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FEASIBILITY OF UTILIZING PLASTIC SOLID WASTE FOR ROAD CONSTRUCTION

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Abstract: The global production of plastics surged to 400.3 million metric tons (Mt) in 2022, marking a slight uptick compared to the preceding year. Of particular significance is the remarkable growth witnessed in the realm of circular plastics, which expanded at a rate 16 times higher than that of fossil-based plastics. This surge has propelled circular plastics to encompass nearly 10% of the total global plastics production. Projections indicate that the momentum behind circular plastics is poised to accelerate further in the forthcoming years, underscoring a pivotal shift towards more sustainable production practices. In Europe, the trajectory towards circularity is even more pronounced. While the production of fossil-based plastics is on a downward trajectory, the output of circular plastics has surged by an impressive 29.2% since 2018. As of 2022, circular plastics command a significant 19.7% share of the overall plastics production landscape in Europe. This trend reflects a concerted effort within the region to prioritize environmentally friendly alternatives and foster a more circular economy.
Keywords – Circular plastic, Fossil-based plastic

1.0 INTRODUCTION

According to the 2023 Plastic Overshoot Day Report by EA, an alarming 68,642,999 tonnes of additional plastic waste is anticipated to be introduced into the environment this year. This report underscores the global plastic pollution crisis, revealing that 52 per cent of the world's mismanaged plastic waste emanates from 12 countries, including India, China, Brazil, and the United States, among others. Despite pledges and efforts to bolster waste management capabilities, projections indicate a troubling trend of escalating plastic production, potentially tripling global plastics pollution by 2040.The report highlights the significance of Plastic Overshoot Day, occurring just four days prior to Earth Overshoot Day on August 2. This observance underscores the pervasive issue of short-life plastics, notably plastic packaging, and single-use plastics, which collectively constitute approximately 37 per cent of the world's annual plastic consumption. Notably, these categories pose a heightened risk of environmental leakage. According to Gitnux Marketdata Report 2024, the global plastic market is anticipated to witness substantial growth, with estimations suggesting an increase from approximately ₹34.45 trillion in 2022 to approximately ₹48.42 trillion by 2029, reflecting a Compound Annual Growth Rate (CAGR) of 5.0%. Concurrently, the plastics industry continues to assert its significance on a global scale, notably ranking as the 8th largest industry in the United States. In 2020 alone, this sector employed approximately 1.5 million individuals and yielded ₹28.95 trillion in shipments. However, alongside this growth, there is a pressing concern regarding plastic waste management.

2.0 SCOPE OF THE STUDY

The construction sector, a pivotal component of modern civilization, plays a significant role in environmental degradation and resource depletion. Conventional construction methodologies heavily rely on materials such as concrete, steel, and timber, leading to substantial energy consumption and the generation of substantial waste. Plastic waste, a prevalent environmental issue, presents a compelling opportunity to address these challenges. By repurposing discarded plastics into construction materials, we can simultaneously alleviate the environmental burden of plastic pollution and advance sustainable construction practices. Plastic waste holds promise for various construction applications, each offering distinct advantages. Recycled plastic aggregates, produced from processed plastic waste, have the potential to replace traditional aggregates in concrete and asphalt, bolstering durability while curbing the need for natural resources. Composite building materials, including recycled plastic lumber and plastic-wood composites, emerge as sustainable alternatives to timber, boasting comparable strength and longevity without requiring virgin materials.

3.0 METHODOLOGY

3.1 Material:

The binders were formulated using pure bitumen with a penetration grade of 50/70 grade. The bitumen was sourced from local vender. For this study, waste plastics intended as modifiers were obtained in powdered form from a recycling facility in Antalya. These waste plastics fall into three categories: ground PVC window, PVC blinds, and PVC cable.

