Journal of Engineering Science 03(1), 2012 121-127

JES
an International Journal

EFFECT OF FILLERS ON BITUMINOUS PAVING MIXES: AN EXPERIMENTAL STUDY

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Received 01 September 2012; Accepted 18 October 2012

ABSTRACT

Fillers play an important role on engineering properties of the bituminous paving mixes. Conventionally, cement, lime and stone dust are used as fillers. In this study, an attempt has been made to assess the effects of different types of fillers (e.g. non-conventional and conventional) on the Marshall properties of bituminous paving mixes. For this purpose, non-conventional filler such as brick dust and conventional fillers such as cement and stone dust were used. All of these materials were tested according to the standard test procedure of AASHTO. Total 15 sets of test specimens were prepared by using different types of filler having different amount in the mix. The Marshall properties obtained for both types of fillers reveal that, brick dust filler specimens have been found to exhibit higher stability value compared to cement and stone dust filler specimens. In addition, mixers containing brick dust filler showed maximum stability at 6.2% bitumen content and the percentage of air voids were found to be decreased with the increase of bitumen content.

Keywords: *Bituminous paving mixes, Brick dust, Cement, Filler, Marshall Mix design, Stone dust*

1. INTRODUCTION

Asphalt pavements are a crucial part of our nation's strategy for building a high performance transportation network for the future. The use of asphalt paving mixture has been developed rapidly around the world after nineteenth century. The continuing rapid growth in traffic demand, along with the increase in allowable axle loads, necessitates the improvement of the highway paving materials. The aim of highway authorities is to provide safe, cost-effective, hard and smooth pavements that are capable to carry the anticipated loads. In order to achieve this aim many studies have been conducted to select the materials.

Filler is one of the components of asphalt concrete mixture. It plays a significant role on the characteristics and performance of the asphalt concrete mixtures (Anderson et al., 1992). A well-built backbone for the mixture is provided by the good packing of the coarse aggregate, fine aggregate and filler (Vavrik et al., 2002; Qiu, 2006). The filler has the ability to increase the resistance of particle to move within the mix matrix and/or works as an active material when it interacts with the asphalt cement to change the properties of the mastic (Kalkattawi, 1993). The addition of mineral filler increases the resilient modulus of asphalt concrete mixture (Anderson, 1987; Tayebali et al., 1998). Excessive amount of filler may weaken the mixture by increasing the amount of asphalt needed to cover the aggregates (Elliot et al., 1991; Kandhal et al., 1998), which affect the workability of the mixture. According to Zulkati et al. (2012), filler influences the mixture's workability because it interacts with asphalt attributable to the fines of the filler. It also contributes to change the visco-elastic properties of the asphalt mastic, which influences the overall performance of the mixture.

According to the Craus et al. (1978), the interactive physio-chemical features between the filler and bitumen are correlated to adsorption intensity at the filler-bitumen interface, and higher surface activity significantly contributes to stronger bonds at the filler-bitumen interface. It can be inferred that the interactive role associated with the physio-chemical reaction, which is influenced by the type of bitumen and filler as well as the selection of the proper type of filler in asphalt mixture that would also improve its properties and enhance the performance of the mixture. The temperature susceptibility and durability of the asphalt binder and asphalt concrete mixture can be improved by fillers (Geber and Gomze, 2010; Wu et al., 2011). The effects of these fillers are also dependent on gradations.

Fillers have traditionally been used in asphalt mixtures to fill the voids between the larger aggregate particles. The influence of different types of fillers on the properties of asphalt concrete mixture varies with the particle size, shape, surface area, surface texture and other physio-chemical properties (Bahia et al., 2011). One of the main problems in the construction of asphalt paving mixture is the insufficiency of amount of fillers from crushing of stone aggregates. Therefore, it is important to come across an alternative type of filler materials. In

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Bangladesh, conventionally cement and stone dust are used as fillers. This study is aimed to investigate the effect of different types of fillers (stone dust, cement and brick dust) on the Marshall properties of asphalt paving mixes. The performance characteristics of the mixture containing different types of filler were evaluated by examining fundamental material properties and by performing various laboratory tests. The potential use of non-conventional filler i.e. brick dust was also investigated.

