Effect of Adding Used-Foundry Sand on Hot Asphalt Mixtures Performance

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ABSTRACT

Highway material researchers have been investigating the use of by product materials such as used-foundry sand as a fine aggregate and mineral filler in asphaltic concrete mixtures to replace the traditional asphalt mixes by new one contain this type of sand. This research show a study using of used-foundry sand as an alternative to filler and fine aggregate in hot asphalt mixture, aims to minimize the environmental effect caused by this waste materials. To evaluate mechanical properties, the mixtures were designed by Marshall method which contain the used-foundry sand and determine indirect tensile strength ratio and then compared with hot asphalt mixtures contained of two types of filler (ordinary cement and limestone dust). The results showing that the reuse of foundry sand in the mixtures of hot mix asphalt as a partial replacement of fine aggregate that retained on sieve No 200 and a total replacement of filler material is viable and can be used in asphalt mixtures production. The hot asphalt mixtures containing of used-foundry sand with cement filler type improved the moisture sensitivity performance as characterized in indirect tensile strength ratio. Furthermore, that the results obtained from Marshall stability test indicate maximum Marshall stability obtained for mixtures with cement and used-foundry sand more than these stabilities for mixes with used-foundry sand and lime stone dust as a filler were (15.3, 12.5 and14.1) respectively **.**

Keyword : used-foundry sand, Marshall stability, indirect tensile strength ratio

INTRODUCTION

Waste recycling in the early 1990s began to focus on high volume discarded materials with potential recyclable value. Over the last two decades, a number of streams previously considered as waste have become valuable byproducts in highway applications. Increased public awareness of green environment gas generation, diminishing nonrenewable natural resources, and the need for environmentally responsible and resource-efficient (sustainable) construction is focusing more attention on increasing the use of recycled materials. These waste material creating environmental pollution in the vicinity because many of them are non-biodegradable. Studies reveal that in recent years, industrial wastes were successful used in road construction in many developed countries. The use of materials in road pavement make is based on economic, and ecological criteria**[1]**.

Mastic material properties of asphalt generally define the hot mix performance to understand the relationship between the asphalt cement and hot mix asphalt properties, it is necessary to understand the effects of different filler types and content in asphalt mastic (asphalt –filler composite) that serves as the binder in hot mix asphalt .According to Dukatz and Anderson (1980) study , when the particle size of the filler are thicker than the binder film, the filler particles contribute to the interlocking of the aggregate. When the filler particles size is smaller than the thickness of asphalt film, the filler particles are suspended in asphalt binder and become mastic **[2].**

Hot mix asphalt (HMA) is generally composed of aggregates, asphalt binders and air voids. Among these components, aggregates composed the highest share amounting 90-96 % by weight and provided the structure for the mix. In a way, most of traffic load is carried by this skeleton of aggregate structures. It is also wise to note that asphalt binders amount 4-6% by weight of the total mix. These components provide the adhesive property in the total mix affecting in their action as visco-elastic material. Fillers material are fine minerals passing the no. 200 sieve . Filler materials in asphalt concrete mixtures have a lot of advantages. In addition to filling the voids, they reducing moisture susceptibility, increasing the bond of aggregate and asphalt and result to increase the stiffness by adding of rigid materials in less rigid matrix **[3].**

However, having too much filler in hot mix asphalt can reduce the cohesive between aggregates and binder as coating of the aggregates by fillers will increase the amount of binders hence weakening the mix. High content of fillers will stiffen the mix to a great extent that the workability is reduced**[4].**

Foundry sand is high-quality uniform silica sand that is used to make molds and cores for ferrous and nonferrous metal castings**[5]**. Recycling of used foundry sand can save energy, reduce the need to mine new materials, and may reduce costs for both producers and end users. Use of foundry sand as a fine aggregate and filler in construction applications offers project managers the ability to enhance green sustainable construction. Asphalt mixtures contained used foundry sand can be designed according to standard asphalt mixture design methods. The quantity of used foundry sand in an asphalt mixture depend on the quantity of fines materials in the foundry sand. Studies have show that used foundry sand can be used to replace between 8 and 25 percent of the fine aggregate and filler material content in asphalt mixes **[6]**.

This study was conducted to determine the performance for asphalt mixture properties containing different filler types. The research plan was designed to analyze the effects of types of filler materials on the properties of asphalt mixture. Tests were evaluated Marshall stability and flow, indirect tensile strength ratio. Three types of filler materials such as (used-foundry sand , cement and limestone dust)were prepared and analyzed for Marshall properties and ratio indirect tensile strength.

EXPERIMENTAL PROCEDURE

Materials Used

Aggregate, filler materials and asphalt cement, used in research have been characterized used of tests and the results were compared with State Corporation for Roads and Bridges specifications (SCRB, R/9 2003)**[7].**The asphalt cement used in this work is 40-50 penetration grades. It was obtained from the Dora refinery. The physical properties of asphalt are shown in **Table (1)**.

Aggregate

The aggregate used in this paper was crushed quartz obtain from asphalt concrete mixture plant located in Taji, its source is Al-Nibaie quarry. This type of aggregate is common used in Iraq for asphaltic mixtures. The coarse and fine aggregates used in this work were sieved and recombined in the suitable proportions to meet the wearing course gradation as required by SCRB specification (**SCRB, R/9 2003**)**[7].** The aggregate gradation curve is shown in **Fig. (1)**.Tests were performed on the aggregate materials to evaluate their physical properties. The results together with the specification limits as set by the SCRB are shown in **Table (2)**. Tests results show that the chosen aggregate met the SCRB specifications.

