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Laboratory investigation on the properties of asphalt concrete mixture with Rice Husk Ash as filler

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HIGHLIGHTS

- New hot asphalt concrete mixtures is generated using Rice Husk Ash instead of conventional mineral filler.
- A substantial improvement in mechanical properties has been revealed for the new asphalt mixtures.
- In terms of water sensitivity results, the new asphalt mixtures are less sensitive to the moisture damage.

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ABSTRACT

Incorporating of waste and/or by-product materials in construction industry such as production of hot asphalt concrete mixtures provide valuable advantages in terms of environmental and economic points of view. Accordingly, in this laboratory study, it was investigated to use Rice Husk Ash (RHA) instead of conventional mineral filler in hot asphalt mixtures.

The mechanical properties were assessed by conducting Marshall Stability and Indirect Tensile Strength tests. While moisture damage and long term aging were inspected by determining Index of Retained Strength (IRS) and Mean Marshall Stability Ratio (MMSR), respectively.

The experimental results have shown a significant improvement in the mechanical properties and a substantial upgrading in durability of the produced mixtures i.e. asphalt concrete mixtures with RHA as a mineral filler (RHAAC) in comparison with the control mixtures which were prepared with OPC as a mineral filler (OPCAC).

As a result of this study, RHA can be incorporated instead of conventional mineral filler in asphalt concrete mixtures particularly in areas where there is extensive RHA waste.

1. Introduction

Asphalt concrete is the most conventional used material in pavement due to its superior service performance in providing driving comfort, stability, durability and water resistance [21,22]. Generally a flexible pavement layers i.e. surface, binder or base course consist of graded minerals held together by a binder i.e. asphalt cement. Asphalt cement is the more traditional binder used in construction road and highways. While, the mineral aggregate including coarse and fine particles acts as the structural skeleton of the pavement and comprises almost 90% of the volume of Hot Mix Asphalt (HMA) [17]. Furthermore, mineral filler tends to stiffen the asphalt cement by dispersing fine materials in it. Several materials such as lime, cement, limestone dust and fine sand normally used as mineral filler in HMA. It's well-known that cement, lime and limestone dust are expensive and used effectively for other purposes. While, fine sand and ash finer than 0.075 mm sieve size appear to be appropriate as mineral filler.

Using of waste powders as mineral filler in HMA have been investigated previously by several researchers. Phosphate waste filler [15], Jordanian oil shale fly ash [11], bag house fines [7], recycled waste lime [10], municipal solid waste incineration ash [23] and waste ceramic materials [3] have been investigated as filler. It was stated that these waste materials could be used in asphalt concrete mixtures without any considerable drop in its performance.

When mineral filler is mixed with less asphalt cement content than the required to fill its voids, a stiff dry binder is obtained which is practically not workable. On the other hand, overfilling with asphalt cement imparts a fluid character to the mixtures

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[12]. The filler has the ability to increase the resistance of particle to move within the mix matrix and/or works as an active material when it interacts with the asphalt cement to change the properties of the mastic [1]. Also, elastic modulus of HMA can be increased by the addition of mineral filler. However, high amount of mineral filler may produce a weak mixtures due to increase the required amount of asphalt cement to cover the aggregates [8,13].

Rice Husk Ash (RHA) is a by-product material from the combustion of rice husk. While, rice husk is generated from the production of the rice which is extremely prevalent in east and south east of Asia. The husk of the rice is removed in the farming process before it is sold and consumed. It constitutes 20% of the approximately 500 million tons of paddy produced in the world [24].

Nowadays, there is an increasing interest in the utilization of waste materials which is one of the main target schemes for the environmentally friendly processes. In the case of construction industry, there was an increasing trend towards the development and consumption of waste as supplementary cementitious materials. The common pozzolanic agents from biomass and industry by products such as RHA, Ground Granulated Blast Furnace Slug (GGBFS) and fly ash are becoming active areas of research due to the positive environmental effects in addition to the economic issue [9,6,4].

A lot of works were conducted about using RHA in the concrete. For example Givi et al. [9], developed the compressive strength, water permeability and workability of concrete by partial replacement of cement with agro-waste RHA. In addition, decreasing RHA average particle size provides a positive effect on the compressive strength and water permeability of hardened concrete but indicates adverse effect on the workability of fresh concrete [9].

