Evaluation of the Effects of using Ceramic Dust and Natural Sand Fines as Filler Material in HMA

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***Abstract:*-Asphalt concrete is a mix of coarse aggregate, fine aggregate, filler and asphalt binder hot mixed in an asphalt plant and then hot lay to form the surface course of flexible pavement. Filler plays a major role in determining the properties and behavior of the asphalt mixes. Fillers serve to fill the voids between the coarse aggregates and improve the bond between asphalt binder and aggregate. This research was focused to evaluate the effects of using ceramic dust and natural sand fines as filler material in hot mix asphalt with 4%, 6% and 8% contents by total weight of the mixes using conventional crushed rock fines as control material. The study compares the performance of asphalt mixes using laboratory tests including Marshall Stability and flow with corresponding volumetric properties and moisture susceptibility using Indirect Tensile Strength (ITS) test. Asphalt mixes prepared with 4% ceramic dust and natural sand fillers had a stability of 10.50kN and 10.35kN which is greater than by 5.7% and 4.3% as compared to control mixes (9.9kN), respectively. However, mixes containing 6% and 8% ceramic dust and natural sand filler attained lower stability. Mixes prepared with 6% and 8% ceramic dust and natural yields the highest and lowest Marshall flow, respectively. Asphalt mixes prepared with ceramic dust and natural sand filler resulted better resistance to moisture induced damage. Asphalt mixes prepared with ceramic dust and natural sand are economical as compared to mixes prepared with crushed rock filler. In general, it can be concluded that ceramic dust and natural sand can be used as filler materials instead of most commonly used conventional fillers such as crushed rock fines.**

Key Words: Fillers, Hot Mix Asphalt, Indirect Tensile Strength Marshall Properties

I. INTRODUCTION

Highway pavement is designed and constructed to provide durable all-weather traveling surfaces for safe and speedy movement of people and goods with an acceptable level of comfort to users. Depending on the way by which traffic loads are transmitted to the subgrade soil, the pavement structure generally classified into two: flexible pavements and rigid pavements. Rigid pavement is cement concrete slab that spread the wheel load over the entire slab area and the structural capacity of the pavement is largely provided by the slab itself. Whereas, flexible pavement is a layer structure which supports the traffic load on its surface and transfers and spreads the load to the subgrade.

Currently, highway pavements are being subjected to constantly increasingly high traffic load. For pavements to resist adequately under these increasingly severe conditions, for both present and future conditions, it is necessary that to consider basic design factors such as traffic loading, environment, failure criteria and better understanding about construction materials.

Performance of hot mix asphalt can be affected by many factors such as material property, traffic load, and environmental condition, paving aging process, design and construction process. Marshall Stability values of hot mix asphalt can improved with the addition filler [1].

Ceramics are inorganic materials (with possibly some organic content), made up of non-metallic compounds and made permanent by the firing process. In addition to clay based materials, today ceramics include a multitude of products with a small fraction of clay or none at all. Ceramics could be glazed or unglazed, porous or vitrified [2]. According to the latest survey conducted by ceramic world review (2016), the ceramic tile production in 2016 amounted to 13,056 million square meters. World ceramic tile production increased in 2016 from 12,357 to 13,056 million square meter (+5.7%) and world tile consumption increased in 2016 from 12,177 to 12,783 million square meter (+5%) from 2015. It has been estimated that about 30% of daily production in the ceramic industry goes to waste [3].

The ceramics industry in Ethiopia includes the manufacture of ceramic products like floor and wall tiles, insulator and sanitary wares, kitchen wares clay structure. Ceramic tiles manufacturing companies in Ethiopia includes Tabor ceramics products manufacturing P.L.C., Meditek ceramics, Kokeb ceramic tile and paint factory, Di Yuan ceramic and about 505,600 ton ceramic tiles manufactured per annum. Raw material used for ceramic production includes feldspar, quartz, kaolin, clay, silica sand and limestone [4].

The utilization of waste material as filler in asphalt concrete mixes gives significant solution to disposal problems to save the environment. Use of waste materials make economic and environmental safe pavement [5, 6 & 7].

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 9 Issue 10, October-2020

The performance of asphalt concrete has long been a major concern. It has to be designed to provide adequate stability to resist deformation under traffic load, durable to resist against weathering and abrasion action, flexible, workable and skid resistance. It is also essential to minimize cracking and rutting in asphalt concrete layers.

Newly constructed highway pavements show failure after a few years the opening of the road for traffic. Consequently, this induces large amount of maintenance and rehabilitation cost that would have negative effect on nation's economy. Therefore, application of new filler materials shall be studied to alleviate the existence of poor Marshall Properties of asphalt mixes. Strong, durable, resistive to fatigue and permanent deformation, environment friendly and economical pavement construction can be achieved through application of new filler materials (ceramic dust and natural sand).

The other main problem in the construction of highway pavements is the shortage of mineral fillers from crushing of aggregates to obtain conventional crushed rock fines. Due to insufficiency of mineral fillers blasting of more quarry areas is required to produce the required amount of mineral fillers. Thus, blasting of more quarry areas may cause environmental deterioration and also its mode of production has made it be expensive.

