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Influence of Rice Husk Ash and Slag as Fillers in Asphalt Concrete Mixes

Rocksana Akter[1], Md. Kamal Hossain[2]
[1]*Assistant Professor, Department of Civil Engineering, Dhaka University of Engineering & Technology, Gazipur, Bangladesh,*
[2]*Professor, Department of Civil Engineering, Dhaka University of Engineering & Technology, Gazipur, Bangladesh*

ABSTRACT: *Filler is an important ingredient of asphalt concrete mixture. Cement, lime and stone dust are used as conventional fillers. In this study, an attempt has been made to assess the influence of non-conventional fillers such as rice husk ash and slag in bitumen paving mixes and also compared with traditional filler stone dust. From the experimental data, it is seen that specimen made with non-conventional fillers (e.g. slag, rice husk ash) are found to have satisfactory Marshall Properties, which are almost same as conventional filler (e.g. stone dust). The optimum asphalt content (5.5%) in case of slag and stone dust are same while for rice husk ash (5.83%), the same is slightly higher. It is seen that maximum stability is observed by rice husk ash followed by stone dust and slag as filler materials. The value of retained stability of the asphalt concrete mixture using stone dust, rice husk ash and slag are 112.2%, 111.52% and 95.68% respectively which satisfies the limiting value 75%. In addition, it has been recommended to use rice husk ash and slag wherever available, not only reducing the cost of execution, but also partly solve the solid waste disposal problem of the environment.*
Keywords*: asphalt concrete, mineral fillers, Marshall properties, retained stability*

I. INTRODUCTION

The continuing rapid growth in population, along with the increase in traffic demand.The traffic demand is increasing day by, along with the increase in allowable axle loads. So, it is necessary to improve the highway paving materials. The main purpose of a highway pavement is to provide a satisfactory surface upon which highway vehicles can operate. A flexible pavement consists of soil subgrade, sub-base course, base course and surface course. The sub-base course, base course and surface course may consist of one or more number of layers of the same or slightly different materials and specifications. The surface course is surfaced with asphalt materials. They are widely used both on rural highways and on city streets that are subjected to large volumes of traffic and severe service conditions. Asphalt concrete is a well graded mixture containing coarse aggregate (50-65%), fine aggregate and filler (35-50%), asphalt (5-8%) of total mass of aggregate [1]. Among them, filler is one of the most important components of asphalt concrete. It plays a significant role on the properties of asphalt concrete [2–4]. Properly designed and constructed surfaces of this general type are capable of carrying almost unlimited volumes of passenger, mixed, or truck traffic, provided only that they are supported by adequate foundation structures. The majority of these surfaces might be expected to have an economic life of 20 years or more.

II. LITERATURE REVIEW

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 physiochemical properties [5]. In previous study, It has been studied that different types of fillers have different effects on the same bitumen content [6].Conventionally, stone dust, cement and lime are used as fillers [4]. many researchers used industrial by products and wastes as fillers that are called non-conventional fillers [7–12]. Ratnasamy Muniandy et al. [3] studied the effect of mineral filler type and particle size on asphalt-filler mastic and stone mastic asphalt laboratory measured properties. The authors defined that the application of industrial and by products wastes as filler improves the properties of asphalt-filler mastic and SMA mixtures. The authors stated that the optimum asphalt content at given filler to asphalt ratio increased with the decrease in filler particle size regardless filler type. It was also determined that filler type and particle directly affect the engineering properties of the asphalt mixtures. In addition to filling the voids, the fillers component interact with the binder present in the mix potentially making it stiff and brittle. The change in mix mix properties is strongly related to the properties of the filler. Ravindra Tomar et al. [5] studied the effect of fillers on bituminous paving mixes. The authors investigated two types of non-conventional fillers such as brick dust and silica fume. The authors observed that bituminous mixes with these non-conventional fillers result in satisfactory Marshall Properties though requiring a bit higher bitumen content, thus substantiating the need for its use. Noor M. Asmael [2] studied the effect of mineral filler type and content on properties of asphalt concrete mixes. The general overview of this study was to evaluate the influence of new different fillers extracted from different local sources on the performance of asphalt mixtures. It was also stated that filler content have a considerable effect on the mixture making it act as a much stiffer, and thereby affect the HMA pavement performance including its fracture behavior. Above the circumstances it is clear that filler is an important component of asphalt concrete mixture. Therefore, it is necessary to investigate which type of filler is effective and economical

III. OBJECTIVES OF THIS STUDY

To determine the effect of type of mineral fillers (stone dust, slag and rice husk ash) on the design of an asphalt concrete mixture. To measure workability, moisture susceptibility these values are affected by mineral filler.

