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Research Article

LABORATORY STUDY OF *SBS POLYMER* IMPACT ON POROUS ASPHALT FATIGUE

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ABSTRACT
Porous asphalt was introduced as a drain layer and is being used in a raised level in the superstructure and especially in the rainy regions. In this mix to create the necessary free space was used of less fine-grained materials and less filler. To this cause, porous asphalt has not a good resistance against incoming loads and fatigue life of it is down and that's why the cost of maintenance and repair is fitted up. According to the conducted research when the mixture does not provide the expected air and water traffic profile, reclaiming is as a way to improve the characteristics. Modifying the properties of bitumen by polymers causes to improve the quality and resistance of asphaltic mixtures. In this study was used of modified bitumen with SBS polymer for producing the porous asphaltic mixtures and the indirect tensile strength to check the fatigue resistance by the UTM device was done and observed that the mixtures with bitumen showed a better resistance from themselves.

Keywords: *Porous Asphalt, SBS Polymer, Indirect Tensile Resistance, UTM*

INTRODUCTION
The performance of asphaltic concrete pavement depends on the properties of bitumen, characteristics of asphaltic concrete and external factors such as the volume of traffic and the environment. The normal bitumen is exposed to the side range of loading and climate conditions. The higher traffic size will create the more tension into the layer that is one of the main factors for destroying the pavement. Today's all people knew the polymeric bitumen as the bitumen having the better technical characteristics to the normal bitumen. Usage of the polymer in the asphaltic mixture as a modifier started from the 80s in the past century and I a series of the world countries was reviewed. It is essential that the polymer effect to be reviewed on the porous asphalt. Therefore in this study, the use of bitumen modified with the SBS and its effect on the porous asphalt fatigue was evaluated. The aim of this study indicated that the significant differences were shown in the porous asphalt with the polymeric SBS bitumen.

Fatigue Destruction
The fatigue destruction in the asphaltic pavement is a complex phenomenon that occurs via the repeated bending that will lead to the fine damages in the asphaltic pavement. This fine damage is a competitive process between the fine cracking and improvement of finding that will be emerged as the reduction in the stiffness of asphaltic pavement and loading capacity and reduces the capability of resistance against the destructions. Stiffness coefficient of asphaltic mixtures depends on the bitumen stiffness coefficient applied in and size ratio of stone materials to the bitumen size that is shown in the EQ.1. The increase of the stiffness coefficient leads to the mechanical characteristics improvement of asphaltic mixture and consequently increase of the fatigue resistance (Tabatabayi, 2011; Jacobs, 1995).

$s_m = s_b[1 + \left(\frac{2\&5}{n}\right)\left(\frac{c_v}{1-c_v}\right)]^n$(Ziyari *et al.*, 1387)

In this equation:

$n = 0/83log10[(4\&5 \times 10^5)/s_b]$

$$c_v = \frac{c_v}{v_a + v_b}$$

Stiffness coefficient of asphaltic mixture based on the Kg/cm2 $= s_m$
Bitumen stiffness coefficient based on Kg/cm2$= s_b$
Stone materials size=v_a

Bitumen size =v_b

Fatigue cracking occurs when the pavement to be in the medium temperatures. Since that the asphaltic pavement is more fragile in medium temperatures to the higher temperatures tends to cracking and deformity under the repeated loading. First of all when in a asphaltic pavement, cracks will be formed, are so little that could not be seen without the microscope, cracks will not be in this point frequent and under the traffic loading performance, these microscopic cracks will grow slowly in their size and numbers till that to be grown in the very great cracks and shown obviously. The severe fatigue cracking often is introduced as the lizard skin cracking.

These great cracks ill affect significantly on the pavement performance and caused a non-smooth surface to be created and allow the water and air to penetrate into the pavement that causes a great damage to be applied to the structure. Finally the fatigue cracking leads to a wide range of cracking, great wells and finally failure of pavement. The fatigue cracks will be created at the top and bottom of a pavement. The fatigue cracking that begins in the bitumen will be created by the tensional tension that resulted from the bending the pavement layer by the pass of traffic (Erkens and Moral, 1996). The fatigue life of a asphaltic pavement directly depends on the various technical characteristics. The complex microstructure of asphaltic cement is related to the bitumen's aggregate, the blank space and connectability of the blank space.

Consequently the fatigue property of asphaltic mixture s is more complicated and sometimes its prediction is difficult (Xiao *et al.,* 2009). The various combinations for elongation of the life span of pavement's service providing was used via the prevention or delay of the crackings in the pavements without the negative effectiveness upon the various functional parameter s of asphaltic mixtures. In the numerous studies were identified that the resistance of asphaltic mixtures against the deformation of the pavement and fatigue and motivator moisture of damage after using the SBS in the bitumen modifier will be increased (Xiao *et al.,* 2009; Ahmadinia *et al.,* 2011).

Fatigue cracking occurs under bottom layer of asphalt where the accumulated damage by the frequent loads more than the failure limit of the asphalt mixture. Besides the current fatigue cracking, several researchers suppose that Fatigue cracking could be occurred by the tensile tensile or shear stresses or combinations from them in the bottom or surface of the cement layer of asphalt be released. Therefore fatigue cracking could be formed in any place of the pavement structure and grown and specially exists in places that tensile and shear stresses or combination from two kind.

The way of applying the tension s by the load of wheels in the asphaltic layers in Figure 1 and also was shown in the tensile and shear stress ranges in the pavement structure (Monismith *et al.,* 1985).