2. METHODOLOGY

This study consists of three stages: characterizing the materials, design the mixtures for the three different fillers and suitability of brick dust as fillers in asphalt concrete mixtures. In the first stage the properties of materials i.e. bitumen, fillers, and aggregates were determined, while in the second stage, the optimum asphalt content for each mixture was determined according to the Marshall Mix Design Method, and in the third stage the suitability of the brick dust was evaluated.

2.1 Asphalt Binder

The asphalt used in the study was penetration grade 80/100 since it is widely used and acceptable for temperature condition of Bangladesh. It was purchased from the local distributor. Various tests were conducted in the laboratory in order to determine the physical properties of asphalt binder. The summary of test results obtained is as shown in Table 1.

Table 1 Asphalt Properties

Property	Test Method	Obtained Values	Standard values (According to ASTM)
Penetration at 25˚C, (1/10 mm)	AASHTO T49	99	80-100
Softening point, ˚C	AASHTO T53	48.50	45-52
Specific Gravity	AASHTO T228	1.03	1.03-1.06
Ductility, cm	AASHTO T179	102	Minimum 100

2.2 Fillers

Three different types of filler were selected in this study. These are stone dust, cement, and brick dust. Cement was purchased from the local distributor of the Meghna Cement Mills Ltd., Khulna and stone dust and brick dust were collected from different local sources. The filler materials were sieved through No. 200 sieve. The specific gravities of different types of fillers are shown in Table 2.

Table 2 Specific Gravity of Filler Materials

Filler type	Test Method	Specific gravity
Cement	ASTM D854	2.75
Stone dust	ASTM D854	2.68
Brick dust	ASTM D854	2.70

2.3 Aggregates

In addition to the asphalt binder and mineral fillers used in the Marshall procedures, crushed stone was also used in the preparation of asphalt concrete specimens. Aggregates which possess desirable strength, hardness, toughness, specific gravity and shape were chosen. The physical properties of aggregates were determined and are shown in Table 3. From the test results, it was found that the properties of aggregates are within the specified limits. The coarse and fine aggregates were separated into different sieve sizes. To produce identical controlled gradation, aggregates were sieved and recombined in the laboratory to meet the selected gradation. Figure 1 shows the midline gradation of the aggregate used in the mix design.

Table 3 Physical Properties of Aggregates

Test description	Coarse aggregates	Fine aggregates	Standard values
Aggregate Crushing Value (%)	25	-	< 30
Aggregate Impact Value (%)	23	-	< 30
Specific gravity	2.60	2.67	2.60 – 2.90
Flakiness Index (%)	12	-	< 25
Elongation Index (%)	14	-	< 25