3.2 To investigate and analyse, from an environmental perspective, the processes involved in converting waste plastics into recycled plastic pellets:

1. Collection and Sorting of Waste Plastic: Waste plastic will be sourced from landfills and industrial facilities. This includes identifying sources with significant plastic waste output and establishing agreements for regular collection. Sorting: The collected plastics will be sorted by grade (e.g., PET, PVC, LDPE, HDPE) to ensure consistent properties in the recycled material. Sorting will be performed both manually by trained personnel and using automated systems equipped with sensors to separate plastics by colour, cleanliness, and type.
2. Processing of Waste Plastic: The sorted plastic will be processed in shredding machines such as horizontal hammer mills to break down the plastic into smaller pieces. Melting and Extrusion: The shredded plastic will be melted in an extruder to form a homogenous mixture. This mixture will then be extruded and cut into pellets of specified sizes.
3. Material Selection: Bitumen will be selected according to Indian Standard Specifications (IS 73) to ensure quality and performance. Aggregates will be chosen based on IRC standards (e.g., IRC:111-2009) to meet the requirements for different mix types such as dense graded and open graded. Fine particles ranging from fine sand to mineral dust, as per IRC guidelines, will be used to enhance mix stability and durability. Recycled plastic pellets will be sieved to ensure particles pass a 2.36 mm sieve and are retained on a 600-micron sieve. Dust and impurities will be limited to not exceed 1%.

3.3 Mix Design:

Incorporation: The experiment will incorporate waste plastic into OpenGraded Premix Surfacing and Mix Seal mixes at varying percentages (3%, 6%, and 9% of bitumen weight). Environmental Sustainability The use of waste plastic aims to reduce reliance on virgin bitumen and promote recycling, contributing to environmental sustainability. To study the physical properties of modified material