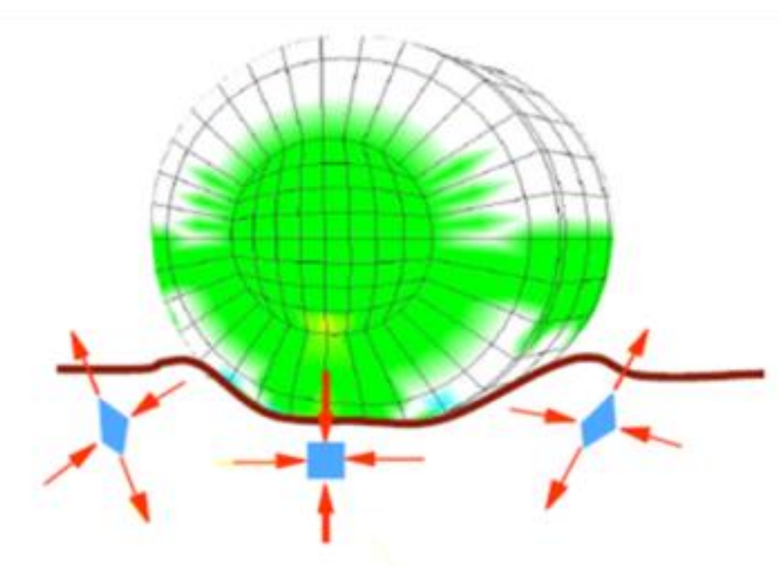

Figure 1: Stress states in a pavement by traffic loading

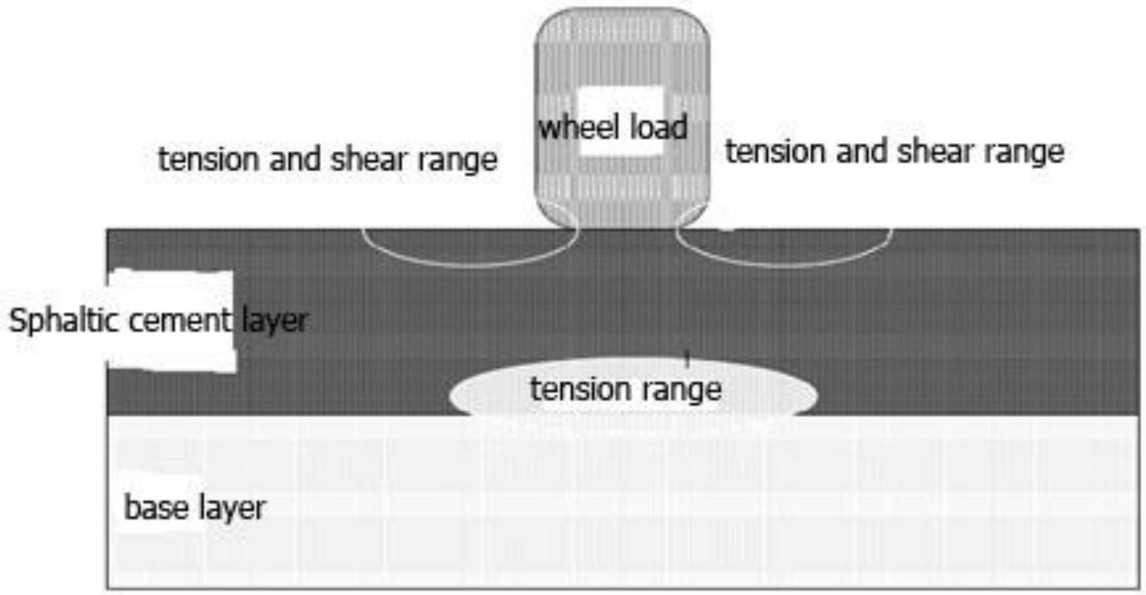

Figure 2: Schematic of shear elasticity and asphaltic cement layers' tension [2]

Totally, the effective parameters upon the fatigue life includes the thickness of asphalt layer, loading limit, form and loading replication, resting duration in loading, compression and asphaltic mixtures properties such as the aggregate size, bitumen type, mixture stiffness , environmental conditions and additives (Hafeez *et al.*, 2013). Epps have investigated the effective factors on the fatigue mage that leads from the bitumen stiffness, aggregate type and seed grading and Air voids content. Another research indicated that the angular aggregates tend to create the stiffest compounds and longer fatigue lives (Monismith *et al.*, 1985). The interaction between bitumen and aggregates in pavements directly affect the Cohesion and bond strength that subsequently affect the crack formation level for traffic level.

The content of aerial cavities has a remarkable effect on the asphaltic cement fatigue life. For achieving the improved aerial cavities, aggregate form, tissue and angularity are considered accurately. The bitumen size which could be attracted in a mixture is related to the mixture level tissue. Aggregates' rough surface provides a best bond between the bitumen and aggregates and such cohesion is require for fatigue resistance (Labib, 1992). Kim *et al.*, (1992) evaluated the effects of mixture variables on the results of tensile fatigue and defined that the bitumen type, aggregate type and test temperature have a remarkable effect upon the fatigue life (Kim *et al.*, 1992). The content of upper air cavity in the porous asphaltic mixtures is the reason of the better performance of this mixture in drainage and noise reduction, but this leads the oxidation rate reduction, adhesive Oil sections' evaporation and Senescence of porous mixture that causes to the stiffness of bitumen and reduced the resistance of asphaltic porous mixture against the tensional strains caused by the traffic loadings and caused to a fatigue cracking during the Lifetime of Service that is the reason of weakness of this kind of asphaltic mixture. Lew and Owski suggested that the main reasons for modification of bitumen materials with different types of additives can be summarized as follows (Lew and Owski, 1994):

Achievement of softer mixtures in low temperatures and reduction of cracking
Achievement of stiffer mixtures in higher temperatures and reduction of shrinkage
Increase of durability and mixtures resistance
Improvement of mixtures' fatigue resistance
Reduction of structural thickness of pavement

Bahia has studied the effect of polymer modification using the electron microscopic images scan. The results showed that the modified asphaltic bitumen mixtures have better the aggregate-bitumen cohesion that leads to the increase of stiffness (Bahia and Anderson, 1995). Bitumen improvement by polymers cause to an improvement in a series of bitumen properties such as more stiffness in higher temperatures, more cracking resistance in low temperatures, better moisture resistance or longer fatigue life (Hafeez *et al.*, 2013). The asphaltic porous mixtures have open Seed composition layout, off course have a little use against the high traffic but have advantages such as reduction in pavement noises, hydroplaning and improvement of penetration and slip resistance. For improvement of indirect tensile strength of mixtures against the fatigue phenomenon based on this fact that the pavement life is one of the important factors for designation of pavement structure based on the economic analysis. Analysis in the porous asphalt for the open structure, oxidation and stiffness, bitumen will be done rapidly. The use of bitumen without additive material in the process of porous mixed asphalts leads that a permanent deformation and bitumen subsidence to be created in high temperatures and long time loading and in low temperatures mechanical cracks in asphaltic mixture under the stiffness of bitumen. The SBS modified bitumen is used for this type of mixture (Alataş and Yilmaz, 2013). A method for overcome to the fatigue cracking is use of asphaltic mixture that adequately to be hard to resist against the deformation and have a sufficient resistance to with stand shear and tensile stresses and may be that the improvement of cracking performance improvement be possible via the asphaltic modifier's usage. The polymers as the most important modifiers family to improve the performance and increase of the bitumen function is added that among the present polymers, SBS polymer is one of the best modifier materials for bitumen (Mayers, 2000).

