Mechanical and Microstructure Characteristic of Oil-based Drilling Cuttings as Mineral Powder Substitute in Hot Mix Asphalt Mixture

Balen Z. Abdulsamad[1†], Ameen A. Muhialdin[2], Tolaz S. Hawez[2] and Rahel K. Ibrahim[2]

[1]Department of Geotechnical Engineering, Faculty of Engineering, Koya University, Koya KOY45, Kurdistan Region – F.R., Iraq

[2]Department of Civil Engineering, Faculty of Engineering, Koya University, Koya KOY45, Kurdistan Region – F.R., Iraq

Abstract—**Beyond the intensive worldwide oil wells drilling activities for seeking energy, the amount of oil-based drilling cuttings (OBDC) increased significantly, OBDC defined as a wasted drilling mud which is used in the drilling operation of oil wells. The OBDC falls under the category of hazardous waste that contains heavy metals and radioactive elements. In this study, OBDC was used as a substitute of mineral powder in hot mix asphalt. Various doses of OBDC (0%, 25%, 50%, 75%, and 100% by weight) were employed to replace the mineral powder. Marshall specimens were prepared to assess the physical characteristics and examine the microstructure. In results, by employing OBDC to 100%, The Marshall stability decreased from 12.1 kN to 9.22 kN, and flow value decreased from 3.96 mm to 3.3 mm compared to control specimen (0% of OBDC) due to the presence of uncoated and agglomeration of large amount of OBDC particle in bitumen constituent as examined by scanning electron microscope. Air voids increase from 3.9% to 4.26% and voids in mineral aggregates increase from 14.63% to 15.20% when mineral powder replaced by OBDC filler from 0% to 100%, respectively, due to the difference between the specific gravity of OBDC and mineral powder, in which higher percentage of OBDC leads to increase the porosity of the specimen. Utilizing 100% of OBDC instead of the mineral powder is compromised because the result falls within the standard ranges.**

Index Terms—**Hot mix asphalt, Marshall stability, Mineral powder, Oil-based drilling cuttings, Scanning electron microscope.**

I. Introduction

Oil shale and gas exploration leads to drilling millions of oil fields around the globe, the drilling process produces a large quantity of solid wastes, which is known as oil-based drilling cuttings (OBDC) (Hu, et al., 2022). With increasing the demands on oil-based products in the world, the amount of OBDC increased significantly, approximately the volume of OBDC reaches nearly 130–560 m^3 per one well (Siddique, et al., 2017; Wang, et al., 2024). Oil well drilling operation requires many types of drilling muds to ease the drilling operation; the drilling mud helps to extract the rock cuttings from the subsurface depth to the surface to proceed the drilling operation into the deeper strata. The rock cuttings come to the surface with the drilling mud, and then the drilling mud separates from the rock cuttings to be reused in the drilling operation, the separation cycle continues until the mud is no longer suitable for reusing. The drilling mud after many cycles of separation can be considered as the OBDC, which is collected at the mud sump (Hussein and Ibrahim, 2023). OBDC filler falls under the category of hazardous material which will pose the severe damage to environment, the presence of heavy metals and radioactive elements (e.g., polycyclic aromatic hydrocarbons [PAHs]) and benzene series in OBDC, increases the possibility of soil and water pollution (Xie, et al., 2021). Following the primary treatment of OBDC at the rig site, a landfill method conducted as a secondary treatment in which the drilling cuttings buried underground but leaching the PAHs in OBDC resulting the unmanaged soil and water pollution include the physical, chemical, and biological pollution which categorized as a secondary pollution (Wang, et al., 2017; Huang, et al., 2018).

Besides the improper landfilling of the OBDC, which cause water and soil pollutions, OBDC can be used as a construction material to decrease its effect on the environment, eliminate the disposal cost, and improve the particular characteristic of the target material. According to the researches, the OBDC can be used in cement production, brick production, sandcrete blocks, and concrete production by replacing the fine aggregate in different percentages (Bernardo, et al., 2007; Ikotun, et al., 2019; Mostavi, Asadi and Ugochukwu, 2015; Foroutan, et al., 2018; Mohammed and Cheeseman, 2011). In this regard, the OBDC can be blended with hot mix asphalt (HMA), HMA is a mixture of asphalt concrete

ARO-The Scientific Journal of Koya University
Vol. XIII, No. 1 (2025), Article ID: ARO.12045. 7 pages
DOI: 10.14500/aro.12045
Received: 09 February 2025; Accepted: 11 May 2025
Regular research paper; Published: 22 May 2025
†Corresponding author's e-mail: balen.zrar@koyauniversity.org