Increasing of economic cost and lack of filler materials create the opportunity to explore easily available material. These industrial waste materials can be suitably used in road construction, the pollution and disposal problems may be partially reduced.

The main focus this paper was, therefore, to evaluate the effects of using ceramic dust and natural sand fines as filler materials in hot mix asphalt. The optimum content of crushed rock, ceramic dust and natural sand filler was determined. The performance of asphalt mixes prepared with ceramic dust and natural sand fillers was evaluated and economic comparison of asphalt mixes was conducted using conventional crushed rock filler as control material.

II. LITERATURE REVIEW

A. General

Flexible asphalt pavement layers consist of mineral filler, coarse and fine aggregates all cemented by the asphalt binder and blended at pre-specified weight proportions determined from the mix design method. Mineral fillers are fine particles or part of the aggregate skeleton of the pavement which passes on No.200 (75µm) standard sieve size that is added or naturally present in the mineral aggregate [8].

The properties of asphalt concrete depend on; the quality of its components (asphalt binder and aggregates), mix proportions and construction process [9]. The blend of mineral filler and asphalt binder forms the asphalt mastic destined to play a major role in controlling the mechanical behavior of its mixture [10].

Mineral fillers are added to asphalt paving mixes to modify asphalt concrete mix. A portion of the mineral filler that is finer than the asphalt film thickness mixed with asphalt binder forms a mortar or mastic and contributes to improved stiffening of the mix. The filler form filler-asphalt mastic which has binder consistency characteristics that improve the bond between asphalt cement and aggregate. The other portion of filler larger than the asphalt film thickness behave as a mineral aggregate and serves to fill the voids between coarser aggregate particles, thereby increasing the density, stability, and toughness of the compacted mix [5, 11 & 12].

B. Effects of Filler on Hot Mix Asphalt

Optimum asphalt binder content can be affected by the type of aggregate, asphalt binder mix design and filler material. It was observed that the mixes prepared with fly ash as filler exhibit marginally inferior properties compared to cement and stone dust control mixes. The use of fly ash as filler material in asphalt mixes is not only reducing the cost of execution but also partly solve the fly ash utilization and disposal problems [7].

The optimum asphalt content is the average of asphalt contents that meet optimum stability, maximum unit weight and 4% air voids. By using different percentages of glass waste of 0%, 5%, 10%, 15% and 20%, the optimum binder content was found to be 5.75%, 5.615%, 5.35%, 5.65% and 5.68% respectively [13].

Using Rice husk ash and Slag as filler material in asphalt concrete mixes yields nearly the same Marshall properties as compared to conventional crushed rock filler [14]. Asphalt mixes prepared with waste concrete dust and brick dust fillers yields nearly the same Marshall Properties as compared to conventional crushed rock filler at 5.33% and 5.37% optimum asphalt binder contents respectively. Addition of waste concrete dust and brick dust fillers in asphalt paving mix produce a more viscous asphalt mix that increases Marshall Stability of the mixture. From the considerations of performance, economy and availability, waste concrete dust and brick dust are suitable as filler as compared with conventional filler [15].

The application of brick dust as filler material had a significant effect on the physical properties of hot mix asphalt. Using brick dust as filler made the asphalt mixes with higher Marshall Stability, lower flow, minimum void filled with asphalt. Hence, brick dust can replace conventional filler (stone dust and cement) in the asphalt paving mix as control material [16].

[17] studied the influence of fillers on paving grade asphalt binder using three types of filler namely cement, fly ash and stone dust. It was observed that unit weight and stability values increase from 4.5% to 5% asphalt binder

content used and decreased for higher asphalt binder content. An Increase binder content yields decrease air void and increase flow value. Asphalt mixes prepared with fly ash show minimum air void and maximum flow relative to mixes prepared with cement and stone dust and cement had maximum stability. Fillers have a vital role in filling voids between aggregates and modify the physical and chemical properties of the mixture that provide improved durable asphalt.

Volumetric properties of HMA are necessary requirements to ensure good performance, and these properties are directly influenced by the mix grading, aggregates surface characteristics and compaction energy. Asphalt mixes prepared with 6%, 9% and 12% hydrated lime, Portland cement, limestone and silica fillers resulted decrease VMA and VFA as the filler content increases and the optimum asphalt binder content increases as the filler content increases. Type and content of filler can affect volumetric properties of asphalt mixes [18].

Adding 6% of glass powder by total weight of aggregates in asphalt mixes leading to increase the Marshall stability by 15.5% and 9.2% compared with ordinary Portland cement and limestone powder respectively. While, the flow decreases by 14.5 %, and increased by 4.4 % compared with ordinary Portland cement and limestone powder respectively. Use of 8% waste glass powder filler by the weight of total aggregates resulted to produce asphalt mixes with higher Marshall stability, lower flow, and lower voids in total mix as compared to ordinary Portland cement and limestone powder [5].

[6] Studied the use of ceramic waste as filler in semi-dense asphalt concrete. Mixes made with 3% and 5% ceramic filler yields higher Marshall Stability values compared to lime. The stability value obtained for mixes containing ceramic waste filler is about 10% higher than conventional lime filler at 5% filler content. Waste ceramic tile can be used as a filler and as well as partially replace as aggregate in flexible pavement [19].

