American Journal of Engineering Research (AJER)
e-ISSN: 2320-0847 p-ISSN : 2320-0936
Volume-6, Issue-7, pp-261-266
www.ajer.org
Research Paper Open Access

Using Hydrated Lime in Hot Mix Asphalt Mixtures in Road Construction

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Abstract: *An increase in predicted pavement fatigue life for lower air void contents and higher asphalt content has been suggested by various investigations on asphalt concrete pavement mixtures. The strength and load carrying capacity of hot mix asphalt results from the aggregate framework created through particle-particle contact and interlock. Fines or mineral filler have a role since their presence directly influences the composition and performance of asphalt mixtures. The coarse aggregate framework is filled by the sand-sized material and finally by the mineral filler. At some point, the smallest particles lose contact becoming suspended in the binder not having the particle-particle contact that is created by the larger particles. In most road project asphalt mixtures, stone dust, cement and lime are used as fillers. The overall effect of mineral filler in hot mix asphalt specimens has been investigated through a series of laboratory tests. It seems that a behavior influenced by the adherence of fines to asphalt film has been developed. The optimum bitumen content requirement in case of stone filler is almost the same as for lime. The Marshall-flow increased with the use of lime filler, suggesting that the resistance of bituminous mixes to permanent deformation is improved.*

Keywords: *environmental impact, heavy metal, pollution, road traffic, soil contamination*

Date of Submission: 10-06-2017 Date of acceptance: 26-07-2017

I. INTRODUCTION

Mineral fillers play a dual role in asphalt mixtures, first; they act as a part of the mineral aggregate by filling the voids between the coarser particles in the mixtures and thereby strengthen the asphalt mixture, second; when mixed with asphalt, fillers form mastic, a high-consistency binder or matrix that cements lager binder particles together; most likely a major portion of the filler remains suspended in the binder while a smaller portion becomes part of the load bearing framework.

Depending on their size, aggregates are classified in coarse grained, fine grained, and fines (particle size fraction of an aggregate which passes the 0.063 mm sieve). Filler is the fine grained portion which passes the # 200 sieve (0.075 mm), according to ASTM standards, while, according to the European Standard EN 12620 [1], filler is defined as the graded fine aggregate material having maximum grain size 2 mm and passing the 0.063 mm sieve at percentages of 70% to 100%.

Commonly, coarse grained and fine grained aggregates will be brought in the asphalt mix production plant in two or more separate fractions. Preferably, filler has to be brought and added separately. In such a way, the stability of asphalt mix in filler content is ensured [2, 3].

Fineness Modulus (FM) comes of as the sum of the cumulative percentages being retained on a specified series of sieves (according to EN 12620: 4 mm; 2 mm; 1 mm; 0.5 mm; 0.25 mm; and 0.125 mm) divided by 100. Fineness Modulus is an index used in determining the fineness of the aggregate and the degree of uniformity of the aggregate gradation. Higher FM values, characterize the coarser the aggregates.

Extensive programs of investigations have been carried out in order to evaluate the suitability of different mineral fillers to substitute the costly fillers, such as ordinary Portland cement and limestone powder, commonly used. Meanwhile, many types of local waste materials can be tested and successfully used as mineral filler in hot asphalt concrete mixtures in place of ordinary Portland cement and limestone powder, such as waste glass, ceramic, bricks [4, 5].

The type and origin of mineral fillers play a critical role in asphalt concrete properties. This was concluded, when in two studies [6, 7] four types of industrial and by-product wastes filler, namely; limestone as reference filler, ceramic waste, coal fly ash, and steel slag were prepared and tested in the laboratory. The fillers were graded with three proportions of particles containing different size distributions. The conclusion was drawn that the filler component, in addition to filling the voids, interacts with the binder present in the mix making it stiff and brittle and that the alteration in mix properties is very much interrelated to the properties of the filler.

The Marshall-mix design method had been used in order to investigate the role of filler on the mechanical performance of asphalt-concrete mixture. For such an evaluation, three wearing course mixtures were selected which were incorporating kaolin, granite, and hydrated lime as filler. The results showed that more asphalt is required with hydrated lime or kaolin due to their relatively higher specific surface area [8]. In the previously mentioned study, hydrated lime yielded the highest stiffness performance. As it has been suggested and in other researches, the presence of filler in an asphalt-concrete mixture affected the mixture's performance mainly in three ways, direct influence on the asphalt content and the workability during mixing and compaction, as well as through the resultant properties of asphalt-filler mastic.

