USABILTY OF WASTE ROOFING SHINGLE, PVC AND PLASTIC GLASSES IN ASPHALT CONCRETE

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ABSTRACT

This study focuses on determining the engineering characteristics of Hot Mix Asphalt (HMA) using waste roofing shingle, PVC and plastic glass scraps. These waste materials were added 1%, 2%, 3%, and 5% mixing ratio in the asphalt concrete which designed with predetermined bitumen content. The asphalt concretes which made of waste roofing shingle, PVC, plastic glass and conventional asphalt concrete were evaluated through their fundamental engineering properties such as Marshall Stability and flow.

The results indicate that stability of Marshall samples using with waste roofing shingle and waste PVC scraps decrease slightly depending on the ratio. Besides, Marshall flows of the specimens increase depending on the these waste material contents. However, these waste materials can be used in HMA in accordance with Turkey General Directorate of Highways (TCK) wearing course within specification limits. Finally, there is a high possibility for waste roofing shingle, PVC and plastic glass can be used in asphalt concrete.

Keywords: Stability, Flow, Waste Shingle, PVC, Plastic Glasses

1. INTRODUCTION

The world population increases continuously and large amounts of waste materials is creating costly disposal problem all over the world. Today, the biggest problem of waste materials is threading to environment and health seriously. Generally, some materials such as glass, aluminum, paper etc. have been recycling commonly. Besides, in developed countries asphalt, concrete, aggregate, roofing shingle, PVC etc. materials have been recycling and reusing in some applications. Therefore, pollution effect on environment of those waste materials has been decreasing. The recycling of industrial waste in civil engineering applications has remarkable potential over a very long time. Owing to needs of so much raw materials, highway engineering is a leader field among the construction sectors [1,2,3].

Previous investigations showed that the use of waste materials such as fiber, crumb rubber, reclaimed asphalt pavement cost-effective, environment friendly and improve some of the engineering properties of asphalt concretes. One of the waste materials which use in transportation engineering is waste roofing shingle. In the US approximately 11 million tons of waste roofing shingles are produced every year. 10 million tons of shingles are generated from reroofing works, the last 1 million tons from manufacturing scraps [4,5]. Evaluation of waste shingles in transportation area is an important topic in the world. Roofing shingles are composed of hard asphalt cement, fine aggregate, mineral filler, organic or inorganic fiber. Organic and inorganic shingle components are presented in Table 1.

Table 1: Shingle Components [5]

Component	Organic Shingle	Fiberglass Shingle
Asphalt	% 30 – 35	% 15 – 20
Felt	% 5 - 15	% 5 – 15
Mineral Filler	% 10 – 20	% 15 – 20
Mineral Grains	% 30 - 50	% 30 - 50

Waste shingles have been using in HMA effectively. With the use of waste shingles in HMA provides significant gains in terms of cost. Because there are bitumen in the roofing shingles and this helps in reducing the rate of optimum bitumen for HMA. Laboratory tests showed that using shingles in asphalt concrete at low temperatures and high temperatures, reduces the thermal cracks and resistance against rutting [6,7]. Şengöz and Topal (2002) investigated using of waste roofing shingle in HMA. Researchers added waste roofing shingles to HMA as % 1, % 2, % 3, % 4 and % 5 ratios. After defined waste shingle ratio which showed best stability value in HMA that they reduced optimum bitumen content and then again conducted Marshall Stability and Rutting tests. Authors indicated that shingle added Marshall samples have better stability and rutting performance in comparison with control samples [8]. Deniz et al (2009) added 1,5% ratio of waste shingle to HMA and run stability and rutting test. They also emphasized that shingle added samples have better rutting performance than conventional asphalt concrete samples [9]. Another study by Aktas et. al. indicated that adding waste roofing shingle can be use in asphalt concrete. Researchers conducted Marshall Stability and flow tests on the specimens which prepared with waste roofing shingle added and control samples for asphalt concrete wearing course. Results obtained from this study showed that Marshall Stability results within the specification limits [10].

