Experimental study of Bituminous Mix Using an Odorless Chemical Additive

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Abstract

Investigations have been carried out in India and countries abroad to find out the properties of bitumen and bituminous mixes and by the methods by which they can be improved to cope up with the above defects of pavements and with the incorporation of certain additives or blend of additives. These additives that are added to enhance the binders are called "Bitumen Modifiers" and the bitumen premixed with these modifiers is known as "Modified Bitumen". Modified bitumen's performance depends upon the degree of modifications and type of additives and modification process used. The time period of next renewal is expected to extend by 50 per cent in case of surfacing with modified bitumen as compared to normal period indicated for conventional bitumen. For example, if normal renewal cycle is 4 years, this may be enhanced to 6 years in case of modified bitumen. Full scale performance studies carried out under the ages of Ministry of Road Transport and Highways, New Delhi , Central Road Research Institute , New Delhi , Highway Research Station, Chennai, Rubber Board, Kottayam, Gujarat Engineering Research Institute ,Vadodara and Kerala Public Works Department revealed that the use of Modified Bitumen in construction/ maintenance of bituminous roads is cost effective, when life cycle cost is taken into consideration. The choice will in nut shell depend ultimately upon life cycle costing of overlays and renewals using ordinary bitumen and modified bitumen for prevailing traffic and climatic conditions. It will also depend upon the type of the pavement constructed. The need for bituminous binders has aroused due to the pavement failures. Pavement failures are one of the important issues in the entire pavement system. The failure can be due to a lot of issues, such as:

- Defects of the materials used
- Defects in the construction method
- Defects in quality control during construction
- Inadequate surface or sub surface drainage
- Increase in magnitude of wheel loads and the number of load repetitions due to increase in traffic volume

Key words: Bituminous mix; Marshall Test; Stability; Aggregates; zycotherm.

I. INTRODUCTION

Bitumen is a mixture of different organic materials, mostly of carbon and hydrogen. It is produced through vacuum distillation of petroleum. The bitumen binder can go through various problems in the field such as stripping from the aggregate, which can lead to cracking, rutting, depressions and potholes etc. Thus the binders can be modified by adding an additive to enhance its various properties. This binder in which an additive is added to make it better in its performance is called as modified binder. Modified binders are those bituminous binders whose properties have been modified by the use of additives. Bitumen binders have been modified in order to:

- stiffen binders and mixes at high temperatures to minimize rutting
- soften binders at low temperatures to improve relaxation properties and strain tolerance thus minimizing non-load associated thermal cracking
- Improve fatigue resistance especially where higher strains are imposed on bituminous mixes.
- Improve aggregate-bitumen bonding to reduce stripping
- Improve bituminous pavement durability with accompanying net reduction in life cycle costs

1.1. Materials and Methodology

The coarse aggregates for this study are taken from Ganderbal stone quarry and have following properties:

i) Nominal size = 10 mm

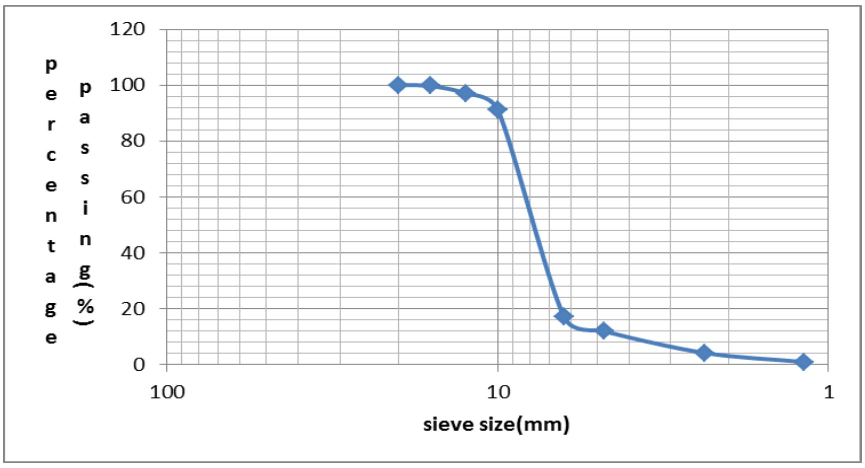

Fig. 1: Sieve analysis of 10 mm nominal size aggregate

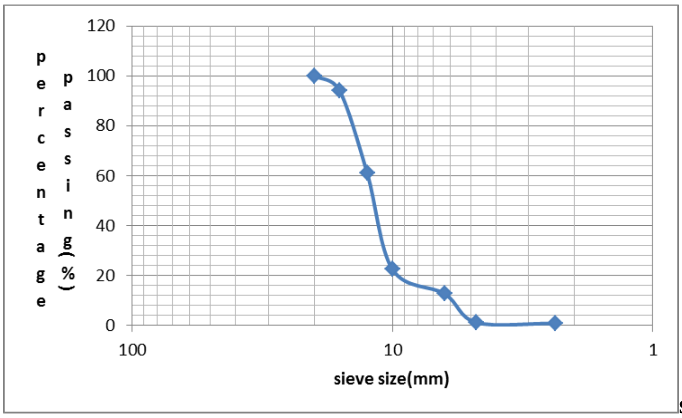

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Fig. 2: Sieve analysis of 20 mm nominal size aggregates

a) FINE AGGREGATES

Fine aggregates generally consist of natural sand or crushed stone with most particles passing through a 3/8-inch sieve. Coarse aggregates are any particles greater than 0.19 inch, but generally range between 3/8 and 1.5 inches in diameter. They shall be the fraction passing 2.36 mm sieve and retained on 75 micron sieve, consisting of crusher run screening etc. They should be clean, hard, durable and free from any deleterious substances.