Hydrated lime has been used in HMA layers since the first decade of the 20th century [9]. The beneficial action of hydrated lime added to HMA mixtures could be summarized as reduction of moisture damage and stripping of aggregates sensitive to moisture. Lime as a filler material reduces the design asphalt content; improves toughness and resistance to fracture growth at low temperatures; reduces age hardening of the asphalt binder; and increases mixture stability and durability. In a recent study [10] Marshall stability and flow tests were carried out on specimens of lime modified asphalt and specimens with conventional asphalt mixture with mineral filler. The results indicated that the Marshall stability for the asphalt concrete with hydrated lime was slightly higher ranging 5.9 kN to 8.2 kN (5.89 kN – 7.90 kN were calculated for the asphalt concrete with mineral filler). Very similar were the values found for the flow characteristic (2.3 mm – 3.3 mm, and 2.4 mm – 3.4 mm for the asphalt concrete with mineral and hydrated lime filler, respectively).

In Europe, large quantities of hydrated lime are used as an additive for asphalt mixtures fulfilling various aims, as has been recorded in recent years. Lime's combined effects give rise to increased durability of the mixtures. Examples for the use of hydrated lime in HMA in European countries are presented in a review article [11] published in 2016. The resistance of mixtures to moisture damage is described using examples of applications in Belgium and France for a Stone Mastic Asphalt (SMA) mixture and a mountainous road with many curves under winter conditions, respectively. Germany and Poland are two countries with asphalt concrete and SMA mixtures, respectively, showing aging resistance. Referring to the effect of binder stiffening, this is highlighted using Austrian (AC) and Italian (Porous Asphalt, SMA) examples. From these case studies, it is concluded that the use of active filler such as hydrated lime makes it possible for the engineers to handle asphalt mixtures properties adjusting them to the technical requirements.

Sangiorgi and his colleagues [12] have tested in the laboratory alternative fillers and compared them to traditional limestone filler. Their results revealed significant differences between the fillers; particularly Rigden Voids seem to have the largest potential influence on the rheology of asphaltic concrete.

Conventionally, stone dust, cement and lime are used as fillers. Ravindra et al. [13] attempted to assess the influence of non-conventional and cheap fillers, such as brick dust and silica fume in bitumen paving mixes. Their work with non-conventional fillers resulted in bituminous mixes presenting satisfactory Marshall properties though requiring a bit higher bitumen content in order to satisfy the design criteria. The fillers used in the investigation gave properties nearly alike to those of conventional fillers and are likely to partly solve the solid waste disposal of the environment.

Further modified mixes can lead to brick dust and silica fume use as fillers in bituminous pavement thus partially solving the problem of disposal of wastes. The properties of Marshall bituminous mixtures containing brick dust and waste concrete dust were also studied by a group of scientists in 2015 [14]. The properties defined were compared with those of mixes containing filler like fine sand and stone dust. The Marshall stabilities of mix types containing filler fine sand and stone dust mixture, waste concrete dust and brick dust were found 9.8 kN, 11.1 kN and 11.3 kN respectively which satisfy the limiting value of 5.33 kN according to Marshall Design criteria, indicating the feasibility of using waste concrete dust and brick dust as filler in bituminous mix.

Since lime is an effective asphalt modifier for improving the moisture resistance of asphalt pavements, is often used as mineral filler in asphalt concrete mixtures. Addition of lime can also improve pavement performance and durability. Hydrated lime added to asphalt can increase penetration and on the other hand can lower the viscosity of asphalt cements [15, 16, 17]. Aljassar et al [18] made reference to an early study where the addition of limestone dust, calcined shale and asbestos as fillers in asphalt concrete led to standard Marshall mix design results showing that calcined shale had better performance as filler than limestone, while the worst behavior was exhibited by asbestos. They have also reported Mean Marshall stability values for 4%, 5% and 6% limestone powder as filler be 15.524 kN, 16.782 kN, and 17.426 kN, respectively. Increasing limestone powder in the mix results in an increase in Marshall stability.

