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Repair of Potholes Using HDPE Plastic Waste

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Abstract- *In India large quantities of plastic is being generated and disposing of this plastic waste is a major challenge. Plastic consumption in India reached 15 million tons by the end of 2020-2021. This approach is harmful to the environment and human health. The variety of plastic waste is mostly available in the form of Polyethylene Terephthalate (PET), High-Density Polyethylene (HDPE) & Low-Density Polyethylene (LDPE). Use of Plastic waste as binder material in repairing the potholes could be a new innovative and Eco-friendly way of disposing it. Generally, potholes on the roads are filled with parent material such as bitumen and concrete. But, in this study the potholes are repaired with the help of HDPE material along with aggregates. Using HDPE plastic waste, the potholes on bituminous roads are filled immediately. This will make repairing of potholes on the location much easier and faster. This study shows that the durability of the potholes filled with HDPE is comparatively more than the potholes filled using conventional method. This method of filling potholes by HDPE material will be helpful to reduce the plastic waste from environment and also it is cost efficient.*

Keywords- *Plastic waste, Pothole, Eco-friendly, HDPE Plastic waste, Bituminous roads, Durability of Potholes, Aggregates*

1. Introduction

India is a growing nation. India has many terrible roads, both in the metropolis and the villages; potholes are frequent in both. Road agencies pay millions of rupees to fix potholes. The lifespan of the road is increased by using plastic to fill potholes, which also takes a lot of time, labor, and human effort to do (Nachivanekar et al. 2019). In addition to causing damage to vehicles, potholes can also result in serious accidents. Water pressure intensifies in wet materials due to high traffic volume, leading to material breakdown. Deficient road maintenance also causes surface cracks to

expand, which allows rainwater to penetrate the layers (Naveen et al. 2018). As per reports of the transport research wing of Ministry of Road Transport and Highways, the number road accidents caused by potholes is 3625 and 1482 people were dead and 3103 were injured in 2022. [1]

The generation of plastic waste has significantly increased as a result of population growth, urbanization, development activities, and changes in lifestyle, making solid waste management one of the biggest environmental challenges in the world. There is a significant issue in disposing of the vast amounts of plastic waste produced in India. India generates 15 million tons of plastic waste every year but only one fourth of this is recycled due to lack of a functioning solid waste management system.[2] Due to population growth, urbanization, development activities, and changes in lifestyle, there is an increase in the quantity of waste plastic in municipal solid waste (MSW), which causes widespread pollution of the environment. Due to their non-biodegradability and unsightly appearance, plastic trash disposal is a danger and a severe problem on a global scale. It is dangerous to the environment because these are not disposed of scientifically and have the potential to pollute the earth and water. In this study, the standard material was partially replaced with this waste plastic in order to improve the needed mechanical properties for a specific road mix.

1.1. Requirement of Use of Plastic in Road Construction

India currently ranks among the nations that are developing the fastest. India boasts a significant road network. There are a lot of dangerous roads in India, whether they are in villages, towns, or cities. Road potholes are a typical sight in both rural and urban India, especially during the monsoon season. The road agencies spend millions of rupees annually on costly pothole patching. Additionally, filling potholes requires a lot of time, labor, and human effort. Heavy vehicles, oil spills, torrential rain, low quality road construction, and other factors are the main causes of potholes. Potholes are primarily caused by water. Animal hooves on the road surface in hot weather, diesel leakage, mechanical damage to vehicle wheels, and poor road construction over some subgrades, such as pricey, collapsible, and dispersive soils, can all contribute to it. Environmental cracking can happen as a result of the

sun's UV rays, heat oxidation, or other factors that cause bitumen to shrink.

Waste plastic is the second significant issue that we all face. Plastic garbage production is significantly rising. Shopping bags, wrappers, cold drink bottles, and all other types of plastic that are only used once cause serious environmental and financial problems. Plastic is omnipresent in today's lifestyles, and getting rid of it is a big concern. Because it is a non-biodegradable product, these materials contribute to environmental contamination and concerns like breast cancer, issues with human and animal reproduction, and genital anomalies. Therefore, plastic waste can be used for pothole repair to solve both of these issues. Effective recycling of waste plastic results in longer-lasting roadways, which benefits everyone.

