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A Study on the Behavior of Speed Breakers using Non-Newtonian Fluid and Comparison with Conventional Speed Breakers

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***Abstract*— Speeding endangers everyone on road particularly in places like residential areas, school and community zones where motorized and non-motorized traffic is high. Even though speed limit signs are located, much is left to the ethics of drivers whether they should abide by them. Hence, controlling vehicular speed is an important outcome in traffic management. One way of controlling speed is to use speed breaker which produces distress which driver experiences while crossing over it. It plays a decisive role in implementing speed limits thereby preventing over speeding of vehicles. It considerably assists to the overall road safety objective through the prevention of accidents. Non-Newtonian fluid speed breaker reduces the speed of any over speeding vehicles travelling on a roadway. It is formed by at least one hollow band of ductile material called polyurethene rubber sheet that is attached to a mild steel plate. Each vessel in it is filled with a dilatants shear-thickening fluid whch is a mixture of nanosilica fumes and polypropylene glycol. If the vehicle travels at a low speed the fluid has a low viscosity and the strip is easily deformed, whereas if the speed of the vehicle is high the viscosity of the fluid is high and as a result has great resistance to deformation thus forming a rigid obstacle to the movement of the vehicle. Drivers must slow down when driving over the conventional speed breaker to prevent damage to their vehicle. However, the Non Newtonian fluid speed breaker is sensitive to the speed of the vehicle. The vehicle needs to slow down only if it is over speeding.**

Keywords*— *Non-Newtonian fluid speed breaker, shear thickening fluid, ductile material, viscosity

1. INDRODUCTION

Traffic calming measures are pretty common in modern society. Traffic calming measures are physical design approach that cultivate or force motorists to drive slow and specific speed. They prevent vehicle from speeding and can increase overall road safety. Traffic calming can also make streets more convenient and comfortable for other users such as pedestrians, cyclists and nearby residents.The main purpose of traffic calming measures is to prevent vehicle from speeding and create a safer and secure traffic environment. A few of the common speed traffic calming measures are speed breakers, rumble strips, lane width restrictions, speed limits, road closures etc. Traditionally most speed breakers have been constructed of asphalt or concrete. Due to the rigidity and durability of these materials, they have more permanence and are more effective at slowing traffic. However, they can be difficult to shape and form into consistent forms and precise dimensions. Two rubber products are pre-shaped to standard sizes to meet industry standards. Preformed rubber products are typically bolted down, making them easier to install or remove. Temporary bolt-down installations can be ideal for planners in testing the use and positioning of speed breakers before implementing them in a larger project. Boltdown products can also be removed or relocated during winter snow period. They are designed to be driven over at a design comfortable speed, while causing exceeding agitate at higher speeds. Drivers must slow down when driving over this speed breaker to prevent damage to their vehicle. Even though there are so many benefits by implementing a speed breaker, there are serious disadvantages coming out of them. Even if travelling at the design speed limit or below, these conventional speed breakers can take a toll on a vehicle's mechanical components, such as the shock absorbers and steering system. In the cases of emergency vehicles, response time is slowing the vehicles. It increases traffic noises, especially when large goods vehicles pass by. Also can cause discomfort for drivers and passengers.

A. History Of speed breaker

On June 7, 1906, The New York Times reported on an early implementation of what might be considered speed bumps in Chatham, New Jersey, which planned to raise its crosswalks five inches above the road level: "This scheme of stopping automobile speeding has been discussed by different municipalities, but Chatham is the first place to put it in practice". The average automobile's top speed at the time was around 30 mph (48 km/h).

Arthur Holly Compton was a physicist and winner of the Nobel Prize in physics in 1927 for his discoveries resulting in major changes in electromagnetic theory. He is commonly known for his work on the Compton Effect with X-rays. He also invented what he called "traffic control bumps," the basic design for the speed hump, in 1953. Compton began designs on the speed bump after noticing the speed at which motorists passed Brookings Hall at Washington University in St. Louis, Missouri, where he was chancellor.

The British Transport and Road Research Laboratory published a comprehensive report in 1973 examining vehicle behavior for a large variety of different bump geometries. At the time speed humps were not permitted on public roads but had been installed on private roads. According to a publication by the Institute of Transportation Engineers, the first speed bump in Europe was built in 1970 in the city of Delft in the Netherlands.

