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Investigating the Effect of Olive Husk Ash on the Properties of Asphalt Concrete Mixture

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ABSTRACT

Technology in transportation used available resources to make it safe, fast, suitable, easy, economic, and environmental to transport people and goods. Olive Husk became an environmental problem as waste materials especially in the Middle East where huge quantities are found. The objective of this research is to investigate the effect of addition of Olive Husk Ash (OHA) on the properties of asphalt concrete mixtures. Marshall Test was used to perform the asphalt concrete mixture by the addition of OHA to the binder of asphalt; different percentages of OHA (0, 5, 10, 15, and 20%) by volume were added to the binder. Five percent of asphalt cements (5, 5.5, 6, 6.5 and 7%) by weight and limestone aggregate were used for preparing asphalt mixture specimens to find the optimum content of asphalt that could be used in the binder. Tests on flow, stability, air void percentage and void in mineral aggregate, retained stability, stiffness, and retained stiffness were made. The principle results on OHA as filler in Asphalt binder improves the Marshall Stability, and void in mineral aggregate and decrease in flow, retained stability, stiffness, and retained stiffness with a 10%-15% of olive husk ash replacement of asphalt binder. The contribution that OHA could be used as a pavement construction material in field.

1. INTRODUCTION

The application of scientific principles and technology in transportation planning, design, operation and management of its facilities can produce a safe, fast, suitable, easy, economical and environmentally sociably acceptable method to transport people and goods.

Al-Omari et al. [1] studied the Waste Vegetable Oil (WVO) as an additive to the asphalt cement, to be used in flexible pavements construction. Addition of 1%, 2%, 4%, 6%, and 8% of waste vegetable oil by volume of the asphalt binder were used. It was found that selecting the appropriate amount of waste vegetable oil will modify most of the tested properties. It was concluded that using the suitable amount of waste vegetable oil as cement improve is feasible, and can be deliberated as a proper and legal method for dumping the waste vegetable oil.

Khedaywi et al. [2] investigated effect of addition of the Olive Waste Ash (OWA) on the properties of asphalt cement (80/100) and limestone aggregate. Different levels of OWA (0, 5, 10, 15, and 20%) by volume of binder were used. Tests on asphalt-ash binder, such as penetration, softening point, ductility, fire and flash point, and specific gravity were performed. Marshall tests and dynamic creep tests were accomplished at different temperatures (20, 30, and 40°C) and load frequency levels (1, 4, and 8Hz). The authors found that both of penetration and ductility have decrease with the increase in OWA content. However, specific gravity, softening point, fire and flash point, voids in mineral aggregate, and air voids all have increased with the increase of the OWA content. It is also found that the dynamic modulus has decreased with the increase of OWA content.

Al-Qadi et al. [3] studied the effect of oil shale ash on rutting of flexible pavement. Oil Shale Ash was added to the asphalt cement concrete mixture. Specimens, with several percentages (0, 5, 10, 15 and 20%) of ash by volume of binder, were prepared. The specimens were exposed to static creep tests through the Universal Testing Machine (UTM). Tests were performed using three testing temperature levels (5, 25 and 40°C). The authors concluded that the use of oil shale ash as additive to hot mix asphalt by (5, 10, 15 and 20%) will reduce the cost of construction of asphalt cement concrete mixtures. An optimum percentage of oil shale ash equal to 12.5 was found to reduce rutting. This has led to an increase in stiffness, resilient modulus, and the accumulated strain of the asphalt cement concrete mixture. Moreover, both of rutting depth and air voids have been decreased.

Al-Zaidyeen and Al-Qadi [4] studied the influence of a waste material called phosphogypsum on the stabilization of the layers of pavement to enhance the properties of the non-plastic soil in the city of Aqaba – Jordan. Several percentages (0, 5, 10, 20, and 25%) of phosphogypsum by weight of soil were used. Specimens were prepared according to an optimized material's formula for the mixture and tested (both sieving and grading of soil, atterberg limit, dry unit weight, moisture content, proctor and California bearing ratio) and the results were reported. The authors found that the best percentage of phosphogypsum is 21% in the all tests.

