Evaluation of Moisture Sensitivity of Various Asphalt Mix

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Abstract

Moisture in the asphalt mix can damage it severely, as it reduces the adhesion between the binder-aggregate interface and cohesive failure within the binder. Moisture damage in asphalt mixture causes reduction in strength, stiffness and life, the damage most commonly known as Stripping. Various tests are available to the resistance of asphaltic mixtures against moisture damage, and one of them is AASHTO T283. In this paper, moisture susceptibility of two different asphalt mixes, i.e. HMA 60/70 and Polymer Modified Bitumen 60/70 is determined and compared using the method describe in AASHTO T 283 (2003 Modified) by forming Marshall specimen. The gradation and various properties of the mix are detailed in the paper. The indirect tensile strength of Marshall Specimens of HMA and PMB was found out using compression Testing Machine. The result shows that PMB specimens have more IDT(Indirect Tensile) strength as compared to conventional Hot Mix asphalt specimens so PMB is more resistance to moisture damage.

Key Words : Adhesion, Stripping, Moisture Susceptibility, Marshall, Indirect tensile strength.

Introduction

Pavement fails prematurely due to presence of water. The failure then shows out in the form of isolated distresses and in the form of early cracking and rutting. Moisture sensitivity has been an important consideration in the design of flexible pavements for a long time. (Hveem,1940) emphasized that the moisture sensitivity is as important as the other parameters that are essential during the selection of quality asphalts for flexible pavement construction. A recent survey carried out (Aschenbrener,2002) by 55 states and federal highway agencies shows that 87% of their moisture sensitivity tests, 82% of highways require some maintenance and treatment to defend against moisture damage. Stripping has a severe effect on the performance of Pavement and unexpected increase in maintenance costs is often experienced. Temperature and seasonal variations and moisture can have an intense effect on the strength and functional performance of flexible pavements. When serious climatic conditions are combined with heavy loading conditions and poor construction materials, early failure may occur due to decrease of adhesion between asphalt binder and aggregate particles.

Problem Statement

The damage caused by moisture on asphalt concrete pavement is known as stripping. Stripping has severed effects on the pavement's structural integrity. Many tests has been developed in the past to for the prediction of moisture sensitivity. In many of the methods developed, thaw freeze cycle is performed on the cores taken from the field and on the Marshall samples prepared in the laboratory. In most of the cases single freeze thaw cycle was applied on the cores. The effects of a no. of freeze thaw cycles on strength of HMA are not well known.

Objectives

The primary objectives of the research are to:

- Explore moisture sensitivity of different asphalt mixes
- Assess the effect of various number of freeze thaw cycles on the tension strength of Marshall Specimens of the mix.
- Compare the moisture sensitivity of asphalt mixes with different binders.

For achieving the above mentioned objectives conditions set by AASHTO T 283 has been used.

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Literature Review

The moisture effect on physical properties and mechanical behavior of asphalt mixtures has been known for many years but even though it has proven to be very difficult to confidently predict this type of distress in the laboratory because of numerous factors involved.

Moisture can effect in different form. Adhesive failure between the bonding material and aggregate results in de-bonding which, in an advanced state, is identified as “stripping” as shown in figure 2. As a result of stripping, high strength HMA pavement layer reduces to weaker untreated asphalt section. When stripping occurs in different isolated regions in pavements, it results in the development of potholes and if it occurs in large area, rutting ad fatigue cracking may develop due to decrease in structural support of the pavement.