2. Literature Review

T. Sarada, G. Sreeja in their paper, 'An Experimental Study on Plastic Blended Bituminous Concrete Mix Roads' [3] state that, there have been numerous changes in this new period. However, there aren't as many new techniques and materials being developed. Some people substitute bitumen and tar only partially, which produces acceptable results. However, additional research has shown that not all of those materials display the necessary characteristics in all respects. During that time, researchers focus on recyclable materials like rubber and plastic. They observed that both materials produced good outcomes. On the other hand, since plastic usage (including that of polyethylene bags, pet bottles, polystyrene, and other plastic products) rises daily, there is an increasing amount of pollution brought on by plastic waste.

Sharma, Sahu, et. al Trivedi in their paper, 'A Review of various methods of road construction using waste materials' [4] state that, they claimed that while some garbage may be disposed of simply, others are always an issue for the ecosystem. Another type of substance whose disposal is usually laborious is plastic. The environment was severely impacted by waste disposal; therefore, numerous studies in various fields are being conducted to securely recycle plastic in order to reduce this impact. Utilizing discarded plastics when building roads is one of its methods. The demand for plastic roads is urgent since they not only help to improve the quality of the road by consuming waste plastic in an environmentally responsible manner.

Supriya Marik and Rishi Singh Chhabra in their paper, 'A review literature on the use of waste plastics and waste rubber tires in pavement' [5] state that, numerous original building materials and techniques have been developed to demonstrate their suitability for pothole design, construction, and maintenance. Plastics and rubbers may be one of them. Taking into account the environmental perspective as well, there is significant environmental damage as a result of the excessive usage of polythene in daily operations. Plastics are increasingly being used in carry bags, mugs, and other items on a daily basis. The requirement of the hour is to use the leftover polythene for some advantageous purposes because polythene is not biodegradable. These materials are inexpensive, environmentally benign, and give the sub-base strength when used in road construction.

Vasudevan, Velkennedy, et.al in their paper, 'Utilization of waste polymers for flexible pavement and easy disposal of waste polymers' [6] state that they have shown that Stone coated aggregate was first coated with plastic generated from wastes like carry bags, films and foams and the plastic waste coated aggregate (PCA) was used as raw material for flexible pavements. PCA is then mixed with 60/70 or 80/100 bitumen. PCA+ bitumen mix showed better binding property, less wetting property, much less voids, higher marshal stability value.by this process a road of 1km length and 3.75m width can consume 100,000 carry bags and the road strength is increased 100% and there is no formation of potholes.

Sunil J. Kulkarni in their paper 'A Review on Studies and Research on Use of Plastic Waste' [7] states that, Minimization of waste material is important aspect of the modern growth and development initiatives. Plastic is used in various domestic and industrial applications. Use of plastic bags and bottles is very common. The disposal of plastic waste is major problem due to non-biodegradable nature of plastic. The plastic can be used as feedstock for ethanol like products. It can be used for road construction and other construction related activities. The current review summarizes the research on use of waste plastic.

2.1. Research Gap

1. Plastic trash is mixed with bitumen during road building to promote stability, strength, durability, and fatigue life. Additionally, it is resistant to damages brought on by water and deformation.

2. The same bitumen and waste plastic mixture is used to fill potholes. In accordance with IRC guidelines, 8% of plastic should be mixed with bitumen before being applied to patch potholes. This method works well, but it may become damaged over time due to heavy traffic and constant water loads during rainstorms. The literature reviews mentioned above demonstrate the usage of plastic waste in conjunction with bitumen for road construction,

but a more novel and creative way to dispose of plastic trash would be to utilize waste plastic in place of bitumen entirely.

3. The method of combining plastic trash with a full bitumen replacement could be a novel, creative way to deal with the pothole problem.

4. On-site melting and mixing of the plastic waste with aggregates. According to tests done on it, as indicated in Table 1, plastic coated aggregates provide greater strength than bitumen coated aggregates. [6]

Table- 1: Test on Aggregate

Sr. No.	Tests on Aggregate	Normal Aggregate result	Plastic Coated Aggregate result
1	Aggregate Crushing test	8	5.2
2	Los Angeles abrasion test	5.5	3.4
3	Impact value test	7	5.2
4	Specific Gravity test on aggregate	2.5-3.0	2.6-3.0

3. Methodology

Vehicular traffic has been rapidly growing over the recent years with more privately owned vehicles taking to the streets each day. The situation is further exacerbated by the decline of railroads. The collapse of railroads makes the situation even worse. Road damage in the form of potholes, as seen in Fig.1, is a significant burden for transportation authorities across the nation due to these factors and bad weather. In addition to seriously harming vehicle suspension systems, potholes can also result in serious accidents and life-altering injuries. Another significant factor in the reduction of state money is the need for ongoing pothole repairs. Therefore, the demand for pothole repair methods that are both affordable and durable is urgent.