Methodology

There are three stages to investigate this study, (1) Determination the material features (2) Mix design for the three fillers with two proportions of filler quantity and determination of the volumetric and mechanical properties of the mixtures (3) Evaluation of mixtures. In the first stage the material properties of the aggregate, asphalt, and fillers were determined. In the second stage the optimum asphalt content for the twelve mix design were determined using the Marshall Mix Design Method ,while in the third stage the optimized mixtures were evaluated by Marshall stability and retained stability.

Materials

Aggregates

The quality of aggregates plays a great role in the performance and long- term economy of the road structure. The aggregates also bear the main stresses occurring in the road and resist wear from surface abrasion. The combined graduation of aggregates was selected to approximately meet the job mix limits of the graduation which specified by the AASHTO T27 and AASHTO T37 for dense graded paving mixtures of surface coarse. According to AASHTO T27 and AASHTO T37 the mix composition and sieve analysis of aggregates are given in Table 1. Aggregates are collected from local sources. The physical properties of aggregates were determined and are shown in Table 2.

Table I: Mix composition and sieve analysis of aggregates

Sieve size	*%Passing*	*Specified limit*	*Cumulative% Retained*	*% Used*	*Wt. of material, gm*
3/4"(19mm)	100	100	0	0	0
1/2"(12mm)	97.2	90-100	2.8	2.8	33.6
3/8"(	79.28	76-90	20.72	17.92	215.08
#4	58.56	44-74	41.44	20.72	248.64
#8	41.5	28-58	58.52	17.08	204.96
#40	26.36	8-27	73.64	15.12	181.4
#80	11.96	5-17	88.04	14.4	172.8
#200(Retained)	8	5-8	92	3.96	47.52
			100	8	96
					Total=1200gm

Table II: Physical properties of aggregates

Property	*Test Method*	*Test value (Coarse Agg.)*	*Test value (FineAgg.)*	*Standard value*
Aggregate Crushing Value (%)	BS812:Part 110:1990	26	-	<30
Aggregate Impact Value (%)	BS812:Part 112:1990	9.0	-	<25
Specific gravity	ASTM C 127, C 128BS812:Part 2:1975	2.630,2.676	2.708	-
Elongation (%)	ASTM D 4791 BS812:Section 105.2:1990	15	-	<25
Flakiness (%)	ASTM D 4791 BS812:Section 105.1:1989	19	-	<25
Water Absorption (%)	ASTM C 127 AASHTO T 85 BS812:Part 2:1975	1.29%,1.19%	-	-

Asphalt Binder

IRC has recommended three types of PG bitumen. There are 50/60, 60/70 and 80/100. But in Bangladesh 80/100 PG bitumen is widely used and acceptable for temperature and weather conditions. So, it is selected to this study. It was collected from local distributor. The important physical properties are summarized in Table 3.

Table III: Physical properties of asphalt binder

Property	*Test Method*	*Test Value*	*Standard Value*
Penetration value	ASTM D5-86	100	85-100
Softening point (°C)	ASTM D36-70	48°C	30°C (Min.)
Specific gravity	ASTM D70-97	1.02	1.01-1.06
Flash and Fire point	ASTM D92-90	320°C,341°C	175°C (Min. flash point)
Solubility		99.4%	
Ductility	ASTM D113-86	100+	50 (Min.)

Mineral Fillers

Fillers play a great role on engineering properties of the bituminous paving mixes. The Asphalt Institute (TAI) uses the No.8 sieve as the dividing line between fine aggregate and filler. Filler is that mineral material that passes a No.200 sieve. The specific gravities of different type's fillers are given in Table 4.

