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INFLUENCE OF FLY-ASH AS A FILLER IN BITUMINOUS MIXES

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ABSTRACT

A bituminous paving mixture is a mixture of coarse aggregate, fine aggregate and bitumen mixed in suitable proportion to result strong and durable mix to withstand traffic load. In this paving mix, normally cement and stone dust are used as filler material. A study has been carried out in this study to explore the use of fly ash, a by-product of a coal based thermal power plant in bituminous paving mixes. For comparison, control mixes with cement and stone dust have also been considered. Marshall test has been considered for the purpose of mix design as well as evaluation of paving mixes. Other performance tests such as indirect tensile strength and retained stability have also been carried out. It is observed that the mixes with fly ash as filler exhibit marginally inferior properties compared to control mixes and satisfy desired criteria specified by a much higher margin. Hence, it has been recommended to utilize fly ash wherever available, not only reducing the cost of execution, but also partly solve the fly ash utilization and disposal problems.

Key words: bituminous concrete, Marshall properties, optimum bitumen content, indirect tensile strength, retain stability.

INTRODUCTION

Aggregates bound with bitumen are conventionally used all over the world in construction and maintenance of surface course of a flexible pavement. The surface course normally comprises of bituminous mixtures comprising of coarse aggregate, fine aggregate and filler heated to suitable temperature, mixed thoroughly with heated bitumen at required viscosity and then compacted. The bituminous mix may be dense graded, gap graded or uniformly graded. Bituminous concrete (BC) is a well graded mixture containing coarse aggregate (50-60%), fine aggregate (40-50%), filler (6-10%), bitumen (5-6%) of total mass of mix. One of the major concerns of mix design of bituminous mix is the type and amount of filler used which may affect the performance of the mix. Various studies have been conducted to study the properties of mineral filler; generally the material passing 0.075mm IS sieve, to evaluate its effect on performance of asphalt paving mixture in terms of consistency, void filling, Marshall Stability and mix strength.

A number of studies have been made on use of different types of fillers in various types of paving mixes which are presented briefly below. Although the filler particles are small in size, it is well documented that filler exerts a significant effect on the characteristics and performance of asphalt concrete mixture. Good packing of the coarse aggregates, fine aggregates, and filler provides a strong backbone for the mixture (Zulkati *et al*., 2011). Higher filler concentrations result in stronger pavement attributable to better asphalt cohesivity and better internal stability. However, an excessive amount of filler may weaken the mixture by increasing the amount of asphalt needed to coat the aggregates (Kandhal *et al*., 1998). In general, type of filler, type of stabilizer, amount of stabilizer affect not only optimum bitumen content (OBC) of paving mixes but also affect the property like Marshall stability, tensile strength, retain stability of mixes. Also OBC of dense graded mix is less than stone matrix asphalt (Brown and Mallick, 1994). An investigation on property of eight different types of mineral filler materials in Europe indicated that the filler quality does not affect the performance of mixture (Mogawer and Stuart, 1996). Waste marble dust obtained from shaping process of marble blocks and lime stone used as filler in hot mix asphalt and optimum bitumen content was determined by Marshall Test and it showed good result (Karaşahin and Terzi, 2007). Similarly a comparative study was done on SMA by taking basic oxygen slag as aggregate with PG 76-22 modified bitumen and lime stone as filler and chopped polyester fibre as stabilizer and SMA without fibre; concluded that modified SMA is superior compared to conventional SMA (Wu *et al*., 2007). SMA prepared with municipal solid waste incinerator (MSWI) fly ash as a partial replacement of fine aggregate or mineral filler and Basic Oxygen Furnace (BOF) Slag as part of coarse aggregate with polyester fibre of 6.35 mm in length obtained from recycled raw materials, PG 76-22 bitumen in the mix and performed Marshall and super pave method of design and found it's suitability for use in the SMA mix (Xue *et al*., 2009). Four types of industrial by-product wastes filler namely, limestone as reference filler, ceramic waste dust, coal fly ash, and steel slag dust increases the stiffness and fatigue life of Stone Mastic Asphalt (SMA) Mixtures (Muniandy and Aburkaba, 2011). Waste glass power as mineral filler on Marshall property of bituminous by comparing with bituminous where lime stone, ordinary Portland cement was taken as filler with varying content (4-7%). Optimum glass power content was found 7%. By using glass power as filler in bituminous its stability increases up to 13%, flow value decreases, density also decreases as compare to bituminous contains lime stone and cement filler (Jony *et al*., 2011).