Polyvinyl chloride (PVC) is one of the most commonly used thermoplastic materials in respect to the worldwide polymer consumption. In the world, demand for PVC exceeds 35 million tons per year. In recent years, the question of the disposal of PVC waste has gained increasing importance in the public discussion, resulting from the rapid growth of the PVC wastes [11]. Waste plastic glass is also a type of polymer (Polyethylene terephthalate (PET)). PET is used in beverage bottles, synthetic fibers, disposable dishes and other similar plastic containers [12,13]. There are several studies about polimer modified asphalt concrete in the literature. Hınıslıoğlu and Ağar studied effect of high density polyethylene (HDPE) bitumen modified with different mixing, temperatures and HDPE content. The results from the study showed that 4% of HDPE content, a mixing temperature 165 ^{o}C and 30 min mixing period is optimum for Marshall stability, flow and Marshall Quotient (MQ) values. Also, they indicated that MQ increased 50% than control mix and modified asphalts had better resistance against deformation and deteriorations [14]. Another study by Tasdemir stated that addition of polyethylene wax on bituminous mixes increased the resistance of asphalts against rutting [15]. Osamu and Masaru also investigated usability of waste plastic materials, polyethylene and polypropylene as part of the aggregate in HMA. Researchers found out addition of polyethylene increase the anti-stripping properties and bending fatigue resistance of dense grade asphalts [16].

The primary objective of this research was to determine the effects of waste roofing shingle, PVC and PET added asphalts on engineering properties of HMA. Marshall Stability and flow tests were conducted on various percentages of waste roofing shingle, PVC and PET added samples and results derived from laboratory tests were evaluated.

2. MATERIAL AND METHOD

2.1. Aggregate

In the experimental studies three different aggregate gradations were used: 10-20mm, 5-10mm and 0-5mm. All of these crushed stones were supplied by Kadıahmetoğulları limestone quarry in Antalya. After determined physical properties of these materials, mix gradation was prepared in accordance with TCK wearing course specification [17]. Physical properties of these materials, mix gradation and specification limits are seen in Table 2, and Figure 1 respectively.

Table 2: The Physical Properties of Aggregates

Experiment	Course Aggregate	Fine Aggregate	Filler	Specification
Bulk Specific Gravity, gr/cm3	2,694	2,669		TS EN 1097 - 6
Apparent Specific Gravity, gr/cm3	2,722	2,712	2,723	
Absorption, %	0,39	0,59		
Mix Effective Specific Gravity, gr/cm3			2,684	
Na_2SO_4 Sulfate Soundness Test, %			3,2	ASTM C - 88
Los Angeles Abrasion Test, %			22,4	AASHTO T - 96
Flakiness Index, %			20	BS 812
Stripping Test, %			70 - 75	TCK-KTŞ Part 403 AppendixA

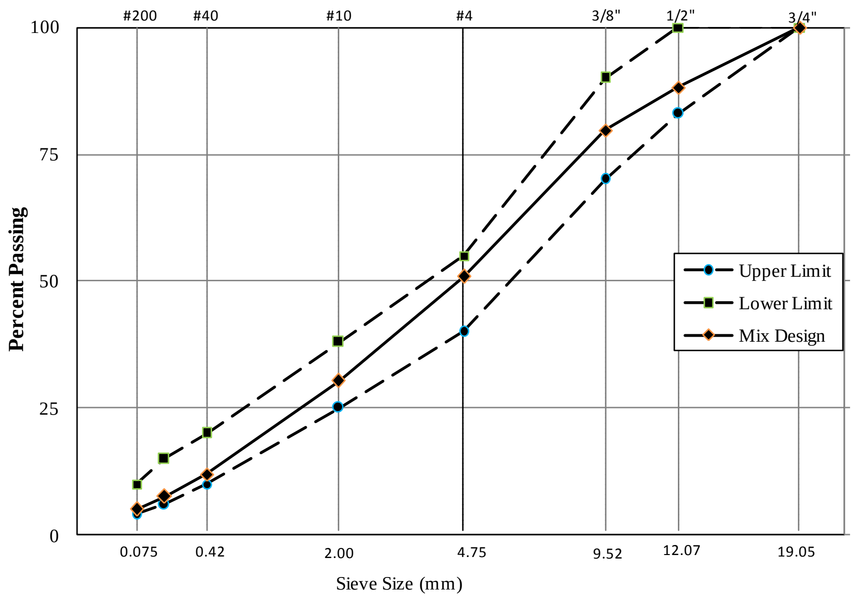

Figure 1: Mix Gradation and Specification Limits for Wearing Course

2.2. Bitumen

Bitumen in 50/70 penetration grade supplied from Tupraş Kirikkale Refinery was used in preparing Marshall samples. Properties of bitumen are presented in Table 3.

