IMPROVEMENT OF ROAD PAVEMENT INFRASTRUCTURE BY USING POLYETHYLEN TEREPHTHALATE & POLYPROPYLENE

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Abstract— Waste production being individual in Malaysia is estimated 3-4.5kg/day/person and 19,000 tons of waste every day, and this is expected to reach 30,000 tons by 2020, only 3-5% of the total solid waste generated in Malaysia is being recycled. The absences of efficient management of municipal solid waste (MSW) regarding to use waste plastic material which inundated our cities and towns is growing challenge for developing countries including Malaysia. Secondly growing traffic on roads, changing environment and their impact on the road pavement resulted road failure and distress caused negative impact on economy of the country. This study examines properties of polymers waste plastic water bottles, polyethylene terephthalate (PET) and disposable plastic cups polypropylene (PP) were added to the normal bitumen penetration grade (80/100) prepared Marshall samples using AC-14 to investigate Marshall parameters of polymer modified bitumen and compare with conventional bitumen. Basic penetration, softening point, ductility and rotation viscosity test was performed and study finding shows that penetration, ductility, viscosity decrease while softening point increase by addition of polymers. Marshall analysis of the study found that by addition of 9% polymers to the bitumen by weight of 5.5% at optimum level increase Marshall properties and give all positive response for both polymers (PET and PP) such as stability increase up to 60-70%, stiffness, flow, density and voids of the polymer modified bitumen found positively improving and enhancement was observed compared to conventional, which is the key objective of this study. In conclusion the polymers modified bitumen improves stability, workability and reduce deformation in road pavement.

Index Terms— Waste Polymers, Polyethylene terephthalate (PET) and polypropylene (PP), Bitumen, Wet process, Marshall Stability

I. INTRODUCTION

Since the last few decades, spending money on new road construction and maintenance has increased (John, 2013). The developing country's urban road infrastructure is not properly developed as yet for heavy transportations. According to Faiz, (2012) globally total length of road is about 33.8 million km and as statistic shown that 57.4% length of the road is paved (flexible and rigid). Worldwide road infrastructure raised by more than 35% (John, 2013). Considerable amount of conventional road materials consume more than 90% by weight of asphalt mixture in road constructions (Huang et al., 2007). Globally, asphalt industry has rapidly grown especially high demand is evident in developing countries because of rapid growth of transport industry, population and high traffic volume on the road acquired construction of additional roads, maintenance of existing roads increase demand for quality bitumen material. To modify traditional bitumen asphalt always been obtained attention to enhance quality and serviceability of roads. There is an evidence of best efforts and practice has been put in the past to improve properties of bitumen using waste polymers materials to enhance road infrastructure. Alternative procedure to modify asphalt drastically is the addition of polymers (Becker et al., 2001). Primary, urgency of this research is to decrease growing pressure of plastic waste polymer material on environment because Malaysia produces 19,000 tons/day waste and expected to touch 30,000 tons/day in 2020 (SWM, 2012). Many possible ways have been prepared to systematically manage polymer waste products and most preferably is to reduce waste generation, followed by recycling, reuse, incineration and land fillings of waste polymer products, however, the most common method adopting in many countries is the direct land falls of waste material instead of preferred to recycle or reuse (Thomas et al, 2011). National solid waste Malaysia, (2010) reported 3-5 % of the total generated waste recycle in Malaysia. The second problem of the research and urgency rapidly growing demand for bitumen and drastically environmental change effect on road pavement lead to several distress issues in road pavement. In pavement engineering, the most serious and common failure cause of road pavement is rutting and to enhance this problem, engineers suggested modifying bitumen by polymers. Modified asphalt increase temperature susceptibility and enhance the property of bitumen (Noor et al., 2011).