b) FILLER

Filler can consist of finely divided mineral matter such as rock, hydrated lime or cement.it should be free from impurities. Cement or hydrated lime is not required when the gravel is limestone.
In this study the filler used was 53 Grade OPC.

c) STONE DUST

Quarry process, also known as QP, dense grade aggregate (DGA), crusher run and road stone, is a combination of small, 3/4-inch-or-less crushed stone and stone dust. Most often it is made out of crushed limestone, granite-gneiss, trap rock or a combination of the aforementioned.

Physical

S NO.	TEST	TEST METHOD	REQUIREMENT	OBSERVED VALUE
1	Los Angeles Abrasion Value	**IS:2386(Part-4)**	40% Maximum	13.08% & 18.92%
2	Aggregate Impact Value	**IS:2386(Part-4)**	30% Maximum	11.25% & 10%
3	Combined flakiness and elongation Indices	**IS:2386(Part-1)**	30% Maximum	20.15% & 20.38%
4	Coating & stripping of bitumen aggregate mixtures	**AASTO T 182**	10% Minimum stripping value	2%
5	Soundness(Loss with sodium sulphate)	**IS:2386(Part 5)**	12% Maximum	10%
6	Specific gravity and water absorption	**IS:2386(Part 3)**	2.5-3.2 and 2% Maximum	2.91 & 1%, 3.07 & 1%

1.2. Physical requirements and the observed values of the coarse aggregates used in the study

S NO.	TEST	TEST METHOD	REQUIREMENT	OBSERVED VALUE
1	Los Angeles Abrasion Value	**IS:2386(Part-4)**	40% Maximum	13.08% & 18.92%
2	Aggregate Impact Value	**IS:2386(Part-4)**	30% Maximum	11.25% & 10%
3	Combined flakiness and elongation Indices	**IS:2386(Part-1)**	30% Maximum	20.15% & 20.38%
4	Coating & stripping of bitumen aggregate mixtures	**AASTO T 182**	10% Minimum stripping value	2%
5	Soundness(Loss with sodium sulphate)	**IS:2386(Part 5)**	12% Maximum	10%
6	Specific gravity and water absorption	**IS:2386(Part 3)**	2.5-3.2 and 2% Maximum	2.91 & 1%, 3.07 & 1%

1.3. Physical requirements as per IS – 73 and the observed values of the binder used in the study

S NO.	CHARACTERISTICS	PAVING GRADE REQUIREMENT (VG 10)	OBSERVED VALUES
1	Penetration at 25 C,100 g, 50 s, 0.1 mm, Min	80	60/70
2	Absolute viscosity at 60 C , Poises	800-1200	1072.3
3	Kinematic viscosity at 135 C, cSt, Min	250	265.27
4	Flash point(open cup), C, Min	220	240
5	Softening point, C, Min	40	48
6	Specific gravity	0.97-1.02	1.01
7	Test on residue from rolling thin film oven test: a) Viscosity ratio at 60 C, Max b) Ductility at 25 C, cm, Min	 4.0 75	 1.029 Above 100

1.4. Proportioning of the materials used for the design mix

	20mm	10mm	Fine Aggt sand	4.75mm down n Dust	Filler	DBC 40mm (2)				
PROPORTIONING OF AGGREGATES										
Size	A	B	C	D	E	LL	UL	MID	GRADATION	SE
26.50	100	100	100	100	100	100	100	100	100	0.00
19.00	91	100	100	100	100	100	100	100	100	0.00
13.20	31	98	100	100	100	90	100	95	99	18.30
9.50	3	52	98	99	100	70	88	79	80	0.28
4.75	3	4	80	98	100	53	71	62	56	41.73
2.36	3	4	96	56	100	42	58	50	44	31.81
1.18	3	1	87	46	100	34	48	41	38	10.64
0.600	2	1	56	33	100	26	38	32	26	32.72
0.300	2	1	38	26	98	18	28	23	20	10.05
0.150	2	1	1	26	98	12	20	16	12	18.58
0.075	1	1	1	9	86	4	10	7	6	2.12
Solution Bar										166.2308
Proportion	0.0000	0.4100	0.2200	0.3500	0.0200		Total Proportion			1.00
Percent	0.00	41.00	22.00	35.00	2.00	0.00	Total Percent			100

Therefore, as per the gradation and as per the specified limits of MORTH the contents used in the mix have following proportions:

a) 20 mm nominal aggregate size = 0%

b) 10 mm nominal aggregate size = 41%

c) Fine aggregate, sand = 22%

d) 4.75 mm down & dust = 35%

e) Filler, cement (53 grade) = 2%

Further, the samples are prepared with bitumen VG 10 binder and are further modified with the nano material Zycotherm. The binder content is changed with different percentages (5.5%, 6%, 6.5%) and the zycotherm percentage is also varied (0.1%, 0.125%, 0.15%) of the binder content.

