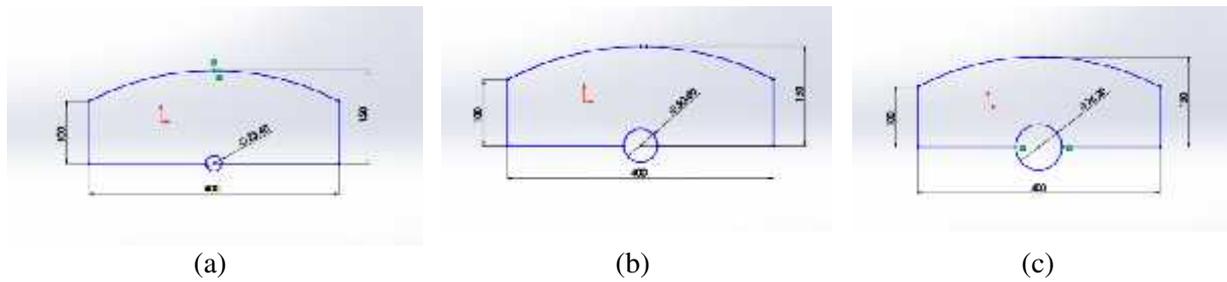


Figure 3. Geometry and dimension of speed bump with single bar (1st Model)
(a) one-inch bar, (b) two-inch bar, and (c) 3-inch bar

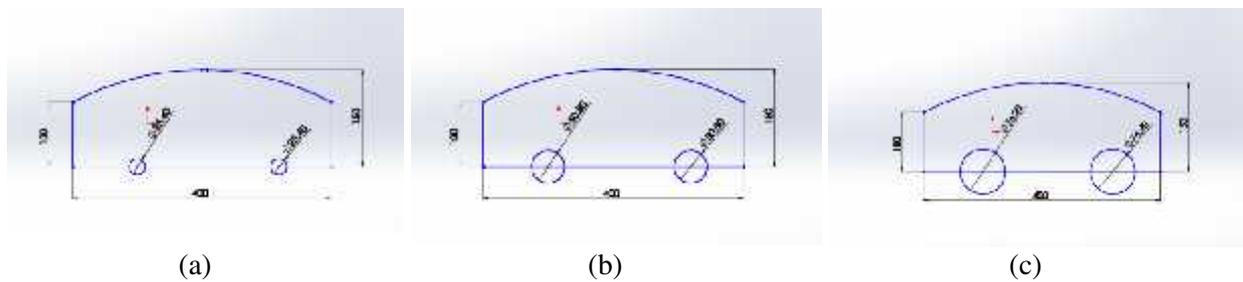


Figure 4. Geometry and dimension of speed bump with double bar (2nd Model)
(a) one-inch bar, (b) two-inch bar, and (c) 3-inch bar

3. Numerical Simulation

3.1. Load Model

In addition to the speed bumps with the geometry and dimensions of the finite element models shown in Figure 3 and 4, we also simulate solid speed bumps enclosed with steel casing (not shown). The latest model is also sought for its structure integrity in terms of stresses due to static loading. We use static load of 3,290 Newton per contact area of 2,000 mm². The load, applied on the crown of the speed bump (Figure 5), was obtained from one fourth of the total of vehicle weight permitted for class III road. Numerical calculation is focused on the stress distribution in x, y, and principle direction using a commercial FEM software, with 3-D elements. For steel case model we also calculate the von-Mises stress (σ_{von}). Let us observe the stress contour of the models one-by-one.

