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THE EFFECT OF FILLER TYPE AND CONTENT ON ASPHALT MIXTURE PROPERTIES

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ABSTRACT

The performance of the asphalt mixture is affected by the properties and specifications of the materials that make up the mixture, like bitumen, aggregate, and the types of the filler mineral material, as it has shown in many studies. In this study, the effect of filling type on asphalt mixture properties were studied using three different types and in different proportions, where Gravel powder, Limestone powder, and Portland Cement were used and with ratios of (3.5%, 5%, 6.5%) of the total weight of aggregate with Bitumen content (3.5%, 4%, 4.5%, 5%, 5.5%). This research is dedicated to study the effect of filler type and amount on the asphalt mixture properties. The general results of the Marshall test showed an improvement in some properties of the asphalt mixture with 5% of Bitumen content, where the results showed that the use of Gravel powder improves the Stability property with an increase rate between 4% to 21% and 8% to 16% Compared to Limestone powder and Portland cement respectively. Also, the value of VMA% of gravel powder samples increased by 5% and 3% for both Limestone powder and Portland cement respectively. There is also a large convergence in the results of Retained Strength for each of Gravel powder and Portland cement, where the percentage of reached more than 98% and 97% for each of Gravel powder and Portland cement respectively.

KEYWORDS: Asphalt mixture, Gravel powder, Limestone powder, Portland Cement, Marshall Stability

1. INTRODUCTION

Asphalt mix consists of three components, aggregate, asphalt binder and air voids [1]. Mineral filler can be defined as that aggregate fraction that passes sieve No. 200. Asphalt binder and filler composite a mortar that is known as mastic which have an important effect on asphalt mix performance [2]. Lime dust and ordinary Portland cement are often used as mineral fillers in asphalt mixture in Iraqi Kurdistan. Although, Gravel dust is available aggregate type, gravel dust is not used in the asphalt mix [3].

In general, filler works as an extender for the asphalt binder to ensure a proper aggregate coating and therefore thicker film thickness. This means that filler can play a major role in asphalt durability, in the same manner filler can enhance the bonding with aggregate and thus reduce moisture damage. Moreover, filler increases the asphalt binder stiffness which directly affect asphalt mix resistance to deformation. The optimum dust to asphalt ratio (D/A) has been a major concern for many researchers. The Strategic Highway Research Program (SHRP), when develop the Superpave system suggested a dust to asphalt ratio of 0.6 to 1.2. However, many countries found that the ratio is not appropriate and the percentage need to be extended up to 1.6 [4]. This difference in (D/A) is due to the change in the filler types through countries which highlight the importance of filler types.

Aljassar et al (2007) [5], states that filler type and amount play a major role on asphalt performance. In Kuwait the main fillers types are ordinary Portland cement and limestone dust. They compared the impact of both filler types with three filler content, on the strength of asphalt mixture (Marshall stability) and retained strength. Both types of filler showed similar influence on Marshall stability, while using ordinary Portland cement showed higher values of retained strength. Furthermore, the asphalt mix needed less ordinary Portland cement than limestone filler to achieve the highest value of Marshal stability.

Buttlar et al (1999) [6], investigated the asphalt mastic behavior through micromechanics to understand how the filler stiffening the asphalt mixtures. Eperimental program was made to

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assess micromechanical properties of mastic on low temperatures and filler contents. A physico-chemical reinforcement that gain the mix rigidity by the interaction or absorption by asphalt and filler particles. They suggests that the stiffening that the mastic showed could be due to volume filling and more volume concentration of rigid inclusions. Also, a similar role is appeared by reinforcement with particle-interaction.

