Studies On Performance Characteristics of Bituminous Mix Using Proteinous and Non-Proteinous Wastes of Leather

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Abstract — The leather industry generates a significant amount of solid waste during the processing of animal hides and skins, including proteinous wastes like chrome shavings and fleshing residues, as well as non-proteinous wastes such as buffing dust. Improper disposal of these wastes poses serious environmental challenges due to their chemical composition, particularly the presence of chromium. This study investigates the feasibility of utilizing these leather industry wastes in the construction of Stone Matrix Asphalt (SMA) pavement layers. In this research, lime obtained from limed fleshing was used as a filler, and chrome shavings were employed as a stabilizing additive in SMA mixtures. The mix designs were prepared in accordance with IRC: SP-79-2008 specifications and tested using the Marshall Method to determine the optimum binder content. Performance evaluation was carried out through various laboratory tests, including Marshall Stability, Indirect Tensile Strength (ITS), Moisture Susceptibility, and Wheel Tracking (Rutting) tests. The results indicated that the modified SMA mixes exhibited enhanced mechanical properties, including improved stability, moisture resistance, and rutting performance, while also meeting all specified standards. Furthermore, the reuse of leather waste materials contributes to sustainable construction practices and offers an environmentally responsible solution for waste management in the leather industry. This study concludes that incorporating leather waste in bituminous mixes is both technically viable and environmentally beneficial, paving the way for eco-friendly and cost-effective road construction solutions.

Keywords: Stone Matrix Asphalt (SMA), Leather Industry Waste, Chrome Shavings, Limed Fleshing, Bituminous Mix, Sustainable Pavement, Waste Utilization, Moisture Resistance, Rutting Resistance, Marshall Stability

I. Introduction

Leather is a material derived from the skin of animals through processes like tanning or similar treatments. It is a natural polymer composed of amino acid monomers. For thousands of years, leather, being one of the collagen-based materials, has been a primary fibrous material utilized by humans. The term "leather" generally refers to hide or skin that retains its original fibrous structure, treated to become non-putrescible through tanning or other preservation methods. Leather's unique structure is formed by millions of tiny fibrils interwoven in a remarkable pattern (Shamsun Nahar et al., 2013).

The outer coverings of large domestic animals such as cows, buffaloes, and horses are referred to as hides, while those of smaller domestic animals like sheep and goats are called skins. Fresh hides and skins typically consist of approximately 60%-65% water, 25%-30% protein, and 5%-10% fats.

The epidermis is a relatively thin layer that forms the upper boundary of the skin. It constitutes only about 1% of the skin's total thickness and serves to protect the corium, which is the most significant part of the skin. The corium is a much thicker layer composed of connective and other tissues that form the true leather-making substance in hides and skins The corium is further divided into two distinct layers:

1) Corium minor or the grain layer, and
2) Corium major or the reticular layer.

The entire corium consists of an interwoven structure made up of numerous fibers held together. Each fibril, in turn, is composed of several proto-fibrils. In practice, the corium, or "true skin," refers to the portion of the hide or skin, known as the pelt, from which the hair has been removed.

The adipose tissue is the layer of tissue adhering to the flesh side of the hide or skin. It is primarily composed of fat cells containing tallow-like fats, along with a few scattered fibers and some muscular tissue. These components are not useful for leather production and must be removed during the fleshing process. This is done after preparing the pelt through soaking and liming.

Therefore, during the preparation of hides or skins, both the epidermis and the adipose tissue are removed, leaving behind the corium, which is then processed and transformed into leather.

A. Proteinous and Non-Proteinous Wastes of Leather

The leather industry generates significant amounts of solid and liquid waste, which can be classified into proteinous and non-proteinous categories based on their composition and characteristics.

1) Proteinous Wastes of Leather

These wastes primarily consist of organic materials rich in proteins, mainly derived from animal skin and connective tissues. Some common proteinous leather wastes include:

- Fleshing Waste – Composed of fat, collagen, and residual skin tissues removed during the initial leather processing.
- Chromium Shavings – Protein-based shavings generated from chrome-tanned leather, containing collagen and chromium compounds.
- Hide Trimmings & Splitting Waste – Leftovers from leather cutting and processing, mainly containing protein fibers.

These wastes have a high nitrogen content and can undergo biological degradation. However, their disposal poses environmental challenges due to the presence of tanning agents like chromium.

2) Non-Proteinous Wastes of Leather

These wastes contain minimal protein and mainly consist of chemical residues, synthetic compounds, and fibrous materials used in leather processing. Common types include:

- Buffing Dust – Fine powder generated during leather polishing and finishing.
- Synthetic Leather Scraps – Non-biodegradable waste from artificial leather manufacturing.
- Fat Liquoring Residues – Oily and waxy residues from the leather softening process.

