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Effect of Using Anti-Stripping on Fracture Behavior of Asphalt Mixtures Using Linear Elastic Fracture Mechanic (LEFM) Technic

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ABSTRACT
Today, cracking asphalt pavement in low temperature is one of the obstacles for protecting pavement in the cold climates. One of important factors in extending of these types of cracking is cooling and heating temperature cycles according to the changes in seasons. Therefore, this research examines these types of asphalt cracking by considering asphalt mixtures and using mechanics science. In this research, cold environmental conditions were determined by making asphalt gyratory asphalt samples and fracture test in -15°C to study the effect of asphalt mixtures important parameters, it means asphalt construction materials textile on fracture resistance of samples. On the other hand, simultaneous effect of two parameters on asphalt fracture resistance was examined by considering the effect of freezing and thawing cycles, as well as using siliceous and calcareous materials. In addition, the effect of this material was studied to improve asphalt properties and fracture resistance by introducing antistripping material.

Keyword:
antistripping, behavior analysis, asphalt mixtures, linear elastic fracture

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INTRODUCTION

Fracture mechanics is one of important issues in mechanical engineering, which studies the fracture process, its prediction, and control in the cracked materials. In this branch of mechanical engineering used extensively today in various engineering fields, germination, and growth of cracks, fracture criteria, and strength, fatigue, and creep phenomena in cracked materials must be examined. Since fracture occurs in many engineering segments and causes their final fracture, it is essential to study fracture mechanical issues to find fracture behavior and properties of cracked samples, and fracture criterions of materials more than ever. Researchers found out in studying the reasons of fracture that designing many structures based on the common methods have been proper; however, it was concluded after research that the main factor of fracture were defects and very tiny fractures in structure or which were made while working with them [1]. According to the energy conception, fracture occurs when the needed energy to grow crack or fracture is enough to cope with the resistances among the present elements. Griffiths used this concept for the first time to examine the fracture behavior of brittle materials.

LEFM theory can states the fracture level approximately if plastic area is smaller than the fracture size. LEFM technology is related to the magnitude of stress and distribution around fracture peal to the partial inserted stress to the structural element. Stress intensity factor (SIF), K_1, will lose its meaning when plastic area is more extended, the critical SIF, K_{1C}, was designed for unstable fracture for mode (I) change and small plastic mode changes. K_{1C} is the instinct ability of materials to resist against the inserted stress intensities in fracture peak and resistance against the extension of tensile stress. (2)

Fracture mechanic theory is mainly generalized for fractures extension parts and assumed that this part has the maximum role in determination resulted damages by load repetitions and the rested lifetime of pavements. There are always porosities in asphalt materials, and fracture develops with higher rate while contacting to porosities. This development continues until it reaches its critical length. In this time, fracture develops suddenly and leads to detachment of layer. Fractures are the most significant failures on pavements that are an inconsistency on pavement with minimum width of 1mm and minimum length of 25mm according to AASHTO regulations [3]. Fracture occurs by various factors such as traffic load, temperature changes, and underlying subsidence. The fracture reason is principally temperature changes and traffic load extend and develop fractures more. In high temperatures, the main model of fracture in asphalt concrete is rutting, but fracture usually occurs in asphalt pavements in low temperature, and this makes asphalt to fracture without so many changes in appearance. Yet, friction between asphalt and the base layer resists against contraction. If the tensile stress made in asphalt equals to the tensile strength is asphalt mixtures, a small fracture is made in edge and surface of asphalt, in lower temperatures the occurred fracture penetrates in all depth and width of asphalt layer. [4]

By literature review, it is understood that selecting the geometry and specifications of laboratory samples of asphalt fracture mechanic are significantly important. Many researchers have studied all various types of proper sample to test fracture in this field. Therefore, Majidazadeh et al. were the first ones who studied about selecting proper sample. [5] Aliha et al. (2013) studied the effect of each asphalt properties such as type of aggregation, type of aggregate, and type of tar based on the latest studies on asphalt fracturing resistance. They conducted fracture mechanics tests using SCB samples in very high number of samples. Aliha et al. tested their samples in -15°C to check low temperature thermal fractures and two siliceous and calcareous samples. The suggested the following results from their experiments using elastic fracture theory in various loading modes.

Li ad Marasteanu conducted semi-circle bending tests and fracture mechanics conceptions in two -30°C and -40°C to examine asphalt mixture in low temperature. In order to make flat bending mode, 3 asphalt samples with 25 mm thickness were prepared. The circular samples with 25mm thickness from the congested asphalt samples were prepared by gyratory compaction technique, which has 150mm thickness (10).

Zollinger and Mossad [8] conducted research about the damages by thermal changes on asphalt in recent years. They studied on fracture resistance against thermal changes using fracture energy level. They showed the adhesion between aggregate and tar in various temperatures which energy levels reduced significantly by increasing relative humidity. On the other hand, researchers [9] didn't work on the effect of humidity sensitivity on fracture resistance of asphalt mixtures anymore. They concluded by offering the following diagrams that anti-stripping agents can have significant effect on fracture resistance and energy level. In addition, they showed that the aggregate sizes could be effective on fracture resistance by thermal changes.