II. LITERATURE REVIEW

Bitumen has been known as one of the oldest engineering materials and utilization for different purposes for thousands of years in the field of engineering such as waterproofing agent, adhesive and binder are on the top uses (Jiqing et al., 2014; Polacco et al., 2006; Morgan et al., 1995). Joint survey report of Asphalt Institute and Eurobitumen, (2011) shows statistically available figures for worldwide bitumen consumption was recorded 1.6

trillion metric tons in 2007 and huge amount is use for the purpose of road pavement. Theory of bitumen modification by using waste polymers is not very new, Numerous attempts for bitumen modification have been exercised in the past, but among all polymer modification was the most notable (Jiqing et al., 2014; Amit et al., 2012). Mechanical properties, rheology, temperature sensitivity, morphology, thermal behavior, storage stability and ageing effect were the main concerning properties for researcher. Jiqing et al., (2014); Alaxender, (2012); Amit et al., (2012); Nasker et al., (2012); Vidual et al., (2012); Kalantar et al., (2010); Al-Hadidy & Yi-Qui ,(2009); Neilson, (2009); Verma, (2008); Huang et al., (2007); Lewandowsk, (1994) waste polymers not only improve properties of asphalt, enhance road quality, performance, prolong lifetime of the road pavement, reduce the cost and pressure on landfills and decrease conventional road materials. Bitumen modification and enhancement by adding polymers depends on the type and properties of polymer material (Jiqing et al., 2014). Bitumen modified by using Styrene-Butadiene-Styrene (SBS) polymer better elastic recovery, higher cracking resistance at low temperatures and higher rutting resistance at high temperatures was evident in various research studies (Bonemazzi et al., 1996; Elmore et al., 1993 and Wardlaw & Shuler 1992). According to Alatas & Yilmaz, (2013); Gorkem & Sengoz, (2009); Tayfur et al., (2007) bitumen properties could be enhanced in term of higher stiffness at high temperature, cracking resistance at low temperature, moisture resistance and improve fatigue life by adding plastomers or elastomers polymers.

A. *Bitumen Modification Using Waste Plastic (PMB)*

Plastic bags, cups and bottles etc are the most common type of plastic made off poly ethylene (PE), poly propylene (PP) and poly styrene (PS). Key benefit of the plastic material is economical and cheap (Alexander, 2012). Zoorob & Suparma, (2000), addition of 30% poly ethylene (PE) to the bitumen enhanced many properties of asphalt like durability; fatigue time minimizes the mix density by 16%, maximizes 250% Marshall Stability and was noted to enhance indirect tensile strength of asphalt concrete. Qadir & Imam, (2005) demonstrated that 15 % substitution, of course aggregate with low density polyethylene (LDPE) significantly improvement seen as double Marshall Stability, rutting and water resistance against. Significant improvement was seen by modifying asphalt used in Bangalore (India) early 2000 laid 2km of plastic roads, smoothness, strength and durability were achieved in plastic road (Amit et al., 2012; Verma, 2008). Huang et al., (2007) reviewed asphalt modifying over waste plastic by some proportion of aggregates study findings shows reduce cracking, prolong the lifetime of road pavement, Marshall Stability increase, rutting effect of the road can improve and the main benefit to protect environment by reducing pollutions and also helpful to recycle plastic waste. Poor storage stability, aging effect and high cost for some polymer modified bitumen was reported the cause of drawback in the past, but depend what type of polymer is used during modification of bitumen (Jiqing et al., 2014; Gawande et al., 2012).

B. *Modification of Bitumen using Waste Polymer (PET & PP)*

Globally, most common packing and carrying beverage container (plastic bottles, jars etc) has been considering polyethylene terephthalate (PET), while polypropylene is available in the form of disposable cups, spoons, drinking water bottles and plates etc (Apurva, 2013). Polyethylene terephthalate (PET) bottles, annually 50billion of water bottles made of PET is wasted and most of them end on landfills, in each second united state of America use 1500 PET bottles (Petz, 2009). Since the situation of disposing of waste polymers on the earth got worse for last few decades, numerous research have been done to reuse or recycle waste polymers materials in different ways and modification over bitumen is among them. Apurva, (2013); Kalanter et al., (2012); Al-Hadidy et al., (2009) revealed that sufficiently mixing of waste plastic bottles, polyethylene terephthalate (PET) and Polypropylene (PP) significantly enhance properties of bitumen among good resistance to chemical, fatigue, creep, low water absorption and good thermal expansion occurred. In addition to, study findings shows that PET & PP has higher softening point which resist more deformation against load durability of asphalt pavement was enhanced, and also performance of pavement improved whether the temperature is high or low. According to Moghaddam et al., (2011); Al-Hadidy et al., (2009) found that bitumen modification with waste plastic of PET and PP are resistive against permanent deformation, enhance the service life of the road pavement and decrease the thickness of the pavement base. Noor et al., (2012); Vasudevan et al., (2012) and Viduala et al., (2012); Dorina (2009) claimed that polyethylene terephthalate (PET) and Polypropylene (PP) has the ability to enhance the mechanical properties of bitumen and give additional strength to asphalt pavement, reduce rutting caused by creep at low temperature but overall polyethylene blend has tended of incompatibility of a long period of time. Polypropylene (PP) is plastomer same like PET these polymers have the ability to increase strength, reduce deformation because of high rigidity (Giovanni et al., 2005). Serkan et al., (2010) stated that polypropylene (PP) increases Marshall Stability 20% of the mix and stiffness as well..

