Journal of the Eastern Asia Society for Transportation Studies, Vol.8. 2010

The Creep Performance of Base and Polymer Modified Bitumen Mixes Containing Different Types of Sand as Fine Aggregate

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Abstract: Exceedingly heavy axle loads to hot mixture asphalt (HMA) can lead to the permanent deformation. It is caused by repetitive traffic load at high temperature. Rutting of these mixes can be predicted by laboratory creep test. The purpose of this paper is to look at some aspects of the effects of fine aggregate physical, chemical and mechanical properties on the creep behavior of HMA. Four types of sand (quarry, river, mining and marine sand) with two conventional binders (PEN 50/60 & 80/100) and four polymer modified bitumen (PM1_76 & PM1_82 and PM2_76 & PM2_82) were studied on hot mix asphalt creep resistance. According to the dynamic creep test results mixtures prepared using fine aggregate that has more angularity, rougher, high shear strength and high percentage of Al_2O_3, presented highest resistance to creep deformation. Also polymer modified mixtures give the best result compared with conventional mix.

Key Words: *fine aggregate properties, hot mixture asphalt, dynamic creep test.*

1. INTRODUCTION

With an increasing demand in highway's construction, scientists and engineers are constantly trying to improve the performance of bitumen pavement. In recent years, the increase in cars and trucks with various environmental effects, the road surfaces have been exposed to the high traffic that causing constant and excessive stresses which leads to permanent deformation (creep deformation) (Chavez-Valencia *et al*., 2007; Wu *et al*., 2007; Abo-Qudais and Shatnawi, 2007; Tayfur *et al*., 2007). Permanent deformation happens when road does not have sufficient stability of the asphalt material in surfacing, insufficient compaction of the pavement and insufficient pavement strength (Robinson and Thagesen, 2004). Visco-elastic behavior for bitumen can also participates in the rutting occurrence of the pavement, because bituminous materials are viscous at high temperatures and elastic at low temperatures exhibiting visco-elastic behavior under intermediate conditions. Rutting can be created also under low stiffness condition namely at high temperature and long times of loading when the mixture is approaching viscous response (Peattie, 1979).

Many studies indicated that physical characteristics (shape and surface texture) affect the workability and optimum bitumen content of the mixture, as well as the asphalt mixture properties (Topal and Sengoz, 2006; Topal and Sengoz, 2005; Eyad *et al*.,2001; Lee *et al*., 1999). Aggregate interlock also becomes more important to provide better performance and less rutting under repeated applications of load (Peattie, 1979). The mechanical properties (shear resistance) of fine aggregate has a big significant on the mixture resistance, the high shear resistance in crush aggregate is a good indicator of resistance to mixture deformation (Topal and Sengoz, 2006). Chemical compositions of aggregate can also effect the mixture performance (Abo-Qudais and Al-Shweily, 2007).

Several researches have been carried out on modifying asphalt using polymer modified bitumen to increase its resistance towards permanent deformation (creep) (Tayfur *et al*., 2007; Sirin *et al*., 2006; Ahmedzade and Yilmaz, 2007; Chiu and Lu, 2007).

2. OBJECTIVE

The main purpose of this paper is to evaluate the effects of fine aggregate and its properties on creep behavior when base and polymer modified bitumen were used. To accomplish this, a laboratory study was initiated to evaluate the effect of fine aggregate properties on creep behaviour susceptibility of HMA.

3. LABORATORY PROGRAM

In this study several tests are carried out to determine the following properties such as specific gravity of coarse aggregate, fine aggregate and filler, physical, chemical and mechanical properties of fine aggregate, physical properties of polymer modified bitumen and base bitumen, optimum binder content and dynamic creep test.

3.1 Materials Used

The materials used in this study were different types of aggregate, asphalt, polymers modified bitumen and are described as follows.

3.1.1 Aggregate

The coarse aggregate used in this study is the crushed granite aggregate. The granite was obtained from quarries around Ipoh. Table 1 summarizes the specific gravity of the aggregate. Well gradations with a maximum nominal aggregate size equal to 20 mm have been used. Fine-grained aggregate samples were obtained from 4 different locations in Malaysia; (quarry, river, mining, and marine sand). The type of filler used was the Ordinary Portland Cement (OPC).

Table 1 Specific gravity of aggregate

Aggregate Types	Quarry/ Region	Specific Gravity(g/cm^3)
Coarse aggregate (Granite)	Quarry	2.655
Fine aggregate (River sand)	River	2.631
Fine aggregate (Mining sand)	Pond	2.695
Fine aggregate (Quarry sand)	Quarry	2.690
Fine aggregate (Marine sand)	Beach	2.710
Filler (Portland cement)	Factory	3.135

3.1.2 Asphalt

Two types of asphalt cement of penetration 50/60 and 80/100 (PEN 50/60 and PEN80/100) are used for the conventional mix. Polymer modified bitumen PM1_82 and PM1_76 and PM2_82 and PM2_76 are used for the modified mixture. All of these binders were used in preparing HMA specimens. The asphalt cement of PEN 50/60 and PEN 80/100 were obtained from Bellamy Precision and Bernesins respectively. While PM1 and PM2 were obtained from PPMS Technologies PETRONAS. Table 2 summarizes the physical properties of the binders.