Table IV: Specific gravities of different typesof fillers

Filler Type	*Test Method*	*Specific gravity*
Stone dust	ASTM D854	2.46
Slag	ASTM D854	5.60
Rice husk ash	ASTM D854	1.8

Filler Chemical Composition And Elemental Analysis Result

The X-ray fluorescence test results of different types of fillers are given in table 5. From Table 6 it is seen that the sum of SiO_2, Al_2O_3, and Fe_2O_3 are 79.76%, 96.733%, and 94.4327% for stone dust, slag, and rice husk ash as fillers respectively. According to ASTM, the sum of SiO_2, Al_2O_3, and Fe_2O_3 should be more than 70%. It is also seen that stone dust and rice husk ash contain high SiO_2 (58.516% and 93.2902% respectively)which related with good mechanical (strength) properties.Steel slag contains high Fe_2O_3 (91.2230%) which related with low moisture sensitivity Also, the percentage of magnesium oxide (MgO) for all types of fillers are within the requirements (less than 5%). It is also known that, the presence of calcium and magnesium are also associated with low moisture sensitivity. On the other hand, high sodium and potassium in alkali feldspars are associated with high moisture sensitivity.

Table V: X-ray fluorescence test results of different types of fillers

Material	*Weight percent*		
	Stone dust	*Slag*	*Rice husk ash*
SiO_2	58.0516	4.9408	93.2902
Al_2O_3	10.4144	0.5691	0.5701
CaO	7.6344	0.5335	1.1266
Fe_2O_3	11.2939	91.2230	0.5724
SO_3	0.2314	0.1727	0.2686
TiO_2	1.4801	0.3141	0.0746
K_2O	3.9270	0.0647	2.3042
MgO	4.3189	1.3187	0.6156
Na_2O	1.9247	0.1447	0.1149
SrO	0.0298	-	0.0045
P_2O_5	0.4163	0.0795	0.8060
BaO	0.0824	0.2066	-
MnO	-	-	0.2165
Cr_2O_3	0.0321	0.0647	-
ZrO_2	0.0794	-	0.0045
ZnO	0.0535	0.1398	0.0168
CuO	0.0126	0.2250	-
Rb_2O	0.0175	-	0.0146

Preparation Of Mix Specimens

The Marshall method of design was originally developed by Bruce Marshall formerly of the Mississippi Highway Department, and improved by the U.S Army Corps of Engineers. The Marshall Test procedures have been standardized by the ASTM and published as ASTM D1559. The samples for bituminous concrete mixtures were prepared as per ASTM D1559 at different bitumen contents for each type of filler used. As a first step in the procedure, the aggregates with the proper graduation are thoroughly dried and heated. Sufficient mixture is generally prepared at each asphalt content. Each specimen will require approximately 1.2 kg of mixture. Then the asphalt and the aggregates are heated separately and then mixed. Next the mixture is placed in the mold, mixed by hand with a trowel, and compacted. The specimens were compacted with a standard hammer device, which weighs 4.5 kg and is designed to drop from a height of 457 mm. A compactive effort 50 blows is specified for medium traffic. The compactive effort is applied to each side of the specimen. After compaction, each specimen is subjected to a density-voids analysis and then tested for stability and flow. The optimum bitumen content for each type of filler in bituminous concrete mix was done as per the normal procedure.

Figure 1: Preparation of mix specimens

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. In Marshall Method uses standard test specimens of 64 mm height and 102 mm in diameter. These are prepared using a specified procedure for heating, mixing and compact the asphalt-aggregate mixture. The two principle features of the Marshall method of mix design are a density –voids analysis and a stability-flow test of the compacted test specimens. The stability of the test specimen is the maximum load resistance that the standard test specimen will develop at 60°C .The flow is measured as a deformation or total movement in units of 0.25 mm between no load and maximum load carried by the specimenduring the stability test. 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 test should be scheduled on the basis of 0.5 percent increments of binder contents with at least two binder contents below the optimum. 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.