One of the most complicated failures in asphalt pavement is the moisture damage, therefore asphalt pavement shows loss in the mixture structure in term of aggregate particles bounding. Since, filler contributes in asphalt durability, it was a major concern for highway engineers to find the effect of filler on asphalt durability. Airey et al, (2008) [7] examined the effect of filler on asphalt pavement moisture damage by AASHTO T283 test and Saturation Ageing Tensile Stiffness (SATS) which was developed in the University of Nottingham and later used to evaluate the moisture damage of asphalt in the UK. Granite filler and hydrated lime was used with conventional limestone filler. The result shown that the granite filler appears to have lesser erformance than the conventional limestone filler. On the other hand, hydrated lime improved the resistance to moisture damages. Thus, filler type may have an impact on the asphalt durability.

Cong and Zheng (2005) [8] studied how performance of hot-mix asphalt could be affected by filler/asphalt ratio by Using two filler types (Gabbro and limestone powder). Marshall method was used to find the optimum binder and the filler content which showed decreasing in the optimum binder content as the filler to the asphalt ratio was increased. Stability was increased and the strain decreased when the filler to asphalt ration increased too. This was probably due to the proper asphalt binder film thickness around aggregate particles and stiffening the mix, however excess of filler in the mixture can make it susceptible to cracks and raveling. Rahman et al (2012) [9] used brick dust as a non-conventional filler and cement and stone dust as conventional fillers. Brick dust filler specimens showed higher stability value compared to the cement and stone dust filler specimens; however, the voids in total mix were found to be high. In general, the voids reached up to the acceptable limit (5% according to Marshal method) with a high binder content. This will make the asphalt mix that used for brick fillers not durable and susceptible to distress.

In northern Iraq, limestone filler and ordinary Portland cement is the most common filler types due to their availably. Gravel dust (filler) is usually thrown away although crushed gravel is the dominant aggregate type there, which makes an environmental issue. This paper investigates using of limestone, ordinary Portland cement and gravel dust as a filler, and displays the impact on asphalt mix properties using the Marshal method. Also, the effect of each type on moisture damage by Retained Strength test using ASTM D 1075 procedure.

2. MATERIALS

2.1 Bitumen

The (40/50) grade of bitumen from Kirkuk refinery was used in this study, such grade is normally used in roads construction projects in Iraqi Kurdistan. The bitumen was already being used in the asphalt binder course layers for the construction of an 18 Km highway (made for heavy load vehicle) in Zakho district, in the North of Iraq. The properties of bitumen as it shown in Table 1.

Table (1): Properties of Bitumen

Property	Value	Specification	Method
Penetration at 25 °C 100g, 5s. (0.1mm)	34	40-50	AASHTO T49
Softening Point °C	52.3		AASHTO T53
Flash point, Cleveland open cup, °C	+300	>232	AASHTO T48
Ductility at 25 °C, 5 cm/min, cm	+100	>100	AASHTO T51
Solubility in trichloroethylene, (%)	99.8	>99	AASHTO T44
Loss in weight by heating (%)	0.337	-	AASHTO T179
Penetration of residue at 25 °C 100g, 5s, original (%)	67.3	>55	AASHTO T49
Ductility of residue at 25 °C, 5 cm/min, (cm)	62	>25	AASHTO T51

2.2 Aggregate Gradation

The crushed aggregate that has been used in the study was collected from an asphalt plant, from the same project that is maintained in 2.1. The sources of aggregate are a river gravel (in a boulder quarry) on Hizel river. The properties of aggregate are shown in Table 2. The selected gradation was for an asphalt binder course as shown in Table 3.

Table (2): Properties of Aggregate (Crushed Gravel)

Property	Value
Percent of crushed stone (Fracture) (%)	92.4
Liquid Limit (L.L) (%)	NP
Plastic Limit (P.L) (%)	NP
Plasticity Index (P.I) (%)	NP
Bulk Specific Gravity (Coarse Aggregate)	2.672
Bulk Specific Gravity (Fine Aggregate)	2.660
Apparent specific gravity (Coarse Aggregate)	2.722
Apparent specific gravity (Fine Aggregate)	2.757
Los Angeles (Mechanical Abrasion) (%)	20.2
Chemical Abrasion (Magnesium) (%)	2.71
Soluble Salts (%)	1.45
Organic Matter (%)	0.3
SO_3 (%)	0.97

