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An Evaluation of Mechanical Behaviors of Baghouse Dust in Asphalt Concrete Mix Using Discrete Element Method (DEM)

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The purpose of this study is to research the mechanical behavior of baghouse dust when integrated into asphalt concrete mixes, utilizing the Discrete Element Method. Baghouse dust, a byproduct of asphalt creation, presents natural removal challenges; nonetheless, its true capacity reuse in asphalt concrete could give an economical arrangement. This study plans to assess the attainability and execution ramifications of utilizing differing extents of baghouse dust in asphalt mixtures and combinations.

The study starts by portraying the physical and synthetic properties of baghouse dust. Accordingly, substantial examples are ready with various rates of baghouse dust to break down what the consideration of this result means for the mechanical properties of the mix.

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The research uncovered that integrating baghouse dust into asphalt concrete by and large decreases the peak stress and strength attributes of the mix. In particular, the stress-strain curves show a lessening in top pressure values as the baghouse dust content increases. For example, the pinnacle pressure for the control mixes (0% residue) is roughly 25 MPa, while for mixes containing 5%, 10%, and 15% residue, the peak stresses are 22 MPa, 20 MPa, and 17 MPa, individually. Regardless of this decrease, the mechanical properties stay inside for specific applications, proposing that baghouse residue can be utilized successfully in non-basic primary layers of asphalts.

Keywords: Baghouse dust; asphalt concrete; compressive strength; modulus of elasticity; stress-strain behavior; mechanical properties; discrete element method; tensile strength.

1. INTRODUCTION

This study aims to investigate the mechanical way of behaving of baghouse dust when incorporated into asphalt concrete mixes utilizing the Discrete Element Method (DEM) [1]. By tending to the difficulties and open doors introduced by this industrial byproduct, the research tries to add to supportable development practices and upgrade the performance of black-top asphalt pavements [2].

Asphalt Concrete is a composite material generally utilized in the development of streets, roads, parkways, air terminals, and other frameworks [3,4]. It comprises fundamentally of asphalt binder and mineral aggregate mixed and laid in layers, then compacted to shape a strong surface [2].

Baghouse dust is a fine particulate material gathered from the air pollution control frameworks of asphalt production plants. These residue particles are caught in baghouse channels, keeping them from being delivered into the environment [3-6]. Albeit generally thought to be a byproduct, baghouse dust contains mineral fines and different constituents that might be reused into new asphalt mixes. Using baghouse dust in asphalt concrete decreases squandering as well as offers likely expense reserve funds and natural advantages [7,5,8].

The Discrete Element Method is a mathematical procedure used to show the behavior of particulate materials by simulating cooperation between individual particles. DEM is especially significant for concentrating on materials like asphalt concrete, where the behavior of aggregates and binders at the tiny level impacts the, generally speaking, mechanical properties of the mix [9]. By applying DEM, this study means acquiring itemized bits of knowledge into how baghouse dust particles associate inside the asphalt framework and influence its performance [10].

Regardless of the expected advantages, the mechanical behavior of baghouse dust in asphalt concrete isn't surely known. There is a requirement for orderly assessment to decide how various extents of baghouse dust impact the strength, solidness, and generally speaking execution of asphalt mixes [11-13].

Understanding these impacts is critical for creating rules and best practices for consolidating baghouse dust into asphalt concrete [14].

The research centers around asphalt concrete substantial samples arranged with baghouse dust gathered from asphalt plants [15-12]. It incorporates both exploratory testing of mechanical properties (like compressive strength, tensile strength, and modulus of elasticity) and DEM simulations to display the inner way of behaving of the mixes. The exploration traverses months, covering material assortment, test readiness, testing, and data analysis [1].

The discoveries of this study have huge ramifications for both the development industry and academic exploration. For the industry, integrating baghouse dust into asphalt concrete can prompt more economical and savvy rehearsals by lessening waste and using byproducts proficiently [16]. Academically, this study adds to the assortment of information on manageable materials and the utilization of DEM in assessing composite materials [17]. The experiences acquired can assist with making ready for additional examinations and advancements in the field of asphalt innovation and economic development materials [14].

In outline, this study means to connect the information hole concerning the utilization of baghouse dust in asphalt concrete, utilizing both trial and reenactment ways to deal with giving an extensive comprehension of its mechanical behavior and possible advantages.