Al Qadi et al. [5] studied effect of crumb rubber (CR) on asphalt cement mixture as a replacement of aggregate (fine or course). For the asphalt cement samples, three sizes (numbers: 4, 8, and 50) of sieves for CR have been used. Several percentages (4, 4.5, 5, 5.5 and 6%) of asphalt cements and several percentages (10, 20, 30 and 40%) of CR all by weight of aggregate have been used for preparation of the samples of the asphalt cement mixture. The hot-mix Asphalt Marshal method of testing was implemented in testing the asphalt mixture samples. Seventy two samples were tested and results of Marshall Properties (flow, stability, bulk density, air void percentage and voids in mineral aggregate) were reported. The authors found that the effect of replacement of CR to the fine aggregate enhances both of stability and flow, better than the effect of replacement of CR to coarse aggregate.

Shu and Huang [6] conducted a review to the use of waste tire-rubber in Portland cement and asphalt. The authors found that, in the asphalt paving industry, the rubber-asphalt mixtures are compatible with both of the extensively used sustainable technologies of the warm-mix asphalt and reclaimed asphalt pavement.

Pettinari and Simone [7] studied the effect of use crumb rubber (CR) in cold mixtures by maximizing the valorization of recycled materials. Two levels of gradation of CR were implemented in the making the cold-recycled asphalt-cement mixture. Both of the indirect tensile stiffness and strength modulus have been reported from the tests. The authors concluded that the gradation of crumb rubber has affected the mechanical and compaction properties of the mixture.

Alsheyab and Khedaywi [8] investigated the influence of electric arc furnace dust to solve the problem of waste by mixing it with asphalt-cement for the purpose of construction of highways. It was added to the asphalt cement mixtures with different percentages by volume of mixture. Ductility, specific gravity, penetration, softening point, flash point, fire point and rotational viscosity were investigated. The authors found that both penetration and ductility have decreased with the increase in electric arc furnace dust concentration of mixture. However, specific gravity, softening point, flash point, fire point and rotational viscosity have increased with the increase in electric arc furnace dust concentration in mixture. The authors concluded that the electric arc furnace dust can be used for road construction.

Gautam et al. [9] investigated effect of using recycled materials in several layers of pavements. The authors indicated that the use of secondary material not only provided an effective waste disposal approach, but also reduced both the request on regular material and the total cost of construction. However, their fields of application were limited. The authors suggested several solutions to encourage the use of recycled material in pavement.

Arafat et al. [10] studied the sustainable lignin that could promote asphalt binder oxidative aging properties and mix properties. Several kinds of lignin were used as substitution to six percent of the asphalt mixture to study their effect on the aged and un-aged asphalt mixture. These kinds of lignin are the: the kraft lignin, lignin experimentally obtained from black liquor, and lignin experimentally obtained from rice hulls using a special kind of solvent. A control asphalt mixture was also prepared. The high-temperature performance grade was better with the lignin additives. The asphalt mixtures with the lignin additives have greater tolerance of strain compared with the control mixture in the sweep test of strain. The long term index of aging is better when adding either of the lignin's obtained from the back liquor or rice hulls to the asphalt mixture. Substitution of the asphalt mixture by six percent of the black liquor lignin is reasonable for hot mixtures and could be to applicable less-hot mixtures.

The objective of this research is to study the effects of replacement of asphalt cement by olive husk ask (OHA) on the properties of asphalt concrete mixture. The optimum concrete mixture is obtained then; several percentages of OHA are added to the optimum asphalt concrete mixtures as replacement to the asphalt cement. Tests on Marshall specimens have been performed and results on properties of asphalt cement concrete mixture are reported and analyzed. This research is expected to help resolve the problem of disposal of the olive husk ash.

2. MATERIALS AND TESTS

The materials used to conduct the tests are asphalt cement, limestone aggregate, and olive husk ash. Asphalt cement grade 60-70 was produced from petroleum Refinery Company in Zerqa, Jordan. Tests on asphalt cement are penetration 64, softening point 50°C, ductility 114 cm, flash point 320°C, fire point 325°C and specific gravity 1.017. Olive husk Ash (OHA) was obtained by burning olive husk at 400°C. The corresponding specific gravity of the OHA is 2.23.

Table 1. Properties and gradation of limestone aggregate [11]

A-Properties of Limestone Aggregate				
Type of Aggregate	**ASTM test Designation**	**Bulk Specific Gravity**	**Apparent Specific Gravity**	**Water absorption (%)**
Coarse Aggregate	C 127	2.581	2.657	3.2
Fine Aggregate	C 128	2.703	2.682	4.5
Mineral filler	C 128	2.667	2.492	5.1

