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Performance Enhancement of Cold Mix Asphalt via Fly Ash Substitution: Marshal Stability Results

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Abstract

This study examines the enhancement of cold mix asphalt (CMA) performance through the substitution of fly ash at varying percentages. Specifically, Marshal stability tests were conducted on CMA mixtures with fly ash content of 0%, 2.5%, 5%, and 7.5%. The results reveal a significant increase in peak loads, with the CMA mixture containing no fly ash achieving a peak load of 0.62 kN, while mixtures with 2.5%, 5%, and 7.5% fly ash exhibited peak loads of 8.80 kN, 9.59 kN, and 11.08 kN, respectively. This marked improvement underscores the beneficial impact of incorporating fly ash as a filler in CMA mixtures. Furthermore, the maximum flow values of the CMA mixtures also showed enhancement with the inclusion of fly ash. The CMA without fly ash had a maximum flow value of 2.83 mm, whereas the mixtures with 2.5%, 5%, and 7.5% fly ash demonstrated improved flow values of 4.15 mm, 3.84 mm, and 3.09 mm, respectively. These findings indicate that the addition of fly ash not only boosts the load-bearing capacity but also enhances the deformability of the CMA mixtures. The study highlights the potential of fly ash as a sustainable and effective filler material in CMA, contributing to improved mechanical characteristics and reduced moisture susceptibility. The utilization of fly ash in CMA not only promotes sustainability by recycling industrial by-products but also aids in the construction of durable pavement structures. This research provides a foundation for further exploration into the use of alternative materials in pavement construction to enhance performance and sustainability.

Keywords: Cold mix asphalt, fly ash, Marshal stability, mechanical characteristics, sustainable construction

INTRODUCTION

The utilization of Cold Mix Asphalt (CMA) in pavement construction has gained significant attention due to its numerous advantages, including ease of construction, reduced energy consumption, and environmental benefits. However, enhancing the performance of CMA to meet the rigorous requirements of modern pavement engineering remains a challenge. One promising approach is the incorporation of fly ash, a byproduct of coal combustion, as a partial substitute for traditional fillers in CMA mixtures.

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The objective of this study is to investigate the effect of fly ash substitution on the performance of CMA. Specifically, the study aims to enhance the mechanical characteristics and moisture susceptibility of CMA through the optimization of fly ash content.

The scope of this study includes the evaluation of Marshall stability, which is a key indicator of the strength and durability of asphalt mixtures. Additionally, the study explores the impact of fly ash substitution on the flow behavior of CMA, which is crucial for determining workability and compact ability during construction.

This research builds upon previous studies that have demonstrated the potential benefits of using fly ash in asphalt mixtures. For example, Skalsky et al. [1] conducted a systematic review and meta-analysis of randomized controlled trials, highlighting the positive effects of fly ash on asphalt performance. Theoretical and experimental methods employed in this research include laboratory testing of CMA mixtures with varying percentages of fly ash. Marshal stability tests are conducted to evaluate the load-bearing capacity of the mixtures, while flow tests are performed to assess workability [2].

By investigating the effects of fly ash substitution on CMA performance, this study contributes to the development of sustainable and durable pavement solutions. The findings of this research are expected to provide valuable insights for pavement engineers and researchers seeking to enhance the performance of asphalt mixtures through innovative materials and techniques Figure 1 and Table 1 [3].