A speed bump is also known as a sleeping policeman in British English, Maltese English and Caribbean English, a judder bar in New Zealand English, and a lying-down policeman in Colombia, Dominican Republic, Croatia, Estonia, Slovenia and Russia. A speed bump is a bump in a roadway with heights typically ranging between 76 and 102 millimetres (3 and 4 in). The traverse distance of a speed bump is typically less than or near to 0.30 m (1 ft); contrasting with the wider speed humps, which typically have a traverse distance of 3.0 to 4.3 m (10 to 14 ft).

Speed bumps vary in length, but it is typical to leave space between the bump and either edge of an enclosed road (i.e. with curbs and gutters) to allow for drainage. Spaces on either side may also allow more expedient passage for emergency vehicles, though effectiveness will depend on the type of vehicle and specific road design.

B. Objectives

- Study and analyse properties of shear thickening fluid (STF) based on literature available.
- To design a speed breaker using shear thickening fluid (STF) as per IRC guidelines

C. Scope Of Study limited to:

The comparison of the installation cost and maintenance cost of non Newtonian fluid speed breaker to conventional speed breaker that is to introduce low cost technologies and its effects on vehicles and the survey have to be conducted at college campus with wheel loads on non Newtonan fluid speed breaker to study its effects on vehicles.

II. LITERATURE SURVEY

Teja Tallam and Jyothi Makkena (2017) aims to find the variation of speeds of different class of vehicles at speed breakers and to develop a model for finding the bump height that should be provided at that particular road for a given safe speed limits of different types of vehicles on that road section. To achieve this, three locations were selected and Volume counts for the above roads were observed for every 15 -minute intervals. The video was recorded during peak hours and the variation of speeds before and after 10 m from speed breakers were calculated at these locations. The average reduction in speed of vehicles with respect to the approaching speed at the distance of 10 m from bump is 52.69%. [1]

Geetham Tiwari (2009) the main conclusion of his studies is that there is an urgent need for Traffic Calming measures in Indian cities. The co DE2`nclusion from this is that “standardised Traffic Calming measures”, primarily by introducing humps at both entrances and exits to intersections and to introduce raised footpaths in all corners to see to it to make the approaches for pedestrians as comfortable and safe as possible by preventing cars from being able to use that space. [2]

S. Revathi and **A. Senthil Kumar** (2020)Compared to the state before the speed bumps were installed, statistically significant speed reducing was achieved.The values of the measured speeds became lower as the speed bumps height raises.At locations where larger pedestrian presence is expected, speed bumps can successfully reduce the speeds of vehicles.The implementation of traffic calming measures, such as speed bumps, significantly contributes to the safety of pedestrians.[3]

Sahoo p.k (2009) he discussed about geometric design of speed control breakers.Dimensions of most speed-control humps are determined from the engineering judgment of design engineers or past experience of the highway agency concerned. Guidelines for analytical design of hump geometry for speed control are studied. A rational approach is presented in which the geometric dimensions of a hump selected are dependent on the choice of a hump-crossing speed and a peak vertical acceleration that governs driver’s choice of hump-crossing speeds. [4]

Ndhlovu Pardon and **Chigwenya Average** (2013) they aims to study the effectiveness in terms of speed reduction of three type of traffic calming measures: speed table, chicane, and road narrowing. The speed analyses regard a series of traffic calming measures located in urban contexts of Catania Province (Italy). For each of these traffic calming measures, experimental investigations were carried out relating to the measurement of speed. The study has shown that the speed tables represent the measure of traffic calming that guarantees the greatest conditioning on speed. Even the chicanes have a significant impact on reducing speed, as well as the speed tables (average speed is reduced by up to 50%), while road narrowing allows maximum reductions in average speed of around 35%. Furthermore, all three traffic calming measures have resulted in a reduction of accidents always greater than 30%. In the case of speed tables, the reduction in accidents exceeds even 40%. [5]

III. MATERIALS OF NON-NEWTONIAN SPEED BREAKER

The major materials used in making of non-Newtonian fulid speed breaker:

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1. *Polypropylene glyol*

Three types of fumed silica nanoparticles (figure 2) with different sizes, which are:

- OX50 with a primary spherical particle size of 40 nm and a specific surface area approximately 50m2/g.
- R972 with a primary spherical particle size of 16 nm and a specific surface area approximately 110 m2/g.
- R974 with a primary spherical particle size of 12 nm and a specific surface area approximately 170 m2/g 20.
-

i. *Preperation*

The carrier fluid is polypropylene glycol (figure 1) (H[OCH(CH3)CH2]nOH) with three different average molecular weight 400 g/mol, 1000 g/mol and 3000 g/mol Preparation The carrier fluid was mixed with fumed silica particles by using a blender to mechanically stir the two components into uniform distribution. In order to get a good dispersion of STF, the suspensions after the stirring procedure were conducted to pass three-roll mill six times. A three-roll mill is a mechanical tool that utilizes the shear force created by three horizontally positioned rolls rotating in opposite directions and at different speeds relative to each other to mix, refine, disperse, or homogenize viscous materials fed into it. Finally, the fully mixed STFs were placed in a vacuum chamber to eliminate bubbles inside the STF. The concentrations of the STF conducted in this study are 7.5%, 10%, and 12.5 %w/w.

ii. Rheological Tests and Results:

As for rheological property tests, rheological measurements were performed on a stress-controlled Rheometrics Scientific AR2000ex rheometer (Figure 3). Varied dynamic frequency tests were conducted by using a 40 mm diameter cone-plate tool with a cone angle of 4 degree and a gap of 0.4 mm between the plate and the twitter. shows the experimental result of relationship between the viscosity and the shear rate of the carrier fluid applied under steady state. It shows that the polypropylene glycol matrix is a Newtonian fluid whose viscosity keeps at constant value under different shear rate.

2. *Polyurethene rubber sheet*

Polyurethane (PUR and PU) (figureis 5 a polymer composed of organic units joined by carbamate (urethane) links. While most polyurethanes are thermosetting polymers that do not melt when heated, thermoplastic polyurethanes are also available. Polyurethane polymers are traditionally and most commonly formed by reacting a di- or triisocyanate with a polyol. Since polyurethanes contain two types of monomers, which polymerise one after the other, they are classed as alternating copolymers. Both the isocyanates and polyols used to make polyurethanes contain, on average, two or more functional groups per molecule. Polyurethanes are used in the manufacture of high-resilience foam seating, rigid foainsulation panels, microcellular foam seals and gaskets, durable elastomeric wheels and tires (such as roller coaster, escalator, shopping cart, elevator, and skateboard wheels), automotive suspension bushings, electrical potting compounds, high-performance adhesives, surface coatings and surface sealants, synthetic fibers (e.g., Spandex), carpet underlay, hard-plastic parts (e.g., for electronic instruments), and hoses. The reason for using polyurethane rubber sheets as a covering for the fluid is due to its high tensile strength and high abrasion resistance. It has good ageing, chemical, oil and solvent resistance, and also it has got good tearing resisitance making it susceptible to be used for the body of the speed breaker.

3. *Mild steel plate*

In the speed breaker system the speed breaker is made up of mild steel strips (8mm thick)(figure 6). The dome is speed breaker is welded with the frame which is rectangular in shape and made of 3 mm angle iron.made of mild steel sheets of 6 mm thickness. Dome of speed breaker is welded with the frame which is rectangular in shape and made of 3 mm angle iron.

Figure 1: Polyethylene glycol

Figure 2: Nano silca fumes

Figure 3: Rheometer

Figure 4: Non Newtonian fluid mix


Figure 5: Polyurethene rubber sheet


Figure 6: Mild steel plate

IV. MAKING OF NON-NEWTONIAN FLUID SPEED BREAKER

A. Fixing dimensions of the hump using IRC

IRC: 99-2018 was used to find the dimensions of the hump. The shape of the hump is taken as circular, since it is easy to make with the fluid. The hump's length is taken as 3.7 m that is for a one way traffic, breadth as 0.2m and the raised height can be taken as 0.1m. This hump can be used in rural roads as well as urban roads (fgure7).