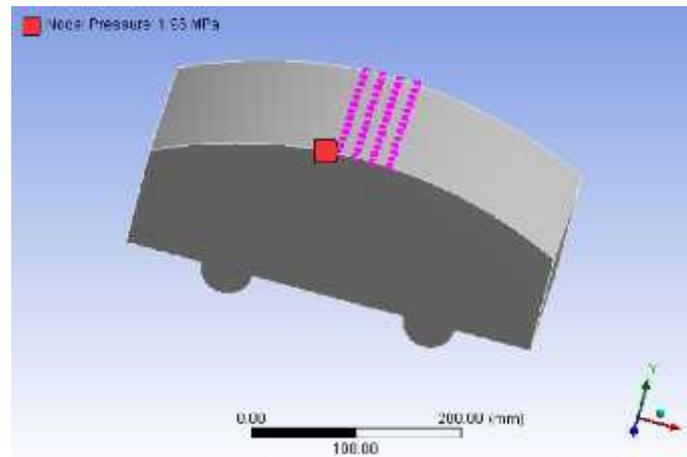


Figure 5. Static load mod

3.2. Stress contour

Figures 6-9 show the stress distributions on x, y, and principle direction on the speed bump models. All calculations are shown in Table 2. We obtained that using double polymeric bar at the bottom of speed bumps reduces the maximum stresses and definitely will also withstand the axial force from vehicle tyres. However, by comparing the static strength of speed bump material with stresses, and in accordance with the static failure theory, speed bumps will fail under static loading, except for bar diameter of three inches. We observed that the bigger size of strengthened polymeric bar significantly decreased the maximum stress from 0.6 MPa to 0.0001 MPa. The result dictates that we may use this design for power generation speed bump.

It is also interesting to observe the response of speed bumps when they are enclosed with steel or polymeric composite bars (reported in other papers). Figure 7 shows response of steel case due to static loading. We observe that the von-Mises stress is lower enough than that of static strength of speed bump material. The results conclude that case-type speed bumps are susceptible to withstand the loading. Thus, they will be potential to be used for speed bump power generation.

Table 2. Max stress in x, y, and principle direction

| | x | y | 1 |
|-----------------------------|-------|-------|-------|
| 1 inch single polymeric bar | 0.389 | 0.530 | 0.587 |
| 1 inch double polymeric bar | 0.531 | 0.199 | 0.483 |
| | x | y | 1 |
| 2 inch single polymeric bar | 0.177 | 0.231 | 0.656 |
| 2 inch double polymeric bar | -0.22 | 0.225 | 0.356 |

Table 2. Cont

| | x | y | l |
|-----------------------------|-------|--------|---------|
| 3 inch single polymeric bar | 0.177 | 0.355 | 0.628 |
| 3 inch double polymeric bar | 0.266 | 0.0001 | 0.00019 |

Table 3. Max stress in x and y, and von Mises stress in steel casing

| | x | y | von |
|--------------|--------|--------|--------|
| Steel casing | 34.979 | 56.870 | 69.967 |