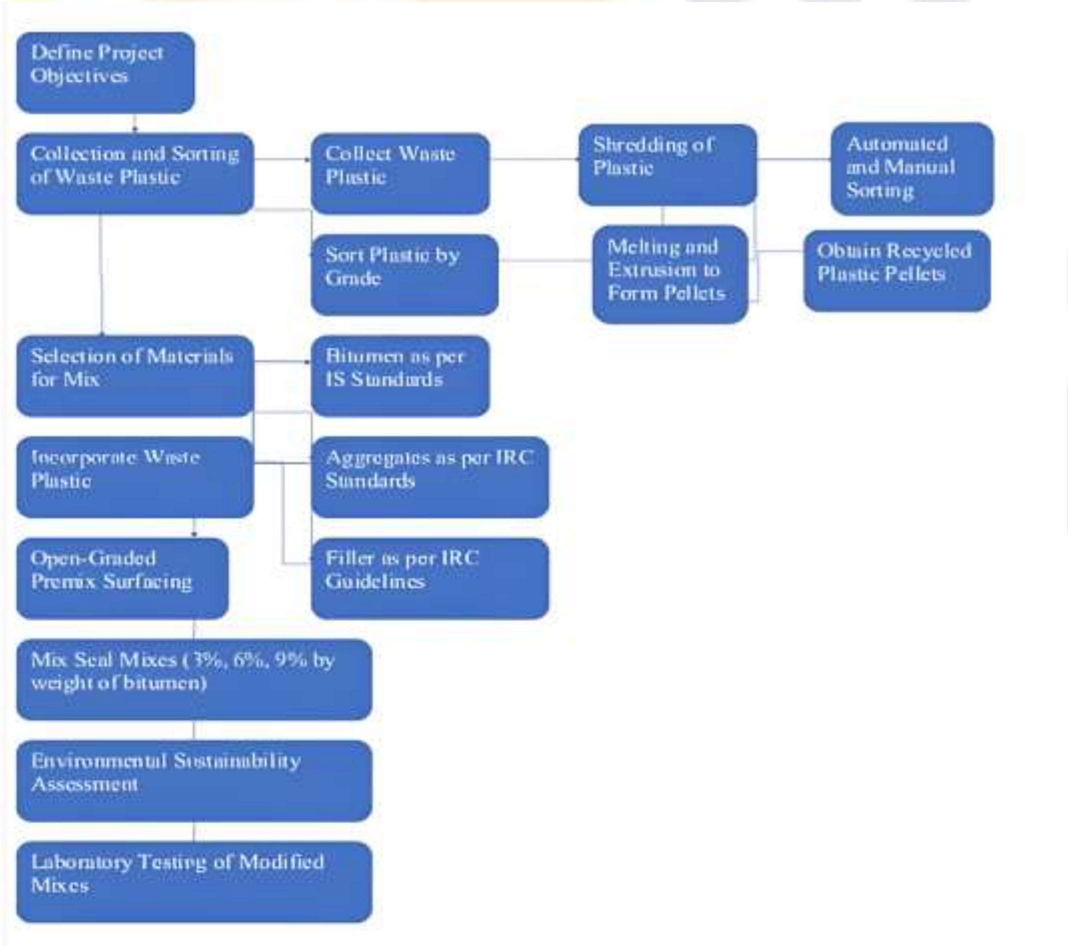

fig 3.1: Flow chart of methodology

4.0 Experiments

4.1 Materials and Modification process

The modification process for the bitumen has following steps involved:

1. Sieve Preparation: Each group of waste plastics in powdered form underwent sieving using a No. 50 sieve in the laboratory. This process ensured that the modifier material achieved the necessary fineness for subsequent experimental studies.
2. Sample Preparation: For each waste material group, samples were meticulously prepared by incorporating the waste materials at varying percentages (5%, 10%, and 15%) of the bitumen weight.
3. Bitumen Heating and Mixing: The bitumen was heated to a temperature range of 110°C in an oven. Once heated, the bitumen was poured into the mixer chamber. The modifier material was gradually added to the bitumen within the mixer, which operated at 500 rpm for approximately 15 minutes. During this time, the mixture temperature reached 120°C. Subsequently, the mixer speed was increased to 1300 rpm, and the mixing process continued for an additional 60 minutes.
4. Sample Storage: The resulting modified bitumen samples were poured into small containers. These containers were covered with aluminium foil to protect the samples. The samples were then stored for use in subsequent study experiments.

5.0 RESULTS AND DISCUSSION

5.1 Tests on Aggregate

1. =Specific Gravity (IS: 2386 Part 3, 1963): The specific gravity test determines the relative density of aggregates. It assesses the quality and suitability of aggregates for concrete. Specifically, it calculates the ratio of the weight of a given volume of aggregate to the weight of an equal volume of water at a specified temperature. Lower specific gravity values may indicate the presence of lightweight or porous aggregates.
2. Aggregate Impact Value Test (IS: 2386 Part 4, 1963): This test evaluates the resistance of aggregates to sudden impact or shock. It involves using a standard steel cylinder with a plunger to subject the aggregate sample to impact. The percentage of fines generated due to impact is calculated. Higher impact values suggest better toughness and durability of aggregates.
3. Aggregate Abrasion Value (IS: 2386 Part 4, 1963): The aggregate abrasion value test measures the abrasion resistance of aggregates. In this test, the aggregate sample undergoes abrasion in a rotating drum containing steel balls. The resulting loss in weight is expressed as a percentage. Lower abrasion values indicate better resistance to wear and tear.
4. Flakiness & Elongation Index Test (IS: 2386 Part 1, 1963): The flakiness index assesses the flatness of coarse aggregates, while the elongation index measures their elongated shape. Both indices help identify irregularly shaped particles. Aggregates with excessive flakiness or elongation may lead to poor workability and reduced strength in concrete. The test involves passing aggregates through specified sieves and calculating the indices.

Table No.5.1 Physical Properties of Aggregates

.Sr. No.	Tests	Result	Acceptable Value
1	Specific Gravity	2.9	2.5-3
2	Flakiness	14	<35%
3	Elongation	32	<35%
4	Impact Value	22.2	10 -20(Strong) 20 -30(Good)
5	Los-Angeles Abrasion Test	20.2	<30%