Filler

The filler is non plastic materials that pass sieve No.200 (0.075mm). Mineral filler used in this work is limestone dust obtained from asphalt concrete mix plant local; its source is the lime factory in Kerbala governorate, ordinary Portland cement, commercially known (Al-mass) and used-foundry sand obtained from waste iron and steel factories local in Iraq, properties of foundry sand in **Table(3)**. And the specific gravity for fillers materials were (3.12 , 2.73,2.70) respectively.

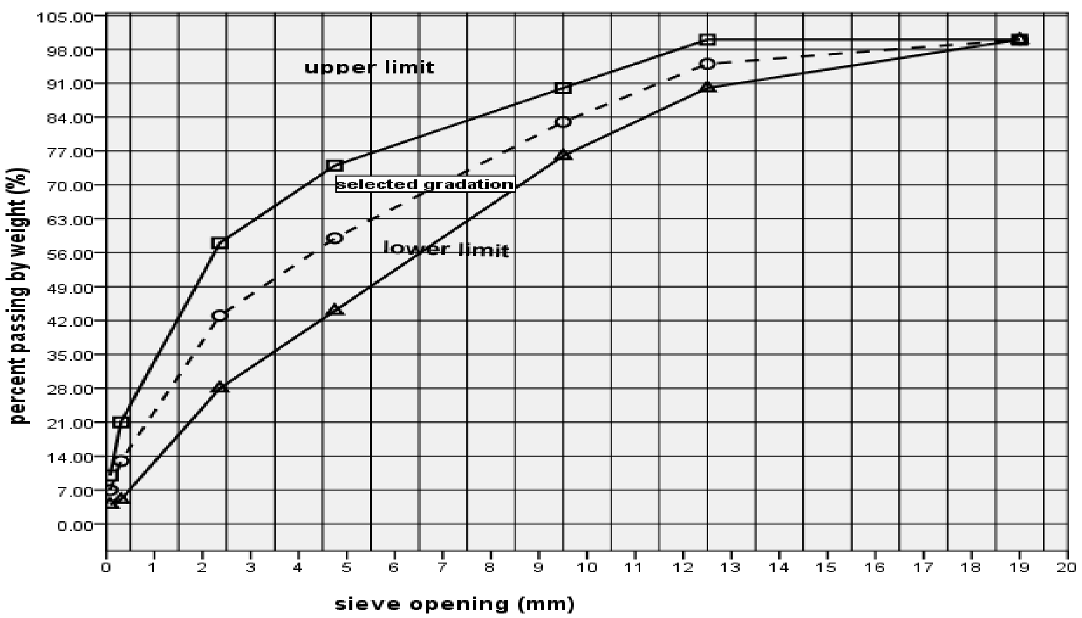

Figure (1) aggregate gradation chart for wearing course

Table 1 Physical properties of asphalt cement.

Test	units	40/50 AC specification	SCRB specification
Penetration at 25C^O 100 gm ,5 sec (ASTM- D5), **[8]**	0.1mm	45	40-50
Softening point R&B (ASTM – D36), **[9]**	C^O	48	----
Specific gravity at 25 C^O (ASTM –D70), **[10]**	-------	1.04	----
Flash point (ASTM –D92) ,**[11]**	C^O	290	Min.232
Ductility (ASTM-D113), **[12]**	Cm	132	Min.100

Table 2 Physical properties of aggregates

Property	ASTM Designation	Test Results	SCRB Specification
Coarse Aggregate :			
1.Bulk Specific Gravity	C-127,**[13]**	2.631	……
2.Apparent Specific Gravity	C-127,**[13]**	2.65	……
3.Water Absorption,%	C-127,**[13]**	0.38	……
4.Percent Wear by Los Angeles Abrasion ,%	C-131,**[14]**	19	35 Max
Fine Aggregate :			
1.Bulk Specific Gravity	C-128**[15]**	2.645	……
2.Apparent Specific Gravity	C-128,**[15]**	2.68	……
3.Water Absorption,%	C-128,**[15]**	0.44	……

Table 3. Properties Of Foundry Sand.

Property	ASTM Designation	Test Results	Limitation of Specification
1. Specific Gravity	ASTM D854-06	2.70	2.39- 2.70
2.Water Absorption,%	ASTMC128-07	0.82	0.76 - 6.20
4. Moisture Content, %	ASTMD2216-05	4	0.1 - 15.0
5. Clay Lumps and Friable Particles,%	ASTM C142-97	10	1-44
6. Plastic Index	ASTM D4318-05	Non	Non plastic to 12
7. Magnesium Sulfate Soundness Loss, %	ASTM C88-05	8	5-15