Although a lot of works were conducted about using RHA in many work areas, there is very little work in the literature about the using of RHA in the asphalt concrete. Sargin et al. [18] have investigated the usability of RHA as mineral filler in HMAs. For this purpose, four different serial asphalt concrete samples were produced using limestone (LS) in different proportions (4%, 5%, 6%, and 7%) as mineral filler. The amount of optimum bitumen and the value of Marshall Stability (MS) were determined with MS test for the samples. Choosing the series of asphalt having 5% filler which has given the highest stability. RHA was changed with LS filler in the rate of 25%, 50%, 75%, and 100%. After that MS test was conducted on the produced samples and the results were evaluated. As a result, especially in areas where there is widespread RHA waste, it can be used instead of mineral filler in asphalt concrete mixtures as mineral filler.

A comparison study between marble dust (which is industrial waste material) and limestone dust as filler has been conducted by Karasahin and Terzi [14]. They concluded that Marshall and plastic deformation tests are comparable for the two asphalt concrete mixtures. On the other hand Sharma et al. [19] have reported that a fly ash with high calcium oxide is effective to govern the strength properties of asphalt concrete mixtures. Also, they stated that up to 7% of the fly ash can be incorporated as mineral filler in HMA.

Furthermore, Chandra and Choudhary [5] investigate the possible use of three industrial wastes i.e. granite and marble dust from the stone industry and fly ash from thermal power plants as filler in HMA and compared the results with other mixtures which were prepared with hydrated lime and conventional stone dust from quartzite in India. They concluded that marble dust is the most promising filler and most economical one as HMA with marble dust have the lowest optimum binder content.

In this study, the utilization of RHA in HMA was studied in order to investigate the stresses occurring due to the proposed traffic loading. For this aim, asphalt concrete surface course mixtures were prepared and evaluated by using RHA as mineral filler content and compared with the control mixtures which have been prepared with the traditional mineral filler i.e. Ordinary Portland Cement (OPC).

2. Materials and type testing

2.1. Materials

The laboratory testing within this study were conducted with two types of mixtures i.e. control (with OPC as filler) and modified mixtures (with RHA as filler). The materials used in this work i.e. asphalt cement, aggregate and filler were characterized using traditional lab tests and the results were compared with the standards which are adopted by the State Commission of Roads and Bridges (SCRB R9) [20].

2.1.1. Aggregates

The aggregate used in this investigation were crushed quartz which is brought from one of the hot mix plants at Al-Najaf city, Iraq that is in turn collected form Al-Nibaee quarry. It is worthy to say that the collected aggregate is mainly used for highway construction. The chemical composition and the physical properties of the selected aggregate materials are shown in Tables 1 and 2, respectively.

The selected gradation of coarse aggregate, fine aggregate and mineral filler is shown in Fig. 1 which comply with the specification for roads and bridges for type IIIA surface course mixtures with 12.5 mm maximum size State Commission of Roads and Bridges (SCRB/R9) 2003.

Table 1
Chemical composition of Nibaee aggregate.

Chemical compound	Results, %
L.O.I.	6.55
SiO_2	82.52
CaO	5.37
MgO	0.78
SO_3	2.7
Fe_2O_3	0.69
Al_2O_3	0.48
Mineral composition	
Quartz	80.03
Calcite	10.92

Table 2
Physical properties of aggregates.

Property	ASTM designation	Test results	SCRB specifications
Coarse aggregate			
Bulk specific gravity	C 127	2.64	...
Apparent specific gravity	C 127	2.695	...
Percent wear by Los Angeles abrasion, %	C131	22.7	30 Max.
Soundness loss by sodium sulphate	C88	3.4	12 Max.
Solution, %	C 4791	5	10 Max.
Flat and elongated particles, %	D5821	96	90 Min.
Degree of crushing, %			
Fine aggregate			
Bulk specific gravity	C127	2.67	...
Apparent specific gravity	C127	2.701	...
Sand equivalent, %	D2419	57	45 Min.
Angularity, %	C1252	54	...
Clay lumps and friable particles, %	C142	1.85	3 Max.