5.2 Tests on Bitumen

1. Ductility Test (IS: 1208-1978): The ductility test measures the distance in centimeters to which bitumen elongates before breaking. It assesses the tensile strength and grade of the bitumen. Adequate ductility is crucial for preventing pavement cracking due to temperature or traffic stresses. The recommended ductility value generally falls between 5 and 100 centimeters.
2. Ring & Ball Test (Softening Point) (IS: 1205-1978): The softening point test is an essential evaluation method that assesses the temperature at which bitumen begins to soften to a designated extent under controlled conditions. This test employs the Ring and Ball apparatus, which provides a standardized approach to determining bitumen's softening characteristics. By establishing the softening point, engineers and material scientists can ascertain the highest temperatures that are suitable for heating bitumen, ensuring its effective application in various road construction and maintenance scenarios. Understanding this parameter is crucial for optimizing the performance and durability of asphalt mixtures in fluctuating environmental conditions.
3. Flash and Fire Point (IS 1209-1978): The flash point refers to the specific temperature at which vapours from bitumen can ignite briefly when exposed to an open flame, occurring under predetermined testing conditions. In contrast, the fire point is identified as the temperature at which continuous burning persists. Understanding these critical temperature thresholds is vital for ensuring safety when handling and storing bitumen, as they provide essential guidance for preventing fires and managing risks associated with this material.
4. Marshal Stability Test (MORTH 500): The Marshal stability and flow test predict the performance of bituminous mixes. It

measures the maximum load supported by a test specimen at a specific loading rate. The stability value is crucial for designing asphalt mixes that can withstand traffic loads and environmental conditions.

Table No.5. 2 Physical Properties of Bitumen

Sr. No.	Tests	Result	Acceptable Value
1	Flash And Fire Point	170°C -200°C	220°C (Min)
2	Ring & Ball Test (Softening Point)	57	47°C(Min)
3	Ductility	54	40cm (Min)

5.3 Determining Optimum Binder Content (OBC):

The optimal binder content (OBC) for the Bituminous Concrete Mix was established by fabricating Marshall specimens with varying binder contents, ranging from 5% to 7%. Stability-flow and volumetric analyses were performed on these specimens, following the specifications outlined by MORTH (2013). The OBC is defined as the average bitumen content corresponding to the peak stability, maximum bulk density, and 4% air voids in the BC mix. The flow value and the percentage of voids in mineral aggregate must comply with the allowable limits set forth by MORTH (2013) for Bituminous Concrete Mix.

5.4 Marshall Sample Preparation and Testing for Modified Binders:

After determining the OBC, Marshall specimens were prepared using the modified binder and the aggregate blend according to standard procedures illustrate the Marshall specimens made with modified binders. The prepared Marshall specimens underwent testing in a Digital Marshall Testing Machine. Each specimen was carefully positioned within the machine's head assembly, ensuring proper alignment for the upcoming load application. The digital testing machine employed a mechanical jack to raise the lower plate steadily as the loading unit initiated the testing process. The load was meticulously applied at a constant rate of 51 millimeters per minute throughout the test. The machine's digital display recorded the maximum load value achieved during the test alongside the corresponding flow readings.

5.5 Stability-Flow and Volumetric Analysis:

These critical analyses were conducted on two distinct bituminous concrete mixes: the controlled mix (CM) and the modified mixes. The controlled mix served as a benchmark for comparison with the mixes incorporating modified binders. The outcomes obtained from these analyses are presented in detail within Table 4.3 to provide a comprehensive understanding of the Marshall properties for each mix variant.

Table No.5.3 Stability-Flow and Volumetric analysis results of BC samples for non-modified and modified mixes

	Composition	**Marshall Stability (60°C)**	**Marshall Flow (60°C)**	**Bulk Density**	**Air Voids**	**Voids in minera**
Test Method		***ASTM: D1559***	***ASTM: D1559***	***ASTM: D2726***	***ASTM: D3203***	***ASTM: D1559***
Units		kN	mm	g/cc	%	%
Pure bitumen	100% B	9.06	3.6	2.326	3.75	12.17
Pure bitumen +3%	97% B + 3% P	9.26	2.60	2.3	4.20	12.72
Pure bitumen +6%	94% B + 6% P	9.90	2.63	2.34	4.32	12.93
Pure bitumen +9%	**91% B + 9% P**	***10.50***	***3.30***	***2.36***	***4.33***	***13.10***
**Specified Limits*	*Bituminous Concrete Mix (Grade 2)*	*>9*	*2 - 4*	*-*	*3-6*	*>12*

5.6 Cost Analysis

An evaluation of the Bituminous Concrete mix's cost was conducted along a section of the National Highway, following the guidelines outlined in IRC 37:2012. The results of this analysis are presented in Tables 4.4.

