The Relationship Between Vertical Stress Due To Attraction Load And Time For Asphalt Mixture Containing Pet Plastic

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Abstract. Various concentrations of PET waste including, 0, 1, and 2% (based on binder weight) in two different size ranges are for asphalt concrete and Marshall stability, Marshall intelligence, indirect tensile strength (ITS) and uniaxial dynamic creep property were evaluated. The results show that Marshall stability and Marshall quotient increase with increasing PET content. Indirect tensile strength test (ITS) results show that the highest ITS is obtained by adding 2% PET to the mixture and beyond that ITS decreases with increasing PET content. Dynamic test results reveal that resistance to permanent deformation decreases with increasing PET content. However, mixtures containing finely graded PET particles have more resistance to permanent deformation than mixtures containing coarse graded PET particles. Comparing the results in rubber modified mixtures in this study with those in conventional mixtures achieved previously revealed that the trends were different.

Keywords: AC asphalt concrete - WC, PET waste, ITS.

1 Introduction

Managing large amounts of solid waste and reducing its negative impact on the environment has become the main concern of the community. Disposal of waste to nature, in addition to occupying valuable land, can be harmful to the lives of humans and other creatures. Therefore, suitable steps must be sought to reduce this impact. Many different solid wastes are produced by households, industries and services. plastic is one of the main solid wastes, which takes a long time to decompose in nature and is considered a hazardous waste.

In the mixing method there are two things of process. The first is the more general method of the wet process, PET platinum waste is first mixed with asphalt cement at high temperatures and using a special mixer, and modified asphalt is mixed with hot aggregates in the asphalt mixer plant. Second, in the dry process, PET Plastic particles are added to the aggregate and then mixed with hot asphalt cement in the asphalt mixer plant.

One key factor in the performance of plastic modified binders is the interaction between the chopped PET plastic and asphalt. Swelling and dissolution are two mechanisms that occur simultaneously during the interaction of added plastic particles [3] - [6]. When plastic chopped particles are added to the hot asphalt binder, the viscosity binder is increased to a factor of 10 [4], [6], [7], [8]. Studies of binders and modified plastic mixtures have revealed improvements in properties such as rutting resistance, and fatigue, thermal and reflective crack resistance [9] - [13].

Among plastic waste, Polyethylene Terephthalate (PET), which is mainly used for packaging drinks, food, cleaners, oil etc. [14], is the most wasted. In the US alone, 2675 tons of PET were wasted in 2010, of which only 29.1% was recycled and the remainder was disposed of [15]. PET is not a degradable material, and it takes centuries to decompose. Its disposal into the environment causes pollution of rivers and oceans and endangers the life of creatures. Therefore, managing PET waste is very important to protect the environment. Finding applications, where high-quality materials are not needed, is a way to reuse PET waste effectively [16]. One potential application for PET is in asphalt mixtures [17] - [22]. Baghaee Moghaddam et al. found that maximum stiffness was obtained at 1% PET content (with an aggregate weight), after which it decreased with increasing PET content [23]. They also found that the fatigue performance of the mixture greatly improved with the inclusion of PET. In another research work, Baghaee Moghadam et al. found that PET inclusion decreased the Marshall stability and indirect tensile strength of the SMA mix [24]. They also found that resistance to permanent deformation diminished with increasing PET content under static loading. However, behavior under dynamic loading is opposite and resistance to permanent deformation increases with increasing PET content. Similar results were found by Ahmadinia et al. [19] who found that under all test conditions, resistance to permanent deformation of mixtures containing PET was higher than control mixes without PET. Ahmadinia et al. found that the highest Marshall stability and Marshall quotient (MQ) were obtained using 2% (based on binder weight) PET in SMA mixtures [18]. They also found that ductile modulus and resistance to drainage were increased with the addition of PET.

The previous research, found that the stiffness and tensile strength of the mixture could be increased by adding 2% (based on the binder weight) of PET to asphalt concrete [14], [21]. By adding PET to the mixture using the wet and dry method, Earnest found that PET modification improved the performance of binders and mixtures at high temperatures, without affecting viscosity and work ability [15]. The wet process is also found to be more effective than the dry process in increasing resistance to permanent deformation and moisture damage.

Hamburg tests and indirect tensile strength (ITS) show that mixtures modified using the dry process show better performance against moisture damage. The dynamic modulus of the mixture modified by PET was found to be lower than, and the phase angle was found to be higher than those of the control mixture without PET. Almeida et al. found that mixtures containing 5% micronized PET had higher indirect tensile strength, resistance to moisture damage and fatigue cracking and ductile modulus than control mixes without PET [25]. However, the amount of mixed flow was found to be lower than the control mixture, indicating that resistance to permanent deformation was reduced with PET modification. They also found that increasing ductile modulus at higher temperatures was less than at medium temperatures.