C. *Advantages of Modifying Asphalt by Using Waste Polymers*

Several advantages of asphalt modifying over waster polymers materials of polyethylene terephthalate (PET) and Polypropylene (PP) have found from the past studies Alaxender, (2012); Amit et al., (2012); Jiqing et al., (2014); Apurva, (2013); Kalanter et al., (2012 Nasker et al., (2012); Vidal et al., (2012); Moghaddam et al., (2011);); Al-Hadidy et al., (2009); Neilson, (2009); Dorina (2009); Verma, (2008); Huang et al., (2007); Lewandowsk, (1994) etc

- To obtain economical asphalt pavement
- Minimize the road surface (pavement) depth (thickness)
- Minimize the viscosity, normal temperature
- Enhance the stability and strength of the pavement
- Increase Marshall Stability and stiffness of the pavement
- Crack, fatigue, abrasion improved, resistance to permanent deformation
- Rheological performance of asphalt by addition of polymers
- Increase adhesion property of bitumen between aggregate and binder to provide stability

III. RESEARCH METHODOLOGY

In this study penetration grade 80/100 bitumen (Unmodified) is selected as binder and aggregate for all the tests from the Ikram.sdn.bhd highway laboratory. Raw waste plastic bottles of polyethylene terephthalate (PET) and disposable waste plastic cups Polypropylene (PP) were gathered from the cafeteria of Infrastructure University of Kuala Lumpur (IUKL) because everyday huge amount of waste plastic water bottles (PET) and disposable waste plastic cups (PP) generated. Appropriate selections of polymer materials are essential and thermal analysis study were conducted using thermogravimetric analysis (TGA) and differential scanning calorimeter (DSC). Both polymers material was further processed for crushing to the nearest plastic industry after ensure materials are properly clean and washed. Waste plastic material was fine grained crushed in to the maximum size of 2mm.

A. *Experiment and Sample Preparation*

Firstly, experimental tests were carried out for unmodified bitumen to evaluate performance of binder properties; penetration test, softening point, ductility, specific gravity and viscosity tests. Wet process of mixing procedure was adopted for this study and various quantity percentage of crushed waste polymers (PET and PP) 3.0%, 6.0%, 9.0% and 12 % by weight of unmodified bitumen were mixed. Unmodified bitumen (80/100) penetration grade of about 500g were heated an oven till fluid condition, shredded pieces of waste polymers (PET) of 3.0% of the weight of bitumen was added and mixture was blend for an hour to produce homogenous mixture, mixing speed was maintained 1500-3000RPM and the temperature was maintained 160-190C0, empirical test like penetration, softening, ductility were performed for modified bitumen and the process was repeated for all various percentage of quantities. Table 1 indicated properties of conventional bitumen as shown below;

Table 1; unmodified bitumen (80/100) test results

Test	Average Value
Penetration (dMM)	85.9
Softening Point (C^0)	48.0
Ductility (cm)	>100
Specific Gravity (g/cm^3)	1.02

Marshall Samples were prepared for each percentage of modified bitumen for both types of polymers following Malaysian Standard of Marshall mix AC-14 as shown in the Table 2. To prepare Marshall Sample, aggregate mixture was heated on fire till temperature 150-160 C0, and first trail sample was prepared by adding unmodified bitumen 4.5% of the weight of the aggregate mix and thoroughly mix at a temperature of 160-170 C0. The mix is placed in a mold and compacted by using Marshall Compactor for 75 blows. To find optimum bitumen content 4.5%, 5.0%, 5.5% and 6.0% bitumen by weight of mineral aggregate was added to the Marshall Mix and cooked and the process was repeated for each sample. After cooling of the sample at room temperature each sample was tested for Marshall Stability and similar process was repeated to study waste polymer modified bitumen of various contents ratio 3.0%, 6.0%, 9.0% and 12% polymer content ratio obtained result is shown below;

