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Developing a Prototype of Non-Newtonian Fluid Speed Hump

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Abstract

The outrageous increase in population and urbanization have led to drastic increment in volume of transportation on the roads. High volume of different transportation on the road triggers traffic related problems. The objective of the study is to develop non-Newtonian fluid speed hump as traffic calming solution and improve road user's safety. Development of non-Newtonian fluid speed hump evolve a methodology of material selection, design determination and prototype development. The performance of the prototype is tested with speed reduction test and noise pollution test. The outcome of the study found that the non-Newtonian fluid placed on the strips at speed hump controls the speed of vehicle due to the shear-thickening properties of non-Newtonian fluid. It can be verified by their speed reduction test of 65.15% compared to 52.60% of conventional speed hump. Also, the noise produced from non-Newtonian fluid speed hump slightly lower than the conventional speed hump. Summing up, the non-Newtonian fluid speed hump is a reliable replacement of the conventional speed hump because of low material and installation cost, more reduction in the vehicles speed and less noise produced. It is proven that the non-Newtonian fluid speed hump can be benefited in improving traffic related problems.

Keywords: Speed Hump, Non-Newtonian Fluid, Traffic Problems, Traffic Calming Measures, Vehicle Speed.

Introduction

Development and urbanization in Malaysia are growing vastly in line with developed countries such as Singapore and Japan. The development of country also resulted to higher volume of people that increase the volume of road movement (Aziz & Mohamad, 2013; Norhisham et al., 2021). The road movement comes from motorized vehicles, non-motorized vehicles, bicycles, and pedestrians. All these transportations may lead to traffic congestion

problems especially in urban areas. Therefore, the traffic calming measures can help reducing the traffic related problems (Rosli & Hamsa, 2012; Zalewski & Kempa, 2019).

There are several types of traffic calming measure which aimed to lessen the speed of vehicles such as bumps, cushions, tables, chicanes, humps, road narrowing, and roundabouts (Abdulmawjoud et al., 2021; Patel & Gundaliya, 2017). Traffic calming is a set of engineering measures that involves physical alterations of the road to reduce the traffic volume, vehicle speed and eventually reduce accidents on traffic road. Park and Bae (2020) highlighted that the severity of pedestrian injuries is directly proportional to the vehicle speed. Implementation of traffic calming measures is highly suggested as it can increase the road user's safety.

Speed humps are the most practical traffic calming measures as they are easy to install and lower costing than traffic lights, speed cameras and chicanes (Pérez-Sansalvador et al., 2020). A raised pavements spanning across a road that forced drivers to lower their vehicle's speed to avoid unnecessary bumping is known as speed hump. Many researchers have verified that usage of speed hump reduced up to 20% of vehicle's speed (Kiran et al., 2020). Also speed hump is a long-term safety solution because it reminds the motorized vehicles physically to stay caution when pass through it especially in high pedestrian area.

Conventional speed hump commonly made up from concrete or asphalt spanning on the road (Zalewski & Kempa, 2019). But poor design parameter pair with imperfect implementation of conventional speed hump has caused wear and tear of brakes and tires and internal component damage of vehicle (Ullah et al., 2016). Different composition of speed hump resulted in different performance on the level of vehicular speed reduction. Chavhan et al (2019) found that non-Newtonian fluid speed breaker is a cost-effective speed hump and does not damage vehicle's components rather than the conventional speed hump.

The objective of the study is to develop a prototype of non-Newtonian fluid speed hump as an alternative of conventional speed hump. The performance of the built prototype is then tested with speed reduction test and noise pollution test. The outcome of the study will verify the effectiveness of non-Newtonian speed hump in reducing traffic congestion and improve the safety of road users.

Methodology

Overview methodology of the development of non-Newtonian fluid speed hump follow the objective of the study. The methods comprised of the prototype of non-Newtonian fluid speed hump and performance of non-Newtonian fluid speed hump.

Prototype of Non-Newtonian Fluid Speed Hump

To develop a prototype of non-Newtonian fluid speed hump, the steps considered are material selection and design determination. The selected material and component for the prototype are corn starch, polyethylene glycol, delivery hose, synthetic rubber sheet. Each of the component and material has its own function in building the prototype of non-Newtonian fluid speed hump.