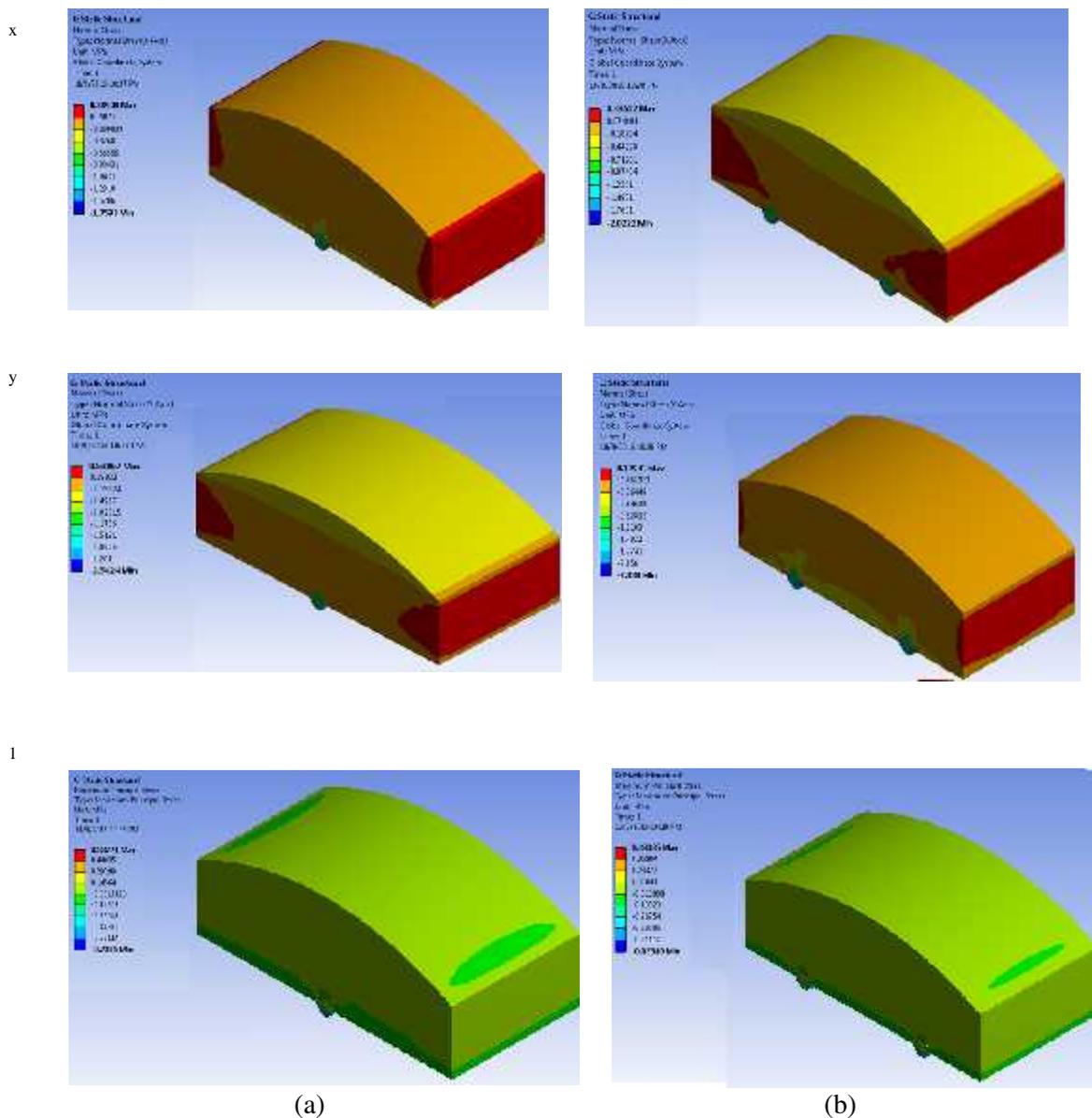