Table No.5.4 Design Data of Cost analysis.

S. No.	Design Parameter	Values
1.	Cumulative number of Standard axles	150 msa
2.	CBR of subgrade	8%
3.	Length of Pavement Section	1 Km
4.	No. of lanes	Unit KM
5.	Width of pavement section	3.5 m

The cost analysis of modified bituminous concrete mixes was conducted along a section of the National Highway, adhering to the guidelines outlined in IRC 37:2012. The evaluation focused on various design parameters and the cost implications of using different compositions of bitumen with additives.

6.0 CONCLUSION

The investigation into the feasibility of utilizing plastic solid waste for road construction has demonstrated promising results from both environmental and performance perspectives. The process of converting waste plastics into recycled plastic pellets has been effectively studied and implemented, providing a sustainable method for waste management. Environmental Perspective Converting waste plastics into recycled pellets addresses environmental concerns by reducing plastic waste in landfills and promoting recycling. This approach aligns with sustainable waste management practices, contributing to a cleaner environment. Material Incorporation Incorporating waste plastics as partial replacements for bitumen in bituminous concrete mixes has shown significant benefits. The modified binder with varying plastic percentages (3%, 6%, and 9%) has led to enhanced Marshall stability and flow properties. Specifically, a 9% plastic content demonstrated the highest stability value of 10.50 kN, indicating improved resistance to deformation and load-bearing capacity.

Physical Properties: The physical properties of the modified material were thoroughly examined. The inclusion of waste plastic resulted in increased bulk density and acceptable levels of air voids and voids in mineral aggregate (VMA). These characteristics are crucial for ensuring the durability and structural integrity of the pavement.5.

The modified binder's performance under field conditions was assessed through a series of tests. The results showed that the incorporation of plastic Feasibility of Utilizing Plastic Solid Waste for Road construction Page | 46 waste improved the overall performance of the bituminous concrete mixes. The increased Marshall stability and controlled flow values suggest better pavement performance under traffic loads.

7.0 REFERENCES

1) Ahmed, S., & Khan, M. (2020). Experimental study on the use of plastic waste for road construction. IOP Conference Series: Materials Science and Engineering, 981, 042039.
2) Al-Hadidy, A. I., & Yi-qiu, T. (2009). Effect of polyethylene on life of flexible pavements. Construction and Building Materials, 23(3), 1456–1464.
3) Anju, M., et al. (2020). Magnetically actuated graphene-coated polyurethane foam as a potential sorbent for oils and organics. Arabian Journal of Chemistry.
4) Appiah, J. K. (2016). Utilization of waste thermoplastic polymers for sustainable infrastructure development: A Ghanaian perspective. Journal of Sustainable Materials and Technologies, 9, 1–6. https://doi.org/10.1016/j.susmat.2016.05.001
5) Bedin, K.C., et al. (2016). KOH-activated carbon prepared from sucrose spherical carbon: adsorption equilibrium, kinetic, and thermodynamic studies for methylene blue removal. Chemical Engineering Journal.
6) Bindu, C. S., & Beena, K. S. (2010). Waste plastic as a stabilizing additive in stone mastic asphalt. International Journal of Engineering and Technology, 2(6), 379–387.
7) Bureau of Indian Standards. (2004). IS: 15462-2004 – Bitumen and Tar – Terminology and Definitions. BIS, New Delhi.
8) Cai, L., et al. (2020). Stabilization of heavy metals in piggery wastewater sludge through coagulation-hydrothermal reaction–pyrolysis process and sludge biochar for tylosin removal. Journal of Cleaner Production.
9) Central Pollution Control Board (CPCB). (2018). Assessment of Plastic Waste Generation and its Management in India. New Delhi, India.
10) Chavan, A. (2013). Use of plastic waste in flexible pavements. International Journal of Application or Innovation in Engineering & Management, 2(4), 540–552.
11) Dalhat, M. A., & Al-Abdul Wahhab, H. I. (2017). Properties of high-density polyethylene and low-density polyethylene-modified asphalt: A performance review. Construction and Building Materials, 153, 105–116. https://doi.org/10.1016/j.conbuildmat.2017.06.143

