

Chapter 6

FACTORS AFFECTING THE FATIGUE BEHAVIOR OF ASPHALT MASTICS

6.1 Prologue

Asphalt mastic is the combination of mineral filler and asphalt binder, which are mixed in a specific proportion known as the filler-binder ratio. Therefore, the fatigue response of the asphalt mastic is influenced by its constituents, i.e., type of filler, grade of binder, and filler-binder ratio. Also, asphalt materials are highly temperature susceptible, due to which a unit change in the temperature may lead to a discrepancy of up to 25% in the complex modulus test results [310]. Therefore, the effect of temperature is also considered one of the influencing factors in this study.

The LAS test is an accelerated fatigue test in which an incremental strain varying from 0.1% to 30% is applied to the sample, making loading magnitude an important parameter affecting the performance of the different mastics. This range of applied shear strain amplitude is very wide, which may also affect the relative ranking between the materials. The difference in the quantification of damage by cylindrical and hyperbolic geometry has already been discussed in Chapter 5 while choosing the better testing geometry. In addition, the effect of test types and analysis procedures is also presented in the same chapter by including two types of fatigue tests (TS and LAS) and three types of analysis procedures (DE, PSE, and fatigue parameter). Hence, the current study integrated the effect of eight different variables (refer to chapter 3 Figure 3.5) which are considered the primary parameters influencing the fatigue behavior of the asphalt mastics.

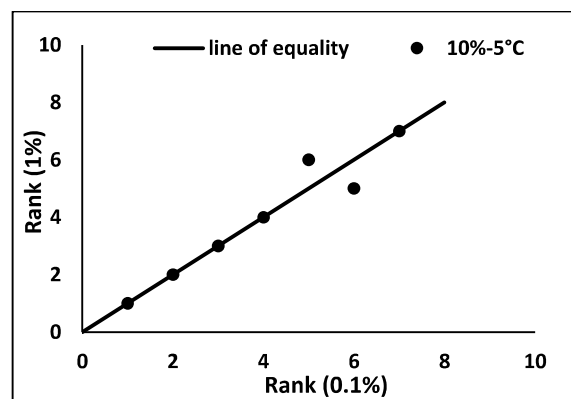
6.2 Effect of Applied Strain

The LAS test applies the incremental strain to the sample ranging from 0.1% to 30%, followed by the VECD analysis, which offers the advantage of determining the fatigue life at any strain amplitude by using the equation (2.10). Due to such a wide range, the behavior of the asphalt binder/mastic is also dependent on the magnitude of applied strain and needs to be chosen judiciously to accurately predict the fatigue performance of the materials. Therefore, a total of five strain values (0.1, 1, 2.5, 5, and 10%) were considered in this study to assess the strain susceptibility of the asphalt binders and the mastics. The aim was to check whether the ranking between the materials was affected by the change in applied strain. The first two strain levels, i.e., 0.1% and 1%, were selected to cover the linear viscoelastic range of the materials. The LVE limits of all the tested materials were found to be in the range of 0.26-1.59, which were more or less nearer to the aforementioned strain values and hence were adopted for the analysis. The 2.5% and 5% strain lies in the non-linear viscoelastic regions and is the most common strain range included in the previous studies as they represent the typical binder strain in strong and weak pavements, respectively [321–324]. Another strain level of 10% was also considered to study the behavior of the binder and the mastics near the failure zone. Table 6.1 and 6.2 shows the relative ranking of binder and the corresponding mastics with respect to five strain levels at a temperature of 5°C and 10% filler content.

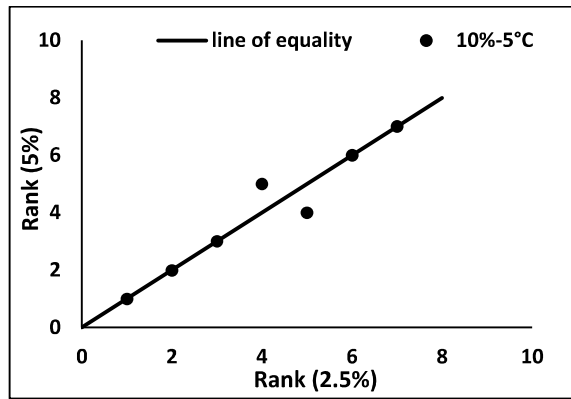
Table 6.1 Ranking of asphalt mastic at different shear strains corresponding to 10% filler content and 5°C testing temperature with VG-30 as the base binder

Filler	% Strain				
	0.1 %	1 %	2.5 %	5 %	10 %
Binder	1	1	3	3	6
RM	7	7	2	1	2
MD	5	6	7	7	7
LS	6	5	6	6	5
GR	2	2	4	5	3
BA	3	3	5	4	1
QZ	4	4	1	2	4

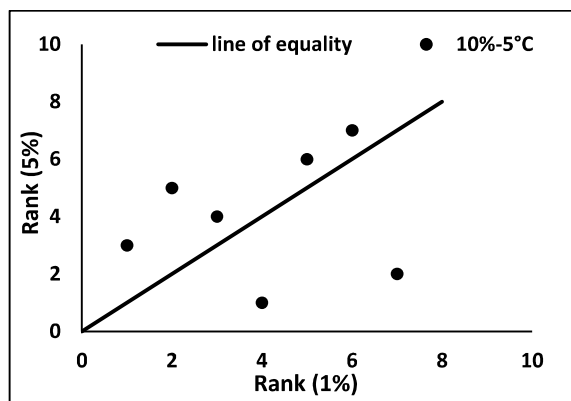
The hypothesis of choosing the strain levels corresponding to LVE, NLVE, and the failure region can be well justified by the ranking analysis. It is noteworthy that the ranking of both strains in the LVE region is similar to each other. Likewise, the ranking at 2.5% and 5% strain levels was also similar. However, the ranking at 10% was different from the other strains.



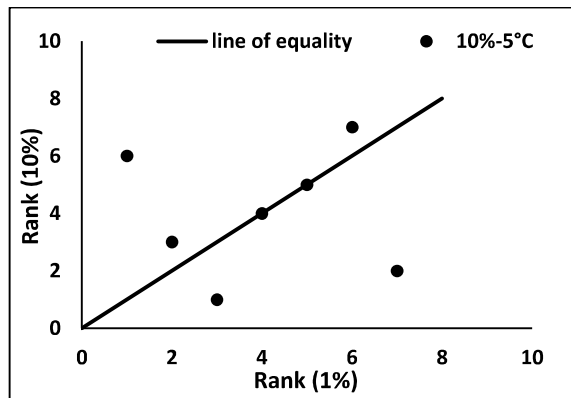
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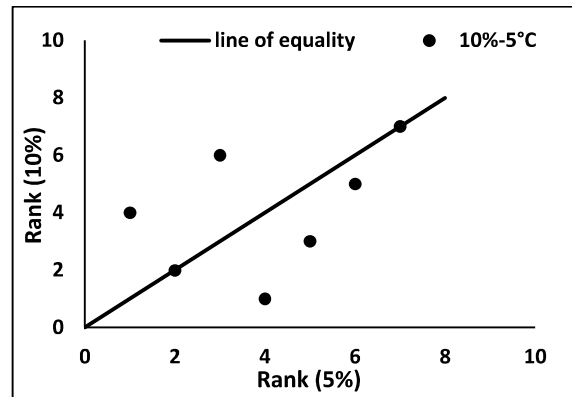
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Figure 6.1 Discrepancy analysis between the various strains used in the study with VG-30 as the base binder

6.2.1 Discrepancy Analysis

Figure 6.1 shows the discrepancy analysis between the rankings obtained at respective strains with respect to 10% filler content and 5°C temperature. It is clear that the discrepancy between the strains within the LVE region (0.1% and 1%) as well as the NLVE region (2.5% and 5%) was very low, with all the data points lying either on the line of equality or in proximity. On the contrary, the discrepancy among the strains from different regions, such as 1% and 5%, 1% and 10%, and 5% and 10%, was very high. These results were observed with VG-30 as the base binder but were equally valid for PMB, as shown in Table 6.2 and Figure 6.2. Similar observations were obtained at all temperatures and filler contents, but only one combination is shown here for brevity.

The observations from ranking analysis and discrepancy analysis proved that the behavior or relative ranking of the materials changes considerably with the change in the magnitude of applied strain (LVE, NLVE, and failure zone), and hence the strain should be selected very carefully for the fatigue analysis. The 0.1% and 1% strains lie within or near the LVE limit of the materials where the behavior of the material is not affected by the magnitude of applied

loading. However, this is not the case with NLVE strains such as 2.5% and 5% where the loading magnitude plays the important role. Therefore, the ranking of the mastics was significantly different at LVE and NLVE strains. Actually, the binder/mastic is mostly subjected to the strains well beyond the LVE limits hence, ranking the performance of the fillers based on these strains will not be accurate. In addition, the 10% shear strain corresponds to the strain, which is more or less similar to the failure strain, so considering that strain will involve post-failure behavior of the sample, which is not in the scope of the present study. On the other hand, the strains corresponding to 2.5% and 5% simulate the actual strains in the binder in a typically strong and weak pavement, respectively [321–324]. Actually, the strain in the strong pavement having a thickness of more than 4 inches is 500 μ , whereas the weak pavement with a thickness of fewer than 4 inches experiences a strain of approximately 1000 μ [325]. Since the strain in the asphalt binder is approximately 50 times the strain in the mixture [326] therefore,

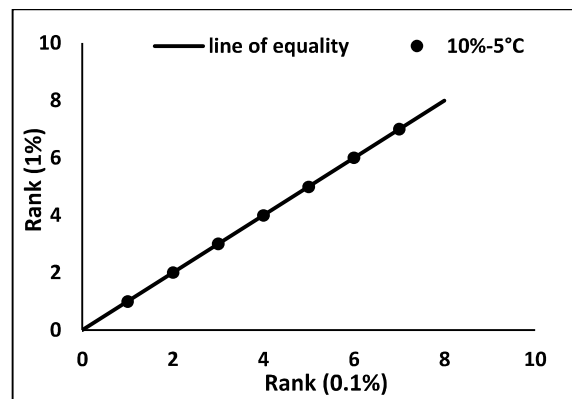
$$\text{Strain in the binder in strong pavement} = 50 \times 500 \times 10^{-6} = 0.025 = 2.5\%$$

$$\text{Strain in the binder in weak pavement} = 50 \times 1000 \times 10^{-6} = 0.050 = 5\%$$

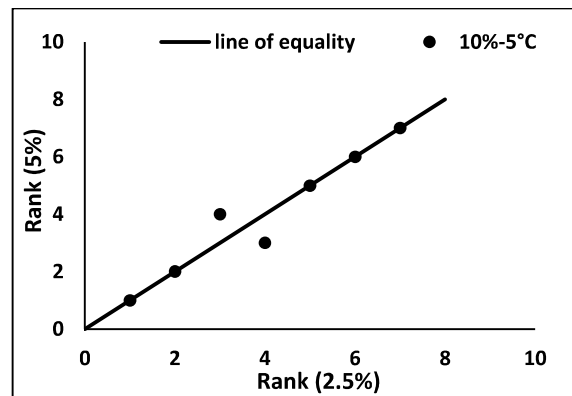
Therefore, 2.5% and 5% strains are the expected strains in the binder and hence should be chosen for the fatigue analysis. Interestingly, the results obtained at both strains showed minimum discrepancy, and either can be selected for further analysis of fatigue properties of asphalt materials. Therefore, the strain level of 5% corresponding to weak pavement was chosen for evaluating the fatigue life of all the materials in this study.