Table 2 Properties of binders

Binder Types	Penetration@ 25^{0}C (0.1mm) ASTM D5	Softening Point (^{0}C) ASTM D36	Ductility (cm) ASTM D113	Specific Gravity at 25 ^{0}C ASTM D04
PEN 50/60	49	52	36.0	1.032
PEN 80/100	90	49	125.6	1.030
PM1_82	39	70	59.1	1.028
PM1_76	47	67	56.4	1.027
PM2_82	48	65	35.5	1.032
PM2_76	48	53	29.6	1.035

Table 2 shows a decrease in penetration and increase in softening point of polymer modified bitumen compared to the base bitumen. This gives a high values of hardness and stiffness for polymer modified bitumen.

3.2 Tests

3.2.1 Physical Properties of Fine Aggregate

The shape, surface texture and particle distribution can be determined by electron microscopy scanning (Xue *et al*., 2006). Figures 1 - 8 show the quarry, river, mining and marine sands physical appearance. According to these micrographs, one can see that quarry sand is more angular in shape, this followed by river and mining sand while marine sand is more rounded in shape (shape and surface texture). The angular property affects the particles interlocking between each other and this reflects the good stability mechanism. In term of the morphology; quarry sand shows different texture and morphology from the natural sand (mining, river and marine sands). This difference makes quarry surface texture rougher as shown in Figure 5, followed by river and mining sands while marine sand represent smooth texture, and of course the roughness is a factor that effects the adhesion ability of aggregates with binder.

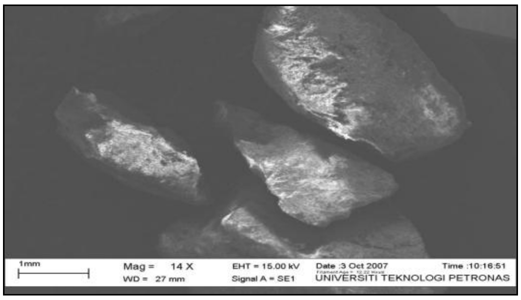

Figure 1 Physical appearance of quarry sand (shape)

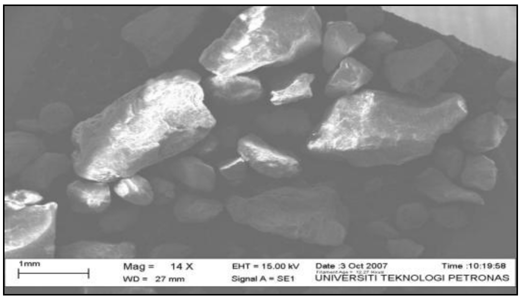

Figure 2 Physical appearance of river sand (shape)

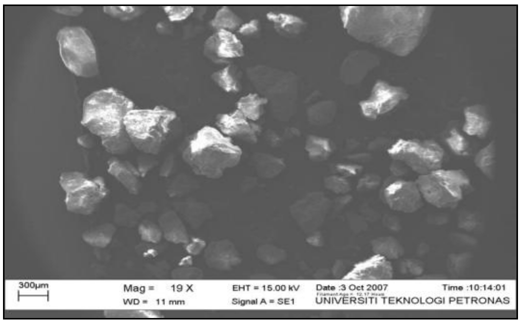

Figure 3 Physical appearance of mining sand (shape)

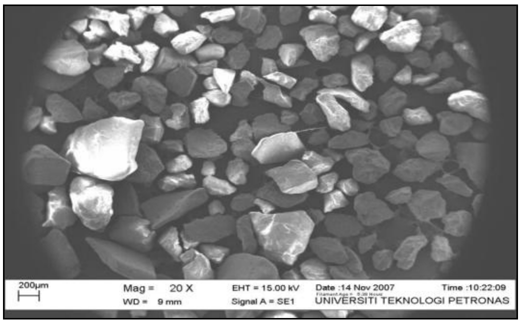

Figure 4 Physical appearance of marine sand (shape)

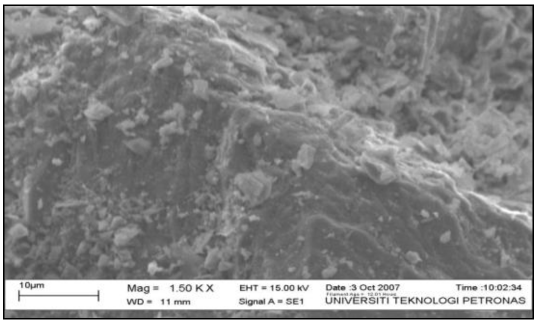

Figure 5 Physical appearance of quarry sand (surface Texture)

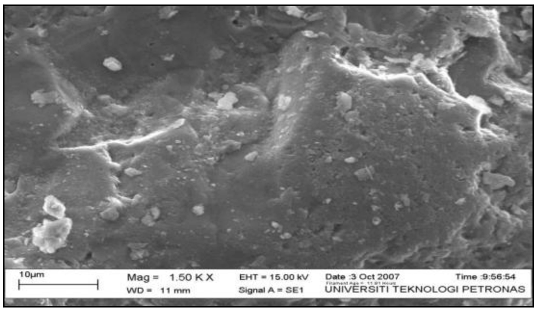

Figure 6 Physical appearance of river sand (surface Texture)