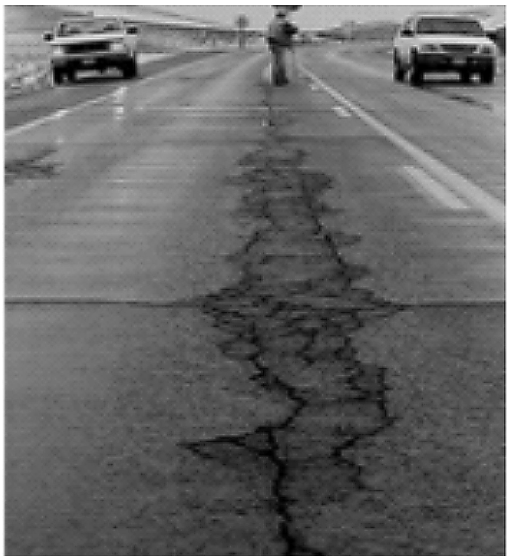

Figure 1 : Fatigue cracking due to stripping in asphalt pavement

Figure 2 : Stripping in asphalt pavement due to lack of bond b/w asphalt and aggregate

(Source:http://www.pavementinteractive.org/article/moisture-susceptibility)

Historical Development

The immersion compression test was the first moisture damage test under ASTM standards introduced in 1950 on the compacted specimens. Thelen conducted work on the surface energy of asphalt and aggregate bonding relationship (Thelen,1958). Andersland and Goetz developed the sonic test to assess the resistance against stripping in HMA samples (Andersland and Goetz,1956). In 1978 the Lottman's laboratory test was a breakthrough in industry for predicting stripping in asphalt concrete. This test was later modified and standardized as AASHTO T 283 1978 the Lottman's. Root and Tunnicliff developed some advancement in Lottman test after an extensive evaluation of anti-stripping additives(Root and Tunnicliff ,1980).

In the 1980s, Kennedy et. al. at University of Texas presented two new test methods to the industry: Freeze-Thaw Pedestal Test (Kennedy et. al.1982) and Boiling Test (Kennedy et. al.1984) **.**The freeze-thaw pedestal test was a modification of the method introduced earlier in 1980 by Plancher et al and the boiling test was similar to the test used by Saville and Axon in 1937. Due to sponsored research by SHRP for assessing better the effect of moisture on various mixes, Al-Swailmi and Terrel develop Environmental Conditioning System (ECS) (Al-Swailmi and Terrel,1992) and Aschenbrener and Currier introduced Hamburg wheel-tracking device in United States (Aschenbrener and Currie,1993).There is an extensive quantity of literature regarding detecting moisture susceptibility of asphalt concrete. However, the research conducted so far is of empirical nature. The general agreement among the designers/engineers is that the tests developed so far could not properly simulate the field conditions and we could not exactly judge the field performance in the laboratory (Roberts et. al. 1996)**.**

Despite of some short comings in AASHTO T 283, it is still the best available procedure to investigate the moisture sensitivity of HMA mixes. NCHRP launched a research program to evaluate the test constraints of AASHTO T 283 with a purpose of improving the consistency of the testing procedure (Epps, et. al. 2000). Anderson and Dukatz in1982 analyzed various anti-stripping additives that are available commercially and their effect on asphalt properties. They came up with the result that anti-stripping additives have a tendency to soften the asphalt, decrease temperature susceptibility, and refine the aging characteristic of asphalt (Anderson and Dukatz, 1982).

Aschenbrener, et. al. (1995) compared the performance of HMA mix of known antistripping potential in field with 04 moisture susceptibility procedures: 1. AASHTO T-283, 2. ASTM D-3625, 3. Environmental Conditioning System, and 4. Hamburg wheel-tracking device. And they concluded that, AASHTO T-283 gave better results by simulating the field conditions in the lab (Aschenbrener 1995). Pan et al in 1999 evaluated seven different mixes using AASHTO T 283 and PUR Wheel tracking device. They concluded from AASHTO T 283 test that stripping resistance of the mixes has influenced by moisture conditioning and from PUR Wheel test that temperature and moisture conditions has greatly affected the severity of stripping (Pan and White, 1999).

(Aiery et al in 2007) introduced a new test known as the Saturation Ageing Tensile Stiffness (SATS) test. The test is a laboratory test in which combined effect of aging and moisture damage is checked. The test consists of initial saturation of the compacted cylindrical specimens before placing them into moist atmosphere, high temperature & pressure for a longer duration. The stiffness modulus and the saturation measured both before and after the test, are used as indication of the sensitivity against moisture damage of the mixes. They concluded that, compared to the AASHTO T283, the SATS test was more aggressive conditioning procedure (Airey et.al. 2008).