12) Das, A., & Pandey, B. (2019). Performance of Plastic-Waste Modified Bituminous Mixes in Indian Conditions. Transportation Research Record, 2673(8), 93–103.
13) Devi, T. B., et al. (2019). Biomass-derived activated carbon loaded with silver nanoparticles: an effective nanocomposite for enhanced solar photocatalysis and antimicrobial activities. Journal of Industrial Engineering Chemistry.
14) Díez-García, I., et al. (2020). Hydrogels based on waterborne poly(urethane-urea)s by physically cross-linking with sodium alginate and calcium chloride. Carbohydrate Polymers.
15) Feng, M., et al. (2021). Rapid, high-efficient, and selective removal of cationic dyes from wastewater using hollow polydopamine microcapsules: isotherm, kinetics, thermodynamics, and mechanism. Applied Surface Science.
16) Fonseca-García, A., et al. (2021). Preparation of a novel biodegradable packaging film based on corn starch-chitosan and poloxamers. Carbohydrate Polymers.
17) Garg, D., et al. (2019). Removal of Direct Blue-86 dye from aqueous solution using alginate encapsulated activated carbon (PnsAC-alginate) prepared from waste peanut shell. Journal of Environmental Chemical Engineering.
18) Indian Roads Congress. (2013). IRC: SP: 98-2013 – Guidelines for the Use of Waste Plastic in Hot Bituminous Mixes (Dry Process) in Wearing Courses. New Delhi, India.
19) Kore, S. B., Dhemare, L. S., Balam, S. V., & Bodake, S. N. (2017). *Use of solid waste material in construction*. International Journal for Scientific Research & Development (IJSRD), 5(2), 493–495.
20) Khan, S. R. (2019). Experimental Evaluation of Polyethylene Modified Asphalt Binders and Mixes (Ph.D. dissertation, Dept. Civil Engg., Jamia Millia Islamia, Delhi, India).
21) Kore, S. B., Patil, S. S., Patil, D. M., Madekar, A. A., & Hadimani, S. S. (2018). *Use of waste plastic aggregate as partial replacement of natural aggregate in concrete mix*. International Journal for Research in Applied Science & Engineering Technology (IJRASET), 6(3).
22) Kumar, P., & Bansal, S. (2015). Use of plastic waste in flexible pavements: A review. Procedia Engineering, 125, 627–636.
23) Ministry of Environment, Forest and Climate Change (MoEF&CC). (2016). Plastic Waste Management Rules, Government of India. [Online]. Available: https://moef.gov.in
24) Modak, P., & Agarwal, A. (2015). Utilization of plastic waste in bituminous mixes for road construction: A review. International Journal of Engineering Research & Technology (IJERT), 4(3), 476–479.
25) National Rural Roads Development Agency (NRRDA). (2012). Guidelines for Use of Waste Plastic in Bituminous Roads, PMGSY.
26) Patil, H. M. (2016). Use of Plastic Waste in Construction of Bituminous Road – A Case Study (M.Tech dissertation, VJTI Mumbai).
27) Patil, Nitish. M., & Khurd, V. G. (2015). *Utilization of waste plastic in road construction*. International Journal of Inventive Engineering and Sciences (IJIES), 3(9), 25–28.
28) Raigandhi, S. D., Mane, S. S., & Kore, S. B. (2015). *Use of recycled concrete aggregates*. International Journal for Research in Applied Science & Engineering Technology (IJRASET), 3(7), 218–221.
29) Reddy, K. S., & Pandey, B. (2018). Utilization of Waste Plastic in Bituminous Mix for Improved Performance of Roads. Journal of Materials in Civil Engineering, 30(5), 04018057.
30) Sharma, B. (2020). Sustainable Road Construction Using Plastic Waste: A Green Approach (M.Tech thesis, NIT Trichy, India).
31) Sharma, R., & Sharma, M. (2020). Plastic Waste as Road Construction Material: State-of-the-Art Review. Transportation Infrastructure Geotechnology, 7, 5–20.
32) Singh, A. (2017). Performance Evaluation of Bituminous Mixes Modified with Waste Plastics (Ph.D. dissertation, Dept. Civil Engg., IIT Roorkee, India).