From above literature it is found that very limited study has been done on dense graded mixes with fly ash as filler. Fly ash is one of the major waste by-products of coal based thermal power stations. At places around such plants, fly ash is not only abundantly available, it finds little use, for which it creates serious waste disposal problems. Hence, in this study, an attempt has been made to explore the use of fly ash, which is mostly passing

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0.075 mm sieve and has been considered to be filler in bituminous paving mixes by studying various fundamental engineering properties.

MATERIALS AND METHODOLOGY

Materials used

Aggregates

For preparation of dense graded bituminous mixtures, the grading of aggregates was adopted as per MORTH (2013) for bituminous concrete given below (Table-1). Coarse aggregates consist of stone chips up to 4.75 mm IS sieve collected from a local source. Its specific gravity found in the laboratory was 2.75. Other physical properties of coarse aggregate are given below (Table-2).

Table-1. Adopted aggregate gradation.

Sieve Size (mm)	**Percentage passing by weight** (Specified range)	**Percentage passing by weight** (Adopted)
26.5	100	100
19	90-100	95
9.5	60-80	70
4.75	35-65	50
2.36	20-50	35
0.30	3-20	12
0.075	2-8	5

Table-2. Physical properties of aggregates.

Property	**Test method**	**Test result**
Aggregate impact value (%)	IS:2386 (Part-IV)	14
Aggregate crushing value (%)	IS:2386 (Part-IV)	13
Los angles abrasion value (%)	IS:2386 (Part-IV)	18
Flakiness index (%)	IS:2386 (Part-I)	19
Elongation index (%)		22
Water absorption (%)	IS:2386 (Part-III)	0.1

Fine aggregate comprises of stone dusts with fractions passing 4.75 mm and retained on 0.075 mm IS sieve were collected from a local crusher. Its specific gravity was found to be 2.65.

The portion of aggregates passing 0.075 mm is known as filler. Normally, cement and stone dust are used as filler in bituminous mixes. In order to explore the use of fly ash a very fine waste product of thermal power station in bituminous paving mix, the same collected from local source has been used. For comparison point of view, cement and stone dust collected from local sources have also been used in this study. The specific gravities of cement, stone and fly ash used in this study were found to be 3.1, 2.7 and 2.2, respectively.

Bitumen

VG 30 grade bitumen has been used as bitumen for preparation of bituminous mixture. The important physical properties are given below (Table-3).

Table-3. Physical properties of VG 30 bitumen.

Property	**Test method**	**Test result**
Penetration value at 25ºC (0.1 mm)	IS:1203-1978	68
Softening point (ºC)	IS:1205-1978	49
Specific gravity	IS : 1202-1978	1.01
Absolute viscosity at 60°C (poise)	IS: 73-1992	2505
Kinematic viscosity at 135°C (cSt)		405

Preparation of mix specimens

The samples for bituminous concrete mixtures were prepared as per ASTM D1559 (1989) at different bitumen contents for each type of filler used. The mixtures with cement and stone dust were considered to be control specimens. The optimum bitumen content for each type of filler in bituminous concrete mix was done as per the normal procedure.

Test program

Marshall test

Marshall Test is a simple and low cost standard laboratory test adopted all over the world for design and evaluation of bituminous mixtures. This test has been fundamentally used in this study to evaluate the different mixture at different bitumen contents and the parameters considered are stability, flow value, unit weight, air voids, voids in mineral aggregates, voids filled with bitumen. The optimum bitumen content was selected to have maximum stability, maximum unit weight and median allowable limits for percentage air voids. The average of bitumen content corresponding to these three parameters is selected as optimum bitumen content. All the Marshall criteria of the mixes at OBC are checked with respect to the same given in MORTH (2013). Although Marshall Method essentially empirical, it is useful in comparing mixtures under specific conditions.