The study reported here examined the Marshall properties of lime-modified asphalt mixture and the conventional asphalt. Marshall method of mix design is the standard method in Greece. The specimens were tested in the Marshall testing machine for stability and flow. The characteristics of mineral filler material have been investigated to determine their potential in upgrading performance of asphaltic concrete, particularly by increasing hot mix stability and durability to lessen problems with shoving and rutting.

II. LABORATORY TESTING

In an effort to investigate the effect of filler type and quantity in asphalt concrete mixtures, a series of laboratory tests have been performed. The concrete prepared had characteristics described in Greek specifications for type of asphalt concrete AC20. Either stone passing the No. 200 sieve or lime has been used as filler material in the specimens. The aggregates used had been received from a supplier in Xanthi area and were fluvial in nature. The crushed aggregates were a mixture of different rocks, mainly limestone, sandstones, and granites. Three samples were used to compose an appropriate for asphalt concrete aggregate mix to be used in the testing program. In Table 1 the grain size distribution of these materials is listed, along with the limit values posed by Greek specifications.

Table 1: Grain size distribution of composite aggregate mix and specification limits

			ASTM Specification limits	
mm	*US sieves*	*Composite*	*min.*	*Max.*
50	2	100.0	100	100
37.5	1 ½”	100.0	100	100
25	1"	100.0	100	100
19	¾"	92.8	90	100
12.5	½"	83.6	65	85
9.5	3/8”	67.6	56	80
4.75	#4	50.6	35	65
2.36	#8	34.6	23	49
1.18	#16	23.7	16	37
0.6	#30	18.0	11	28
0.3	#50	13.7	6	19
0.15	#100	6.3	3	15
0.075	#200	4.0	2.0	8.0

Lime has been used as a replacement of mineral aggregate filler in asphalt concrete. It was supplied by a local limekiln in the Regional District of Drama Northern Greece. It could be characterized as a typical commercial hydrated calcitic lime having a relatively high CaO content (over 60%) in its synthesis. The chemical properties of the lime given in Table 2, show that the material has a loss on ignition (LOI) value of about 33% and the remaining constituents were various oxides in rather small proportions ranging from 0.01% to 0.50%.

Table 2: Chemical properties of lime

Parameter	*Percent of composition*
SiO_2 (silicon dioxide), %	0.01
Al_2O_3 (aluminum oxide), %	0.01
Fe_2O_3 (iron oxide), %	0.11
CaO (calcium oxide), %	65.25
MgO (magnesium oxide), %	0.50
K_2O (potassium oxide), %	0.01
Na_2O (sodium oxide), %	0.01
S (sulfur, 1000^{o}C), %	0.13
C (carbon), %	4.50
Loss on Ignition, %	33.25

Cylindrical Marshall specimens were prepared according to ASTM D1559-92 [19] method using 1,200 g of a composite aggregate having a grain size distribution shown in Table 1 and paving grade asphalt contents 4%, 4.5%, 5%, and 5.5%. For each percentage of asphalt, 3 specimens were formed with 75 blows on each face of the specimen. The specimens had been cured for 24 hours in room temperature conditions and left for 30 minutes in water bath of 60^{o}C before their placement in the Marshall apparatus for the determination of stability.

The stability, air voids, apparent specific gravity and deformation of the specimens with stone filler and lime filler are shown diagrammatically in Figures 1, 2, 3, and 4, respectively.

Marshall stability was affected by the addition of lime as filler material leading to higher values than in mixtures with stone filler. When lime was used as filler, the range of stability values covered the interval from 10.73 to 11.91 kN. The higher stability value for the specimens with stone filler (9.23 kN) has been received for 5% asphalt content in the specimen.

The percent of air voids contained in samples with lime was generally lower than in samples with mineral aggregate filler. The air voids decreased with increasing hydrated lime content. The asphalt mixture specimens composed with lime as filler material were more workable.

Due to lower weight of lime, the apparent specific gravity values of specimens containing lime filler ranged in a lower band (2263.61 kg/m^3 to 2325.24 kg/m^3) compared with those of mixtures having mineral aggregate filler.