Marshall Mix Design, Preparation and Test

The mix design and preparation followed the Marshall method as summarized in the standard ASTM- **D6927,[16]**.The asphalt cement percentages by the total weight of the specimens are in the range of (4.0%,4.5%,5%,5.5%,6%) for the surface course. Three samples were prepared for each percent. The property results take the mean value of the tests of the three. Mixtures with an interval of 0.5% in each range were studied. The fifteen samples were made and tested and the optimum asphalt content is obtained as a percentage by weight of the mixture. The compacting effort was 75 blows per face using the Marshall compactor to meet the criteria of design for air voids that ranging between (3 to 5)%. Followed placed the specimens in a water bath at 60 °C for 30 to 40 min. and tested for Marshall Stability and flow .The air void percentage (ASTM D3203),**[17]**, bulk density and specific gravity (ASTM D2726),**[18]** and the maximum (theoretical) specific gravity (no voids in mix) (ASTM D2041),**[19]** were calculated in terms of the following definition:

$$A.V. = 100 * \frac{Gmm - Gmb}{Gmm} \quad .... \qquad (1)$$

$$G_{mb} = \frac{Wa}{Wssd - Ww} \quad .... \qquad (2)$$

$$Gmm = \left(\frac{100}{\left(\frac{\%CA}{SGCa} + \frac{\%FA}{SGFa} + \frac{\%F}{SGF} + \frac{\%Binder}{SGbinder}\right)}\right) \quad .... \qquad (3)$$

Optimum Asphalt Content (OAC)

The OAC is determined based on the main parameters namely: Bulk Density, Air voids , Marshall Stability, values must be evaluated with reference to specifications. All parameters shall be plotted in graphical format versus the asphalt Content .Based on **Fig. 2** For bulk density, **Fig. 3** for air voids and **Fig. 4** for stability it can be conducted that the optimum percentage of mixtures with added used-foundry sand appear to have a higher asphalt content than the mixture with other types of filler such as lime stone dust and cement. The mixtures of UFS , LSD and OPC have the OAC values of 5.2%, 5.1% and 5%, respectively.

The Indirect Tensile Strength (ITS) Test

The indirect tensile strength test, marshall sample is subject to compressive loads along two generators which creating tensile stresses perpendicular to and along the diametric plane causing a splitting failure. Testing procedure is carried according to **ASTM D4867**,**[20]**.The test is normal carry out were the first subset was tested in a dry condition (soaked in water for 2 hours at 25 C^o).The second subset was tested in wet condition were inundated for 24 hours at 60 C^o followed by 25 C^o for 2 hours in water bath. All specimens are tested to determine their indirect tensile strengths using a Marshall loading frame fitted with 12.5mm wide concave surface loading strips below and above the Marshall sample and the rate of loading is the same as in the Marshall Stability test, i. e. 50.8 mm per minute. The ITS value is calculated using the following formula:

$$ITS= \frac{2P}{\pi * t * d} \quad \ldots \qquad (4)$$

Where:

ITS = indirect tensile strength (kPa); Pmax = maximum load at failure (N); t= thickness of sample (mm); d= diameter of sample (mm).

The evaluation of moisture induced damage can be made by determining the Tensile Strength Ratio (T.S.R) as follows:

$$T.S.R = \frac{\text{ST of conditioned (wet) specimen}}{\text{ST of unconditioned dry specimen}} \quad \ldots \qquad (5)$$

Results and Discussion

The bulk density of hot asphalt mixture obtained at various asphalt contents as shown in **Fig.2**. It can be seen that as the asphalt content increases the bulk density also increases until maximum is reached. The maximum value is obtained at 5 percent asphalt content. Possible way to explain the bulk density trend as related with asphalt content for hot asphalt mixture which show increasing with increase the percentage of asphalt content. In other hand the result is showing a increasing of density. And after certain percentage which known an optimum percentage ,the asphalt material which starting to form film of much thickness which leading to reduce the contact distance between aggregate particles and that decreasing in sample density. Bulk density values of mixtures with cement filler type are higher than the mixtures with limestone dust filler type and mixtures with used-foundry sand . This can be attributed to the low specific gravity of lime stone dust and used-foundry sand as value (2.73,2.70) respectively with compared with that of the cement type was (3.12).

Fig.3 shows that, initially, as the binder content increases, the air voids decrease rapidly, up to last percentage of binder content. It may be explained by the fact that as more binder is added into the matrix more voids are filled with binder and therefore the percentage of air voids decreases. In general, the range of air voids percent for hot asphalt mixture about (3-5) % which matching with Iraqi specification . Air voids values of mixtures with cement filler type are slightly lower than the mixtures with limestone dust filler type and mixture with used-foundry sand filler . The reduction in air voids is due to the cement particles filling up more of the void space available in the mixture due to fineness of cement particles, increasing packing, and therefore reducing porosity. Also, due to the low density of used-foundry sand compared with that of the replaced other types of filler such as limestone dust and cement type, and this is attributed to the increase of air voids for mixtures with used foundry-sand and mixtures with limestone dust .

Fig. 4 Show that the Marshall stability increases continuously as the binder content increases up to a certain percentage of binder content and after this point the stability dropping down with increment of binder content. The difference in Marshall stability within mixtures with regard to added asphalt content can be principally attributed to the degree of coating, since all the other factors which might influence the stability were kept constant, i. e. compaction level, type of asphalt and aggregate gradation. As the percentage of asphalt content was increased, the rate of coating of the aggregates was improved. Which leads to better distribution of binder and reduction in the percentage of uncoated aggregates both of which contribute towards better stability. Although an increase in the amount of asphalt content improves the coating of the aggregate and results in better dry stability, an excessive amount of asphalt content will produce a very wet mix and therefore the aggregate percentage as compared with other mixes for less asphalt content is reducing which play important role in Marshall stability, due to the aggregate particles is more stronger from asphalt material and asphalt mastic. Also **Fig. 4** show that the Marshall stability for mixtures with filler of cement type was higher than that of the mixtures with of filler used-foundry sand type and limestone dust type. The increase in Marshall stability for mixtures with filler of cement type can be attributed to the cement is finer than limestone dust and used-foundry sand. The replacement of lime stone dust and used-foundry sand by cement as filler increases the stiffness of the mixture, because of the addition of cement increases the viscosity of the asphalt mastic which constituted the film around the aggregate particles . for the above reasons, the porosity will be reduced and increasing the bond between the cement with asphalt material which increasing the stiffness and rigidity of mixtures. Therefore, surface texture for used-foundry sand filler type is angularity and contained of wastes includes iron alloy which increased the interlocking with asphalt material and strengthen of interface transition zone of mixture ,but with higher value of air voids . And this does not occur with the mixtures with filler of limestone dust type. Thus the Marshall stability for mixtures with cement type of filler is higher than that of mixtures with used-foundry sand type and limestone dust type of filler .From the above results , can be concluded that the using of used foundry sand gives a results conform with Iraqi specification