B. Study of rheometer

We use rheometer to test the shear thickening fluid and determine its dynamic viscosity and shear rate. There are many types of rheometer, but we take rotational rheometer to test the sample. Samples are loaded between two plates, or other similar geometry such as cone and plate or alternatively a cup and bob or vane system. Applying a torque to the top plate exerts a rotational shear stress on the material and the resulting strain or strain rate (shear rate) is measured. Rotational rheometers and viscometers share the same operating principle, but the former have far greater functionality. This is most evident in the accuracy and range over which shear stress can be applied, their facility for oscillatory testing and the level of control over the normal force applied during rotational testing. Mainly, dynamic viscosity of the sample is determined by applying torque that is by rotating the sample in the rheometer. A plot of shear amplitude v/s complex viscosity at different angular frequencies is obtained. After getting the viscosity, we can measure the shear rate at which the sample will behave as a solid or liquid.

1. *Rheometer setup*

Be sure that the Rheometer is securely mounted to the Laboratory Stand, leveled and zeroed with no cone or cup attached and 0% torque is displayed. Connect the sample cup inlet/outlet ports to the water bath inlet and outlet and set the bath to the desired test temperature. Allow sufficient time for the bath to reach the test temperature. The Rheometer has been supplied with a special cone spindle which contains the Electronic Gap Setting feature. With the motor off, thread the cone spindle byusing the spindle wrench to secure the rheometer coupling nut gently push up on the coupling nut and hold this securely with the wrench. Thread the cone spindle by hand. Attach the cup, taking care not to hit the

cone with the cup by positioning the cup against the mic ring and swinging the tension bar under the cup. The tension bar should have plastic tubing in place.

2. *Setting up the gap*

Move the toggle switch to the right; this will turn on (enable) the Gap Setting Feature. The Pilot (red) light will be illuminated. Note: The motor should be OFF. If the contact light (yellow) is illuminated, turn the micrometer adjustment ring clockwise (as you look down on the instrument) until the light is no longer illuminated. If the yellow contact light is not illuminated, slowly turn the micrometer adjustment ring in small increments (one or two scale divisions) counterclockwise. Continue moving the the contact light (yellow) first turns on. This is the "HIT POINT." Adjust the sliding reference marker, right or left, to the closest full scale division mark. Turn the micrometer adjustment ring one scale division to the left to meet the line on the sliding reference marker. The yellow contact light should go OFF. You have established the gap space needed for measurement. Now turn the toggle switch OFF (left); the red pilot light should go off. Carefully remove the sample cup.

3. *Varifying calibration*

Determine the appropriate sample volume. Refer to Table to determine the correct samplevolume required for the spindle to be utilized. Select a Brookfield Viscosity Standard fluid that will give viscosity readings between 10% and 100% of full scale range. With the motor off, remove the sample cup and place the viscosity standard fluid into the cup. Attach the sample cup to the Rheometer and allow sufficient time for the sample, cup and cone to reach temperature equilibrium. Turn the motor on. Set the desired speed. Measure the viscosity and record the reading in both % torque and centipoise (cP). Verify that the viscosity reading is within the allowable 1% deviation, as explained earlier, for the specific viscosity standard fluid that you are using.

Cone Part No.	Sample volume
CPA-40Z, CPE-40, CP-40	0.5 mL
CPA-41Z, CPE-41, CP-41	2.0 mL
CPA-42Z, CPE-42, CP-42	1.0 mL
CPA-51Z, CPE-51, CP-51	0.5 mL
CPA-52Z, CPE-52, CP-52	0.5 mL

Table 1

Characteristics Of Breaker	Conventional Speed Breaker	NonNewtonian Fluid Speed Breaker
Nature	Permanent	Mobile
Sensitivity	Not sensitive to speed of vehicle	Sensitive
Speed restriction	Slow on every condition	Slow only when overspeeding
Fuel efficiency of vehicle	Decrease	Increase
Toll on mechanical components of vehicle	Yes	No
Installation method requirement	Technical skilled labour	No technical skilled labour
Installation cost pollutionI ncrease Decrease	High	Low
Maintenance Cost	High	Low
Medical probem arise	Spinal damage	Not damaged
Weight	Heavy	Light
Response time of vehicle	Slow down	Does not affect
Traffic noise pollution	Increase	Decrease