Natural sand is unconsolidated and highly variable mixtures of different constituents. The construction industry utilizes natural sand mainly from streambeds, which are commonly derived from quartzo-feldspathic basement rocks, sandy marine sediments, and alluvial deposits [20].

Economic evaluation of asphalt mixes prepared with 7% and 7.85% wood ash and fly ash filler yields less cost as compared to control mixes prepared with crushed rock fines. However, mixes made with fly ash filler indicated lower cost than mixes containing wood ash filler [21].

C. Moisture Susceptibility of Hot Mix Asphalt

Premature failure may result due to stripping when critical environmental conditions act together with poor and/or incompatible materials and traffic. Moisture susceptibility is a problem that typically leads to the stripping of the asphalt binder from the aggregate, and this stripping makes an asphalt concrete mixture ravel and disintegrate. Moisture damage can occur due to three main mechanisms: loss of cohesion of the asphalt film, failure of the adhesion between the aggregate particles and the asphalt film, and degradation of aggregate particles due to freezing [22].

Pavements are susceptible to low temperature cracking. Particularly in colder area the tensile strength of pavements at low temperature should be adequate enough to resist cracking. Asphalt mixes containing 7% marble dust yields maximum tensile stress (18.2kg/cm2) as compared to mixes made with stone dust filler (9.53kg/cm2). Thus, marble dust yields better performance in the cold region [1].

[23] Studied the performance changes and fundamental material characteristics associated with moisture damage due to various anti-stripping additives in hot mix asphalt (HMA) through various experimental approaches and a numerical solution. Moisture susceptibility evaluation of asphalt mixes were conducted using two alternative additives (fly ash and cement) and hydrated lime as control mix. The test results showed that all mixes performed good resistance to moisture-induced damage.

Moisture damage in asphalt mixtures refers to loss in strength and durability due to the presence of water. Many variables affect the amount of moisture damage which occurs in an asphalt concrete mixture. Some of these are related to the materials forming hot mix asphalt such as aggregate and asphalt binder. Others are related to mixture design and construction (air void level, film thickness, permeability, and drainage), environmental factors, traffic conditions and type, and properties of the additives. The presence of moisture, combined with the repeated action of traffic, accelerates damage to the asphalt pavement [24].

III. METHODOLOGY

The study has involved the collection of materials for the preparation of asphalt mixes. The material used for this study includes coarse and fine aggregates, ceramic waste, natural sand and 80/100 penetration grade asphalt binder. Different laboratory investigations were carried out to determine aggregates and asphalt binder quality. Properties of asphalt mixes were described according to Marshall mix design procedure and criteria. Economic evaluation of asphalt mixes prepared with ceramic and natural sand fillers was conducted as compared to asphalt mixes prepared with crushed rock filler.

A. Preparation of Marshall specimens

A total of 135 HMA specimens were prepared which are 45 specimens for each filler type with 4%, 6% and 8% content by weight in the mix. In accordance with the Marshall mix design procedure and criteria, asphalt mixture properties were analyzed. The mixtures prepared with crushed rock were considered to be control specimens.

B. Moisture Susceptibility

Moisture susceptibility of a mix can be determined by indirect tensile strength test. The indirect tensile strength (ITS) test involves loading a cylindrical specimen with a compressive load along two opposite sides in the diametrical plane. Tensile strength ratio (TSR) is the relation of the strength values before and after water storage. The indirect tensile strength (ITS) was calculated using the equation given in ASTM D 6931.

$$St=2000P/\pi DH \quad (1)$$

Where St= Tensile strength (kPa)
P= maximum load (N)
D= Diameter of the specimen (mm)
H= thickness of specimen (mm)

C. Test Program

Marshall test specimens were prepared using different types of mix separately according to the selected aggregate grading for 4% to 6% asphalt binder content. The specimens were subjected to Marshall Stability and flow test as per AASHTO T245-82. The cylindrical specimens were then compressed on the lateral surface at a constant rate of 2 in/min (50.8 mm/min.) until the maximum load (failure) is reached. The load resistance and the corresponding flow value were recorded. Volumetric analysis was made for each series of test specimens after the completion tests.

Moisture susceptibility of mixes was determined by using indirect tensile strength test (ITS). It involves loading a cylindrical specimen with a compressive load along two opposite sides in the diametrical plane. The result was expressed in terms of Tensile strength ratio (TSR). It is the ratio of the tensile strength of water conditioned specimen, (ITS wet, 60˚C, and 24 h) to the tensile strength of unconditioned specimen (ITS dry) which is expressed as a percentage. The tensile strength ratios were calculated using the following equation:

$$TSR=St(cond)/(St(uncond) \quad (2)$$

Where TSR= Tensile Strength Ratio (%)
St(cond) = Average tensile Strength of Conditioned Sample (kpa)
St(uncond) = Average tensile Strength of Unonditioned Sample (kpa)

D. Statistical Analysis Using ANOVA

Based on the result obtained from laboratory investigation, statistical analysis was performed to evaluate the significance of filler content and type in asphalt mixes using analysis of variance (ANOVA).

