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Improvement of Bituminous Mix for Flexible Pavement Using Tannery Waste

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Abstract
Flexible pavements with bituminous surfacing are widely used in India. Exponential increase in traffic, overloading of commercial vehicles and significant variations in daily and seasonal temperatures have shown some limitations of conventional bitumen performance. Early developments of distress symptoms like cracking, rutting, ravelling, undulations, shoving and potholing of bituminous surfacing have been reported for flexible pavements. A bituminous mixture needs to be flexible enough at low service temperatures to prevent pavement cracking and to be stiff enough at high service temperature to prevent rutting. The improvement of bituminous mixes for flexible pavements using tannery waste has gained attention as a sustainable solution to enhance road construction materials while addressing environmental concerns. Tannery waste, primarily consisting of solid by-products like lime sludge, chromium-rich leather scraps, and other residues, poses significant disposal challenges. However, these waste materials can be repurposed to improve the properties of bituminous mixes used in road construction. This study investigates the potential of incorporating tannery waste into bituminous mixtures, focusing on its effects on the performance and durability of flexible pavements. The tannery waste is treated and processed before being added to the bitumen, with various proportions tested to evaluate their impact on the mix's mechanical properties, such as stability, flow, and resistance to deformation. Additionally, the study examines the environmental benefits of using tannery waste, including reduced landfill disposal and the recycling of hazardous materials.

Keywords: Recycled Tannery, Aggregate, Bituminous mix, Marshall Stability, Waste Management, Tannery Properties, percentage

I. Introduction

The use of tannery waste in bituminous mixes represents a forward-thinking and sustainable solution in the construction and road infrastructure industries. Tannery waste, primarily composed of leather scraps, chemicals, and sludge produced during the tanning process, poses significant environmental challenges due to its difficult disposal and potential to contaminate water and soil. As the world moves toward more sustainable practices, repurposing this waste material in bituminous mixes for road construction has gained considerable attention. Bituminous mixes, which are commonly used in the production of asphalt for road surfaces, can benefit from the incorporation of tannery waste, not only as an effective waste management strategy but also as a means to improve the performance of the asphalt. When mixed in appropriate quantities, tannery waste has been found to enhance properties such as durability, load-bearing capacity, water resistance, and resistance to cracking and deformation, potentially extending the lifespan of road surfaces. Furthermore, the inclusion of tannery waste in bituminous mixes can contribute to a reduction in the need for conventional raw materials like bitumen and aggregate, leading to more cost-effective and eco-friendly road construction. The growing interest in this practice aligns with global trends toward the circular economy, where byproducts are seen not as waste but as valuable resources. However, despite its promise, the successful incorporation of tannery waste into bituminous mixes requires careful research to determine the optimal proportions, understand its long-term effects on road performance, and ensure that any potential environmental hazards are mitigated. As the research continues to evolve, the use of tannery waste in bituminous mixtures presents a compelling opportunity to address waste disposal issues while simultaneously advancing the performance of road construction material.

II. OBJECTIVE

- To Prepare Bituminous Mix Samples using Plastic Waste and without Plastic Waste.
- To Check the Properties of Aggregate Coated with Plastic Waste.
- To Evaluate Stability and Workability of Mix Samples Prepared using Plastic Waste with Marshal Stability Test.

III. Literature Review

The following research studies highlight different methodologies and findings:

1. **Recycling Leather Waste: Preparing and Studying on the Microstructure, Mechanical, and Rheological Properties of Leather Waste/Rubber Composite (Renivaldo J. 2015)**
   Researchers have been developing new methods in order to recover the chromium from leather waste and implement it in the process for obtaining HC-FeCr alloys [15], besides the insertion of this waste as organic complement to the soil with phosphorus and potassium [16]. Another way is to use the waste to produce activated carbon by burning it for the removal of toxic materials [17, 18]. Furthermore, it is known the use of chromium of leather waste in the manu facture of pigments for ceramics [19].
2. **Utilization of Micro Fibrous Carbon Matrix from Tannery Solid Waste for Making Pavement Materials (S. Swarnalatha 2016)**
   The study deals with the pyrolysis of TBS generated from leather industry. Chromium containing TBS was successfully pyrolysed and was converted to MFC, thereof, was solidified / stabilized and investigated for the best mode of utilization as low cost hollow cement bricks and modified bitumen blocks. The leaching characteristics hollow cement bricks and modified bitumen blocks were studied through TCLP and the results confirmed the effective stabilization of chromium i.e. the metal fixing capacity was below the detectable limit. MFC increases the compressive strength when replaced for sand wherein for cement the compressive strength was not comparable. The penetration test results depict the increase in MFC percentage decreases the penetration value, ultimately it is observed addition MFC improvises VG30's characteristics to VG40.

