PERFORMANCE EVALUATION OF ASPHALT CONCRETE USING WASTE BLISTER PACK AS ADDITIVE

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ABSTRACT

Disposal of non-decaying wastes, including blister packs, has become a significant concern in developed and developing countries. Blister pack waste materials were used as an additive to in this to enhance the performance of asphalt concrete mixes. Four different asphalt concrete combinations were produced using shredded waste blister packs (WBP) at distinct proportions to achieve research goals, including 0.25%, 0.50%, and 0.75% by weight of total aggregate. Afterward, Marshall properties (i.e., density, stability, flow value, air void, voids in mineral aggregate, voids filled with asphalt, and retained stability) were evaluated to check the performance of asphalt concrete and later on to determine the optimum asphalt content. It was investigated that the specimens made with 0.25% and 0.50% (by weight of total aggregate) WBP satisfied all Marshall criteria including significant stability and retained stability value. The percentage of optimum asphalt content was lowest for the mixes with 0.75% WBP content, followed by 0.50%, 0.25% and 0%. Meanwhile, highest stability was found for the mixes with 0.50% WBP content. All the properties at 0.25% and 0.50% WBP content showed better results than the control mix (i.e., 0% WBP).

Keywords: Waste blister pack, Marshall properties, Optimum asphalt content

1.0 INTRODUCTION

Asphalt concrete (AC) is the most widely used paving material around the world. It contains 92 to 95% mineral aggregate and 5 to 8% asphalt binder [1]. Construction of pavements should be done as it is strong and durable for their design life. Asphalt pavement performance is affected by several factors, e.g., the properties of the components (binder, aggregate, and additive) and the proportion of these components in the mix. The performance of asphalt mixtures can be improved with the utilization of various types of additives, these additives include polymers, latex, fibers, and many chemical additives [2; 3]. El-Saikaly (2013) used waste plastic bottles (WPB) as an additive and suggested that WPB can be conveniently used as a modifier for asphalt mixes for sustainable management of plastic waste as well as for the improved performance of asphalt mix. The stability value of this mixture is 24% higher than the conventional mix and shows lower bulk density [4]. Modified asphalt with the addition of processed plastic waste of about (5-10)% by weight of asphalt as a modifier and found that the value of Marshall stability strength, fatigue life, and other desirable properties of the asphalt concrete mix has been improved [5]. Prasad *et. al.* (2013) added (1-9)% plastic waste by the weight of the recycled asphalt in hot mix asphalt concrete, and the mixtures showed better binding property, stability, density, and more resistance to water [6]. By adding the fine size of the shredded plastic waste particle (passing sieve #16 (1.18mm)) to the asphalt mixture increases Marshall stability and index of retained strength by 18% and 12% respectively, as compared with the conventional mix [7]. The use of these technologies not only strengthens the road but also enhances the durability of the road as well as helps to improve the environment and generate revenue.

Various types of waste materials are produced due to industrial growth with a growing population. Blister pack is one of them. The use of blister packs has been increasing day by day. Blister packs are used for packaging products such as toys, hardware, medication, etc. It was reported that in 2016 [8], the world created 242 million tons of plastic waste, 12 percent of all metropolitan solid waste. This waste has begun from three locales, 57 million tons from East Asia and the Pacific, 45 million tons from Europe and Central Asia, and 35 million tons from North America. Another report was mentioned that in 2019 [9], the world's cities created 2.01 billion tons of solid waste, summing to an impression of 0.74 kilograms per individual per day. With quick populace development and urbanization, the yearly waste era is anticipated to extend by 70% from 2016 levels to 3.40 billion tons in 2050. Disposal of the massive sum of waste, particularly non-biodegradable waste has made different sorts of issues and produces a destructive impact on the environment. So, these tremendous sums of plastic waste are destructive for the city. Researchers and analysts, the world over have put themselves to the assignment to investigate the reusing of waste material to the advantage of the environment as well as the economy. Most critically, the authors endeavoured to see into the possibility of the re-use of solid waste material within the development of streets. According to [10], the best way to get rid of the excessive solid wastes accumulating in urban and industrial areas is to implement the re-use of waste material. Using recycled materials in road pavements is nowadays considered not only as a positive option in terms of sustainability but also, as an attractive option in means of providing enhanced performance in service [11]. It's proven that the addition of certain polymers to asphalt binders can improve the performance of road pavement [12]. The addition of polymers typically exhibits greater resistance to rutting and thermal cracking. Besides, it decreased fatigue damage, stripping, and improved temperature susceptibility. Polyethylene is an extensively used plastic material, and it is one of the most effective polymer additives [10; 3].