IV. RESULTS AND DISCUSSIONS

A. Properties of Materials

Aggregates

To investigate physical properties of aggregates and their suitability in road construction, various tests were conducted, and the results are indicated in Table 1 and Figure 1 presents gradation of aggregate, which satisfies the requirements of Ethiopian Road Authority (ERA) specification.

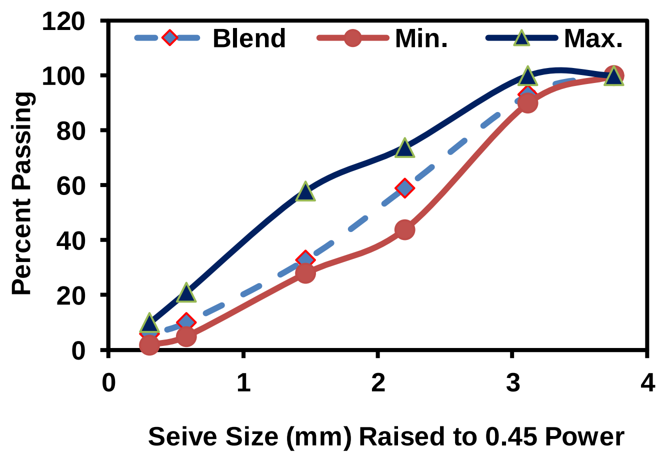

Figure 1 Aggregate Gradation

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 9 Issue 10, October-2020

Table 1 Physical Properties of Aggregate

Test Description	Test Method	Average Test Result	Spec. (ERA, 2013)
Los Angeles Abrasion, (%)	AASHTO T96	15%	< 30
Specific Gravity (Bulk) i. Coarse Aggregate ii. Fine Aggregate	AASHTO T85 AASHTO T84	2.71 2.69	- -
Flakiness Index, (%)	BS 812, Part 105	22%	< 35
Soundness, (%)	AASHTO T104 Coarse Fine	1.0 0.9	< 10 < 16
Aggregate Crushing Value, ACV, (%)	BS 812, Part 110	14.4%	< 25
Water Absorption, (%)	AASHTO T-182	1.2	<2

Mineral Filler

To investigate physical properties of fillers and their suitability in road construction, various tests were conducted, and the results are presented in Table 2.

Table 2 Physical Properties of Fillers

Test	Filler Type		
	Crushed Rock	Ceramic Dust	Natural Sand
Bulk specific gravity (oven Dry)	2.619	2.570	2.514
Bulk specific gravity (SSD)	2.658	2.597	2.551
Apparent specific gravity	2.727	2.642	2.610
Water Absorption (%)	1.516	1.051	1.458
Percent passing on 0.075mm sieve	8.51	43.98	7.66

Asphalt Binder

A series of asphalt tests, including penetration, softening point, flash point, solubility in trichloroethylene, ductility, loss on heating and specific gravity were conducted. Table 3 depicts the physical properties of 80/100 penetration grade asphalt binder.

Table 3 Physical Properties of Asphalt Binder

Test Description	Test Method	Spec. (ERA, 2013)	Test Result
Penetration at 25°C	AASHTO T49	80-100	86
Softening Point (°C)	AASHTO T53	42-51	47
Flash Point (°C) Min	AASHTO T48	219	586.4
Solubility in Trichloroethylene (%) Min	AASHTO T44	99	99.9
Ductility at 25°C Min	AASHTO T51	75	100+
Loss on Heating (%) Max	AASHTO T240	0.8	0.2
Penetration of Residue (% of original)	AASHTO T49	50	89.5
Ductility Residue, cm	AASHTO T51	-	100+
Specific Gravity	AASHTO T228	-	1.013

B. *Marshall Properties of Mixes*

Three specimens for each combination were prepared and the average of these results has been reported. The results obtained for asphalt mixes prepared with 4%, 6% and 8% contents for each filler type at their optimum asphalt binder content are given in Table 4.

Table 4 Effect of Filler Type and Content

Filler Type	Filler Content (%)	OAC (%)	Unit Weight (kg/m^3)	Air Voids (%)	VMA (%)	VFA (%)	Stability (kN)	Flow (mm)
Crushed Rock (CR)	4	5.7	2350	4.60	17.7	73.00	9.90	3.10
	6	5.2	2380	4.40	16.2	72.02	10.20	2.88
	8	5.1	2392	4.22	15.6	72.00	9.70	2.75
Ceramic Dust (CD)	4	5.5	2358	4.71	17.2	72.66	10.50	3.03
	6	5.3	2436	4.20	14.1	69.89	9.60	2.90
	8	5.0	2437	4.09	14.0	70.36	8.11	2.83
Natural Sand (NS)	4	5.4	2363	4.80	16.8	72.60	10.35	3.00
	6	5.3	2368	4.60	16.5	72.05	8.30	2.85
	8	5.2	2376	4.40	15.9	72.00	8.00	2.70

Optimum Asphalt Binder Content (OAC)

Figure 2 presents the relationship between filler content and optimum asphalt binder content. The optimum asphalt binder content decreases as the content of filler increases due to the fact that the void space between aggregates filled by filler materials, there will be a small room for asphalt binder to occupy. Mixes prepared with 6% ceramic dust and natural sand filler exhibit similar optimum asphalt binder content (5.3%).