Considering the low temperature fractures in this research as the most important present fractures on asphalt pavements in the cold climates, they studied the effect of aggregates on asphalt fracture resistance. On one hand, fracture melting and glacial cycle as one of the most important factor of humidity sensitive was analyzed as an effective factor on asphalt fracture resistance. On another hand, using LEFM equations showed the effect of each main parameters of asphalt on fracture resistance or fracture toughness. It must be mentioned that humidity sensitivity was calculated by TSR criterion for research samples and their relationships with fracture toughness was examined. Consequently, simultaneous effect of melting and glacial cycle and type of consumed materials aggregates was studied on fracture toughness.

Methods and Materials:

Various asphalt mixtures for laboratory plan were considered in this research for fracture mechanics tests. The used stone materials to prepare asphalt concrete mixtures must be clean and dust free. Coarse sand and aggregates are loader elements in asphalt mixtures, in this research, material, was used from two calcareous and siliceous materials were used to study one of the most important parameters. Calcareous stone materials were prepared from

Asbcheran mine in Rudehen city and siliceous material was prepared from mine of Shahray Karaj city

Table (1): specifications of stone materials

Specifications	*Siliceous materials*	*Building lime*	*Limits*	
			Esther	*procedure*
Maximum wear by Los Angeles	14%	21.1%	40	30
The maximum ductility coefficient method BS812	8%	9%	30	25
The minimum percentage of fractures on both sides of the sieve (4)	92%	93%	80	90
The maximum water absorption of coarse aggregate	1.8%	2.1%	2.5	2.5
The maximum water absorption aggregate	1.3%	2.4%	2.8	2.8

In this research, the consumed tar was net tar type 60/70 prepared from Pasargad Oil Company. Various experiments were conducted on tar specifications, which are shown in table (2).

Table (2): Consumed tar specifications

Specifications	*Bitumen 60/70*	*Test*
Specific gravity at 25 ° C	1.02	ASTM D-70
Penetration at 25 ° C	63	ASTM D-5
Softening point (° C)	51	ASTM D-36
Gum plasticity at 25 ° C	104	ASTM D-113
Flash point	297	ASTM D-92

Materials aggregations were based on the present seize in Iran asphalt pavements routs regulations for No.4 (journal 234) aggregates. The element application and extensive laboratory application of this aggregate is the reasons of using this number.

Table (3) – aggregates No. 4, (journal 234)

Screen size (Mm)	*Rejected wt% of each sieve*	
	upper line	*Low*
19	100	100
12.5	100	90
4.75	74	44
2.36	58	28
0.3	21	5
0.075	10	2

Determination of Marshall resistance and versatility amounts of asphalt samples: after determination of the specific real weight of asphalt mixtures, samples put in full-water plate in 60°C for 30 min. Then, Marshal System gets warm and lubricated. After the determined time, samples were put inside system one by one, and then jack of loading Marshal system is inserted with 50.8 mm/min to samples, and maximum load on sample and maximum deformation by sample were recorded which were proposed as versatility . These two numbers were resistance and versatility of each sample. Resistance based on kg and versatility based on mm is recorded. After determination of the samples heights, Marshal resistance are modified based on reported ones in table of ASTM-D1559.

Rice test: Rice test was conducted to determine the porosity percentage and maximum specific weight of asphalt mixture, which are used to calculate the maximum specific of asphalt mixture. This test is conducted as warming two asphalt samples from different tar percentages, which are near to each other and consider for test. After warming and rushing them, they were put in 150gr in air evacuation containers to excavate air of sample completely. Then, it must be weighted accurately. Consequently, certain relations calculate the maximum specific weight of asphalt concrete.

Fracture test: in this part, experimental fracture test is explained. Calcareous and siliceous samples were put in refrigerator, respectively in -15°C for 24 hr. fracture apparatus is transferred with 60 ton capacity transfers the inserted loads to it by the beneath connected fixture device and load-movement is recorded by computer. First, fixture is set to put fulcrums in proper places. According to experiment values, the distance of fulcrums from load insert place was 5 cm in mode 1. After fastening fulcrum, samples were put out, put on fulcrums, set on constant rate of 3 mm/min by computer. Results as load-movement diagrams were recorded after loading with the mentioned rate.

Modeling the samples software: in this research, finite element meshing is shown for 2800 eight-point elements in flat tension mode. Since materials are under 0°C, model is linear and homogenous elastic. Young's modulus and Poisson's modulus for materials of SCB samples were considered 12500Mpa and 0.35 Mpa, respectively. For the modeled sample, load is inserted in the central axial point fir 1kN. Boundary conditions include replacement in two prohibited direction using the constraints in left and right fulcrums to prevent from vertical replacements in fulcrums. Finally, stress intensity factor (SIF) is calculated using ABAQUS software and line integral method. SIF is calculated for various fracture points having S_1 and S_2 and knowing fracture length. [29]

Findings

Many analyses were conducted on them after determination SIF and TSR amounts of laboratorial samples. In this research, the effect of each parameter is studied such as adding additives in asphalt mixture and thermal cycle effect.