The Flow values for hot asphalt mixtures are represented in **Fig.5** it is found that the flow values initiated to increases with increasing of asphalt content until reached to maximum value at the higher percentage of asphalt content. Also it can be noted that the flow values for mixtures with filler of cement type is lower than that for mixtures with limestone dust filler and mixture with used-foundry sand filler. This can be attributed to the high rigidity, stiffness and low air voids of mixtures with cement filler and this improves the flow values.

Fig.6 show comparison of bulk density for mixtures contained of different types of filler . Also it can be noted that the value of bulk density for mixtures with filler of used-foundry sand and cement type higher than that for mixtures with other types of filler. This is behavior is attributed to specific gravity of cement as value (3.12) and the interlocking with cement and asphalt material leads to filling voids in interface transition zone of mixture and obtained an optimum thickness form film for mastic asphalt which leading to increase the bulk density of mixture.

Fig.7 show comparison of air voids for mixtures contained different types of filler. It is found that the air voids values were reduced for mixtures with filler of used-foundry sand and cement type filler ,due to Cement particles filling up more of the void space available in the mixture due to fineness of cement particles, increasing packing, and therefore reducing porosity and mixtures with filler of used-foundry sand and cement type filler gave high bulk density from other mixtures.

Fig.8 show comparison of Marshall stability for mixtures contained different types of filler. It can be seen that Marshall stability value for mixtures with filler of used-foundry sand and cement type filler are higher than the mixtures with other types of filler. This can be attributed to two reasons, first reason is surface texture for used- foundry sand is angularity and contained of wastes includes iron alloy which increased the interlocking with cement and asphalt material .Second reason, because of the addition of cement increases the viscosity of the asphalt mastic which constituted the film around the aggregate particles and the porosity will be reduced and increasing the bond between the cement with asphalt material which increasing the stiffness and rigidity of mixtures.

Fig. 9 show comparison of flow value for mixtures contained different types of filler . It is found that the flow values for mixtures with filler of used-foundry sand and cement type filler lower than that for mixtures with other types of filler ,due to the high rigidity, stiffness and low air voids of mixtures with of used-foundry sand cement filler and this improves the flow values.

Fig.10 show that the dry Indirect tensile strength for mixtures with filler of used-foundry sand type is higher than that for mixtures with filler of cement type and for mixtures with filler of limestone dust type . This is due to surface texture for used- foundry sand filler type is angularity and contained of wastes includes iron alloy which increased the interlocking with asphalt material and strengthen of interface transition zone of mixture , and this does not occur with the mixtures with other types of filler . The mixtures containing cement filler having high rigidity, stiffness, higher density and low air voids .

Fig. 11 show that the wet indirect tensile strength for mixtures with cement filler is higher than that for mixtures with used-foundry sand filler and limestone dust filler. This is behavior is attributed to the low air voids of hot asphalt mixture with cement filler leading to low water absorption. Therefore, the moisture effects on mixtures with filler of cement type are lower than that for mixtures with filler of limestone dust type and used-foundry sand filler type. And that can be attributed to the cement which reacts with water at first hours and developed hydration products which would reduce porosity and increasing the bond cement between cement and asphalt binder material and increasing the stiffness and rigidity of mixtures with filler of cement type. This did not occur for mixtures with filler of limestone dust type.

Fig. 12 show that the indirect tensile ratio for hot mixtures with filler of cement type was higher than the mixtures with filler of used-foundry sand type and limestone dust type.

CONCLUSIONS

1. The used foundry sand is suitable used as a partial replacement as a fine aggregate and used as a total replacement of filler for production hot asphalt mixtures .

2. The suitable partial replacement of used-foundry sand as fine aggregate for hot asphalt mixtures contained of cement filler and limestone dust filler .This procedure produces appropriate properties such as bulk density ,air voids ,Marshall stability and indirect tensile strength ratio of hot asphalt mixture .

3.The hot asphalt mixtures containing fine aggregate such as used-foundry sand with cement filler type improved the moisture sensitivity performance as characterized in Tensile Strength Ratio testing procedures and having high indirect tensile strength.

4. The results obtained from Marshall stability test indicate maximum Marshall stability obtained for mixtures with cement filler is 13.6kN and 12.5kN for mixtures with used-foundry sand filler and 11.25kN for mixtures with lime stone dust.

5. The hot asphalt mixtures containing fine aggregate such as used-foundry sand that retained on sieve No 200 with other types of filler improved the mechanical properties of hot asphalt mixtures containing fine aggregate such as natural sand .