Indirect tensile test (IDT)

In this test a compressive load is applied on a cylindrical Marshall specimen along a vertical diametrical plane through two curved loading strips of 75mm long, 13 mm wide and 13 mm height; having inside diameter same as that of Marshall sample. The static indirect tensile strength of a given specimen was determined using ASTM D 6931 (2012) at temperature vary from 5^0C to 40^0C at

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increment of 5^0C. For this test the specimens were prepared at their respective OBC. The IDT was calculated using the equation given in ASTM D 6931 (2012).

$$S_T = \frac{2000P}{\pi D H}$$

Where S_T = Indirect tensile strength (kPa)
P = Maximum load (N)
D = Diameter of specimen (mm)
H = Thickness of specimen (mm)

Moisture susceptibility test

Water is the worst enemy of the bituminous-concrete mixtures. The premature failure of a flexible pavement may be caused by the presence of water. To determine the moisture susceptibility of the mixtures, retained stability (RS) test was performed. RS is expressed as the ratio of average Marshall stability of the particular specimen which are conditioned by immersing in water at 60ºC for two hours to the average Marshall stability of the respective unconditioned specimen. This ratio gives an indication of resistance to moisture induced damage to the bituminous mixture.

RESULTS AND DISCUSSIONS

Marshall Properties

Three specimens for each combination were prepared and the average of these results has been reported. The results of Marshall Tests have been presented in Figures 1 through 6, in which the variations of Marshall Properties with respect to bitumen contents for all the three types of fillers considered in this study are shown. It is seen from Figure-1 and Figure-2 that the Marshall stability and unit weight increase with bitumen content up to 5% after which these two parameters decrease. At any bitumen content the stability value and unit weight are highest for mixes with cement as filler followed by that with stone dust and fly ash. However, the variations are only marginal and the variation, particularly, stability is not significant to be considered.

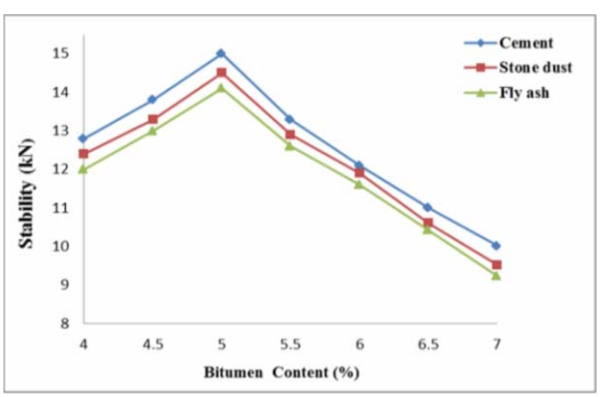

Figure-1. Variation of Marshall stability value with bitumen content for mixes with different fillers.

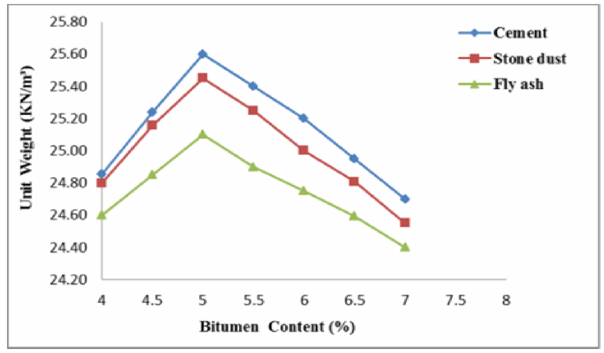

Figure-2. Variation of unit weight with bitumen content for mixes with different fillers.

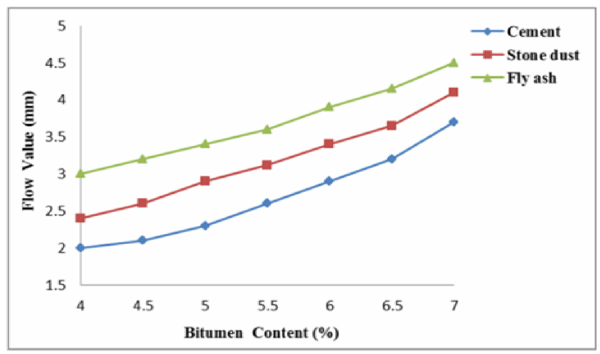

Figure-3. Variation of flow value with bitumen content for mixes with different fillers.