Table (4): results of TSR test on various samples

Material	***Type***	***Dry tensile strength***	***Saturated tensile strength***	***TSR***
Siliceous	pure	483	312	64%
	With antistripping	490	407	83%
Mountainous	pure	539	476	88%
	With antistripping	541	485	90%

As it is observed in table (4), the siliceous and calcareous aggregates in both groups were increased by adding TSR antistripping to samples. Consequently, resistance increased against humidity. Another result is resistance against humidity in asphalt samples made by calcareous aggregates is more than by siliceous aggregates. The results of fracture test in saturated and dry modes are shown in table (5) by considering the mean SIF for experimental data analysis:

Table (5) – summary of fracture test results

Material	***Temperature condition***	***Mixture type***	***K in dry mode***	***K in saturated mode***
Siliceous	Constant	pure	1.11	1.03
		With antistripping	1.10	1
	Cyclic	pure	1	0.79
		With antistripping	1.04	0.99
Mountainous	Constant	pure	1.28	1.22
		With antistripping	1.29	1.22
	Cyclic	pure	1.21	1.14
		With antistripping	1.21	1.16

One of the objectives of his research is examining the effect of adding additives to modify the asphalt samples. The possibility of improving asphalt mixture performance against humidity sensitivity is conducted as following:

According to figure (1) and (2), it can be inferred that adding antistripping additive as resistance increasing materials against humidity sensitivity in asphalt mixtures has significant effect in melting and freezing conditions with siliceous materials. Actually, it can be claimed that antistripping can increase TSR pf samples. However, additive does not have significant effect for siliceous materials in constant temperature and its resistance doesn't so much changed. Consequently, according to table (4) and figure (1), siliceous asphalt mixtures in melting and freezing conditions can modify humidity using antistripping and has significant effect on increasing humidity sensitivity that is one of the most important problems of made asphalt mixtures with siliceous materials. This resistance increase is more tangible in saturated mode.

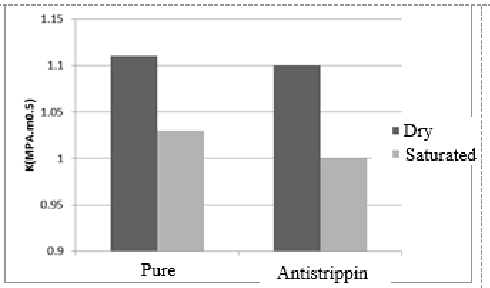

Fig (2) - effects of additives on siliceous asphalt mixtures and constant temperature conditions

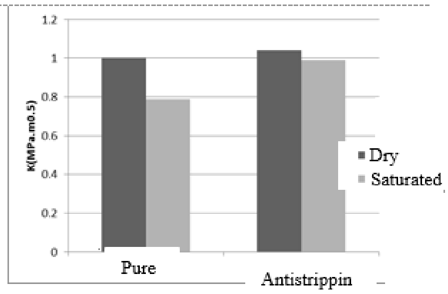

Fig (1) –effects of additives on siliceous asphalt mixtures and cyclic temperature conditions

Effect of Additives on Calcareous Asphalt Mixtures

As it is observed in figure (3) and (4), the presence of anti-stripping in asphalt mixtures with calcareous materials doesn't have significant effect on fracture resistance in dry and saturated modes. According to table (5), it can be found out that the humidity modifier material doesn't have significant effect on TSR. Consequently, anti-stripping can't make significant modification in calcareous materials. On the other hand, it must be noticed that fracture resistance in saturated mode is less than dry mode in both pure and with snit-stripping states, and humidity is less just while using humid modification material.

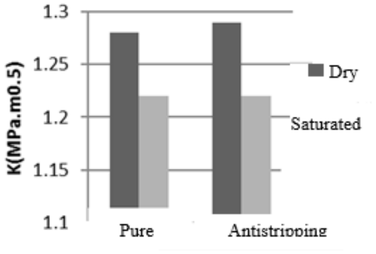

Fig (4) -effects of additives on calcareous asphalt mixtures and constant temperature conditions

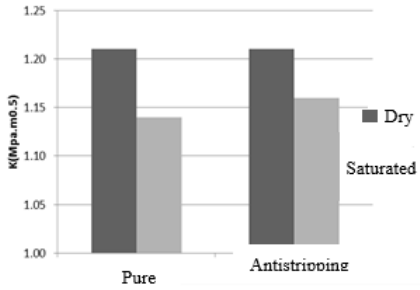

Fig (3) -effects of additives on calcareous asphalt mixtures and cyclic temperature conditions

Conclusion

According to experiments and analyses in this research, the summary of he obtained results show that antistripping material increases TSR of asphalt samples with siliceous and calcareous materials. However, effect of this material on TSR is more vivid in siliceous materials. In addition, the modified samples with antistripping under the constant temperature have higher fracture resistance in calcareous samples than siliceous samples. On the other hand, fracture resistance in constant temperature for siliceous materials is more than in cyclic conditions. Moreover, adding antistripping in cyclic conditions reduced in mode of resistant against fracture in spite of having significant effect in non-modifier mode. Moreover, adding antistripping additives on calcareous samples didn't have significant effect.

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