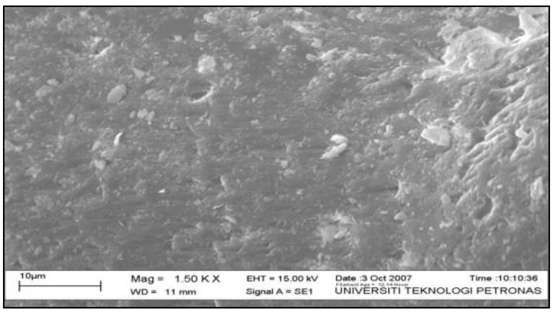

Figure 7 Physical appearance of mining sand (surface Texture)

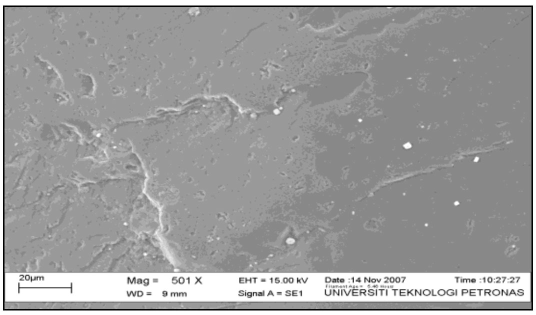

Figure 8 Physical appearance of marine sand (surface Texture)

3.2.2 Fine Aggregate Angularity

Four different types of sand were selected and tested for the fine aggregate angularity (FAA) test. FAA is measured by determining the percentage of voids in the sand The higher the percentage of voids the more angular the fine aggregate. The results of fine aggregate angularity are shown in Table 3, it can be noticed that quarry sand has more angularity compared with the other types of sand. This is followed by the river sand, mining sand and marine sand respectively. It was found by Fernandes and Gouveia, that fine aggregate with higher values of FAA produce more angular particles and greater rough surface texture, resulting in a larger interlock between the particles consequently resulting in a higher shear strength.

Table 3 Fine aggregate angularity (FAA) for fine aggregates

Aggregate Types	Quarry/ Region	Fine Aggregate Angularity (FAA) %
Fine aggregate (Quarry sand)	Quarry	46.91
Fine aggregate (River sand)	River	43.05
Fine aggregate (Mining sand)	Pond	42.58
Fine aggregate (Marine sand)	Beach	40.32

3.2.2 Chemical Properties of Fine Aggregate

The composition of sand is highly variable depending on the rock sources and conditions. Table 4 shows the chemical composition of quarry sand, river sand, mining sand, and marine sand obtained from the X-ray fluorescence (XRF) test. The composition consists of CaO, SiO_2, Al_2O_3, Fe_2O_3, K_2O and Na_2O in different proportions. SiO_2 constitute represents the highest chemical composition in all sand types. Table 4 also shows that other elements are also present in varying degree of chemical composition.

Quarry sand has the highest total percentage of Al_2O_3, and Fe_2O_3, i.e. 17.9%, while river sand consists 11.30%, followed by mining sand 11.18%, and marine sand 4.87%. The hematite (Fe_2O_3) has the smallest particle size, followed by alumina (Al_2O_3) and silica (SiO_2). The size of particles also has some effect on the performance of paving mixtures. Smaller particle tend to decrease the void within the bituminous mixture which consequently will increase the resistance to permanent deformation. This phenomenon will be reflected on the fine aggregate performance.

Quarry sand has the highest total percentage of alumina (Al_2O_3) that is 12.6% compared with other types of sand, followed by mining sand which contains 8.98%, river sand 8.6% and marine sand 1.67%. The Al_2O_3 content is related to the hardness of the material.

The oil absorption property is needed to absorb the extensive oil in the bitumen mix, this relatively could decrease the rutting, because rutting occurred by bleeding at high temperature (Wu *et al.*, 2207). Al_2O_3 has the highest value of the oil absorption property (25-225), followed by Fe_2O_3 and SiO_2 respectively. Results show that quarry sand has the highest amount of Al_2O_3, followed by river and mining sand which have almost the same amount of $Al_2 O_3$. Meanwhile, marine sand has the least amount of Al_2O_3.

Table 4 Chemical composition result for sands

Fine Aggregate Types	CaO	SiO_2	Al_2O_3	Fe_2O_3	K_2O	Na_2O
Quarry sand	7.19 %	66.1 %	12.6 %	5.30 %	10.5 %	1.95 %
River sand	0.4 %	76.8 %	8.6 %	2.7 %	9.3 %	0.5 %
Mining sand	3.6 %	80.0 %	8.98 %	2.2 %	2.2 %	0
Marine sand	33.5 %	57.5 %	1.67 %	3.20 %	1.71 %	0.31 %

3.2.3 Mechanical Properties (Shear Strength) of Fine Aggregate

The angle of internal friction (Ø) or shear strength is an indication of particle interlocking and hence particle shape and surface texture (Park and Lee, 2002). The shear strength is determined by shear box test. Results from direct shear tests show that quarry sand have the highest Ø value (45^0) followed by river sand (37.8^0). Mining and marine sands registered the lowest Ø value (33.7^0). However, their C values are different. Mining sand has higher C value (50 kNm^2) than the marine sand (18 kN/m^2). This indicates that mining sand is stronger than marine sand. Therefore, crush aggregate like quarry sand as expected, has higher shear resistance compared with natural aggregates. High shear resistance is indicator of resistance to the mixture's deformation (Topal and Sengoz, 2006).