Erol Islander et. al. in 2007 compared the laboratory samples with the field sample by taking cores from wearing course of identical sizes, like Marshall Samples, for dense graded asphalt mixtures. Both the types were subjected to three different moisture conditions and indirect tensile strength was carried out to compare the performance of both types of samples. Laboratory mixtures gave 1.22 and 1.30 times more values as compared with field samples at 10 C and 20 C respectively in the indirect tensile strength test. Marshall Samples gave higher resilient modulus for all control and conditioned mixtures (Erol and Atakan, 2012).

Methodolgy

As from the literature studied above the AASHTO T 283 is the best available procedure so far for detecting moisture sensitivity of compacted HMA specimens, so this method is used. The test is performed by compacting specimens at an air void level of six to eight percent. Two samples were tested as a control samples and tested as dry, and four samples are selected to be conditioned by saturation with water undergoes several cycles of freeze-thaw different from both type of mixtures i.e. -HMA 60/70 and PMB 60/70. The samples were then tested for indirect tensile test. The tensile strength of the conditioned sample was compared with the specimen unconditioned / control ratio to determine the tensile strength. (TSR)

1. Flow Sheet of Sampling And Testing

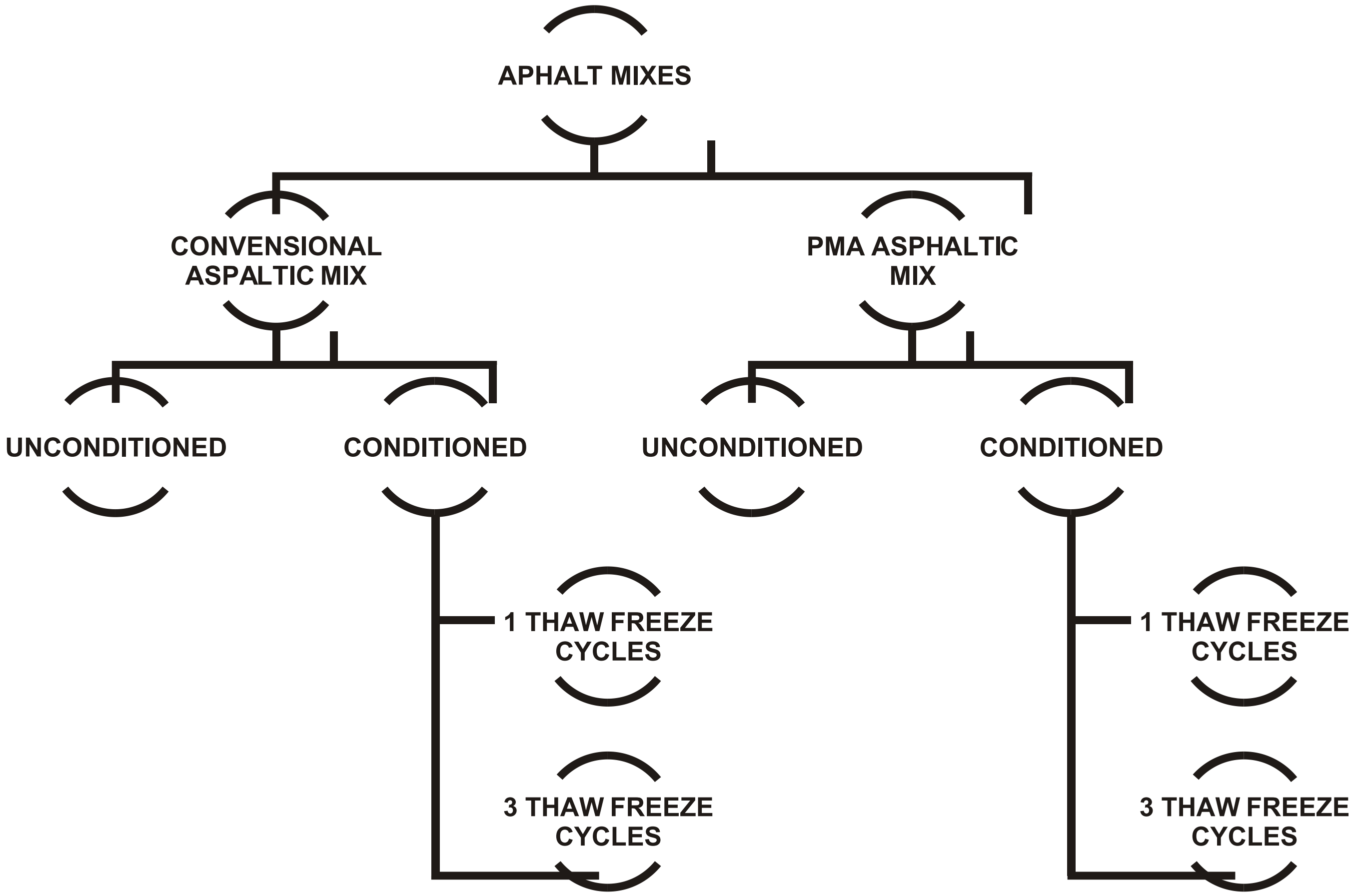

Figure 3 : Flow Chart of condition of mixes for testing

2. Testing Matrix

Table 1 : Testing, Standards and Apparatuses used in Test

Description	Standards	Apparatus
Gradation of Aggregates	NHA class A	Sieves analysis Balance
Optimum Asphaltic Content	Marshall method	Marshall stability & flow tester
Sample Preparation	Job Mix Formula	Marshall compactor
Gmb of Samples	AASHTO T 166	Gmb apparatus
Gmm of Samples	AASHTO T 209	Vacuum container
Grouping of samples	AASHTO T 269	
Testing of conditioned samples(S2)	ASSHTO T 283	Compression testing Machine
Testing of unconditioned samples(S1)	ASSHTO T 283	Compression testing Machine
Determination of tensile strength ratio	ASSHTO T 283	TSR= S2/S1