Design of the prototype is determined based on the function of the material and component. Mixture of corn starch powder and water make the fluid hard when sudden external force applied. But, when the force reduces, the elements in the solution separated from each other and return to its normal fluid state (Soundararajan et al., 2013). While polyethylene glycol is used in fluid speed hump which preserve the material that have been retrieved from underwater. A study by Babu et al (2021) also used polyethylene glycol in the non-Newtonian fluid speed breaker and this showed that the material is commonly used in speed breaker or speed hump. Neoprene synthetic rubber sheet is lined inside the delivery hose to protect the delivery hose from heat and gas barrier (Mandlekar et al., 2021). The delivery hose will be filled with non-Newtonian fluid speed hump.

Performance of Non-Newtonian Fluid Speed Hump

The performance of the prototype is validated using speed reduction test and noise pollution test. Speed reduction test closely related to the usage of speed hump as vehicle must slow down when approaching it. Also, the speed profiles and the acceleration or deceleration data from the test can be used to determine the spacing of several temporary speed humps and speed tables (Hallmark et al., 2002; Kiran et al., 2020). The procedure to check the speed reduction using the prototype of non-Newtonian fluid speed hump is by placing it on the road and let vehicle with the same load hit on it. The speed of the vehicle is taken using speedometer application. Results on vehicle's speed when pass through the non-Newtonian is compared with the conventional speed hump with same load of vehicle.

High vehicle speed increases the noise pollution coming from the tire-street interactions. The speed hump reduces the vehicle speed because the driver is avoiding any discomfort passing through it. The noise pollution study is performed to evaluate the noise level due to speed humps. Many researchers applied noise pollution study to check the performance of speed hump, including Behzad et al (2007); Džambas et al (2021); Wewalwala and Lanka (2011). The step of noise pollution test on non-Newtonian fluid speed hump is a vehicle hit the speed hump with different speeds of 10, 20, 30, 40, and 50 km/h. The noise level of each speed on the speed hump is tracked using noise level meter application. The tracker is placed 1 meter apart from driving lane, away from obstacles, and 1.5 meter above the road level. The noise pollution of the conventional speed hump and steady state also being tested to differentiate with the non-Newtonian fluid speed hump.

Result and Discussion

The results of the prototype of non-Newtonian fluid speed hump and its performance are presented in this section. Furthermore, the results will be discussed thoroughly to draw a solid conclusion on the prototype of non-Newtonian fluid speed hump.

Prototype of Non-Newtonian Fluid Speed Hump

The prototype of non-Newtonian fluid speed hump is developed using the material and design determination discussed in methodology. Firstly, the non-Newtonian fluid is formed from the mixture of corn starch, water, and polyethylene glycol. Before mixing three of the components, corn start powder is microwave up to 100°C to prevent biological growth and the water is heated up to the same temperature of 100°C to avoid any contamination in water. As those three materials are combined, non-Newtonian fluid is formed and filled into the delivery hose. The delivery hose filled with non-Newtonian fluid is sealed with silicone

sealant. Hence, a prototype of non-Newtonian fluid speed hump is ready to be used by vehicles for performance check.

Performance of Non-Newtonian Fluid Speed Hump

The average vehicle speed for non-Newtonian fluid speed hump compared to conventional speed hump is illustrated in Figure 1. The non-Newtonian fluid speed hump showed lower average speed than conventional speed hump. Hence, the non-Newtonian fluid speed hump reduced the vehicle speed better with percentage of speed reduction at 65.15%. While conventional speed hump recorded percentage of speed reduction at 52.60%. It is also proven than the non-Newtonian fluid speed hump reduced the speed when a vehicle is over speeding (Parmar & Mattu, 2021).

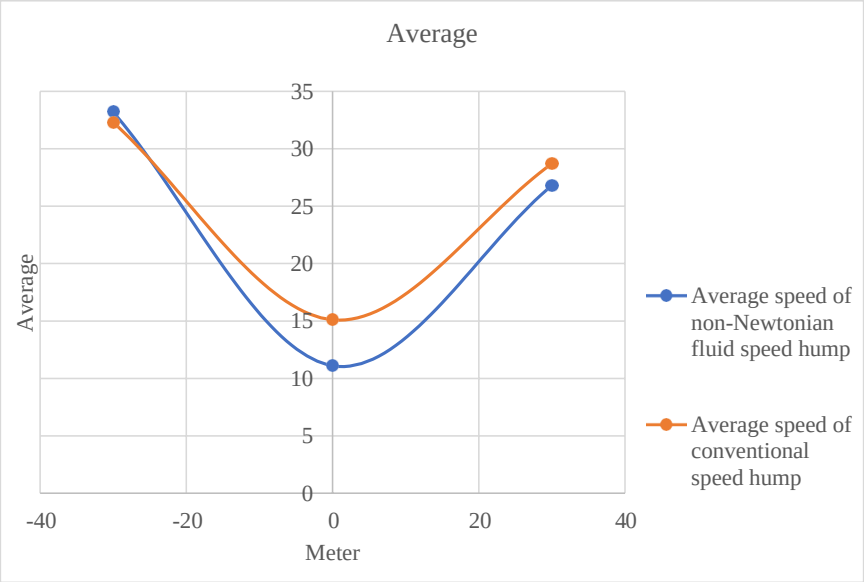

Figure 1. Comparison on Average Speed of Conventional and Non-Newtonian Fluid Speed Hump

