NON-NEWTONIAN FLUID AS A COMPOSITE FILLER FOR FILLING POTHOLES

HONAL VENESSA MARTIS[1], DEEPESH R SHETTY[2], PROF. THUSHAR S SHETTY[3]

[1,2]*Student, Department of Civil Engineering, NMAM Institute of Technology, Nitte, Udupi, Karnataka, India.*
[3]*Assistant Professor, Dept. of Civil Engineering, NMAM Institute of Technology, Nitte, Udupi, Karnataka, India*

Abstract -*Non-Newtonian fluids exhibit variable viscosity dependent on applied stress or shear rate, distinguishing them from Newtonian fluids like water, which maintain a constant viscosity. This variable behavior can be described through complex rheological properties and is often measured using advanced instruments such as rheometers. In practical applications, such as road maintenance, the challenge of effectively repairing potholes is exacerbated by delays in traditional methods and the severe impact on safety and infrastructure. This study investigates the application of non-Newtonian fluids combined with waste rubber tubes as a novel solution for pothole repair. By integrating these materials, we aim to create a cost-effective, durable, and environmentally friendly repair method. The use of waste rubber tubes enhances the composite's strength and weather resistance, while the non-Newtonian fluid properties allow for adaptive filling and better handling of road stresses. This innovative approach seeks to address the inefficiencies in current pothole repair methods and improve road safety and passenger comfort.*

1. INTRODUCTION

The study of fluid dynamics encompasses a range of behaviors exhibited by different fluids, with the distinction between Newtonian and non-Newtonian fluids being a fundamental aspect. While Newtonian fluids, such as water, have a constant viscosity that simplifies their behavior analysis, non-Newtonian fluids present a more complex challenge. Their viscosity changes with applied stress or shear rate, which necessitates more advanced methods to describe their behavior accurately. Non-Newtonian fluids, characterized by their variable viscosity and complex flow behavior, are of significant interest in various industrial applications, including material science, biomedical engineering, and environmental management. The ability to model and manipulate these fluids can lead to innovations in diverse fields, from enhancing manufacturing processes to improving environmental remediation strategies. The study of these fluids is crucial for applications where traditional viscosity measurements fall short. In the realm of civil engineering and transportation, potholes represent a significant challenge, particularly in regions prone to heavy rainfall and fluctuating temperatures. Potholes, which result from the combination of water infiltration and vehicular stress, pose serious risks to road safety. The existing methods for pothole repair often face delays due to bureaucratic processes, exacerbating the risks and inconveniences for drivers. Notably, in India, the consequences of inadequate pothole maintenance have been severe, with thousands of fatalities reported over recent years. Addressing this issue, our research explores the potential of utilizing non-Newtonian fluids as temporary fillers for potholes. This innovative approach leverages the unique properties of non-Newtonian materials to provide a more adaptable and effective solution for road repairs. To enhance the effectiveness and sustainability of this method, we propose the use of waste rubber tubes as a packing material. Rubber tubes, with their high elasticity and durability, offer a cost-effective and environmentally friendly alternative. The combination of synthetic and natural rubber in these tubes provides the necessary strength and weather resistance, making them an ideal candidate for this application. By integrating non-Newtonian fluid mechanics with recycled rubber materials, our research aims to improve both the safety and comfort of road users while addressing the pressing issue of pothole repair in a more sustainable manner.

2. OBJECTIVES

- To make an attempt in using non-Newtonian fluid as a composite filler for potholes
- To improve the safety and comfort level of the passengers
- To determine the optimal combination of non-Newtonian fluid for pothole filling
- To find the appropriate packing material for the non-Newtonian fluid
- To evaluate the performance of non-Newtonian fluid by comparing it with the laboratory test results
- To obtain a composite filler material for potholes which is economical when compared to bituminous patch work

3. METHODOLOGY

3.1 Preliminary survey of the site

The survey was conducted near the college premises, approximately 3 km from NMAMIT, Nitte. Given that the area is industrial, it experiences significant vehicular traffic. On average, about 3 two-wheelers and 1 four-wheeler pass through the road each hour. The road in question is approximately 90 meters long and 3 meters wide. Its GPS coordinates are 13.1831202, 74.9383543. This road was identified as an ideal location for installing a speed breaker and conducting further tests on the sample.

3.2 Materials

3.2.1 Packing Material

Attempt 1

The rice bags were stitched professionally, but the procedure had a problem: fluid started leaking from the bags, which compromised their durability and reduced their lifespan.

Attempt 2

In this attempt we decided to use rubber tube as a packing material. First we decided to cut the rubber tube into suitable size and decided to use rubber tube as a packing material through out the process.

