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Investigating The Effect of Acrylic Latex on Moisture Susceptibility of Hot Mix Asphalt

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Keywords
Acrylic latex,
Bitumen modification,
Indirect tensile strength,
Moisture susceptibility

Abstract: Polymers are popular materials as an additive to improve the performance of hot mix asphalt (HMA). To this aim, acrylic latex was chosen to improve the performance of asphalt mixture. In this study, it was investigated that the performance of hot mix asphalt with acrylic latex additive in three percentages (1%, 2% and 3%). Design bitumen contents were determined for all acrylic latex additive. Indirect Tensile Strength and moisture susceptibility of acrylic latex added HMA was conducted using test procedure of AASHTO T283. According to the results, design bitumen contents were increased by acrylic latex. Although the bitumen content was increased, both the indirect tensile (IDT) strength and the moisture resistance were improved by acrylic latex. Best performance was obtained by 3% acrylic latex additive. It is suggested that the percentage of acrylic latex would be increased for further researches.

Akrilik Lateksin Bitümlü Sıcak Karışımların Nem Hassasiyeti Üzerindeki Etkisinin Araştırılması

Anahtar Kelimeler
Akrilik lateks,
Bitüm modifikasyonu,
İndirekt çekme dayanımı,
Nem hassasiyeti

Özet: Polimerler Bitümlü Sıcak Karışımların (BSK) performansını artırmak amacıyla kullanılan popüler katkı malzemeleridir. Bu çalışmada, asfalt karışımların performansını artırmak amacıyla akrilik lateks seçilmiştir. Akrilik lateks karışıma üç farklı oranda (%1, %2 ve %3) karıştırılarak bitümlü sıcak karışımların performansı incelenmiştir. Dizayn bitüm içerikleri her bir oran için ayrı ayrı belirlenmiştir. Akrilik lateks ile karıştırılmış BSK için İndirekt çekme dayanımı ve nem hassasiyeti AASHTO T283 test prosedürü dikkate alınarak belirlenmiştir. Elde edilen sonuçlara göre, dizayn bitüm içeriği artırılmıştır. Bitüm içeriği artmasına rağmen, hem indirekt çekme (IDT) dayanımı hem de neme karşı dayanımda iyileştirme elde edilmiştir. En iyi performansı gösteren akrilik lateks katkı oranı %3 olarak belirlenmiştir. Sonraki çalışmalar için akrilik lateks oranının artırılması önerilmektedir.

1. Introduction

Increasing demand on oil industry force researchers to find a new binder or regeneration agent. For example, researchers are focus on bio-binders obtained from natural bio wastes. Also, polymers are generally used to modify binder. Rutting and fatigue cracking are mostly encountered problems occur in asphalt pavements caused by significant increase in traffic volume. Structural performance of asphalt pavement reduced by these problems. Bitumen modification with polymers is a popular method to prevent performance reduction.

Sutanta et al. [1] examined the performance of latex and rubber modified bitumen. Three percentages were used in the study (4, 6, 8%) for the rubber and latex. Dynamic Shear Rheometer (DSR) test was used to evaluate the rheological properties. Results were showed good performance in rutting. Wen et al. [2] investigated the natural rubber latex addition as renewable material in asphalt mixtures. The authors found that the rubber latex can be used as a renewable material in asphalt mixtures. Shafii et al. [3] investigated the natural rubber latex in asphalt emulsions. Result of the study indicated that maximum percentage was found as 7% and blending time was 20 min. Cai et al. [4], examined the performance of SBS latex modified bitumen emulsion. As a result, it is found that the SBS latex was beneficial for bitumen. Shaffie et al. [5], examined the physical properties of natural rubber latex modified