The highest value of optimum asphalt binder content (5.7%) was obtained for mixes prepared with 4% crushed rock, while the lowest value (5%) was obtained for mixes prepared with 8% ceramic dust. This may be due to the reason that ceramic had more asphalt binder absorption property. ANOVA analysis was performed to evaluate if the difference between the means is significant. At α=0.05 significance level, the null hypothesis which is all the means are equal is rejected for the content of filler. Therefore, it can be conclude that the percentage filler material used can affect the optimum asphalt binder content.

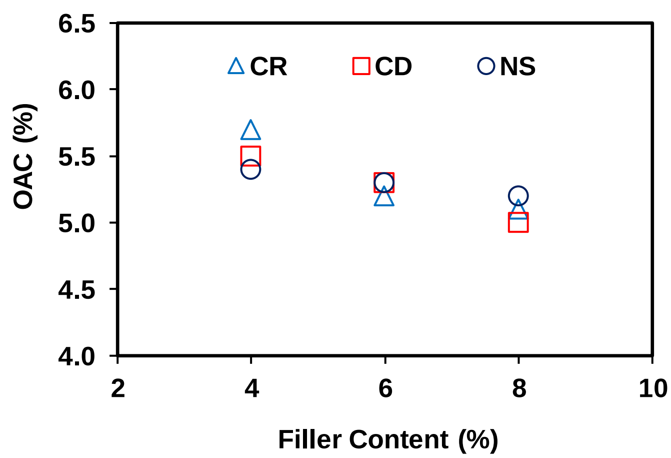

Figure 2 Effects of Filler on Optimum Asphalt Binder Content

Unit Weight

Figure 3 depicts the relationship between unit weight and optimum asphalt binder content for non-conventional and conventional filler types. The result indicates that the weight of compacted specimen increases with an increase in filler content due to the reason as filler content increases in the mix, filler fills out the air voids which allows for denser compaction.

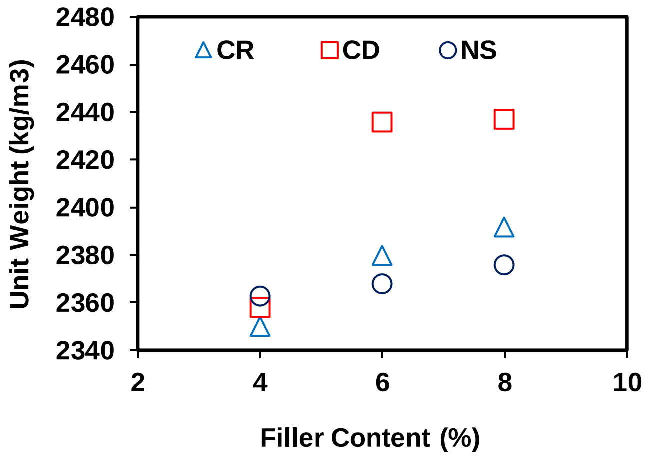

Figure 3 Effects of Fillers on Bulk Specific Gravity

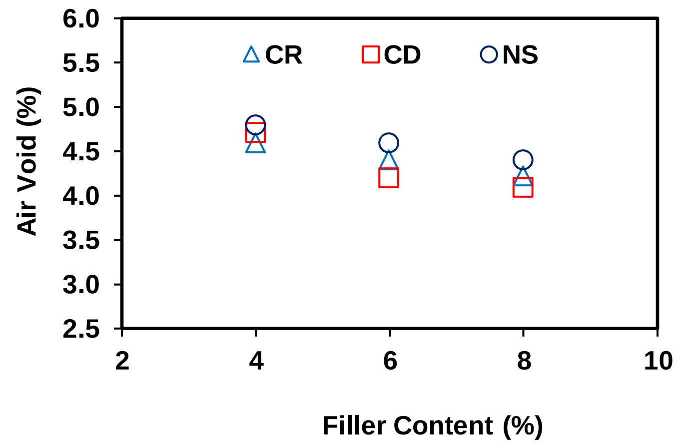

Figure 4 Effects of Fillers on Air Voids

As the result obtained, at 6% and 8% filler content mixes prepared with ceramic dust filler attained the highest unit weight value i.e. 2436 kg/m^3 and 2437 kg/m^3 respectively. While at 4% filler, mixes prepared with crushed rock filler attained the lowest unit weight (2350 kg/m^3) and highest unit weight value obtained for mixes prepared with natural sand filler (2363 kg/m^3). For mixes prepared with ceramic dust filler the unit weight value increases up to a maximum point and then decreases as filler content increases. This may be due to the fact that as filler content increases in the mix, increase the unit weight by filling the voids. However, at higher filler content the mix becomes stiffer that needs greater compaction effort then consequently lower dense mixtures may be obtained.