http://dx.doi.org/10.14500/aro.12045

which is widely used in road pavements in which the material mixed at 160°C–170°C (Ferrotti, et al., 2024). The most important composition in the HMA mixture is a stone dust filler (Natural mineral powder). Basically, stone dust filler is used to strengthen the asphalt concrete in terms of higher stability, moisture susceptibility, higher stiffness, and better affinity (Kumlai, Jitsangiam and Nikraz, 2022). Stone dust fillers produced from crushing the mountain stones (e.g., Marble Stone, Limestone, Dolomite, Granite, and Andesite) to a particle smaller than 0.075 mm by size, produced stone dust fillers from mountain stones falls under the category of destruction the natural resources, and continuously using these material leads to drastic decrease of these natural resources (Khan, et al., 2023; Gedik, Selcuk and Lav, 2021). OBDC can be used as a substitute of stone dust filler in HMA preparation; regarding to this, only few researches have been carried out on using OBDC as a replacement of stone dust filler in HMA mix, and many of them only concentrated on the mechanical characteristic of the specimen without investigating the specimen microstructure. Khodadadi, et al. (2020) used washed and unwashed OBDC in preparation of the HMA mixture as the replacement of fine aggregate. They only focusing on the mechanical properties of the specimens, such as the Marshall stability, indirect tensile strength, dynamic creep test, and resilient modulus. According to their result, the Marshall stability, resilient modulus, and indirect tensile strength gradually increased by using washed OBDC, which makes the OBDC as additive more feasible to use as a substitute of stone dust filler. At the same time, the unwashed OBDC has a reverse effect on the mechanical characteristic of the mixture compare to the washed OBDC.

In this study, the OBDC used as a partial and complete replacement of stone dust filler (Natural mineral powder) in preparing the HMA for pavement binder course, and Marshall stability, flow, air voids (VA), voids in mineral aggregates (VMA), and microstructure were investigated. The results of this study are applicable to determine the optimum replacement percentage of OBDC in which the range of the mechanical characteristic falls within the standard range. Besides the evaluation of mechanical characteristic, the microstructure investigation by scanning electron microscopy (SEM) helps to understand the integration between the OBDC and bituminous material, which directly effect on the mechanical characteristics of the pavement material.

II. Materials and Methods

A. Standards and Specifications

The standard ranges used to compare the test results adopted from a manual No.2 (MS-2) of Mix Design Methods for Asphalt Concrete and Other Hot-Mix Types by Asphalt Institute in 1979, as shown in Table I.

TABLE I
Standard Specification of HMA Mixture for Binder Course Layer (Asphalt Institute, 1979)

Properties	Binder course Type II
Stability, kN	7 (Min)
Flow, mm	2–4
Air Voids (VA), %	3–5
Voids in mineral aggregate (VMA), %	13 (Min)

B. OBDC Powder

The OBDC was collected from the mud sump at the rig site and air-dried. After prepared air-dried OBDC, it's burned in a furnace at 600°C for 2 h to calcinate, which also served to eliminate organic materials. After calcination, the OBDC was milled using a Los Ageless machine and sieved through a 200 μm screen to produce an OBDC powder, preparation steps shown in Fig. 1, and the chemical composition tabulated in Table II.

TABLE II
Chemical Composition of Oil-based Drilling Cuttings

Chemical compositions	Mass percentage, %
BaO	30.5
SO_3	18.1
SiO_2	15.4
TiO_2	9.54
CaO	7.19
Al_2O_3	3.26
Fe_2O_3	2.83
MgO	2.74
ZrO_2	2.48
V_2O_5	1.98
Cl	1.22
K_2O	1.2
Other	3.56

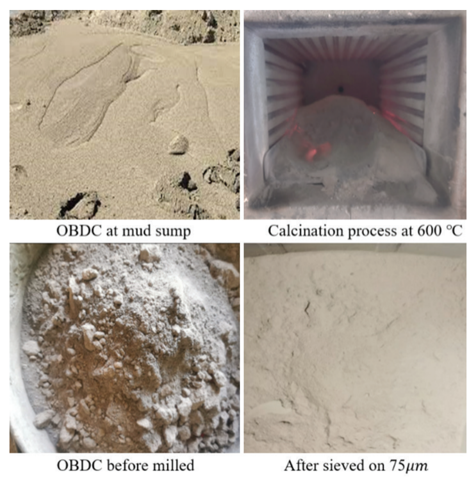

Fig. 1. Steps of preparing the oil-based drilling cuttings powder.

C. Mineral Powder

The mineral powder is a by-product of crushing limestone in the aggregate production plant. A major portion of the mineral powder passes through sieve No.200, and the particle size distribution of the mineral powder is shown in Table III.