3. **Alternative uses for tannery wastes: a review of environmental, sustainability, and science(Cesar Vinicius Toniciolli Rigueto 2020)**
   Regarding the perspectives, it is emphasized that these products obtained from leather wastes for applications in the mentioned areas, would guarantee greater profit ability for the leather processing industries, in addition to the development of new economic models exclusively for the processing of wastes. We believe that a greater focus on researches on the sustainable management of solid tannery wastes will enable improvements and advances to be achieved in the various application areas addressed, contributing directly to scientific develop ment and environmental preservation.
4. **Use of Tannery Sludge Ash as Filler in Waterproofing Membranes(Monica Puccini 2014)** The technical feasibility in the use of this waste was demonstrated: the polymer modified compounds containing CaCO3 or TSA showed comparable morphologies and properties in terms of penetration and softening temperature and the produced membranes showed similar cold flexibility independently of the filler used. Preliminary leaching tests indicated that membranes containing tannery sludge ash as filler can be used safely from an environmental point of view. Consequently, the incorporation of tannery sludge ash into stable bituminous membranes would be a valuable utilization of this type of waste, which is generated in relatively large amounts from tannery sludge thermal treatment plants, enlarging its actual application fields or finding a possible alternative to the disposal of in controlled land sites.
5. **Conversion of leather wastes to useful products (Onur Yılmaz 2006)**
   In this study, three types of leather wastes were pyrolyzed at the temperatures of 450 and 600◦C under nitrogen atmosphere. Pyrolysis of leather wastes yielded the charred residue andammoniumcarbonatebesidesgasandoilproducts.Pyrolysisyieldsvariedwiththetype of leather waste. Pyrolysis temperature significantly affected the acid solubility of inorganic constituents in chars.
6. **Performance Evaluation of Asphalt Binder Modified by Bio-oil Generated from Waste Wood Resources (Xu Yang 2013)**
   In this study, the performance evaluation of asphalt binders modified by bio-oils derived from waste wood resources is conducted through laboratory binder tests. Based on the test result, some conclusions are made: The addition of bio-oil can reduce the rotational viscosity of virgin asphalt binders, and hence can reduce the mixing temperature.
7. **Nano fibrous carbon produced from chromium bearing tannery solid waste as the bitumen modifier (K. Patchai Murugana, M. Balaji 2020)**
   The morphology analysis of the modified bitumen showed that non-uniform blending in conventional type of heating and homogeneously blended mixture in microwave type of heating. The penetration value decreases by increasing the quantity of NFC from 5 to 25% in modified bitumen, which may be due to the intercalation of NFC in between the layers of bitumen. The decrease in penetration value is higher in microwave heat mixing (from 69dmm to 36dmm for 25% NFC modified bitumen) than the conventional heat mixing. No leaching of chromium is observed in both the type of mixing in all the composition blocks, but one month acetate buffer immersion leach ability.

IV. METHODOLOGY

Using tannery waste in bituminous mixes is an innovative approach to both recycling and road construction. Tannery waste, which includes byproducts like leather scraps, sludge, and chemical residues from the tanning process, is often harmful to the environment if not disposed of properly. Instead of letting this waste pile up in landfills, researchers have found ways to incorporate it into the bituminous mix used for paving roads. By processing tannery waste, it can be added to the asphalt to improve its durability, strength, and resistance to cracking, while also making the road surface more sustainable. This method not only reduces the environmental impact of tannery waste but also offers a cost-effective alternative to traditional construction materials. By using these waste products, we can create more eco-friendly, durable roads and reduce the overall waste in our communities. The incorporation of tannery waste into bituminous mixes presents an opportunity to create more sustainable infrastructure, contributing to a circular economy where waste is minimized, and valuable resources are reused. By doing so, we can improve the quality of roads, reduce the cost of construction, and help address the growing concerns over waste disposal and environmental pollution. Systematic flow chart of methodology shown in **''fig-1''**