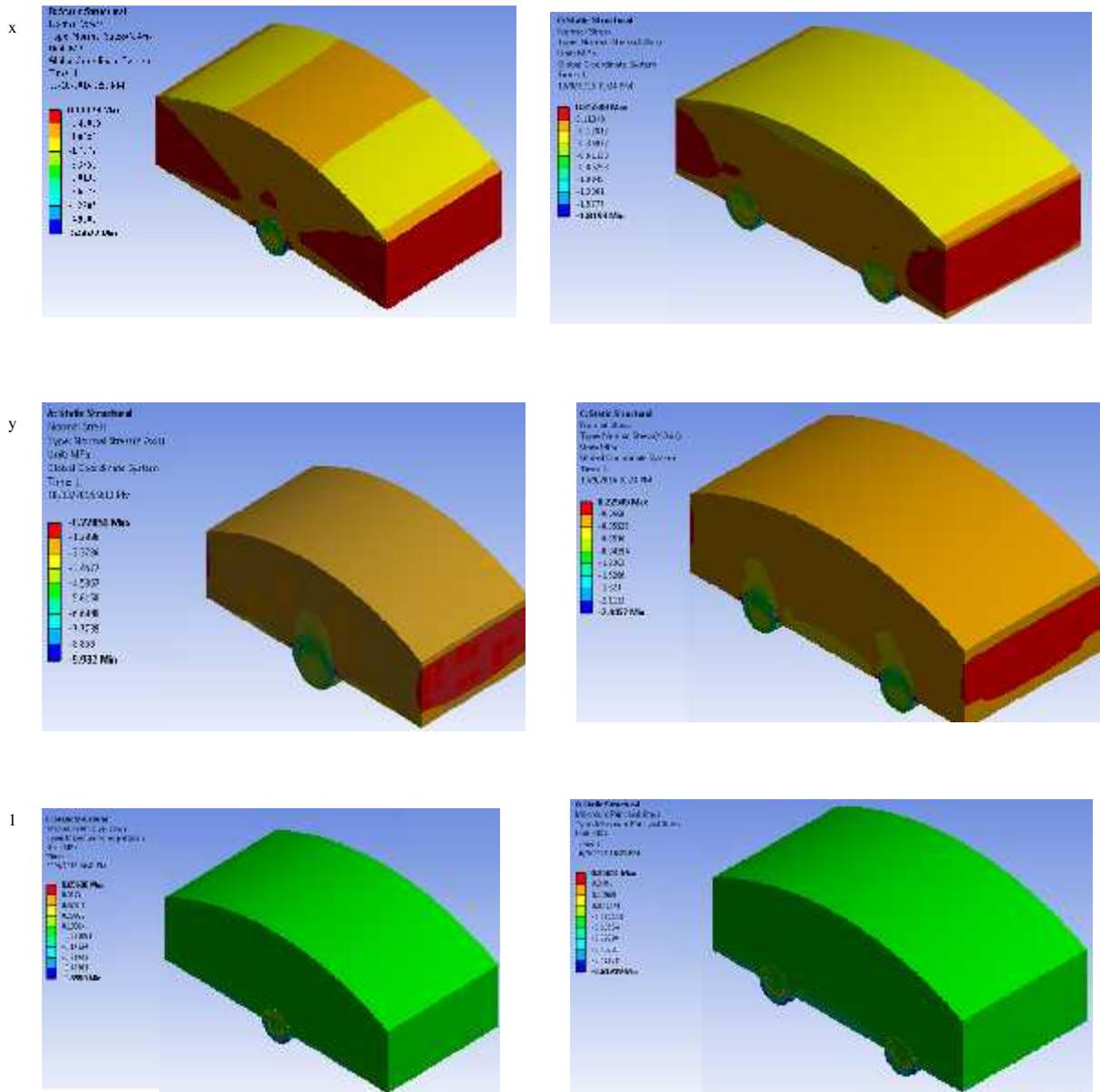