As shown in Figure-3 flow value increases with bitumen content. However, the flow value is lowest for mixes with cement as filler compared to stone dust and fly ash. This is because cement makes the mix stiffer compared to the other two materials.

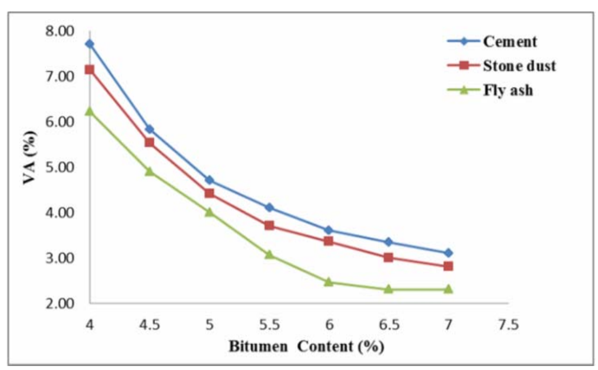

Figure-4. Variation of air voids with bitumen content for mixes with different fillers.

In the similar manner, Figure-4 shows that the air void decreases with increase in bitumen content. However it is to be highlighted that the fly ash causes maximum reduction of air voids compared to the other two fillers. This may be due to the fact that fly ash being too fine having highest surface area fills the voids more effectively.

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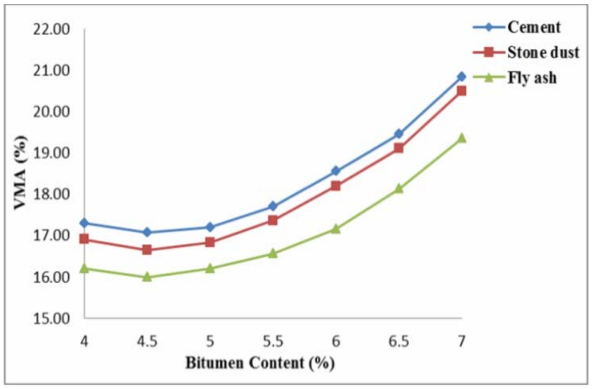

Figure-5. Variation of voids in mineral aggregate with bitumen content for mixes with different fillers.

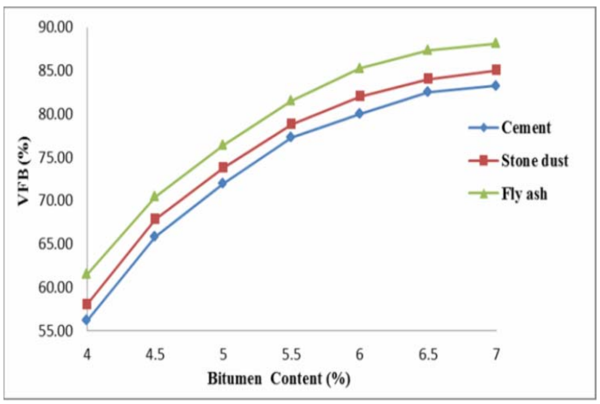

Figure-6. Variation of voids filled in bitumen with bitumen content for mixes with different fillers.

Generally OBC is appreciably affected by the mineral aggregates, bitumen and mix design. As presented in Table-4 the optimum bitumen content is also affected by different types of filler materials. Fly-ash absorbs slightly higher bitumen than other fillers like cement and stone dust so that it requires higher asphalt content. Bitumen content corresponds to maximum stability, maximum unit weight and the median of designed limits of percentage air voids in total mix. As per MORTH (2013), the OBC has been estimated on the basis of 4% of air voids in the mix. At OBC, the stability value, flow value, air voids, unit weight, VMA and VFB for mixes with three types of fillers considered in this study are also summarized (Table-4). It is to be noted that all the Marshall criteria as per MORTH (2013) are satisfied for all types of mixes covered under this study. The Marshall Stability value of mixes with fly ash is found only to be marginally smaller compared to the other two mixtures.

Table-4. Marshall characteristics of bituminous mixes at optimum bitumen content.