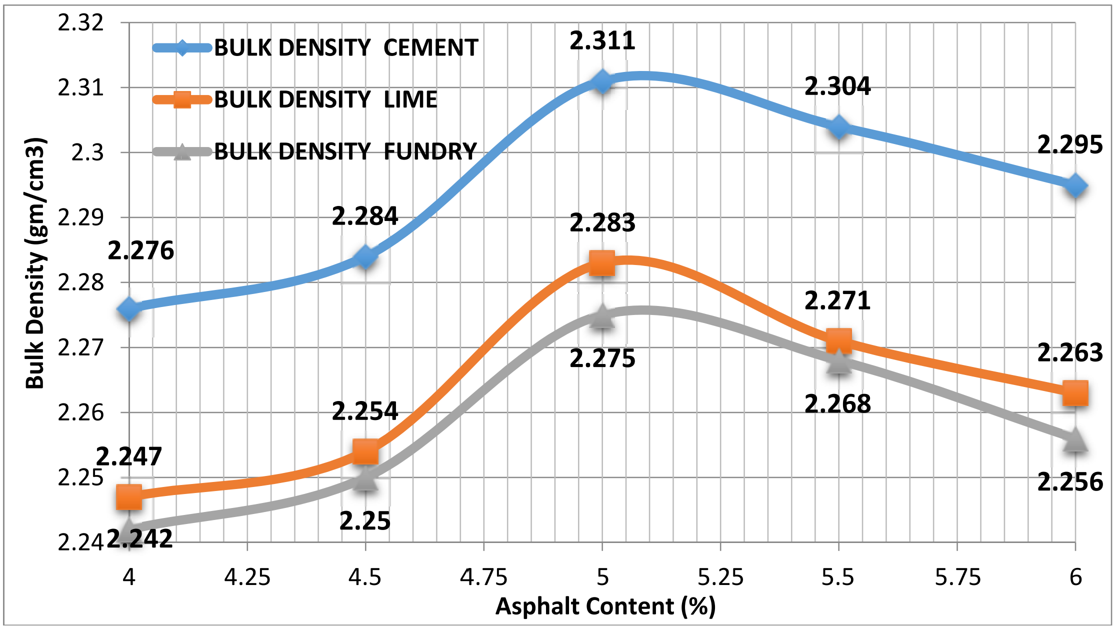

Figure2. Bulk density with asphalt content (%) for different types of filler.

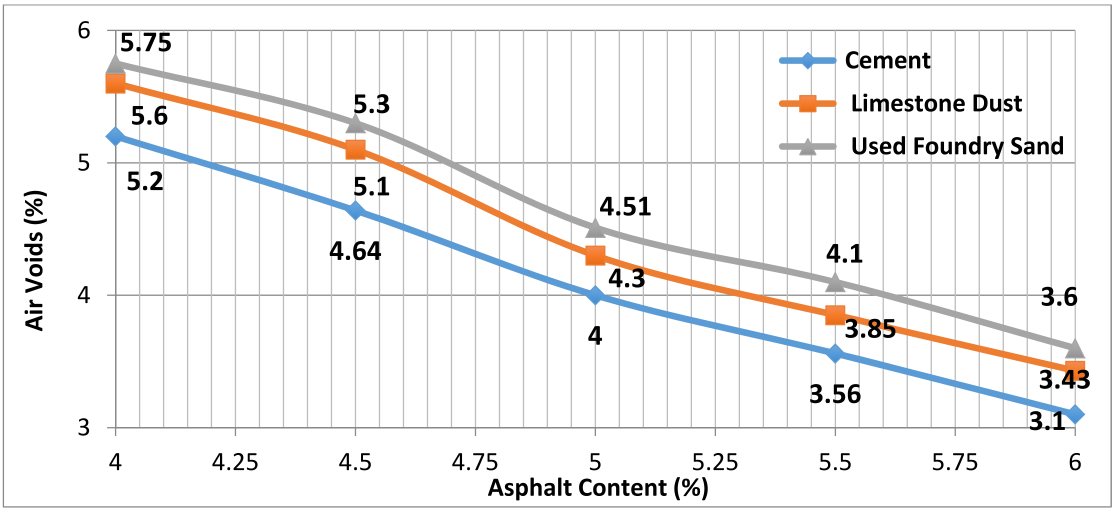

Figure3. Air voids with asphalt content (%) for mixtures with different types of filler.

