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EVALUATION OF FATIGUE RESISTANCE USING ELVALOY MODIFIED BINDER

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ABSTRACT: *Hot Mix Asphalt (HMA) is a widely used material for paving purpose as these pavements are constantly subjected to changing wheel loads and environmental factors. Combination of environmental actions and the imposed stresses from the repeated traffic loads results in moisture damage and causes reduction in pavement life due to the formation of "cracking failures".*

The present study envisages to find out modification in Elvaloy modifier and to further improve the properties of asphalt mixture in terms of Fatigue Cracking. The gradation is tested using Margalla quarry aggregate and bitumen grade 60/70 of Attock Oil Refinery. The binder was modified with different ratios of Elvaloy. The maximum asphalt content of the binder has been determined using the Marshall Mix Design (MS-2) method, and then volumetric of sample has been figured out.

Besides, performance test i.e. Indirect Tensile Fatigue Test (ITFT) was carried out on the mixes used in determination of the optimum asphalt content. The results showed significant increase in resistance to fatigue cracking using Elvaloy as modifier. At the end, the results derived from ITFT were subjected to statistical analysis and it was observed that temperature being the most significant factor, followed by gradation and Elvaloy content.

INTRODUCTION

The roadway network plays an indispensable role in socio-economic growth of a country, Moreover, with the onset of globalization and burgeoning population, the road congestion increases because of the ownership of vehicle and development of world transportation. This kind of situation increases the volume of traffic, traffic loads and tire pressure. Resultantly, these factors would play a pivotal role in pavement deformation such as fatigue cracking. In hot mix asphalt pavements, asphalt is an indispensable part of wearing surface of road structure because it plays pivotal role as a binder so, it has been modified a number of times against its failure (Muhammad Hussain et al., 2015). Unluckily, most of the valuable assets have been lost due to the premature development of cracks in the asphalt bound layers progressing rapidly to levels of high severity in asphalt concrete pavements in Pakistan. The road network plays an indispensable role in socio-economic growth of a country as it provides better accessibility to markets, employments and additional investments (Hanaa Mohammed Mahan, 2013). The network of Pakistan roads broadly consists of flexible pavement. In Pakistan, flexible pavements undergo premature failure, i.e. Fatigue.

Fatigue is a major distortion factor in flexible pavements, which is developed in different layers of flexible pavements due to perpetual traffic loading, inducing permanent strains. Fatigue cracking is also a matter of great concern regarding tolerance and design of hot mix asphalt (HMA) pavements since these are being the used the world over. Owing to repeated number of traffic loads, structural failure occurs in the pavements that causes fatigue cracks (Saad F. Ibrahim et al, 2014).

OBJECTIVES

Scope of the present study covers the following aspects:

i. Work out volumetric properties of unmodified and modified Hot Mix Asphalt (HMA) samples containing Elvaloy.
ii. Determine the fatigue cracking of neat and modified asphalt mixtures.
iii. Conduct statistical analysis on the lab. Result i.e. Fatigue test to compare results with simple 60/70 binder (Neat and Modified).

SCOPE

To accomplish the objective mentioned above, a comprehensive study plan was prepared, and the following tasks were highlighted.

i. Literature review of the previous studies carried out.
ii. Preparations of specimens with the help of super pave gyratory compactor to find out optimum asphalt content, through volumetric properties of the gyratory samples.

iii. Elvaloy with different percentage including 1%, 2% and 3% is used in samples and volumetric properties were find out.
iv. 1% Elvaloy is used in the laboratory samples and performance tests were carried out and results were compared with un-modified samples.

Table 1: Test Matrix

Method	Aggregate Source / Size	Binder Type	Modified with Elvaloy	Samples		
				Indirect Tensile		Total
				25°C	40°C	
NHA Class-B	Margalla Crush / NHA Class-B	ARL 60/70	0 %	3	3	6
			1 %	3	3	6
			2 %	3	3	6
			3 %	3	3	6
Total Number of Samples				12	12	24

RESEARCH METHODOLOGY

This chapter elaborates the procedure used in conducting research work to achieve the objectives. Tests on laboratory prepared samples were conducted in three stages. In first phase, Marshall Mix design (MS-2) method was adopted to determine the volumetric properties of bituminous mixes using Elvaloy as modifier. In the second and final stage, indirect tensile fatigue test was performed on compacted HMA mixes with Elvaloy as modifier.