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bitumen. It was found that the natural rubber latex was suitable to modify the bitumen and enhanced the bitumen performance. Daniel et al. [6], examined the properties of latex modified bitumen. Latex percentages were 2.5%, 5.0%, 7.5% and 10% used in the study. It was found that latex was hardened the bitumen and provided better rutting performance. Shafie et al. [7] investigated the stripping performance of natural rubber latex polymer modified asphalt mixtures. The investigation resulted in the improvement of stripping performance of hot mix asphalt with 8% natural rubber latex modified bitumen. Zhang et al. [8], examined the performance of SBR modification in asphalt emulsion. As a result, optimum latex modification percentages were found as 4.0% to 5.0%. Forbes et al. [9], examined the microstructure of polymer modification in asphalt emulsions. Improved performance was found as a result. Abedini et al. [10], investigated the low-temperature performance of polymer modified bitumen emulsions in chip seal with SBR latex. It is found that SBR latex leads to increased aggregate retention and resulted in lower bitumen aggregate adhesion. Khadivar and Kavussi [11], examined the rheological properties of SBR and natural rubber modified bitumen. As a result, stiffness was increased with natural latex and SBR was sensitive to applied stress.

In literature, acrylic latex was used as an additive to obtain the asphalt emulsions, mostly. Different from literature, in this study, acrylic latex was mixed into asphalt mixtures directly. In this study, acrylic latex was mixed with asphalt mixture in three percentages (1, 2 and 3%) to investigate the performance of asphalt mixture. Superpave mix design was used and the design bitumen contents were determined. The mixtures were compacted using Superpave Gyratory Compactor (SGC). Finally, tensile strength ratio (TSR) was determined against moisture susceptibility.

2. Materials and Methods

2.1. Aggregate and gradation of mixture

HMA mixtures were prepared according to wearing course mix design criteria. Dense graded HMA was prepared by Superpave™ guidance and gradation curve was selected as shown in Figure 1. Aggregate properties were also given in Table 1.

2.2. Bitumen

In this study PG 64-22 base bitumen was chosen. Bitumen characteristics were examined in terms of Dynamic Shear Rheometer (DSR), Bending Beam Rheometer (BBR), Rotating Thin Film Oven Test (RTFOT) and Pressure Aging Vessel (PAV) in convenience with Superpave. Rheological properties were determined in terms of penetration, ductility, rotational viscometer and softening point and the results were given in Table 2.

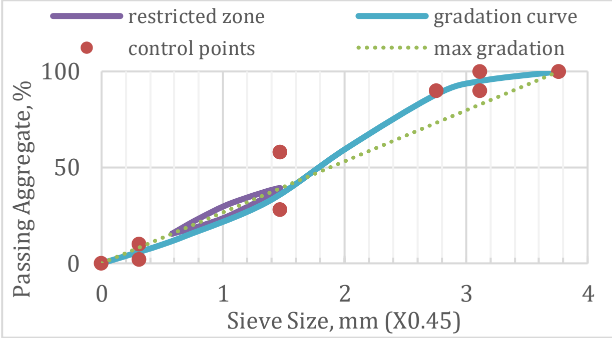

Figure 1. Gradation curve

Table 1. Properties of limestone aggregate

Sieve Diameter (mm)	Specific Gravity (g/cm³)	Absorption of water (%)	Los Angeles Abrasion Loss (%)	Flatness Index
25-4.75	2.747	2.895	20.50	
4.75-0.075	2.665	0.129		18%
≤0.075	2.683			