Fig-1: Pothole

3.1. Recycled Plastic waste

Plastic waste is processed into new goods through the recycling process. Recycling helps conserve resources, protect the environment from plastic pollution and greenhouse emissions, and lessen reliance on landfills.

3.2. Waste plastic and its source

1. Low-Density Polyethylene (LDPE): Carry bags, sacks, milk pouches, bin lining, cosmetic, and detergent bottles.

2. High-Density Polyethylene (HDPE): Carry bags, bottle caps, household articles.

3. Polyethylene Terephthalate (PET): Drinking water bottles etc.

4. Polypropylene (PP): Bottle caps and closures, wrappers of detergent

5. Polystyrene (PS): Yogurt pots, clear egg packs, bottle caps. Foamed Polystyrene: food trays, egg boxes, disposable cups, protective packaging, etc.

6. Polyvinyl Chloride (PVC): Mineral water bottles, credit cards, toys, pipes and gutters; electrical fittings, furniture, folders and pens, medical disposables, etc.

3.3. Guidelines on use of plastic waste in road construction

The following are the guidelines published by Ministry of Railway (Government of India) in 2019[8]

1. This guideline (IRC: SP:98-2013) deals with the specifications and use of waste plastic in wearing course using dry process, their advantages, application, manufacturing, transportation, storages, and quality testing requirements.

2. Advantages and limitation of using waste plastic as modifier and binder: Laboratory as well as field performance studies/investigations carried out in India (In Tamil Nadu, Karnataka and Delhi) identifies following advantages in using waste plastic in bituminous mixes.

i. Higher resistance to deformation, water induced damages.

ii. Increased durability and improved fatigue life, stability and strength.

iii. Disposal of waste plastic and thereby environment friendly. However following need to be ensured in order to achieve the advantages of laid down specifications;

iv. The material shall consist of only low-density polyethylene (LDPE) or high-density polyethylene (HDPE), PU (available in limited quantity as waste) and PET.

v. Black colored plastic waste is a result of repeated recycling and should not be used.

vi. PVC shall not be used since they release lethal levels of dioxins.

vii. The Thermo Gravimetric Analysis (TGA) of thermoplastics has revealed gas evolution and thermal degradation may occur beyond 180°C. Thus, miss use or wrong implementation of this technology may result in release of harmful gases, premature degradation, if the temperatures are not maintained during construction.

viii. HDPE material can be used for road construction in accordance with the Guidelines on Use of Plastic Waste in Road Construction.

3.4. Materials used

3.4.1. HDPE Material

HDPE is a type of polyethylene, the most common plastic which accounts for over 34% of the global plastic market. The properties of HDPE are listed in Table 2.

Table 2. Properties of HDPE

Particulars	Values
Density	940 kg/m^3
Melting point	130.8 °C
Temperature of crystallization	111.9 °C
Thermal conductivity	0.44 W/m °C
Specific heat capacity	1330 to 2400 J/kg °C
Specific heat (solid)	1.9 J/kg °C
Crystallinity	60%

3.4.2. Aggregates

The primary materials used to produce pavement are aggregates, which make up the majority of the pavement's structure. Wheel loads on the surface course and the pavement cause stresses in the aggregates that must be supported. They must also withstand damage brought on by the abrasive action of traffic. The findings of the numerous tests performed on aggregates in the lab, including the Los Angeles test, crushing test, impact test, flakiness test, and elongation index, specific gravity, are listed in Table 3 below.

Table 3. Test Results of Aggregate

Sr. No.	Test	Property Determined	Results
1	Los Angeles test	Abrasion	24.58%
2	Crushing test	Crushing strength	27.5%
3	Impact test	Toughness	6.72%
4	Flakiness index test	Shape	13%
5	Elongation index	Shape	12.3%
6	Specific Gravity of Aggregates (20 mm)	Specific gravity	2.69%
7	Specific Gravity of Aggregates (6 mm)	Specific gravity	2.74%

3.5. Research work

These days, it is normal practice to employ plastic waste when building roads. Bitumen often has about 8% of plastic waste added to it to improve its characteristics. The advantages of putting plastic in bitumen include:

1. A 10% reduction in bitumen consumption.

2. Develop environmentally friendly technology.

3. Enhancements to the road's fatigue life.

4. Strengthen the road and improve its functionality.

Road potholes are a serious issue that needs to be fixed in order to reduce accidents. The typical plastic-blend bitumen is used to patch potholes. However, constant traffic and high-water pressure during the rainy season cause pothole damage. To solve this issue, plastic trash might be used with aggregates to completely replace bitumen, which could be a novel and inventive method of patching potholes. During this repair, the plastic is combined with aggregates and coated with aggregates. According to tests done on aggregates, these plastic-coated aggregates are stronger than the bitumen-coated aggregates.