Table 2; AC-14 Marshall Sample

Marshall Ingredients	Size (mm)	Percentage (%)	Weight in gram (gm)
Coarse aggregate	14mm	13%	145.6gm
Fillers	10mm	28%	313.6gm
Quarry Dust		57%	638.4gm
Ordinary Portland cement		2.0%	22.4gm
		100%	1120gm

IV. RESULTS

As in previous section explained adopted methodology and performed tests of conventional binders and mixing of bitumen penetration grade 80/100 with shredded wasted plastic bottles polyethylene terephthalate (PET) at 3.0%, 6.0%, 9.0% and 12% and the same procedure was followed for the test of wasted plastic cups made of

Polypropylene (PP) bitumen was modified, after modification for each percentage Marshall samples were prepared.

A. *Penetration Test*

Penetration test was performed to measure the consistency of the traditional and modified bitumen and was measured for both waste polymers polyethylene terephthalate (PET) and Polypropylene (PP) separately on trials for each sample and average value is taken as shown in the Figure 1 indicated penetration value of PET and PP modified bitumen. Findings on the penetration value test for polymer modified bitumen shows lower penetration compared to conventional bitumen (80/100) used in this study, which indicate that by increasing polymer contents in the bitumen reduce the penetration value of the mix and this result is further justify following authors. Muthu, (2013); Afroz et al., (2012); Amit et al., (2012); Kalantar (2012); Dorina, (2009); Casey et al., (2008) stated that by increasing polymer contents with the bitumen penetration value decrease. Less the penetration value of modified bitumen resulted harder and consistent bitumen, which enhance rutting properties of the mix, but in contrary it affect the flexibility of the bitumen

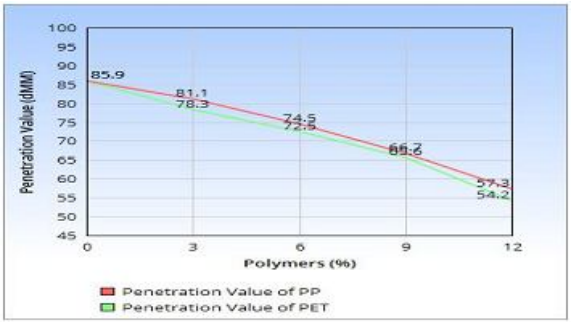

Figure1; Penetration value of modified bitumen

This study further pointed storage stability of the modified bitumen; observation of the study shows that the samples prepared earlier has penetration difference and found the sample will be more viscous if store for long duration. Another observation is witnessed in this study is modified bitumen has a tendency of separation from the bottom to the top of the mix, it might be in the result of the insufficient mixing, imbalance temperature of heating during the mixing process, lastly incompatibility between additive polymers and conventional bitumen. Similar results were documented by Dornia, (2009) in his final research study report.

B. Softening Point

Softening test was performed for conventional bitumen and polymer modified bitumen, Figure 2 shown below is the result of the study which indicated that softening point is the reverse of penetration value by increasing contents of polymers softening point is also increased due to the high viscosity of the bitumen mix. It was found that polyethylene terephthalate (PET) modified bitumen has a higher softening point compared to polypropylene (PP) and traditional bitumen used in this study. Afroz et al., (2012); Akbari et al., (2012); Nurfazilah, (2010) claimed addition of various polymers (PP, PS, PE and PET) softening point increase with respect to conventional bitumen contents and in the result temperature susceptibility increase. Findings of the study indicated that addition of polymers increase the softening point in result temperature susceptibility of the bitumen mixture increase, the fact of increasing softening point of polymers modified bitumen indicates resistance of the bitumen to the heat susceptibility in hot weather. The higher softening point may offer better rutting resistance at high temperature. This is expected that bitumen modifying by PET and PP will resist the flexible pavement against permanent deformation and rutting due to the higher softening point.