3. Testing Procedure.

Six Samples of HMA and PMB each are prepared. Marshal samples of standard sizes are made. After mixing, pour it in the marshal moulds. Compact the mix to the 7 percent air voids level, using Marshall Hammer. Then allow the specimens to remain at room temperature for 24 hours. Calculate the theoretical maximum specific gravity (Gmm), bulk specific gravity (Gmb), height, volume and air void content (Va) of each sample. Divide the six samples of each

type, into three subsets of two. The average air void content (Va) for each subset should be similar. One subset will be "unconditioned" (tested in a dry state) and the other will be "conditioned" (tested in a saturated state).
The inputs for the research regarding Marshall Samples Gradation, Physical properties of Aggregate, Properties of asphalt binders, Properties of Mix are given in tables below.asphalt binders, Properties of Mix are given in tables below.

Table 2 : Adopted Gradation

SLEVE SIZE		Combined gradation, asphalt wearing course class A	
Inch	Mm	Adopted gradation	NHA specifications class A
1	25	100	100
3/1	19	90	90-100
1/2	12.50	-	-
3/8	9.50	56	56-70
#4	4.75	35	35-50
#8	2.36	23	23-35
#50	0.300	5	5-12
#200	0.075	2	2-8

Table 3 : Physical properties of Aggregates

Text description	**Specification reference**	**Result**	**Test description**	**Specification reference**	**Result**
Aggregate crushing value (ACV)	BS 812, PART 1	22.5	Aggregate impact value (AIV)	BS 812 PART 3	13.5
Toughness index (TI)	BS 812, PART 1	74	Los-Angeles abrasion value (LAA)	ASTM C131	23%
10% fine value (TFV)	BS 812, PART 3	0.70	Elongation index (EI)	BS 812, PART 1	11%
Sod. Sulphate soundness value	AASHTO T104	3.32%	Flakiness index (FI)	BS 812, PART 1	4.75%

Table 4 : Properties of different type of Asphalt Binder

Sr. No.	**Description**	**PMA (1.6+Elvaloy4170)**	**Asphalt penetration grade "60/70"**
1	Type	Modified	Neat
2	Ring & ball softening pt	58	49
3	Penetration	46	65
4	Ductility@25^{O}C	45	100
5	Specific gravity	1.023	1.03

Table 5 : Hot Mix Asphalt and Polymer Modified Asphalt (optimum asphalt content) design properties.