2. METHODOLOGY

This segment subtleties the systems and strategies utilized to direct this exploration on assessing the mechanical behavior of baghouse dust in asphalt substantial mixes utilizing the Discrete Element Method (DEM). This section frames the exploration plan, materials utilized, exploratory methodology, data collection, analysis strategies, and approval techniques to guarantee the accuracy and dependability of the discoveries.

This study embraces a trial and simulation-based way to deal with a survey of the effect of consolidating baghouse dust into asphalt concrete.

2.1 Method of Obtaining Data

Baghouse dust was gathered alongside the asphalt binder and aggregate materials were obtained to guarantee consistency with typical asphalt concrete utilized in the region.

The baghouse dust was sieved to eliminate any huge particles and guarantee uniformity. The asphalt concrete samples were prepared with varying extents of baghouse dust: 0%, 5%, 10%, and 15% by weight of the total aggregate. Standard mix design methods were adhered to produce the asphalt concrete samples.

The DEM simulations were aligned utilizing experimental data to guarantee exactness. Key boundaries included particle size distribution, particle shape, contact firmness, friction coefficients, and damping factors. These parameters were changed by matching the actual properties of the asphalt concrete and baghouse dust.

2.2 Techniques

a) Comparative analysis where results were contrasted with DEM simulation yields to approve of the models with charts. Statistical analysis:
b) Measurable strategies were utilized to investigate the changeability and meaning of the results with a pie chart.
c) Graphical representation: Stress-strain curves were utilized to picture the information and key discoveries on a graph.

3. RESULTS AND DISCUSSION

A. Graphical Representation with Charts for the Mechanical Properties

3.1 The Compressive Strength vs. Baghouse Dust Content

This trend suggests that moderate additions of baghouse dust can enhance compressive strength, but excessive amounts may weaken the mix.

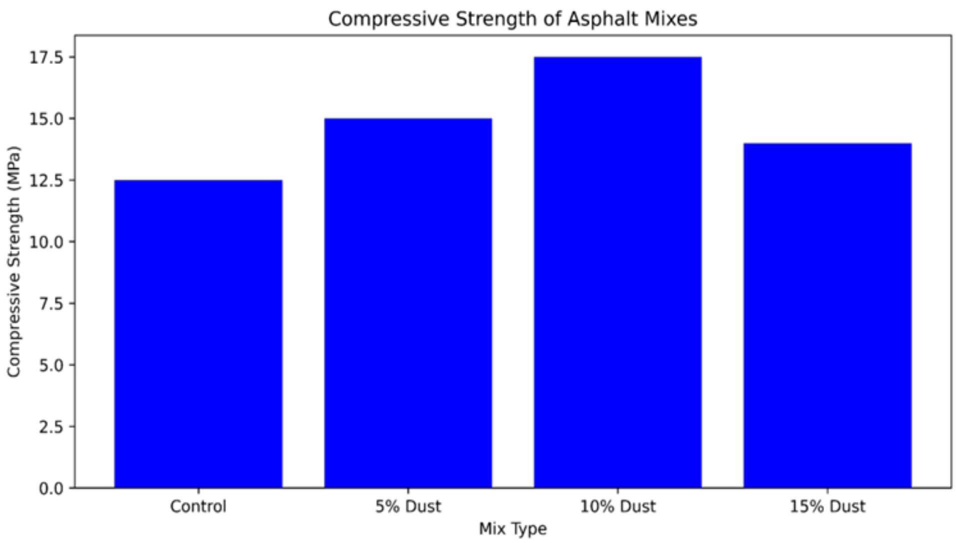

Fig. 1. The Compressive Strength vs. Baghouse Dust Content Chart

3.2 Elastic Modulus Comparison

The chart shows a gradual increase in the elastic modulus as the baghouse dust content rises, indicating an increase in stiffness up to a certain point. However, at 15% dust content, the modulus decreases slightly, suggesting a reduction in stiffness.

3.3 Tensile Strength vs. Baghouse Dust Content

The chart demonstrates a decreasing trend in tensile strength with increasing baghouse dust content, highlighting that higher dust content may weaken the tensile properties of the asphalt mix.

3.4 Distribution of Different Mechanical Properties

The pie chart at the maximum dust content percentage illustrates the relative proportions of compressive strength, tensile strength, and modulus of elasticity, providing a visual representation of the mechanical property distribution at the highest dust content level.