Table 6.2 Ranking of asphalt mastic at different shear strains corresponding to 10% filler content and 5°C testing temperature with PMB-40 as the base binder

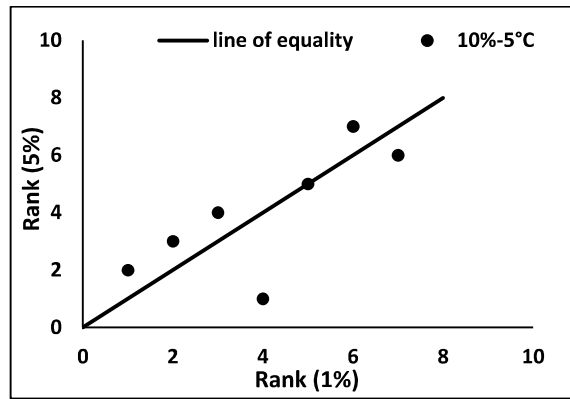
Filler	% Strain				
	0.1 %	1 %	2.5 %	5 %	10 %
Binder	4	4	1	1	4
RM	7	7	6	6	6
MD	6	6	7	7	7
LS	5	5	5	5	5
GR	3	3	3	4	2
BA	1	1	2	2	1
QZ	2	2	4	3	3



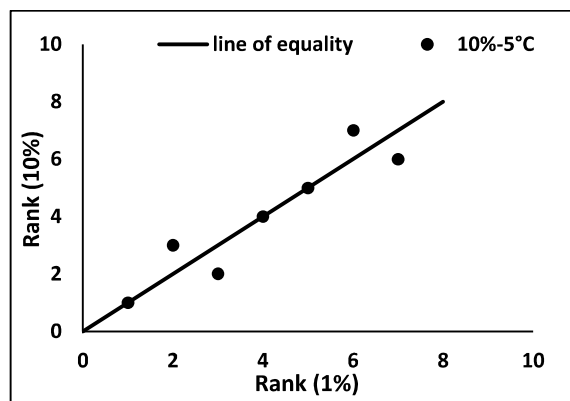
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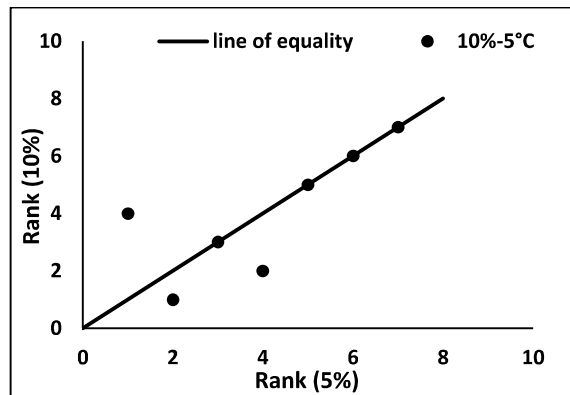
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Figure 6.2 Discrepancy analysis between the various strains used in the study with PMB-40 as the base binder

6.3 Effect of Temperature

Figure 6.3 presents the effect of change in temperature on the fatigue life of neat binder as well as polymer modifier binder. It is observed that the fatigue life consistently increases with the increase in temperature for both binders.

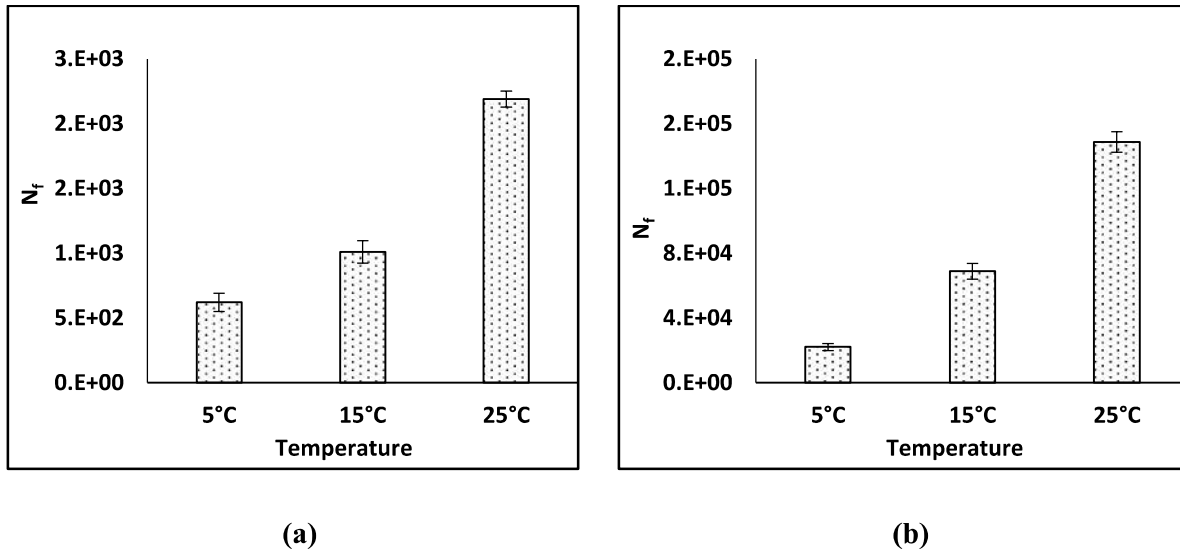
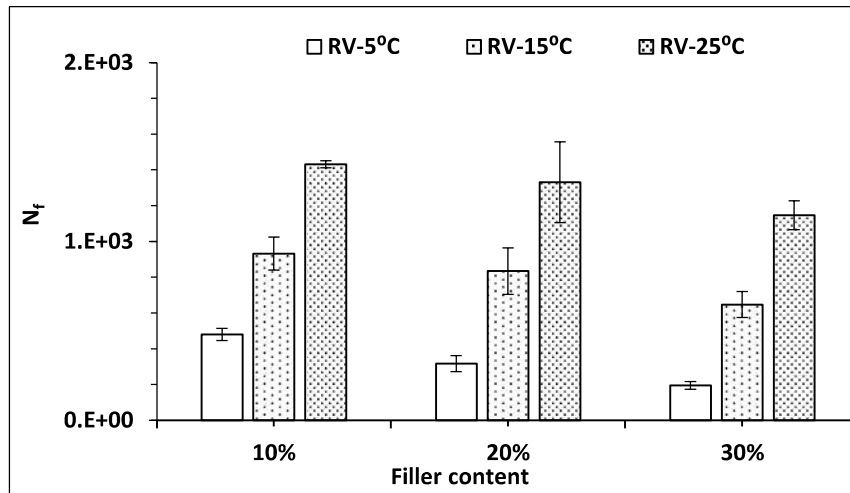
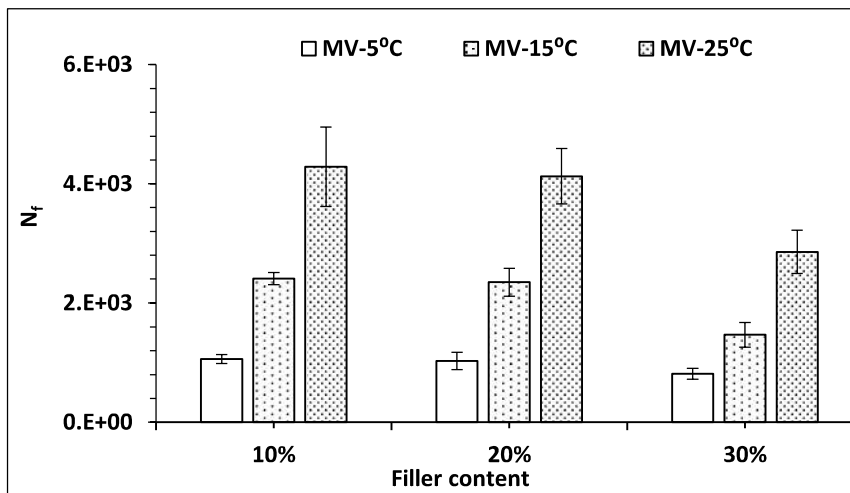


Figure 6.3 Variation in fatigue life of (a) neat binder and (b) polymer modified binder with change in testing temperature

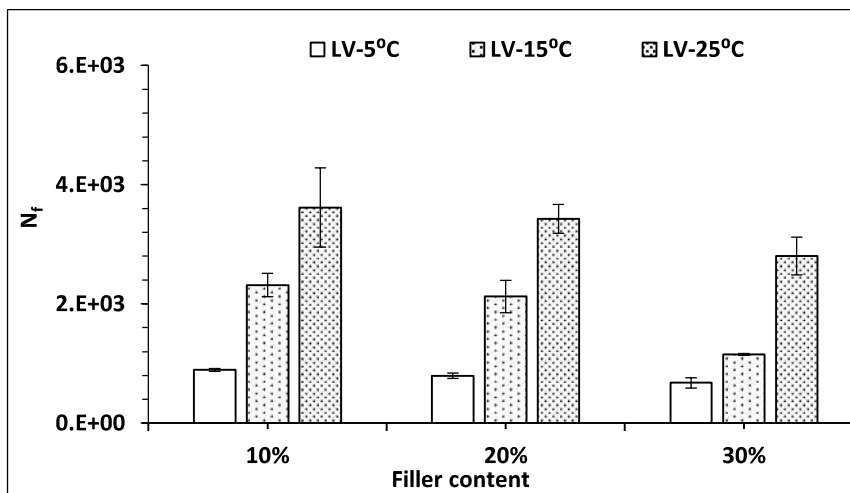
The effect of temperature on the asphalt mastics with VG-30 and PMB-40 as the base binder is shown in Figure 6.4 and 6.5, respectively. The first letter in the legend refers to the type of filler (R-RM, M-MD, L-LS, G-GR, B-BA, Q-QZ), whereas the second letter denotes the base binder (V: VG-30, P: PMB-40) followed by the testing temperature. The temperature played a significant role in the fatigue behavior of asphalt mastics, as evident from the enhanced fatigue lives at higher temperatures, irrespective of the filler content. The increase in temperature makes the binder softer, due to which the material can sustain more repeated cyclic loading before failure; hence the fatigue life increases. The increment in fatigue life was also observed at all filler contents irrespective of the filler type in the case of polymer modified mastics, but the increment rate was more uniform in neat mastics as compared to the PMB mastics owing to the complex polymer chain network inside the binder.