MIX TYPES	OAC (%)	Gsb	Gmm	Gmb	VA (%)	VMA (%)	VFA (%)	Stability (kg)	Loss of Stability (%)	Flow (0.25mm)	Stiffness Index Stab./flow
1a PMA	3.83	2.65	2.52	2.37	5.9	13.90	58	1378	11	10.58	128
1b 60/70	3.87	2.65	2.51	2.37	5.7	13.99	59	1305	14.30	11.00	119

4. Results

The results of the testing are shown below in tables and graphs.

Table 6 : Sample standard size

Dia. inch	thick inch	Vol. inch^3
4	2.5	31.4
Dia. cm	**Thick cm**	**Vol. Cm^3**
10.16	6.35	514.55

Table 7 : Calculation of Bulk Specific Gravity Gmb of each Sample

S. No.	Wt. of Dry sample A grams	Wt. of SSD B grams	Wt. of submerged C grams	Gmb Bulk Sp. Gravity
1	1179	1185	648	2.195
2	1209	1219	662	2.17
3	1196	1207.6	653	2.16
4	1211	1222	660	2.154
5	1174	1185	636	2.14
6	1120	1127	625	2.23
7	1185	1196	639	2.13
8	1203	1211	655	2.16
9	1177	1185	633	2.13
10	1191	1202	645	2.14
11	1219	1225.5	659	2.15
12	1207	1217	659	2.16

Table 8 : Calculation of Max. Specific Gravity Gmm of each Sample

S.No.	Wt. of Dry Sample A grams D grams	Wt. of Con. + water E grams	Wt. of Con. + Water +Sample	Gmm Max. Sp. Gravity
1	1179	18886	19568	2.37
2	1209	18886	19582	2.356
3	1196	18886	19573	2.35
4	1211	18886	19578	2.33
5	1174	18886	19564	2.367
6	1120	18886	19553	2.47
7	1185	18886	19570	2.36
8	1203	18886	19574	2.225
9	1177	18886	19563	2.35
10	1191	18886	19567	2.33
11	1219	18886	19588	2.36
12	1207	18886	19571	2.31

Table 9 : Calculation of Vol. of absorbed water for Conditioned Samples

Sample	wt. of Dry sample A grams	wt. of SSD B grams	Vol of ab. Water J cm^3
F2	1196	1227	31
F6	1209	1239	30
E1	1174	1211	37
F3	1120	1158	38
S5	1177	1212	35
S4	1191	1221	30
S3	1219	1253	34
S6	1207	1241	34

Table 10 : Indirect tensile strength of Samples

S. No.	Sample	Cond-ition	Gmb.	Gmm.	Va %	Va cm^3	J=B-A cm^3	S=100 J/Va %	load KN	Load lb	Indirect tensile Strength psi	
					Gmm-Gmb/ Gmm *100	Va% E/100	Vol. of Ab. water	Deg. of Satur-ation				
1	F4	DRY	2.195	2.37	7.38	37.97	--	--	10.5	2360.50	150.35	HMA 60/70
2	F5	DRY	2.17	2.356	7.66	39.41	--	--	10	2248.1	143.19	
3	F2	CON 1	2.16	2.35	8.1	41.7	31	74.34	5.5	1236.4	78.75	
4	F6	CON 1	2.154	2.33	7.55	38.85	30	77.2	6	1348.8	85.91	
5	F1	CON 2	2.14	2.367	9.6	49.4	37	74.9	4.5	1011.6	64.43	
6	F3	CON 2	2.23	2.47	9.7	49.9	38	76.15	4	899.2	57.27	
7	S1	DRY	2.13	2.36	9.7	49.9	--	--	12.2	2742.7	174.69	PMB
8	S2	DRY	2.16	2.225	7.5	38.6	--	--	12	2697.7	171.83	
9	S5	CON 1	2.13	2.35	9.3	47.85	35	73.1	8	1798.4	114.55	
10	S4	CON 1	2.14	2.33	8.1	41.67	30	72	7.5	1686.1	107.39	
11	S3	CON 2	2.15	2.36	8.9	45.8	34	74.23	6	1348.8	85.91	
12	S6	CON 2	2.16	2.31	6.5	33.44	34	80.7	6	1348.8	85.91	