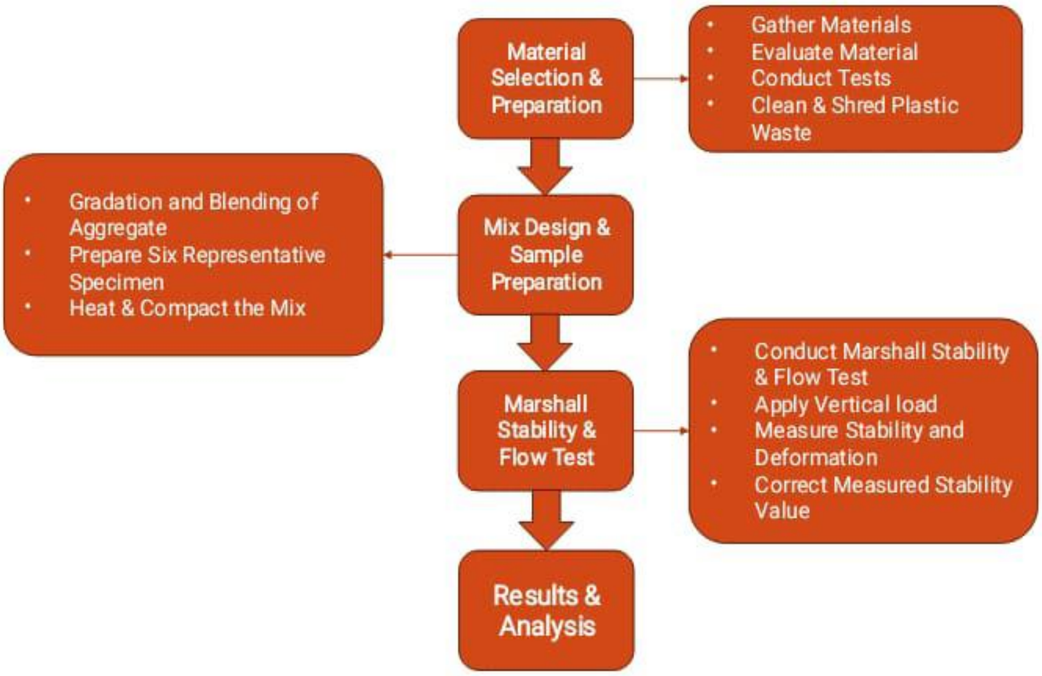


Fig.1-Flow Chart Evaluate Stability and Workability of Mix Samples Prepared using Plastic Waste'

V. RESULT AND ANALYSIS

Using tannery waste in bituminous mixes is an innovative idea aimed at improving both the environment and the quality of road construction. Tannery waste, which is often full of chemicals like chromium and lime, is typically hard to dispose of properly. By mixing it into asphalt (bituminous) mixtures used for road paving, we can reduce waste and possibly even improve the properties of the asphalt itself.

Table-1 Results of tests on Aggregate

Aggregates	% of Tannery Waste	Los - Angeles Abrasion Value (%)	Aggregate Impact Value (%)	Specific Gravity	Stripping Value (%)
Without Tannery	0	16.88	14.89	2.62	2%
With Tannery	5	14.57	12.33	2.6	Nil
	10	11.8	10.56	2.6	Nil
	15	10.67	9.84	2.73	Nil

Tannery waste in aggregate improves resistance to wear and impact, crucial for stability in asphalt mixes. Specific gravity remains uniform across both aggregate type, ensuring predictability in asphalt mix performance. Absence of stripping in aggregates with plastic waste suggests enhanced asphalt binder-aggregate adhesion, potentially boosting pavement durability. Result on aggregate shown in **''Table-1''**

The test result indicate that the bitumen meets the required specifications for the Marshall stability test demonstrating adequate ductility, penetration, softing point, flash point, and fire test. Results of tests on bitumen shown in **''Table-2''**

Table-2 Results of Tests on bitumen

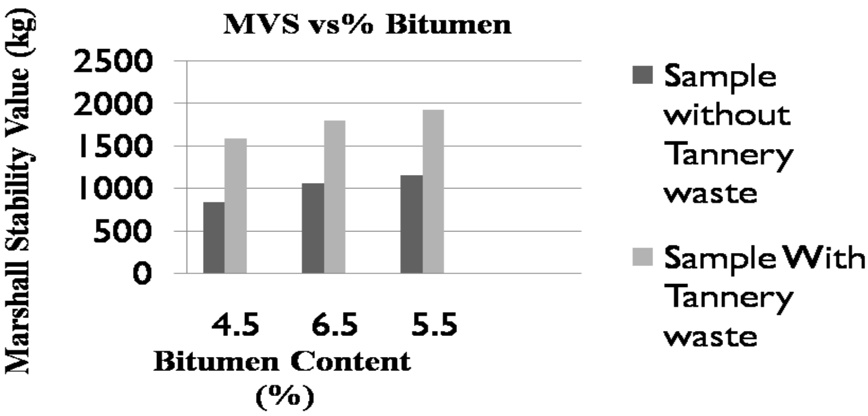
Test	Result	Range
Ductility	80 cm	Minimum 100 cm
Penetration Value	83 cm	80-100 mm
Softening Point Test	48.25 ^{0}C	45-60 ^{0}C
Flash Point Test	270 ^{0}C	>157 ^{0}C
Fire Point Test	290^{0}C	

