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Application of coal waste powder as filler in hot mix asphalt

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HIGHLIGHTS

- This study focussed on application of coal waste powder (CWP) in hot mix asphalt.
- The use of CWP had no detrimental effects on stability and stiffness of HMA.
- The moisture resistance indices in CWP mixes was even higher than the reference mix.
- The CWP mix had higher toughness index or flexibility than the reference mix.
- Combination of CWP and limestone in equal proportion attained a mix with higher water resistance.

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ABSTRACT

The main objective of this research was to investigate the effect of coal waste powder as filler material in hot mix asphalt. After sampling the coal waste material from a coal washing plant, it was processed to achieve natural coal waste filler. Furthermore, after incinerating the natural coal waste powder at 750 °C, the coal waste ash was produced. The results of an X-ray diffraction test revealed pozzolanic compounds which encouraged the application of these materials as active filler in hot mix asphalt. The main laboratory program consisted of Marshall stability, indirect tensile strength and resilient modulus tests conducted in dry and saturated conditions. Based on the obtained results in comparison to the reference mix (i.e. a mix containing limestone powder) the coal waste and its ash resulted in higher stability and resilient modulus. Furthermore, the combination of coal waste and limestone powders in equal proportion resulted in a desirable mix with high water resistance. Moreover, the water sensitivity of mixes was also improved by coal waste powder and especially its ash. Considering the stress–strain curve obtained from indirect tensile strength the toughness index parameter was determined which is an indicator of energy absorbency or material flexibility. Results indicated that the hot mix asphalt containing coal waste powder exhibited more flexible behavior than the reference mix.

1. Introduction

The continuing rapid growth in traffic demands along with the increase in allowable axle loads, necessitates higher quality for highway paving materials. The main highway authorities' obligation is to provide safe, economical, durable and smooth pavements that are capable of carrying anticipated loads. To achieve this goal, many experts, engineers, and researchers are devoted to selecting paving materials that can reduce the severity and density of distress and improve the overall performance of asphalt pavements [1]. Because of high construction costs, research studies should concentrate on correct design and choosing appropriate materials which can increase the construction efficiency and extend the pavement service life [2]. Research studies showed that the strength of hot mix asphalt (HMA) depends on different factors such as filler and aggregate type, and bitumen grade. Among these, filler material plays a major role in various properties of HMA, especially those related to mixture compatibility and aggregate-bitumen adhesion [3]. Furthermore, it also affects several HMA properties such as workability, moisture sensitivity, stiffness, durability, fatigue behavior and long term characteristics of HMA. [4]. Fillers vary in physical and chemical properties, shape and texture, size, and gradation. Therefore, selection of suitable filler is very vital for ideal performance of HMA [5]. Nowadays due to environmental and economic concerns the use of recycled waste materials in road pavements has considerably extended [6]. In this regard, several research studies have been performed by environment and transportation organizations which relate to using recycled waste materials as filler in pavement applications [7–9]. In recent researches, materials such as recycled waste lime, phosphate

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waste filler, baghouse fines, municipal solid waste incineration ash and waste ceramic materials were satisfactorily used as filler in different asphalt mixes [10–13].

Sargin et al. evaluated rice husk ash (RHA) as filler in HMA. Based on their report the combination of 50% RHA and 50% limestone powder as filler had the best result and caused improvement in Marshall Stability and reduced Marshall flow in comparison to reference specimens [14].

Chen et al. studied the potential use of recycled fine aggregate powder as filler in asphalt mixture. The recycled aggregates used in the abovementioned study were by-products of the concrete pavement recycling process. The research outcomes indicated that recycled fine aggregates can improve the water sensitivity and fatigue resistance properties of the mixes studied. However, it was reported that the use of recycled fine aggregates may have contrary effects on the low-temperature characteristics of HMA [15].

Sung et al. investigated the potential use of waste lime as filler material in HMA. Finally they inferred that the use of waste lime as mineral filler can improve the permanent deformation, stiffness and fatigue properties of HMA [10].

During a laboratory investigation, Thanaya et al. examined the effect of coal ash on the technical properties of hot and cold mix asphalts. They obtained results showing that the coal ash was a suitable material for use as filler in both cold and hot mix asphalts. According to their recommendation, both cold and hot mixes containing coal ash were suitable to be used in low to medium trafficked areas, pedestrian ways and foot paths [16].