Tracing the literature shows that the effect of adding waste PET on modified plastic asphalt concrete has not yet been carried out, while there are some contradictions among the studies studied carried out on the effects of using PET waste in conventional mixtures. Therefore, in this study, it aims to study the effect of the addition of PET waste on some properties of asphalt concrete engineering made of binders modified with plastic.

2 Literature Review

2.1 Material

Four types of materials including PET soil waste, limestone aggregate, and modified cement asphalt cement have been used in previous studies. PET soil waste particles are obtained from grinding bottled wastewater. First, the lid and bottle label are removed. Then, they are washed and cut into small pieces. Then, they are crushed into finer particles using a special crusher. In this study PET particles are used in two different size ranges. In this paper, fine-grained and coarse particles are each marked by P 50, and P16. After sieving the crushed PET, the P50 particle was obtained from a No. sieve pass. 30 and stick to sieve No. 50, and particle P16 was obtained from sieve No. sifter. 8 and stick to sieve No. 16. Fig. 1, Tables 1 and table 2, respectively show fine and coarse PET particles, fine gradation and coarse PET particles and the properties of PET used in this study.

Fig 1. Coarse and fine PET particles

Table 1. PET particle size distribution

No.	Shieve size (mm)	Shieve passed (%)
	Coarse graded PET	
1	2,36	100
2	1,18	5
	Fine graded PET	
3	0,6	100
4	0,3	5

Modified Asbuton asphalt concrete obtained with Buton asphalt grains which have undergone a semi-extraction process and is called Asbuton modification (or commonly known as Retona Blend 55). modified by 2% used PET plastic chopped used as a binder in the mixture. The plastic is added to the binder using the Dry method, at 180C, and mixed for 2 hours using a high speed mixer at 1000 rpm. The aggregate used in this study was sourced from natural stone and collected from a local asphalt plant in the city of Makassar. National specification requirements are met by aggregate groups. Moisture absorption of fine and coarse particles was measured to 0.1 and 1.2%, respectively. The bulk density of coarse, fine and filler fractions are 2.65, 2.66 and 2.65, respectively. According to national specifications [26], solid gradations with a maximum aggregate size of 19 mm are selected from the mixture. Figure 2 shows the gradation of the mixture and the lower and upper limits of the specifications.

Table 2. Some waste properties added in this study

Properties	Standard method	Value
Density (gr/cm^3)	ASTM D792	1,35
Moisture absorption %	ASTM D570	0,1
Melting point (°C)		250
Tensile strength (kPa)	ASTM D638	850
Glass Transition temperature (°C)		75

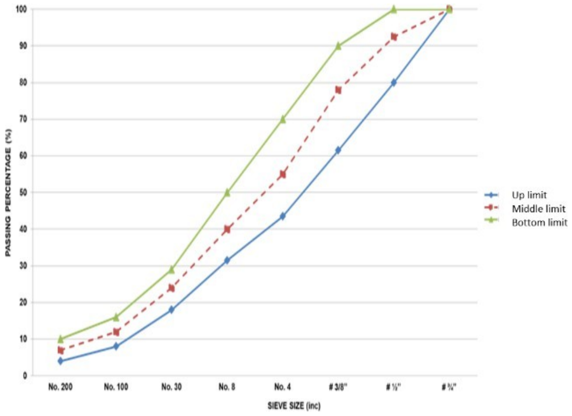

Fig 2. Gradation of mixtures used in this study

2.2 Plan and making of test objects

The optimal binder content of the mixture without PET is obtained by following the Marshall mixture design method, according to ASTM D1559. The optimal binder content of the mixture made by plastic asphalt modified with modified Asbuton binder material obtained with asphalt Buton grains that have undergone a semi- extraction process and called as modified Asbuton (or commonly known as Retona Blend 55) is determined 4.5 each and 6%. Previous studies have shown that the optimal binder content of a modified PET mixture is similar to a mixture without PET [20], [24]. Therefore, the mixture is made by 6% of the binding content. The volumetric nature of the mixture is examined to meet the requirements of the specifications [26]. The Marshall method, following the ASTM D1559 standard, is used for making cylindrical specimens used for testing. First, the heated aggregate and binder are mixed for 5 minutes, after that, the required amount of PET particles is added to the mixture and mixed thoroughly for 2 minutes until the aggregate and PET particles are completely coated with asphalt. This mixing method ensures maintaining the semi-crystalline state of PET and the occurrence of minimum changes in the properties and shape of PET particles. PET has a glass transition of around 70 ° C. The amorphous portion of PET was melted at the mixing temperature, resulting in increased binding cohesion, while the crystalline portion did not change. The cavity between the aggregate particles is filled with the PET crystal portion, resulting in an increase in the stiffness of the mixture. The mixture is placed in a mold and compacted by applying 75 blows to each side. Compacted test pieces are removed from the mold after 24 hours of compaction, and stored until used in the experiment. A total of 176 test specimens were made in this study.