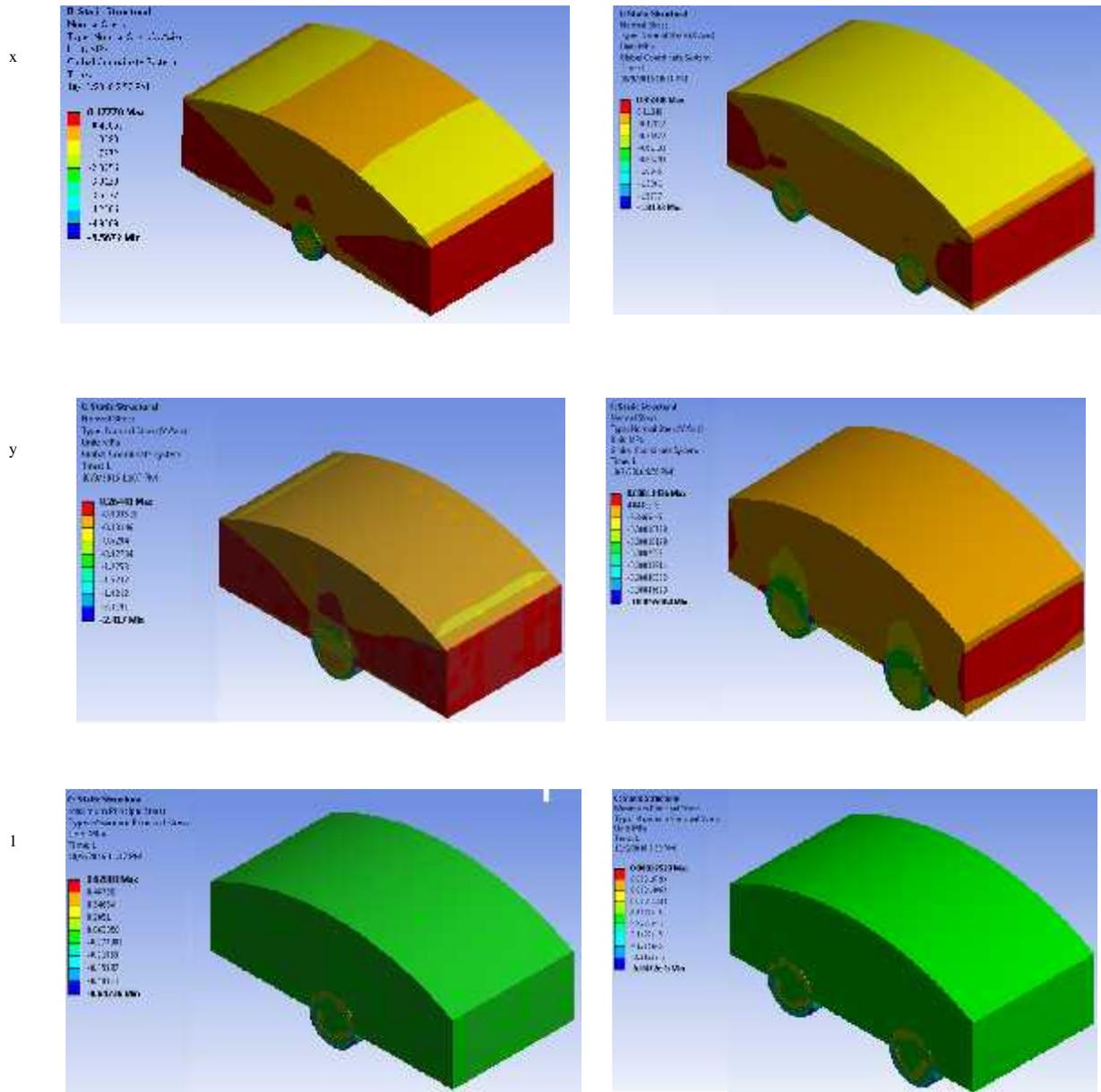
Figure 6. Contour stress distribution
 (a) a single bar d=1 inch (b) a double bar d=1 inch