3.2.4 Marshall Test

Determination of optimum asphalt content by weight of total mix is done by using Marshall Mix design method (Aksoy *et al*., 2005). The procedure involves 75 blows per face for each specimen. Three specimens of each asphalt cement contents (3.5 %, 4.0%, 4.5%, 5.0%, 5.5%, 6.0%, 6.5%, and 7%) are prepared. A total of 576 specimens have been tested with the stability, flow, air voids, unit weight, voids filled binder and voids in mineral aggregate (Ahmedzade and Yilmaz, 2007; Ahmedzade *et al*., 2007). The optimum binder content is calculated as the average of asphalt contents that meet the maximum stability, maximum unit weight, minimum voids in mineral aggregate and 5.0% air voids criteria.

3.2.5 Dynamic Creep Test

A total of 72 specimens were prepared to perform dynamic creep tests using the Universal Testing Machine (UTM) as shown in Figure 9. It applies a repeated pulsed uniaxial stress/load to a mixture specimen and measures the resulting deformations in the same axis using Linear Variable Displacement Transducers (LVDTs). The conditions of the test are; the temperature was 40 ^{0}C, 2 minutes for preloading at 12 kPa, and 1hour for loading options (Ahmedzade and Yilmaz, 2007; Cabrera and Nikolaides, 1988). The data of the creep test were plotted to show the relationship between permanent deformations (mm) versus cycles.

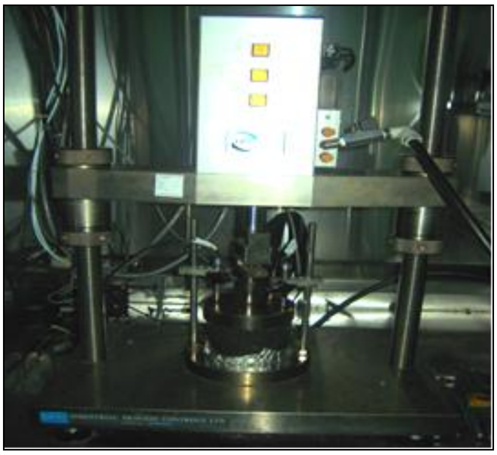

Figure 9. Creep test apparatus

4. RESULTS AND ANALYSIS

4.1 Physical Properties of Binder

Before actual stress tests were performed on the bituminous mixtures, the mechanical properties of the binders were determined through various tests which include penetration test, softening point test, ductility test and specific gravity test. These tests were performed in order to identify the consistency of binders. The results of the consistency tests which are penetration and softening point values of conventional binder were obtained to confirm the bitumen specifications provided by suppliers. The results showed that bitumen used, meets the specification as outlined in the various ASTM standard as shown in the Table 2. The consistency tests proved that bitumen PEN 50/60 has higher consistency than bitumen PEN 80/100. The ductility results indicate that bitumen PEN 80/100 is more flexible than bitumen PEN 50/60, because bitumen PEN 80/100 has higher value of ductility than bitumen PEN 50/60. The softening point results show that bitumen PEN 50/60 needs higher temperature to soften than bitumen PEN 80/100. The results proved that bitumen PEN 50/60 is harder than bitumen PEN 80/100.

The density of binders was determined using calibrated pycnometer of 25 ml volume. It is noted that the density of bitumen PEN 50/60 is higher than that of bitumen PEN 80/100. This is because bitumen PEN 50/60 is harder than bitumen PEN 80/100. PM2 polymer modified has a higher density than PM1 polymer modified and conventional bitumen. These results agreed with the ductility results where PM2 polymer modified is less ductile compared to PM1 polymer modified and conventional binders. This means PM1 polymer modified has high tensile strength, even though the high flow resistance makes the PM1 polymer modified hard and able to resist deformations at high temperature better than PM2 polymer modified. All the specific gravity results are within the standard range (1.0-1.04) (Brown *et al*., 1996).

It can also be noticed that PM1_82 and PM1_76 polymer modified bitumen have lower penetration and higher softening point and ductility values as compared to the PM2_82 and PM2_76 polymer modified bitumen. This is because PM1 consist of SBS polymer modifier, which consists of hard polystyrene end blocks and rubbery midblock. The hard polystyrene end blocks give high tensile strength and flow resistance at high temperature, whereas the rubbery midblocks are responsible for the elasticity, fatigue resistance and flexibility at low temperature (Airey, 2003; Ahmedzade *et al*., 2007). After the process of modifying, the polystyrene end blocks domains rehardened and form physical crosslinks with the rubbery mid blocks, forming a strong, elastic and three-dimensional network (Ahmedzade *et al*., 2007; Wekumbura *et al*., 2007). It can also be noticed that PM1_82 is harder than PM1_76 as shown by their consistency tests result. This is because of the SBS polymer modified can work well in term of homogeneity with base bitumen and it can give more hardness or stiffness when mixed with softer bitumen.

4.2 Marshall Test Properties

4.2.1 Optimum Binder Content (OBC).

The OBC values for four types of the sand were varies. From Figure 10, it can be noticed that OBC is higher in the mixture having mining sand, followed by river, marine and quarry sand respectively. This refers to mining sand had more fines (small particle), this means large or more surface area needed more binder to cover all the particles. The quarry sand has large particles, meaning small surface area which required small amount of binder to cover all the particles.