Fig: Rubber tube

3.2.2 Sealing

Attempt 1

One end of the rubber tube was sealed with synthetic rubber-based adhesive glue, and a load was applied to ensure it was securely closed. We then began filling the fluid inside the rubber tube, applying adhesive glue to the other end and applying a load to seal it. However, the procedure had a problem: fluid began leaking from both ends of the rubber tube.

Fig: Load applied Fig: Packing material

Attempt 2

In this attempt, we used the rubber tube as a packing material. The tube was cut to a suitable size, and a black vulcanizing solution was applied to the inner side. Bonding gum was then applied to the tube to create a strong bond. Finally, we employed specialized heat-pressing techniques to seal one end of the rubber tube.

Fig: Heat pressing techniques Fig: Sealed one end of the rubber

3.2.3 Preparation of non-Newtonian Fluid

Corn starch: Corn starch or maize starch is the starch deduce from the corn (maize) grain. The starch is derived from the endosperm of the kernel. Chemical Formula $C_{27}H_{48}O_{20}$

Appearance Amorphous White Powder

Molecular Weight 692.661g/mol

Density 1.5 g/cm^3

Fig :- Corn Starch

3.3 Procedure

- Add 0.5 kg of dry cornstarch to the bowl and about 1 liter of water to the cornstarch. Stir slowly, maintaining a 2:1 ratio of water to cornstarch. Add the water gradually while stirring until all the cornstarch is fully wetted.

- Continue to add water until the cornstarch mixture behaves like a liquid when stirred slowly. When you tap the liquid with your finger, it should not splash but should become hard. If the mixture is too liquid, add more cornstarch. The goal is to create a mixture that feels like a stiff liquid when stirred slowly but feels like a solid when tapped with your finger or a spoon.

- Scoop the cornstarch mixture into the palm of your hand and slowly work it into a ball. As long as you apply pressure by rubbing it between your hands, it remains solid. When you stop rubbing, it will "melt" into a puddle in your palm. Use this packing material to fill the pothole.

- Pour the freshly prepared fluid into the rubber tube after sealing one end. Fill the tube up to three-quarters of its capacity, then seal the other end using the same heat-pressing techniques.

Fig: Filling the fluid inside the tube

- Once the liquid is poured into the rubber tube, the other end is sealed in the same manner. Specifically, black vulcanizing solution is applied to the inner side of the tube, followed by bonding gum to create the bond. Specialized heat-pressing techniques are then used to seal the other end.

Fig: Heat pressing technique to seal other end

3.4 Selection of the potholes and installation

- Proper site is selected for filling the potholes using non-Newtonian fluid which is mostly applicable in rural bituminous pavement.

Fig: Selection of potholes

- Once the potholes are cleaned the packing material are placed in the centre of the potholes. Since different sizes of packing materials are prepared, the bigger one is placed at the centre and smaller one at the side along with the covering material.

Fig: Placing the packing material

4.RESULTS

The significance of the result is assessed with reference to the tests carried out.

4.1 Liquid Test

The liquid prepared has been tested for changes occurring in its physical characteristics with time. A small amount of liquid has been prepared and placed in an air tight container and stored in a dark place. It is being checked for time periods of 1 day, 2 day, 5 days and 10 days. It was found out to be stable through out the test time. The solid part started to settle down after 3 days. With a small vibration the liquid was behaving like it was freshly prepared.

Fig:Non-Newtonian fluid stored in a container

4.2 Water Absorption Test

In this test the specimen is dried first and weighed, the recorded weight is taken as (W1). Then it is immersed in water for 24 Hours. Then remove the specimen from the water and weigh it, the recorded weight is taken as (W2). i.e, (Weight of water absorbed rubber).

Fig: Water absorption test on rubber

Sl. No	Weight of dry rubber(W1)	Weight of water absorbed rubber (W2)	Water absorption $= \frac{W2-W1}{W1} \times 100$
1	508.6 g	512.4 g	Water absorption $= \frac{512.4-508.6}{508.6} \times 100$ = 0.747%

Result : Water absorption(%) = **0.747**

4.3 Temperature Test

Temperature test refers to perform extreme temperature tests on products or samples.Temperature forcing systems allow users to set a precise thermal environment and temperature cycling, with units that can quickly increase temperature. First, packing material was kept in oven till 100^0 C, rubber material did not show a sign of melting.

4.4 Speed Test

Based on the tests carried out on various speeds it can be concluded that the safe approach speed at which the packing and covering materials works efficiently can be set as 35 Kmph.