B-Aggregate Gradation, Wearing Layer, Medium Traffic		
Sieve Size	**MPWH specification**	**% passing**
1" (25.00 mm)	100.0	100
1/4 " (19.00 mm)	90-100	95
1/2 " (12.5 mm)	71-90	80.5
1/8 " (9.5 mm)	56-80	68
No. 4 (4.75mm)	35-56	45.5
No. 8 (2.35 mm)	23-38	30.5
No. 20 (850 µm)	13-27	20
No. 50 (300 µm)	5-17	11
No. 80 (180 µm)	4-14	9
No. 200 (75 µm)	2-8	5

Table 2. OHA on Marshall properties of asphalt concrete mixture

Properties		OHA By Volume of Binder (%)				
		0	5	10	15	20
Marshall Stability (kg)	Dry	1550	1720	1680	1700	1780
	Wet	954.79	940	1140	1190	1600
Marshall Flow (25mm)	Dry	21	22	17.3	16	14.66
	Wet	21	24	21	22	20
Unit weight (kg/m^3)		144.120	142.56	141.721	140.191	141.044
Voids in Mineral Aggregate (%)		17.1	18.4	19.1	20.3	20.1
Air Voids (%)		5.2	6.2	3.9	5.4	5.4
Retained Stability (%)		61.5	54.6	67.8	70	80.8
Marshall stiffness (kg/mm)	Dry	205.2	312.7	388.4	425	485.6
	Wet	181.7	156.6	217.1	216.3	320
Retained stiffness (%)		61.5	50.0	55.9	50.9	65.8

Limestone aggregate was obtained from Al-Huson quarries located in Northern Jordan. The specifications of Jordanian Ministry of Public Works and Housing (MPWH), Directorate of Planning and Development [11] were implemented in grading. The properties and gradation of aggregate are listed in Table 1.

The optimum asphalt content was determined following the procedure described in the MS-2 Manual [12] and ASTM D1559 [13] standards for Marshall mix designs. The percentages of the asphalt cement by volume of the asphalt concrete mixtures are equal to 5%, 5.5%, 6%, 6.5%, and 7%. Three samples from each of the Marshall mix designs were tested for flow, stability, air voids, voids in mineral aggregated, and unit weight. The average value of asphalt cement content that satisfies the max. unit weight, optimum stability, and four percent of air voids, is the optimum asphalt cement content. This average value is for asphalt cement percentage equal to 5.25 of the asphalt concrete mixture.

Asphalt cement content at maximum stability = 5.2%

Asphalt cement content at 80% VFB = 5.5%

Asphalt cement content at max unit weight = 5.0%

Asphalt cement content at 4% air voids = 5.3%

Asphalt cement content = (5.2 + 5.5 + 5.0 + 5.3)/4 = 5.25%

For Marshall tests, a 1200 gm. of aggregate was used in the mix design. The aggregate was washed, dried and sieved according to MPWH specifications. Both the aggregate and molds were placed in the oven to heat for 149°C for one day. Similarly, the asphalt cement was left to heat under same temperature as aggregate for only sixty minutes. After that, the aggregate was mixed with the asphalt cement until full coating was attained. Mixing was performed manually. The asphalt cement aggregate mixture was filled in a Marshall mold. Medium traffic was indicated by compacting 50 blows on both faces of the specimen. Specimens were left to cool at room temperature before extruding from the mold.

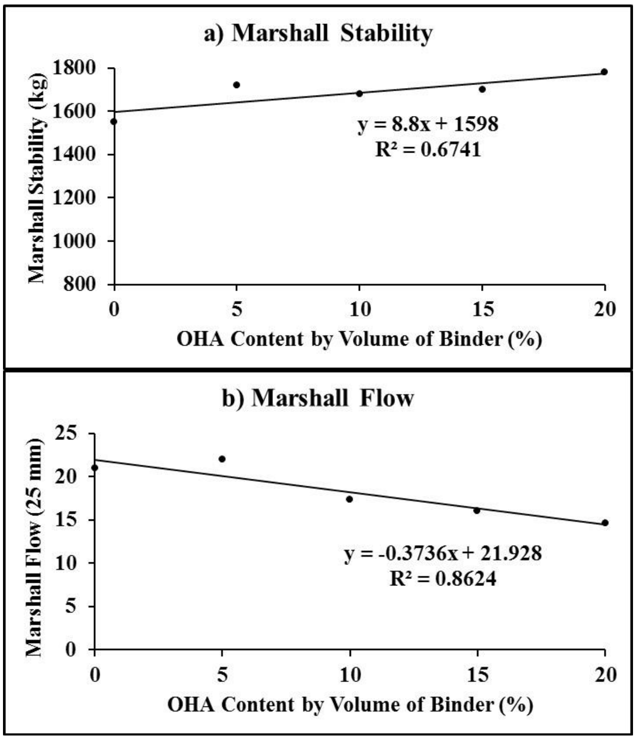
Three specimens from each mix were prepared. The specimens were forced out of the Marshall molds after one day. The hot samples were immersed in water at 60°C for forty minutes. The Marshall Apparatus was used for testing the specimens to obtain the results listed in Table 2.