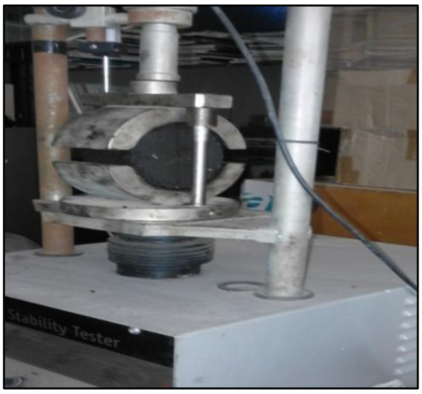


Figure 2: Marshall Test of specimens

IV. RESULTS AND DISCUSSIONS

The Marshall properties of each specimen such as stability, flow value, air void (V_a), voids in mineral aggregate (VMA), unit weight, voids filled with aggregate (VFA) are tabulated in tables 6 through 8.The graphical representations are also shown in Figures 3 to 5. To measure moisture susceptibility the value of retained stability are also expressed in Figures 4 to 6.

Table VI: Marshall properties of specimen with stone dust

Asphalt Content (%)	*Unit wt.(gm/cc)*	*VMA*	*Va*	*VFA*	*Stability (kN)*	*Flow (mm)*	*Stability(kN) (after 24h)*	*Retained stability*
5	2.384	15.02	6.03	59.84	16.86	2.31	18.37	108.96
5.5	2.407	14.65	4.37	70.17	14.67	2.33	16.46	112.20
6	2.417	14.75	3.71	74.88	14.24	2.38	15.14	106.32
6.5	2.399	15.83	3.19	79.86	11.09	2.92	14.25	128.49
7	2.40	16.25	2.44	84.99	9.43	3.61	11.4	120.89

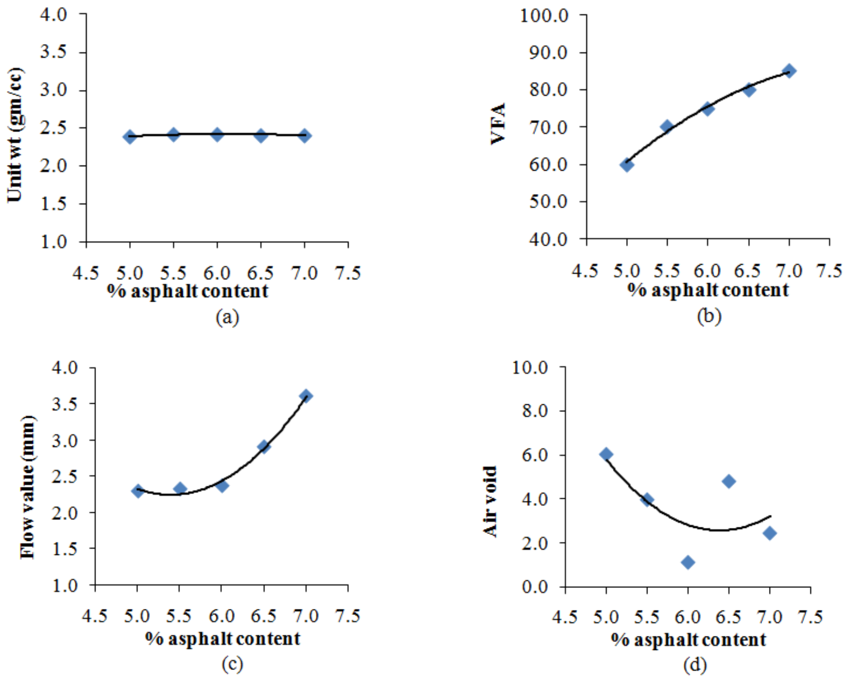
Table VII: Marshallproperties of specimen with slag

Asphalt Content (%)	*Unit wt.(gm/cc)*	*VMA*	*Va*	*VFA*	*Stability (kN)*	*Flow (mm)*	*Stability(kN) (after 24h)*	*Retained stability*
5	2.430	17.81	6.02	66.19	18.18	1.531	16.734	96.46
5.5	2.460	17.24	4.09	76.26	13.624	2.45	15.923	111.52
6	2.487	16.78	2.28	86.41	14.406	2.48	13.75	95.46
6.5	2.472	17.73	2.11	88.09	15.809	2.51	10.683	70.28
7	2.455	18.72	2.00	89.34	10.524	2.52	8.58	88.84