These non-proteinous wastes are chemically treated and often contain synthetic polymers, making their disposal and reuse more challenging.

3) Significance in Bituminous Mixes

Both proteinous (e.g., chromium shavings) and non-proteinous (e.g., buffing dust, synthetic scraps) leather wastes can be utilized in bituminous pavement construction to enhance properties like moisture resistance, stability, and durability, while also addressing waste disposal concerns in the leather industry.

Would you like me to focus on specific aspects of their application in road construction?

II. Objective

1) To utilize proteinous and non-proteinous leather industry wastes (like chrome shavings and limed fleshing) as sustainable additives in Stone Matrix Asphalt (SMA) mixes.
2) To improve the mechanical performance of bituminous mixes by enhancing stability, rutting resistance, moisture resistance, and durability.
3) To assess the environmental impact of using leather waste by analyzing chromium leaching and its effects on soil and groundwater.
4) To optimize the mix design by determining the ideal proportion of leather waste additives while meeting IRC and MORTH standards.
5) To evaluate economic and practical feasibility by conducting cost-benefit and performance comparisons with other industrial waste-modified SMA mixes.

III. Methodology

1) Material Collection and Preparation

Bitumen (VG-30 grade), aggregates, and leather industry wastes such as chrome shavings and lime from limed fleshing were collected.

Leather waste was dried, ground, and prepared for use as a stabilizing additive and filler.

2) Mix Design of Stone Matrix Asphalt (SMA)

SMA mixes were designed as per IRC: SP-79-2008 using four different gradations.

The mix consisted of 70–80% coarse aggregates, 6–7% bitumen, 8–12% filler, and 0.3–0.5% leather-based stabilizing additives.

3) Marshall Mix Design Method

The Marshall Method was used to determine the Optimum Binder Content (OBC) based on achieving 4% air voids and minimum 17% voids in mineral aggregates (VMA).

Volumetric analysis was conducted to ensure stone-on-stone contact and mix stability.

4) Laboratory Testing

Various tests were conducted to assess mix performance:

- Marshall Stability Test
- Indirect Tensile Strength (ITS) Test
- Rutting Resistance Test (Wheel Tracking)
- Moisture Susceptibility Test

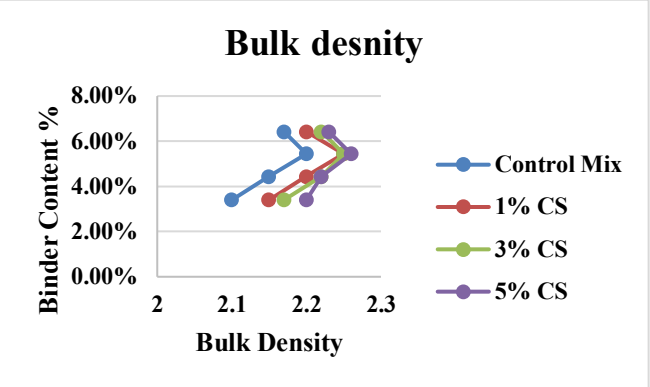
Tests followed IS codes, IRC SP:79, and AASHTO T-283 standards.

5) Analysis and Evaluation

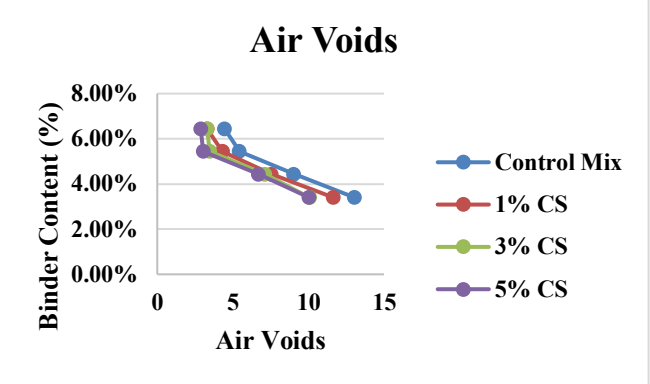
Test results were analyzed to evaluate the effect of leather waste on stability, rutting, moisture resistance, and environmental impact.

The performance of leather waste-modified mixes was compared with conventional SMA and other industrial waste-based mixes.