Table 3: The Physical Properties of B50/70 Bitumen

Bitumen Specific Gravity, gr/cm3	1,024	TS 1087
Bitumen Penetration, dmm	61	TS EN 1426
Softening Point, ^{0}C	49	TS EN 1427

2.3. Waste Roofing Shingle, PVC and Plastic Glass Scraps

Waste materials, these are roofing shingle, PVC and PET scraps were taken from YALTEKS incorporated company in TURKEY. Waste roofing shingle, PVC and PET particles have dimensions ranging from 5-12mm, 0-4mm and 0-1mm respectively. These materials were added to asphalt samples in this form. A photographic view of utilized materials is shown in Figure 2.

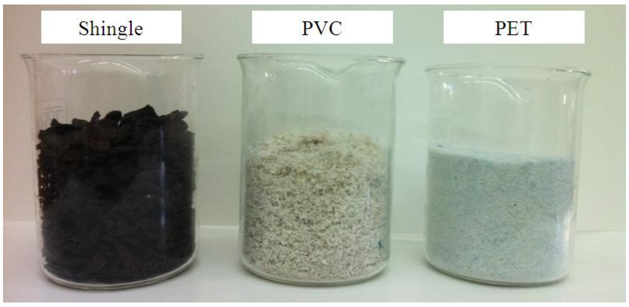

Figure 2: Photographic view of utilized waste materials

3. RESULTS AND DISCUSSIONS

3.1. Determining Optimum Bitumen Content

In order to determine optimum Bitumen Content (AC), Marshall stability and flow tests were carried out on compacted specimens at various bitumen based on ASTM D1559. AC was determined using with values of maximum bulk specific gravity, maximum stability, 4% air voids in the total asphalt and 80% voids in the aggregate filled with asphalt (VMA) [18]. Asphalt samples were prepared on the basis of 0,5% increment of bitumen content. The specimens were preheated to a prescribed temperature which is 60 ^{o}C placed in the special test head and the load was applied at a constant stain (2 in/min). While the stability test is in progress, the dial gauge was used to measure the vertical deformation of the specimens; the deformation read at the load failure point is expressed in units of 0,25mm and is called the Marshall Flow value of the specimen. The tests were repeated for the each bitumen content and optimum AC value was determined. After that maximum bulk specific gravity, corrected Marshall stability, Marshall flow, air voids in the total mix and VMA curves versus AC were plotted. To determine the optimum AC for the asphalt design, average value of the following AC obtained from the graphs were considered:

a) AC content corresponding to maximum stability.
b) AC content corresponding to maximum bulk specific gravity.
c) AC content corresponding to the median of designed limits of percent air voids in the total asphalt.
d) AC content corresponding to between 65 and 78% of voids filled with bitumen.

The stability value, flow value and VFA at the optimum bitumen were determined from the curves and it was ensured that each of these values correspond with the Marshall design specification values. Following this, the optimum asphalt contents versus specifications Marshall flow and % VMA were checked.

Table 4: Wearing Coat Design Limits for Marshall Method in accordance with TCK [17]

Mix Criteria	Wearing Course	
	Min.	Max.
Number of Blows	75	-
Marshall Stability, kg	900	-
Percent Air Voids,%	3	5
VFA (%)	65	75
Flow (mm)	2	4
Filler/Bitumen Rate	-	1,5
Bitumen content rate,%	4	7
VMA,%	14	-

In order to determine optimum bitumen content, created charts of the Marshall design are shown in Figure 3. According to these results optimum bitumen content was found as % 4,8.