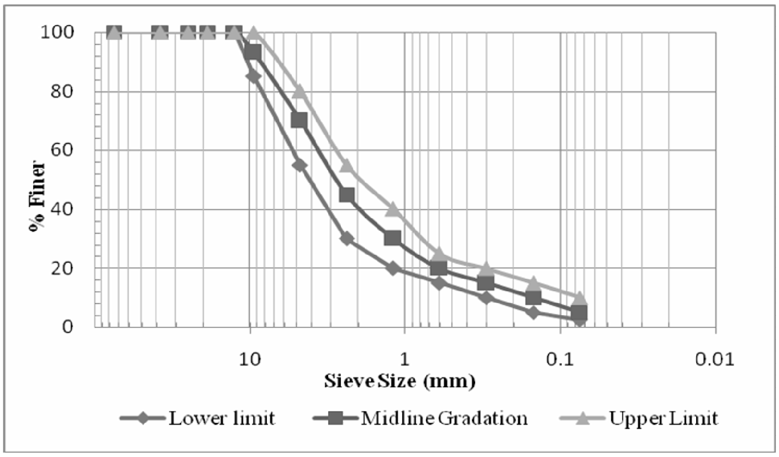

Figure 1 Aggregate gradation used in asphalt concrete Mixture

2.4 Marshall Mix Designs

Marshall Stability test was carried out for determining the optimum bitumen content and the test specimens were prepared by adding varying percentages of bitumen from 4.5% by weight of aggregates to 6.5% with an increment of 0.5% for each type of fillers. Specimen preparation, compaction and testing were conducted according to ASTM D1559 (Marshall Mix Design Method). Marshall Stability and flow tests were performed on each specimen, where the cylindrical specimen was placed in water bath at 60^0C for a period of 30 to 40 minutes and then compressed on the lateral surface at constant rate of 2 inch/min until the maximum load was reached. The maximum load resistance and the corresponding flow value were recorded. Three specimens for each combination were tested and the average results were reported. The bulk specific gravity and density (ASTM D2726), theoretical maximum specific gravity (ASTM D2041) and percent air voids (ASTM D3203) were determined for each specimen.

3. RESULTS AND DISCUSSIONS

The relationships between binder content and the properties of mixtures such as stability, flow, voids in mineral aggreate (VMA), unit weight, and voids in total mix (VTM) for each mixture as a part of the Marshall Mix design method were developed. Tables 4 to 6 show the mix design data obtained for the three mixtures. The graphical representations are as shown in Figures 2 to 4.

Table 4 Marshall Properties of samples with Brick dust

Bitumen (%)	Stability (kN)	Flow value (mm)	Unit weight (g/cc)	VTM (%)	VMA (%)
4.5	8.37	2.4	2.21	10.1	20.05
5.0	9	2.6	2.23	8.5	19.6
5.5	11.5	2.75	2.26	6.9	18.96
6.0	12.5	2.9	2.27	5.8	19.2
6.5	10.7	3.5	2.26	4.9	19.5

Table 5 Average Marshall Properties of samples with Cement

Bitumen (%)	Stability (kN)	Flow value (mm)	Unit weight (g/cc)	VTM (%)	VMA (%)
4.5	9.06	2.4	2.24	8.94	18.96
5.0	9.32	2.45	2.27	7.1	17.2
5.5	10.86	2.55	2.31	5.1	16
6.0	10.92	2.65	2.33	3.73	15.2
6.5	9.96	3.2	2.31	3.2	15.9

Table 6 Marshall Properties of samples with Stone dust

Bitumen (%)	Stability (kN)	Flow value (mm)	Unit weight (g/cc)	VTM (%)	VMA (%)
4.5	5.67	1.67	2.18	11.24	20.76
5.0	6.6	1.85	2.20	9.84	19.4
5.5	7.4	2.1	2.29	5.76	18.1
6.0	7.9	2.45	2.29	4.69	17.91
6.5	7.1	2.9	2.29	3.9	18.4