Table (3): Aggregate gradation (Binder Course)

Sieve Size		Percent Passing by Weight		
Inch	mm	Job Mix Tolerance	Average Job Mix formula	Specification Limits Binder Course
1	25	100	100	100
¾	19	85.6 - 97.6	91.6	90 - 100
½	12.5	71.2 – 83.2	77.2	76 - 90
3/8	9.5	52.1- 64.1	58.1	56 - 80
No. 4	4.75	34.8 – 46.8	40.8	35 - 65
No. 8	2.36	24.9 – 32.9	28.9	23 - 49
No. 50	0.425	8.3 - 16.3	12.3	5 -15
No. 200	0.075	2.8 - 6.8	4.8	3 - 9

2.3 Mineral Fillers

Three types of mineral fillers have been used in this research those were: limestone powder, gravel powder and ordinary Portland cement. The properties of fillers are shown in Tables 4 an d 5. Limestone dust was collected from crusher plant situated at Bekher Mountain in Zakho district, in North of Iraq. The Gravel dust used in the study was collected from the asphalt plant that is using river gravel (in a boulder quarry) on Hizel river. The Portland cement that been used is form Mass cement plant.

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Table (4): Properties of Gravel and Limestone fillers

Property	Limestone Powder	Gravel Powder
Percentage Passing by Weight, Sieve No.50 (0.3 mm)	99	100
Percentage Passing by Weight, Sieve No.200 (0.075 mm)	79	73
Specific gravity, Gs		
Liquid Limit (%)	NP	NP
Plastic Limit (%)	NP	NP
Plasticity Index (%)	NP	NP
Linear Shrinkage (%)	NP	NP
Swelling (%)	2.41	1.31
MDD (g/cm3)	1.847	1.675
OMC (%)	12.4	17.3
CaCO3 (%)	98	73

Table (5): Physical and chemical properties of Portland cement filler

Property	Value
Percentage Passing by Weight, Sieve No.50 (0.3 mm)	100
Percentage Passing by Weight, Sieve No.200 (0.075 mm)	100
Specific gravity, Gs	3.03

3. METHODOLOGY

3.1 Mixture Design

The Marshall design method for asphalt mixtures was used to design all the mixtures. These mixtures have the same aggregate type and gradation with same bitumen type but with different filler types and contents. This is to investigate the effects of filler type and contents on the properties of HMA mixtures. To remove any trace of filler, from the aggregate and before adding filler typed, sieve No. 200 was used washed the aggregate with water. Three types of filler (limestone powder, gravel powder and the ordinary Portland cement) were added in different percentages (3.5%, 5%, 6.5%) into the aggregate to produce the gradation as maintained before. The required bitumen content (AC%) for each mixture with different filler types and amount was founded using the Marshall design method.

3.2 Sample Preparation

To prepare the samples, bitumen binders, fillers and aggregate were heated in an oven to 160C°. To achieve the desired gradation, all were weighed and mechanically blended in a pre-heated container on an electric hot-plate set with a temperature of 160C°. The hot mix asphalt samples specimens were made with a cylindrical sample (62.5mm high by 100mm in diameter) which were compacted by the Marshall hammer. 15 samples were made for each filler type and contents, then, the mixture properties like air voids (Va), void in mineral aggregate (VMA), void filled with asphalt (Vfa) were calculate.

3.3 Marshall Test

Marshall method of mix design is one of the most popular design methods worldwide, and its used as a standard method in Iraqi specification for road and bridges. The standard Marshall procedure ASTM D 1559 was followed to perform the test, specimens for the three filler types considered at the three filler contents. By 75 blows were applied on both sides of the specimen that was carried out to compact for each sample using an automatic Marshall hammer compactor. The Marshall stability and flow were tested by Marshall testing machine to determine the optimum bitumen content by increment of 0.5% for each type and content of filler. The bulk specific gravity and the theoretical maximum specific gravity was measured and calculated for each three specimens for each combination. The specimen was immersed in water bath at 60C for 40 minutes and then pressed on side surface at rate of 2 inch/min to the maximum load. The resistance (maximum load) and the value of the flow were recorded.