Table VIII: Marshall properties of specimen with rice husk ash

Asphalt Content (%)	*Unit wt.(gm/cc)*	*VMA*	*Va*	*VFA*	*Stability (kN)*	*Flow (mm)*	*Stability (kN) (after 24h)*	*Retained stability*
5	2.386	12.35	4.52	63.38	9.033	1.84	8.301	103.25
5.5	2.372	13.32	4.35	67.31	15.147	1.9	13.304	102.10
6	2.365	14.03	3.90	72.20	16.959	2.34	13.469	92.38
6.5	2.360	14.67	3.40	76.84	17.918	2.37	14.23	95.70
7	2.345	15.67	3.30	78.94	21.451	2.49	16.297	88.33

To find the optimum bitumen content five 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 3 through 5, 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.



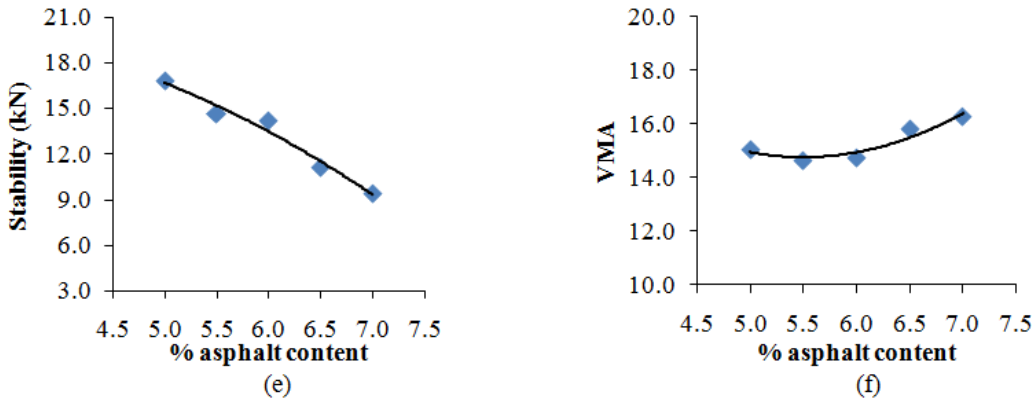


Figure 3: Marshall properties vs asphalt contents for specimens prepared with stone dust as filler

