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MECHANICAL PERFORMANCES OF WARM ASPHALT MIXTURES CONTAINING WASTE FILLERS POWDERS

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Abstract

The effect of waste fillers on the volumetric and mechanical performances of warm asphalt mix was studied in this research. The cationic emulsified asphalt combining with cement kiln dust, fly ash, and hydrated lime as fillers were mixed with quartz aggregate following the Marshall design of mix. Two waste fillers contents 50%, and 100% percent of limestone filler were replaced. For the performance assessment of the warm asphalt mixes, the Marshall stability, the indirect tensile strength, moisture susceptibility, and repeated loads tests were carried out. Results of this work exhibited that the use of waste materials as a filler were beneficial in improving the mechanical performances of the warm asphalt mixtures. Generally, it was found that the stability and moisture resistance of modified warm asphalt mixtures improved. Furthermore, the use of cement kiln dust and hydrated lime can improve the rutting performance at high temperatures (55) ^{o} C. Besides the results show that the stability and indirect tensile strength were improved to about (15.8, 13.7) kN and (860,715) kPa, respectively. In addition, the C.K.D and H.L. fillers at 100% of replacement were the best anti-stripping agent, due to improves the resistance of moisture susceptibility by increasing the T.S.R. to about (96.7 and 94.5) respectively.

Keywords: Marshall properties moisture susceptibility, Uni-axial repeated loading, Warm asphalt mix, Waste fillers.

1. Introduction

In recent times, global warming, CO_2 gas emissions, and the continuing consumption of energy costs represent actual difficulties, which are placing pressure on the manufacturing processes in general. Additional pressure in the construction of flexible pavements further to the above is the safety and health matter, with the use of hazardous high temperatures degrees plus exposure to fumes and dust through the production of hot asphalt mixtures. All these increase important considerations to invention more economic and sustainable alternatives [1]. Therefore, the warm asphalt mixture technique has to pay attention to numerous researchers and huge efforts have been expended to progress this mixture.

The warm asphalt mix is a sustainable alternative in the construction of flexible pavements. The warm asphalt mixture technology, which is used commonly in recent decades, permits the asphalt mix to be mixed at (10-50) °C lower than ordinary hot asphalt mix. The main objective of warm asphalt mix is to produce the asphalt mix with the same characteristics as strength, durability, and performance for hot asphalt mix using lower mixing and compaction temperatures. This decrease in the HMA mixing and compaction temperatures will provide many advantages; including saves energy, decreases CO_2 gas emissions and fumes released during the construction of hot asphalt pavements and creates it more environmentally friendly [2]. Lower mixing and compaction temperatures can also possibly develop the performance of flexible pavement by decreasing asphalt binder ageing process, which permits for using greater quantities of recycled asphalt pavement without addition any asphalt binder rejuvenators [3]

The main mode of failure in pavements is permanent deformation (rutting). The specialists seek to control this failure to satisfactory limits within a pavement design life. The permanent deformation is produced by the slow accumulation of irreversible strains under repeated loading which develops into a measurable rut. These strains are, attribute to the main effects as viscous-elastic behavior of the asphalt binder under dynamic loading, traffic considerations, and environmental conditions [4, 5].

The waste materials reprocessing into beneficial products has become a chief solution to waste problems. Many studies are conducting concerning the feasibility, environmental suitability, and performance of using recycled materials in the construction of highway pavements. Waste materials can generally be characterized as manufacturing wastes such as silica fume, slag, cement kiln dust, fly ash, used-foundry sand and recycled concrete [6-9].

The term filler material is usually referred to as the fine powder with particle size passing of the standard sieve no. (200). Because it accounts for more than 90% of the total aggregate surface area, it forms the interface transition zone of the aggregate and asphalt binder [10]. The filler material is considered as a fine powder which can be used to modify the characteristic of the asphalt binder and mix. To this point, limestone dust, hydrated lime, fly ash, and cement kiln dust powders are counted as fillers materials. A lot of researches focused on the role of fillers materials in the asphalt binder mixture, the results showed that the performance of the asphalt mixture is improved in terms of different physical characteristics such as the stability, stiffness, moisture damage resistance, and permanent deformation resistance [11-13].

This research aims to assess the influence of using four types of waste materials termed fly ash (F.A.), cement kiln dust (C.K.D.), hydrated lime (H.L.), and limestone dust (L.S.) as mineral fillers by two contents; 50%, and 100%, by filler percent on the Marshall properties and moisture susceptibility of warm asphalt mixture. Also, to assess the rutting performance of the warm asphalt mixture using repeated loads test.

2. Research methodology and Experimental procedures

The crushed quartz aggregates provided from the Al-Nibaay quarry, located at the at the Northwest region of Baghdad city were used for this research. This aggregate type is commonly used in Iraq for producing the asphalt mixtures. Four types of waste materials powder were separately used as filler material in this research, which are fly ash (F.A.) powder brought of the local market, cement kiln dust (C.K.D.) powder obtained of the plant of cement in the Najaf governorate, hydrated lime (H.L.), and limestone (L.S.) dust powders obtained from plant of lime in the Karbala Governorate.