It is important to note that most of the previous studies used either plastic bottles or polyethylene as additives considering environmental issues. None of the prior research considered waste blister packs as additives in the asphalt concrete mixes. Considering this, this study focused to explore the performance of waste blister pack (WBP) as additive including optimum percentage in asphalt concrete mixes that will eventually reduce the disposal problems of the blister packs.

2.0 MATERIALS

2.1 Aggregate

Stones are most commonly used in asphalt concrete as aggregate. The different properties of aggregate have a large impact on the stability, flow, and different Marshall properties of asphalt concrete. Locally available aggregate was used in this study. The properties of the used aggregate are shown in Table 1.

Table 1: Physical properties test results of aggregate

Test Name	Test Standard	Result (%)	Standard Value
Los Angeles Abrasion (LAA)	AASHTO T 96	19.12	≤30
Aggregate Impact Value (AIV)	BS 812: Part 112: 1992	19.30	≤25
Aggregate Crushing Value (ACV)	BS 812: Part 110: 1992	22.81	≤30
Elongation Index (EI)	BS 812: Section 105.2: 1990	22.42	≤30
Flakiness Index (FI)	BS 812: Section 105.1: 1990	22.50	≤30
Specific Gravity (Coarse Aggregate, Fine Aggregate)	AASHTO T 85	2.65, 2.74	-

2.1.1 Gradation of Dense Graded Aggregate

Aggregates of various sizes are used in asphalt concrete. The particle size distribution of aggregate is termed gradation. The sieve analysis is conducted to determine the particle size distribution. In this study, and aggregates were screened by AASHTO T27 specified sieve ¾ inch to # 200. The combined gradation of aggregate and filler is shown in Table 2.

Table 2: Selected combined gradation of aggregate and filler

Coarse Aggregate (C. A) = 52%, Fine. Aggregate (F. A) = 42% & Mineral Filler (M. F) = 6%				
Sieve Size	**% Passing**	**Specified limit (AASHTO T27)**	**Cumulative % Retained**	**% Used**
3/4"	100	100	0	0
1/2"	97.4	90-100	2.6	2.6
3/8"	80.76	76-90	19.24	16.64
#4	61.52	44-74	38.48	19.24
#8	47.14	28-58	52.86	14.38
#40	33.30	8-27	66.70	13.84
#80	16.92	5-17	83.08	16.38
#200	06	5-8	94	10.92
#200 (Retained)			100	6
			Total	100

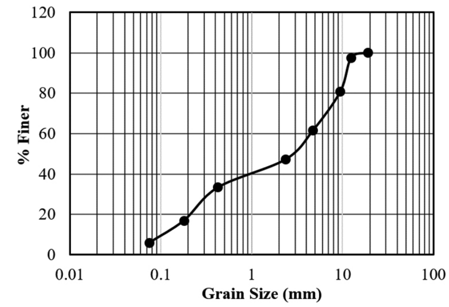

Figure 1: Grain Size Distribution Curve

2.2 Mineral Filler (M. F)

The fillers are sieved through No. 200 sieve. It offers permeability, stiffens the binder, and fills the voids in aggregates. In this research work, dust is used as filler whose specific gravity was 2.57.

2.3 Asphalt

Asphalt is used in the aggregate as binding materials and it also acts as a filler and stabilizer in asphalt mixture. It offers impermeability and particle adhesion cause asphalt fills the void. The properties of used asphalt are shown in Table 3.

Table 3: Physical properties test results of asphalt binder

Test Name	Test Standard	Test Value	Standard Value
Penetration grade	ASTM D 5-86	66	60-70
Softening Point	ASTM D 36-70	51ºC	30ºC to 80ºC
SG	ASTM D 70-76	1.02	0.97 to 1.02
Ductility	ASTM D 113-86	100+	100+
Flash point	ASTM D 92-90	308ºC	Minimum 175ºC
Fire point	ASTM D 92-90	337ºC	Minimum 200ºC

2.4 Waste Blister Pack

Waste Blister packs (WBP) were collected from locally available sources including hospital and pharmacy. It is one kind of Polyvinyl Chloride (PVC) plastic [13] and most PVC sheets for pharmaceutical blisters are 250μ or 0.25 mm in thickness [14]. The specific gravity of WBP used in this study was 1.25 and melting temperature of WBP with asphalt was 150°C. First, the collected WBP cleaned by water then dried in sunlight. Next, the cleaned WBP was cut into small pieces, i.e., approximately 10 mm length and 1 mm width sizes. The photo views of WBP before and after shredded have been shown in Figure 2. Three different percentages of WBP 0.25%, 0.50%, and o.75% (by weight of total aggregate) were selected for this study.