Fig: Speed Test

5. PROS & CONS

5.1 PROS

- Eco-Friendly: The preparation of this packing material does not cause pollution. The materials used are biodegradable, non-toxic, and do not pose any threat to the environment.
- Reduces Wear and Tear on Shock Absorbers: Potholes cause vehicle shock absorbers to wear out and require frequent repairs. By providing a temporary solution to fill or patch potholes, the material helps reduce this wear and tear, making shock absorbers more effective over time.
- Easy Installation: This material is portable and can be shifted based on the user's needs. Installation takes up to 30 minutes at most.
- Increased Comfort for Passengers: The ride height of the vehicle remains unchanged, resulting in increased comfort for passengers and reduced back pain.
- Reduces Fuel Consumption: Properly patched potholes help prevent vehicles from having to climb over rough terrain, which in turn reduces extra fuel consumption.
- Simple Setup: The setup is completely mobile and maintenance-free, and the installation process does not require technical expertise.
- Economical: The cost of the fluid and packing material is lower compared to bituminous patchwork.
- Reduces Accidents: Potholes are a significant cause of accidents. In India, potholes have been linked to an average of 9 deaths per day, based on data from the Road Transport Ministry since 2014.

- Reduces Noise Pollution: Potholes cause continuous bumping, which leads to noise pollution and vibrations in the surrounding area.

5.2 CONS

- Vulnerable to Vandalism: The packing material is susceptible to damage from vandalism. For example, it can be easily cut by someone with a knife, and people wearing spiked shoes might not be able to walk over it without causing damage.
- Wear and Tear: The packing material is not permanent and is subject to wear and tear over time, which may reduce its effectiveness.
- Speed Limitation: The material is effective only for vehicles traveling at speeds of 35 km/h or higher. Vehicles traveling below this speed may experience noticeable jerks.
- Concept Stage: The material is still in the concept stage and may require further development and testing before it can be widely implemented.

6. What if no vehicle passes over it for 3 days ?

In the liquid test we have seen that the solid settles down in a period of 3 days if it is undisturbed. But when a small vibration was provided the liquid started to behave like it was freshly prepared. So, it will not be effective on the first vehicle passing over it after 3 days but will work perfectly fine on the succeeding vehicles.

7. CONCLUSIONS

Based on our attempt on making a non-Newtonian fluid as a composite filler for potholes the following conclusion can be drawn:

- The composite filler is not suitable for all vehicle types. It has a maximum bearing capacity above which it fails. So only specific vehicles carrying lighter loads can operate on these.
- The advantages include comfort of the passengers and reduced load on the shock absorbers
- If there are any sharp stone in the potholes, the packing material may tear
- Only vehicles which move with speed of 35kmph or above will not experience any jerk
- The packing material is eco-friendly and doesn't cause pollution. It is biodegradable, non toxic and do not pose any threat to future
- It also economical when compared to bituminous patch work
- To obtain smooth surface to the vehicles and passengers

8. REFERENCES

1. Pooja J. Chavhan, Runal Pawar, Shruti Donode, Rehan Pathan, Himanshu Damahe, "Non-Newtonian Fluid Speed Breaker", International Journal of Innovations in Engineering and Science, Vol. 4, No. 5, pp.4-10, (2019).

2. M. Liua, S. Hana, W. Shangb, X. Qia, S. Donga, Z. Zhanga, "New polyurethane modified coating for maintenance of asphalt pavement potholes in winter-rainy condition", Progress in Organic Coatings, Vol. 133, pp. 368–375, (2019).

3. Aleksandar Hejna, Jersy Korol, Marta ,Lukasz Zedler, Krzysztof Formela, "Waste tire rubber as a low cost and environmentally-friendly modifier in thermoset polymer", Waste management,Vol.108, pp.106-118, (2019).

4. M Nuzaimah, S M Sapuan, R Nadlene, M Jawaid, " Recycling rubber as filler " , Material science and engineering, Vol 368, pp. 1088-1757, (2018).

5. Rafiqul A Tarefder, Mohiuddin Ahmad, Mohammad I. Hossain "Pavement maintenance procedures with and without milling materials"pp.21-29 (2016).

6. Experiment on the viscosity and freezing point of a starch water and mixtureChunyang Ding , Alice Huang (2015).

7. Non-Newtonian Fluids in Circular pipe flow – J.P.Harnett & Y.I.Cho (2014).

8. Amir Heydari, Iran Alemzadeh, Manouchehr Vossoughi" Functional properties of biodegradable corn starch nanocomposites for food packaging applications" pp. 954-961. (2013).

9. Davide Lo Presti, "Recycled tyre rubber modified bitumens for road asphalt", Construction and Building material , Vol 49, pp.863-881,(2013).

10.V. Tserki, P. Matzinos, C. Panayiotou, "Novel biodegradable composites based on treated lignocellulosic waste flour as filler Part II. Development of biodegradable composites using treated and compatibilized waste flour", Composites: Part A 37, pp. 1231–1238, (2006).

11. http://dro.dur.ac.uk/305/1/305.pdf