D. Aggregate

The HMA mixture which used in this research designed for a binder course layer, the nominal maximum aggregate

TABLE III
Particle Size Distribution of Mineral Powder

Sieve size		Passing (%)	Standard range	Test standard
Inch	mm		%	
No. 30	0.6	100.0	100	
No. 50	0.30	98.22	95–100	ASTM D546
N0.200	0.075	81.04	70–100	

TABLE IV
Blending Material for Binder Course According to Marshall Mix Design

Sieve size		Replacement percentage of OBDC				
Inch	mm	0%	25%	50%	75%	100%
		Mass of each size fraction, g				
1	25	0	0	0	0	0
^3/4	19	95.2	95.2	95.2	95.2	95.2
^1/2	12.5	84.3	84.3	84.3	84.3	84.3
^3/8	9.5	60	60	60	60	60
No. 4	4.75	312.9	312.9	312.9	312.9	312.9
No. 8	2.36	189.9	189.9	189.9	189.9	189.9
No. 50	0.3	246.8	246.8	246.8	246.8	246.8
No. 200	0.075	84.2	84.2	84.2	84.2	84.2
Natural filler (within the aggregate)		7.59	7.59	7.59	7.59	7.59
Mineral powder		69	51.7	34.5	17.3	0
OBDC filler		0	17. 3	34.5	51.7	69
Bitumen binder, %		5.1	5.1	5.1	5.1	5.1
Bitumen binder mass, g		61.8	61.8	61.8	61.8	61.8
Total aggregate mass for making one Marshall mold, g		1150	1150	1150	1150	1150

OBDC: Oil-based drilling cuttings

size is 19.0 mm, the aggregate crushed and having sharp edges in different angles as per standard requirement, four different size fractions (25–12.5 mm, 12.5–4.75 mm, 4.75–0.075 mm, and <0.075 mm) blended together in accordance with Marshall mix design as shown in Table IV.

E. Bitumen Binder

Penetration grade bitumen 40/50 was used for this study, and passed through a series of laboratory testing programs in accordance with the ASTM standard, the test results compared with standard ranges shown in Table V to check the physical properties of the bitumen binder.

F. Job Mix Formula (JMF)

A JMF has been formulated based on the Marshall method shown in Table IV, the proportions are controlled by mass in accordance with the physical properties of materials, such as aggregates (coarse and fine aggregate), bitumen binders, mineral powder, and OBDC filler as outlined in Table IV. The OBDC filler has been incorporated as a partial replacement for the mineral powder across various percentages by mass: 0%, 25%, 50%, 75%, and 100%. Each replacement percentage was represented by three Marshall specimens, 4 inches (101.2 mm) in diameter, prepared in accordance with ASTM D6926. A series of laboratory testing programs was conducted to assess the strength parameters and other physical attributes of the specimen. The Marshall

TABLE V
Physical Characteristics of the Bitumen Binder

No.	Test details	ASTM designation	Results	Standard range
1	Penetration, 25°C, 100 g, 5 s	ASTM D5-05a	44	40/50
2	Softening Point (R&B)	ASTM D36-06	51.1°C	---
3	Flash and fire Point	ASTM D92-05a	292°C	>232°C
4	Ductility at 25°C, 5 cm/min	ASTM D113-99	>150 cm	>100 cm
5	Viscosity	ASTM D2170	530 cP	>400 cP
6	Specific gravity	ASTM D70-03	1.03	---
7	Solubility	ASTM D2042	99.8%	>99%
8	Loss of heating	ASTM D1754	0.08%	0.2 max
9	Retain penetration	ASTM D2872	65%	>55%
10	Retain ductility	ASTM D2872	145 cm	>25 cm

TABLE VI
Specific Gravity and Combined Volume of Mineral Powder and OBDC Filler

Specific gravity of mineral powder	2.725				
Specific gravity of OBDC filler	3.552				
Mass of mineral powder according to the mix design	69 g				
	Replacement percentage of OBDC				
	0%	25%	50%	75%	100%
Mass of mineral powder, g	69	51.7	34.5	17.3	0
Mass of OBDC filler, g	0	17. 3	34.5	51.7	69
Volume of mineral powder, cc	25.3	18.9	12.6	6.3	0
Volume of OBDC filler, cc	0	4.8	9.7	14.6	19.4
Combined mass of mineral powder and OBDC filler, g	69	69	69	69	69
Combined volume of mineral powder and OBDC filler, cc	25.3	23.7	22.3	20.9	19.4

OBDC: Oil-based drilling cuttings

test was performed according to ASTM D6927 to assess the strength parameters (e.g., stability and flow) and physical properties of the specimens (e.g., VMA and VA). The results were compared against the standard ranges specified by the Asphalt Institute as tabulated in Table I. In addition, the microstructure was examined by using SEM alongside the evaluation of strength parameters and physical properties of the specimens.

III. Results and Discussion

A. Effect of OBDC Filler on VA and VMA

VMA represent the volume of void spaces between aggregate particles in a compacted bituminous mixture, encompassing both the spaces filled with bitumen and air. As a key parameter in asphalt mix design, VMA significantly influences the mixture's durability, stability, and resistance to deformation. Furthermore, VA are the small pockets of air trapped within a compacted bituminous mixture (Asphalt Institute, 1979; Roberts, 1991). In this study, mineral powder substituted by OBDC filler partially and completely, the properties of such a combination varied in some aspects. The particle size of both mineral powder and OBDC filler are very similar in size which pass through the sieve No.200, but the specific gravity of OBDC filler