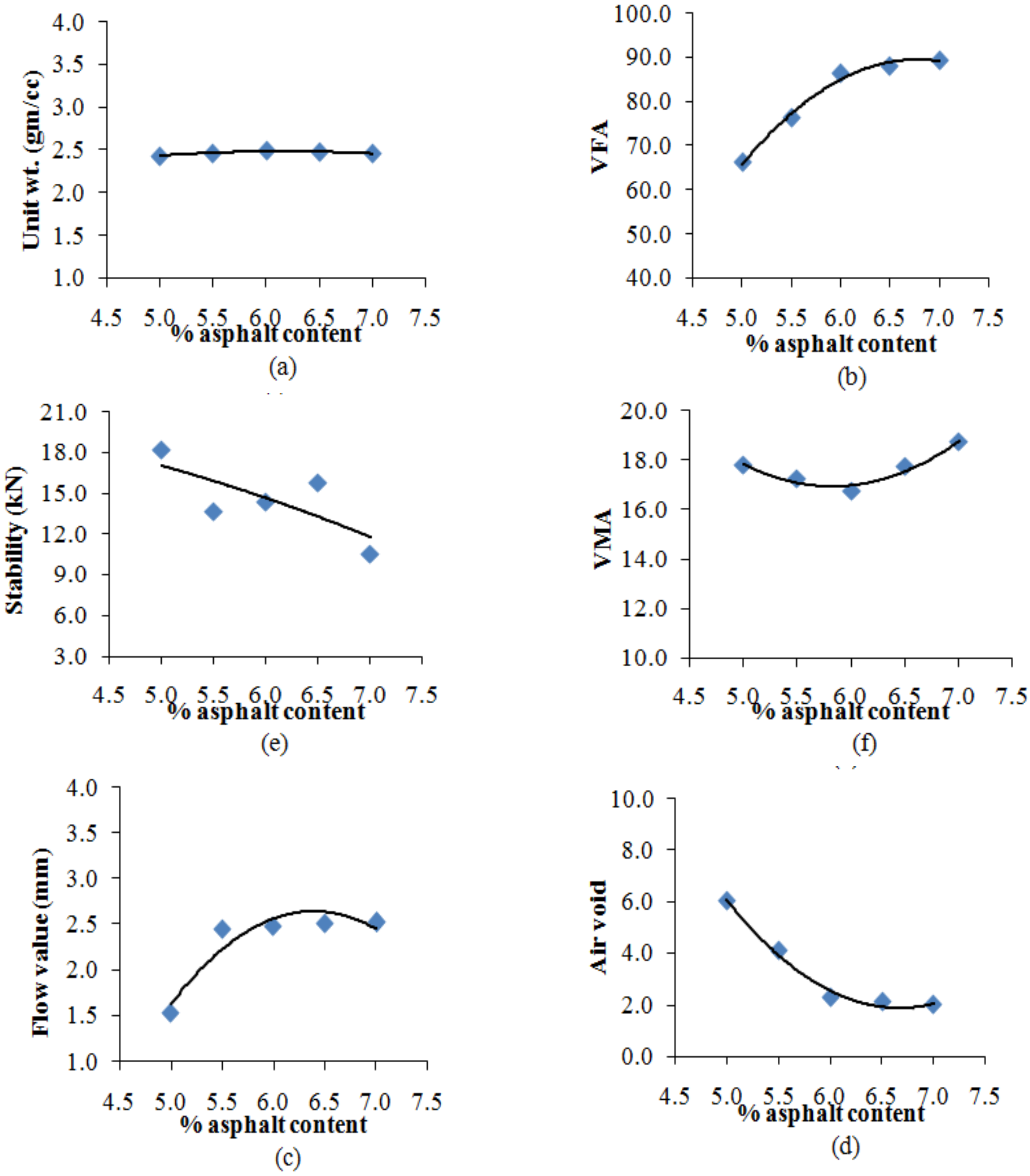


Figure 4: Marshall properties vs asphalt contents for specimens prepared with slag as filler