In the initial phase, aggregate gradations Marshall Mix Design (MS-2) and two binders i.e. virgin and Elvaloy modified, were used to determine the volumetric properties of laboratory prepared HMA specimens.

RESULTS AND ANALYSIS

This chapter enunciates the analysis of data that is obtained from laboratory testing. The effectiveness of Elvaloy as anti-stripping agent in order to reduce fatigue failure was illustrated. The Indirect Tensile Fatigue Testing was conducted via UTM-25. The initial analysis, to determine the initial strain for each specimen, was performed using Microsoft Excel as the data from the output of the software did not include the initial strain values. Once the initial strain values were determined, the results were compiled to develop relationship between the log of number of cycle to failure and the log of initial strain values. The screened data was further analyzed using SPSS and MINITAB-17 software to develop fatigue curves for each type of mix. The results established by analyzing the data are presented using graphs, figures and residual plots.

INDIRECT TENSILE FATIGUE TEST RESULTS

The research included the performance test of Indirect Tensile Fatigue that was performed on two gradations that were modified with Elvaloy. Testing was conducted on two different temperatures i-e 25°C and 40°C and the load applied on the samples were taken 2500N. There were two replicate samples tested for each gradation both conventional and unconventional for both the temperatures. Test results at 25 ^{o}C are shown in Table 2 and Figure 1, while Table 3 and Figure 2 contain test results at 40 ^{o}C.

Table 2: Table Cycles to Failure of NHA Class-B Gradation @ 25^{o}C

	Cycles to Failure		
Sample	Unmodified Mix	Modified Mix	Improvement (%)
1	13169	15548	15.31
2	14669	16839	12.88
3	13919	16193	14.04

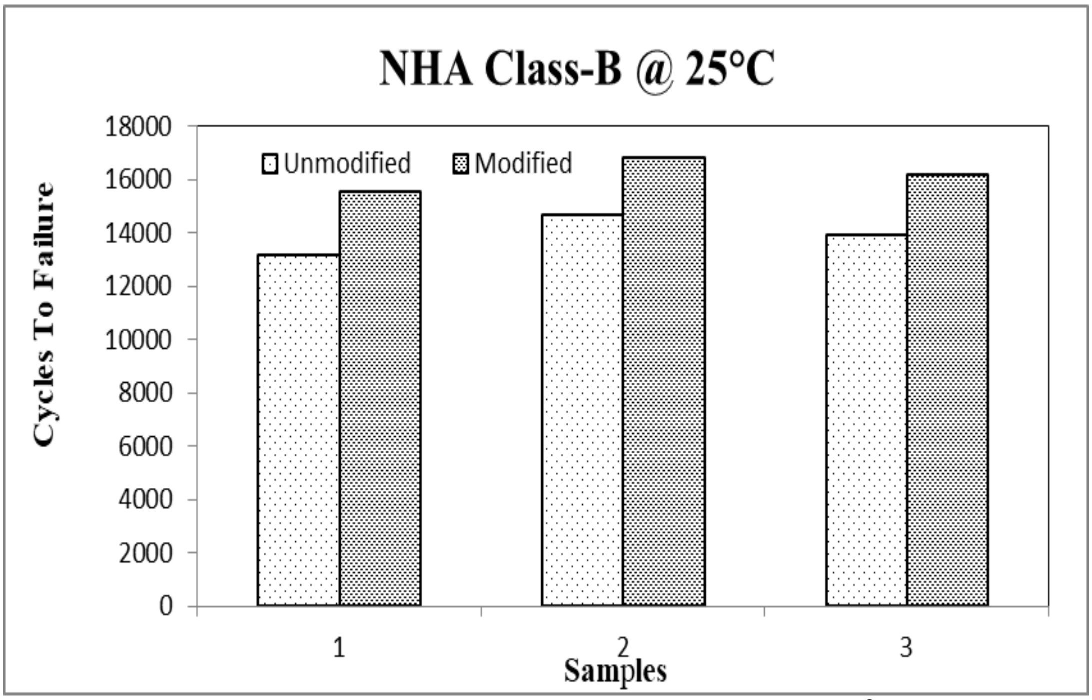

Figure 1: Cycle to failure of NHA Class-B Gradation @ 25°C

Table 3: Cycles to Failure of NHA Class-B Gradation @ 40°C

	Cycles to Failure		
Sample	**Unmodified Mix**	**Modified Mix**	**Improvement (%)**
1	2109	2321	9.13
2	1979	2298	13.88
3	2044	2309	11.47