3.4 Retained Strength Test

Retained strength test as per (ASTM D 1075) is a popular method that been used to evaluate the resistance of the asphalt mixture to moisture damage and it’s specified by Iraq specification. This test is used to evaluate the effect of filler type and content (with optimum AC%) on loss of compressive strength of asphalt mixes after immersion in water. The measured index in term of retained strength is calculated using the following equation:

$$\text{Index of retained strength (\%)} = \frac{S2 \times 100}{S1}$$

Where:

S1: is compressive strength (dry specimen).

S2: compressive strength (immersed specimen).

4. RESULTS AND DISCUSSION

4.1 Marshall Test

4.1.1 Effect of filler content on Stability:

The Marshall stability can give an idea of the performance of asphalt mix, figure 1 shows the relationship between filler to bitumen ratio and the stability. In general gravel powder has the most effectiveness on stability which can be due to less amount of bitumen binder with increase filler content. Although adding more filler can increase the strength of the asphalt mixtures, its brittleness can cause less resistance to fatigue cracking. The maximum stability value of 21.1 KN is observed at 1.25% filler to bitumen ratio in case of gravel powder as a filler, while in case of cement and limestone fillers, a maximum stability value of 17.8 KN is obtained also at 1% filler to bitumen ratio. Gravel powder filler has a higher value of stability comparative to the cement and limestone fillers about 19% and that is due to the properties of gravel powder.

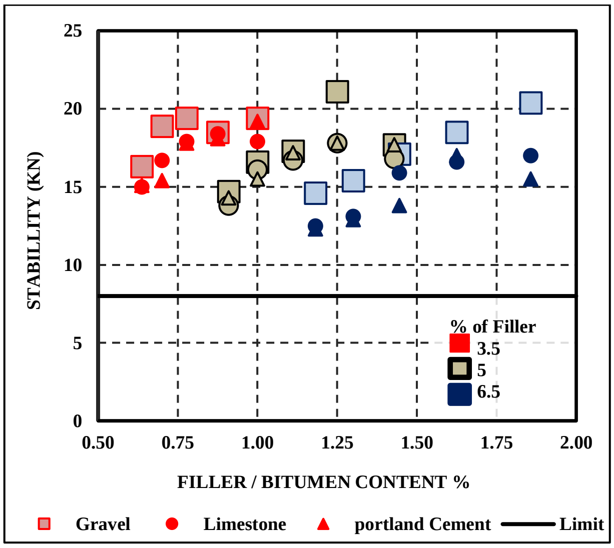

Fig. (1): Effect of filler/bitumen content % on stability of Asphalt mixture

4.1.2 Effect of Filler Content on Air Voids:

Air voids contents have a significant effect on asphalt mix performance and durability. The variation of Marshall Air Voids with filler/bitumen content results shown in Figure 2. It can be seen that the Air void decease with the increase in filler/bitumen ratio. More filler content mean more lubricates the aggregate and therefore easer to compact less air voids. However, a mix with (3 to5) % air void is required for design purposes, which was achieved with different bitumen/dust ratio (%). Minimum air void of 1.4% is observed at 5.5% bitumen content in case of gravel powder as a filler and in case of cement and limestone fillers, while the minimum air void of 1.5% and 1.8% are obtained at 5.5% bitumen content respectively. The best Air voids percent was at 4% of bitumen content with 5% of filler which it was 4.5% for Portland cement, 4.7% for limestone powder, and 4.8% for gravel powder.