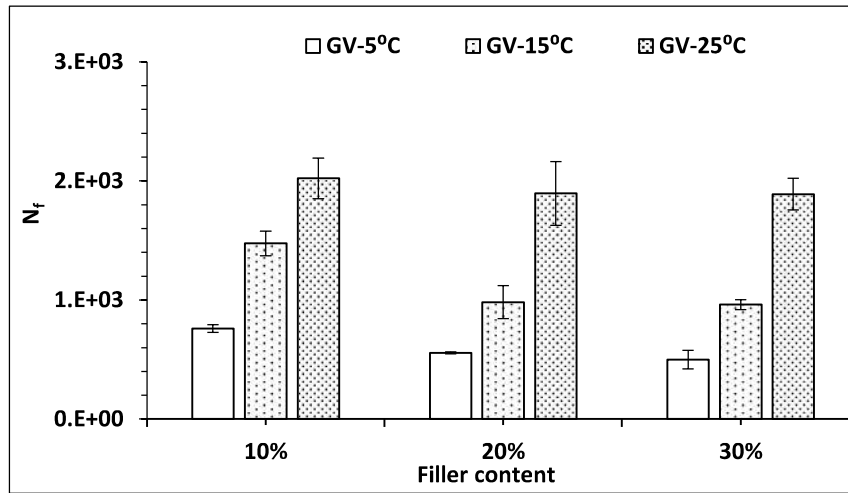
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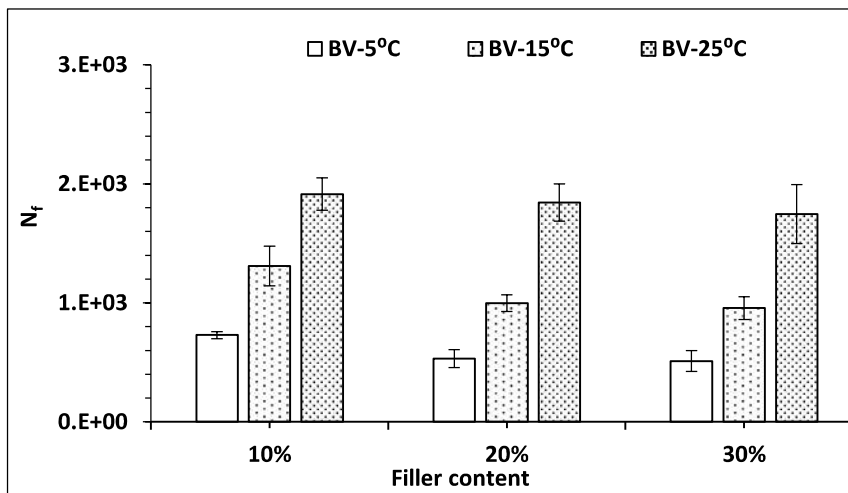
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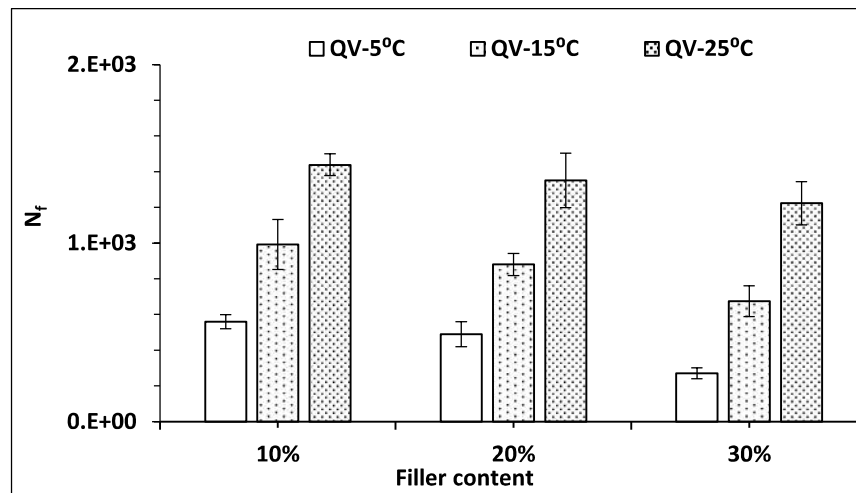
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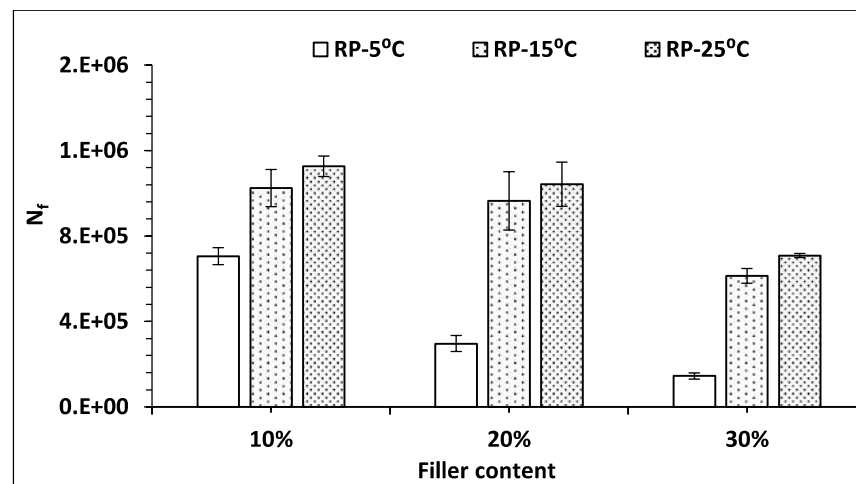


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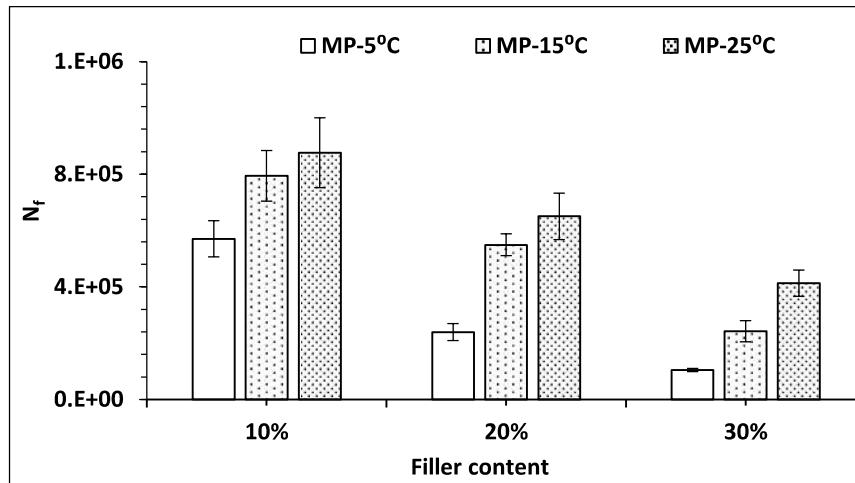


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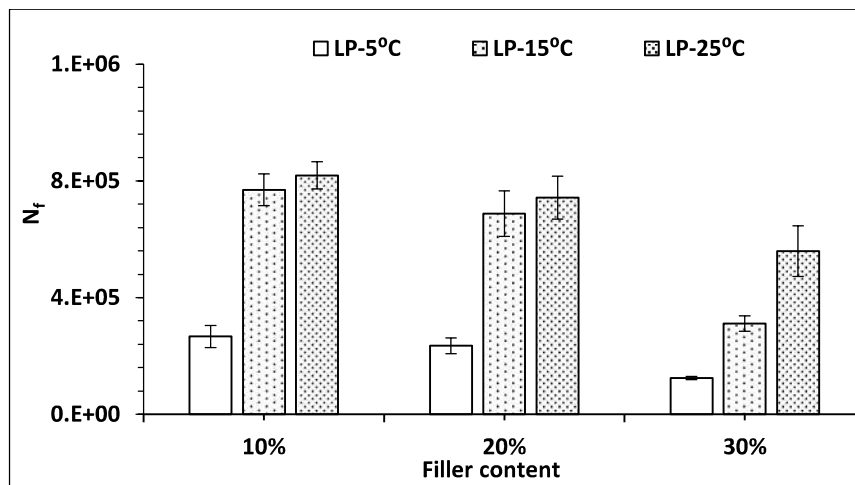
Figure 6.4 Variation in fatigue life of asphalt mastics prepared with neat binder and different fillers at varying filler contents with change in testing temperature