 http://dx.doi.org/10.14500/aro.12045

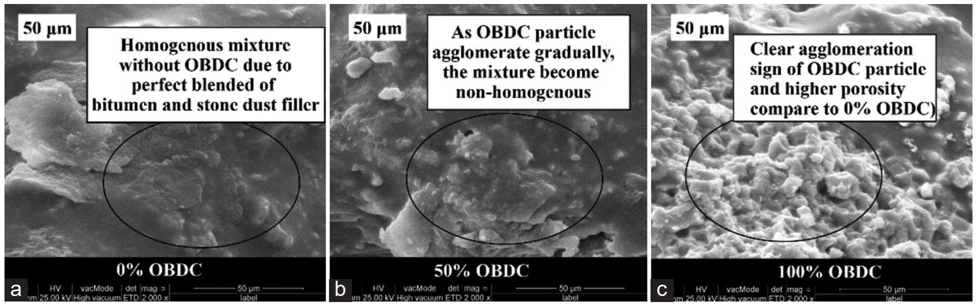

Fig. 2. (a-c) Microstructure 50 µm at different percentages of oil-based drilling cuttings.

is higher than the specific gravity of mineral powder; for that reason, the total volume of solid particles of OBDC filler with the same mass against the mineral powder is lower as shown in Table VI. By increasing the replacement percentage of OBDC filler, the combined volume of mineral powder and OBDC filler decrease compare to the control specimen due to the difference in specific gravity of both combinations.

According to the analysis shown in Table VI, the total volume of solid particles of filler material (combination of mineral powder and OBDC) decreased by 5.9 cm^3 and thus create more voids compared to control specimen (0% of OBDC) when 100% of mineral powder replaced by OBDC filler (100% of OBDC), this is mean that the volume of voids between the total aggregate mix at (100% of OBDC) increased by 5.9 cm^3 compare to control specimen (0% of OBDC). This finding also revealed by SEM images, in Fig. 2c shows the higher porosity at (100% of OBDC) compare to Fig. 2a (0% OBDC), it's clear that those voids cannot be filled with the bitumen binder as the mass of bitumen binder is fixed between all replacement percentage of OBDC as shown in Table IV.

In results, from 0% to 100% of OBDC, the VA increase from 3.9% to 4.26% as shown in Fig. 3, and VMA increase from 14.63% to 15.20% as shown in Fig. 4. Moreover, replacing 100% of mineral powder by OBDC filler, the VA and VMA falls within the standard limit as shown in Table I.

B. Effect of OBDC Filler on Marshall Stability and Flow

Marshall stability is defined as the maximum load an asphalt specimen can endure before failing in the Marshall test, a widely used method to evaluate the strength and performance of asphalt mixtures, also Marshall flow is the measure of an asphalt pavement's ability to resist deformation and retain its structural integrity under repeated loads. It is expressed as the amount of deformation (in millimeters) that an asphalt sample experiences when subjected to a standard load during the Marshall test, which evaluates the mixture's stability and overall performance (Cui, et al., 2023; Azadgoleh, et al., 2022; Roberts, 1991). The Stability and flow for the Marshall samples decreased by increasing the percentages of OBDC filler, as shown in Figs. 5 and 6, respectively. The Marshall stability decreased from 12.1 kN to 9.22 kN, and the flow value decreased from 3.96 mm to 3.3 mm when mineral powder replaced by OBDC filler from 0% to 100%, respectively.

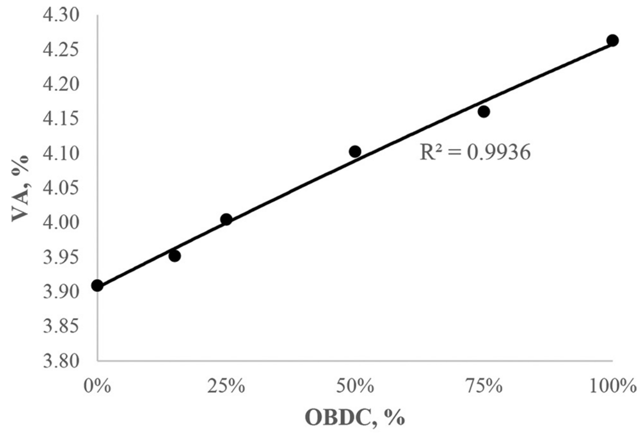

Fig. 3. Effect of different replacement percentage of oil-based drilling cuttings on air voids.

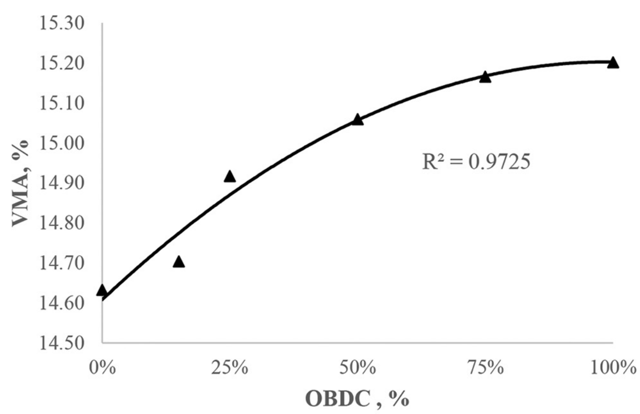

Fig. 4. Effect of different replacement percentages of oil-based drilling cuttings on voids in mineral aggregate.