According to the literature waste coal has already been used in concrete blocks for paving, soil stabilization, building materials, production of cement and blended cement. Dos Santos et al. used coal waste as fine aggregate in concrete blocks for paving. Considering the mechanical properties and environmental safety they determined the proper coal waste content that could be used as a part of fine aggregates [17].

Fríasa et al. used coal waste as a pozzolanic additive in blended cement. Results revealed that using up to 20% coal waste by the weight of cement in cement paste increased the 7-day compressive strength of cement mortar [18].

In another study coal waste was used to stabilize base and subbase materials. It was concluded that incorporating coal waste increased the 7, 28 and 90 days compressive strength of stabilized materials [19].

Coal is one of the most abundant resources used to produce energy. Coal production across the world is about 5.5 billiard tons per year and the volume produced in Iran reaches about 310 million tons per year.

The Alborz Markazi coal washing plant which is located in the north of Iran, is one of oldest mines of Iran with 557 million tons of probable reserves. At present, more than 2 million tons of coal waste dumps are available which leads to several environmental problems [20]. Generally the issue of pollution in coal waste is due to pyrite oxidation. When pyrite and materials containing iron are exposed to open air or water or both, they undergo rapid oxidation which results in acidic water. Pollution originating from acid mine drainage (AMD) is considered the most important water pollutant formed around coal mines and coal washing factories. It contains ferric sulfate and other materials that might contaminate water resources [21]. AMD contains high quantities of iron, SO_2 and various quantities of toxic metals [22,23]. One of the solutions for the environmental issue is the use of these coal wastes in various industries such as highway construction.

Coal waste powder (CWP) contains pozzolanic compounds including silica and alumina and can have similar properties to type F pozzolans. The goal of the present study is to investigate the applicability of CWP as filler material in HMA.

2. Coal waste production process

Coal preparation involves physical processes like regulation, gradation and reducing of mineral substances such as ash and sulfur which improve the coal quality. The most important of these operations include screening, cleaning, crushing and separation. Common methods used for coal preparation are gravity concentration (Jig) for coarse and intermediate size coal and the floatation process which is applied for fine size coal [24].

The coal waste used in this study was prepared from the Alborz Markazi coal washing plant located in the northern part of Iran. Raw coals obtained from different mines located in this area are gathered to undergo the preparation process in this coal washing plant. The schematic of the coal washing process is shown in Fig. 1. Raw coals are mixed together and after crushing by special crushers they are screened and divided into two parts. The first part includes coal pieces larger than 80 mm which are returned

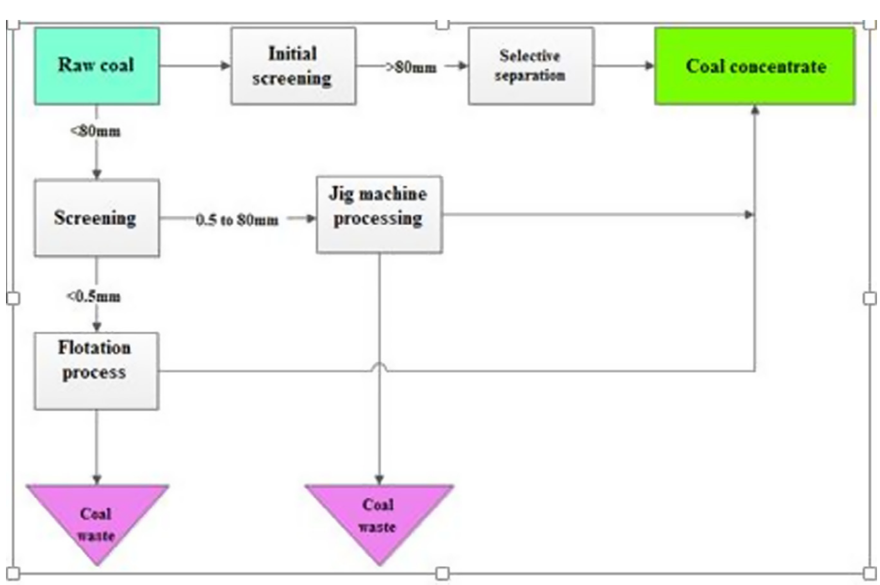

Fig. 1. The schematic of a coal washing plant.