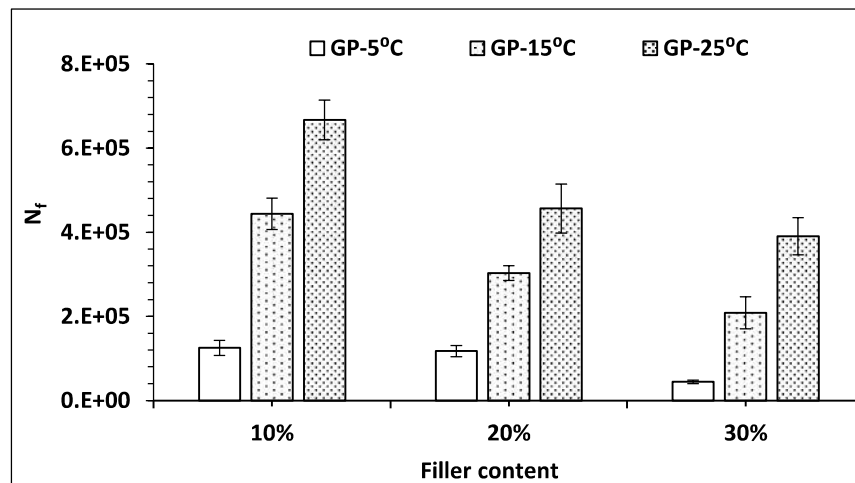
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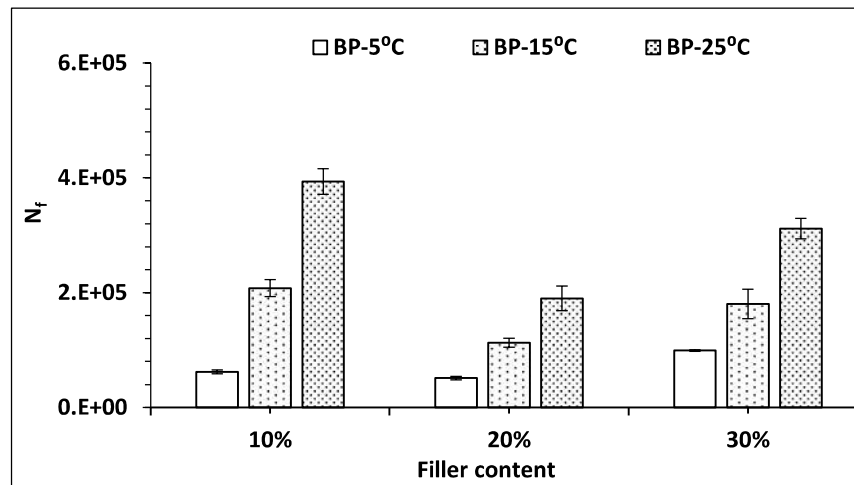
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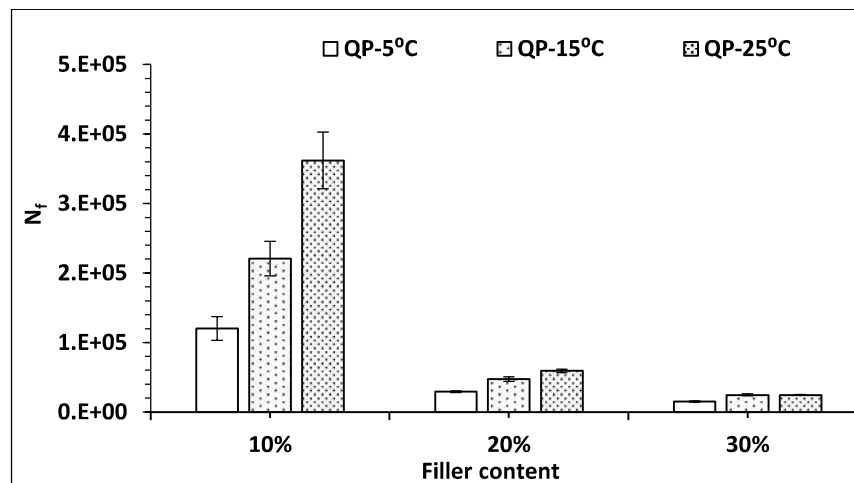
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Figure 6.5 Variation in fatigue life of asphalt mastics prepared with polymer modified binder and different fillers at varying filler contents with change in testing temperature

6.4 Effect of Filler Type

The resistance against fatigue cracking is variable for different asphalt mastics owing to the wide range of filler characteristics. Table 6.3 shows the relative ranking of the fillers based on the fatigue performance of the corresponding asphalt mastics with VG-30 as the base binder.

A total of nine combinations, i.e., 3 temperatures and 3 filler-binder ratios, were incorporated to rank the fillers. It is observed that the ranking of MD based mastics was highest, followed by the mastics prepared with LS at all combinations of temperatures and filler-binder ratios. The RM yielded the worst fatigue performance along with QZ, whereas GR and BA were the average performing fillers.

Table 6.3 Ranking of the binder and the mastics prepared with different fillers at corresponding filler content and testing temperatures with VG-30 as the base binder

Filler	Filler content and Testing temperature								
	10%- 5°C	20%- 5°C	30%- 5°C	10%- 15°C	20%- 15°C	30%- 15°C	10%- 25°C	20%- 25°C	30%- 25°C
Binder	3	5	5	3	5	4	5	5	3
RM	1	1	1	1	1	1	1	1	1
MD	7	7	7	7	7	7	7	7	7
LS	6	6	6	6	6	6	6	6	6
GR	5	4	3	5	3	5	4	4	4
BA	4	3	4	4	4	3	3	3	5
QZ	2	2	2	2	2	2	2	2	2

The RM filler has the highest specific surface area ($SSA=27.825 \text{ m}^2/\text{g}$), Rigden voids ($RV=45\%$), and lowest fineness modulus ($FM=4.32$), owing to which the contact points between the filler and the binder became very high. This resulted in the highly stiff mastics, due to which the RM based mastics exhibited the lowest fatigue performance. On the other hand, the asphalt mastics prepared with MD and LS fillers were more fluid and workable owing to lower SSA, RV, and higher FM and hence emerged as the best performing fillers. On the contrary, the QZ filler, despite having lower SSA showed lower fatigue performance which is attributed to the finer particle size distribution (second lowest FM) and higher RV. This showed that only one filler property might not be conclusive when deciding the corresponding mastics' relative fatigue performance.

Hence, the three filler parameters, fineness modulus, specific surface area, and Rigden voids, were found to have the primary influence on the behavior of mastics and may be used as fatigue indicators. Based on them, a mathematical parameter was proposed in this study called FSR. It is the ratio of FM and the product of SSA and RV expressed by the following equation:

$$\text{FSR} = \frac{\text{FM}}{\text{SSA} * \text{RV}} \quad (6.1)$$

Table 6.4 presents the FSR values corresponding to all the fillers in which RM and QZ were found to have lower FSR, whereas the magnitude of FSR was higher in MD and LS, with GR and BA yielding average values.

Table 6.4 FSR values corresponding to each filler

Filler	Filler characteristics			
	SSA (m ² /g)	RV (%)	FM	FSR
RM	27.83	45.7	4.32	0.003
MD	1.21	12.1	6.06	0.415
LS	0.75	22.4	5.81	0.344
GR	2.44	27.6	5.7	0.085
BA	11.87	6.33	6.13	0.082
QZ	3.32	27.8	5.12	0.055

Lower FSR signifies a lower value of FM and a higher magnitude of SSA and RV. The lower magnitude of FM represents the higher percentage of the finer particle size distribution of the fillers. Also, higher SSA corresponds to the presence of finer particles within the filler sample. Due to this, the fillers were not able to compact to the full extent resulting in higher Rigden voids. Hence, a lower magnitude of FSR produces stiffer and more brittle mastics, which is not desirable from a fatigue point of view. On the other hand, with higher FSR, the mastic system becomes more flowable or workable and can resist higher strain magnitude compared to the stiffer mastic in which the constituents are in a more rigid state. Therefore, as far as the filler

characteristics are considered, a higher value of FSR may result in better fatigue performance. This hypothesis was verified using the ranking analysis of fillers between FSR and fatigue life of mastics. Table 6.5 presents the fatigue ranking of asphalt mastics prepared with the different fillers and the ranking of fillers based on the FSR parameter. Interestingly, the fatigue ranking of the fillers was exactly similar to the ranking yielded by the FSR parameter. This is quite encouraging because the FSR was able to rank the relative fatigue performance of the asphalt mastics composed of various fillers only based on three simple filler characterization tests.

Table 6.5 Comparison between the ranking of fillers based on FSR parameter and the fatigue performance of asphalt mastics in the case of VG-30 binder

Filler	FSR	Filler content and Testing temperature								
		10%- 5°C	20%- 5°C	30%- 5°C	10%- 15°C	20%- 15°C	30%- 15°C	10%- 25°C	20%- 25°C	30%- 25°C
RM	1	1	1	1	1	1	1	1	1	1
MD	6	6	6	6	6	6	6	6	6	6
LS	5	5	5	5	5	5	5	5	5	5
GR	4	4	4	4	4	4	4	4	4	4
BA	3	3	3	3	3	3	3	3	3	3
QZ	2	2	2	2	2	2	2	2	2	2

The fatigue results with PMB were considerably different than those with VG-30 binders (Table 6.6). The asphalt mastics exhibited better fatigue performance than the asphalt binder regardless of the type of filler, temperature, and filler content, which shows that adding filler improves the fatigue susceptibility of the polymer modified binder irrespective of the type of filler.

Table 6.6 Ranking of the binder and the mastics prepared with different fillers at corresponding filler content and testing temperatures with PMB-40 as the base binder

Filler	Filler content and Testing temperature								
	10%- 5°C	20%- 5°C	30%- 5°C	10%- 15°C	20%- 15°C	30%- 15°C	10%- 25°C	20%- 25°C	30%- 25°C
Binder	1	1	2	1	2	2	1	2	2
RM	7	7	7	7	7	7	7	7	7
MD	6	6	5	6	5	5	6	5	5
LS	5	5	6	5	6	6	5	6	6
GR	4	4	3	4	4	4	4	4	4
BA	2	3	4	2	3	3	3	3	3
QZ	3	2	1	3	1	1	2	1	1

Another interesting observation is that the red mud, which manifested the least performance with VG-30 based mastics, was found to be the best filler with polymer modified binder irrespective of the filler-binder ratios and temperatures. This behavior of red mud based mastics can be better explained by shear stress-shear strain diagrams. The peak stress and the failure strain are the parameters that can effectively quantify the response of the material against the applied loading. The material resists deformation, due to which the stress within the material increases with the rise in strain level, reaches the maximum value, and starts decreasing. The sudden decrease in the shear stress indicates damage. This maximum value is known as peak shear stress, and the corresponding strain is called failure strain (Figure 6.6). The peak stress signifies the stress resistance of the material up to the failure, whereas the failure strain determines the strain tolerance of the sample. The stiffer materials contribute to higher peak stresses, resulting in lower failure strain. The material can sustain a higher magnitude of stresses but fails early owing to the higher rigidity. In other materials, which are relatively softer, the magnitude of peak stress is lower but can sustain higher applied strains before

failure. The ideal fatigue resistant material should be able to resist higher stresses and can also withstand higher shear strains before failure.

In the case of VG-30 based mastics, the finer particle size distribution and higher specific surface area of the red mud make the corresponding mastics very stiff, exhibiting the highest peak stress and lowest failure strain, as evident from Figure 6.6. Due to this, the fatigue life of the red mud based mastics was lowest at all combinations of temperatures and filler-binder ratios. On the other hand, the polymer modified binder aids in overcoming the incompetency of asphalt mastics to resist higher strains. Likewise, the red mud-based mastics yield the highest peak stress and failure strain, due to which it can resist stresses and withstand strains resulting in the highest ranking (Figure 6.7). The polymer modified binder (PMB-40) used in this study consists of styrene butadiene styrene (SBS) copolymer which is an elastomer. The physical cross-linking between the molecules imparts strength and elasticity to the SBS. The copolymer has exceptional elasticity owing to the presence of polybutadiene rubbery matrix mid-blocks. Due to the high elasticity of the PMB-40 and stiffness imparted by RM filler, the corresponding asphalt mixture withstand higher loading and was able to resist the deformations to a higher extent. Hence, the higher fatigue life was obtained with red mud filler. Therefore, it is evident that the stiffer combination of filler and binder can be adopted with polymer modified binder only since it may be detrimental with a neat binder from a fatigue point of view. This also showed that both peak stress and failure strain should be considered while determining the fatigue behavior of the materials. Moreover, the relative performance of other fillers in PMB based mastics more or less remained the same compared to the unmodified mastics.