Microstructure analysis revealed the significant uncoated and agglomerated of OBDC filler within the bitumen constituent, as shown in Figs. 2 and 7. This phenomenon can clearly explain the reduction in Marshall stability and flow value attributed to the significant presence of uncoated and agglomerated filler material in the microstructure. Besides the agglomerating and uncoating the OBDC filler within the bitumen constituent, the difference between specific gravity of mineral powder and OBDC filler makes the VMA and VA to be increased as the mixture designed based on weight, and when the porosity of the samples increases, the load carrying capacity which is directly related to Marshall stability will decreased. Despite the slight decrease of stability and flow at 100% of OBDC compared to the control specimen (0% of OBDC), the results fall within the standard range as shown in Table I.

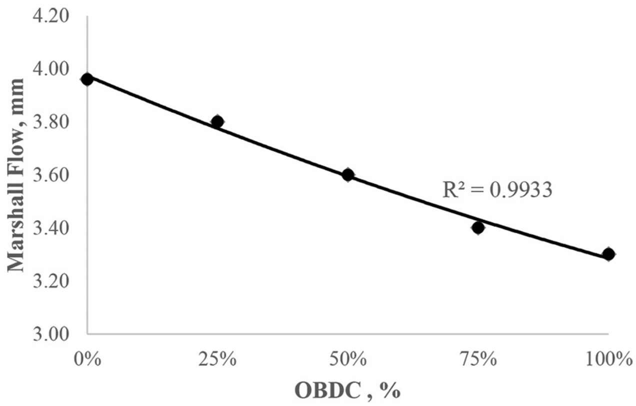

Fig. 5. Effect of different replacement percentages of oil-based drilling cuttings on flow.

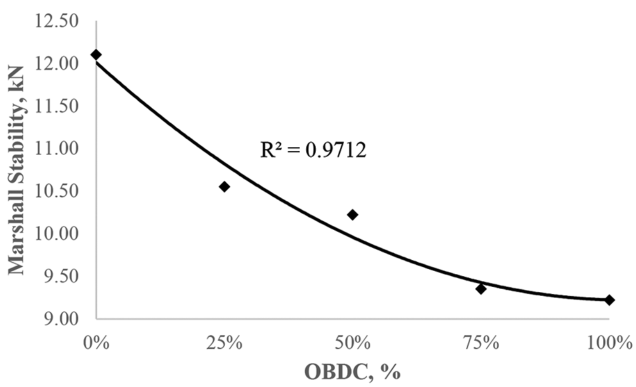

Fig. 6. Effect of different replacement percentages of oil-based drilling cuttings on Marshall stability.

The outcomes of stability and flow attained in this research closely align with findings from analogous studies on OBDC in HMA mixtures (Khodadadi, et al., 2020; Cui, et al., 2023). Despite substantial variations in methodology, material properties, OBDC fineness, chemical composition of OBDC, and mix proportions, the utilization of OBDC in HMA mixtures generally results in a slight decrease in stability and flow.

C. Microstructure and Macrostructure Investigation by SEM

The microstructural analysis at 100 µm, as shown in Fig. 7 illustrates a notable disparity between samples with varying percentages of OBDC filler. At 0% OBDC filler replacement (Fig. 7a), where mineral powder constitutes 100%, a homogeneous blend of bitumen and mineral powder is evident, depicted by a consistent dark brown coloration. In contrast, at 100% OBDC filler replacement (Fig. 7f) with 0% mineral powder, a discernible agglomeration of OBDC is observed, alongside a large amount of uncoated OBDC filler, the mixture of bitumen and OBDC filler appears non-homogeneous, characterized by a lighter brown hue. Furthermore, the SEM investigation confirms that the ratio of uncoated filler increased with increasing the replacement percentage of OBDC.

As shown in Fig. 2, when the samples were further focused from 100 µm to 50 µm and mineral powder was completely replaced with 100% OBDC, a significant agglomeration of OBDC particles was observed despite the OBDC particles being uncoated. Practically, this indicates that the bitumen film is missing in some areas where the agglomeration occurred. Consequently, the unbound aggregated particles reduce the stability value. Besides the unbound aggregate particle in the agglomeration zone, the porosity of the sample with higher dosage of OBDC is higher than those samples with lower or without OBDC as shown in Fig. 2c and 2a, this finding reflect the cause of increasing VMA and VA as described in section