Filler type / Parameter	Cement	Stone dust	Fly ash
OBC (%)	5	5	5.2
Stability (kN)	15	14.5	14.1
Flow value (mm)	2.3	2.9	3.4
Air voids (%)	4.7	4.41	4.0
Unit weight (kN/m^3)	25.60	25.45	25.10
VMA (%)	17.20	16.83	16.20
VFB (%)	72	74	75

Results of static indirect tensile strength test

Figure-7 shows the variation of indirect tensile strength with temperatures for three types of mixtures. It has been seen that the IDT strength generally decreases with increase in test temperature. At lower temperature the mixes have higher tensile strength. Though from this Figure it is observed that at a particular temperature the mixture made with fly ash as filler has lower tensile strength as compared to other two fillers, the shape of variation in case of mix with fly ash is relatively gentler, concluding that the temperature susceptibility of mixes improves with use of fly ash.

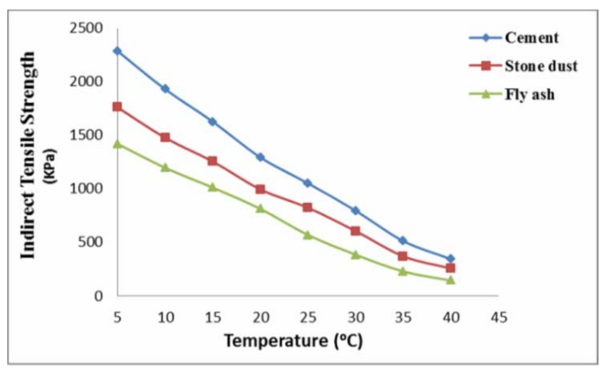

Figure-7. Variation of IDT strength with test temperatures for mixes with different fillers.

Retained stability of bituminous mixture

The variation of retain stability for various types of mixes prepared at their OBCs considered in this study is presented in Figure-8. It has been observed that the mix prepared with fly ash exhibits lowest retained stability (RS) value compared to mixes with other two types of fillers. This may be due to the fact that the fly ash used contains certain amount of lime which helps in anti-stripping property of bituminous mixes. It is to be noted that all mixes satisfy the minimum requirement of 75% specified by MORTH (2013).

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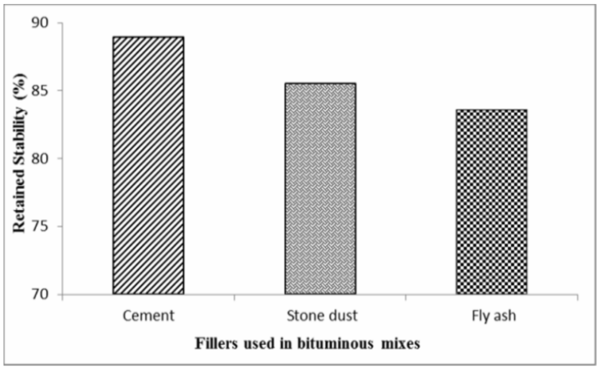

Figure-8. Variation or retained stability for mixes with different types of fillers.

CONCLUSIONS

In this laboratory study, the influence of fly ash, a waste by-product of coal based thermal power station, as filler on dense graded bituminous concrete (BC) paving mixes in terms of various engineering properties, has been investigated. For comparison purposes, fillers normally used, like ordinary Portland cement (OPC) and stone dust have also been considered separately as control specimens. From the results of Marshall Tests and other performance tests conducted to explore the suitability of fly ash as filler in BC mixes, the following conclusions have been drawn.

- Maximum Marshall stability and unit weight values are observed by cement followed by stone dust and fly-ash filler. As usual, the results of the flow value show the reverse trends. However it has been observed that the variation is nominal and at optimum bitumen content the mixes satisfy all the Marshall criteria.
- The optimum bitumen content requirement in case of cement and stone dust are same while for fly ash, the same is slightly higher. Considering the free and abundant availability of fly ash particularly at places near thermal power plants and where coarse aggregates are scarce, use of fly ash shall be cheaper compared to other two types of fillers.
- At a particular temperature, the indirect tensile strength of BC mixes with cement as filler has the highest value followed by stone dust and fly-ash. As temperature increases, ITS value in general decreases. However, the temperature susceptibility improves for mixes with fly ash, which is an added advantage.
- It is observed that the value of retained stability (RS) for mixes prepared with cement as filler offers highest retained stability value followed by stone dust and fly ash filler. However, the variations are so small to be considered significant and all the mixes satisfy the minimum retained stability value requirement i.e. 75%. It means all the mixes including that with fly ash as filler have very good resistance to moisture induced damages.