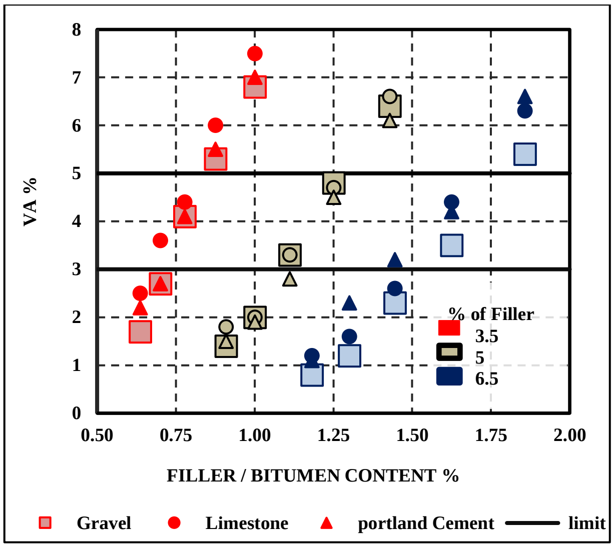

Fig. (2): Effect of filler/bitumen content % on percent of air voids.

4.1.3 Effect of Filler contents on Voids in Mineral Aggregates (VMA)

A proper void in mineral aggregates (VMA) percentage can represent the bitumen film thickness which have a major effect on asphalt packing. VMA in asphalt mixture is highly affected by the type and characteristics of the mineral fillers, also, it is based on the nominal maximum particle size used and the design air voids of a mix. In figure 3 the effect of the material filler and bitumen content on the value of VMA%, and in general, the higher filler/bitumen ratio the lower the VMA become due to thicker bitumen film and less void between aggregate particle. The results for the variation of VMA with filler/bitumen content at 5% of filler were shows that the VMA value decreases with bitumen content 4.5%, and then increased by up to 5.5%. The minimum VMA% value of 12.7% is observed at 4.5% bitumen content in case of Portland cement and 12.8% in case of gravel powder which it is obtained at 4.5% and 5% bitumen content, while for limestone powder the Min. VMA% was 13.4% at 5% of bitumen content. In general, using Limestone powder filler will give the highest value of VMV% at all percentage of bitumen content comparative to the cement and gravel powder limestone fillers and that is out of limitations.

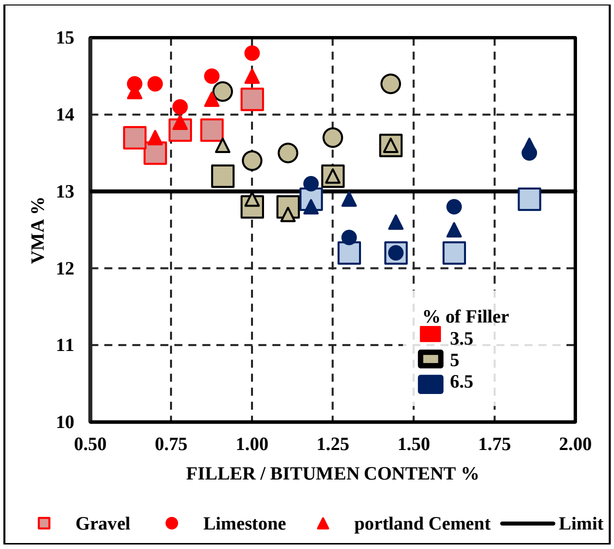

Fig. (3): Effect of filler/bitumen content ratio on percent of voids in mineral aggregate.

4.1.4 Summary of Marshall Test Result

In general, the filler type and content have a notable effect on asphalt mix performance and properties. Gravel could be used in an asphalt mix and give an acceptable result in term of Marshall stability and mix volumetric properties. Figure 4 to 6 shows only the result of the samples that meet the design specification.

Figure 4 shows the comparison between the stability results and filler/bitumen ratio of the asphalt mixture samples with different filler types.