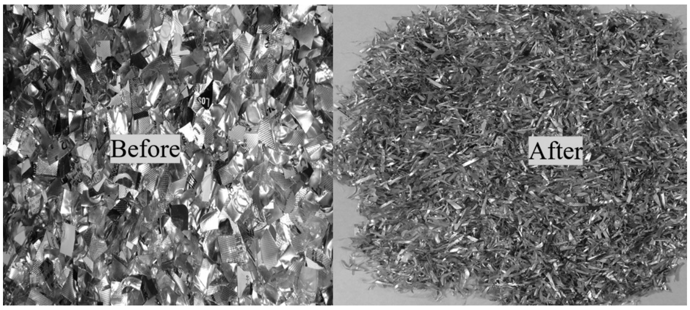

Figure 2: Waste Blister Pack (Before and After)

3.0 EXPERIMENTAL WORK

3.1 Preparation of Marshall Specimen

The samples for bituminous concrete mixtures were prepared as per ASTM D1559 at different asphalt contents. As a first step in the procedure, the aggregates with the proper graduation were thoroughly dried and heated. A sufficient mixture was generally prepared at each asphalt content. Each specimen has been required approximately 1.2 kg of mixture. Then the asphalt with WBP and the aggregates were heated separately and then mixed. Next, the mixture was placed in the mold, mixed by hand with a trowel, and compacted. After compacting the mould was placed in air to cool for 30 minutes and removing the specimen from the mould after a predefined time. After removing the sample, the required dimensions were taken and then submerged into the water bath at 60ºC for 35 minutes.

3.2 Marshall Stability, Flow and Marshall Quotient

After finishing the required time in a water bath, the sample was placed in a Marshall stability tester machine to determine stability, flow value, and the Marshall quotient (MQ). All samples were tested under the Marshall stability tester machine.

4.0 RESULTS AND DISCUSSION

This research evaluated the performance of asphalt concrete mixtures with different percentages of WBP. After completing the stability and flow tests the Marshall properties of asphalt concrete mixture specimens have been explored to achieve research goals. Then evaluated the optimum asphalt content (OAC) for each WBP content. The results that were obtained were presented in detail in the subsequent section through Figure 3.

4.1 Density Void Analysis

Figure 3(a) shows the Marshall Stability curves of different percentages of waste blister pack (WBP). Stability is the maximum load required to produce a failure of the specimen when the load is applied at a constant rate. Stability values increase with the asphalt content increase till it reaches the peak and then it started to decline gradually with higher asphalt content. But at 5% asphalt content, all specimens show better stability. It was also observed that the stability of the modified asphalt mixture increases as the WBP content increases up to 0.50%, but it started to decline at higher WBP (0.75%). A similar study conducted by Awaeed et al. (2015) reported that using (2-10%) waste plastic bottles (WPB) by weight of the optimum asphalt percent (5.0%) as a modifier to enhance the properties of asphalt mixtures. The authors found that all the values of stability for different modified asphalt percentages were higher than the stability of conventional mixture value (10.318 KN), while the maximum stability value was found nearly (14.489 kN) at 8% WPB content [15]. Figure 3(b) shows the relationship between flow value and asphalt content with different percentages of WBP. The flow of the modified asphalt mixture was lower than the conventional asphalt mixture value and the flow decreased continuously when increasing WBP content.