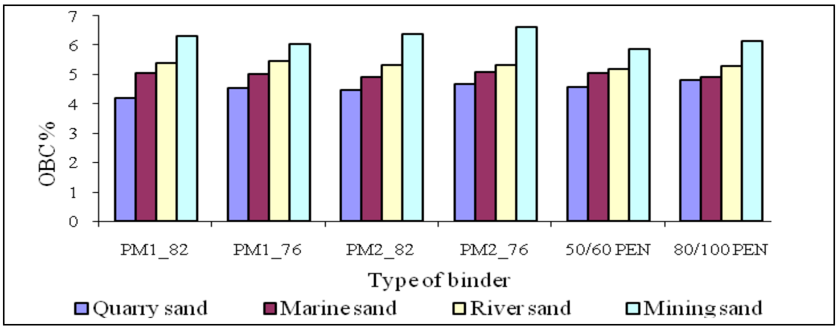

Figure 10 OBC of bituminous mixture based on types of binder and fine aggregate.

4.2.2 Marshall Stability

The stability was higher for quarry sand as shown in Figure 11, followed by the river, mining and marine sand respectively. This refers to the quarry sand having more angularity which provides a better interlocking property. It has rough surface to provide a greater bonding strength with asphalt cement and frictional resistance between particles. This is shown in scanning electron microscopy in Figures 1 and 2.

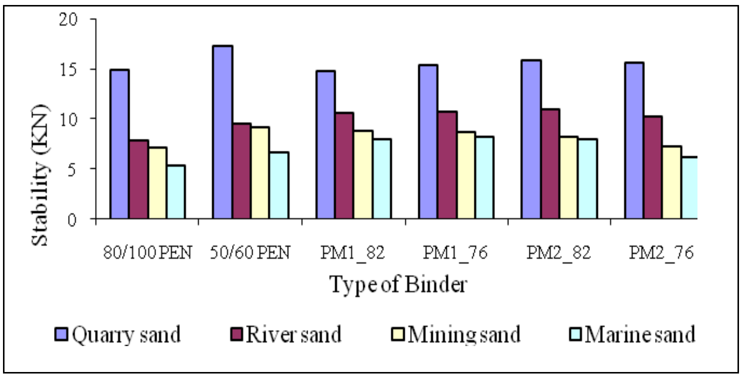

Figure 11 Stability of bituminous mixture based on types of binder and fine aggregate.

4.2.3 Marshall Density

The density was higher for quarry sand as depicted in Figure 12, followed by the marine, river and mining sand respectively. This refers to the roughness of the surface texture which provides a greater bonding strength with bitumen and frictional resistance between particles. This is shown in scanning electron microscopy in Figures 5 and 8.

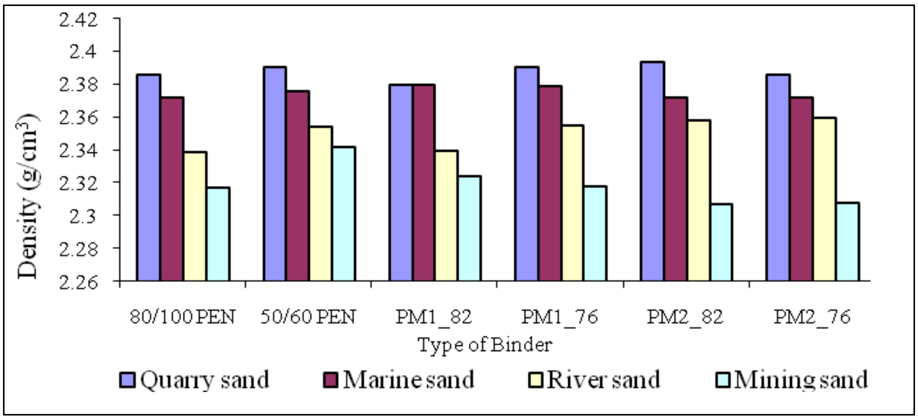

Figure 12 Density of bituminous mixture based on types of binder and fine aggregate.

4.3 Dynamic Creep Test Properties

The stiffness values of different types of bitumen were shown in Figure 13. The stiffness value was obtained from the Van der Poel's Nomograph which depends on; time of loading (S), penetration index (PI), and temperature difference (temperature of the test and ring and ball temperature) (Pell, 1979). The loading time is the same as creep loading times and the temperature equal to the test temperature (40^0C). As shown in Figure 13 polymer modified bitumen has the highest stiffness compared to the conventional bitumen. That means the polymer modified bitumen is harder because it has higher softening point and lower penetration compared to conventional bitumen. The highest stiffness is shown by PM1_82 followed by PM1_76, PM2_82, PM2_76, PEN 50/60, and PEN 80/100.