Air Void (Va)

Figure 4 indicates the relationship between percent air voids in total mix and asphalt binder content. Asphalt mixes prepared with 4% natural sand had the highest percentage of air voids (4.8%) at 5.5% optimum asphalt binder content relative to the value obtained for mixes prepared with 4% ceramic dust and crushed rock (4.71% and 4.6%) at 5.4% and 5.7% optimum asphalt binder content respectively. Higher percentages of air voids were obtained from mixes prepared with natural sand filler. This may be due to the fact that natural sand filler is coarser than ceramic dust and crushed rock fine fillers. Asphalt mixes prepared with 6% and 8% ceramic dust filler had the lowest percentage of air voids. Therefore, natural sand provides more passageways through the mix for the entrance of air and water. ANOVA analysis was performed to evaluate if the difference between the means is significant. At α=0.05 significance level, the null hypothesis which is all the means are equal is rejected for both content and type of filler. Therefore, the difference between the means is significant.

Voids in Mineral Aggregate (VMA)

Figure 5 shows the relationship between percent voids in mineral aggregate and filler content. The percentage of voids in mineral aggregates decreases initially with an increase in filler content. Mixes prepared with 6% and 8% ceramic dust filler had a minimum value of voids filled in mineral aggregate (14.1% and 14%) respectively and mixes prepared with 4% crushed rock filler had a maximum value of voids filled in mineral aggregate (17.7%). For all filler types and contents, the percentage of voids filled in mineral aggregate satisfies the minimum requirement (14%) recommended by (Asphalt Institute MS-2, 1994) for 12.5mm nominal aggregate size at optimum asphalt binder content.

Higher percentage of voids in mineral aggregate was obtained for mixes prepared with 6% and 8% natural sand filler. Therefore, the more space is available for the film of asphalt. However, mixes prepared with 4% crushed rock and ceramic dust filler yields higher voids in mineral aggregates respectively. Voids in mineral aggregates (VMA) is the percentage of void spaces between the granular particles in the compacted paving mixes, including the air voids and the volume occupied by the effective asphalt content. As a result, percentage voids in mineral aggregates decreases as the content of filler increases in the mix. Asphalt mixes prepared with 6% and 8% ceramic dust filler resulted minimum voids in mineral aggregates due to the fact that the mix attained the lowest percent of air void and effective asphalt binder. ANOVA analysis was performed to evaluate if the difference between the means is significant. At α=0.05 significance level, the null hypothesis which is all the means are equal is accepted for both content and type of filler. Therefore, the difference between the means is not significant.

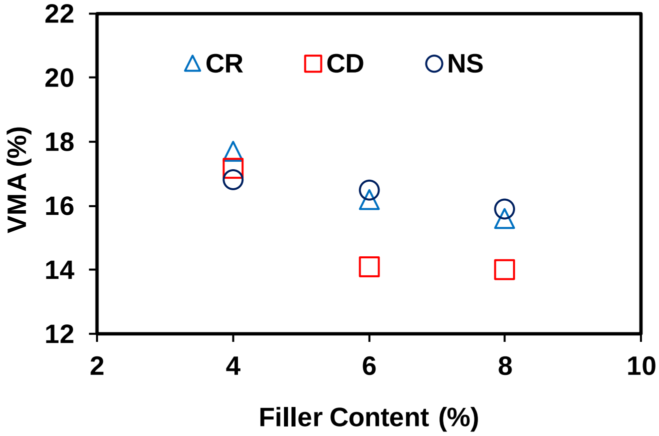

Figure 5 Effect of Fillers on Voids Filled in Mineral Aggregate (VMA)

Voids Filled With Asphalt Binder (VFA)

Figure 6 presents the relationship between percent voids filled with asphalt binder and filler content. Percentage of VFA of compacted specimens decreases with an increase in filler content and then increases and/or remain constant. Mixes prepared with ceramic dust resulted lowest percentage of voids filled with asphalt binder.

Mixes prepared with 6% ceramic dust filler results a minimum value of voids filled with asphalt binder (69.89%) and mixes prepared with 4% crushed rock filler yields a maximum value of voids filled with asphalt binder (73%). For all filler types and contents, the percentage of voids filled with asphalt binder is in the (Asphalt Institute, MS-2, 1994) specification limit (65%-75%) at optimum asphalt binder content. ANOVA analysis was performed to evaluate if the difference between the means is significant. At α=0.05 significance level, the null hypothesis which is all the means are equal is accepted for all used filler contents. Therefore, the difference between the means is not significant. However, the null hypothesis is rejected for mixes prepared with natural sand filler. Since the difference between the mean is significant for natural sand.