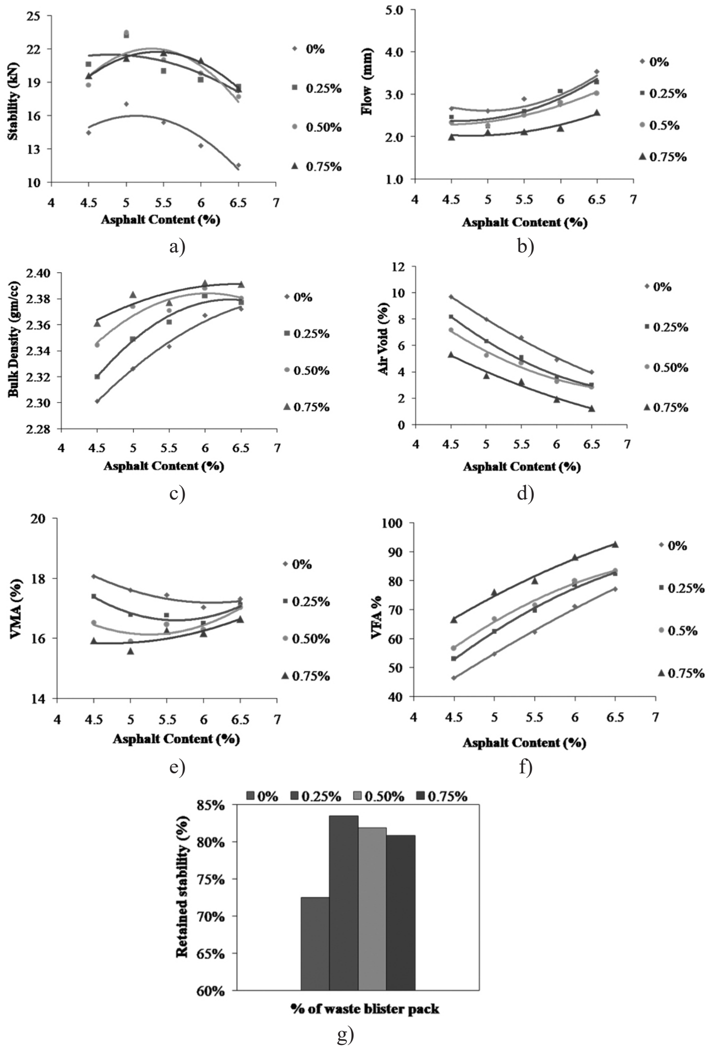

Figure 3: Marshall Properties Curves (i.e (a) Stability, b) Flow, c) Bulk Density, d) Air void (%), e) VMA%, f) VFA%, and g) Retained Stability Curves

Figure 3(c) shows the relationship between bulk density and asphalt content for different percentages of the WBP. Bulk density increased with the increasing of asphalt content for all types of specimens. The bulk densities of all specimens using waste blister pack modified asphalt mixture were higher than the conventional asphalt mixture value. The maximum bulk density was (2.39 gm/cc) at waste blister pack content (0.75%). This is due to the fact that the addition of high concentrations of waste blister packs into the mixtures. Figure 3(d) shows that the air void (%) of Marshall Specimen at different asphalt content for the different percentages of the WBP. The air void (%) has been decreased with increasing asphalt content for all cases. The air void proportion of the modified asphalt mixture was lower than the conventional asphalt mixture. The air void (%) of the modified asphalt mixture decreased gradually as the waste blister pack content increased up to highest content (i.e. 0.75%).

In general, as shown in Figure 3(e), the voids in mineral aggregate (VMA) % percentage of the modified asphalt concrete mixtures was lower than the conventional asphalt concrete mixture, the (VMA) decreases continuously as the WBP modifier content increases. Besides, It is seen from Figure 3(e) that the VMA values of all specimens decrease as the asphalt content increases to 5.0%, and then it started to go gradually up to higher asphalt content. When the binder is applied in a mixture, the aggregate first absorbs the binder, then the binder fills the void of the mixture. As a result, the VMA value has been decreased initially and then increased because the void space available includes air voids and the effective asphalt content not absorbed into the aggregate. Figure 3(f) shows that the voids filled with asphalt (%) of Marshall specimen at different asphalt content for the different percentages of the waste blister pack. The VFA value increased with increasing the asphalt content for all mixtures. Besides, the VFA percentage of the modified asphalt concrete mixtures was higher than the conventional asphalt concrete mixture. Figure 3(g) shows the percentage of retained stability for different percentages of WBP. The values of retained stability have been increased by adding of waste blister pack used as an additive. All the retained stability values of Marshall mixes with different percentages of a blister pack are greater than the conventional mix. The graph shows that maximum retained stability was found when 0.25% WBP was added with the conventional mix. Maximum retained stability value for the conventional/control mix was found 73% and for modified mixes with 0.25%, 0.5% and 0.75% of WBP were found 83%, 82%, and 81% respectively.