3. RESULTS AND DISCUSSION

The Marshall stability test gives a good indication of asphalt mixtures stiffness. The volumetric analysis of the tested specimens can be used to determine mixture density, voids in mineral aggregate (VMA), void filled with bitumen (VFB) and absorbed asphalt which are very important parameters in understanding the behavior of asphalt cement concrete mixtures.

It should be mentioned that the Marshall stability test does not always provide a complete explanation of all asphalt cement concrete mixture properties. There were several specimens with a high Marshall stability that showed rutting ability. However, the Marshall stability test has the advantage of shorter time of testing since it only needs one hour of curing and fifteen minutes of testing for all of the fifteen specimens that have been used in the current study. This is a relatively short time compared with twenty-four hours' time in controlled environmental chamber and one hour for a specimen test using of the static creep test. In addition, the Marshall stability test is an available method of testing that is not costly. Therefore, it has been used to give an indication of the behavior of asphalt cement concrete.

Equations and R-squared values have been displayed on all figures to illustrate the trends and strength of relationships, respectively. The effect of olive husk ash content on Marshall stability is shown in Figure 1(a). It can be seen that increasing the OHA content has resulted in increase in Marshall stability. This result can be explained by the fact that adding OHA increases asphalt cement binder stiffness and tensile strength.



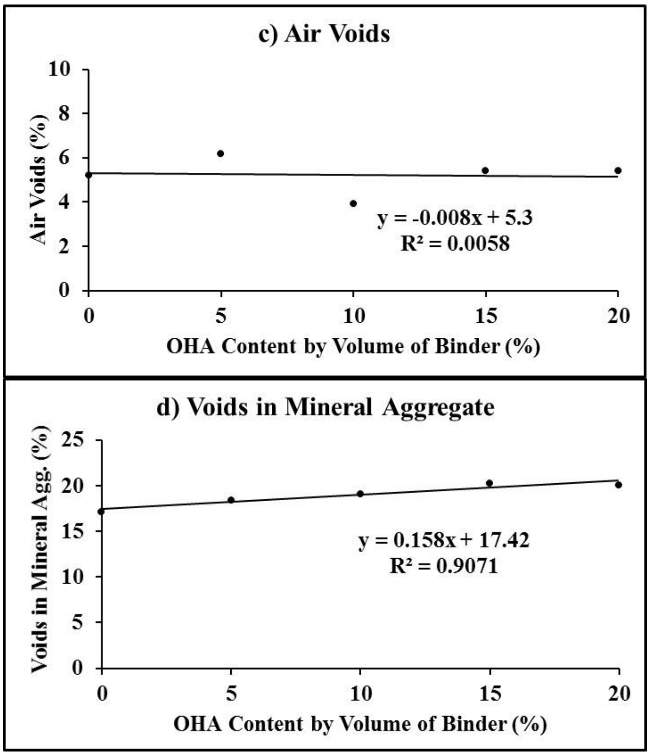


Figure 1. Effect of olive husk ash on properties of asphalt cement concrete mixture

Flow is defined as the vertical deformation under a load of the compacted mixtures. The effect of OHA content on flow is shown in Figure 1(b). It can be seen that increasing the OHA content has resulted in decrease in the flow. This is due to the decrease of the amount of asphalt cement in the binder which reduces lubrication between the aggregate particles. Thus, the addition of OHA increases the asphalt cement binder hardness. The effect of OHA content on air voids is shown in Figure 1(c). It can be seen that the increase in OHA content has no effect on air voids. This result indicates that the increase in OHA content has no effect on the resistance for weathering actions even though the open structure of the OHA traps a lot of interstitial space.

Voids in mineral aggregates (VMA) is defined as the volume of inter-granular void spaces between the aggregate particles of compacted paving mixture that includes the air voids and the effective asphalt content. VMA is expressed as a percentage of the total volume of the sample. The effect of OHA content on voids in mineral aggregate is shown in Figure 1(d). It can be seen that increasing the OHA content has resulted in increase in voids in mineral aggregate. The increase of OHA content has resulted in increase in asphalt cement binder viscosity so that its ability to fill all voids will decrease. As the percentage of OHA increases, the absorption of aggregate decreases, so the effective binder content increases, which improves the interlocking flexibility of the asphalt concrete mixtures increases. The voids in mineral aggregate were obviously lower when the OHA content was 20%, than that when the OHA content was 15% suggesting the that a 10%-15% of olive husk ash replacement of asphalt binder will improve the results.