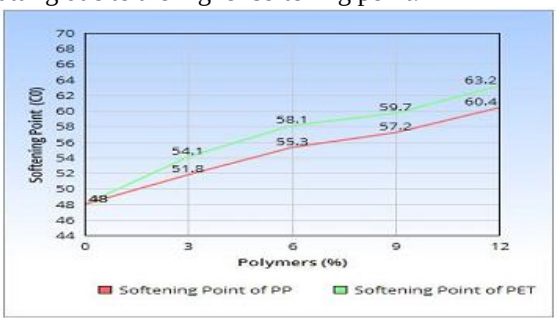

Figure 2; Softening Point of modified bitumen

C. Ductility

In the study, Malaysian standard test procedure was followed for bitumen ductility test for conventional and modified bitumen of (PET and PP). The sample was tested in standard ductility machine at 25C0 with a speed of 5cm/min. Findings of the study indicated that ductility of the unmodified bitumen was greater than 100cm while ductility of waste polymers (PET and PP) modified bitumen were less than the unmodified bitumen. Result of the Study indicated that ductility of modified bitumen slightly decrease and depends on the polymers percentages added to the bitumen, higher percentage/concentration of the modified bitumen decrease ductility due to toughness increase.

Akbari et al., (2012); Shahrzad, (2011); postulated that by increasing polymers contents in the bitumen ductility of the modified bitumen rapidly decrease. Result of the study is shown in Figure 3.

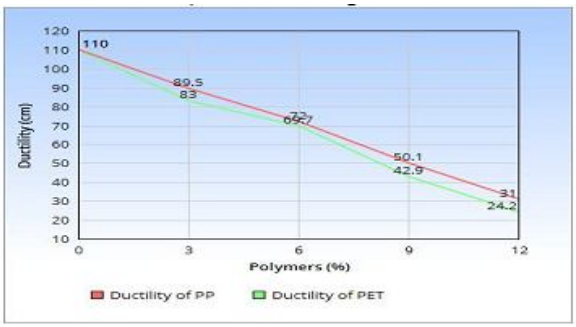

Figure 3; Ductility of Modified bitumen

D. Rotational Viscosity

The asphalt may not coat the aggregate properly if the viscosity is too high, in other case asphalt fluidity a likelihood might be occur if the viscosity is too low in the process transportation and material storage. To find an appropriate temperature range for mixing and compaction of the binder, conventional and polymer modified bitumen was tested using standard rotational viscometer (RV) procedure using Brickfield Viscometer in this study. Viscosity is significantly important above 135C0 for mixing and compaction purpose. Study observation indicated that by increasing polymer contents in the base bitumen viscosity increase, general trend of increasing concentration of polymers to the base bitumen shows that modified bitumen are more viscous than unmodified asphalt. Table 3 is the short summary of the viscosity test result for unmodified and modified bitumen contents at 135 C0 temperatures and shows the modified bitumen viscosity is higher than the base bitumen.

Table 3; Viscosity ratio of polymer modified bitumen at 135 C0

Bitumen Samples (%)	Viscosity(mPas)	Viscosity Ratio
Bitumen	989	------
PET 3.0	1013	1.02
PET 6.0	1109	1.10
PET 9.0	1125	1.13
PET12	1221	1.23
PP 3.0	1052	1.06
PP 6.0	1103	1.11
PP 9.0	1218	1.23
PP 12	1273	1.28

V. MARSHALL STABILITY ANALYSIS OF UNMODIFIED BITUMEN

In order to determine optimum bitumen content (OBC), density, stability, VTM, VFB, flow and stiffness are the parameters, and applying these parameters study found that at 5.5% of bitumen higher stability was achieved and further verify result with to the public work department, Malaysia (PWDM) standard JKR/SPJ/2008-S4 to determine OBC. Conventional bitumen Marshall Result is shown in Table 4 while Table 5 indicated standard value of Marshall Parameters.

Table 4; Marshall Result for conventional Bitumen

Bitumen Contents (%)	Density (Kg/cm^3)	Stability (N)	VTM %	VFB %	Flow (mm)	Stiffness (N/mm)
4.5	2.24	7227.6	9.39	51.24	2.540	2845.51
5.0	2.35	9554.0	5.24	66.73	2.89	3306.61
5.5	2.39	15530	3.51	76.18	3.56	4362.35
6.0	2.37	12491.5	2.76	82.62	4.07	3069.16

Table 5; Analysis parameter and JKR standard for optimum bitumen content (OBM)