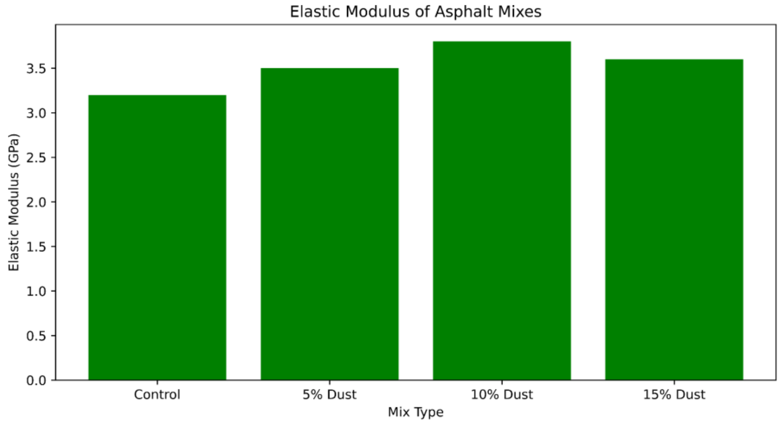

Fig. 2. Elastic Modulus Comparison Chart

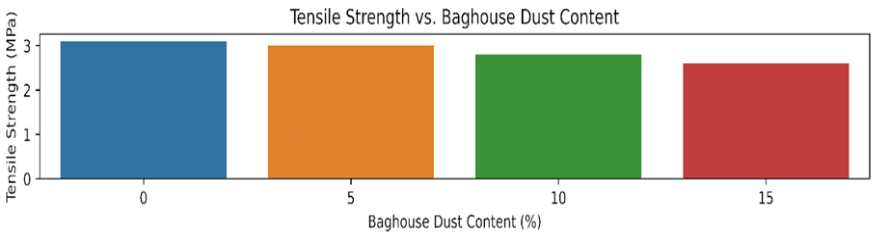

Fig. 3. Tensile Strength vs. Baghouse Dust Content Chart

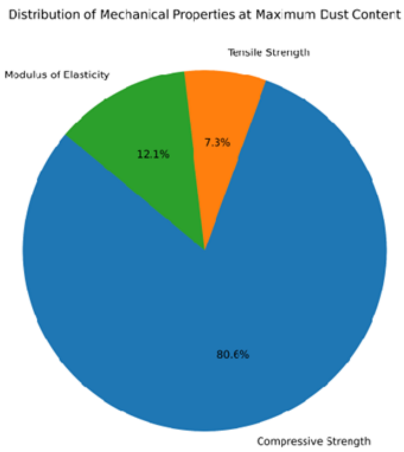

Fig. 4. Pie chart showing distribution of different mechanical properties (Compressive Strength, Tensile Strength, Modulus of Elasticity)

B. Graphical Representation of the Stress-Strain Behaviors

3.5 Stress-Strain Curves for Different Baghouse Dust Contents

The stress-strain curves indicate that higher baghouse dust content generally results in lower peak stress and earlier deviation from linearity. This suggests a decrease in material strength and ductility with increased dust content.

3.6 Compressive Strength, Tensile Strength, and Modulus of Elasticity Plotted Against the Baghouse Dust Content

This graph provides a comparative view of how the mechanical properties change with varying levels of baghouse dust. It highlights the balance between the different properties and the optimal content for maintaining performance.