Table 2. Characteristics of base bitumen

Test		Unit	Base Bitumen
Penetration @25 °C ASTM D5 [12]		0.1 mm	62.2
Softening Point Ring&Ball ASTM D36 [13]		°C	49.9
Ductility @25°C, 5 cm/min ASTM D113-17 [14]		cm	>100
RV @135 °C, ≤3Pa.s ASTM E3116-18 [15]		Pa.s	0.475
RV @165 °C		Pa.s	0.15
DSR G*/sinδ>1 kPa @10 rad/s ASTM D7552-09 [16]	Fail Temp.	°C	67.9
	Grade	°C	64
Mass Loss		%	0
Permanent Penetration		%	70.4
Change in Softening Point		°C	+3.2
DSR G*/sinδ>2.2 kPa @10 rad/s	Fail Temp.	°C	67
	Grade	°C	64
DSR G*.sinδ<5.000 kPa @10 rad/s	Fail Temp.	°C	28.6
	Grade	°C	22
BBR S≤300 MPa, m≥0.300,@60s ASTM D6648-08 [17]		°C	-12
	m-value		0.325
	Stiffness	MPa	213
	Performance Grade		PG 64-22

2.3. Acrylic latex

In this study, acrylic latex was used in three percentages (1, 2 and 3% by weight of bitumen). The percentages were chosen in accordance with the literature. Acrylic latex properties were given in Table 3.

Table 3. Properties of acrylic latex

Property	Value
Appearance	milky white liquid
Specific Gravity	1.065
Solubility (in water)	<1 mg.L^{-1} at 20 °C
Maximum weight-percentage of residual impurities	<0.4%
Boiling temperature	152.4 °C

2.4. Experimental

Mixing the acrylic latex with hot mix asphalt was investigated. DSR, BBR, RTFOT and PAV was adopted to determine the rheological properties of base bitumen. Compaction effort was performed with Superpave Gyratory Compactor (SGC) for the acrylic latex modified asphalt mixtures. Design bitumen content (DBC) was determined for acrylic latex modified mixtures separately. Modified Lottman procedure was adopted to determine the moisture susceptibility.

2.5. Mix Design

DBCs of acrylic latex modified mixtures were determined by Superpave™ mix design. 4% air void is aimed for compaction. Samples were compacted in different bitumen contents (3.5%, 4%, 4.5% and 5%) to find out the design bitumen contents at 4% air void. DBC of base HMA was found as 4.5%. Graphs of design bitumen were drawn. DBC was checked whether the limit value is ensured for VMA and VFA.

2.6. Moisture Susceptibility

Modified Lottman procedure is adopted to evaluate the moisture sensitivity. IDT strength and moisture susceptibilities of HMA was determined according to AASHTO T283 [18] test procedure. Samples are compacted as conditioned samples and unconditioned samples (three samples for dry and three samples for wet). Each sample is vacuum saturated to condition. A freeze thaw cycle was conducted and saturation level was achieved (55 to 80%). Tensile strength and tensile strength ratio (TSR) are determined. Moisture damage resistance is determined as a ratio of the tensile strength of dry sample to wet sample.

3. Results and Discussion

3.1. Design bitumen contents

Design bitumen graphs were drawn and VMA and VFA were checked and ensured by 4.5% DBC of HMA (Figure 2) for control HMA. Same graphs were drawn for acrylic latex, separately and DBCs were determined for all content of acrylic latex modified HMA as 6.34% for 1% modification, 5.49% for 2% modification and 5.78% for 3% modification (Figure 3, 4 and 5). VMA and VFA was checked also for modified samples. Only the 1% acrylic latex modified HMA hasn't ensure the VFA limit values.