(a)

(b)

Figure 7. Contour stress distribution
 (a) a single bar $d=2$ inches (b) a double bar $d=2$ inches



(a)

(b)

Figure 8. Contour stress distribution
 (a) a single bar $d=3$ inches (b) a double bar $d=3$ inches

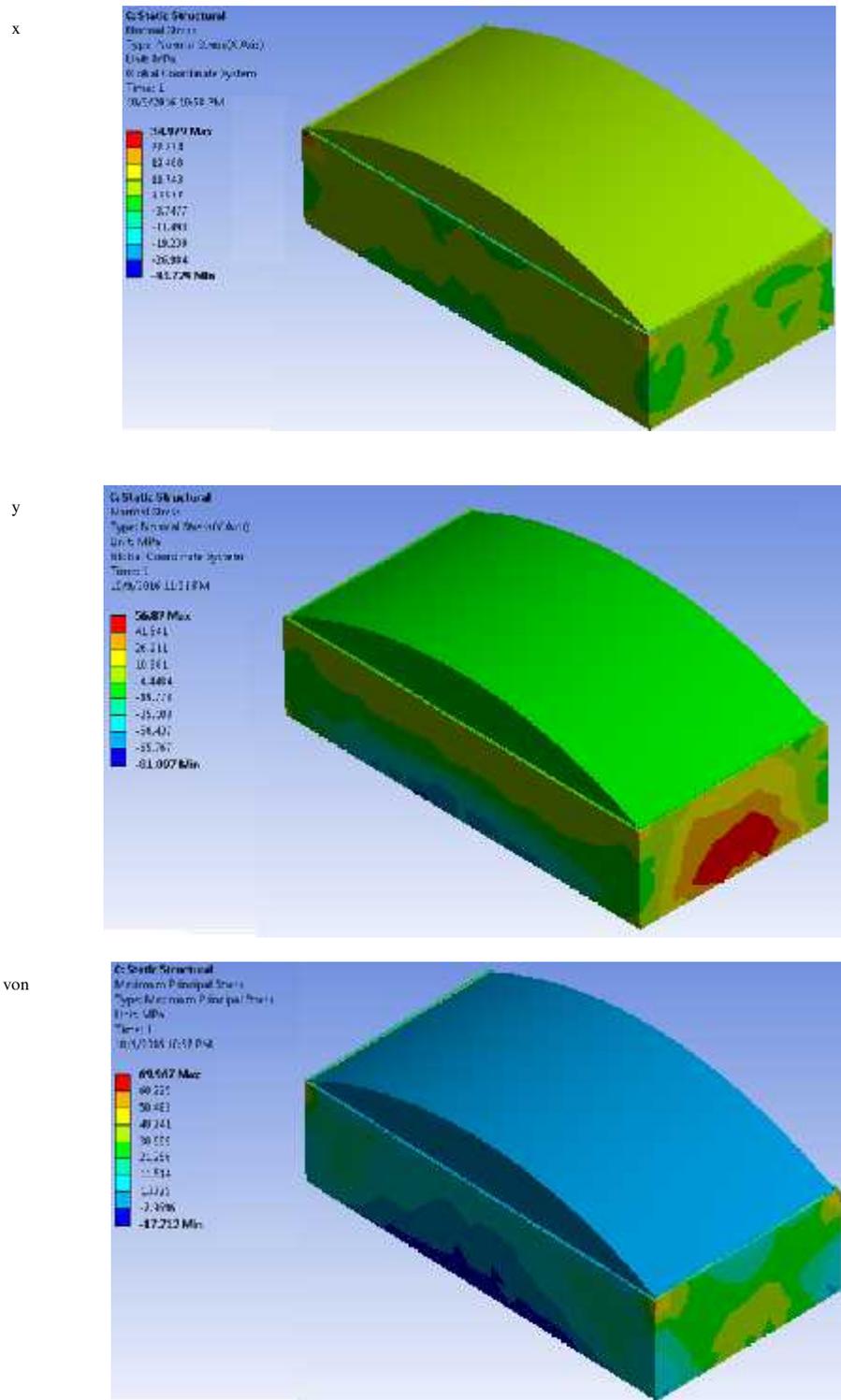


Figure 9. Contour stress distribution Speed bump with steel casing

4. Conclusions

This paper discussed the analysis of speed bump made of concrete foam composite which is used to generate electrical power. Three models were proposed, they are: (a) single polymeric bar speed bump with diameter ranges from 1 inch, 2 inches, and three inches, (b) double polymeric bars speed bump with diameter ranges from 1 inch, 2 inches, and three inches, and (c) solid bar speed bump enclosed with steel casing. To observe the structure integrity of the speed bumps the models were analyzed using a FEM-based numerical softwares. It was obtained that solid polymeric bar reduces the stresses and may absorb axial loading resulted from vehicle tyres; however, it fails to sustain radial loading, except for the diameter of 3 inches or bigger. From the FEM analysis we also found that speed bumps enclosed with steel case are also suitable for use as part of a system in producing electrical energy.

Acknowledgements

The authors acknowledge the research fund obtained from Kemenristekdikti under PUPT scheme 2016.

References

- [1] Syam, Bustami, B. Wirjosentono, dan S. Rizal, "Pengembangan Bahan Komposit Busa Polimer (Polymeric Foam Composite) Diperkuat Serat Tandan Kosong Kelapa Sawit (TKKS) untuk Pembuatan Berbagai Produk Industri Transportasi dan Olah Raga", Laporan Akhir PENPRINAS MP3EI, DIKTI, 2013.
- [2] Ade Irwan, Bustami Syam, dan Basuki W.S, Analisa Respon Mekanik Genteng dari Bahan Confoam Diperkuat Serat TKKS Akibat Beban Impak Hujan Es, Prosiding Seminar DIES USU 2016
- [3] Dino Hastrino, Imalsyah Pasi, Maraghi Muttaqin, Bustami Syam, Basuki WS, M. Sabri, dan S. Abda, Analisa Struktur Speed Bump Paduan Bahan Concrete Foam dan Polymeric Foam dengan Variasi Rongga Menggunakan Software Ansys 14.5, Prosiding Seminar DIES USU 2016
- [4] http://id.wikipedia.org/wiki/Polisi_tidur