According to IRC regulations, the material must only be made of low-density polyethylene (LDPE) or high-density polyethylene (HDPE), PU (which is only seldom available as waste), and PET. Thermogravimetric Analysis (TGA) of thermoplastics has shown that heat deterioration and gas evolution may take place above 180°C. Thus, melting HDPE material above that point is not advised.

3.6. Experimental work

This section comprises of two parts. The first part comprises the study on the preliminary binding capacity of PET and HDPE materials with aggregates for repair of Potholes. The second part comprises of the repair of potholes using HDPE plates.

3.6.1. Preliminary binding of PET and HDPE material

The pothole filling is done by using the PET material-Shredded plastic bottles are used to fill the potholes, and they are melted with the aid of a blow torch. Aggregates are then placed over the melted surface and properly bonded with a rammer. The same procedure was followed using HDPE material.

The experiment involving PET and HDPE material indicates that the HDPE material exhibits a greater bonding strength with aggregate and the existing bituminous surface. and after heating, HDPE material quickly becomes cemented, making potholes capable of withstanding the weight of moving vehicles right away. Whereas, the PET material lost its bond and got eroded off. Thus, repair material HDPE was chosen for preparation of HDPE plate. The product composed of HDPE material prepared for the simplicity of quickly filling potholes is called HDPE plate, shown in Fig. 2.

Fig-2: HDPE Plate

3.6.2. Process of Making HDPE Plate

1. Equipment: Gas Cylinder and Blowtorch assembly, Aluminum Mold, Gas lighter.
2. Material: HDPE in the form of Small Pellets
3. Procedure:

Take an aluminum mould that is the appropriate size for the pothole as shown in Fig. 3. Place the HDPE pallets uniformly inside the aluminum mold, being careful to distribute it evenly on a plate with a thickness of around 5 mm as shown in Fig. 4.

Fig- 3: Aluminum Mould

Fig- 4: HDPE in Mould

Use a blowtorch to melt the HDPE material; the temperature must not exceed 180°C as shown in Fig.5, making sure the material has melted all the way to the bottom of the mould. Permit it to cool for 15 to 20 minutes. After cooling, the HDPE plate should be carefully removed from the mould as shown in Fig.6. Depending on the type and size of the pothole, HDPE plates can be molded into a variety of shapes and sizes.

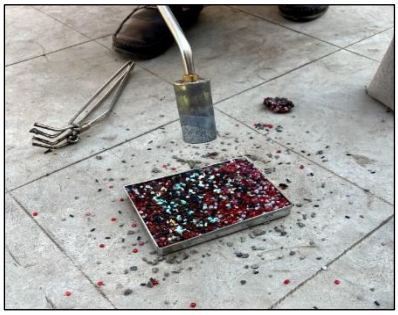

Fig- 5: Melting HDPE

Fig- 6: Final HDPE Product

3.6.3. Procedure of Filling Potholes with HDPE Plate

1. Equipment: Blower, Gas Cylinder and Blowtorch assembly, Rammer, Gas lighter.
2. Material: HDPE material, Aggregates.
3. Procedure:

To remove large fragments of rock or soil, a blower or broom is used to properly clean the pothole as shown in Fig. 7. Then the proportions of the pothole are examined. To create a solid base for the layer of HDPE plate, the pothole is filled with a layer of aggregates of uniform thickness, which is then compacted as shown in Fig. 8. Put the HDPE plate in the pothole such that it covers nearly all of them as shown in Fig. 9.

Fig- 7: Cleaning the Pothole

Fig- 8: Pothole Covered with Aggregate

Fig- 9: Placing the HDPE Plate

HDPE plate is positioned over the aggregates and heated with a blowtorch equipped with a gas cylinder at 160°C to melt the plate as shown in Fig. 10. Heat the plate until a semi-solid condition is achieved. Spread heated aggregates over the melted surface, and then use a rammer to ram the pothole thoroughly as shown in Fig. 11. Spread some stone dust on the surface that has been mended, then let traffic pass over the pothole as demonstrated in Fig. 12.