Operation Mechanism of SBS in Bitumen

SBS includes two polymer blocks which the final block is transverse-connected to the middle blocks of poly-butadiene in a 3d net. The hard final blocks of Polystyrene in the high temperatures by increase of soft point and reduction of penetration degree cause to improve the resistance of shrinkage and bitumen subsidence in the asphaltic mixture, while that among the rubber blocks, are responsible for its flexibility and fatigue resistance in low temperatures. When the bitumen and SBS are mixed together, the final blocks regions of Polystyrene begin to soften and crossover structure of polymer weakens and the middle blocks of poly- Butadiene attracts the bitumen's Maltyn section and will be swollen 9-10 times of its original volume.

This inflation causes that the rubber phase of SBS overcomes the bitumen phase and leads to a new modified bitumen that contains important rubber properties. After being cold the modified bitumen, the polystyrene block's regions again becomes hard and creates cross connections among the rubber blocks and forms a powerful 3d net (Vonk *et al.*,; Mahmoud, 1995).

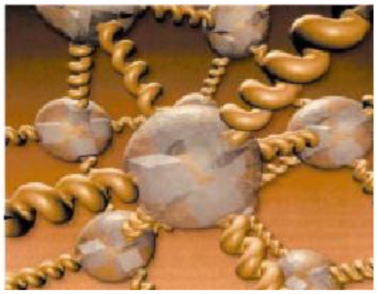

Figure 3: Schematic design of combination of SBS molecules with bitumen, polymer volume increases 9 times after exposure to bitumen (Morgan and Mulder, 1995)

By increasing the SBS polymer to the bitumen, its permeability will be decreases, and its reason is this that the SBS polymer at the same time has the elasticity and Thermoplastic property. Therefore, a 3D net composed of polystyrene and the middle part of Poly-butadyiene are created in bitumen that polystyrene parts causes the viscosity of bitumen to be increased and as a result causes the bitumen penetration grade to be decreased. The reason for increase ins softness point with the increase in the amount of SBS polymer is ties that by increasing the temperature, the polystyrene parts melt and Thermoplastic elastomer achieve the molted state, that its result is forming the Flexible polymer chains in the bitumen environment and finally forming the 3d net in the internal structure of bitumen that increases the elasticity and also viscosity of the mixture, and consequently increased fluidity of bitumen at higher temperatures. SBS polymer by creation of 3d continuous nets in the bitumen, by increase of bitumen viscosity and cooping the bituminous materials in it prevent weight loss of it in effect of bitumen's resins and preventing from bitumen stiffness. Reduction of Firas reduction point, by ***polymer increase*** could be due to this that SBS polymer has the styrene-butadiene links. Poly-butadiene elastomer due to having the more elastic feature, within the SBS polymer net causes to flexibility in bitumen and finally its cracking will be reduced that is counted as important issues in low temperatures (Ziyari *et al.*, 1999). Isacsson (1995) indicated that using the modified polymeric bitumen is achieving to the better functionality of asphaltic pavement for long life the aim of bitumen improvement is production of bitumen materials modified ideally with high resistance for permanent deformation and fatigue cracking, and modified bitumen mixtures of SBS have long lasting life than common mixtures (Isacsson and Lu, 1995).

For modified asphaltic polymeric mixtures, the other studies showed that the fatigue life of samples which were modified by polymer are approximately 2-4 times more than the simple cases and this is for the reduction of fine cracks that is because of polymeric chain in asphalt (Newman, 2004). The modified mixtures of SBS polymer have a high ratio of energy than the non-modified mixtures and ties leads to a better resistance against the cracking from top to down. As a result SBS polymeric modifiers have a high effect upon the time-dependent response to the Reactionary response of mixtures and improve the mixture resistance to the cracking beginnings (Kim *et al.*, 2013). Kim *et al.*, (2013) suggested that the advantage of SBS in asphaltic mixtures in delaying the fatigue cracking growth is more principle than the beginning the fatigue under the indirect tensile loading (Kim *et al.*, 2013).

Awanti *et al.*, (2008) have identified that Marshal resistance and polymer Asphalt's stability is more than the usual asphalt and indirect tensile strength of polymer asphalt is more than the common asphalt in the various temperatures and sensitivity of polymer asphalt is low than the common asphalt against the moisture (Awanti *et al.*, 2008). Khalid (2011) base on a research indicated that the penetration grade of bitumen will be decreased by its modification and also by increasing the Co-polymer 's content, the bitumen stiffness is increased too and also suggested that the increase of polymer causes that the resistance significantly to be increased against the deformation and marshal resistance (Khalid, 2011). By studying the functional properties of SBS is identified that is one of the polymer types for improvement of porous asphalt fatigue properties.