Note:DRY: Unconditioned Samples, CON 1: Specimens subjected to one freeze-thaw cycles, CON 2: Specimen subjected to three freeze- thaw cycles.

Form the above results following comparison tables are made to compare the performance of conventional Mix and Polymer modified bitumen.

Table 11 : The comparison of indirect tensile Strength of HAM and PMB mix.

S. No.	Sample	HMA 60/70	Sample	PMB 60/70	Cond.
1	F4	150.35	S1	174.69	DRY
2	F5	143.19	S2	171.83	DRY
3	F2	78.75	S5	114.55	CON 1
4	F6	85.91	S4	107.39	CON 1
5	F1	64.43	S3	85.91	CON 2
6	F3	57.27	S6	85.91	CON 2

Table 12 : Comparison of Avg. Tensile strength in psi of HMA and PMB.

S. no	Condition	average Strength psi	
		HMA 60/70	PMB
1	Dry	146.77	173.26
2	CON 1	82.33	110.97
3	CON 2	60.85	85.91

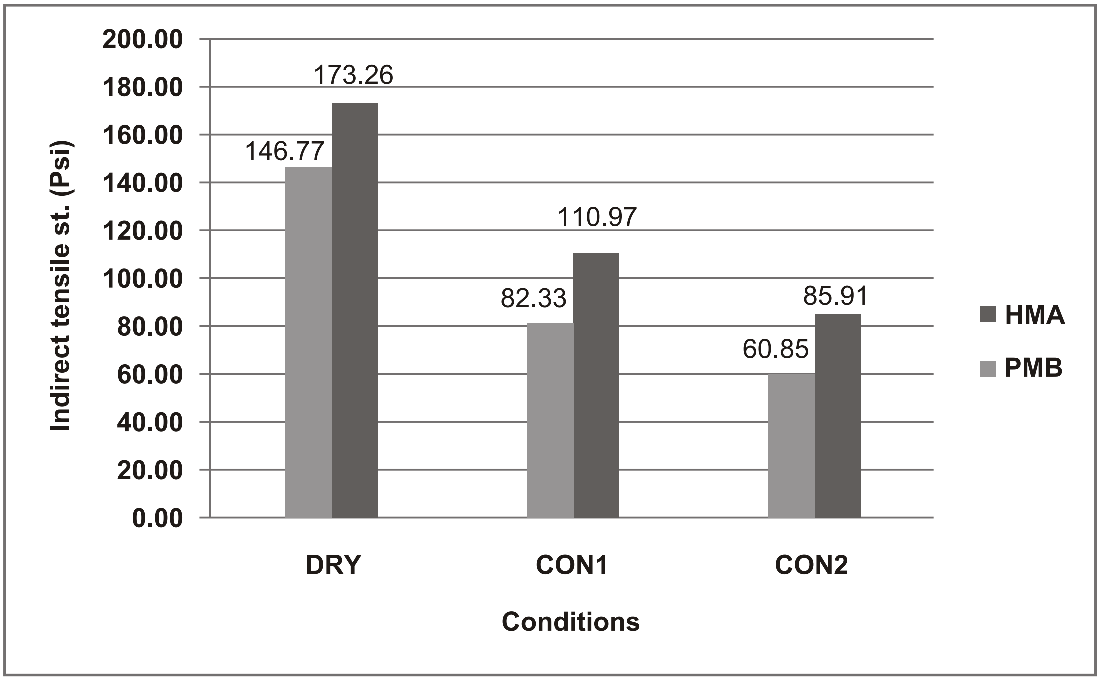

Figure 4 : Comparison of Avg. tensile strength in psi of HMA and PMB.