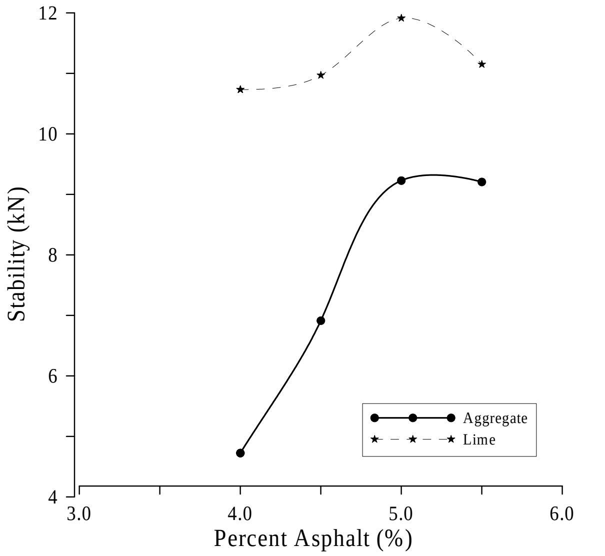

Figure 1: Stability versus percent asphalt for aggregate and lime fillers.

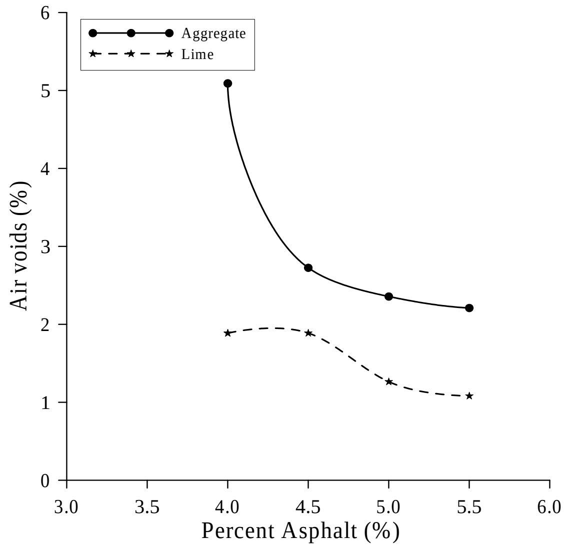

Figure 2: Asphalt mix air voids versus percent asphalt for aggregate and lime fillers.

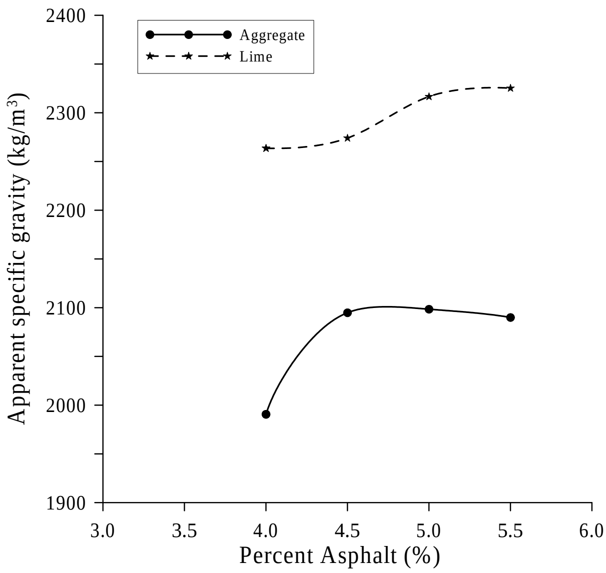

Figure 3: Apparent specific gravity versus percent asphalt for aggregate and lime fillers.

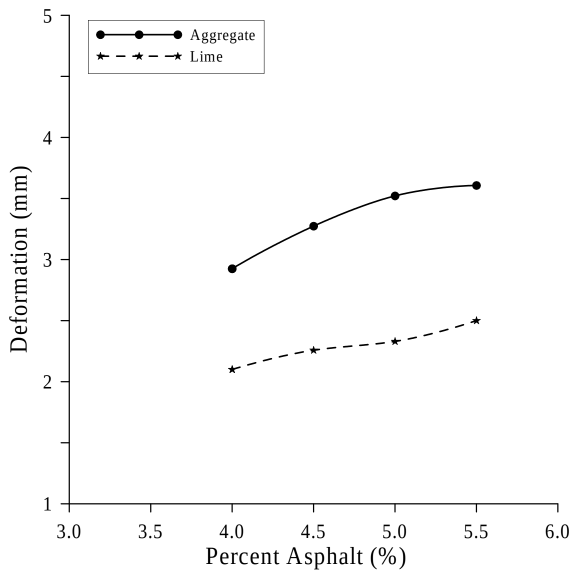

Figure 4: Deformation versus percent asphalt for aggregate and lime fillers.