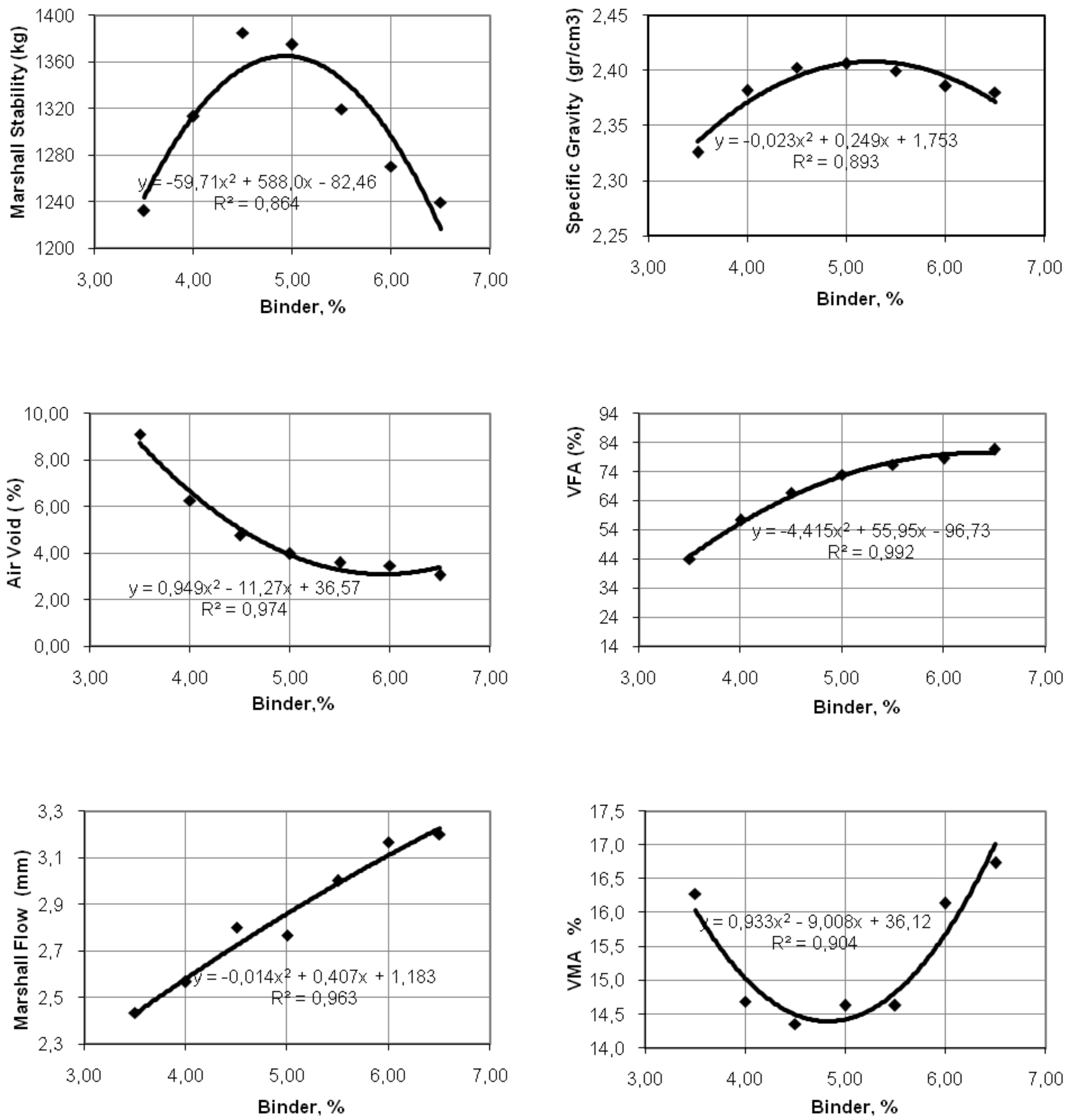

Figure 3: Marshall Test Results for Determining Optimum Bitumen Content

3.2. Marshall Stability Tests for Waste Materials Added Samples

After determined optimum bitumen content, new Marshall specimens were produced with using waste roofing shingle, PVC and plastic glass scraps. Figure 4 illustrated the Marshall Stability value versus different roofing shingle, PVC and plastic glass content for optimum bitumen content. The chart shows that the Marshall Stability values change depend on waste materials content. After adding waste roofing shingle and PVC scraps stability value decreased slightly until 5%. However, stability decreasing for PET added samples is so steep. The Marshall Stability values of control asphalts were higher in comparison to waste materials added samples. Although waste materials added specimens have lower stability values than control samples, waste shingle and PVC added asphalts pass the standard criterion (9 kN) all content. In PET added samples also pass standard stability criterion until 3% but after that its stability value decreasing for optimum asphalt content.