Table2

Figure 7: Non Newtonian fluid speed breaker

V. COMPARIOSN BETWEEN CONVENTIONAL SPEED BREAKER AND NON-NEWTONIAN FLUID SPEED BREAKER

VI. RESULTS AND CONCLUSIONS

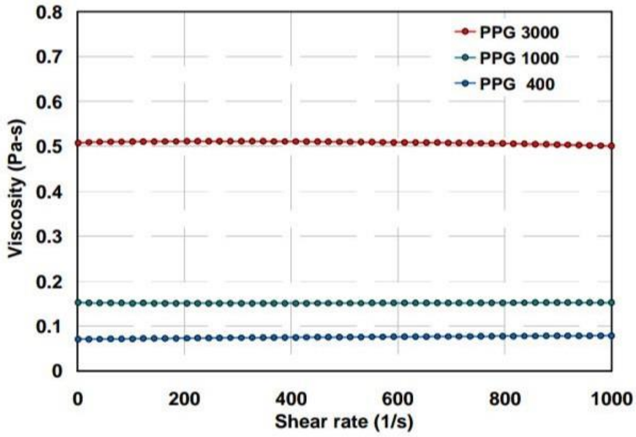


Figure 8: viscosity as a function of shear rate for PPG

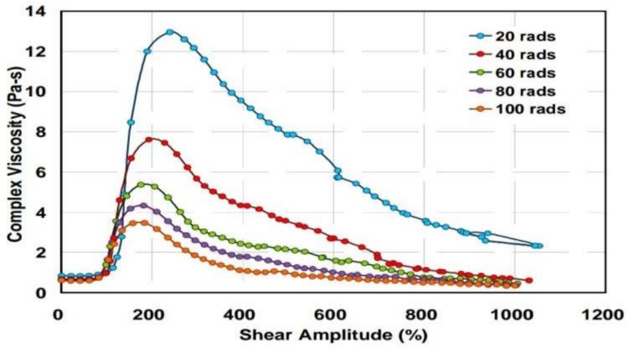


Figure 9: Dynamic strain sweeps at different angular frequencies for 10% (w/w) STF

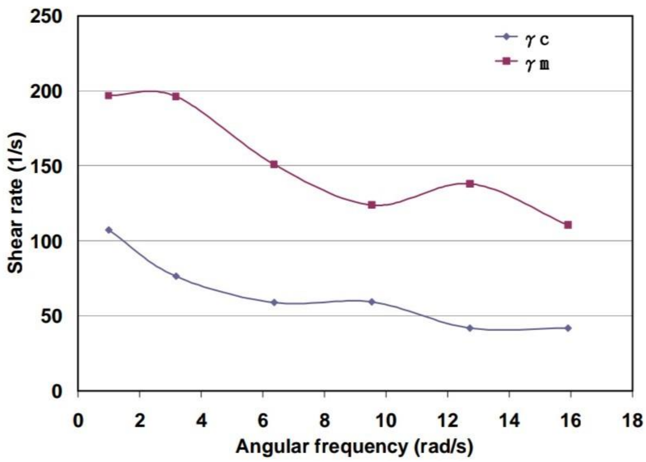


Figure 10: γc and γm as a function of angular frequency

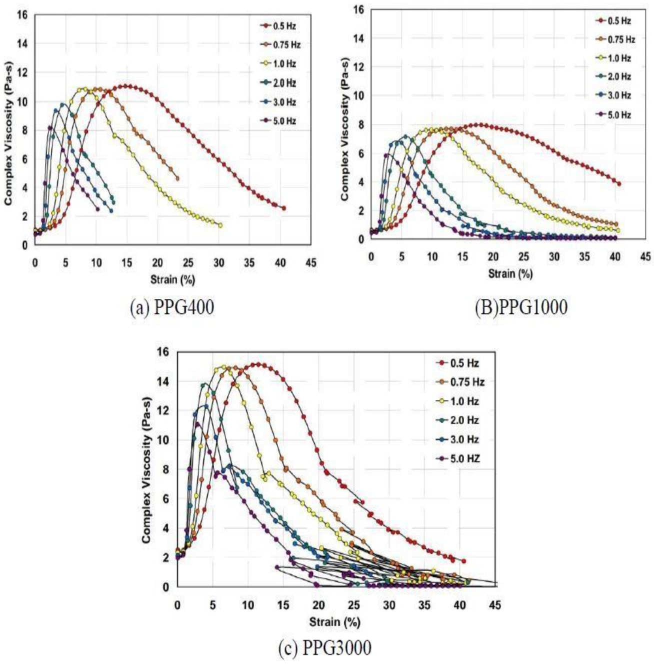


Figure 11: Rheological curve of STF for different carrier fluids (10% w/w STF with R974 nanoparticles)