Results obtained from Marshall Stability Test shown in ''Table-3''.To analyze the test results plots were made between Bitumen Content as shown in**''chart-2''**

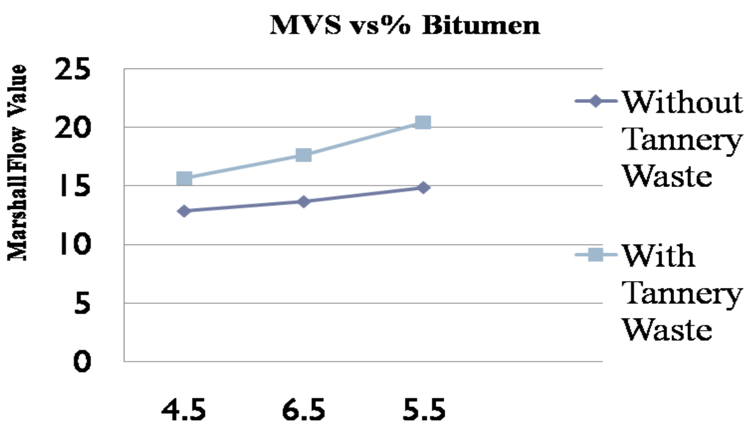
Table-3 Marshall Stability Test Results

Sample	Bitumen Content (%)	Plastic Content (% by Weight)	Marshal Stability (kg)	Marshall Flow Value (.25 = 1 MFV)
BM_1	4.5	0	830	12.8
BM_2	5.5	0	1060	13.6
BM_3	6.5	0	1150	14.8
BM_4	4.5	5	1580	15.6
BM_5	5.5	10	1790	17.6
BM_6	6.5	15	1920	20.4

Result obtained from Marshall Stability Test shown in **''Table-3''.** To analyze the test results plots were made between Marshall Stability value (MVS) vs%
Bitumen Content as showning**''Chart-1''**.and Marshall flow value (MSV) vs % Bitumen Content as shown in **''Chart-2''.**
As the percentage of bitumen content increases from BM1 to BM3bin **''Chart-1'',** there is a noticeable improvement in Marshall Stability. This indicates that higher bitumen content leads to better cohesion and strength in the bituminous concrete mix.
Introduction plastic content in **''chart-1'',** shown a signification increase in Marshall Stability compared to sample without plastic. This suggests that the addition of plastic contributes positively to the strength and stability of the mix, likely due to the reinforcing properties of the plastic fibers



''Chart-1'' Comparison of MSV of Sample with Tannery Waste and Without Tannery Waste
Generally for both sample with and without tannery waste an increase in bitumen content corresponds to a higher flow value as shown in chart-2. This indicates that higher bitumen content results in greater flow ability of the bituminous mixture.
When comparing sample with the same bitumen content. Those with Tannery waste (BM4, BM5,&BM6) tend to have higher flow values compared to sample without tannery waste(BM1,BM2, and MB3). This suggests that addition of plastic waste may influence the flow characteristics of the asphalt mixture. Potentially leading to increased flow ability



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''Chart-2'' Comparison of MSV of sample with Tannery Waste and without Tannery Waste.

VI. C0NCLUSION

Increasing bitumen content enhances Marshall Stability, indicating improved cohesion and strength in bituminous concrete mixes .The addition of Tannery waste significantly boosts Marshall Stability, likely due to the reinforcing properties of plastic fibers. Higher bitumen content generally leads to greater flow ability, regardless of the presence of Tannery waste. Tannery waste incorporation influences flow characteristics, resulting in increased flow ability in asphalt mixes. Optimal bitumen-plastic ratios can be explored to balance stability and flow characteristics effectively. These findings highlight the potential for sustainable utilization of tannery waste in enhancing the performance of bituminous concrete mixes for road construction.

VII. FUTURE SCOPE & LIMITATIONS

Future Scope-

- Assessing the long-term durability and environmental sustainability of Tannery -modified bituminous concrete mixes through field trials and accelerated lab testing.
- Evaluating the environmental footprint of tannery-incorporated mixes versus conventional ones, considering carbon emissions and energy consumption, using life cycle assessments.
- Exploring new methods like microwave processing or chemical modification to efficiently integrate different tannery waste types into bituminous mixes, improving sustainability and cost-effectiveness.

Limitations-

- The study assesses only Marshall Stability and Flow Values, neglecting key factors like rutting resistance and fatigue performance crucial for asphalt mix evaluation.
- With only six samples, the study's findings may lack generalizability due to the limited variability in asphalt mixtures tested.

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