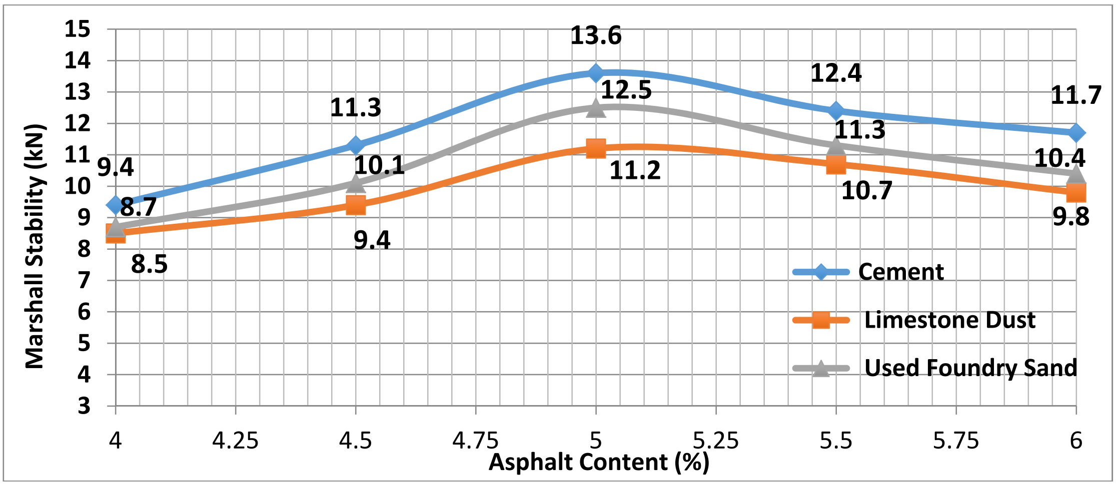

Figure 4. Marshall stability with asphalt content (%) for mixtures with different types of filler.

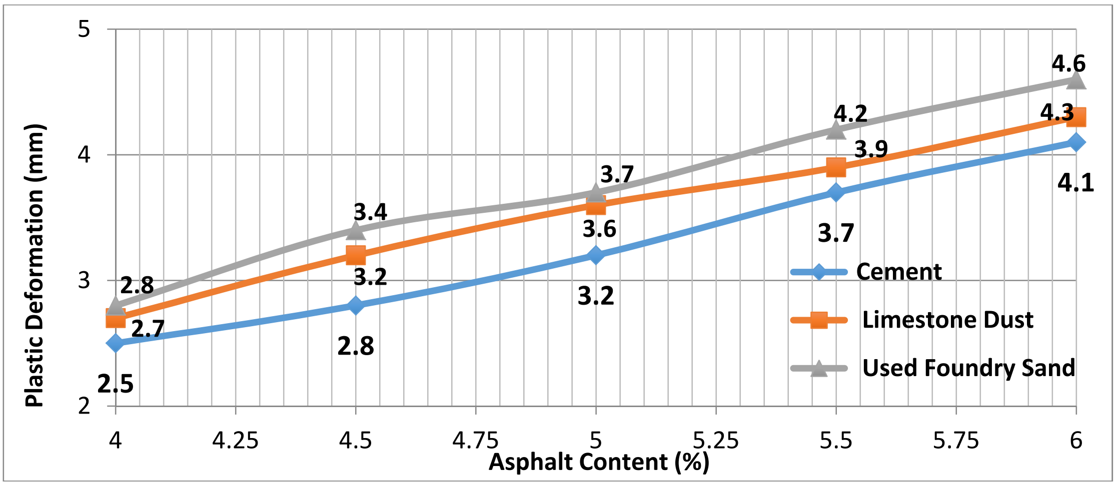

Figure 5. Flow value with asphalt content (%) for mixtures with different types of filler.

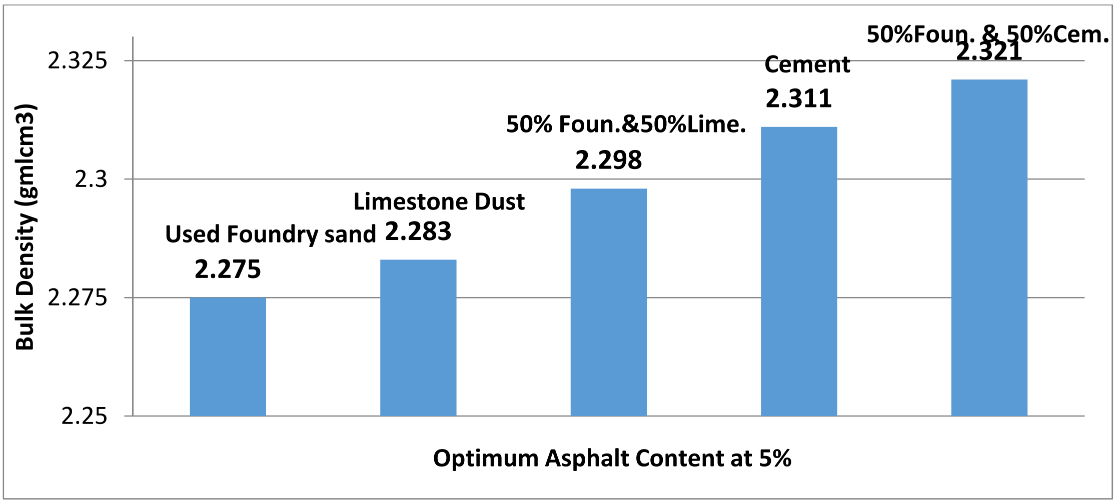

Figure 6. Comparison of bulk density with asphalt content at (5%) for mixtures with different types of filler.