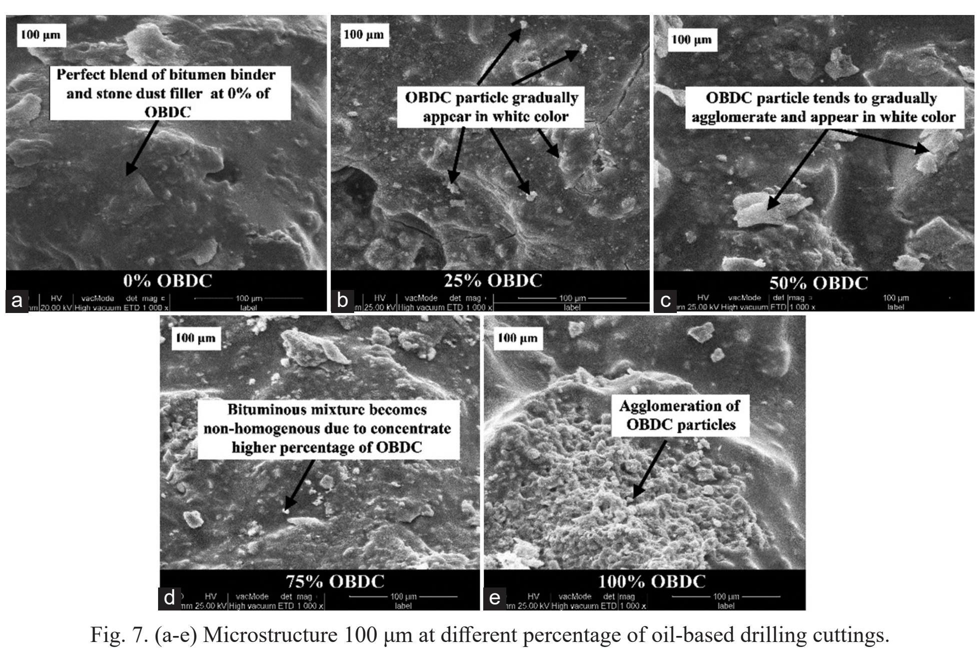

Fig. 7. (a-e) Microstructure 100 µm at different percentage of oil-based drilling cuttings.

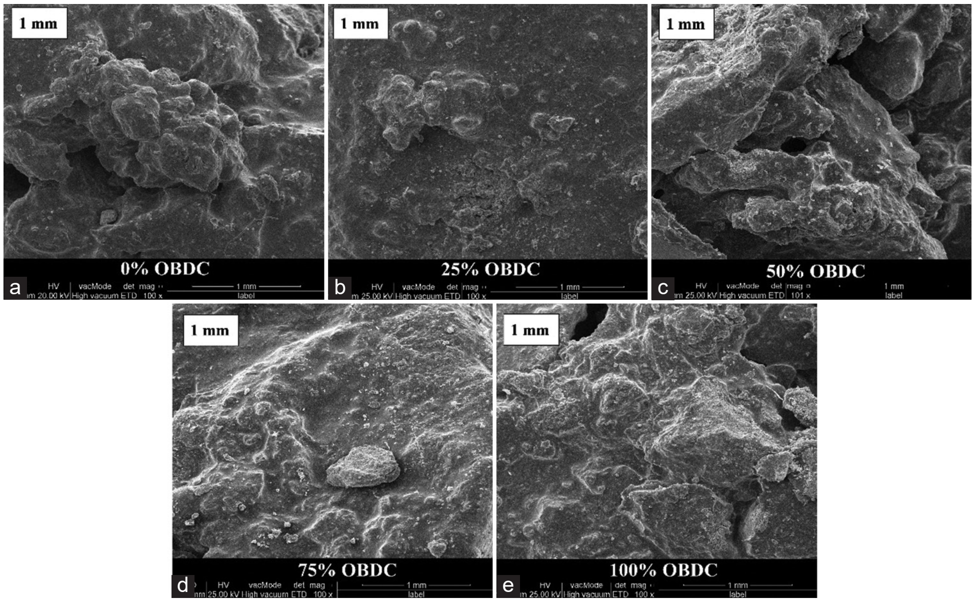

Fig. 8. (a-e) Macrostructure 1-mm at different percentage of oil-based drilling cuttings.

(3.1) and numerically proved in Table VI based on difference in specific gravity of OBDC and mineral powder.

The homogenous constituent of bitumen binder and filler material is important because the filler is a key material to strengthen the bitumen binder (Kumlai, Jitsangiam and Nikraz, 2022), any significant agglomerated and uncoated filler particle as revealed by microstructure investigation will make the bitumen mixture vulnerable to fail and deform under the particular loads which results to obtain lower Marshall stability and flow.

SEM images show that at the macrostructural level (1 mm), there is no significant difference between samples with varying OBDC replacement percentages. The samples appear similar in color and heterogeneity, as shown in Fig. 8. This suggests that at the macrostructure level, samples with 100% OBDC resemble those without OBDC, as they are visually indistinguishable. However, when zooming into the microstructure (e.g., at 100 µm and 50 µm), the SEM images reveal clear agglomeration of OBDC particles and a non-homogeneous bitumen mix, as seen in Figs. 2 and 7. This agglomeration negatively impacts the OBDC's ability to improve flow and Marshall stability, as shown in Figs. 5 and 6, respectively.