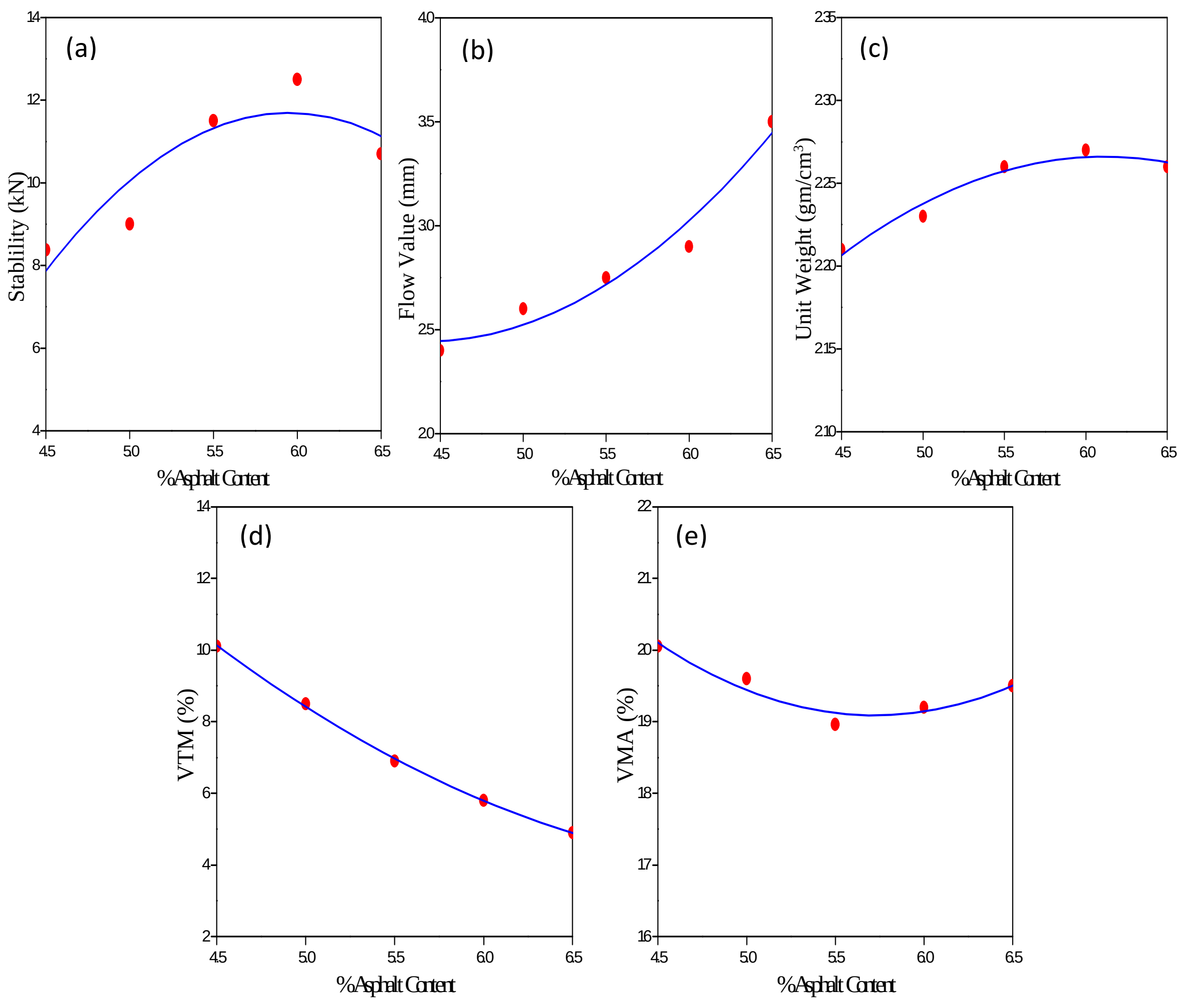

Figure 2 Mashall Mix Design properties using brick dust as filler

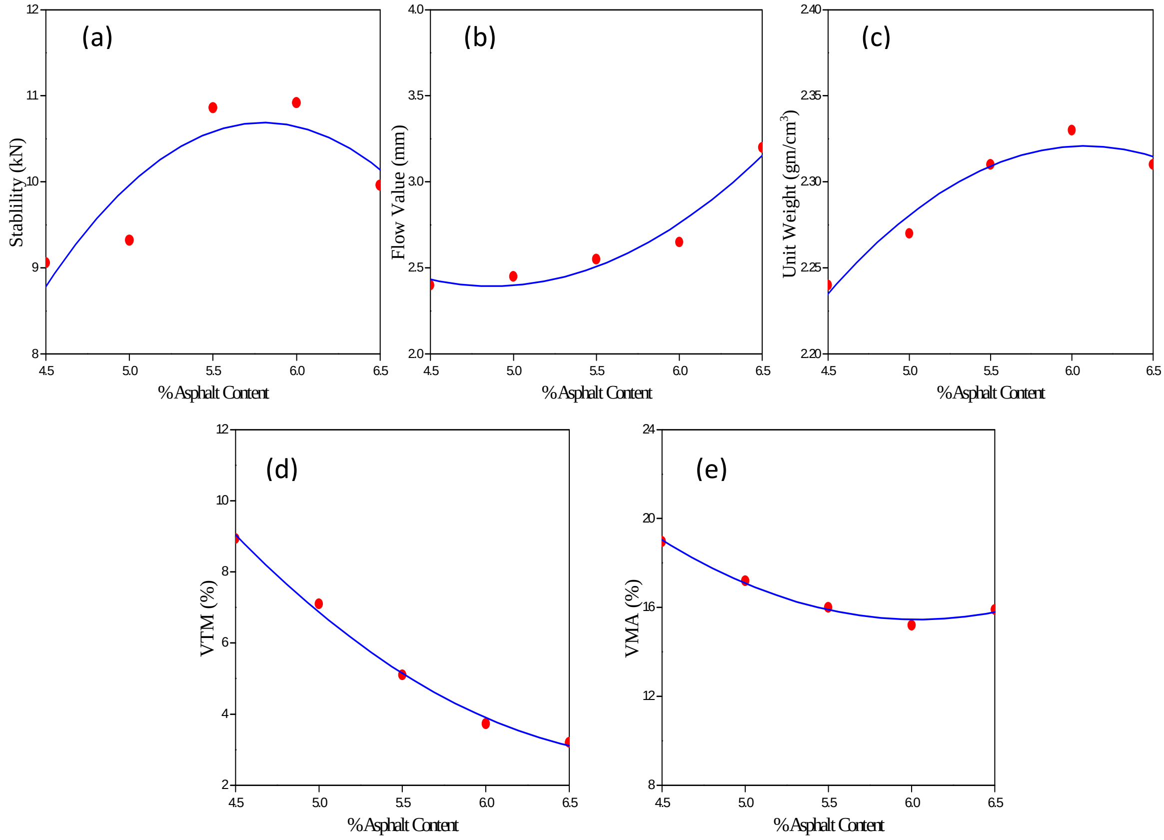

Figure 3 Marshall Mix Design properties using cement as filler

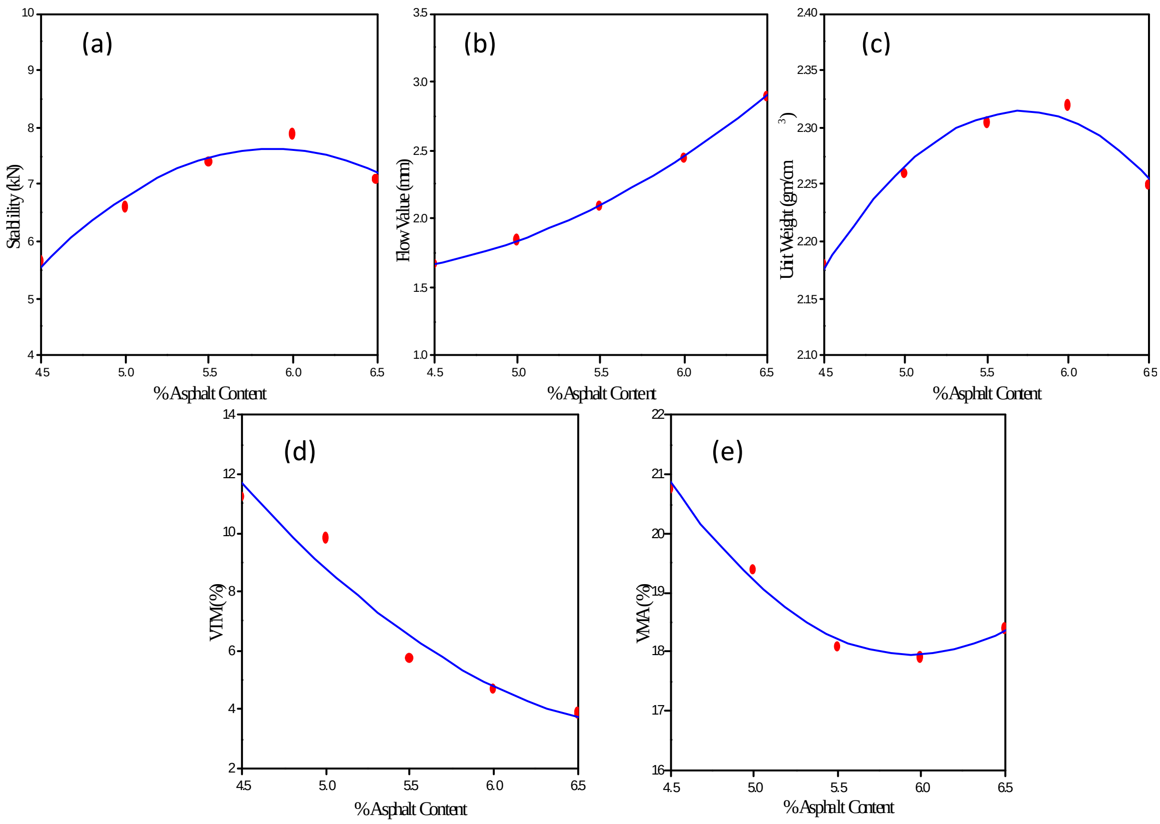

Figure 4 Mashall Mix Design properties using stone dust as filler

An optimum asphalt content of 6.2% (by weight of aggregate) was obtained for the mixtures which contain brick dust as filler material (Figure 2(a) to (e)). At this optimum value, the Marshall Stability, flow, unit weight, %VTM and %VMA values were 11.5 KN, 3.20 mm, 2.27 g/cm^3, 5.50% and 19.25%, respectively. An optimum asphalt content of 6.1% (by weight of aggregate) was obtained for the mixtures which contain cement as filler material (Figure 3(a) to (e)). At this optimum value, the Marshall stability, flow, unit weight, %VTM and %VMA values were 10.70 kN, 2.80 mm, 2.32 g/cm^3, 3.80% and 15.50%, respectively. When stone dust was used as filler then an optimum asphalt content of 6.3% (by weight of aggregate) was obtained for the mixtures (Figure 4(a) to (e)). At this optimum value, the Marshall Stability, flow, unit weight, %VTM and %VMA values were 7.50 kN, 2.75 mm, 2.29 g/cm^3, 4.00% and 18.10%, respectively.