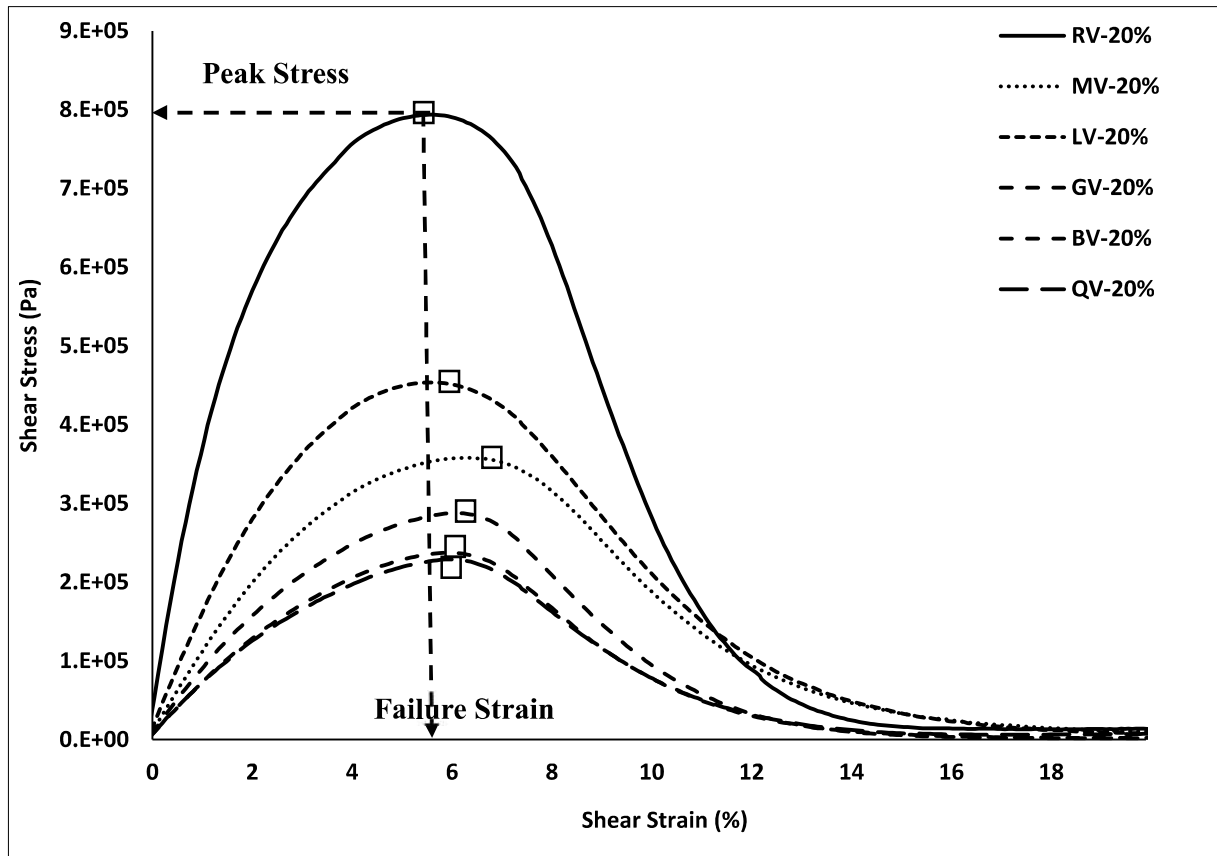


Figure 6.6 Shear stress vs shear strain curves for the unmodified mastics at 20% filler content and 15°C temperature

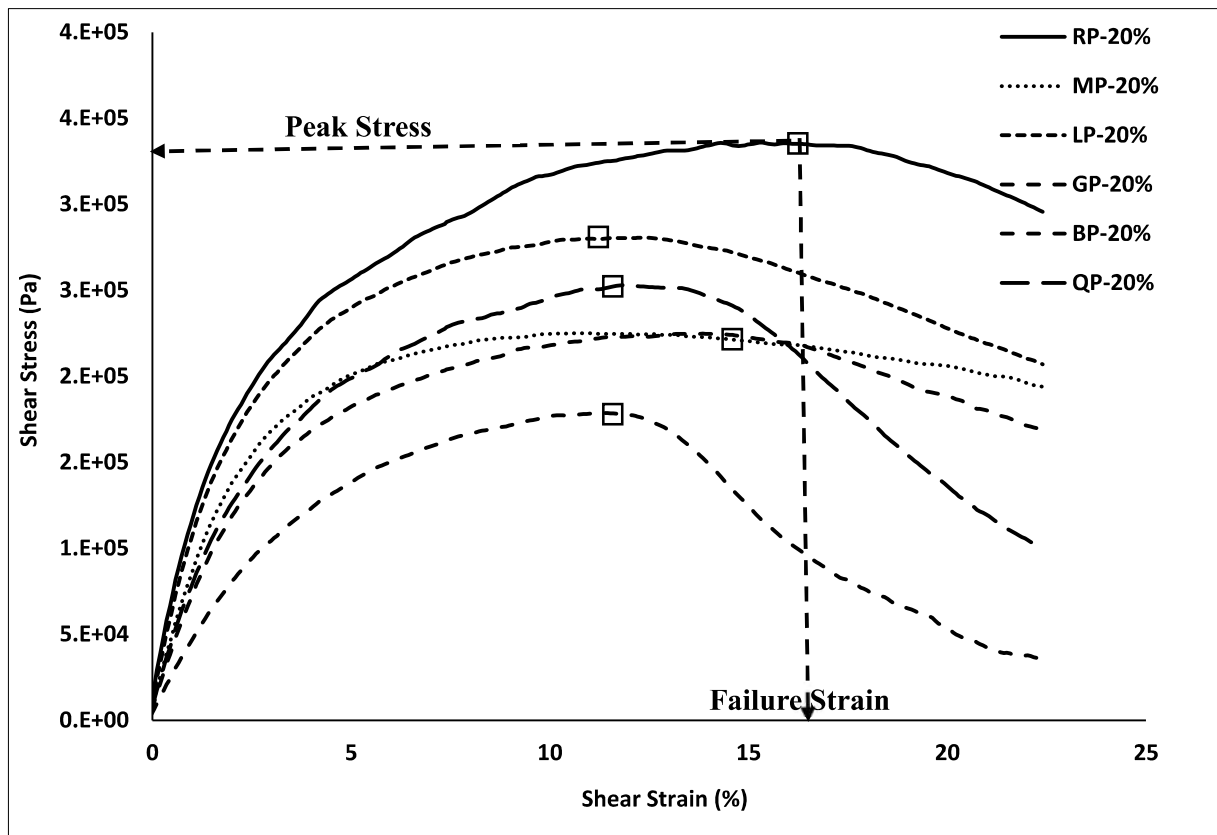


Figure 6.7 Shear stress vs shear strain curves for the polymer modified mastics at 20% filler content and 15°C temperature

Table 6.7 compares the ranking of fillers obtained from FSR and fatigue testing with PMB-40 as the base binder. It is observed that the ranking was more or less similar for all the fillers except the red mud. Also, the rankings in VG based mastics were more consistent along different temperatures and filler-binder ratios as compared to the PMB based mastics. Hence, the relative fatigue performance of the fillers can be assessed with the help of the FSR parameter, preferably with the unmodified binder.

Table 6.7 Comparison between the ranking of fillers based on FSR parameter and the fatigue performance of asphalt mastics in the case of PMB-40 binder

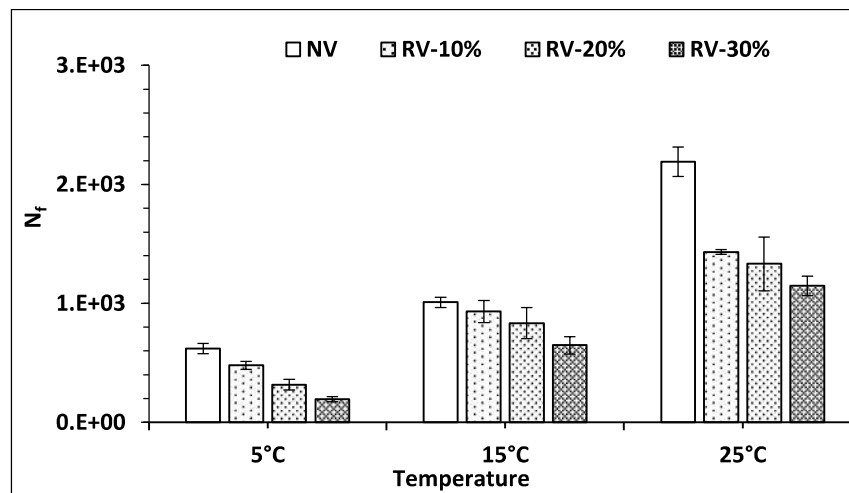
Filler	FSR	Filler content and Testing temperature								
		10%- 5°C	20%- 5°C	30%- 5°C	10%- 15°C	20%- 15°C	30%- 15°C	10%- 25°C	20%- 25°C	30%- 25°C
RM	1	6	6	6	6	6	6	6	6	6
MD	6	5	5	4	5	4	4	5	4	4
LS	5	4	4	5	4	5	5	4	5	5
GR	4	3	3	2	3	3	3	3	3	3
BA	3	1	2	3	1	2	2	2	2	2
QZ	2	2	1	1	2	1	1	1	1	1

6.5 Effect of Filler-Binder Ratio

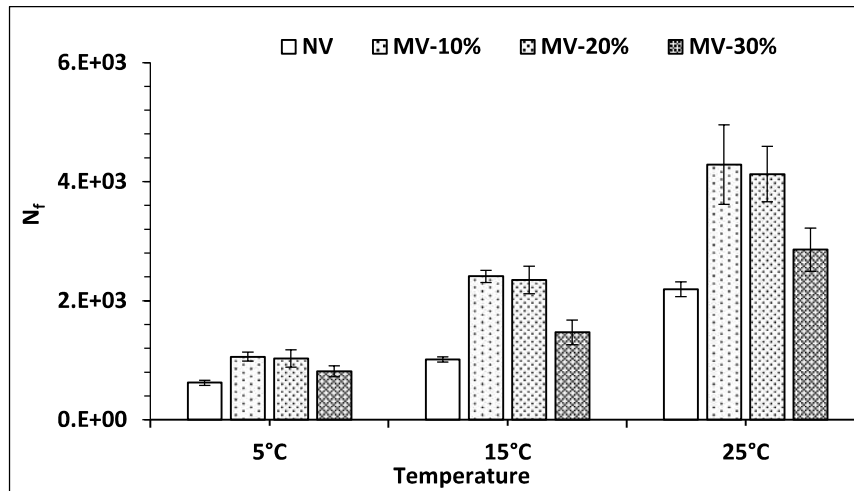
The effect of the filler binder ratio was not consistent because of its dependency on the type of filler. The variation in the fatigue life of asphalt mastics was divergent for different fillers based on the filler characteristics. Figure 6.8 presents the comparative analysis between different F-B ratios in the case of VG-30 binder based mastics. The fatigue life of neat binders is also shown in the same graph as a reference to study the effect of filler contents. The first letter in the legend refers to the type of filler (N-Neat binder, R-RM, M-MD, L-LS, G-GR, B-BA, Q-QZ), whereas the second letter denotes the base binder (V: VG-30, P: PMB-40) followed by the filler content.