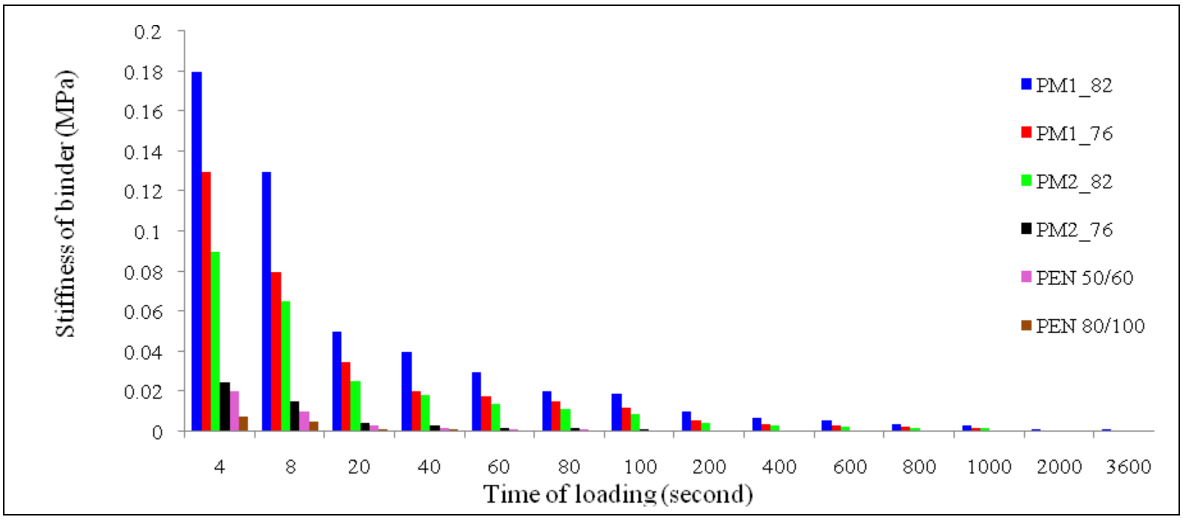

Figure 13 Stiffness comparisons for different types of bitumen

The formula which was used to calculate the rut depth of the pavement from laboratory creep test results was initially proposed by Hills et al, and Van der Loo (Cabrera and Nikolaides, 1988).

$$RD = C_m \times H \times \sigma_{av} / S_{mix.creep} \qquad (1)$$

Where RD is the calculated rut depth of the pavement, C_m is the correlation factor for dynamic effect, varying between 1.0 and 2.0, H is the pavement layer thickness, σ_{av} is the average stress in the pavement, related to wheel loading and stress distribution, and $S_{mix.creep}$ is the stiffness of the design mixture derived from creep test at a certain value of stiffness which is related to the viscous part of the bitumen. Results of estimated rut depth presented in this section were derived from Van der Loo`s equation with the following numerical assumptions:

$$T_w = 0.02 \text{ sec}, \; C_m = 1.5, \; \text{H} = 100 \text{ mm, and } \sigma_{av} = 0.25 \text{ MPa}$$

Results of rut depth estimation are shown in Figures 14, 15, 16 and 17. The results presented the rut depth estimation related to the number of standard axle repetitions. The results indicate that a highly significant correlation exist between estimated rut depth and number of standard axle repetitions. The estimated rut depth of all mixture containing polymer modified binder is lower than estimated rut depth of the conventional mixture. Because polymer modified bitumen is more viscous binder results in an increased stiffness of the bitumen as shown in Figure 13 and hence stiffer mix, therefore, deform less under traffic loading (Ahmedzade *et al*, 2007). For different types of sand the estimated rut depth of all mixture containing quarry sand is lower than estimated rut depth of the other sands, followed by river, mining, and marine sand respectively. This refers to the characteristic of fine aggregate as shown in the previous results.

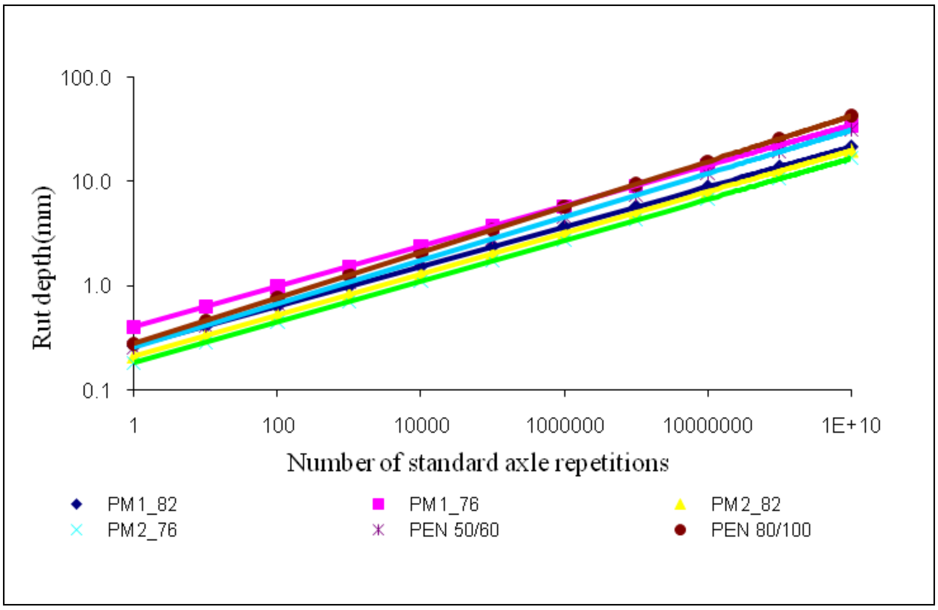

Figure 14 Rut depth estimation related to the number of standard axle repetitions for quarry sand mixture.