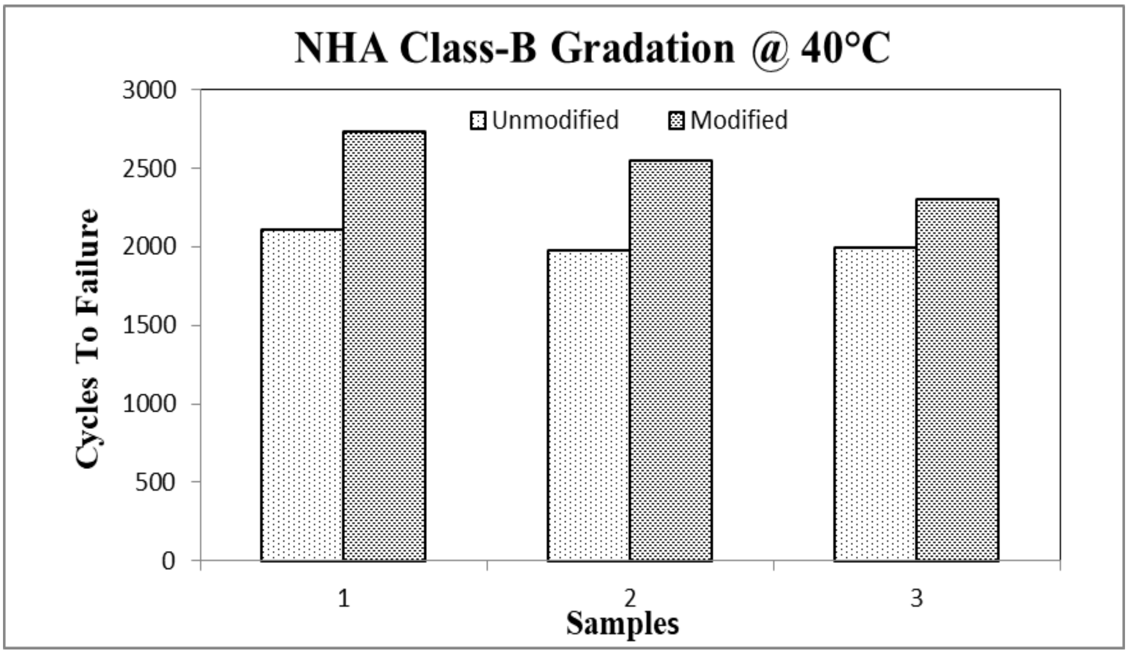

Figure 2: Cycle to Failure of NHA Class-B Gradation @ 40°C

Discussion of ITFT Results

It is cogent from the Table 2 that for NHA Class-B gradation, the number of cycles to failure of modified sample is 15548 for sample 1 and 16839 for sample 2. On taking average of both the values, the average value became 16193. On the other hand, the values of unmodified samples were 13169 and 14669 and their average became 13919. Conclusively, it showed that average improvement in NHA Class-B gradation with 1% Elvaloy was notes as 12-16%. So it is proved that samples that are modified with Elvaloy showed better resistance to fatigue cracking than that of unmodified samples. The graphical illustrations of NHA Class-B gradation test results are shown in Figures.

FULL FACTORIAL DESIGN OF INDIRECT TENSILE FATIGUE TEST

The statistical analysis of Indirect Tensile Fatigue Test data for NHA Class-B with two different temperatures and Elvaloy as modifier were carried out. Therefore, 2^3 full factorial design of experiment was performed using MINITAB-15 software. Table 4 shows the factors that have been considered in the factorial design with their high and low levels and abbreviations for both stages.

Table 4: Factors and their Level for Factorial Design

Notations	Parameters	Low	High	Units
1	Gradation	NHA Class B		mm
2	Temperature	25	40	^oC
3	Elvaloy	0	1	%

Significant Effects

In terms of Normal probability plot and Pareto plot generated using Minitab 15 software the factors and interaction of factors, which are most significant and affect fatigue cracking of asphalt mixtures, are also shown. Figure 4 shows the Pareto plot having a reference line with red color which shows that beyond this reference line a significant variable came up and have greater effect on the fatigue cracking. It is obvious that, temperature showed significant result and have greater influence on fatigue cracking of lab prepared mixtures at 5% significance level. The other plot is the normal probability plot which also shows the significant main effect as shown in Figure. In the normal probability plot the factors or interactions away from the reference line are significant at 5% significance level and the factors which are near the reference line or on the reference line, are insignificant.