The fatigue life of asphalt mastics prepared with RM and QZ as filler was always lower than that of the neat binder, irrespective of the filler content and testing temperature. Hence, the addition of RM and QZ was proven to be detrimental, showing that the RM and QZ filler act as stiffening agents only, due to which the stiffness of the mastics increased, resulting in lower

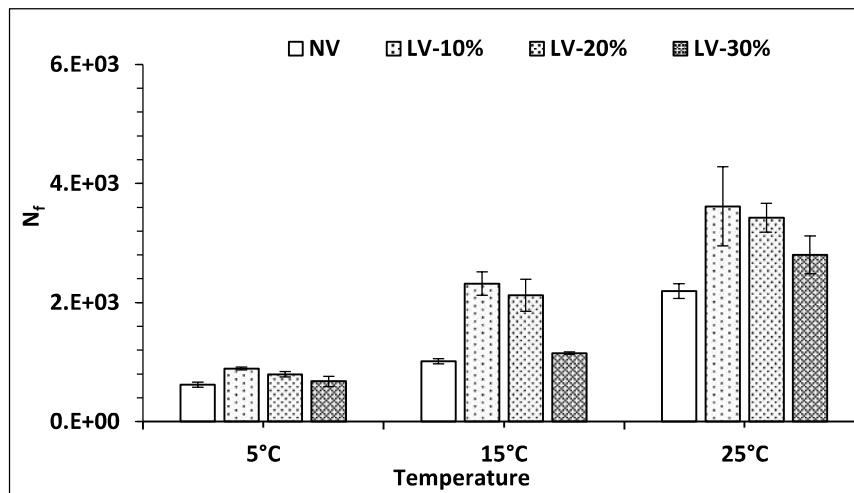
fatigue life. The effect of filler can be considered as a stiffening agent, or it may act as a reinforcement. As the name suggests, the stiffening agent's role is to increase the stiffness, i.e., the complex shear modulus of the binder, and it does not contribute to the cracking resistance. On the other hand, adding filler may provide reinforcement within the asphalt matrix by increasing the stress tolerance of the binder without compromising the failure strain to a higher extent owing to which the binder can bear a higher magnitude of stresses without failure. Hence, the stiffening agent aggravates the fatigue cracking, whereas the reinforcing agent enhances the fatigue performance. In addition to that, the presence of filler can also act as a barrier in the path of crack propagation, hindering crack growth and hence exhibiting better fatigue performance. This phenomenon is commonly known as crack pinning in asphalt materials [18,19].



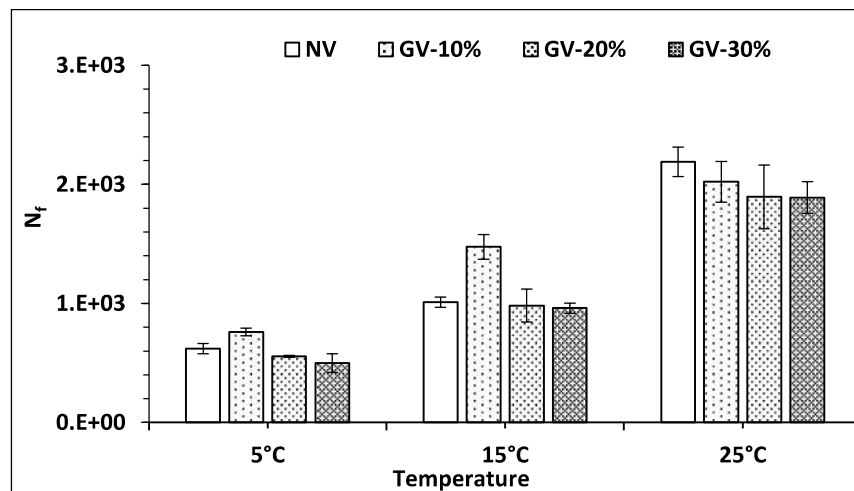
(a)



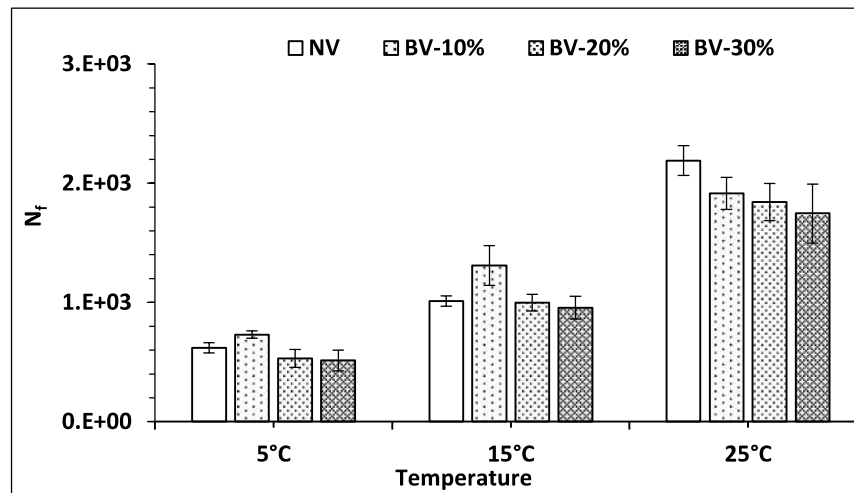
(b)



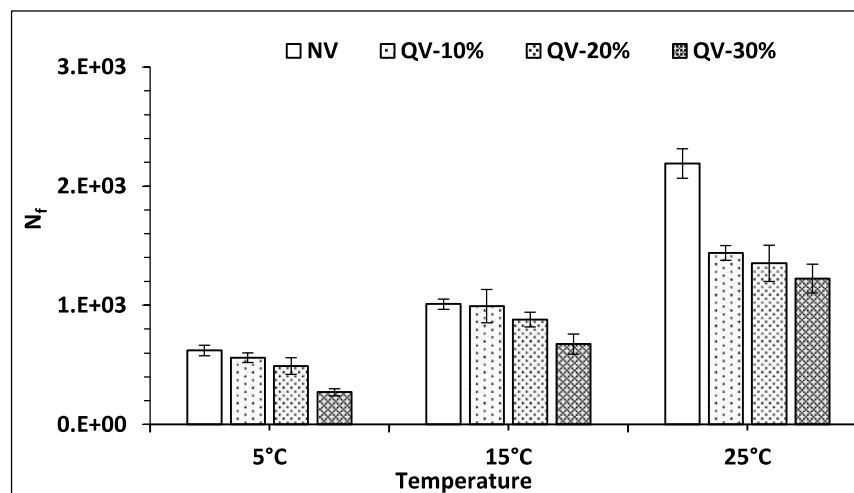
(c)



(d)



(e)



(f)

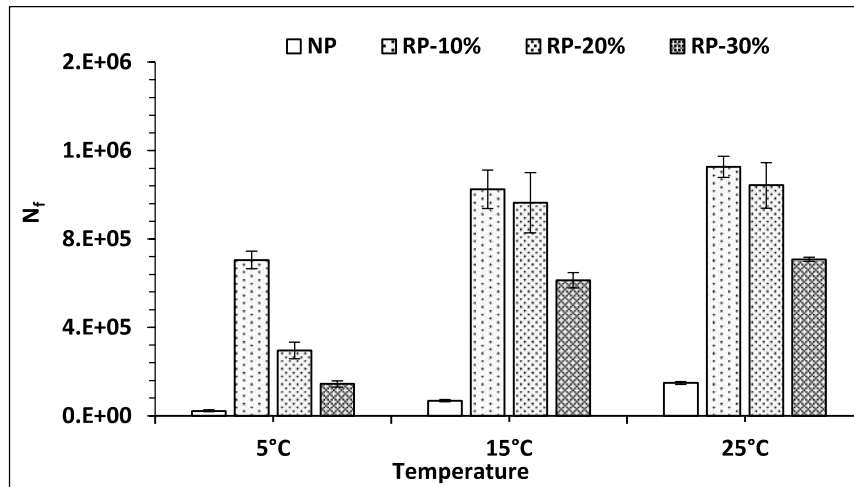
Figure 6.8 Variation in fatigue life of asphalt mastics prepared with neat binder and different fillers with change in filler content and tested at different temperatures

It is to be noted that the addition of filler improved the fatigue performance of the binder in the case of MD and LS fillers. This was evident from higher failure cycles of asphalt mastics at all filler contents. It is also noteworthy that even the fatigue performance of asphalt mastic with 30% filler content was better than the neat binder. This shows that adding filler may not necessarily be detrimental in terms of the fatigue performance of the material. The addition of

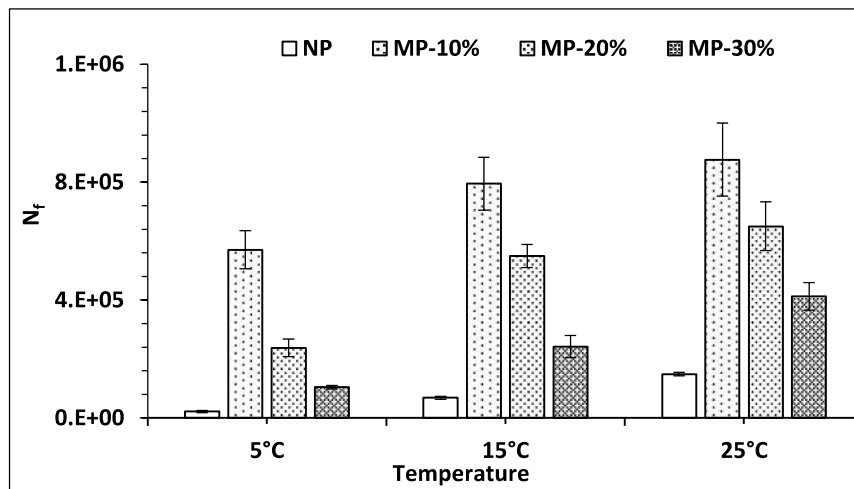
filler increased the stress tolerance of the binder, and the resulting mastic was able to sustain a higher magnitude of stresses without failure. In the continuation, the MD and LS did not make the binder so stiff that it compromised the binder's strain tolerance. Hence, the MD and LS based mastics performed better than the neat binder. For GR and BA, the response of the mastics against fatigue damage was a temperature dependent phenomenon, i.e., the behavior at 5°C and 15°C was different from that at 25°C. At 5°C and 15°C, the N_f increases at 10% filler content, but it was lower than the base binder at 20% and 30% filler volume concentration. However, at 25°C, the N_f of the binder was higher than that of mastics.