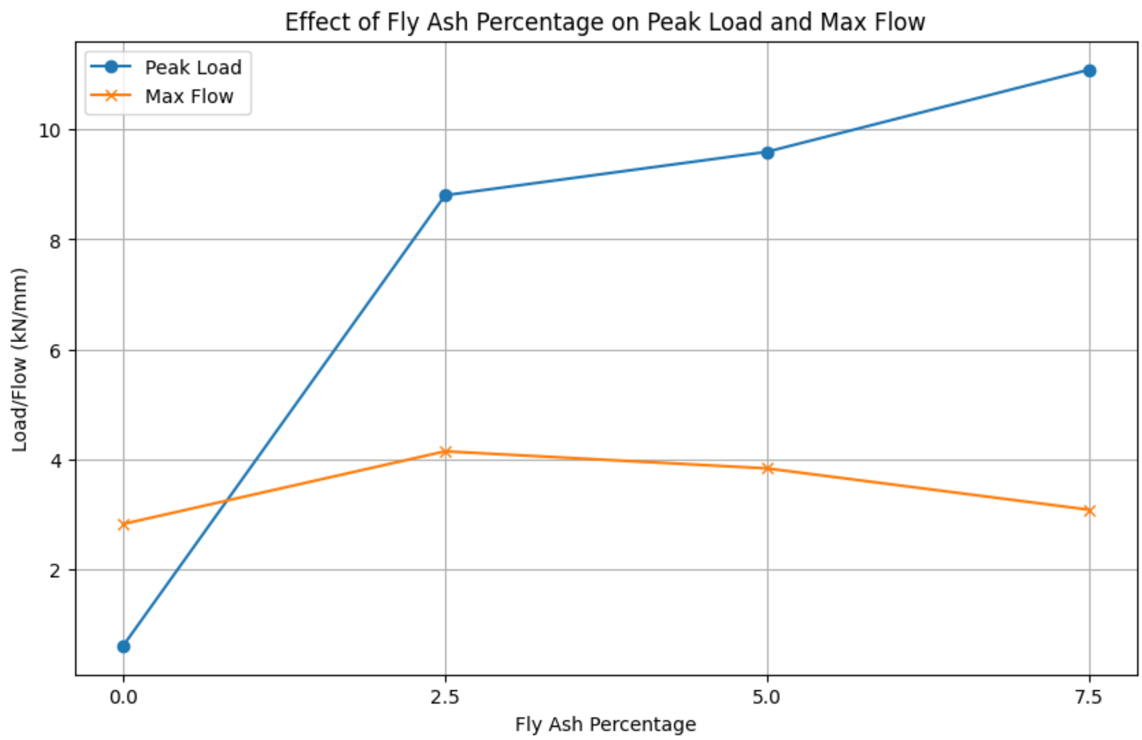

Figure 1. Effect of fly ash percentage.

Table 1. Marshall stability test result on peak load and max flow.

S.N.	Fly ash %	Peak Load	Max Flow
1	Nominal (0%)	63.4kg (0.62KN)	2.83mm
2	2.5%	898.2kg (8.80KN)	2.83mm
3	5%	978.2kg (9.59KN)	2.83mm
4	7.5%	1130.6kg (11.08KN)	2.83mm

METHODOLOGY

Materials

Cold Mix Asphalt

The basic ingredients of CMA include aggregate (such as gravel, sand, or stone) and a binder (usually bitumen or asphalt emulsion). Unlike HMA, which requires heating during mixing and laying, CMA can be mixed and placed at ambient temperatures, making it more convenient for small-scale repairs and maintenance work. The production process of CMA involves mixing the aggregate and binder together, either on-site or at a central plant, to form a workable mixture. This mixture can then be applied directly to the repair area and compacted to form a durable surface [4, 5].

Fly Ash

Fly ash, flue ash, coal ash, or pulverized fuel ash coal combustion residuals (CCRs) – is a coal combustion product that is composed of the particulates (fine particles of burned fuel) that are driven out of coal-fired boilers together with the flue gases. Ash that falls to the bottom of the boiler's combustion chamber (commonly called a firebox) is called bottom ash. In modern coal- fired power plants, fly ash is generally captured by electrostatic precipitators or other particle filtration equipment before the flue gases reach the chimneys. Together with bottom ash removed from the bottom of the boiler, it is known as coal ash [6].

Marsall Stability Test

Sample Preparation

To calculate the amounts of fly ash to be added to the 1200 grams of cold mix asphalt for 2.5%, 5%, and 7.5% fly ash content, the following formulas is used:

For 2.5% Fly Ash Content

Amount of fly ash = (2.5/100) * 1200 grams

For 5% Fly Ash Content

Amount of fly ash = (5/100) * 1200 grams

For 7.5% Fly Ash Content

Amount of fly ash = (7.5/100) * 1200 grams

Calculating Each

For 2.5% Fly Ash Content

Amount of fly ash = (2.5/100) * 1200 grams
= 0.025 * 1200 grams
= 30 grams

For 5% Fly Ash Content

Amount of fly ash = (5/100) * 1200 grams
= 0.05 * 1200 grams
= 60 grams

For 7.5% Fly Ash Content

Amount of fly ash = (7.5/100) * 1200 grams
= 0.075 * 1200 grams
= 90 grams

So, 30 grams, 60 grams, and 90 grams of fly ash for 2.5%, 5%, and 7.5% fly ash content, respectively, to the 1200 grams of cold mix asphalt.