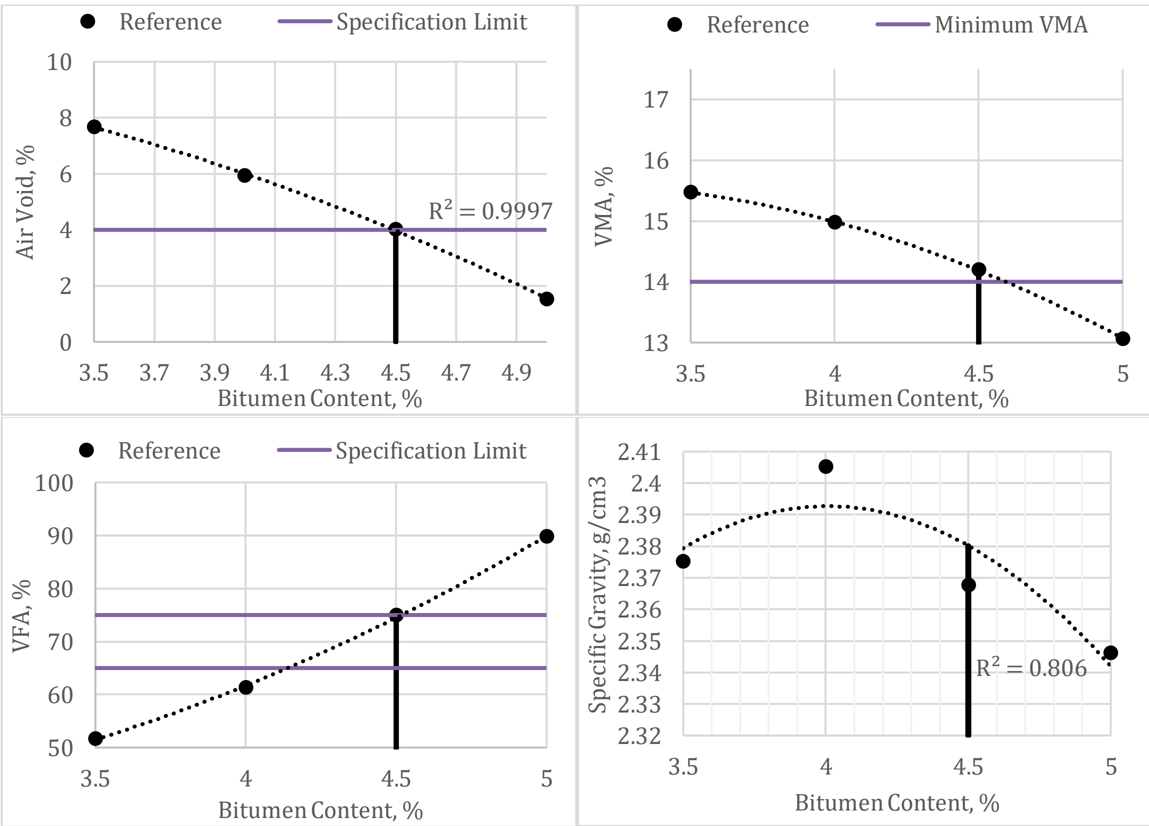

Figure 2. Design bitumen content for base HMA

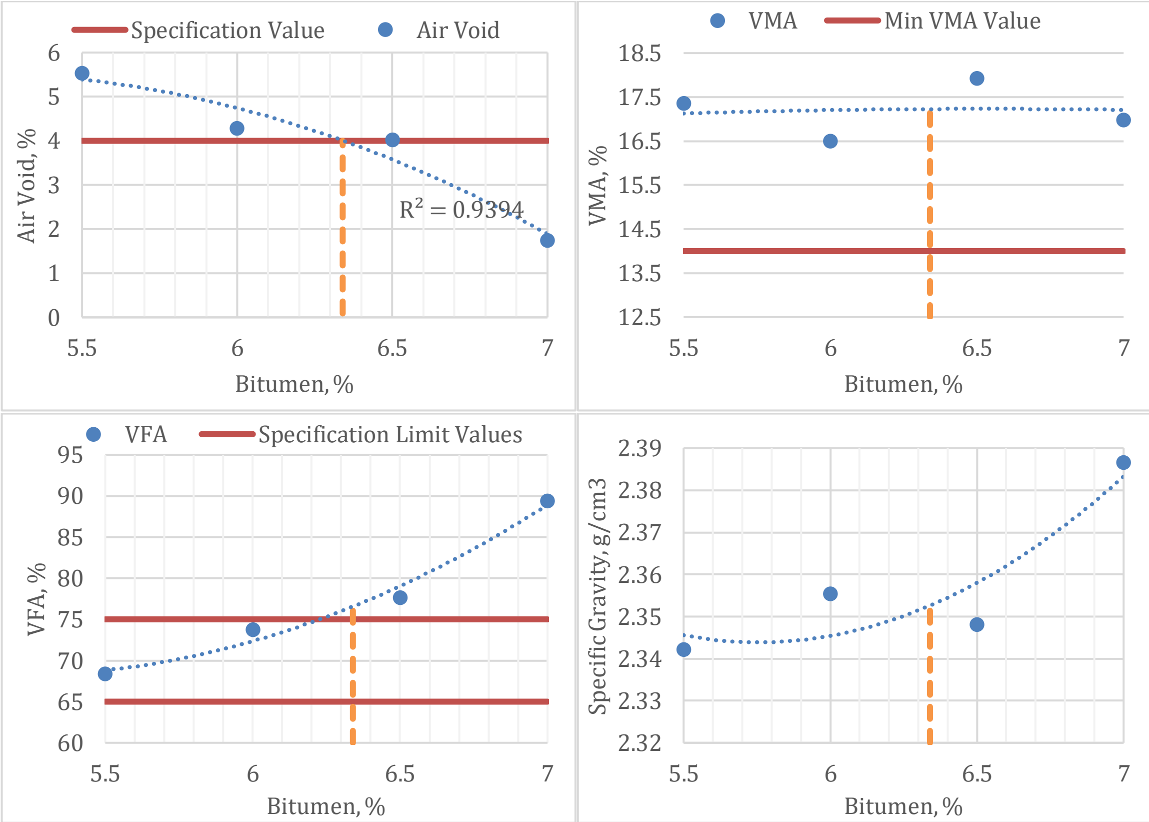

Figure 3. Design bitumen content for 1% acrylic latex

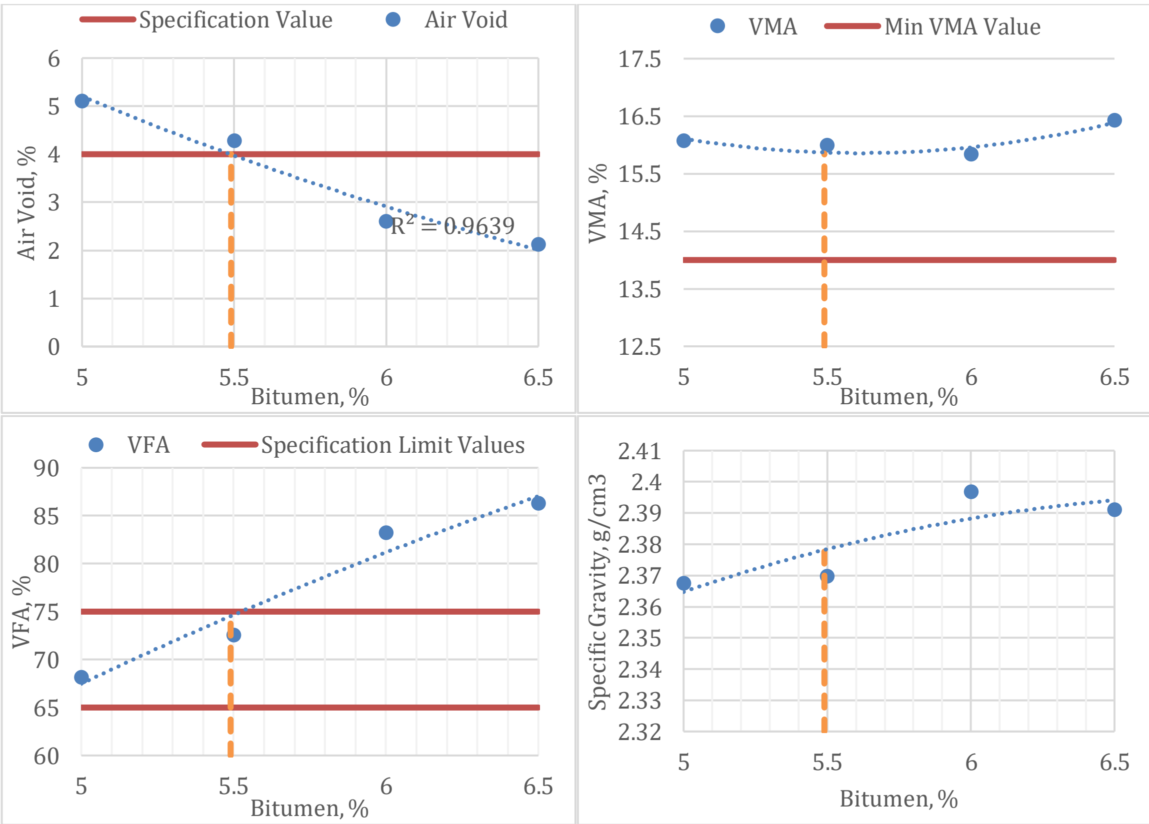

Figure 4. Design bitumen content for 2% acrylic latex

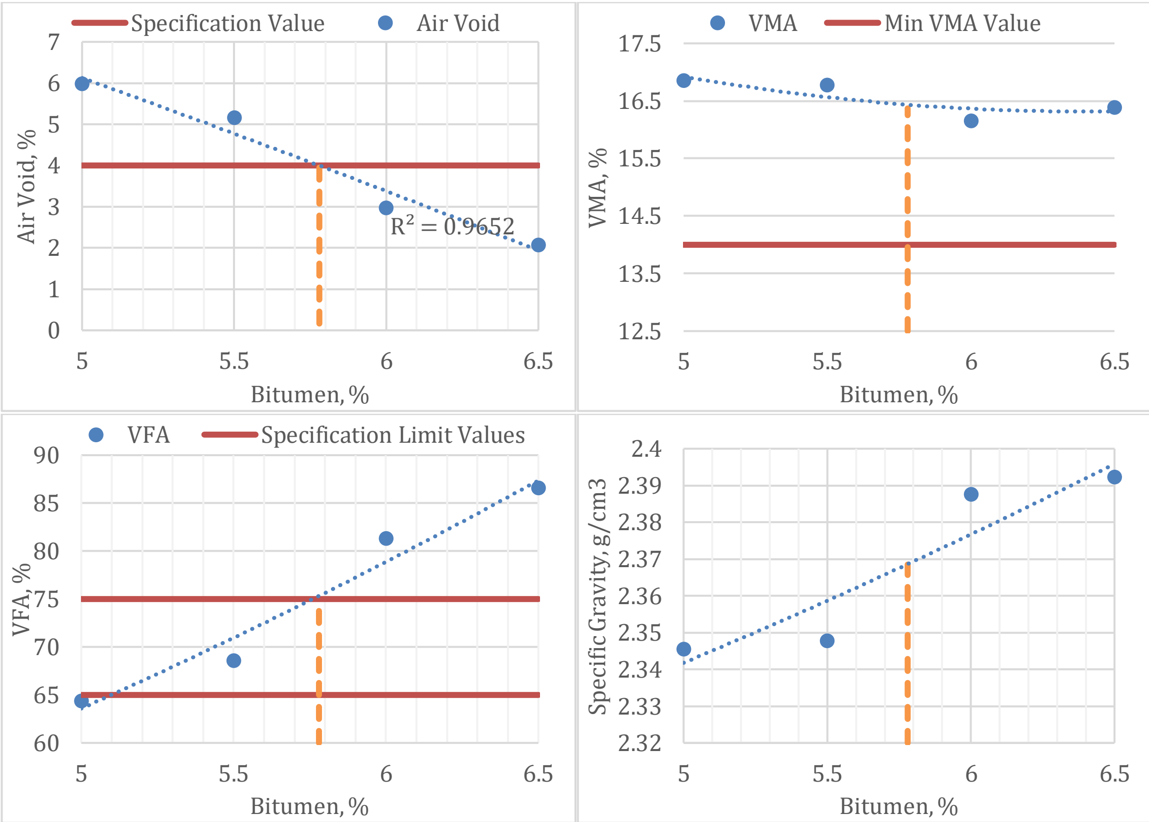

Figure 5. Design bitumen content for 3% acrylic latex

3.2. Moisture susceptibility

IDT of acrylic latex added HMA was identified. According to the results, increasing IDT was obtained with the increase of the acrylic latex content (Figure 6). IDT