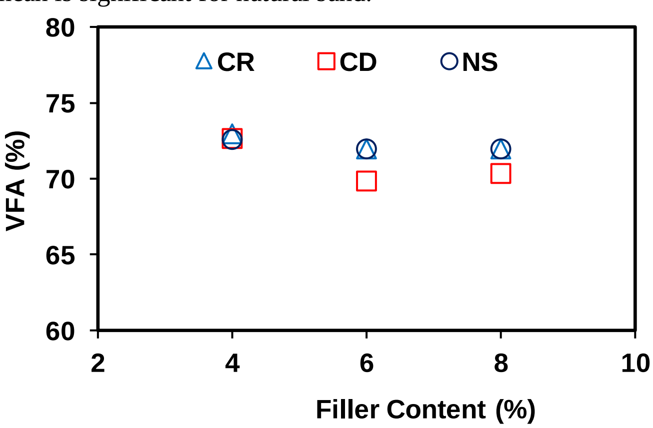

Figure 6 Effect of Fillers on Voids Filled With Asphalt Binder (VFA)

Stability

Figure 7 depicts the relationship between Marshall Stability and filler content. Asphalt mixes prepared with 4% ceramic dust resulted higher stability (10.5 kN) at 5.5% OAC as compared to the value obtained for mixes prepared with 4% natural sand and crushed rock filler (10.35 kN and 9.9kN) at 5.4% and 5.7% OAC respectively. As the percentage of filler content (ceramic dust and natural sand) increases in the asphalt mixes, the stability value decreases significantly. This may be due to the reason that stability is a function of aggregate interlocking and as filler content increases low interlock and internal friction between aggregate particles occur which makes the mix lower stability. However, for mixes prepared with crushed rock filler Marshall Stability increases up to maximum then decreases gradually.

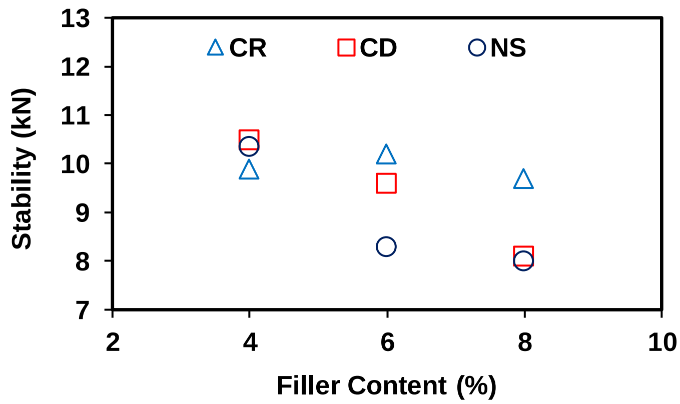

Figure 7 Effects of Fillers on Marshall Stability

Flow

Figure 8 indicates the relationship between flow value and filler content. Mixes prepared with 6% and 8% ceramic dust filler resulted the highest flow. Flow increases with an increase in asphalt binder content because friction between aggregate particles decreases with thicker asphalt binder films. Since flow decreases with an increase in filler content due to the fact that as filler content increase, friction between aggregate particles increases. The flow values at 4%, 6% and 8% filler content of the mixes for all filler materials are within the limits (Asphalt Institute MS-2, 1994).

Mixes prepared with 4% crushed rock filler yields the highest flow i.e. 3.1mm at 5.5% optimum asphalt binder content as compared to the value obtained for mixes prepared with 4% ceramic dust and natural sand (3.03mm and 3mm) at 5.4% and 5.7% optimum asphalt binder content respectively. However, at 6% and 8% filler content, asphalt mixes prepared with ceramic dust results the highest flow (2.9mm and 2.8mm). ANOVA analysis was performed to evaluate if the difference between the means is significant. At α=0.05 significance level, the null hypothesis which is all the means are equal is rejected for both content and type of filler. Therefore, the difference between the means is significant.

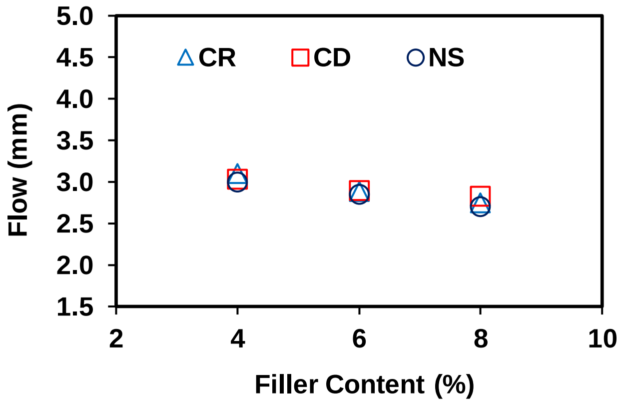

Figure 8 Effects of Fillers on Marshall Flow

C. Indirect Tensile Strength

Figure 9 presents the test result of the indirect tensile strength (ITS) for mixes prepared with crushed rock, ceramic dust, and natural sand filler at 4%, 6%, and 8% contents. Asphalt mixes prepared with 4% ceramic dust filler attained the highest percentage of tensile strength ratio i.e. 87.09% as compared to the value obtained for mixes prepared with 4% natural sand and crushed rock (86.27% and 85.46%) respectively. While, for 6% and 8% filler contents, mixes show lower tensile strength ratio. As a result, the indirect tensile strength value was decreased linearly with increasing filler content. This result may come up because as filler content increases, low interlock and internal friction between aggregate particles which lead the mix had poor internal resistance against external loads. ANOVA analysis was performed to evaluate if the difference between the means is significant. At α=0.05 significance level, the null hypothesis which is all the means are equal is rejected for all filler content used and mixes prepared with natural sand filler. Therefore, the difference between the means is significant.