Marshal Properties	JKR/SPJ/2008-S4	Results (AC-14)	Status
Stability	>8000 N	15530 N	OK
Flow	2-4mm	3.56mm	OK
Stiffness	> 2000 N/mm	4362.35N	OK
VFB (Voids filled bitumen)	70-80 %	76.18 %	OK
VTM (Voids in total Mix)	3% -5 %	3.51 %	
Density	Not required	-	-

A. *Marshall Properties for Polyethylene* terephthalate *(PET) and Polypropylene (PP) Modified Bitumen*

Optimum bitumen content (OBM) was obtained for conventional bitumen which was determined 5.5% from the Marshall tests. The waste polymers (PET and PP) plastic bottle content and disposable cups used AC-14 was added as 3.0%, 6.0%, 9.0% and 12 % by the weight of OBC.

Density (Kg/cm3): Modified bitumen density which is lower than the conventional bitumen and indicated that maximum density was obtained by addition of 9.0% waste polymers individually PET density is recorded lower than PP. In other words result indicated that increasing waste polymers contents in the bitumen increase the density until certain level and then decrease. Figure 4 shows the obtained result density of polymer modified bitumen.

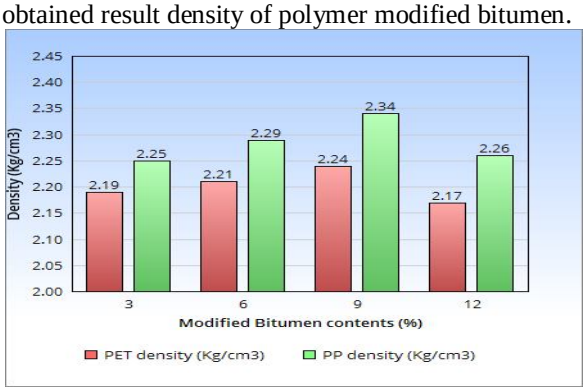

Figure 4; Density of polymer modified bitumen

Marshall Stability (N): Study found that addition of waste polymers contents increase the stability of the bitumen compared to normal bitumen contents in the Marshall and higher value is achieved at 9.0% addition of waste polymers to the 5.5% bitumen contents. Stability enhancement due to addition of waste polymer to normal bitumen can be elucidate as

it possible due to better adhesion build between bitumen and waste polymer (Polyethylene terephthalate & Polypropylene) intermolecular bonding and due to high bonding increase strength of asphalt mix which help to improve durability and stability of the asphalt mix. PET modified bitumen shows higher stability compare to PP and indicate higher molecular bond and higher tendency of compatibility. Figure 5 shows the stability of PET and PP modified bitumen;

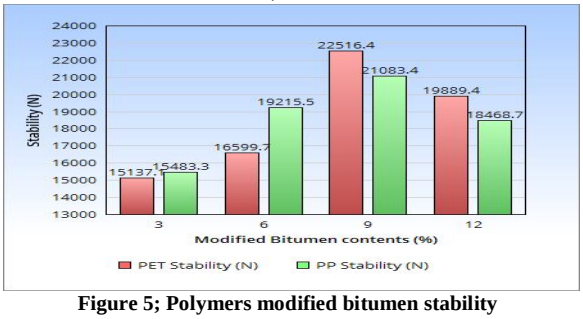

Figure 5; Polymers modified bitumen stability

Void Total Mix (VTM %): Generally voids total mix decrease by increasing bitumen contents in the mix. Various agencies recommend void total mix percentage 3-6 % while public work department, Malaysia recommendation is 3-5 %. Study result shows PET modified bitumen void total mix value lie 3-3.50 at the ratio of 6% and 9% , in contrast PP modified bitumen recorded higher VTM and range value at 9% obtained 4.11% , study believe that voids ratio in the total mix depend on the compaction higher compaction reduce voids present in the total mix. Figure 5 is the result of VTM of polymer modified bitumen. Due to the week bonding between polymers and bitumen effect voids ratio, but in this study shows that increasing contents of polymers decrease the voids ratio which further proves that PET and PP waste polymers are suitable and has strong bonding with bitumen.