Based on Figure 2, the noise level of the conventional speed hump at the initial speed of 10 km/h was 71.86 dB, while the noise level for the non-Newtonian fluid speed hump was slightly lower at 70.89 dB. At the initial speed of 20km/h, the conventional and non-Newtonian fluid speed are at 72.86 dB and 71.89 dB respectively. The non-Newtonian fluid speed hump still showed a lower noise level than conventional speed hump. The noise level for non-Newtonian fluid speed hump has a slightly higher at 74.20 dB compared to conventional speed hump at 74.07 dB for starter speed of 30 km/h. This may cause by the increase in the surrounding area.

And for the other two initial speed of 40 km/h and 50 km/h, the noise pollution for non-Newtonian fluid speed hump is lower than conventional speed hump. Four out of five initial speed of vehicle produced lower noise pollution for non-Newtonian fluid speed hump because of its properties. The properties of shear thickening act as an absorbent of the friction between the tyres and the speed hump. Also, the non-Newtonian fluid speed hump is also proven by other studies (Mhatre & Maji, 2021; Parmar & Mattu, 2021) that it reduces noise pollution compared to the conventional speed hump.

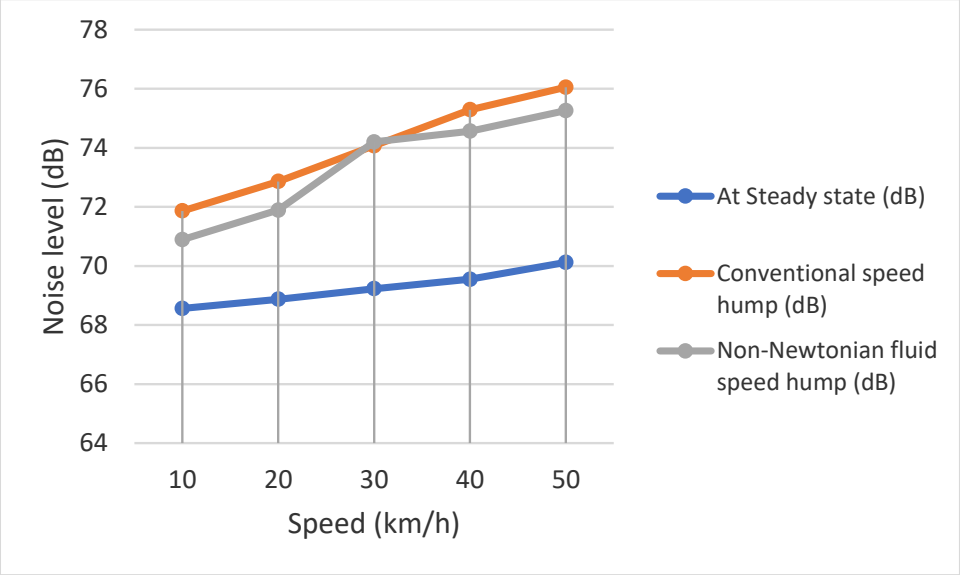

Figure 2. Noise level of vehicle at steady state, conventional speed hump, and non-Newtonian speed hump

Conclusion

Developing a prototype of non-Newtonian fluid speed hump is easy with low installation and maintenance cost compared to the conventional speed hump. The procedure took around one hour and completely portable. The performance of non-Newtonian fluid speed hump is great in terms of the speed reduction test and noise pollution test. The percentage of speed reduction of non-Newtonian fluid speed hump is 65.15% while conventional speed hump is 52.60%. The noise produced from the non-Newtonian fluid speed hump is lower than conventional speed hump for initial speed of 10, 20, 40, and 50 km/h. Only at initial speed of 30 km/h, the noise pollution for non-Newtonian fluid speed hump slightly higher due to the surrounding noise during the test. Overall, non-Newtonian fluid speed hump is a great alternative to replace conventional speed hump as a traffic calming measures. The study can be improved by testing a greater number of vehicles and different type of vehicle on the prototype and conventional speed hump. Also, data collection of the study is recommended to consider road users opinion on the difference of the speed humps.

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