unconditioned values indicate the strength of the mixtures. So that, the strength of the acrylic latex modified asphalt mixtures were increased. The IDT unconditioned value of control mix was determined as 7.2 kPa, and the acrylic latex modified samples 1%, 2% and 3% was determined as 9.95, 10.53, 10.8 kPa, respectively. Acrylic latex was found beneficial to the strength of the asphalt mixtures.

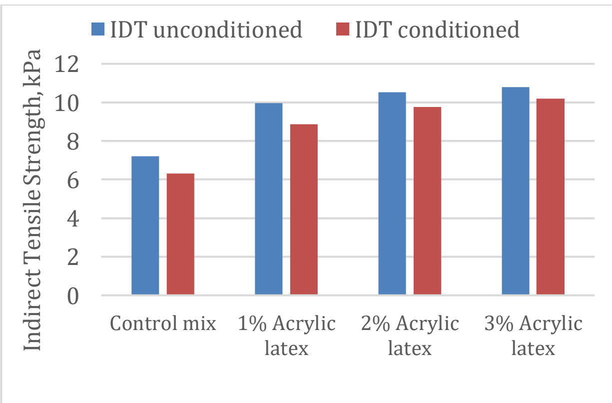

Figure 6. IDT test results for acrylic latex

Moisture susceptibility of acrylic latex modified asphalt mixture was determined by