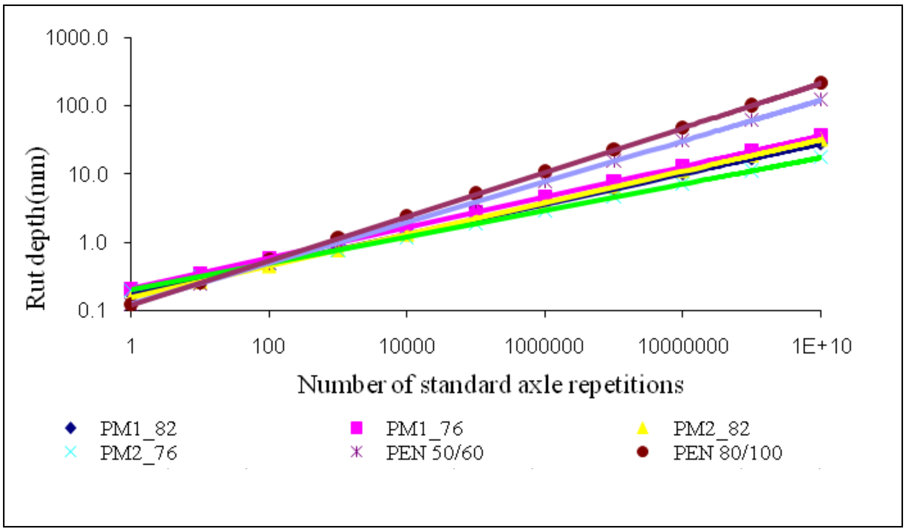

Figure 15 Rut depth estimation related to the number of standard axle repetitions for river sand mixture.

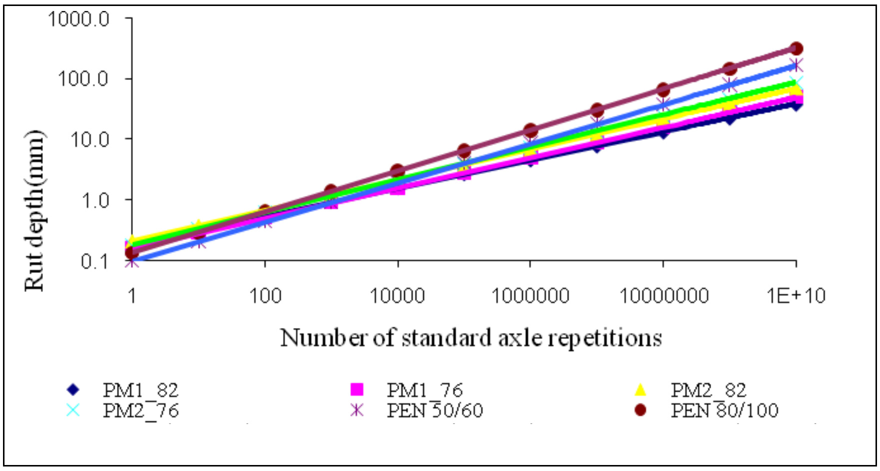

Figure 16 Rut depth estimation related to the number of standard axle repetitions for mining sand mixture.

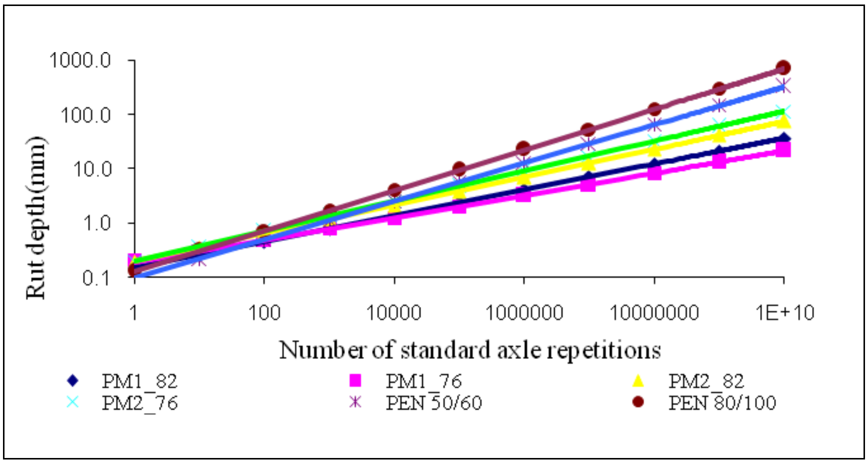

Figure 17 Rut depth estimation related to the number of standard axle repetitions for marine sand mixture.

Table 5 presents the creep characteristics equations and shows the values of slope “b”, which represents deformation and the constant coefficient “a” which represents the magnitude of creep stiffness for all types of sand/binder mixtures. The values of “a” and “b” were obtained from the plot of rut depth vs. the number of standard axle repetitions. From Table 5, it can be noticed that polymer modified bitumen have small slope compared to the conventional bitumen. PM1_82 is less susceptible followed by PM1_76, PM2_82, PM2_76, PEN 50/60, and PEN 80/100 respectively. That refers to their physical properties. But PM2_76 has smaller slope than PM2_82 in quarry sand, and smaller than all types of binder in river sand. PM1_76 has smaller slope than any type of binder in marine sand. The *“a”* value is bigger for polymer modified bitumen compare to the conventional bitumen. This is due to polymer modified bitumen ability to improve the creep resistance better than conventional binders (Ahmedzade and Yilmaz, 2007). This phenomenon is shown in all types of sand except in quarry sand PEN 50/60 and 80/100, which have a bigger *“a”* value than the PM2_82 and PM2_76. In general we can say that PM1_82 and PM1_76 have the highest resistance to permanent deformation (creep), however, PM2_82 and PM2_76 can increase resistance to rutting and mix cohesion better compared to PEN 50/60 and 80/100. In term of fine aggregate, quarry sand has the lowest slope followed by river sand, mining sand, and marine sand. This refers to the physical, chemical and mechanical properties of sand, since quarry sand is most angular in shape, rougher in texture, having the highest shear resistance, high oil absorption value and more hardness. One can concludes that fine aggregate’s physical, chemical and mechanical properties could significantly affect the creep resistance (Peattie, 1979; Abo-Qudais and Al-Shweily, 2007).