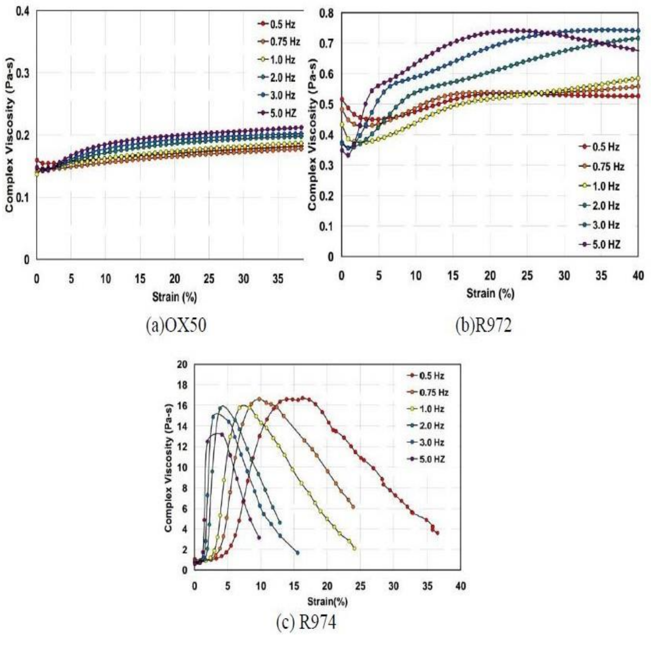
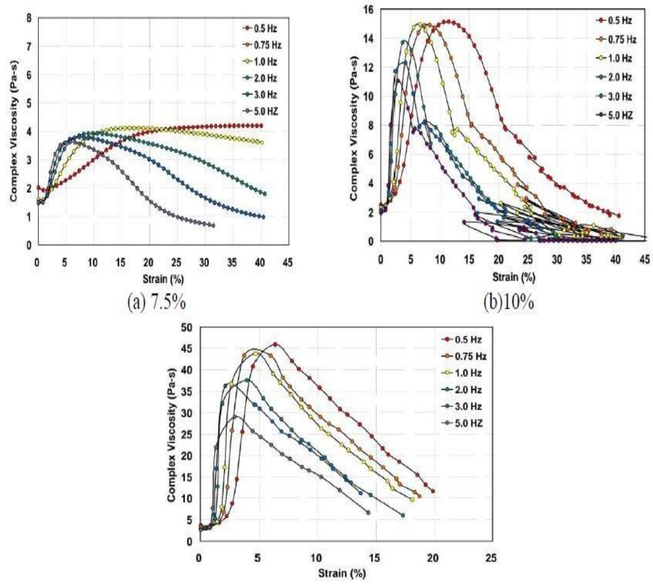


Figure 12: Rheological curve of STF for different nanoparticles (400 g/mol PPG and 12.5% w/w STF)



Fgure 13: Rheological curve of STF for different concentration STFs (3000 g/mol PPG with R974)

From analysis of literature, arrived at following conclusions:

- The viscosity of STF and amplitude of shear thickening increase as the molecular weight of carrier fluid increases.
- The Non -Newtonian fluid speed breaker help in increasing the fuel efficiency of vehicles up to a large extent.
- Vehicles need not come to a complete halt in from of speed breaker, reducing traffic congestion.
- The installation cost and maintenance cost of non Newtonian fluid speed breaker is comparatively low as compare to conventional speed breaker.
- It does not damage on a vehicle's mechanical components, such as the shock absorbers and steering system if the vehicle is following the speed limit.
- The setup is completely mobile and can be installed within an hour Designed a speed hump which work on the principle of STF as per IRC guide lines.

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