The Slow-setting cationic emulsified asphalt low viscosity type (Css-1) was used in this research, attribute to the compatibility with a varied range of aggregate. The emulsion (Css-1) type was imported from MEGA Company located in Turkish, it is usually used as binder material to produce a dense-graded mix. It is experimental that the product mixes are workable satisfactorily during the mixing process with a sufficient coating rate. Mixing technique and coating rate for warm asphalt mix; many trials were carried out to select the appropriate mixing technique which would attain the good coating rate.

All mixing techniques were achieved by hand in a steel container using the big spatula. The proper mixing technique includes preheating the aggregates and fillers in an oven at 105 to110 °C and mixed together for two hours. Then, gradually added of emulsified asphalt contents as (5.45, 6.36, 7.27, 8.18, and 9.1)% by total weight of mixture, combined to the hot aggregates and fillers in steel container applied on the electrical oven for 10 minutes to obtain a suitable coating rate of the warm mix.

3. Laboratory Tests of Warm Asphalt Mixtures

Marshall Test carried out the control warm asphalt mixture with limestone dust of filler type. This test was done according to the standard specification by five contents of the emulsified asphalt. Then, determining the optimum emulsified content. The percentages of replacement of filler types were 50% and 100% by filler percent. Besides, assess the Marshall properties, moisture susceptibility, and permanent deformation of the modified warm asphalt mixture with waste materials.

3.1. Marshall characteristics of warm asphalt mixtures

Five contents of the initial emulsified content were selected, as (5.45, 6.36, 7.27, 8.18, and 9.1)% by total weight of the mixture, were prepared to determine the optimum emulsified content for each mixture. The (15) Marshall Samples were cast and tested according to the standard specification [14].

3.2. Indirect tensile strength (I.T.S.) test of warm asphalt mixtures

The indirect tensile strength test is indicated to assess the moisture susceptibility of the warm asphalt mixture according to the standard specification [14].

3.3. Uni-axial repeated loading testing (URLT)

In this research, a systematic repeated controlled stress via URLS [14] were subjective to carry on the cylindrical warm asphalt mixes that have dimension 101.6 and 203.2 mm for diameter and height respectively. A compressive load repetition in the shape of the rectangular wave was detected under the vertical stress level of 20 and a fixed loading frequency of 1 Hz 0.1 s load and 0.9 s for load and rest period.

4. Results and Discussion

Figur1 shows various emulsified amounts of warm asphalt mixtures. The emulsified content increases the bulk density. The peak value of density is achieved at 7.27% of emulsified content. The sample's volume reduces as its weight rises, increasing the bulk density. A thicker film is formed after the ideal emulsified content, lowering the aggregate contact distance. Sample volume rose while bulk density dropped. fn (2) Values of air voids vs. emulsified content. The emulsified content reduces the air spaces. Adding emulsified material to the mix reduces air spaces and causes emulsified content to fill voids. Air gaps are allowed in hot asphalt mixtures up to 3%.

The emulsion stability values, emulsification promotes stability, as demonstrated in the graph. The emulsified content raises aggregate coating degree. Increasing the emulsified content diminishes the stability, resulting in softer mixes [15].

In Fig. 2, the modified warm asphalt mixes at replacement contents 50%. These results are attributed to improving the stiffness of the modified emulsified binder by hydration reactions between C.K.D. filler with available water in the mix and produced the hydration products as (C.S.H) gel and resulted enhance the density and the voids filling of this mixture.

Figure 3 shows several emulsified heated asphalt mixes 5). Emulsification raises bulk density. 7.27% emulsified content density Volume shrinks as weight increases, increasing bulk density. After the optimal emulsified content, a thicker film forms, reducing aggregate contact, sample volume rising.

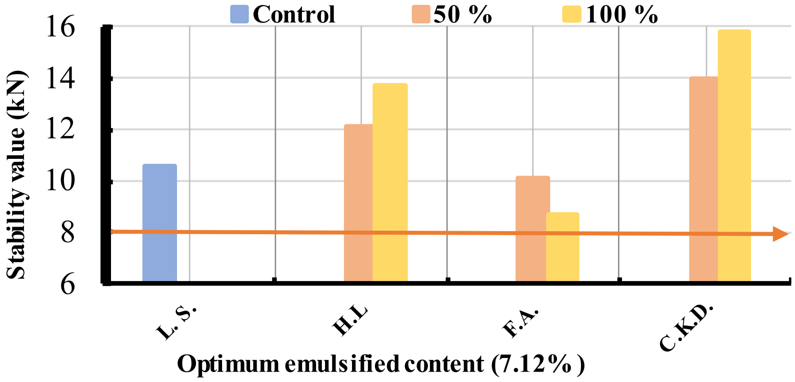

Fig. 1. Stability values at the optimum emulsified content (%) for warm asphalt mixtures modified with various fillers types.