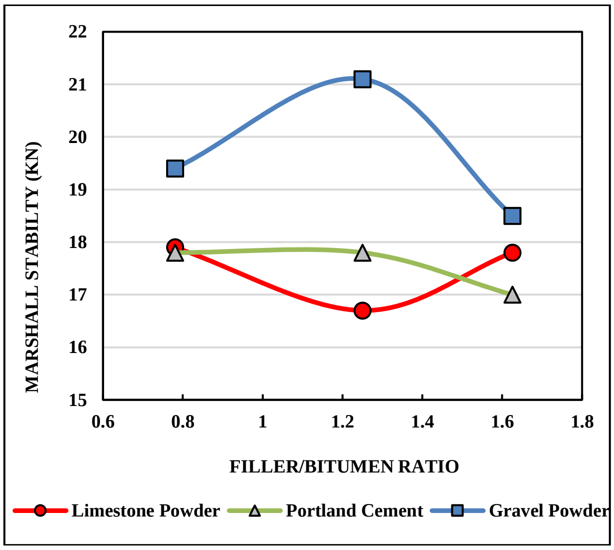

Fig. (4): Marshall Stability vs Filler bitumen ratio

It clearly appears that using the gravel powder as a filler improves the stability of the mixture ranging between 4% - 21% in comparison to mixtures with Limestone, while the improvement ranges between 8% - 16% when compared to the mixture with Portland cement.

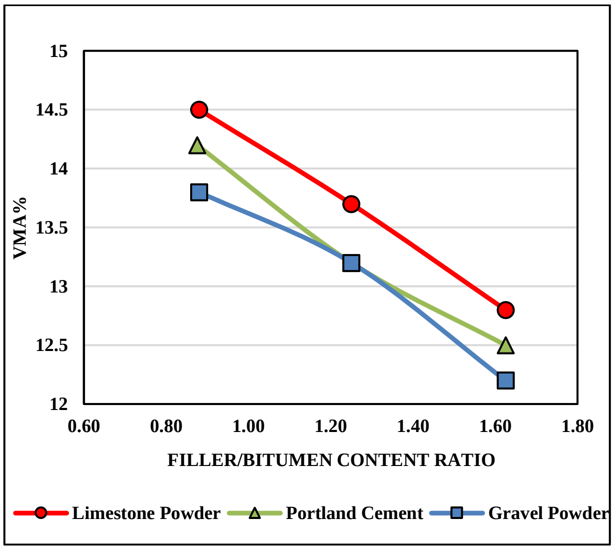

Fig. (5): VMA vs Bitumen filler ratio

Figure 5 shows the comparison between the filler type to the filler/bitumen ratio and the percent of voids in mineral fillers. It is appearing that there is an inverse relationship between VMA% and the filler/bitumen content due to increasing in film thickness and therefore closer packing between aggregate particles. The variation in VMA% between gravel powder samples and the limestone samples about 5%, while the difference in VMA% between gravel powder and Portland cement ranges between 3%-2%.

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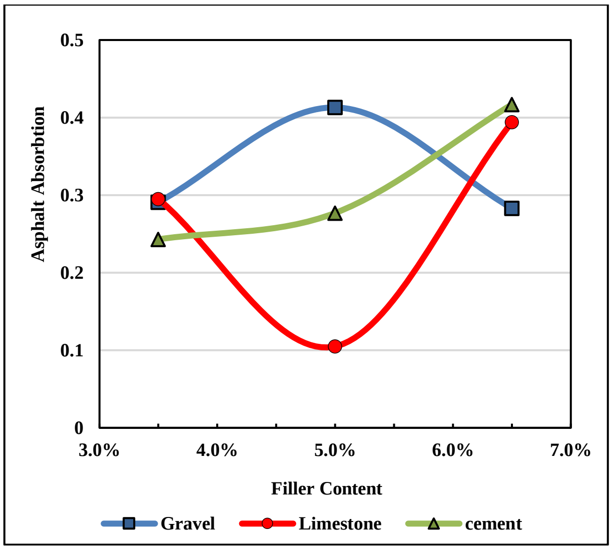

Fig. (6): Relationship between filler content % and asphalt absorption.