The main objective of this research is to investigate the effects of PET particle size and content on several engineering properties containing modified plastic asphalt concrete. PET particles in two different size ranges were added to the mixture at 3 different contents 0, 1, and 2% (with binder weight) and Marshall stability and flow, indirect and dynamic tensile strength have been investigated.

2.3 Testing Method

Marshall tests were carried out on specimens according to the ASTM D1559 standard method. Specimens were placed in a water tank that was set at 60˚C for 30 minutes, after that, they were loaded using a set Marshall test, at a constant rate of
50.8 mm / min, and the force needed to break the specimen was measured as Marshall stability, and diameter deformation The specimen at failure is measured as a Marshall flow. In this study, the indirect tensile strength test (ITS) was carried out on specimens at 25 ° C according to the AASHTO T283 standard method. Three replicate specimens from each mixture were made with an air cavity of 7 ± 0.5%, as required in the AASHTO T283 standard method. Indirect tensile strength (ITS) is measured after placing it in a plastic bag and sinking in a water tank set at 25 ° C. ITS's specimens are measured by placing them in an ITS frame and loaded using the Marshall test which is set at a rate of 50.8 mm / min until failure. The force

required to solve a specimen is measured and the tensile strength indirectly calculated using Equation (1)

$$ITS = \frac{2000}{\pi D} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

where, ITS is the indirect tensile strength in kPa, P is the maximum load applied to breaking the specimen in N, D is the specimen diameter in mm, and t is the thickness of the specimen in mm. An average of 3 specimens in each group was calculated and used as a mixed ITS.

Resistance to permanent mixture deformation was evaluated using a uniaxial dynamic creep test. Dynamic creep tests are carried out following the standard EN 12697-25 method by the UTM-10 engine. The test is carried out at the same temperature of 40 ° C, and by applying a constant vertical voltage of 300 kPa with a frequency of 0.5 Hz. In each test, to ensure that the specimen is homogeneous at the test temperature, the specimen is placed in a temperature-controlled cabinet two hours before starting the test. Each test is set to finish after 10,000 loading cycles or reach 4% vertical strain. During the test period, deformation and vertical loads are monitored by software connected to the test settings. Before applying a main stress level of 300 kPa in each test, a vertical voltage of around 30 kPa was applied for 10 minutes. This voltage is applied to ensure that the loading plate is placed completely on the specimen and eliminates possible gaps between the platen and the specimen.

3 Result and Discussion

Figure 3 shows the relationship of Vertical Strain to Time with Variations in PET plastic content respectively 0%, 1% and 2% show that for PET plastic 0% Vertical Strain average at 0.4 kPa obtained an average time of 4.8 seconds , for PET levels 1% Average Vertical Strain at 0.4 kPa obtained an average time of 6.9 seconds, for PET plastic levels 2% Vertical Strain Average at 0.4 kPa obtained an average Time of 14, 23 seconds.

Furthermore, the relationship of Vertical Maximum Strain to Time with Variations in PET plastic content respectively 0%, 1% and 2% shows that for PET plastic levels 0% Maximum Vertical Strain Average at 1 kPa obtained an average time of 29.97 seconds, for content plastic PET 1% Maximum Vertical strain Average at 1 kPa obtained an average time of 33.31 seconds and for plastic levels 2% PET maximum Maximum Vertical strain at 1 kPa obtained an average time of 21.3 seconds

From the results of the Vertical Strain relationship with time with variations in PET plastic content varied 0%, 1% and 2% found that:

1. With increasing levels of PET plastic, the mixture will break faster or brittle
2. By looking at the relationship of the vertical strain to the elastic time, the increasing level of PET plastic has a higher elastic level

By comparing the concentration of other pollutants with the concentration of PM_{10}, the most likely point of origin can be determined through analysis of the data. Below shows the concentration of the pollutants mentioned on a monthly basis from the year 2015. Hubungan vertical terhadap waktu kadar PET 05 1% dan 2%