Comparing among mastics, the fatigue life showed a steady decrement with higher filler contents independent of the filler type and the temperature, but the relative effect of filler content was alike and was dependent on the type of filler. For RM and QZ, the rate of change of fatigue life is similar from 10 to 20% and to 30%, but in the case of MD and LS, the N_f showed comparatively less decrement on increasing the filler content from 10 to 20% as compared to that from 20 to 30%. Moreover, the fatigue performance was similar at 20% and 30% in mastics prepared with GR and BA.

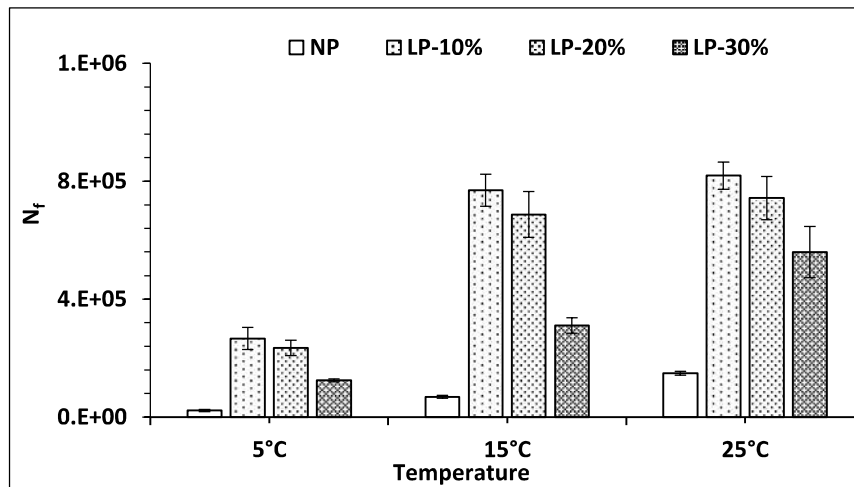
Interestingly, after the preliminary analysis of the effect of the filler-binder ratio, the selected fillers can be divided into three groups. For example, the performance or behavior of RM and QZ is similar. Also, MD and LS behave similarly; the same is true for GR and BA. The categorization of all the fillers into three groups based on similar behavior was also justified by the FSR parameter. The combination of RM and QZ, MD and LS, and GR and BA have lower, higher, and average FSR values, which can be attributed to their similar behavior.



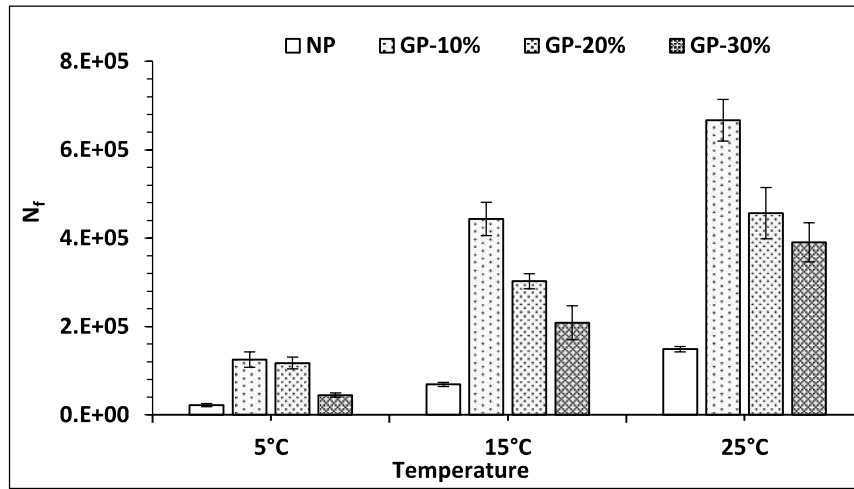
(a)



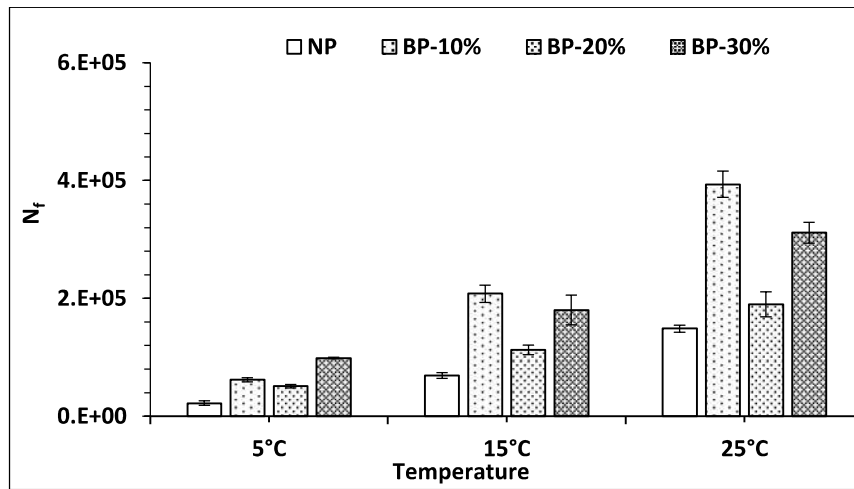
(b)



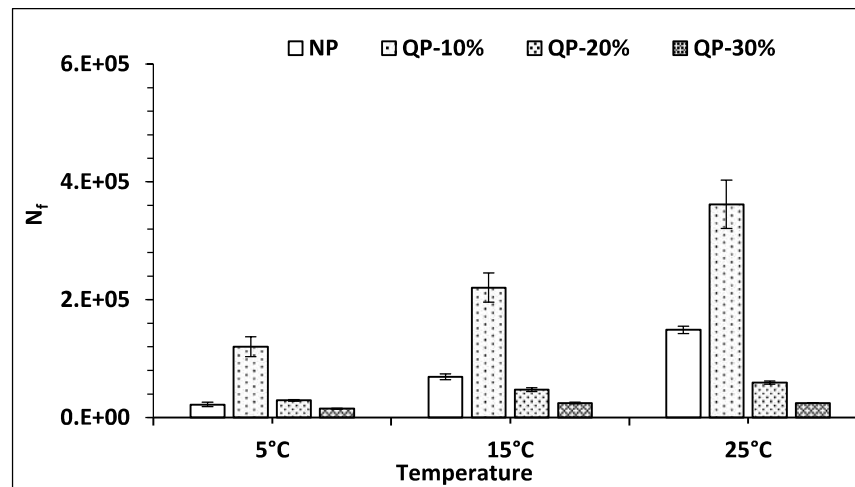
(c)



(d)



(e)



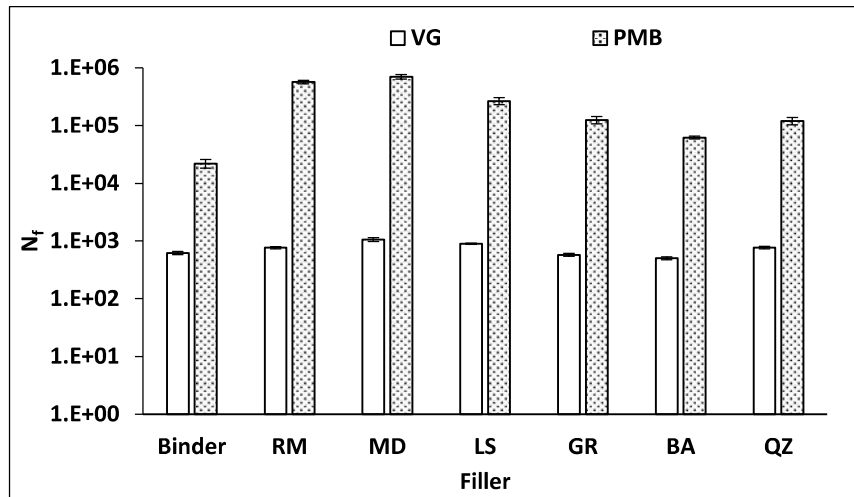
(f)

Figure 6.9 Variation in fatigue life of asphalt mastics prepared with modified binder and different fillers with change in filler content and tested at different temperatures

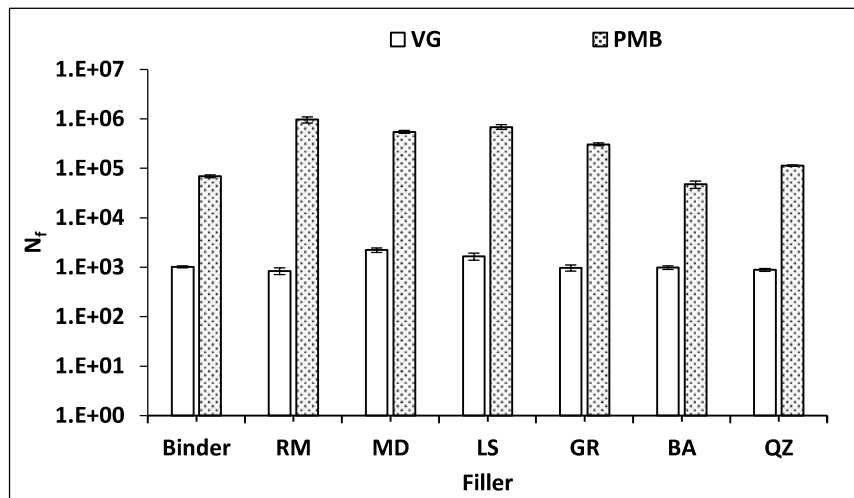
Figure 6.9 shows the fatigue life of asphalt binder and mastics at varying filler contents with PMB as the base binder. The relative behavior of the mastics with respect to the binder was found to be similar irrespective of the type of filler. Also, it is observed that the fatigue life of mastics was always higher than that of the base binder at all temperatures and filler volume concentrations. The presence of a polymer chain inside the asphalt mastics imparts elasticity to the mastic system, which results in the high strain tolerance of the material.