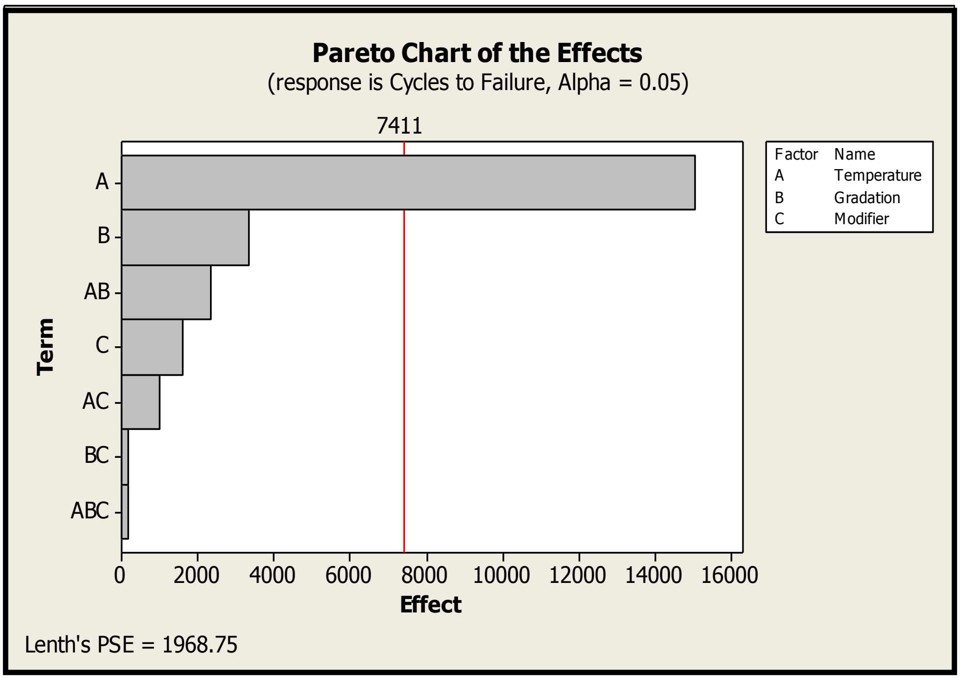

Figure 3: Pareto Chart of Samples

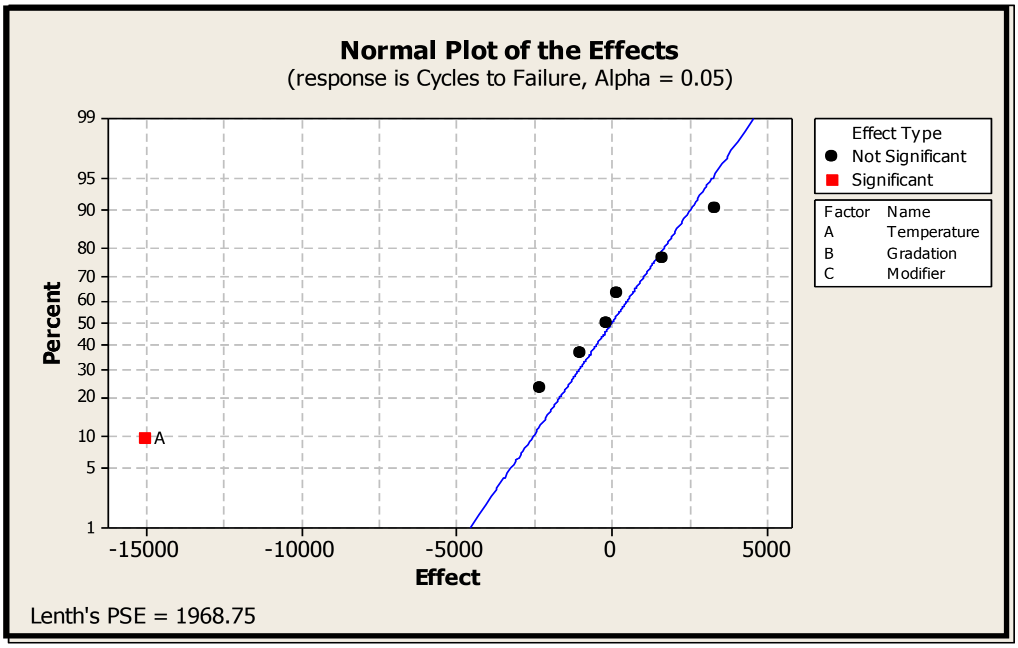

Figure 4: Normal Chart of Samples

Factorial Plots

The interaction and significant effects obtained from the Pareto chart and Normal Probability Chart can be described in detail by factorial plots. The effects of main factors are shown by main effects plot.