The deformation values increased gradually with the percent of asphalt in both filler cases. For the stone filler the rate of increase is more intense.

The optimum asphalt content was approximately equal for the two filler materials and about 4.8%. With this percentage of asphalt, specimens were prepared having filler contents of 2%, 4%, 6%, and 8% reducing accordingly the fraction between #100 and #200 sieves in the initially defined aggregate composition.

Mixtures with low voids in mineral aggregate are advantageous since will flush if slightly excessive in asphalt content, and will be dry and brittle if slightly deficient in asphalt content. If high stability values are due to high density and low voids, then it is undesirable. This type of have mixtures an excess of filler material and are deficient in bitumen binder. Generally speaking, it is preferable to have lack and not excess of filler material in the asphalt mixtures used in highway construction projects.

In Figs. 5 to 8 the results of testing in the Marshall apparatus are presented as a function of percent filler, both for stone material and lime. The behavior of the asphalt concrete materials was more consistent with the use of mineral aggregate filler. The stability values ranged from 8.16 kN to 9.58 kN. When 4% of lime was added as filler material a peak on the stability curve (11.91 kN) appeared. A corresponding peak has been appeared with 6% stone filler in the mix. For the same percentage in the mix, lime filler occupies larger volume than the stone filler, because the later has a higher specific gravity. This outlines the reason for the peaks appearing in mixtures with different contents in stone or lime filler.

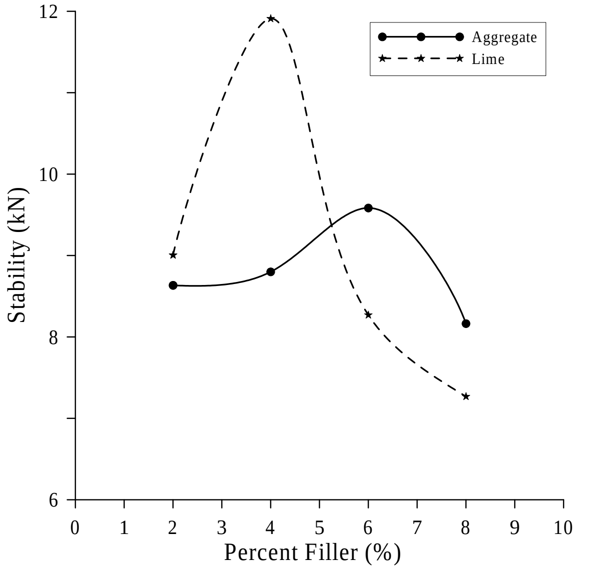

Figure 5: Stability versus percent asphalt for aggregate and lime fillers.

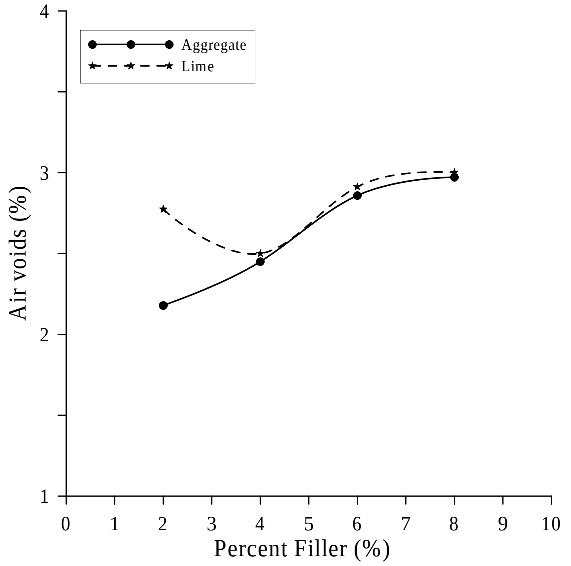

Figure 6: Asphalt mix air voids versus percent asphalt for aggregate and lime fillers.