IV. Conclusions

This research focuses on the suitability of OBDC as a substitute of mineral powder in HMA mix toward more sustainability in terms of cost and environmental concerns, the following conclusion can be drawn:

- Marshall stability and Marshall flow slightly decrease when 100% of mineral powder is replaced by OBDC filler; the result at the minimum level falls within the standard range.
- VMA and VA increase when 100% of mineral powder is replaced by OBDC filler; the result at the minimum level falls within the standard range.
- The SEM image at the level of microstructural (e.g.,100 µm, 50 µm) shows a notable disparity between samples with varying percentages of OBDC filler. When the mineral powder constitutes 100% (0% of OBDC), a homogeneous blend of bitumen and mineral powder is evident. In contrast, when the OBDC constitutes 100% (0% mineral powder), a discernible agglomeration of OBDC is observed, alongside a large amount of uncoated OBDC filler, the mixture of bitumen and OBDC filler appears non-homogeneous. This evidence indicates that OBDC filler does not integrate as effectively with the bitumen material compared to mineral powder, and also resembles the reduction of Marshall stability and flow when 100% of OBDC is utilized.
- The SEM image at the macrostructure level (e.g., 1 mm) shows no significant difference between samples with varying OBDC replacement percentages. The samples appear similar in color and heterogeneity, with those containing 100% OBDC being visually indistinguishable from those without OBDC.
- The microstructure investigation shows that the utilization OBDC by 100% leads to increase the porosity, this evidence proved mathematically as the specific gravity of OBDC is larger than the specific gravity of mineral powder, the total volume of solid particles of OBDC with the same mass is lower than the mineral powder in the mixture as the JMF is designed based on mass not volume. For that reason, the VMA increases, and thus the VA due to decreases, the total volume of solid particles of OBDC at each higher dosage of OBDC compared to the previous dosage of OBDC. When the volume of solid particles decreases, the porosity (Volume of voids) will increase; this phenomenon is well defined by the SEM images at the microstructure level. Besides the effect of porosity on VMA and VA, the Marshall stability and flow are also affected in a negative side.
- OBDC filler proves to be a viable alternative to mineral powder, as indicated by stability, flow, VA, and VMA values

falling within the standard ranges as shown in Table I. This outcome represents a satisfactory compromise, enabling the complete replacement of mineral powder with OBDC filler in the HMA mixture.

- Replacing 100% of mineral powder by OBDC filler helps the preserving natural resources of stones, and eliminates the production cost of mineral powder.
- Using OBDC as a filler in HMA mix as a cost-free waste material helps to decrease or eliminate the environmental concerns of OBDC, and also eliminates the cost of treatments and landfilling of OBDC.

References

Asphalt Institute., 1979. *Mix Design Methods for Asphalt Concrete and Other Hot-Mix Types. Manual Series No. 2 (MS-2).* Asphalt Institute, Lexington, KY.

ASTM., 1999. *Standard Test Method for Ductility of Bituminous Materials*. ASTM D113. ASTM, West Conshohocken, PA.

ASTM., 2002. *Standard Test Method for Effect of Heat and Air on Asphaltic Materials (Thin-Film Oven Test).* ASTM D1754. ASTM, West Conshohocken, PA.

ASTM., 2003. *Standard Test Method for Specific Gravity and Density of Semi-Solid Bituminous Materials (Pycnometer Method).* ASTM D70. ASTM, West Conshohocken, PA.

ASTM., 2005. *Standard Test Method for Penetration of Bituminous Materials*. ASTM D5. ASTM, West Conshohocken, PA.

ASTM., 2006. *Standard Test Method for Softening Point of Bitumen (Ring-and-Ball Apparatus)*. ASTM D36. ASTM, West Conshohocken, PA.

ASTM., 2007. *Standard Test Method for Kinematic Viscosity of Asphalts (Bitumens)*. ASTM D2170. ASTM, West Conshohocken, PA.

ASTM., 2015. *Standard Test Method for Marshall Stability and Flow of Asphalt Mixtures*. ASTM D 6927. ASTM, West Conshohocken, PA.

ASTM., 2017. *Standard Test Method for Sieve Analysis of Mineral Filler for Asphalt Paving Mixtures*. ASTM D546. ASTM, West Conshohocken, PA.

ASTM., 2018. *Standard Test Method for Flash and Fire Points by Cleveland Open Cup Tester*. ASTM D92. ASTM, West Conshohocken, PA.

ASTM., 2020. *Standard Practice for Preparation of Asphalt Mixture Specimens Using Marshall Apparatus.* ASTM D6926. ASTM, West Conshohocken, PA.

ASTM., 2022. *Standard Test Method for Effect of Heat and Air on a Moving Film of Asphalt Binder (Rolling Thin-Film Oven Test).* ASTM D2872. ASTM, West Conshohocken, PA.

ASTM., 2022. *Standard Test Method for Solubility of Asphalt Materials in Trichloroethylene or Toluene.* ASTM D2042. ASTM, West Conshohocken, PA.