The effect of OHA content on retained stability is shown in Figure 2. It can be seen that increasing the OHA content has resulted in increase in retained stability. This is expected because the increase of OHA will increase the asphalt cement binder resistance to stripping.

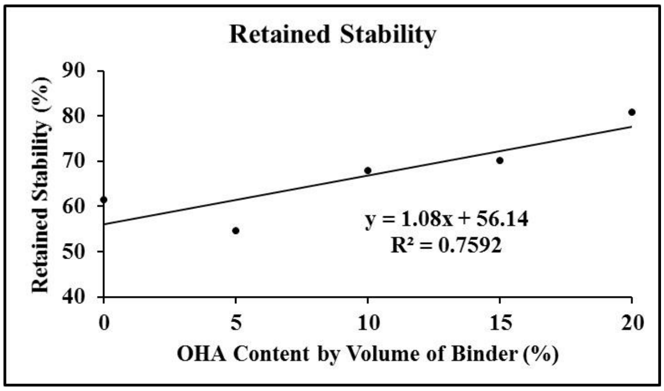


Figure 2. Effect of olive husk ash on retained stability of asphalt cement concrete mixture

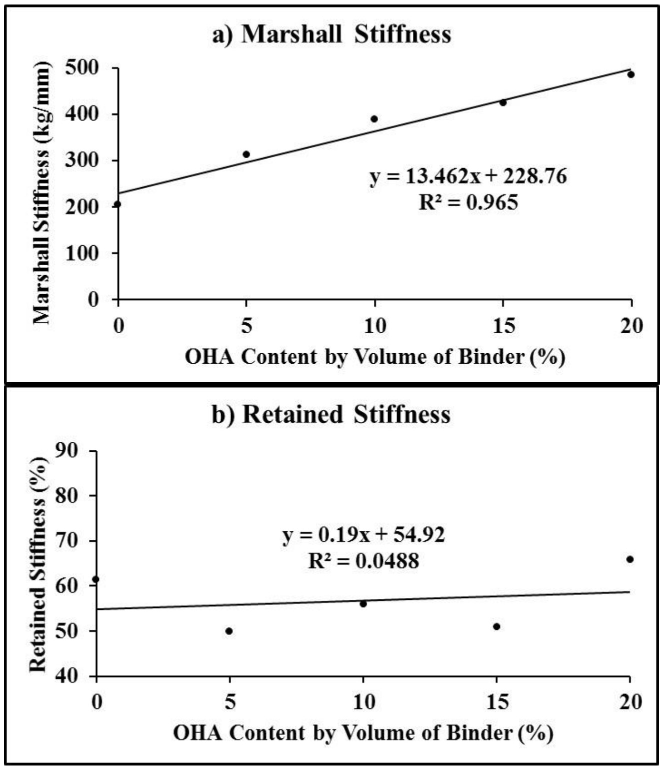


Figure 3. Effect of olive husk ash on Marshall and retained stiffness of asphalt cement concrete mixture

The effect of OHA content on Marshall stiffness is shown in Figure 3(a). An increase in OHA content has resulted in increase of the Marshall stiffness. The increase of OHA will increase the hardness and cohesion of asphalt cement binder. The effect of OHA on retained stiffness is shown in Figure 3(b). The increase in OHA content will increase the retained stiffness. As stated before, the increase of OHA will increase asphalt binder resistance to stripping.

4. CONCLUSIONS

The Marshall test method of design was used to estimate the optimum asphalt cement content which was equal to 5.25%. The replacement of OHA to the asphalt cement by (0, 5, 10, 15, and 20%) is then performed on the asphalt cement aggregate mixture. Marshall properties of the asphalt cement concrete mixtures were evaluated. Results indicate that:

(1) Both of Marshall and retained stability in addition to

voids in mineral aggregate are all directly proportional to the OHA content.

(2) Marshall flow is inversely proportional to the OHA content while Air voids are not affected by the OHA content.

(3) The use of OHA as a replacement to the asphalt cement in asphalt cement aggregate mixtures is a promising technique to resolve the environmental problem of the OHA waste and to reduce the demand on the non-renewable asphalt cement material.

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