Fig- 10: Melting the HDPE Plate

Fig- 11: Compaction with Rammer

Fig- 12: Filled Pothole with HDPE Plate

4. Result and discussion

4.1. Observations on the condition of the repaired pothole

1. The observed potholes were subjected to a variety of traffic loads over the course of the 16-week period, including both light and heavy vehicles. Additionally, the potholes were subjected to a range of climatic changes, such as the cold of winter and the heat of summer, allowing researchers to assess how well the repaired potholes could tolerate temperature changes, moisture intrusion, and thermal stress. Additionally, the pothole saw a week of rain.
2. The restored component has shown extraordinary stability and resilience over the course of this 16-week monitoring period, with no appreciable alterations or deteriorations being noted. Reaffirming the efficiency and long-lasting nature of the pothole repair procedure, the repaired area has amazing resilience, withstanding the test of time, various weather conditions, and varied traffic loads without any discernible symptoms of distress.
3. Based on the observation, it has been proven without a reasonable doubt that pothole repairs made with the use of HDPE plates have a far higher level of wear and tear resistance and a longer lifespan than potholes filled with bitumen.

4. Compared to bitumen and aggregate, HDPE and aggregate have a stronger connection.

Fig-13: Before Filling the Pothole

Fig-14: Pothole filled on 28th January 2023

Fig-15: After 56 Days- 25th March 2023

Fig-6: After 112 Days- 28th May 2023

4.2 Cost comparison

This section studies the cost comparison between Conventional Method & the method implemented by using HDPE material.

1. Cost Comparison between Bitumen & HDPE material:
i. Cost of Bitumen – INR 72 / kg.
ii. Cost of HDPE material – INR 30 / kg.

As per, Conventional method and method implemented using HDPE material on site, material required for 1m. X 1m. X 0.05m. of one Pothole is,

i. Bitumen- 0.5 kg.
ii. HDPE material- 0.2 kg
2. Cost of Bitumen and HDPE for repairing one pothole,
i. With Bitumen – INR 36
ii. With HDPE – INR 6

4.3. Discussion

1. In addition to ensuring safety, using high-density polyethylene (HDPE) material as a sustainable alternative for filling potholes supports an environmentally beneficial method of waste disposal.

2. The entire costs related to road repair can be greatly decreased, resulting in significant financial savings, by replacing bitumen with high-density polyethylene (HDPE) material, an inventive and cost-effective alternative.

3. By adopting this effective method of road repair, significant advantages can be realized, such as a notable decrease in the amount of time needed to fill potholes, a decreased demand for labor, and a decreased need for expensive equipment, streamlining the process of general road maintenance.

4. By utilizing the newly created high-density polyethylene (HDPE) plate, pothole filling can be done more quickly, and the repaired potholes can be put back into service more quickly, leading to better road conditions and greater overall transportation efficiency.

5. This method of pothole filling has a number of outstanding advantages over more conventional ones, including its adaptability to be carried out successfully even during the rainy season. By utilizing the characteristics of the produced HDPE plate, road maintenance personnel may effectively repair potholes no matter the weather, providing ongoing road maintenance and reducing commuter aggravation all year long, regardless of bad weather patterns.

5. Conclusions

1. Compared to bitumen-filled potholes, those fixed using HDPE can resist heavy traffic and exhibit greater longevity.
2. A significant decrease in the resources and equipment needed from the beginning stage is accomplished by using HDPE pellets instead of bitumen.
3. The updated approach successfully does away with the need for a hot mix facility. As a result, substantial cost reductions are made from the very beginning.
4. Choosing bitumen requires a drawn-out and complex process before it can be used on site, which also necessitates ongoing heating. While using HDPE pellets offers a more streamlined method because only when filling the pothole do the pellets need to be heated.
5. Because this method can resist wet weather, it can be used to patch potholes during the rainy season.
6. HDPE plate manufacturing makes storage and transit easier. It can be effectively transported and stored because to its consistent shape.
7. In comparison, bitumen costs 72 rupees per kilogram, whereas HDPE costs only 30 rupees per kilogram, making the usage of HDPE economical.
8. By using this novel method, it is possible to totally replace bitumen with HDPE throughout the pothole repair procedure.
9. Kolhapur City can easily use this extremely efficient and environmentally friendly technology, which will undoubtedly help reduce plastic waste and improve the standard of road repair.

6. Future scope

1. Future studies can be done to see whether additional plastic polymers can be used to patch potholes.

2. Research can be done on a substitute substance for the stone aggregate. The durability and sustainability of pothole repairs can be improved through the use of recycled materials.

3. To drastically shorten the time, it takes for the HDPE to melt during the pothole repair procedure, an ignitable material can be inserted into the HDPE plate. Replacement of the blowtorch assembly for melting the HDPE, which will alleviate the need of carrying the gas cylinder.

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