Table 13 : the tensile Strength Ratios of HMA and PMB

MIX	Condition	Ratio
HMA	Con 1	0.6
	Con 2	0.4
PMB	Con 1	0.65
	Con 2	0.5

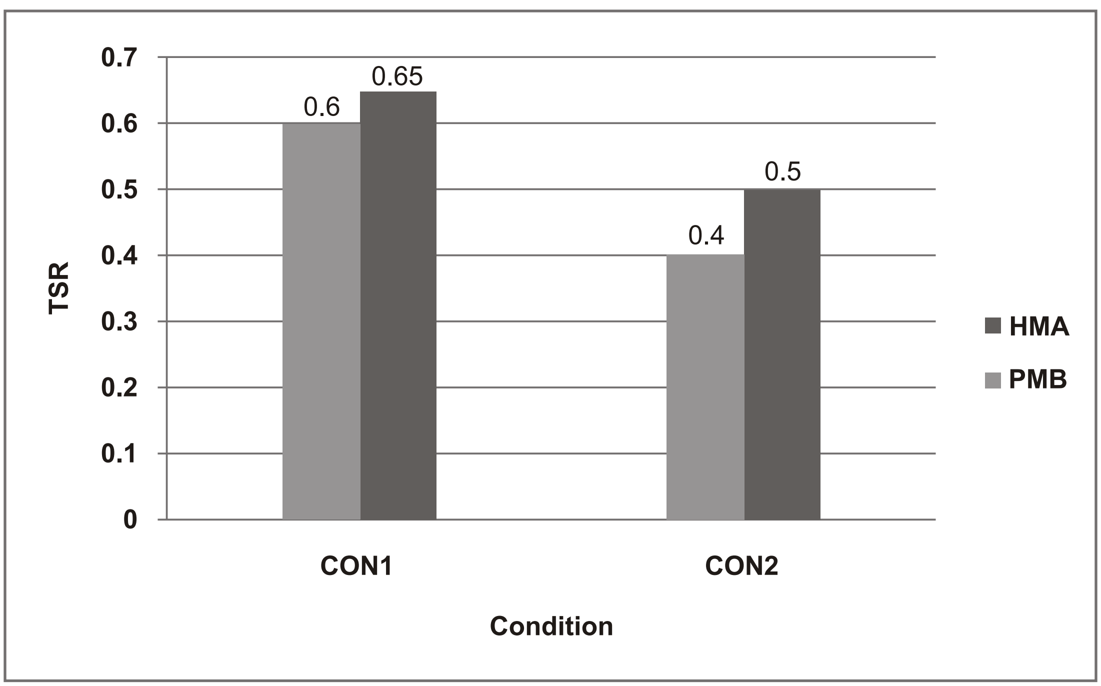

Figure 5 : Comparison of TSR of HMA and PMB

The tensile strength ratio (TSR) was calculated by dividing the average tensile strength of the conditioned samples by the average tensile strength of the unconditioned control samples.80 percent TSR is normally required for the mixes to be resistance against moisture damage.

Conclusion

After experimentation it has been concluded that:

1. Effect of thaw-freeze cycle on all type of binder mixes has been significant as the Tensile strength reduces very much after first cycle.
2. Average tensile strength of both Binders mixes decreases with number of freeze-thaw cycles, and this decrease.
3. The avg. tensile strength of PMB mixes in all conditions is more than HMA 60/70 mixes' strengths, which shows that PMB mixes have more resistance against moisture damage.
4. The TSR of HMA and PMB are both less than the required, but the PMB has more TSR as compared to their HMA counterpart.
5. The required TSR are 0.7-0.8, so this means that the NHA Class A gradation (coarser Side) is less efficient against Moisture induced Damage.

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