The asphalt absorption property is increased depending on the pores presented, the type of aggregate used and the filling material. The content and type of filler particle plays a major role in asphalt absorption since same aggregate and bitumen type are used, in Figure 6, it could be noted that the absorption of the asphalt mixture gradually increased with an increase in the Portland cement percentage, as it increased from 0.243 at 3.5% to 0.277 at 5% and finally 0.417 at 6.5%. While there was a clear increase in absorption from 0.291 at 3.5% to 0.413 at 5% of gravel powder, then a clear decrease followed by 0.283 when the ratio increased to 6.5%. In the case of limestone use, it is noted that the behavior of the asphalt mixture is completely opposite to the results of the gravel powder where there will be a significant decrease in absorption from 0.295 to 0.105 when the percentage of filler increases from 3.5% - 5%, followed by an increase in permeability to 0.394 at 6.5%

This diversity and change in the absorption property depend largely on the chemical composition and the size of the particles, which depends on the type and proportion of the filler. Through the results shown in Figure 6, it is clear that both gravel powder and cement had more acceptable results at 5%, because the molecules of these materials fill the voids between the components, which leads to an increase in the rate of absorption in the asphalt mixture.

4.2 Retained Strength

The effect of the types of filler on the retaining strength of asphalt mixture is illustrated in figure 7. The diagram shows that using the gravel powder as a filler in an asphalt mixture has the highest retaining strength percent with more than 98%, and it is excessing the Portland cement with 97.5%, while it is87.1% for the lime stone. This refers to the fact that gravel powder and ordinary Portland cement have better moisture resistance than Lime dust and could be used to construct roads in rainy or wet area.

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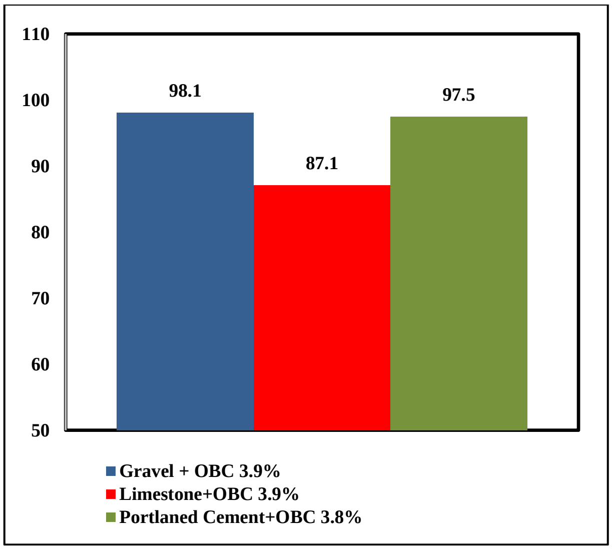

Fig. (7): Effect of filler type on Retained Strength of asphalt mixture.

5. CONCLUSION

The asphalt mixture properties are affected by the types and amount of the mineral fillers. In general, the results of using 5% of the gravel powder showed a notable improvement in comparison to limestone and Portland cement. Also, the gravel powder improvement includes the stability and absorption property of the mixture. This should have a positive impact, both economic and environmentally wise. Through this study, it is possible to summarize what was concluded with the following.

- Using gravel powder as a filler in the asphalt mixture will increase the stability of the mixture by about 19%.
- Gravel powder will improve the stability of the asphalt mixture by about 21% with 1.25% filler/bitumen content compared to Limestone.
- The Min. value of VMA% when using gravel powder and Portland cement is 12.8% and 12.7% respectively observed at 4.5% bitumen content while the Min. VMA% for Limestone samples was out of limitations.
- The use of gravel powder in asphalt mixture increases the rate of absorption in the mixture compared to the use of limestone and Portland cement by an amount of 75% and 33%, respectively.
- From the results of the Retained Strength percent of the asphalt mixture, it is clear that the gravel powder and Portland cement were the highest in comparison with the limestone powder.

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