SBS Levels Used in Modified Bitumen

Dosage of polymeric content defined for most of usages generally is various between 2 % and 10 % of bitumen content. Of course the most common cases of ratios were about 5 or 6 %. These low percentages (lower than 4 %) of bitumen polymer, the phase is periodic and polymeric phase will be released via it. Briefly, the outspread polymer phase will strengthen the bitumen properties in low and high temperatures. In the other words, polymer increases the useful temperature range for asphalt (Becker *et al.*, 2001). Airy investigated the SBS polymer modification upon the common polymer. Although the reduction in the penetration relatively is along with the increase in the polymer content but significant increase in the softness point in the polymeric content higher than 5 % and 7 % exists. Besides the increase in the stiffness, more penetration index indicates the significant reduction in the temporal sensitivity by the polymeric modification especially in the polymeric content (Airey, 2003). Lu and Isacsson indicated that the modification by SBS polymer increases the bitumen stiffness in high temperatures and causes to improve the flexibility in low temperatures. In a research by Shahabi *et al.*, (2012) indicated that SBS content determined for increase of the fatigue life of improved asphalt approximately 5 % of bitumen weight (Shahabi *et al.*, 2012). Most of the modified mixtures by SBS polymer tend to being used in polymeric concentrations about 3 % of bitumen weight. Of course in Australia, SBS concentration in one range of 3 % will cover to more than 7 % (Oliver *et al.*, 2012). Kumar and Singh (2013) have suggested that the modified bitumen is stiffer than the usual bitumen and the increase of resistance in the polymer content is between 3-5 % more. The increase of SBS content leads to a reduction of penetration grade to a critical concentration about 5 % and when the SBS polymer concentration is up to 55 %, the polymer

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phases both will be periodic; therefore the 5 % concentration is suggested as the improved content for improvement of penetration grade (Singh *et al.*, 2013). On the modification level with 4% of SBS is possible that the expanded polymer not to be existed in the bitumen or only to be as a brittle phase. This causes that the resistance of shrinkage to be improved and fatigue resistance also principally to be improved too. But the better improvement is done when the developed polymer occupies the periodic phase and a polymer0rich phase for achieving the improved resistance is required for cracking. This continuity of polymer-rich phase generally occurs 5 % more. When the concentration of polymer increases, SBS gradually is being inflated by the Maltyn section of bitumen and forms a continuous phase. In 5 % concentration of SBS is a reverse-phase condensation that severely changes the modified morphology by SBS and a variation can be shown in the softness point and intrusive profiles. For lower concentration than Reverse phase condensation, SBS will form a discrete phase. On the other hand for more concentrations, bitumen will achieve a discrete phase. Chen *et al.*, have investigated the effect of SBS on the PMA function and suggested that when the polymer concentration is about 5%, bitumen and polymer phase are both periodic. Each phase forms a matrix connected together. In the concentration more than %, SBS of matrix becomes superior and forms an alternate strip around the approximate bitumen molecules. Besides, due to the improvements of softness and permeability degree beings to being fixed in the concentrations more than 6 % (Chen and Huang, 2006). The results by Airey *et al.*, (2002) showed that SBS concentrations are required from 4-8 % for producing the a polymeric net for bitumen modification (Airey *et al.*, 2002). One of the outstanding methods for improving the asphaltic functions is entering the polymer in range of percentages from 3-7% of bitumen weight (Modarres, 2013). The use of SBS content in high ration is expensive and it is possible leads to a mixture with Less functionality. In the action use of 6 % additive or less is common. Although, economically it is not acceptable that we use more than 6 % (Mahmoud, 1995). Faraj (2010) for investigation of polymer effect on the comprehensive asphalt's fatigue resistance used of 60.70 that modified by SBS in 4 levels of various modification of bitumen volume (3%, 5 %, 7 %, 10 %). The use of polymer in 3 % of bitumen weight has no effect on physical and mechanical feature of bitumen and in these percentages, polymers acts as a filler material. The impact of modification levels of 5, 7 and 10 % of weight of bitumen is like the 5 % functional level then the improved modification level is 5 % (Khodary, 2010). According to the performed studies which showed the bitumen modification by SBS polymer caused for bitumen features improvement and this issue affects the increase of resistance in fatigue of asphaltic mixtures, in this research according to the aforementioned research records, we started the modification levels of bitumen from 3 %.

Evaluation of Fatigue Resistance using the Tension Method or Constant Strain

The evaluation of fatigue resistance is performed in several methods, the fatigue method based on Fracture mechanics, tension method or constant strain. Khattak and Baladi (2001) reported that two types of controlled loading could be applied, control tension and strain control. In the strain control test, the strain remains stable and load or tension will be reduced with number of repetitions, in the control test of tension, the tension is stable, but the strain with the number of repetition is increases till the rupture occurred.

The application of a constant tension has advantages that caused to a faster failure and is defined easier. The relation between the number of cycles for rupturing and initial tension or initial strain can be presented with bellow equation (Khattak and Baladi, 2001).

$$Nf = a(\frac{1}{\varepsilon_0})^b *$$

$$Nf = d(\frac{1}{\sigma_0})^e *$$

That Nf is the number of cycles led to rupture

$first\ tension$
$first\ strain =$
$mixtures\ stiff$

a, b, c, d, e, f Experimental Defined Coefficients
Hadley in 1970 evaluated the asphaltic cement features using the indirect tensile test the general conditions which can be identified from the indirect tension includes the elastic features, fatigue cracking and features related with permanent deformation (Hadley *et al.,* 1970). Read *et al.,* (1996) used the indirect tensile fatigue test for evaluation of fatigue life of asphaltic cement mixtures. The deformation of horizontal deformation during the indirect tensile fatigue test is registered as a function of loading cycle (Read, 1996).

The Consumed Materials

The bitumen used for mixture is the 60.70 bitumen from Tehran refinery that some of these bitumen according to the performed experiments are as table 1.

Table 1: Results of 60.70 bitumen experiments

Results	**Experiment method**		**Pure bitumen testing**
	AASHTO	**ASTM**	
1.1016	T228	D70	**Specific gravity at 25.c**
65	T49	D5	**Degree of penetration at 25 ° c**
49	T53	D36	**Soft spot in centigrade**
291	T48	D92	**the degree of combustion Depending on centigrade**
1001	T201	D2170	**Slow kinematics at 120 °**
457	T201	D2170	**Slow kinematics at 135 °**

According to the presented contents in this research for evaluation of fatigue resistance and structure of porous asphalt mixture from 60.70 pure bitumen as the base bitumen was used that for modification of its properties was used of SBS polymer. SBS with 4 levels of 3 % and 5 % and 6 % and 7 % of base bitumen weight and temperature of 5 and 25 degrees under the 200 k Pascals and were performed an experiment of indirect tensile fatigue. In this research for construction of porous asphalt mixture was used of aggregate size presented in the Iran Pavement Regulations according to the table 2 and performing the required experiments on the stone aggregates was identified that whole properties is in is the extent permitted by Iran pavement regulations [2].