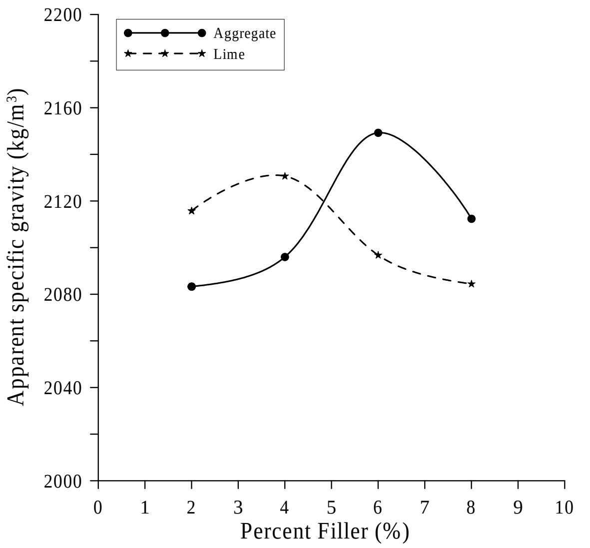

Figure 7: Apparent specific gravity versus percent asphalt for aggregate and lime fillers.

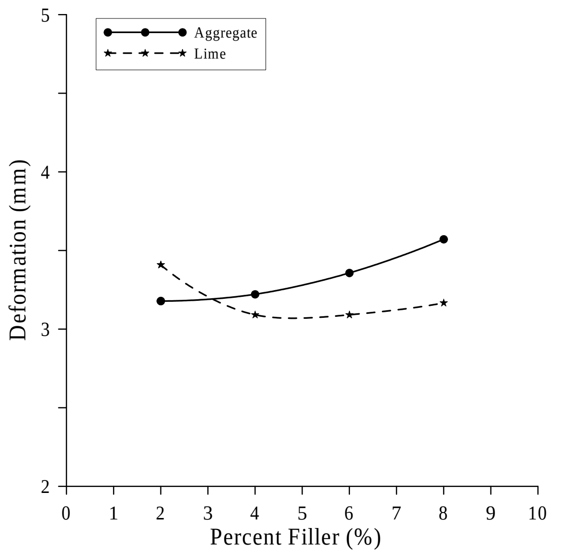

Figure 8: Deformation versus percent asphalt for aggregate and lime fillers.

As is seen in Fig. 6, the asphalt mix air voids depend on the percent filler for aggregate and lime in different ways. Lime gave in all percentages added values higher than those resulted when the mineral aggregate was present in asphalt concrete specimens.

The apparent specific gravity versus percent filler for aggregate and lime fillers curves had a decreasing bell-shaped form in both cases. The deformation showed an almost similar trend with the values obtained from aggregate filler being concentrated in a narrower zone than those of the lime specimens.

III. CONCLUSION

Based on the experimental program performed using local materials in Xanthi, Greece, it is verified that inclusion of lime in place of conventional stone filler can be efficiently used in asphalt concrete mixture as a filler replacement from the viewpoint of stability, deformation, and voids characteristics. Hence, it is generally concluded that the lime can effectively be used as filler in paving mixes in place of most commonly used fillers such as ordinary Portland cement and stone dust. Portland cement returns a high cost and the latter may be costly at certain places where coarse aggregates are scarce. Of course, further modification in design mixes in technical specifications, which can result in utilization of lime as filler in bituminous pavement, is needed.

The results indicate that the replacement of the mineral filler with lime improves the stability of the mixtures, while there is a slight increase in the flow of the mixture with hydrated lime. The slight increase in stability and flow values may be attributed to the complete replacement of the mineral filler with lime and the high lime content used in the study. The Marshall Flow value increased with the use of lime filler. It is thus indicated that, with the addition of lime, the resistance of bituminous mixes to permanent deformation is improved. The optimum bitumen content requirement in case of stone filler is almost the same as for lime.

More studies need to be carried out to confirm the Marshall properties evaluated for mixtures with the mineral filler partially replaced with lime and for varying proportions of the lime content in the asphalt mixture.

The properties of the filler determine its interaction with asphalt and its contribution to the mixture's performance. This finding has to be further verified with the use of different asphalt binders and lime percentages from various sources.

REFERENCES

[1]. European Standard EN 12620 Aggregates for concrete. *European Committee for Standardization, ICS 91.100.15; 91.100.30*, 2013.

[2]. H.M. Mahan, Influence of mineral filler-asphalt ratio on asphalt mixture performance. *Journal of Babylon University-Engineering Sciences, 21(4)*, 2013, 1213-1222.