4.2 Optimum Test Results

The summary of optimum test results is summarized in Table 4. It is evident from Table 4 that the use of waste blister packs gives better results as compared to the control mix. Also, a higher percentage of WBP content shows lower values of flow value, OAC, air void %, VMA, and higher values of stability, density, VFA, and retained stability. It is also seen that all the values are within the specified limit in exception of 2 or 3 cases. Besides, the Marshall quotient values are within the limit. The permanent deformation, shear stresses, and rutting characteristics of asphalt concrete can be measured by MQ value, and the high MQ values indicate a high stiffness mix and resistance to creep deformation [16].

It is also observed from Table 4 that when increasing WBP, the OAC values had been decreased. It was explained that an increased amount of WBP content in the mixture fills the voids in the aggregate. Besides, it acts as a binder, as a result, lower space is available for asphalt. This, subsequently, decreases the voids in the mineral aggregate and air void (%). Marshall stability also increases up to maximum then decreases. This is because at lower WBP content, it contains higher voids. So, when increasing WBP fills the voids, it may make dense-graded mixtures as a result, higher the stability. As can be seen from the table that the values of VFA for samples have been increased when increasing WBP content. This is because with increasing WBP more voids are filled with waste. From the table, it is also seen when increasing WBP contents increase the density. That is why increasing this reduces the void as a result of increased density.

Table 4: Results summary concerning optimum asphalt content

Properties	**Waste Blister Pack (WBP)**				
	0	0.25%	0.50%	0.75%	Standard Values AASHTO T 27
OAC (%)	6.03	5.93	5.80	5.63	-
Stability (kN)	13.68	20.5	22	21.5	5.34 kN (minimum)
Flow (mm)	3.0	2.8	2.6	2.2	2-4
MQ (kN/mm)	4.56	7.32	8.46	9.77	2-5
Density (gm/cc)	2.36	2.376	2.38	2.384	-
Air Void (%)	4.8	4	3.8	2.8	3-5
VMA (%)	17.2	16.6	16.2	16	-
VFA (%)	70	76	78	82	65-78
RS (%)	73	83	82	81	70% (minimum)

However, it's far seen that all the mixes satisfy the minimal retained stability value requirement, i.e., 70%. It indicates that each one mix with these fillers has excellent moisture resistance caused damages.

5.0 CONCLUSIONS

Through this experimental investigation, an effort has been made to improve the state of knowledge on the effects of WBP as an additive material in the asphalt concrete mixes. So, Marshall properties of AC containing WBP as additive has been evaluated and compared with the standard specification. In this regard, the physical properties of the raw materials (i.e., aggregate, asphalt and additive) were ascertained. After that, prepared Marshall specimens containing WBP were evaluated for several Marshall properties, including stability, density, air void (%), flow value, VMA (%), and VFA (%) for different WBP contents (0, 0.25, 0.50, and 0.75%).

In this study, asphalt concrete mixes containing 0% WBP were considered as control mixtures. Evidently, the specimens made without WBP satisfied all Marshall criteria (Table 4). But, 0.25 and 0.50% WBP containing AC mixtures show better results than the control mixture. However, 0.50% WBP containing specimen showed highest stability (22 kN) and the value is 60.81% more than the control specimen stability value. The OAC (%) decreased while increasing additive content and 0.75% WBP containing specimen showed the lowest value (5.63%). Also, 0.75% WBP containing specimen satisfied all Marshall criteria in exception of air void (%) and VFA (%). The results of 0.25% and 0.50% containing WBP specimens are near to each other. Therefore, mixes containing 0.25% and 0.50% WBP additive content may be effectively used in AC to enhance the properties of mixtures.

It can be concluded that by using WBP in asphalt concrete mixture gives a better result than conventional mix. Moreover, the plastic is made of good bonding with aggregate and asphalt. It is expected that this study gives information to the professional's engineers and academicians for using WBP as an additive in asphalt concrete. Using WBP in asphalt concrete mixture not only improves the properties of asphalt concrete but also solve the solid waste disposal problem in the environment. Further experimental investigation on properties including resilient modulus, rutting, fatigue test should be carried out before using WBP as an additive material on the pavement.

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