Main Effect Plots

The effects of gradation, temperature and Elvaloy %age of lab Prepared specimens are shown in Figure 5. The graph between temperature and fatigue cracking reveals that with increase in temperature the number of cycle to failure decreases.

The graph between fatigue cracking and gradation indicates direct relationship i.e. the number to cycle failure increases if nominal maximum aggregate size increases. So from this analysis it is quite obvious that the temperature has greater effect on fatigue cracking as in the below figure, it is clear that the slope of temperature vs number of cycles is greater. Moreover, nominal maximum aggregate size has also greater impact on fatigue cracking as it also showed greater slope. At last, modifier also showed impact on fatigue cracking behavior as its slope in the figure is also liner and inclined that showing effects on fatigue cracking.

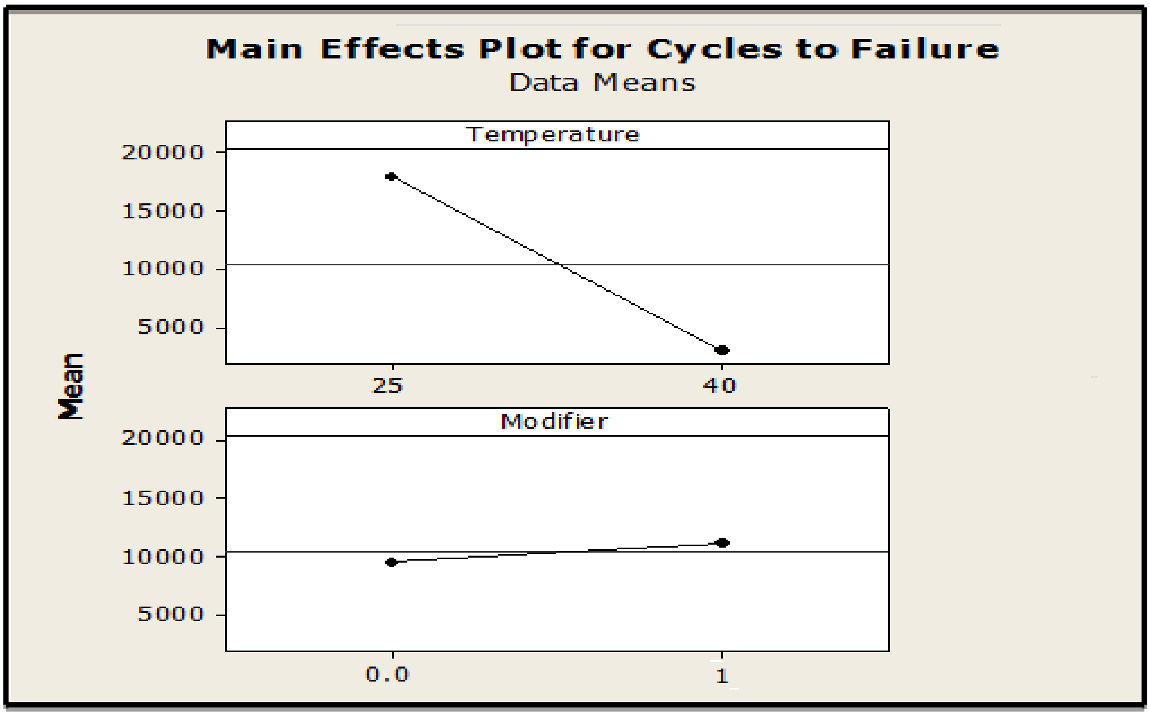

Figure 5: Main Effects Plot

CONCLUSIONS

Following conclusions are drawn from this study

i. With modification of Elvaloy the asphalt mixtures shows higher resistance to fatigue cracking as it is used as a mineral filler and an anti-stripping agent in HMA mixtures and has also been recognized to improve the properties and perform and at 40^{o}C, 13.88% improvement in resistance to fatigue cracking is observed in NHA Class-B gradation in Elvaloy modified mixtures.

Statistical analysis shows that temperature is the most significant factor which affects the Indirect Tensile Fatigue Test (ITFT) values followed by gradation and Elvaloy content.

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