Table 5 Creep characteristic equations

Mixture	Equation	“a” value	“b” Slope
quarry sand PM1_82	$y = 0.2673x^{0.1903}$	0.2673	0.1903
quarry sand PM1_76	$y = 0.4035x^{0.1931}$	0.4035	0.1931
quarry sand PM2_82	$y = 0.2131x^{0.1968}$	0.2131	0.1968
quarry sand PM2_76	$y = 0.1829x^{0.1958}$	0.1829	0.1958
quarry sand PEN 50/60	$y = 0.2608x^{0.2077}$	0.2608	0.2077
quarry sand PEN 80/100	$y = 0.2837x^{0.2178}$	0.2837	0.2178
river sand PM1_82	$y = 0.1754x^{0.2205}$	0.1754	0.2205
river sand PM1_76	$y = 0.2129x^{0.2236}$	0.2129	0.2236
river sand PM2_82	$y = 0.1553x^{0.2316}$	0.1553	0.2316
river sand PM2_76	$y = 0.2007x^{0.1948}$	0.2007	0.1948
river sand PEN 50/60	$y = 0.1277x^{0.2979}$	0.1277	0.2979
river sand PEN 80/100	$y = 0.1235x^{0.3237}$	0.1235	0.3237
mining sand PM1_82	$y = 0.1894x^{0.2307}$	0.1894	0.2307
mining sand PM1_76	$y = 0.1644x^{0.2477}$	0.1644	0.2477
mining sand PM2_82	$y = 0.2169x^{0.2511}$	0.2169	0.2511
mining sand PM2_76	$y = 0.1832x^{0.2677}$	0.1832	0.2677
mining sand PEN 50/60	$y = 0.1018x^{0.3213}$	0.1018	0.3213
mining sand PEN 80/100	$y = 0.1397x^{0.3359}$	0.1397	0.3359
marine sand PM1_82	$y = 0.1522x^{0.2383}$	0.1522	0.2383
marine sand PM1_76	$y = 0.1924x^{0.2049}$	0.1924	0.2049
marine sand PM2_82	$y = 0.1967x^{0.2582}$	0.1967	0.2582
marine sand PM2_76	$y = 0.2007x^{0.2756}$	0.2007	0.2756
marine sand PEN 50/60	$y = 0.0980x^{0.353}$	0.098	0.353
marine sand PEN 80/100	$y = 0.1328x^{0.3724}$	0.1328	0.3724

5. CONCLUSION

This study aimed to evaluate the effect of fine aggregate properties on the creep performance of bituminous mixture when base and polymer modified bitumen are used. Based on the study results, the following conclusions can be drawn:

- The penetration and softening point results have demonstrated that the use of polymer modifier increased the stiffness of the binder at high pavement service temperature. This has the potential to improve the creep resistance of the polymer modified bituminous mixture.

- Quarry sand exhibits best physical appearance, highest FAA and highest shear strength, this is followed by river sand**,** mining sand, while marine sand exhibited the worst physical appearance, lowest FAA and shear strength.

- High content of Al_2O_3 in fine aggregate increase the hardness and the ability to absorb the extensive oils of the mix, this will increase the resistant to rutting. Quarry sand shows the highest value of hardness and oil absorption, while marine sand showing the least. Quarry sand has the highest content of Fe_2O_3 which will result in increasing the density for the mixture, and this will increase the mixture resistance to the permanent deformation, this followed by the marine sand, river sand and mining sand respectively.

- Quarry sand mixture exhibited the highest stability, density and stiffness and lowest VFB and VMA compared to the other sands. Polymer modified mixtures generally have higher stability and stiffness compared to the base mixtures, also the VMA and AV are slightly increased for polymer modified bituminous mixtures. The optimum bitumen content (OBC) for bituminous mixtures containing quarry sand is lower than those obtained from mixtures containing natural sands. Polymer modified bituminous mixtures have a higher OBC content compared to the base mixtures.

- PMB mixture has higher rutting resistance compared to the base mixture. The orders in decreasing the rutting resistance are PM1_82, PM1_76, PM2_82, PM2_76, PEN 50/60 and PEN 80/100. Fine aggregate that has more angular particles, rougher surface texture, higher shear strength and higher hardness and oil absorption value contributes to increased creep resistance of hot mixture asphalt. A mixture containing quarry sand exhibits higher creep resistance compared to the mining sand mixture.

- Strength, angular, rougher texture, bigger size, and good distribution of particles were contributed to the mixture strength that is reflected in better creep resistance. Modification of bitumen with polymer highly increases the creep resistance of the pavement. The results obtained from the Marshall and creep tests provide an insight view that physical, chemical and mechanical properties of sand could improve the mixture properties and its creep performance.

ACKNOWLEGEMENT

The authors would like to express their thanks to civil engineering department of Universiti Teknologi PETRONAS for helping in conducting the experiments in their well equipped laboratory and also to the technologists of civil engineering department.

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