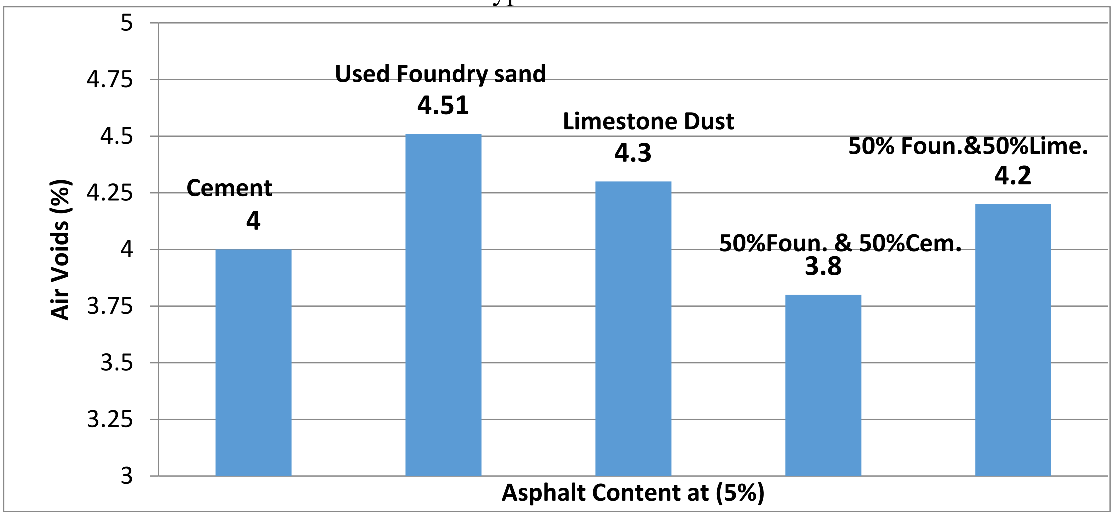

Figure 7.Comparison of air voids with asphalt content at (5%) for mixtures with different types of filler.

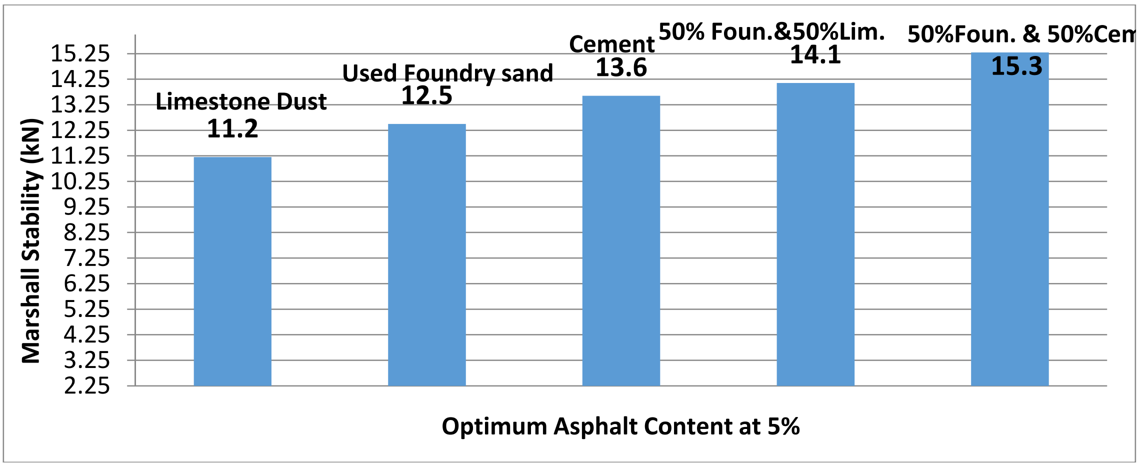

Figure 8.Comparison of Marshall stability with asphalt content at (5%) for mixtures with different types of filler.

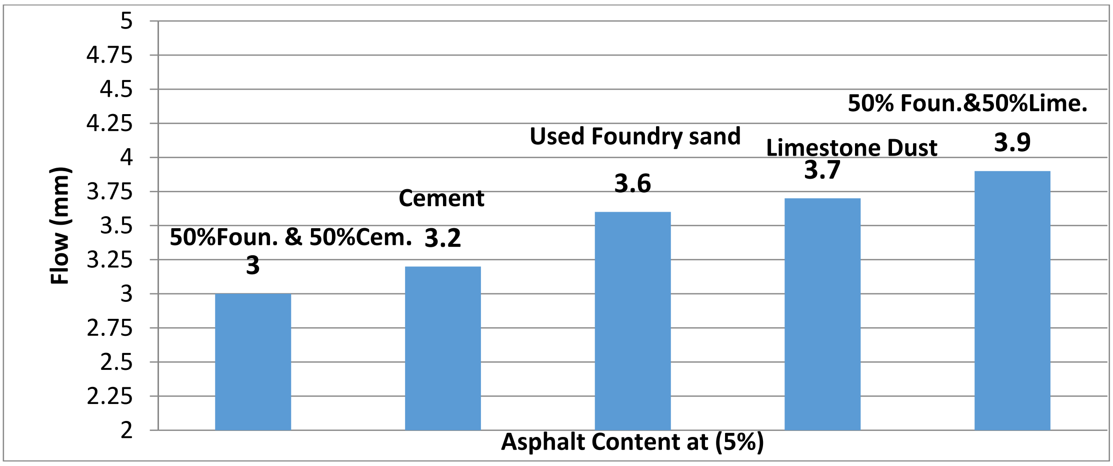

Figure 9.Comparison of flow value with asphalt content at (5%) for mixtures with different types of filler.

