Structural integrity of power generating speed bumps made of concrete foam composite

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Abstract. In this paper concrete foam composite speed bumps were designed to generate electrical power by utilizing the movements of commuting vehicles on highways, streets, parking gates, and drive-thru station of fast food restaurants. The speed bumps were subjected to loadings generated by vehicles pass over the power generating mechanical system. In this paper, we mainly focus our discussion on the structural integrity of the speed bumps and discuss the electrical power generating speed bumps in another paper. One aspect of structural integrity is its ability to support designed loads without breaking and includes the study of past structural failures in order to prevent failures in future designs. The concrete foam composites were used for the speed bumps; the reinforcement materials are selected from empty fruit bunch of oil palm. In this study, the speed bump materials and structure were subjected to various tests to obtain its physical and mechanical properties. To analyze the structure stability of the speed bumps some models were produced and tested in our speed bump test station. We also conduct a FEM-based computer simulation to analyze stress responses of the speed bump structures. It was found that speed bump type 1 significantly reduced the radial voltage. In addition, the speed bump is equipped with a steel casing is also suitable for use as a component component in generating electrical energy.

1. Introduction

Oil palm empty fruit bunches (EFB) is the waste produced by palm oil processing plant. Palm oil production in Indonesia reaches up to six million tons per year, as a matter of fact it also produces solid waste up to about 2.5 million tons per year [1]. In our laboratory the waste has been intensively used for several products, such as for several light structure products: tiles, parking bumper, and speed bumps [2-4].

In search of energy harvesting originated from waste materials in oil palm industry, empty fruit bunches (EFB) were used to produce EFB concrete composite to form a speed bump. As shown in Fig. 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 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.

In this paper, the structural integrity of the speed bump is checked using static load, the net weight of vehicle. The analysis was carried out using ANSYS 17.0. In addition, the speed bumps are also subjected to loadings generated by vehicles pass over the power generating mechanical system.
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 (figure 2). 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.

There are several classes of the confoam materials. In this research we choose type A5 [6] in which its physical and mechanical properties of the material are shown in table 1.

![Figure 1. Energy harvesting (power generation) using speed bump](image1)

![Figure 2. Speed bump power generation station](image2)

**Table 1.** Confoam mechanical properties

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

2.2. Geometry and Dimension
Geometry and dimensions of the speed bumps is shown in figure 2, respectively.
3. Numerical Simulation

3.1. Geometry and Load Model
The geometry and dimensions of the finite element models are shown in Figure 3. For simulation, one model is fixed on the bed plate and the second model is enclosed with steel casing (not shown). The latest model is actually the one that meets speed bump requirement in strength. We use static load of 3.29 tonf calculated from one fourth of vehicle weight permitted for class III road. We use ANSYS 17.0 to calculate the stress distribution in x, y, principle direction using 3-D elements. For steel case model we also calculate the von-Mises stress.

3.2. Stress Contour
Figure 4 shows the stress distributions on x, y, and principle direction on the speed bump models. All calculations are presented in Table 2. It can be shown that the normal stress $\sigma_x$ is obtained that However, by comparing the static strength of speed bump material with stresses, and in accordance with failure theory the speed bumps will fail under static loading, except for bar diameter of three inches. We observed that it decreased the maximum stress significantly 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 paper) and shown in Table 3.

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

| Calibration | Speed bump concrete foam (without steel plate) | Speed bump using steel plate |
|-------------|------------------------------------------------|-----------------------------|
| $\sigma_x$  | 0.17152                                        | 25,514                      |
| $\sigma_y$  | 0.213                                          | 45,889                      |
| $\sigma_1$  | 2.2312                                         | 56,254                      |
Figure 4. Contour stress distribution speed bump  
(a) without steel plate  
(b) Using Steel Plate
Table 3. Photographs of the tested materials

| Type | Photo | Static Structural | Crack or not |
|------|-------|-------------------|--------------|
| A1   | ![Photo A1](image) | ![Static Structural A1](image) | Crack        |
| A2   | ![Photo A2](image) | ![Static Structural A2](image) | Not cracked  |
| B1   | ![Photo B1](image) | ![Static Structural B1](image) | Not Cracked  |
| B2   | ![Photo B2](image) | ![Static Structural B2](image) | Not Cracked  |
| C1   | ![Photo C1](image) | ![Static Structural C1](image) | Crack        |
| C2   | ![Photo C2](image) | ![Static Structural C2](image) | Crack        |

4. Conclusions
This paper discussed the analysis of speed bump made of concrete foam composite which is used to generate electrical power. Two models were proposed, they are: (a) speed bump without steel plate, (b) speed bump using 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 speed bump without steel plate reduces the stresses and may absorb axial loading resulted from vehicle tyres; however, it fails to sustain radial loading, except for the using steel plate. From the FEM analysis we also found that speed bumps enclosed with steel case (or polymeric case) are also suitable for use as part of a system in producing electrical energy.

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