Table 7 shows the Asphalt concrete mix design properties by using cement, stone dust and brick dust as filler materials. Test results indicate that bituminous mixes with non-conventional filler (e.g. brick dust) are found to have satisfactory Marshall Properties, which are almost same as those of conventional fillers (e.g. cement and stone dust), thus substantiating the need for its use.

The optimum bitumen content for brick dust (6.20%) is almost same as that of conventional fillers (stone dust and cement) which indicates that brick dust will provide the same surface area to absorb bitumen. The Marshall properties obtained for both types of fillers reveal that due to having slightly higher bitumen content, non-conventional filler specimens are found to exhibit higher stability value (11.50 kN) compared to conventional filler specimens (10.70 kN & 7.50 kN). Anything that increases the viscosity of the asphalt cement increases the Marshal stability. Addition of brick dust filler in the mixture may produce a more viscous asphalt cement/dust mixture binder thus increasing the Marshal stability. In addition, bituminous mixes containing brick dust as filler showed maximum stability at 6.20% asphalt content showing increasing trend of flow value with bitumen content. Lower flow values were obtained for crushed stone and cement filler because they are finer than brick and thus stiffen the mixture more than brick dust fillers. More fine the material the more it modifies the asphalt mixtures by extending the asphalt binder, hence would rather give lower stability values.

Table 7 Asphalt Concrete Mix Design Result

Properties	Brick dust	Cement	Stone dust	Standard values (according to RHD, Bangladesh)
Optimum Asphalt Content, %	6.20	6.10	6.30	4.9-6.5
Stability (kN)	11.50	10.70	7.50	Min.
Flow value (mm)	3.20	2.80	2.75	2-4
Unit weight (gm/cc)	2.27	2.32	2.29	--
VTM (%)	5.50	3.80	4.00	3-5
VMA (%)	19.25	15.5	18.10	15-20

It is seen that for samples made by stone dust, cement and brick dust fillers, the values of unit weight increases up to maximum point then decreases. This is because while asphalt content increases in the mix, it fills the voids hence increase unit weight. However, at higher asphalt content the mix becomes stiffer that needs greater compaction effort than consequently lower dense mixtures. It is seen that brick dust specimen display higher percentage of air voids (5.50%) and low unit weight (2.27 gm/cc) in comparison with cement and stone dust. High voids should be reduced to acceptable limits (3-5%), even though the stability is satisfactory. This can be achieved by increasing the amount of mineral filler dust in the mix by weight of total mix.