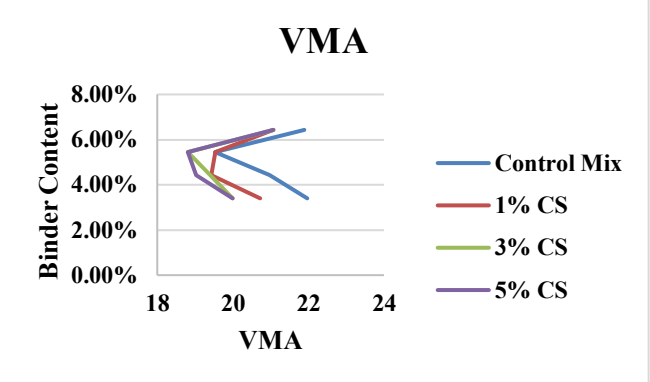
IV. Result



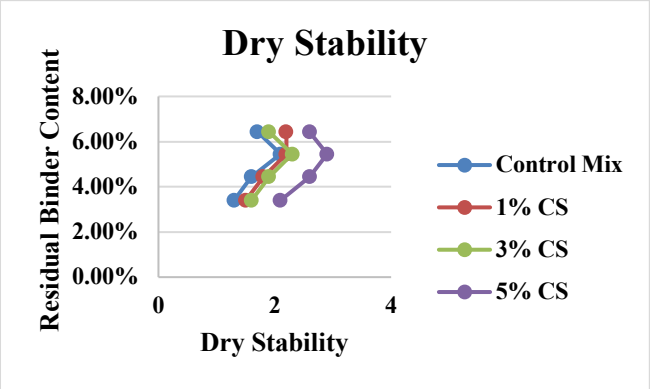
Graph 1: Bulk Density Vs Residual Binder Content



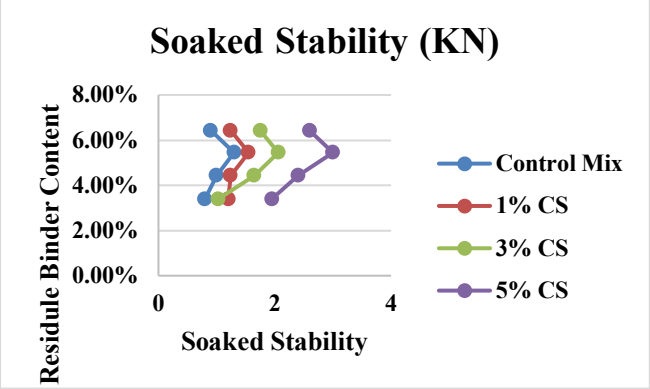
Graph 2: Air Voids vs Residual Binder Content



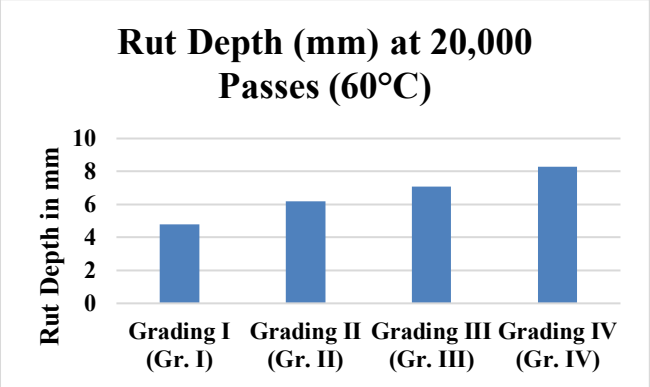
Graph 3: VMA Vs Binder Content



Graph 4: Dry Stability Vs Residential Binder Content



Graph 5: Soaked Stability Vs Binder Content



Graph 6: Different Grading Vs Rut Depth

V. Conclusion

1) This study successfully demonstrates the potential of utilizing proteinous and non-proteinous wastes from the leather industry—such as chrome shavings and lime from limed fleshing—in Stone Matrix Asphalt (SMA) mixtures. The key conclusions are as follows:
2) Sustainable Utilization of Waste: Leather industry wastes can be effectively reused as stabilizing additives and fillers, offering an environmentally friendly alternative to conventional materials.
3) Enhanced Pavement Performance: Modified SMA mixes showed improved mechanical properties, including better stability, rutting resistance, moisture resistance, and overall durability compared to conventional mixes.
4) Environmental Benefits: Incorporating leather waste in road construction helps reduce solid waste disposal issues and minimizes environmental pollution from chromium-containing waste.
5) Compliance with Standards: The leather waste-modified SMA mixes met the performance requirements outlined in IRC: SP-79-2008 and relevant IS codes, proving their technical viability.
6) Economic Feasibility: The approach presents a cost-effective and sustainable solution by reducing the demand for natural resources and lowering the cost of raw materials in road construction.

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