Hence, it is generally concluded that the fly ash can effectively be used as filler in paving mixes in place of most commonly used fillers such as ordinary Portland cement and stone dust. The former leads to high cost and the latter may be costly at certain places where coarse aggregates are scarce. Moreover, use of fly ash in paving mixes may give a solution to the fly ash utilisation and disposal problems and also give a means to make the environment safe and clean.

REFERENCES

ASTM D 1559. 1989. Test Method for Resistance of Plastic Flow of Bituminous Mixtures Using Marshall Apparatus. American Society for Testing and Materials, Philadelphia, USA.

ASTM D 6931. 2012. Indirect Tensile (IDT) Strength for Bituminous Mixtures. American Society for Testing and Materials, Philadelphia, USA.

Brown E. Ray and Mallick Rajib B. 1994. Stone matrix asphalt-properties related to mixture design. NCAT Report 94-2, National Center for Asphalt Technology, Auburn, Alabama, USA.

Chakraborty P. and Das A. 2003. Principals of transportation engineering. PHI learning publication. pp. 294-309.

IS: 73, 2006. Paving bitumen-specification (Second Revision). Bureau of Indian Standards, New Delhi, India.

IS: 1203, 1978. Methods for Testing Tar and Bituminous Materials: Determination of Penetration. Bureau of Indian Standards, New Delhi, India.

IS: 1205, 1978. Methods for Testing Tar and Bituminous Materials: Determination of Softening Point. Bureau of Indian Standards, New Delhi, India.

IS: 2386 (Part I). 1963. Methods of test for aggregates for concrete. Bureau of Indian Standards, New Delhi, India.

IS: 2386 (Part III). 1963. Methods of test for aggregates for concrete. Bureau of Indian Standards, New Delhi, India.

IS: 2386 (Part IV). 1963. Methods of test for aggregates for concrete. Bureau of Indian Standards, New Delhi, India.

Jony H. H., Al-Rubaie M. F. and Jahad I. Y. 2011. The Effect of Using Glass Powder Filler on Hot Asphalt Concrete Mixtures Properties. Engg and Technology Journal. 29(1): 44-57.

Karaşahin M. and Terzi S. 2007. Evaluation of marble waste dust in the mixture of asphaltic concrete.

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Construction and Building Materials, Elsevier. 21: 616-620.

Kandhal P. S., Lynn C. Y. and Parker F. 1998. Characterization tests for mineral fillers related to performance of asphalt paving mixtures. Transportation Research Record: Journal of the Transportation Research Board. 1638(1): 101-110.

Ministry of Road Transport and Highways (MORTH). 2013. Specifications for Road and Bridge Works, Section 500, Fifth Revision, Indian Roads Congress, New Delhi, India.

Mogawer W. S. and Stuart K. D. 1996. Effects of mineral fillers on properties of stone matrix asphalt mixtures. Transportation Research Record: Journal of the Transportation Research Board. 1530(1): 86-94.

Muniandy R. and Aburkaba E. 2011. The effect of type and particle size of industrial wastes filler on Indirect Tensile Stiffness and Fatigue performance of Stone Mastic Asphalt Mixtures. Australian Journal of Basic and Applied Sciences. 5.11, pp. 297-308.

Suchismita Arpita. 2009. A Study of Effects of Bitumen Quality and Natural Fiber on Stone Matrix Asphalt Mixtures. Unpublished M. Tech Thesis, NIT Rourkela, Odisha, India.

Wu S., Xue Y., Ye Q. and Chen Y. 2007. Utilization of steel slag as aggregates for stone mastic asphalt (SMA) mixtures. Building and Environment, Elsevier. 42(7): 2580-2585.

Xue Y., Hou H., Zhu S. and Zha J. 2009. Utilization of municipal solid waste incineration ash in stone mastic asphalt mixture: pavement performance and environmental impact. Construction and Building Materials, Elsevier. 23(2): 989-996.

Zulkati A., Diew W. Y. and Delai D. S. 2011. Effects of Fillers on Properties of Asphalt-Concrete Mixture. Journal of Transportation Engineering, ASCE. 138(7): 902-910.