Azadgoleh, M.A., Mohammadi, M.M., Ghodrati, A., Sharifi, S.S., Palizban, S.M.M., Ahmadi, A., Vahidi, E., and Ayar, P., 2022. Characterization of contaminant leaching from asphalt pavements: A critical review of measurement methods, reclaimed asphalt pavement, porous asphalt, and waste-modified asphalt mixtures. *Water Research*, 219, p.118584.

Bernardo, G., Marroccoli, M., Nobili, M., Telesca, A., and Valenti, G.L., 2007. The use of oil well-derived drilling waste and electric arc furnace slag as alternative raw materials in clinker production. *Resources Conservation and Recycling*, 52(1), pp.95-102.

Cui, C., Yan, D., Liu, M., Wang, J., Li, L., Chen, C., and Huang, Q., 2023. Utilization of oil-based drilling cuttings as asphalt pavement surface: Study on the mechanical characteristics and long-term environmental impact. *Environmental Technology and Innovation*, 30, p.103052.

Ferrotti, G., Mancinelli, E., Passerini, G., and Canestrari, F., 2024. Comparison of energy and environmental performance between warm and hot mix asphalt concrete production: A case study. *Construction and Building Materials*, 418, p.135453.

Foroutan, M., Hassan, M.M., Desrosiers, N., and Rupnow, T., 2018. Evaluation of the reuse and recycling of drill cuttings in concrete applications. *Construction and Building Materials*, 164, pp.400-409.

Gedik, A., Selcuk, S., and Lav, A.H., 2021. Investigation of recycled fluorescent lamps waste as mineral filler in highway construction: A case of asphaltic pavement layers. *Resources Conservation and Recycling*, 168, p.105290.

Hu, Y., Chen, X., Mu, S., and Li, Q., 2022. Extraction and separation of petroleum pollutants from oil-based drilling cuttings using methanol/n-hexane solvent. *Process Safety and Environmental Protection*, 168, pp.760-767.

Huang, Z., Xu, Z., Quan, Y., Jia, H., Li, J., Li, Q., Chen, Z., and Pu, K., 2018. A review of treatment methods for oil-based drill cuttings. *IOP Conference Series Earth and Environmental Science*, 170, p.022074.

Hussein, N.S., and Ibrahim, R.K., 2023. Fresh and mechanical properties of concrete containing oil-well cutting material. *ARO The Scientific Journal of Koya University*, 11(1), pp.72-78.

Ikotun, J.O., Okeniyi, J.O., Akinlabi, E.T., Akinlabi, S.A., Okeniyi, E.T., and Olanrewaju, D.O., 2019. Physicochemical and mineralogical characterization datasets from oil drill cuttings in comparison with other cement types for cement partial-replacement in concrete. *Chemical Data Collections*, 19, p.100176.

Khan, D., Khan, R., Khan, M., Alam, M., and Hassan, T., 2023. Performance of hot-mix asphalt using polymer-modified bitumen and marble dust as a filler. *Journal of Traffic and Transportation Engineering (English Edition)*, 10(3), pp.385-398.

Khodadadi, M., Moradi, L., Dabir, B., Moghadas Nejad, F., and Khodaii, A., 2020. Reuse of drill cuttings in hot mix asphalt mixture: A study on the environmental and structure performance. *Construction and Building Materials*, 256, p.119453.

Kumlai, S., Jitsangiam, P., and Nikraz, H., 2022. Assessments of moisture damage resistance of asphalt concrete mixtures and asphalt mastic with various mineral fillers. *Transportation Engineering*, 7, p.100106.

Mohammed, B., and Cheeseman, C.R., 2011. Use of oil drill cuttings as an alternative raw material in sandcrete blocks. *Waste and Biomass Valorization*, 2(4), pp.373-380.

Mostavi, E., Asadi, S., and Ugochukwu, E., 2015. Feasibility study of the potential use of drill cuttings in concrete. *Procedia Engineering*, 118, pp.1015-1023.

Roberts, F.L., 1991. *Hot Mix Asphalt Materials, Mixture Design, and Construction*. National Asphalt Pavement Association, United States.

Siddique, S., Kwoffie, L., Addae-Afoakwa, K., Yates, K., and Njuguna, J., 2017. Oil based drilling fluid waste: An overview on environmentally persistent pollutants. *IOP Conference Series Materials Science and Engineering*, 195, p.012008.

Wang, C.Q., Lin, X.Y., He, M., Wang, D., and Zhang, S.L., 2017. Environmental performance, mechanical and microstructure analysis of concrete containing oil-based drilling cuttings pyrolysis residues of shale gas. *Journal of Hazardous Materials*, 338, pp.410-427.

Wang, X., Jin, W., Li, Y., Liu, S., Xu, J., Liu, J., Li, H., and Long, T., 2024. Treatment advances of hazardous solid wastes from oil and gas drilling and Production Processes. *Chemical Engineering Journal*, 497, p.154182.

Xie, B., Qin, J., Sun, H., Wang, S., and Li, X., 2021. Leaching behavior of polycyclic aromatic hydrocarbons (PAHs) from oil-based residues of shale gas drill cuttings. *Environmental Pollution*, 288, p.117773.