Table 2: Size of aggregate mixture

Screen size	**3.4 inch**	**1.2 inch**	**3.8 inch**	**4**	**4**	**200**
Percent rejected	100	99	75	18	8	2

In this research for modification of bitumen was used of SBS and its characteristics is in table 3.

Table 3: Physical characteristics of SBS

Physical properties (SBS)	**Unit**
Density	^{3}1240kg/m
Young's modulus (E)	Mpa2800-3100
(σ_t)Tensile strength	Mpa 30-50
Melting point	180 ° C

In order to mix process, initially bitumen will be heat to 160 ° c in the oven then SBS polymer particles is added to the 60.70 bitumen within the mixer and during 10 min with low cycle 200 rpm was mixed with bitumen to the initial mixture and the initial net formed with polymer within the bitumen prevents from more variation of bitumen properties under the effect of increase in temperature for the second mixture. Then bitumen increases to the 180 degrees.
And SBS polymer ad bitumen with high speed 3000 rpm during 30 min will be mixed with together. The mixer that was shown in figure 4 have two shaft that one with rotation, powdered uniformly the polymer particles and other one with rotation will create the sheer force.

Figure 4: Mixer having the shear and rotation shafts for production of polymer bitumen

MIX Plan of Porous Asphaltic Mixture
In the process of porous asphalt for the structural features of this asphalt, preparation of maximum blank space, marshal perseverance, minimum allowed subsidence and Kantabro Abrasion as the main criteria.
In this method, a minimum and maximum rate for improved bitumen is defined that minimum rate of it is identified based on the erosion of asphalt in the experiment of Kantabro and maximum rate of bitumen according to the subsidence limit of bitumen is identified (Ruiz *et al.*, 1990).
For identifying the percentage of improved bitumen, with percentages of 4.5-5.5 were prepared and after the processing, using the Aggregator Device, the special weight of compacted samples were identified.
Also in each percentage of bitumen, two non-compacted asphaltic mixture were prepared and maximum specific weight of theory and subsidence percentage of bitumen of mixture were identified and based on the ASTMD7064 standards, the 5 % improved bitumen was selected that for producing the porous asphalt in this research was used, the technical characteristics of produced sample with improved bitumen is in accordance with table 4.

Table 4: Asphalt sample characteristics with 5 % of improved bitumen and comparison with standard range ASTMD7064

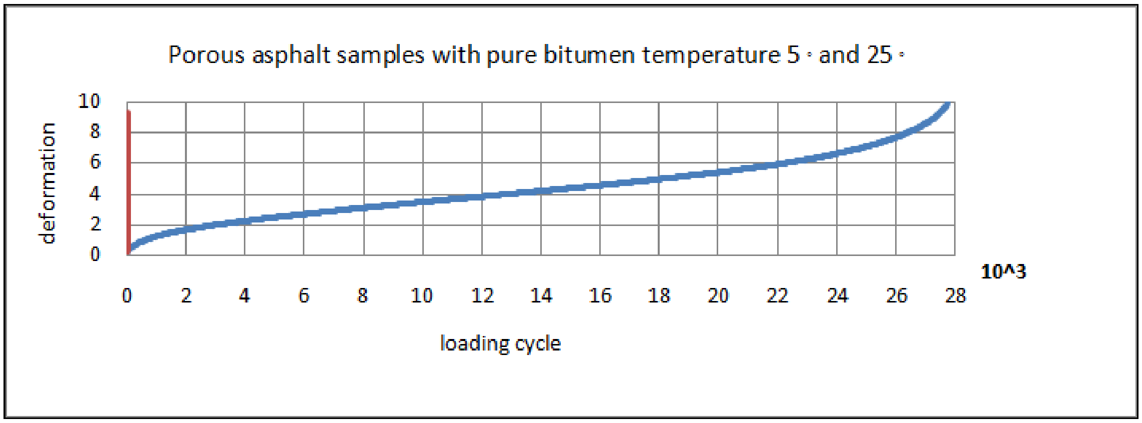
Specifications	The mean specific weight (G_{mb})	The theoretical maximum specific (G_{mm})gravity	Subsidence of the asphalt	Percentage of free space (Va)	Percent of the wear indicator
Experiment method	3203 ASTM D	209 AASHTO-T	6390 ASTM D		
amount	**1.9**	**2.524**	**0.06**	**25**	**24.3**
standard			**0.03□**	**□18**	**□25**

Evaluation of Porous Fatigue Resistance with Polymeric Bitumen
Test of indirect tensile fatigue for calculation of required loading for creation of rupturing in a sample by beginning of cracking is used. To evaluate the polymer bitumen effect on the porous asphalt fatigue

resistance was used of indirect tension test and UTM-14P apparatus. This method covers the loading size, repeat and times of loading.
As is seen in figure in this apparatus by applying the constant tension by loading shaft, the deformation rate was measured in two sensors every time and is recorded by record system and this loading continues to the rupture moment. Kim (2003) reported that the fatigue cracking is an asphalt failure that usually will occur in medium temperatures. According to this, 25 ° c is identified as the test temperature for identifying the fatigue life of asphaltic cement mixtures was selected. Roberts *et al.*, (1996) suggested reasons for use of modifiers in asphaltic cement for production of softer mixtures in low service temperature for achieving a Thermal cracking and improvement of fatigue resistance of asphaltic pavement (Kim *et al.*, 2001; Roberts *et al.*, 1996). Modarres (2013) by investigating the fatigue resistance indicated that in the heavy loading conditions, fatigue rupturing in low temperature to medium is more critical and in the lighter loading conditions , the fatigue rupturing in the low temperature is not critical (Modarres, 2013).
According to the researcher were done, temperatures that are recommended as standards including the 5 and 25 degrees. Tension level that in this test was used 200 k Pascal and test temperatures is 5 and 25 degrees.