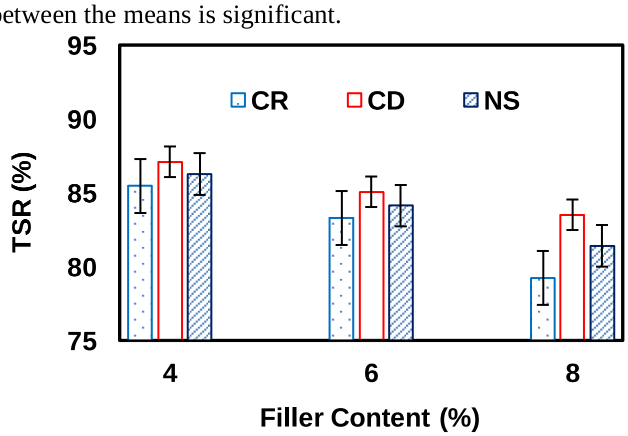

Figure 9 Effects of Filler on Moisture Susceptibility of HMA

D. Economic Evaluation

Construction of asphalt pavements needs the highest budget. The components of hot mix asphalt influence the economy of the pavement construction. Mineral filler is one factor that affects the economy of hot mix asphalt construction. In order to found out an economical asphalt mix, economic evaluation of filler material is necessary. The result obtained for optimum asphalt binder content was selected for economic analysis of hot mix asphalt using ceramic dust and natural sand as filler material as compared to conventional crushed rock fine. The evaluation was conducted by considering cost of asphalt binder and filler for each mix combination and assuming 1 km of 4 cm thickness wearing course per meter width. Figure 10 indicates economic evaluation of asphalt mixes.

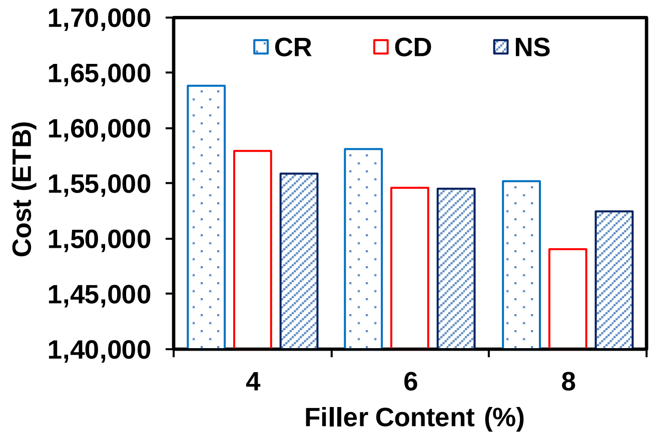

Figure 10 Economic Evaluation

V. CONCLUSION

This study presents the effects using ceramic dust and natural sand as filler material in hot mix asphalt. The study compared the performance of asphalt mixes prepared with ceramic dust, natural sand, and conventional crushed rock fillers material. A detail laboratory investigation was conducted to determine Marshall Stability and flow with corresponding volumetric properties. Based on the results obtained from the study, the following conclusion can be made;

- The weight of compacted specimen increases with an increase in asphalt binder content due to the reason as asphalt binder content increases in the mix because asphalt binder fills out the air voids and lubricates the aggregates movement which allow for denser compaction.
- The optimum asphalt binder content decreases as filler content increases due to the fact that the void space between aggregates filled by filler materials, there will be a small room for asphalt binder to occupy.

- The optimum asphalt binder content obtained for mixes prepared with ceramic dust and natural sand fillers were found nearly the same as the optimum asphalt binder content value obtained for conventional crushed rock filler.
- Higher percentages of air voids were obtained from mixes prepared by natural sand filler. At 6% and 8% filler content mixes prepared with ceramic dust filler had the lowest percentage of air voids.
- Asphalt mixes prepared with 4% ceramic dust and natural sand fillers yields a stability of 10.50kN and 10.35kN which is greater than by 5.7% and 4.3% as compared to control mixes (9.9kN), respectively.
- Marshall flow decreases with an increase in filler content due to the fact that as filler content increase, friction between aggregate particles increases. Asphalt mixes prepared with 6% and 8% ceramic dust had the highest flow (2.9mm and 2.8mm).
- The indirect tensile strength value decreased linearly with increasing mineral filler content. Mixes prepared with ceramic dust and natural sand filler provide better resistance to moisture induced damage.
- Using Ceramic dust and natural sand fines as filler materials in hot mix asphalt construction can save about 2% to 5% of the project cost.
- Generally, ceramic dust and natural sand can be used as filler materials instead of most commonly used conventional fillers such as crushed rock fines.

VI. ACKNOWLEDGMENT

Authors would like to thank Addis Ababa Science and Technology University and Ethiopian Roads Authority for joint sponsorship program. The authors also wish to thank Core Consulting Engineers PLC, Ethiopian Construction Works Corporation Transport Infrastructure Center, Ethiopian Construction Design and Supervision Works Corporation Research, Laboratory and Training Center, and Tabor Ceramic Manufacturing PLC for their unreserved support.

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