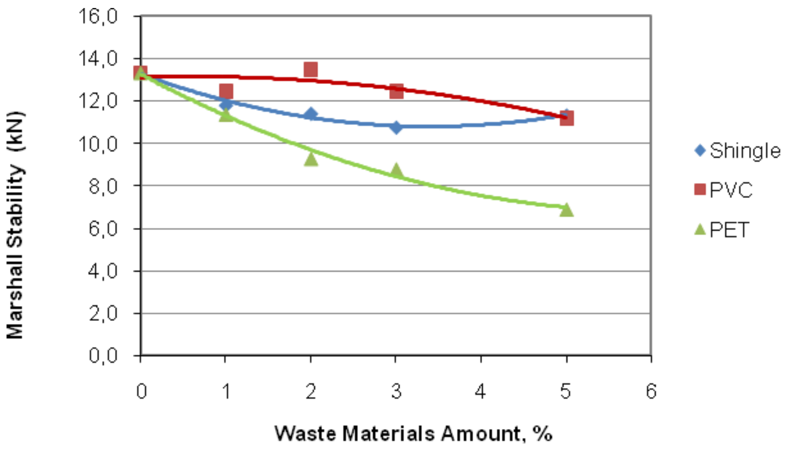

Figure 4: Marshall stability test results

3.3. Marshall Flow Tests for Waste Materials Added Samples

The maximum flow value, indicated in ASTM specifications, controls the plasticity and maximum AC content of the asphalts. The minimum flow value controls the brittleness and strength of the asphalts. As illustrated in Figure 5, increase of the waste roofing shingle, PVC and PET causes the flow value changes to an upward movement. While flow value of shingle added samples increasing slightly, flows of PVC and especially PET added samples increasing so steep. The highest flow value was observed %5 ratio PET added asphalts for optimum AC. In the graph which presents the air void curves of the specimens, air void of PET added samples are higher values than PVC and roofing shingle added samples.

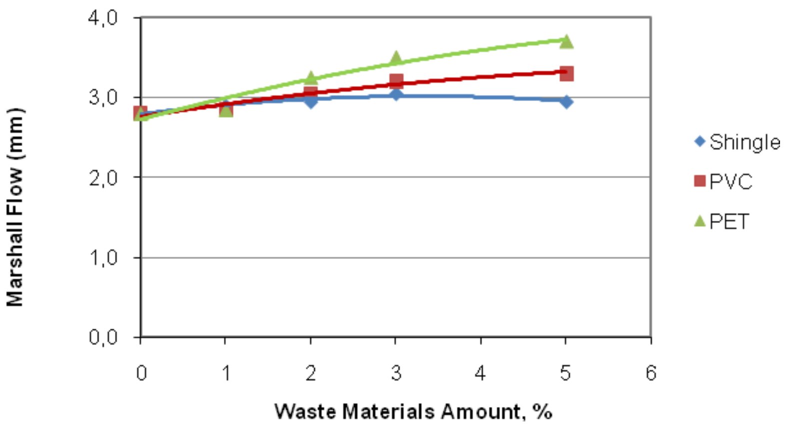

Figure 5: Marshall flow test results

3.4. Marshall Quotient for Waste Materials Added Samples

Marshall Quotient (MQ) is an indicator of the resistance against the deformation of the bituminous asphalt [14,19,20,21]. MQ values of all waste materials added samples and control samples are calculated to evaluate the resistance of the deformation. As Figure 4 shows that waste roofing shingle, PVC and PET added samples have a lower MQ for 4.8% optimum bitumen content in comparison to control asphalt. MQ of PET added samples decrease much more than PVC and roofing shingle samples. It means that waste roofing shingle and PVC asphalt concrete in % 4,8 optimum bitumen content have better resistance against deformation as a result of heavy loading in comparison to PET.