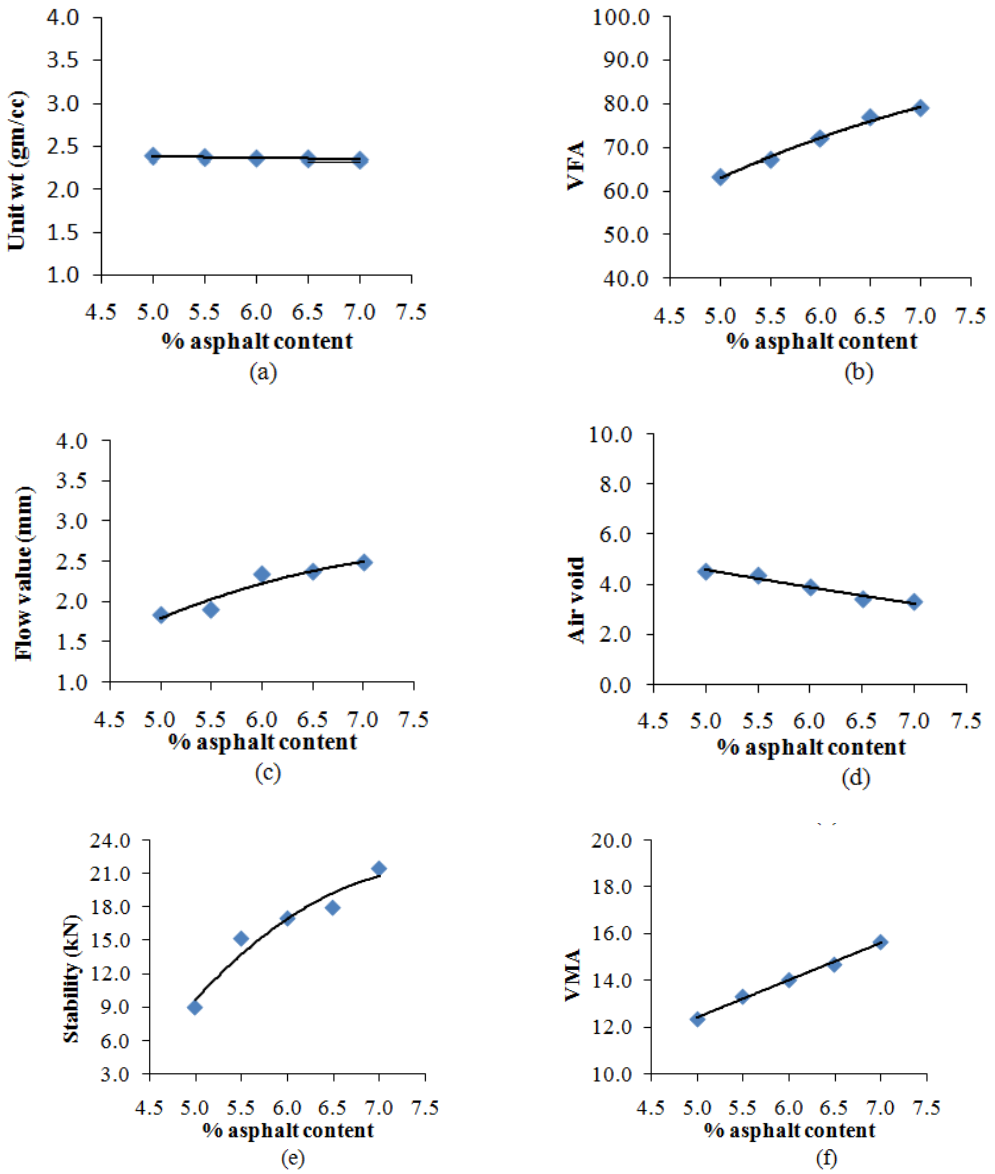


Figure 5: Marshall properties vs asphalt contents for specimens prepared with rice husk as filler

The relationships between filler content and Marshall Properties of mixtures for stone dust as filler have been shown in Figure3 (a) through 3(f). It is seen that the maximum stability (16.86 kN) is obtained at 5% asphalt content, the values of flow, VFA & VMA are increased by increasing the filler content, unit wt are increased up to maximum point then decreases in exception at 7% asphalt content and the air void is increased by increasing the filler content. In Figure4 (a) through 4(f) shows the relationship between filler content and Marshall Properties of mixtures for slag as filler. It has been shown that the maximum stability (18.18 kN) is obtained at 5% asphalt content, the values of flow, VFA are increased by increasing the filler content, the values of VMA are also increased by increasing the filler content in exception at 5% & 5.5% asphalt content, unit wt. are increased up to maximum point then decreases and the air void is increased by increasing the filler content.

In Figure5(a) through 5(f) also shows the relationship between filler content and Marshall Properties of mixtures for rice husk ash as filler. It has been shown that the maximum stability (21.45kN) is obtained at 7% asphalt*content;*the values of flow, VFA & VMA are increased by increasing the filler content, unit wt are increased up to maximum point then decreases and the air void is increased by increasing the filler content. The results of this study have been shown that the use of rice husk ash as a filler at 7% is the maximum stability among the three types of fillers. The asphalt concrete mix design properties by using stone dust, slag and rice husk ash as mineral fillers have shown in Table 9.The results show that specimen made with non-conventional fillers (e.g. slag, rice husk ash) are found to have satisfactory Marshall properties, which are almost same as conventional filler (e.g stone dust). The optimum asphalt content (5.5%) in case of slag and stone dust are same while for rice husk ash (5.83%), the same is slightly higher. It is seen that maximum stability is observed by rice husk ash followed by stone dust and slag as filler materials. As usual, the results of flow value and unit wt. show the reverse trends. However, it has been seen that the variation is nominal and the all values of Marshall Properties are within the specification limits of AASHTO.