Figure 5: Scheme of loading shaft and measurement sensors of UTM deformation

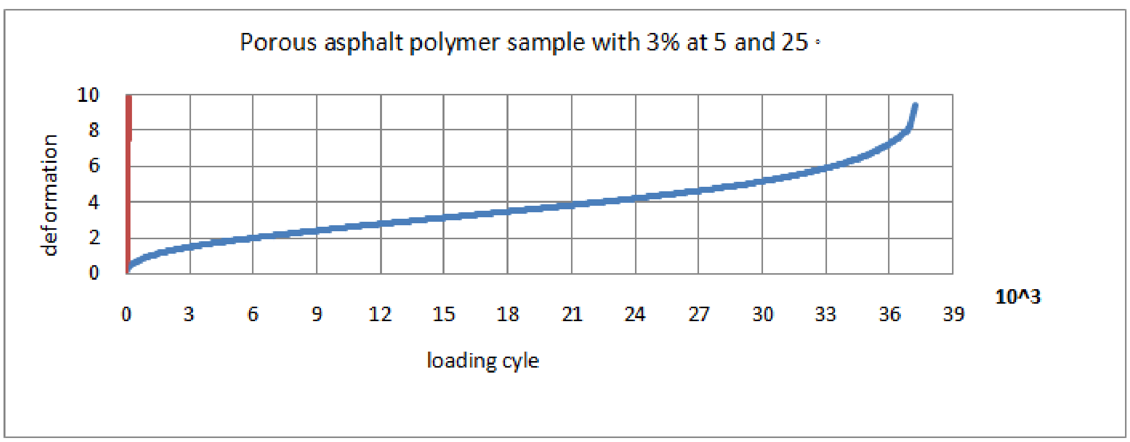
4 inch Cylindrical specimens of asphaltic porous mixture by Spin density method and With 50 rotation using the pure bitumen and modified bitumen with 3, 5, 6 and 7 % of bitumen weight was made. In this experiment, loading cycle time is equal with 1500ms, time of applying the load equals to 250 ms and resting time in each loading time equals to 1250 ms were used. After placing the samples in the apparatus, they were under the repeated diametrical loading and horizontal diametrical loading using two LVDTs was measured that each one were placed in one 90 axis of applied force. Totally two LVDTs installed for controlling the vertical deformation to 10mm was used.
Fatigue Test Results
Number of loading cycle's number for rupturing of sample is defined as the fatigue life for asphaltic cement mixtures. It can be seen that the modified bitumen function will improve the mixtures features. According to these results, using the SBS modifier, vertical deformation will be reduced significantly. The resistance in front of stable deformation is related to the type of modifier and modification level. The non-modified asphaltic cement mixtures having the high deformation and bear less loading cycles to the rupturing level. First of all, asphaltic mixtures made by pure bitumen in 5 and 25 degrees were under indirect tension fatigue that its results are seen in figure 6. As is seen by increase of temperature, the resistance of porous asphaltic mixture is reduced that indicates the weakness of this mixture in high temperature. By increasing the temperature, the bitumen viscosity is reduced that causes a subsidence in bitumen and reduction in continuity between bitumen and aggregate that by repeated loading causes to a repeated deformation of asphaltic mixture. Then we need to a better resistance that in the next experiments, the effect of this modification to be investigated.



------ With pure bitumen in 5 ° c
------ With pure bitumen in 25° c

Figure 6: The deformation graph in front of loading cycle in asphaltic loading with pure bitumen in 5 and 25° c

In figure 7 is indicated that by adding 3 % SBS polymer, we have not a significant increase in the number of loading cycles. Due to that in the low percentages, bitumen polymer is the periodic phase system and will be scatted by it and finally does not affect the physical and mechanical characteristics of porous asphaltic mixture and more acts as filler.

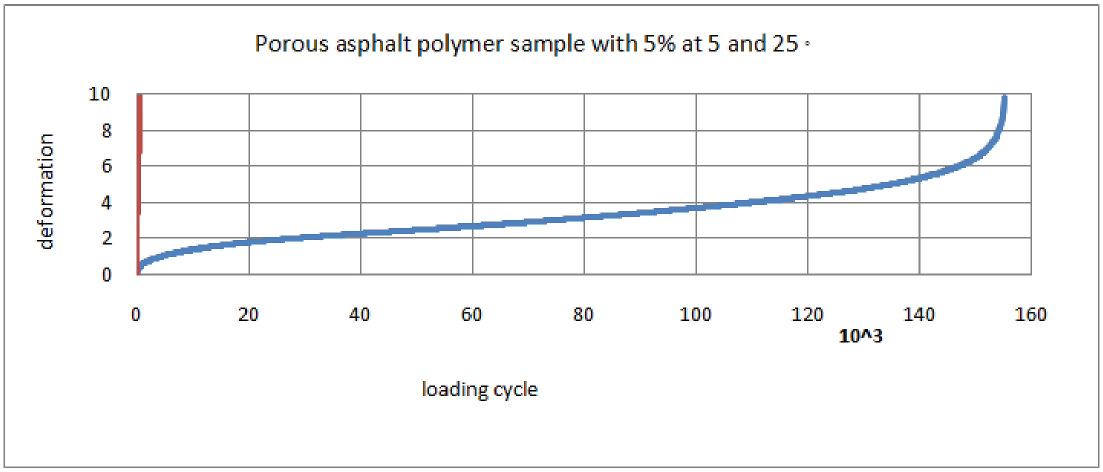


------ With 3% bitumen in 5° c
------ With 3 % polymer in 25° c

Figure 7: Deformation graph in front of loading cycle in asphaltic mixture with modified bitumen with SBS 3 % polymer in temperature of 5 and 25 ° c by 5 % increase of SBS polymer

There was seen a significant improvement in number of loading cycles in 5 and 25° c in figure 8 according to the SBS polymer structure that includes the polystyrene and poly-butadiene that simultaneously have the thermoplastic and rubber properties.