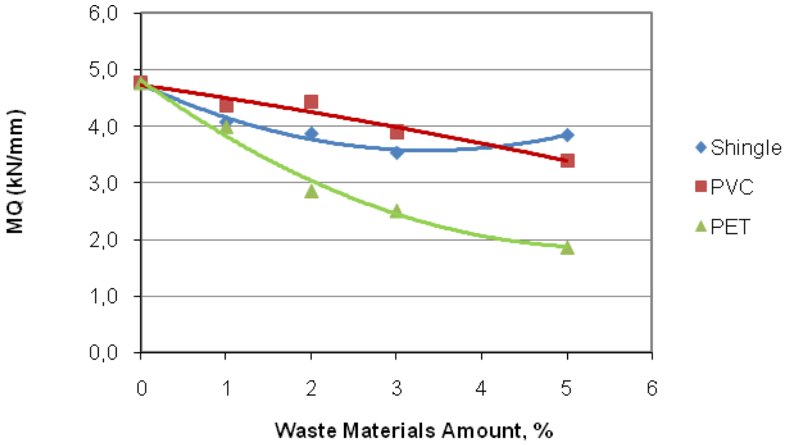

Figure 6: Marshall Quotient results

3.5. Bulk Specific Gravity

Bulk specific gravity of the waste roofing shingle, PVC and PET added asphalts were lower than that of control samples. As in Figure 7, it is shown that bulk specific gravity of each amount of utilized waste materials. Increasing used waste materials in asphalt cause them to reduce the bulk specific gravity because of their lower bulk specific gravity in comparison with the mineral aggregates.

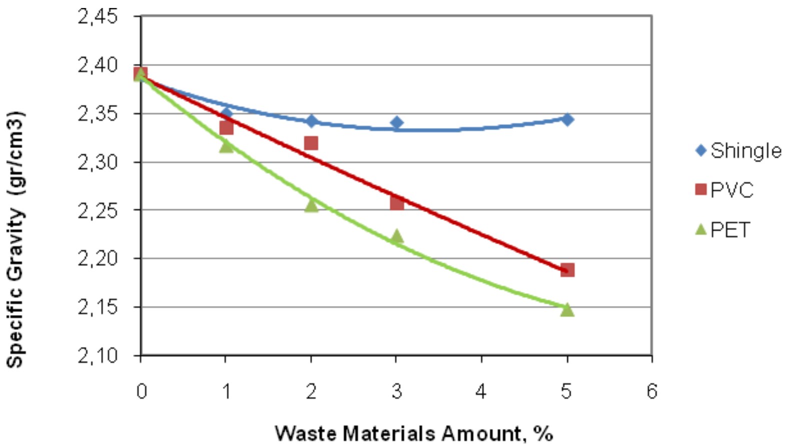

Figure 7: Bulk specific gravity results

3.6. Air Void

The air void in HMA is one of the most important parameters for pavement design and performance. Excessive air voids cause cracking due to the insufficient bitumen coating the aggregate, while low air voids may cause more plastic flow (rutting) and asphalt bleeding [19,22,23]. Figure 8 shows, increasing the waste roofing shingle, PVC and PET content in the asphalt induce more air voids in the asphalt as a result of the waste material dimensions. PET particles in the asphalt have higher surface area in comparison with roofing shingle and PVC scraps. Therefore, PET added samples need more bitumen than other specimens. Since all the specimens was prepared 4.8% bitumen content, air void of PET added samples has occurred much more than other. Changing of air void value of waste roofing shingle used samples slightly, while waste PVC and PET used sample have serious changing. The possible reason is PVC and PET which remained in the form of crystal, thereby increasing the surface area. The increased surface area, however, needs to be wetted with bitumen, which would finally lead to an increase in voids in the asphalt. Furthermore, when PET was used in the asphalt, it seemed to reduce its compact ability, therefore, a higher air void value might be obtained.