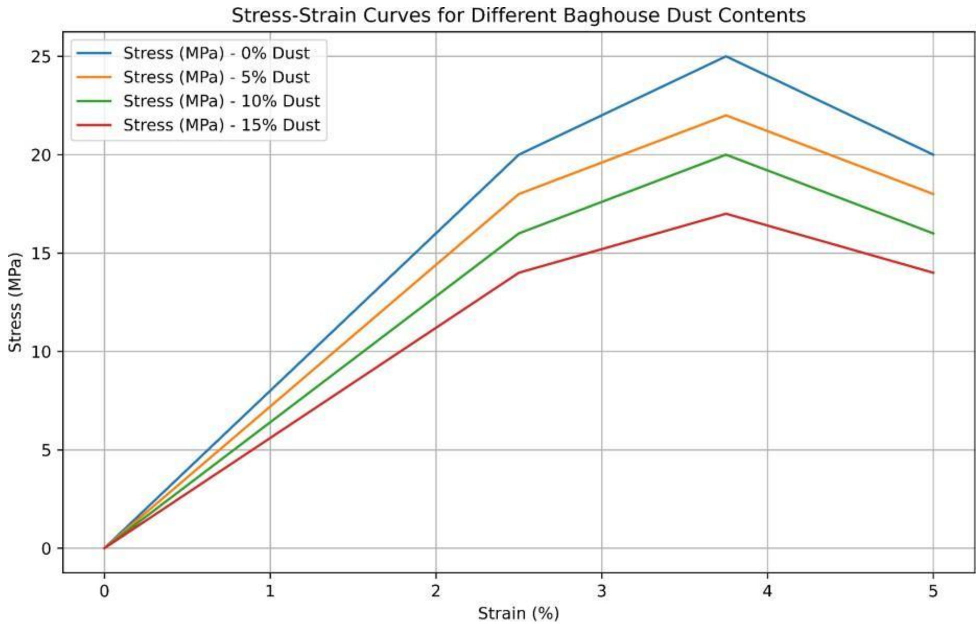

Fig. 5. Graph of Stress-Strain Curves for Different Baghouse Dust Contents

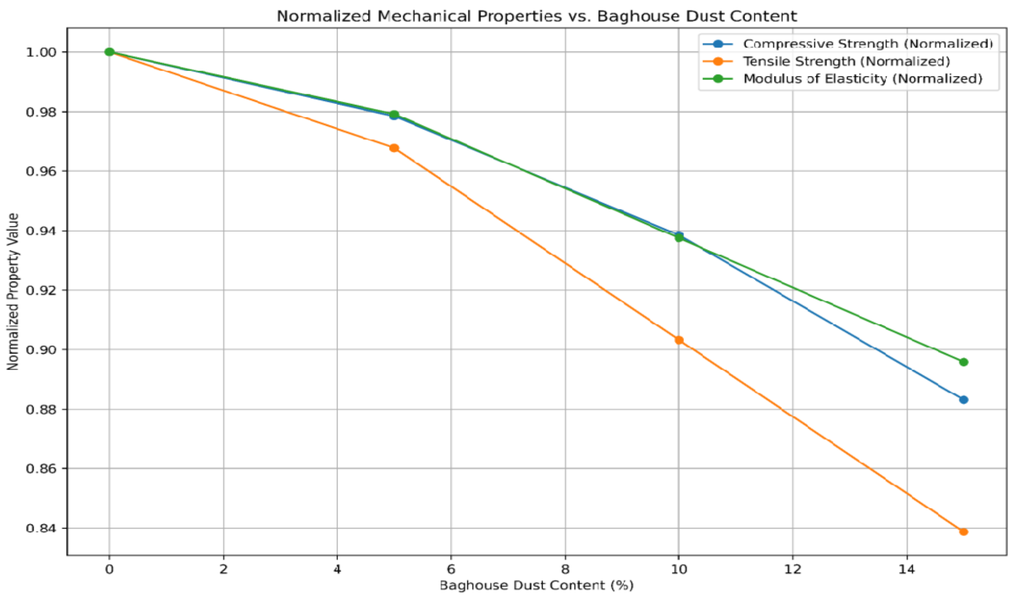

Fig. 6. Graph of Compressive Strength, Tensile Strength, and Modulus of Elasticity plotted against the Baghouse dust content

4. CONCLUSION

The result of the research assesses the mechanical behavior of baghouse dust in asphalt concrete mixes utilizing the Discrete Element Method (DEM). The findings show that consolidating baghouse dust into asphalt concrete can improve specific mechanical properties up to a particular cutoff. Keynotes include:

- Consolidating up to 10% baghouse dust works on compressive strength and elastic modulus, making the mix stiffer and more hearty.
- The ideal baghouse dust content for upgrading mechanical properties without compromising strength is approximately 10%.
- Higher baghouse dust content expands the flexibility of the asphalt mix however diminishes peak stress values and firmness.
- Durability as far as water responsiveness and weariness life improves with the expansion of baghouse dust up to 10% yet diminishes at 15%, showing an edge for powerful dust content.

5. RECOMMENDATIONS

In light of the outcomes of this research, the following recommendations are made:

- Asphalt plants ought to consider integrating up to 10% baghouse dust into their mixes to improve mechanical properties and advance supportability.
- Further research ought to be directed to investigate the impacts of various particle sizes and states of baghouse dust on asphalt mix properties.
- Execute field testing of asphalt mixes in with baghouse dust to approve the research discoveries
- Assess the natural effect of utilizing baghouse dust in asphalt mixes, zeroing in on the decrease of waste and expected outflows during production.

6. LIMITATIONS

- The composition of baghouse dust can shift contingent on the source and production processes, possibly influencing the consistency of the outcomes.
- The study didn't evaluate the drawn-out exhibition and strength of asphalt mixes with baghouse dust under fluctuating climate and burden conditions.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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