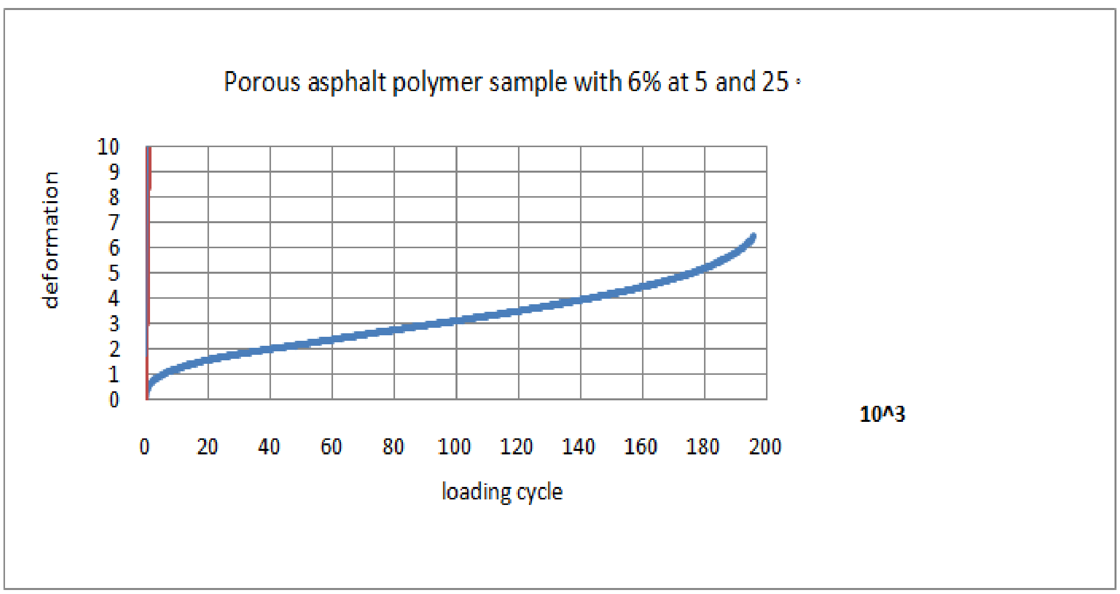
That in high temperature, poly-styrene increases the viscosity and finally reduction of bitumen penetration degree and increase of continuity of bitumen and aggregate and in low temperatures due to the presence of poly-butadiene molecules having the tensile properties and increases the flexibility and friability of it will be reduced and its fatigue resistance of porous asphaltic mixture was improved.



------ With 5 % polymer in 5° c
------ With 5 % polymer in 25° c

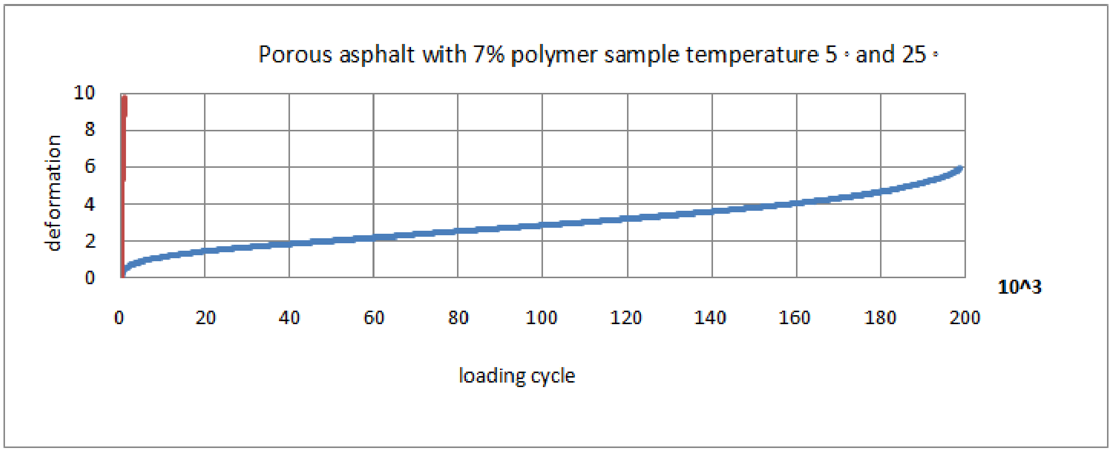
Figure 8: The graph of deformation in front of loading cycle in asphaltic mixture with modified bitumen by 5 % SBS polymer in 5 and 25 degrees

As is seen in figure 9 and 10 by adding 6 and 7 % of SBS polymer, the loading cycles numbers has 5 % increase to the modification level and the rate of deformation is reduced. Due to the time limit of performing the experiment loading was done to 200000 cycles. In these two levels of modification the rate of deformations and number of loading cycles are very close to together that its reason could be the stability of geological features of bitumen in the modification level higher than 6 %.



------ With 6 % polymer in 5° c
------ With 6 % polymer in 25° c

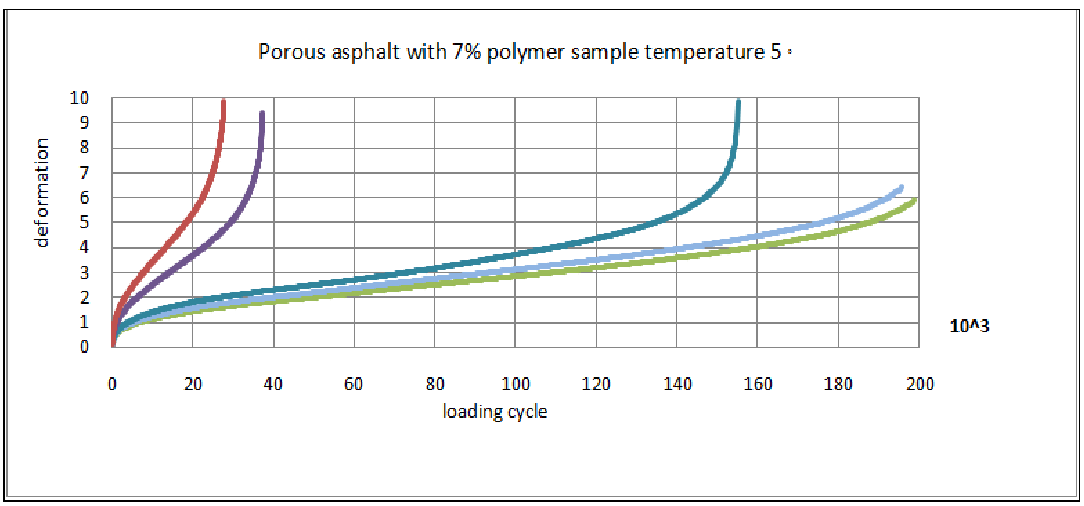
Figure 9: The deformation graph in front of loading cycle in the asphaltic mixture with modified bitumen by 6 % SBS polymer in 5 and 25 degrees