To find out how much cold mix asphalt remains after adding 30 grams, 60 grams, and 90 grams of fly ash for 2.5%, 5%, and 7.5% fly ash content, respectively, you can subtract the amount of fly ash from the total 1200 grams of cold mix asphalt [7, 8].

For 2.5% Fly Ash Content

Cold mix remaining = 1200 grams - 30 grams
= 1170 grams

For 5% Fly Ash Content

Cold mix remaining = 1200 grams - 60 grams
= 1140 grams

For 7.5% Fly Ash Content

Cold mix remaining = 1200 grams - 90 grams
= 1110 grams

Therefore, after adding 30 grams, 60 grams, and 90 grams of fly ash for 2.5%, 5%, and 7.5% fly ash content, respectively, there will be 1170 grams, 1140 grams, and 1110 grams of cold mix asphalt remaining.

To confirm that adding the 30 grams, 60 grams, and 90 grams of fly ash to the subtracted amounts of cold mix asphalt for 2.5%, 5%, and 7.5% fly ash content, respectively, results in a total weight of 1200 grams, we can perform the following calculations:

For 2.5% Fly Ash Content

Total weight = Cold mix remaining + Amount of fly ash
= 1170 grams + 30 grams
= 1200 grams

For 5% Fly Ash Content

Total weight = Cold mix remaining + Amount of fly ash
= 1140 grams + 60 grams
= 1200 grams

For 7.5% Fly Ash Content

Total weight = Cold mix remaining + Amount of fly ash
= 1110 grams + 90 grams
= 1200 grams

Therefore, in each case, adding the specified amount of fly ash to the remaining cold mix asphalt results in a total weight of 1200 grams [9, 10].

Step-by-Step Description for the Marshall Stability Test Procedure

Preparation of Sample

- Keep the sample and the mold in an oven at a temperature between 50 to 60°C to maintain the temperature
- Temperature. Mix the cold mix asphalt with the specified percentage of fly ash thoroughly mix's.

Preparation of Mold

- Heat the mold to the same temperature as the sample in the oven.
- Apply a thin layer of oil to the inside of the mold to prevent sticking.

Filling the Mold

- Fill the mold completely with the mixed sample.
- Place filter paper on both sides of the specimen collar and position it in place on the mold.

Compaction

- Place the filled mold in a mechanical compactor machine.
- Compact the sample with 75 blows on each side of the mold to ensure uniform compaction.

Curing

- Allow the compacted sample to cool down in the mold for 24 hours.

Testing

- Remove the mold from the sample after 24 hours of curing.
- Perform the Marshall Stability test on the specimen to measure its resistance to deformation and its ability to support a load [11–13].

CONCLUSION

The results of this study demonstrate that the substitution of fly ash in cold mix asphalt (CMA) can significantly enhance its performance. As the percentage of fly ash increases, there is a notable increase in the peak load-bearing capacity of the mixture, indicating improved strength and durability. Additionally, the maximum flow values decrease with higher fly ash content, suggesting better workability and compact ability of the CMA mixture.

These findings highlight the potential of fly ash as a sustainable alternative filler in CMA, offering both economic and environmental benefits. By reducing the reliance on traditional fillers and utilizing a byproduct of coal combustion, this approach can contribute to the development of more sustainable pavement solutions.

Future work in this area could focus on further optimizing the percentage of fly ash to achieve the optimal balance between strength, workability, and cost-effectiveness. Additionally, long-term performance studies could be conducted to assess the durability and resistance to environmental factors of CMA mixtures containing fly ash.

Overall, this study contributes to the body of knowledge on enhancing CMA performance through fly ash substitution and provides valuable insights for pavement engineers and researchers seeking to develop sustainable and durable pavement solutions.

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