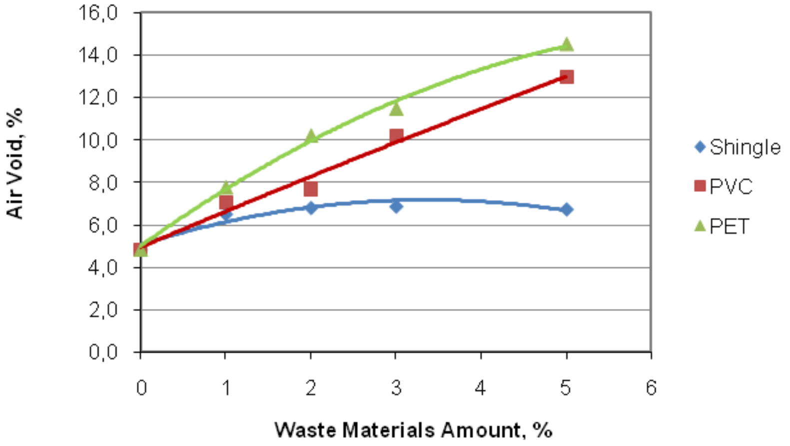

Figure 8: Air voids of Marshall specimens

3.7. Void in Mineral Aggregate

Voids in mineral aggregate (VMA) provide space for bitumen films on the aggregate particles. The durability of the asphalt increases with the film thickness on the aggregate particles. In order to have the required durability of the asphalt, minimum VMA requirements are recommended in the specification [17]. The VMA value versus waste roofing shingle, PVC and PET added specimens for a optimum bitumen contents is displayed in Figure 9. It is clear in the figure, VMA values, in relation to various the roofing shingle, PVC and PET content. At the same bitumen content, increasing waste materials lead to increasing VMA values of the samples. The values of VMA were also higher than control specimens.

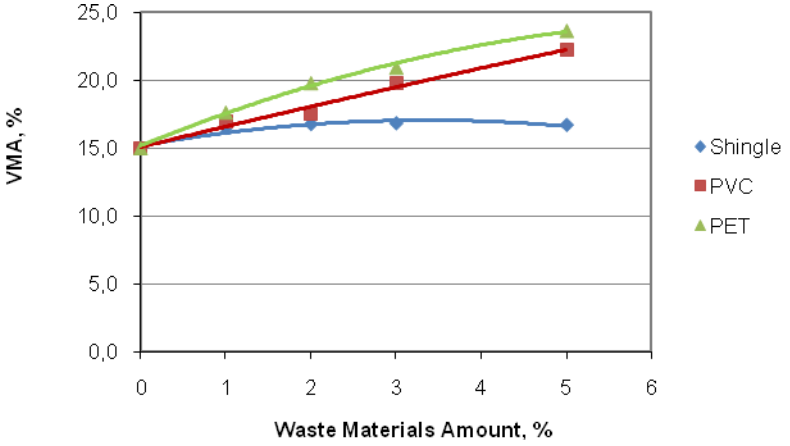

Figure 9: VMA values of Marshall specimens

4. CONCLUSIONS and RECOMMENDATIONS

The objectives of this study were to assess the usability of waste roofing shingles, PVC and plastic glass in asphalt concrete. Marshall stability and flow tests were carried out to evaluate the characteristics of asphalt concrete by varying the content of those waste materials. From the test results, the following conclusions can be drawn:

- Regarding to Marshall stability results of the specimens, after adding waste roofing shingle and PVC scraps stability value of the samples decreased slightly until 5% of waste materials added. However, stability decreasing for PET added samples is so steep. The Marshall stability values of control asphalts were higher in comparison to waste materials added samples. Although waste materials added specimens have lower stability values than control samples, waste shingle and PVC added asphalts pass the standard criterion (900 kg) in all contents. While PET added Marshall samples also pass standard stability criterion in accordance with TCK until 3%, after this value its stability decreasing.

- The highest flow value was observed %5 ratio PET added samples for predetermined bitumen. PET particles in the asphalt have higher surface area when compare to roofing shingle and PVC scraps. Therefore, PET added samples need more bitumen than other specimens. Since all the specimens was prepared 4,8% bitumen content, air void of PET added samples has occurred much more than other. All the asphalt samples within the limits in accordance with TCK.

- PVC and PET added samples have a lower MQ for 4,8% predetermined bitumen content in comparison to control asphalts. MQ of PET added samples decrease much more than PVC and roofing shingle samples. It means that waste roofing shingle and PVC asphalts have better resistance against deformation as a result of heavy loading in comparison to PET in % 4,8 predetermined bitumen content.

In this study different amount of waste materials added to asphalt concrete samples which has predetermined bitumen content. The conclusions gained through this study can contribute to the encouragement of waste material re-use in the asphalt concrete to help more economical and solve some environmental problems. To determine exact amount of bitumen for waste materials added asphalt, Marshall samples which have various amount of bitumen should be prepared and evaluated for various amount of waste materials add. Purpose of this study is to demonstrate that there is a high possibility for waste roofing shingle, PVC and plastic glass can be used in asphalt concrete, and there should be further studies by conducting field tests for application of these waste materials in asphalt concrete.

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