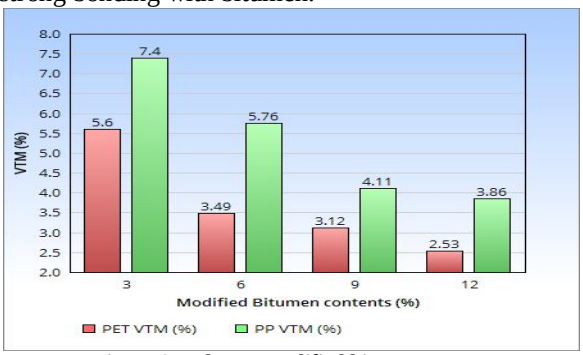

Figure 6; Polymer modified bitumen VTM

Voids Filled with Bitumen (VFB%): General trend shows that voids filled with bitumen increase by increasing polymers contents, Moreover, voids filled contents has strong relation with voids total mix and density, range voids contents was determined in at polymer addition of 9.0% by weight of optimum bitumen contents (OBC) which was 5.5 %. Study founding further shows that PP contents filled more voids compared to PET and this indicate bonding between polymers and bitumen contents PWD-2008 speciation recommends 70-80 % voids filled bitumen contents for Marshall. Figure 8 shows the VFB in polymers contents

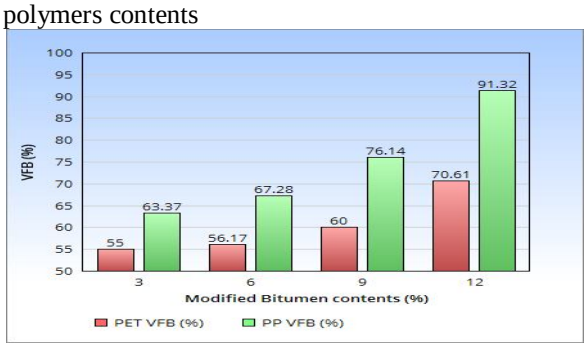

Figure 7; Polymer modified Bitumen VFB

Flow (mm): Flow value increase with increasing modified bitumen contents. Flow of the sample is the flexibility of the mix greater flow value indicate more flexibility of the mix. Minimum flow value is 2mm according to Malaysian public work department, 2008 and maximum allowable flow value is 4mm but some others agencies like Indian work department allowable flow value for Marshall mix is 2-5mm. Polypropylene has higher flow value compared to PET due to stiffness of the material. PET flow value gradually increase compared to PP and conventional bitumen. Overall result indicate that both of material is suitable for road payment as a modifier at percentage of 9.0% by weight of the bitumen sustain flow and reduce deformation of the pavement surface. Figure 9; represent flow value of the polymer modified bitumen.

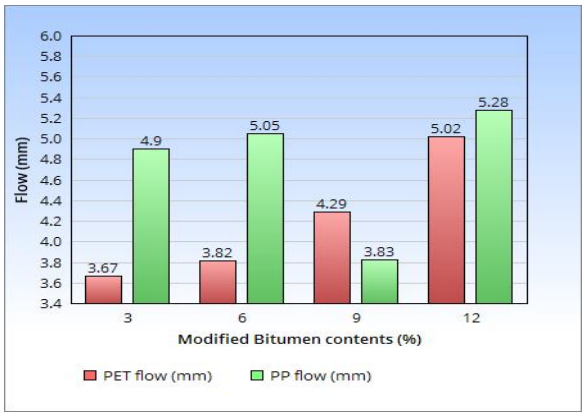

Figure 8; Flow value of Polymer Modified Bitumen

Stiffness (N/mm): Mixture stiffness is significant because higher stiffness resists against rutting and can show that mixture can stand on heavier load without any deformation.

In Figure 10 polymer modified bitumen shows that polypropylene (PP) mixture is stiffer than polyethylene terephthalate (PET). Increase the polymer contents in the mix decrease the stiffness shows from the obtained result maximum stiffness for both polymers was obtained at 9.0% addition of polymer by weight of bitumen. A higher value of

stiffness by adding polymers were found in the past studies indicates stiffer mixture and enhance resistance against deformation is documented.