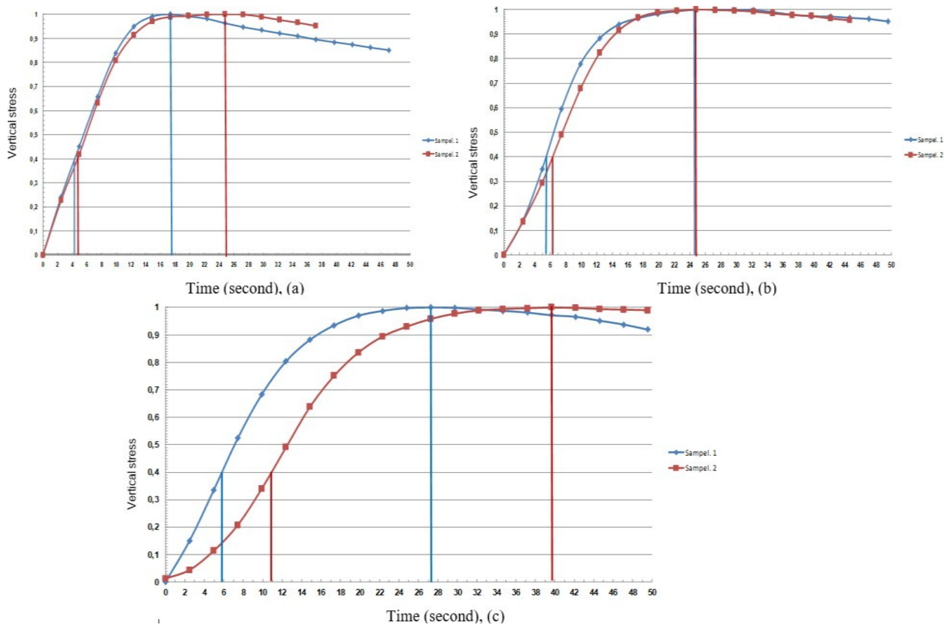

Fig. 3 Relationship of Vertical Strain to Time with Variations in PET Levels

Table.3 Relationship of Vertical Strain to Time to PET Plastic Mixes with several variations

No Sample	PET (%)	Vertical stress	Time (sec)	Time average
1	0%	0,4	4,4	4,80
2	0%	0,4	5,2	
1	1%	0,4	5,4	5,80
2	1%	0,4	6,2	
1	2%	0,4	5,9	9,95
2	2%	0,4	11	

Table.2 Relationship of Max Vertical Strain to Time to PET Plastic Mixes with several variations

No Sampel	PET level (%)	Vertical Max Strain	Time (sec)	Average time
1	0%	1	17,2	21,10
2	0%	1	25	
1	1%	1	24,9	25,00
2	1%	1	25,1	
1	2%	1	27,2	25,55
2	2%	1	23,9	

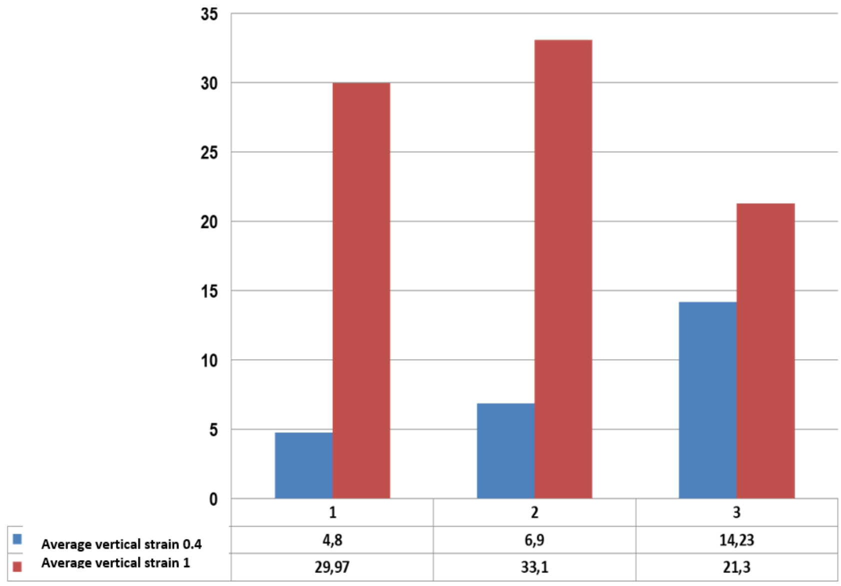

Fig. 4 Relationship of between Vertical Strain and Average Time

4 Conclusion and recommendation

Different percentages of PET particle waste are added to asphalt concrete made from modified plastic asphalt and Marshall stability, indirect tensile strength and dynamic properties of the mixture are evaluated.

The following are brief results.

a. Marshall stability increases with increasing PET content, with a higher value for PET with fine gradations than PET particles with coarse grading.

b. The indirect tensile strength increases until the addition of 2% PET into the mixture, beyond that it decreases with increasing PET content. Higher ITS can be obtained using fine stratified particles rather than coarse PET particles.

c. Resistance to permanent deformation decreases with increasing PET content. Higher resistance can be achieved by adding fine-grained particles rather than coarse-grained particles.

d. Comparing the results with the literature in conventional mixtures shows that the addition of PET to the modified plastic asphalt mixture follows a different trend, which is thought to be caused by interactions between PET polymers.

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