Tensile Strength Ratio (TSR). According to the results, moisture susceptibility was decreased when increasing the acrylic latex content (Figure 7). Meaning that, acrylic latex modified HMA was found to be resistive against moisture. The TSR was determined as 88%, 92% and 94% for 1%, 2% and 3% acrylic latex modified HMA, respectively. The moisture resistance was increased by using acrylic latex compared to control HMA. It can be concluded that acrylic latex was effective for stripping.

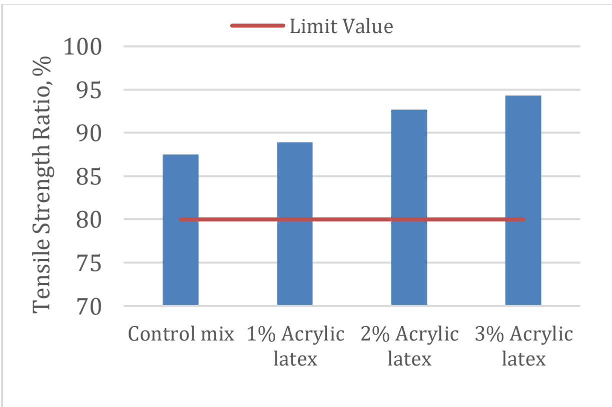

Figure 7. TSR results for acrylic latex

4. Conclusion

In this study, acrylic latex additive was used in HMA to improve the moisture resistance. To this aim, 1%, 2% and 3% acrylic latex was added to the HMA. According to test results conclusions can be drawn as follows:

- The design bitumen contents were increased with the acrylic latex additive.
- IDT strengths were increased with the increase of acrylic latex additive.
- Moisture susceptibility was decreased with the addition of acrylic latex.
- Best performance was obtained by 3% acrylic latex additive.

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