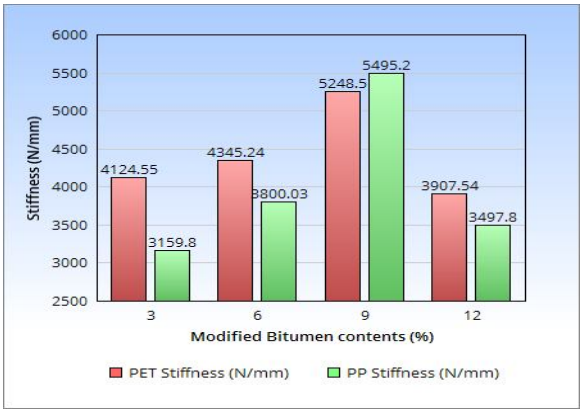

Figure 9; Stiffness of the Polymer Modified Bitumen

DISCUSSION

Bitumen is hydrocarbon material and polymers does too with long hydrocarbon, having many similarities of bonding with bitumen and study finding shows that due to strong bonding nature polymers modified bitumen improved various properties and characteristic of the unmodified bitumen such as penetration, softening point, ductility and Marshall Stability of the Marshall Mix. Penetration value of the conventional bitumen and polymers modified bitumen was compared in this study, finding result shown that by addition of polymers in this study polyethylene terephthalate (PET) and polypropylene (PP) reduce penetration value of the traditional bitumen in the result reduce rutting properties of the pavement. Study pointed that lower penetration value of the bitumen enhance properties of the pavement materials. Softening point of the polymers modified bitumen shows that softening point of the modified bitumen increase which further justified literature where various authors claimed that addition of polymers to the bitumen increase softening point in the result reduce permanent deformation and rutting due to higher softening point. A finding of the study shows that PET modified bitumen has higher softening point compared to PP modified bitumen. Study further proceeded with experimental result obtained from the ductility test of both polymers contributed in this research (PET & PP) and their result indicated that polymers modified bitumen has lower ductility, study evidence of the PET modified bitumen more lower ductility compared to the polypropylene (PP) bitumen.

Past studies result reported rapidly decreasing ductility of the bitumen after addition of the polymers. Rotational viscosity test was performed using Brickfield viscometer to attain the temperature of mixing and compaction of the Marshall Mix, various samples were tested as conventional bitumen, PET modified and PP modified bitumen of different percentage of polymers added to the bitumen. Finding of the study indicated that increasing contents of the waste polymers to the base bitumen increase viscosity of the bitumen. Study observed that modified bitumen is more viscous than conventional bitumen.PET and PP modified bitumen Marshall result shown that addition of 9% of polymers to the mix maximum improvement has been recorded such as PET modified bitumen found more dense compare to PP modified bitumen. More generally result found that addition of the polymers to the bitumen density decrease when polymers contents increase maximum density found addition of 9.0% contents of the polymer. Stability of the Marshall mix found highest at 9.0% where both polymers resulted for higher stability of the polymer modified bitumen and comparison to the base bitumen stability of the modified bitumen is much higher than while PET modified bitumen found higher stability. Percentage of the void total mix found to decrease while increasing modified bitumen contents in the Marshall Mix. In flexible material higher flexibility is the result of the higher flow value, polymer modified bitumen shows higher flow value when increasing polymer contents in the bitumen, recommended and allowable flow value is 2-5mm, in this study result shows that modified bitumen values is in the range but shown increasing beyond the recommended value at 12% of the addition of the polymers. Marshall analysis of the study shows that adding of 9.0% of polymers to the bitumen by weight of 5.5% at optimum level increase Marshall properties and give all positive response for both polymers (PET and PP) such as stability increase up to 60-70%, stiffness, flow, density and voids of the polymer modified bitumen found positively improving and enhancement was observed compared to conventional bitumen of this study. In short conclusion shows that polymers modified bitumen improve stability, workability and minimize deformation.

CONCLUSION

Polyethylene terephthalate (PET) and polypropylene (PP) by addition of 9.0% to the weight of conventional bitumen decrease penetration and ductility while increase softening point and viscosity of the modified bitumen. Modified bitumen mix has a tendency of separation from the bottom to the top of the mix; it might be in the result of the insufficient mixing, imbalance temperature of heating during the mixing process. Marshall Stability analysis was deeply studied and concluded that polymer modified bitumen has higher stability compared to normal bitumen up to certain limit as by the addition of 9.0% polymer contents increased 50-70% stability value of the Marshall mix. Study revealed that stiffness of the modified bitumen is significantly improved which shows highly resistance against rutting and permanent deformation. In short, study concludes that using

waste polymers of Polyethylene terephthalate (PET) and polypropylene (PP) significantly enhanced properties 80/100 bitumen and Marshall Stability and stiffness of the pavement increased remarkably.

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