Higher percentages of voids in mineral aggregate were obtained from mixes prepared by brick dust filler. This may be due to the fact that brick dust filler is coarser than stone dust and cement type fillers. A certain Minimum percentage of VMA is necessary in mixtures to accommodate enough asphalt content, so that aggregate particles can be covered with sufficient asphalt. This consequently results in a durable asphalt paving mixtures. The brick dust specimens have found to give satisfactory results with respect to Roads & Highways Department of Bangladesh, only the exception is %VTM, which is slightly more than the standard value.

4. CONCLUSIONS

Bituminous mixes containing brick dust as fillers are found to have Marshall Properties almost same as those of conventional (stone dust and cement) fillers. However, the brick dust specimens provide satisfactory results according to the Roads & Highways Department specification of Bangladesh with an exception of %VTM, which is slightly more than that of standard value. Mixtures using different percentage of brick filler content can be analysed in the laboratory to optimize the air void and stability. The influence of size and gradation of brick filler on the mix can also be studied for better understanding of the behavior on asphalt pavement. The effect of brick dust filler on asphalt binder composition and resistance against moisture damage can also be evaluated. This study concludes that brick dust can be successfully utilized in the production of bituminous concrete mixes for the highway construction. It is expected to provide an economical, environment friendly and long lasting solution for construction of asphalt pavement in Bangladesh.

REFERENCES

American Society for Testing and Materials (ASTM): Road and Paving Materials; Vehicle Pavement System, Annual Book of ASTM Standards, Section 4, Volume 04.03, 2003

Anderson, D.A., Bahia, H.U. and Dongre, R.: Rheological properties of mineral filler asphalt mastics and their relationship to pavement performance, ASTM STP 1147, Richard C. Meininger, Ed., American Society for Testing Materials, Philadelphia, U.S.A., 1992.

Bahia, H.U., Zhai, H., Bonnetti, K., and Kose, S.: Non-linear visco-elastic and fatigue properties of asphalt binders, Journal of Association of Asphalt Paving Technology, 68, 1-34, 1999

Craus, J., Ishai, I., and Sides, A.: Some Physico-Chemical Aspects of the Effect and the Role of the Filler in Bituminous Paving Mixtures, J. Assn. of Asphalt Paving Technologists, Vol. 47, 1978, 558-588,1978.

Elliot, R.P., Ford, M.C., Ghanim, M., and Tu, Y.F.: Effect of aggregate gradation variation on asphalt concrete mix properties, Transportation Research Record, 1317, National Research Council, Washington, D.C., 1991.

Geber, R. and Gomze, L.A.: Characterization of mineral materials as asphalt fillers, Material Science Forum, 659, 471-476, 2010

Kalkattawi, H. R.: Effect of Filler on the Engineering Properties of Asphalt Mixes, M.S. Thesis, King Abdul Aziz University, Jeddah, Saudi Arabia, 1993.

Kandhal, P.S., Lynn, C.Y., and Parker, F.: Characterization tests for mineral fillers related to performance of asphalt paving mixtures, NCAT Rep. No. 98-2, 1998.

Qiu, Y.: Design and performance of stone mastic asphalt in Singapore conditions, PhD thesis, Nanyang Technological University, Singapore, 2006.

The Asphalt Institute, Mix Design Methods for Asphalt Concrete and other Hot Mix Types, MS-2, Sixth Edition, 1993

Vavrik,W.R., Pine, W.J., Carpenter, S.H., and Bailey, R.: Bailey method for gradation selection in hot-mix asphalt mixture design, Transportation Research Board, National Research Council, Washington, D.C., USA, 2002

Wu, S., Zhu, J., Zhong, J., and Wang, D.: Experimental investigation on related properties of asphalt mastic containing recycled brick powder, Construction Building Materials, 25(6), 2883-2887, 2011

Zulkati, A., Diew, W. Y. and Delai, D.S.: Effects of Fillers on properties of Asphalt-Concrete Mixture, Journal of Transportation Engineering, ASCE, Vol. 138, No. 7, 902-910, 2012.