[3]. R.S. Jaya, Asif, Determination of binder film thickness for bituminous mixtures prepared with various types of fillers. *6th International Conference on Structural Engineering and Construction Management 2015, Kandy, Sri Lanka, 11th-13th December* 2015, 31-37.

[4]. N.A.H. Al-Saffar, The effect of filler type and content on hot asphalt concrete mixtures properties. *Al-Rafidain Engineering, 21(6)*, 2013, 88-100.

[5]. I.M. Ud Din, and S. Marik, Influence of fillers on paving grade bitumen. *International Journal of Innovative Research in Science, Engineering and Technology (IJISERT), 4(12)*, 2015, 12549-12554.

[6]. R. Muniandy, E. Aburkaba, L.M.J. Mahdi, Effect of mineral filler type and particle size on asphalt-filler mastic and stone mastic asphalt laboratory measured properties. *Australian Journal of Basic and Applied Sciences, 7(11)*, 2013, 475-487.

[7]. R. Muniandy, E. Aburkaba and R. Taha, Effect of mineral filler type and particle size on the engineering properties of stone mastic asphalt pavements. *TJER, 10(2)*, 2013, 13-32.

[8]. A. Zulkati, Y.D. Wong and D.S. Delai, Effects of fillers on properties of asphalt-concrete mixture. *Journal of Transportation Engineering ASCE, 138(7)*, 2012, 902-910.

[9]. EuLA (European Lime Association), Hydrated lime: a proven additive for durable asphalt pavements: Critical literature review. *European Lime Association / Asphalt Task Force Report*, September 2010, 96 p.

[10]. O.M. Ogundipe, Marshall stability and flow of lime-modified asphalt concrete. *6th Transport Research Arena April 18-21, 2016, Transportation Research Procedia 14*, 2016, 685-693.

[11]. D. Lesueur, C. Denayer, H.J. Ritter, C. Kunesch, S. Gasiorowski, A. d'Alto, The use of hydrated lime in the formulation of asphalt mixtures: European case studies. *E&E Congress 2016, 6th Eurasphalt & Eurobitume Congress, 1-3 June 2016, Prague, Czech Republic*, 2016, 1-9.

[12]. C. Sangiorgi, P. Tataranni, F. Mazzotta, A. Simone, V. Vignali and C. Lantieri, Alternative fillers for the production of bituminous mixtures: A screening investigation on waste powders. *MDPI Coatings, 7(6), 76*, 2017, 12 p.

[13]. T. Ravindra, R.K. Jain and M.K. Kostha, Effect of fillers on bituminous paving mixes. *International Journal of Engineering Research & Science & Technology, 2(4)*, 2013, 137-142.

[14]. D. Sutradhar, M. Miah, G.J. Chowdhury and M. Abdus Sobhan, Effect of using waste material as filler in bituminous mix design. *American Journal of Civil Engineering, 3(3)*, 2015, 88-94.

[15]. J.C. Peterson, Lime-treated pavements offer increased durability. *Roads and Bridges Journal 26(1)* 1988, 85-87.

[16]. H. Wang, I.L. Al-Qadi, A.F. Faheem, H.U. Bahia, S.-H. Yang and G.H. Reinke, Effect of mineral filler characteristics on asphalt mastic and mixture rutting potential. Transportation Research Record: *Journal of the Transportation Research Board, No. 2208, Transportation Research Board of the National Academies*, Washington, D.C., 2011, 33-39.

[17]. N.K. Rashwan, Hot Mix Asphalt (HMA) performance as affected by limestone powder filler content. *World Applied Sciences Journal 34 (2)*, 2016, 237-244.

[18]. A.H. Aljassar, S. Metwali and M.A. Ali, Effect of filler types on Marshall stability and retained strength of asphalt concrete. *The International Journal of Pavement Engineering, 5(1)*, 2004, 47-51.

[19]. American Society for Testing and Materials ASTM, ASTM D 1559-92: Test method for resistance to plastic flow of bituminous mixtures using Marshall apparatus. Annual Book of ASTM Standards 2000, Sec. 4 — Construction, Vol. 04.03, Road and Paving Materials; Vehicle – Pavement Systems, West Conshohocken, PA. ASTM International.

G. Kollaros. "Using Hydrated Lime in Hot Mix Asphalt Mixtures in Road Construction." American Journal of Engineering Research (AJER) 6.7 (2017): 261-66.