6.6 Effect of Binder

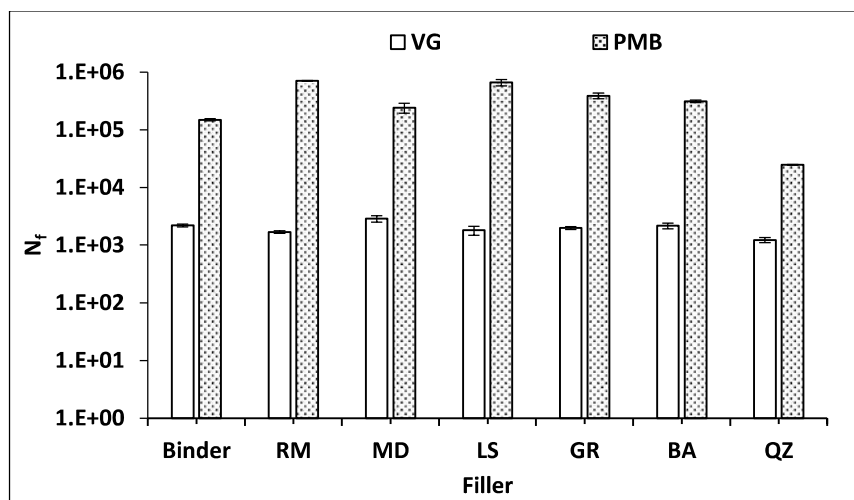
Figure 6.10 compares the fatigue lives of unmodified and modified binders and their corresponding mastics. It is observed that the fatigue life with PMB-40 as a base binder was always higher than that of their VG-30 counterparts, which can be attributed to the flexibility characteristics imparted by the SBS polymer to the binder. This is just a direct comparison of the fatigue life; however, the effect of the binder has been described subsequently while studying the effect of other parameters, i.e., type of filler, temperature, F-B ratio, and strain in sections 6.2-6.5



(a) 10%-5°C



(b) 20%-15°C



(c) 30%-25°C

Figure 6.10 Comparison between fatigue life of asphalt mastics prepared with both binders at (a) 10% filler content, 5°C temperature (b) 20% filler content, 15°C temperature (c) 30% filler content, 25°C temperature at 5% strain

6.7 Glover-Rowe (GR) Parameter

The evaluation of the cracking resistance of the asphalt binder via rheological testing in the LVE domain has been attempted by several researchers using a mathematical parameter known as the GR parameter [327,328]. It is calculated from the frequency sweep test and can be expressed as:

$$GR \equiv |G^*|_{LVE} \frac{\cos^2 \delta_{LVE}}{\sin \delta_{LVE}} \quad (6.2)$$

where $|G^*|_{LVE}$ and δ_{LVE} are the LVE complex shear modulus and phase angle at the temperature of 15°C and the angular frequency of 0.005 rad/s. The obtained values were plotted in Black space where they could be easily compared with the boundary values of 180 and 600 kPa representing the onset of cracking and the cracking damage zone, respectively [247,329,330]. Higher values of the GR parameter indicate a higher susceptibility to cracking [331].

The GR parameter can be a very useful tool to rank the materials in terms of their cracking resistance without actually doing the concerned tests. The efficacy of the GR parameter has been acknowledged by various scholarly articles; however, the applicability of the parameter with asphalt mastics has not been explored with enough rigor. The validity of the GR parameter was assessed by comparing it with the results of the LAS test in this study. Table 6.8 shows the ranking between the mastics obtained from the LAS test (in terms of fatigue life, N_f) & GR parameter for the VG-30 base binder. Since the lower value of GR is desirable for better

cracking resistance, a better ranking was assigned to the material having a lower magnitude of the GR parameter.

Table 6.8 Ranking analysis between the GR parameter and N_f at 15°C temperature for mastics prepared with neat binder at different filler contents

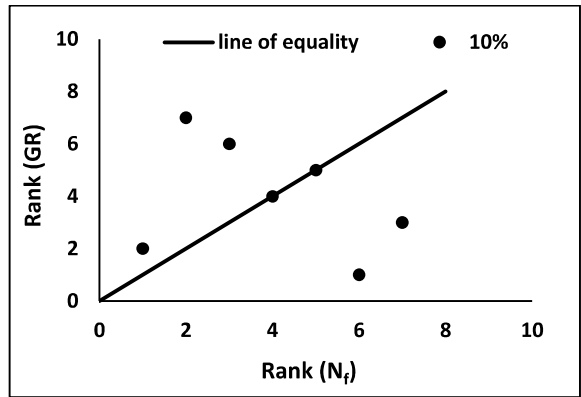
	Filler Content					
	10%		20%		30%	
	N_f	GR	N_f	GR	N_f	GR
Binder	3	6	5	7	5	6
RM	1	2	1	1	1	1
MD	7	3	7	3	7	3
LS	6	1	6	2	6	2
GR	5	5	3	6	4	7
BA	4	4	4	5	3	4
QZ	2	7	2	4	2	5

Table 6.9 Analysis between the GR parameter and N_f at 15°C temperature for mastics prepared with polymer modified binder at different filler contents

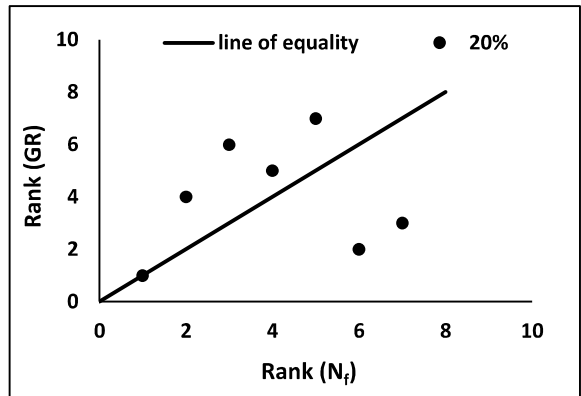
	Filler Content					
	10%		20%		30%	
	N_f	GR	N_f	GR	N_f	GR
Binder	1	5	2	5	2	6
RM	7	1	7	1	7	1
MD	6	3	5	2	5	4
LS	5	2	6	3	6	2
GR	4	4	4	4	4	3
BA	2	6	3	7	3	5
QZ	3	7	1	6	1	7

The ranking between the mastics was found to be drastically different for N_f and the GR parameter at all filler contents, i.e., 10, 20, and 30%. Similar outcomes were observed for PMB based mastics, too (Table 6.9). The majority of the data points were very far from the line of equality, signifying a high discrepancy between the N_f & GR parameter independent of the type of binder and the filler volume concentration (Figure 6.11 and 6.12). Hence, it can be

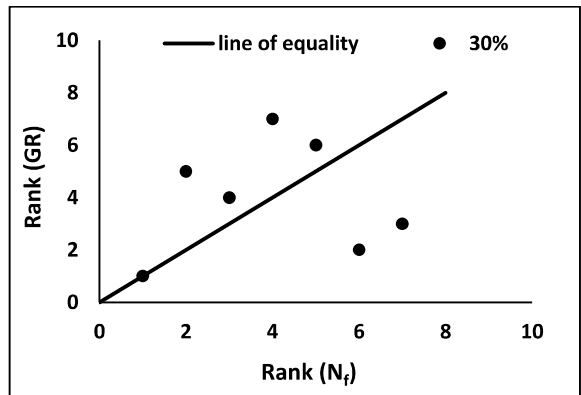
concluded that the GR parameter was not able to rank the different mastics correctly & it is not a valid parameter for characterizing the fatigue behavior of asphalt mastics.



(a)

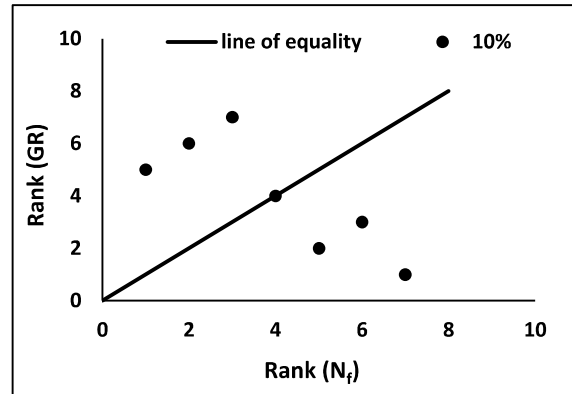


(b)

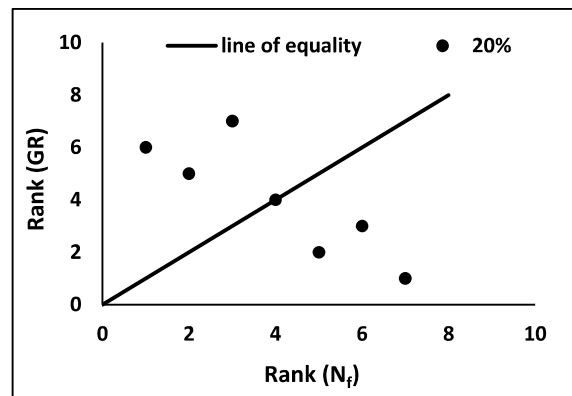


(c)

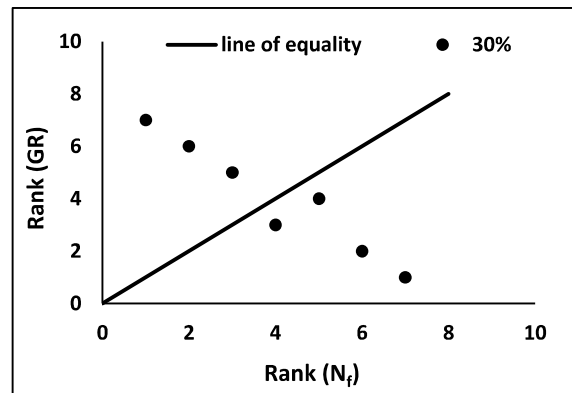
Figure 6.11 Discrepancy analysis between the GR parameter and the N_f at 15°C temperature and filler content of (a) 10% (b) 20% (c) 30% for mastics prepared with an unmodified base binder



(a)



(b)



(c)

Figure 6.12 Discrepancy analysis between the GR parameter and the N_f at 15°C temperature and filler content of (a) 10% (b) 20% (c) 30% for mastics prepared with a modified base binder

6.8 Summary

The asphalt mastic is a heterogeneous mixture of filler and binder, due to which the behavior is dependent on the type of filler, binder, and the filler-binder ratio. In addition, the testing variables such as temperature, geometry, applied strain, type of test, and analysis procedure also affect the response of mastics against fatigue damage. Therefore, this study encompassed eight different variables and investigated their effect on the fatigue behavior of asphalt mastics and binders.

The ranking of the mastics was found to be dependent on the magnitude of the applied strain, as evident from the variable ranking corresponding to the strain in LVE, NLVE, and failure region, and the strain amplitude of 5% was found to be suitable for comparing the test results. The effect of temperature was straightforward, as evident from enhanced fatigue performance at higher temperatures, irrespective of the testing conditions. The relative ranking of the fillers was approximately similar for both neat and polymer modified mastics except for RM. The effect of the filler-binder ratio was found to be dependent on the type of filler with unmodified mastics, whereas the binder played the dominant role in PMB based mastics. With respect to the binder, the mastics prepared with PMB outperformed the neat mastics. The FM, SSA, and RV were found to be the primary filler characteristics affecting the fatigue performance of the asphalt mastics, whereas the GR parameter was unable to characterize the fatigue behavior.