------ With 7 % polymer in 5° c
------ With 7 % polymer in 25° c

Figure 10: Deformation graph in front of loading cycle in asphaltic loading with modified asphalt with modified bitumen with SBS 7 % in 5 ° and 25° c

By modifying the bitumen by SBS polymer in 5 degree and comparing it with the porous asphaltic mixture made by pure bitumen as is observed in figure 11. The cycles of loading have been increased that this is in the porous asphaltic mixture with 3 % polymer about 1.5 time and with 5 % of polymer to more than 5 time and in the porous asphaltic mixture with 6 % and 7 % of polymer to more than 7 time is reached. The increase of fatigue life in low temperature of modified mixtures with SBS can be related with the effect of middle of rubber blocks of poly-butadiene that by creating the more Resilience and flexibility state, the asphaltic mixture features in the low temperatures will be improved.



------ With 7 % polymer in 5° c
------ With 6 % polymer in 5° c
------ With 5 % polymer in 5° c
------ With 3 % polymer in 5° c
------ With pure bitumen polymer in 5° c

Figure 11: The graph of deformation in front of loading cycle in asphaltic mixture with modified bitumen and pure bitumen in 5° c

By increase of temperature to 25 °c and implementing the fatigue tests as is shown in figure 12.
The porous asphaltic mixture without polymer additive could not show any resistance from itself and in the same initial cycles were ruptured but in the asphaltic mixtures with polymer indicated a significant resistance. That this resistance in the asphaltic porous mixture was improved with 3 % of polymer about 6 time and 5 % of polymer about 29 time and in the asphaltic mixture with 5 % of polymer about 36 time and 7 % of polymer about 38 time that this indicates the weakness of asphaltic porous mixture in high temperature and needs the use of modified bitumen. By modification of SBS polymer, 3d net made of polystyrene and middle parts of poly-butadiene in the bitumen will be created that increases the viscosity of bitumen in high temperatures and increase of continuity between bitumen and aggregate and this increase in the viscosity increases the tensile and compressive pressure of asphaltic mixtures. Since that the fatigue is created by tension, improvement in the tensile resistance feature of mixture is found in form of improvement in the fatigue resistance that this issue indicating the relation between the improvement of fatigue resistance and use of polymeric bitumen.

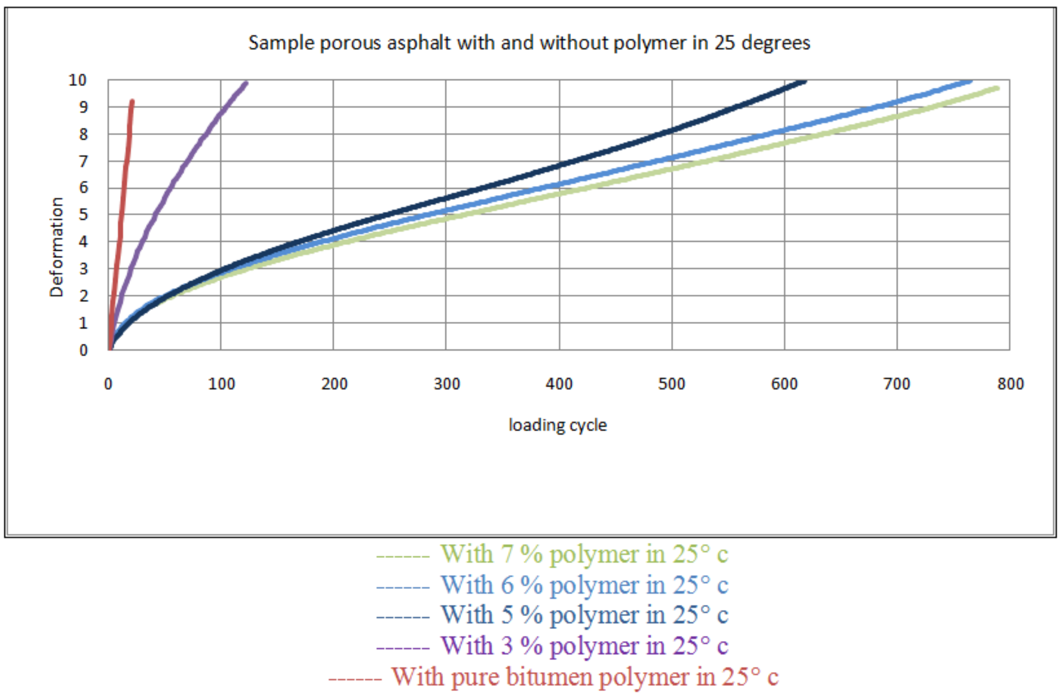


Figure 12: The deformation graph in front of loading cycle in asphaltic mixture with asphaltic mixture modified and pure in 25 degrees

Conclusion

After performing the indirect tensile fatigue tests of porous asphaltic mixtures with SBS and after data analysis and comparison of results, the following results are achieved:

1- The modified asphaltic mixtures showed from themselves better fatigue resistance in comparison with non-modified mixtures.

2- Totally, the use of SBS polymer in asphaltic mixture reduces the deformation of asphalt and produces the fatigue resistance and better continuity between the bitumen and aggregates.

3- Since that behaviors and results of porous asphaltic mixtures tests with 6 and 7 % 0f polymer are close together and due to economic considerations, the modification level of 6 % is suggested as the improved percentage.

4- Although the use of polymeric bitumen causes the initial expenses of project to be increased but this expense causes the continuity and stability of pavement function during the exploitation of it to be in an acceptable level and finally reduces the maintenance costs of porous asphalt mixtures.

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