Table IX: Marshall properties of specimen with rice husk ash

Properties	*Stone dust*	*Slag*	*Rice husk ash*	*Standard values according to AASHTO*
OAC (%)	5.50	5.5	5.83	-
Stability (kN)	14.67	13.624	16.343	5.34kN(medium traffic)
Unit wt. (gm/cc)	2.417	2.46	2.367	-
Air void	3.97	4.09	4.05	3-5
Flow value (mm)	2.33	2.45	2.19	2-4
VMA	14.29	17.24	13.79	-
VFA	72.21	76.26	70.54	65-78
Retained stability	112.20	111.52	95.68	75(minimum)

The values of retained stability for optimum mixes with different types of fillers have been shown in Figure6. It has been seen that the value of retained stability for mixes prepared with stone dust as filler offers highest retained stability value followed by slag and rice husk 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 indicates that all mixes with stone dust, slag and rice husk ash as filler have good resistance to moisture induced damages.

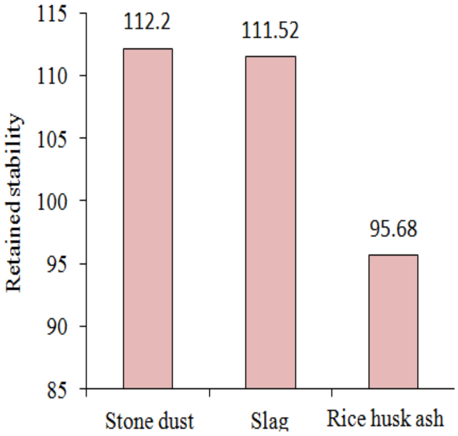


Figure 6: Retained stability for mixes with different types fillers

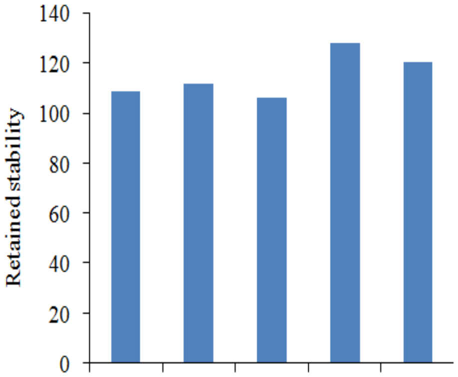


Figure7: Retained Stability for mixes with stone dust only

The values of retained stability for mixes with different types of fillers have been shown in Fig. 7, 8, & 9. It has been seen that the value of retained stability for all mixes prepared with these fillers satisfy the minimum retained stability value requirement i.e.75%. It is also seen that the mix prepared with 6.5%, 5.5%, and 5% asphalt content of stonedust, slag and rice husk ash respectively offer highest retained stability value.

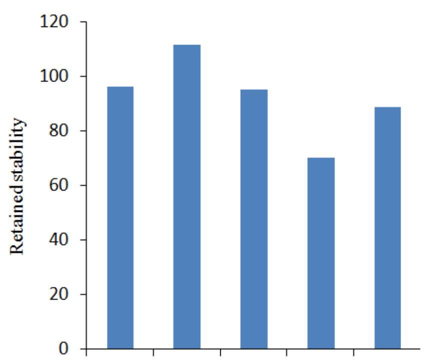


Figure 8: Retained Stability for mixes with slag only

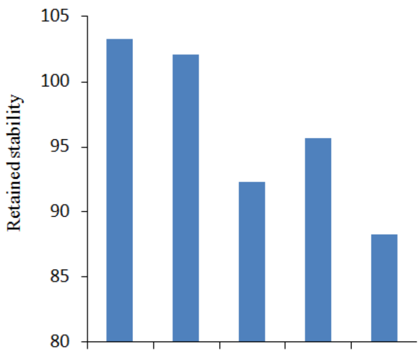


Figure9: Retained Stability for mixes with rice husk ash

V. CONCLUSION

In the above circumstances, we say that slag and rice husk ash can effectively be used as filler in paving mixes in place of most commonly used filler such as stone dust. It is also evident that by using slag and rice husk as fillers in paving mixes partly solve the solid waste disposal problem of the environment.

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