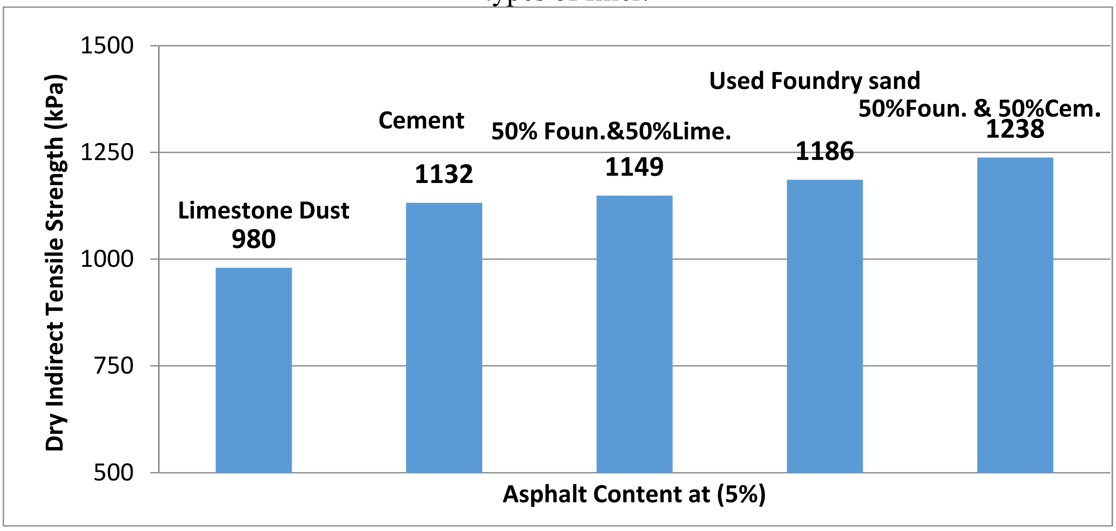

Figure 10. Dry indirect tensile strength (kPa) with asphalt content at (5%) for mixtures with different types of filler.

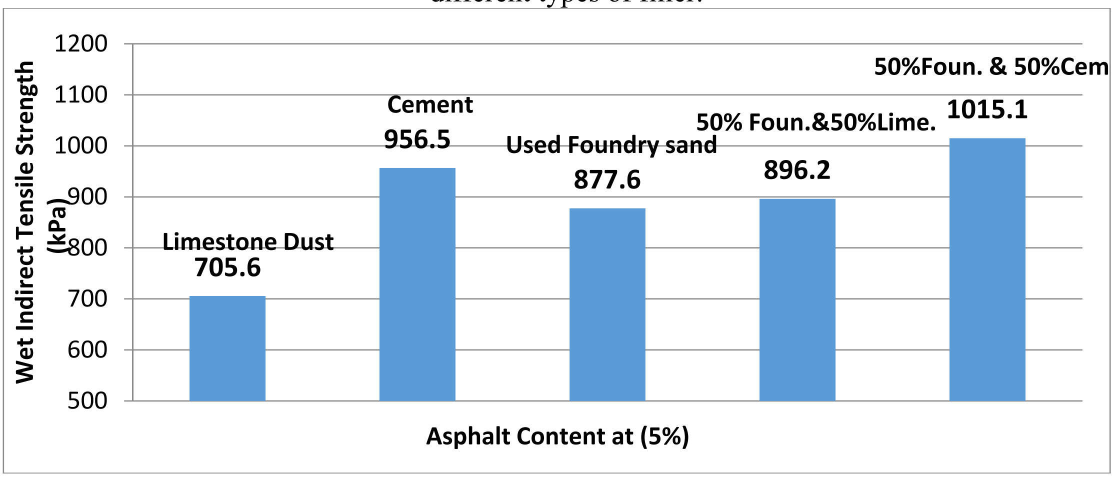

Figure 11. Wet indirect tensile strength (kPa) with asphalt content at (5%) for mixtures with different types of filler.

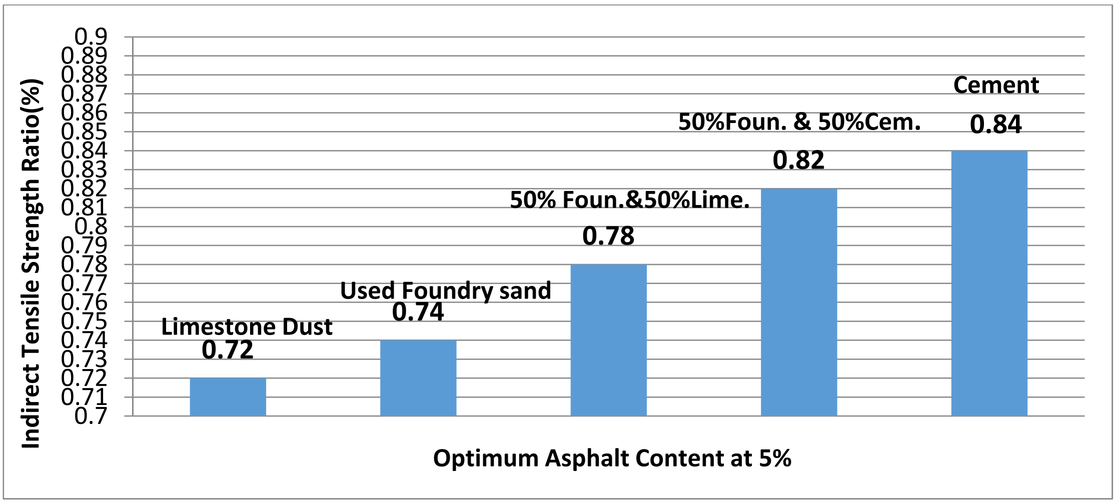

Figure 12. Indirect tensile strength ratio with asphalt content at (5%) for mixtures with different types of filler.

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