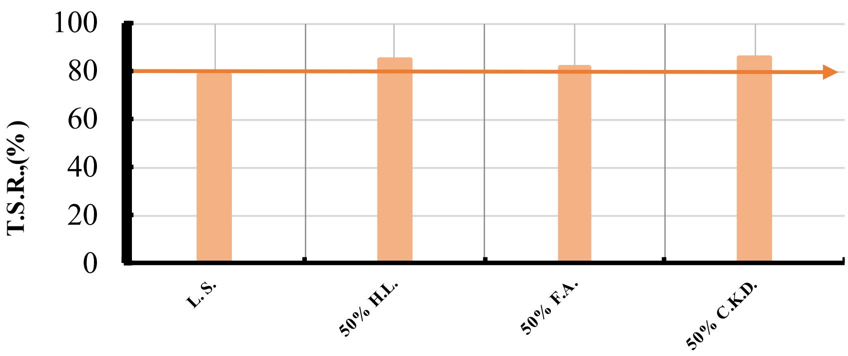

Fig. 2. T.S.R. values at the optimum emulsified content (%) for warm asphalt mixtures modified with various fillers types.

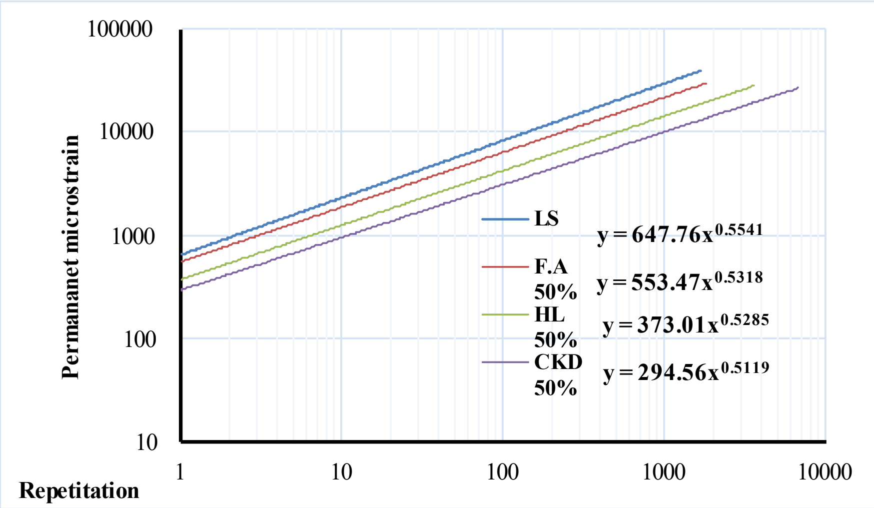

Fig. 3. Rutting resistance at the optimum emulsified content (%) for warm asphalt mixtures modified with various fillers types at 55 °C.

5. Conclusions

Based on the results of the experimental tests, the following conclusions were drawn:

- The emulsified asphalt type (CSS-1) mixed with the crushed quartz aggregate type at optimum emulsified contents, the mixes provided a suitable mixing process and have a coating rate more than 75% by optical inspection.
- Preheating the aggregates and fillers in an oven at (105-110°C) for two hours is recommended. Then, for ten minutes, progressively add emulsified asphalt contents (5.45, 6.36, 7.27, 8.18, and 9.1) percent by weight to the hot aggregates and fillers to get an appropriate coating rate of warm asphalt mix.
- From several trial warm asphalt mixes, it is concluded that the best range of contents for initial emulsified to produced satisfactory results of the mixing process, coating rate, and stability are ranged from (5.45, 6.36, 7.27, 8.18,

and 9.1)% by total weight of the mix and hence the optimum emulsified content is 7.12%.

- Mechanical properties of warm asphalt mixtures such as Marshall Stability and indirect tensile strength were improved to about (15.8, 13.7) kN and (860,715) kPa, respectively. When C.K.D and H.L. were used as a replacement for limestone dust at 100%.
- Using fly ash filler as a replacement for limestone filler reduced the stability by approximately (8.7) kN, besides it has improved the T.S.R. about (88) kPa, at the at 100% percent of replacement. The enhancement in the indirect tensile strength value for the wet state is more than for the dry state.
- The permanent deformation behavior parameters slope and intercept were greatly influenced by substituting 50% and 100% for H.L. and C.K.D. The permanent deformation slope and intercept were reduced. This waste mineral filler improves the elastic modulus of warm-mix asphalt. Unlike F.A., the robust modulus increases when L.S. is substituted with H.L. or C.K.D. The usage of F.A. as a limestone substitute results in a 2.4% and 1.2% increase L.S.

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