In this study, we investigate the effect of a Nano-material with the trade name of zycotherm. Manufacturer of zycotherm which is produced by Nano-technology claims that it can improve the coating properties of bitumen on silica aggregate and make it better and more integrated compaction and also eliminate stripping and therefore provide asphalt with better durable properties and lifetime.

Zycotherm is a chemically reactive performance enhancing Cum Moisture Resistant additive to modify the aggregates for stronger adhesion with the Asphalt Binder and eliminate damage to the bitumen layers due to moisture ingress. Key benefits are detailed below:

- Eliminates De-bonding / Stripping due to improved adhesion of asphalt binder with aggregates
- Higher Marshall Stability
- Improved compaction densities with same compaction effort / lower passes
- Higher rut resistance
- Odor less, non –corrosive, non-flammable.
- Dosage - 0.05% to 0.1 % by wt. of asphalt binder
- Stable on storage for above 15 days and suitable for terminal blending.
- Eliminates stripping - Residual water in aggregate at lower mix temperature helps to promote reactivity with aggregate

Mixing of Bitumen and Additive: As according to its manufacturer company, the mixing dosage of zycotherm is 0.05 to 0.15 of weight percent of bitumen, we selected the mixing does of **0.1, 0.125, and 0.15** percent for manufacturing of bitumen with additive. We measured and calculated specific gravity, air void, Marshall Resistance and Plastic Flow of samples after producing them.

Results of Marshall test: Determination of density and void analysis

G1 = apparent specific gravity of coarse aggregates = 2.8

G2 = apparent specific gravity of fine aggregates = 2.07

G3 = apparent specific gravity of filler = 1.4

G4 = apparent specific gravity of bituminous binder = 1.01

W1 = % by wt. of coarse aggregates in total mix = 492 g

W2 = % by wt. of fine aggregates in total mix = 264 g

W3 = % by wt. of filler = 420 g

W4 = % by wt. of bituminous binder in the total mix (66 g, 72 g, 78 g)

Marshall Test: Determination of density and voids

Sample no.	Bitumen content,%	Zycotherm content,%	Height of sample, mm	Dia of sample, mm	Weight, g		Bulk Density, Gm	Theoretical density, Gt	Vv	Vb	VMA	VFB
					In air	In water						
1	**5.5**	**0**	65.8	101.72	1228	699	2.32	3.10	3.10	7.91	11.01	68.58
2			65.3	102.1	1226	697						
Average			65.55	101.91	1227	698						
1	**5.5**	**0.1**	62.44	104.46	1268	743	2.48	3.07	4.40	7.93	11.70	66.50
2			61.02	101.62	1258	755						
Average			61.73	103.04	1263	749						
1	**5.5**	**0.125**	62.7	101.04	1268	757	2.51	3.20	4.20	7.95	11.40	68.50
2			62.3	103.06	1272	767						
Average			62.5	102.05	1270	762						

1	**5.5**	**0.15**	62.72	101.13	1288	765	2.51	3.30	3.90	8.00	11.60	68.50
2			64.08	101.01	1276	777						
Average			63.4	101.07	1282	771						
1	**6**	**0**	64.3	100.94	1288	766	2.35	3.2	4.00	7.92	11.71	70.53
2			64.1	101.01	1284	764						
Average			64.2	100.97	1286	765						
1	**6**	**0.1**	63.1	100.85	1276	772	2.53	3.21	4.50	7.93	11.92	69.21
2			62.88	101.34	1268	765						
Average			62.99	101.09	1272	768.5						
1	**6**	**0.125**	62.82	101.72	1272	770	2.54	3.57	4.30	7.94	11.80	67.31
2			62.9	101.39	1268	756						
Average			62.86	101.55	1270	763						
1	**6**	**0.15**	62.28	101.26	1274	772	2.55	3.78	4.10	7.95	11.60	71.57
2			63.02	101.58	1268	769						
Average			62.65	101.42	1271	770.5						

1	**6.5**	**0**	62.21	101.27	1262	768	2.47	3.31	4.20	7.93	11.90	72.34
2			62.15	101.30	1262	770						
Average			62.18	101.28	1262	769						
1	**6.5**	**0.1**	62.13	101.15	1264	764	2.55	3.35	4.60	7.94	11.98	71.01
2			62.81	101.2	1266	766						
Average			62.47	101.17	1265	765						
1	**6.5**	**0.125**	61.18	101.6	1262	763	2.56	3.75	4.40	7.95	11.73	69.86
2			62.63	101.4	1260	765						
Average			61.90	101.5	1261	764						
1	**6.5**	**0.15**	61.72	101.9	1260	764	2.58	3.78	4.10	7.97	11.70	73.01
2			62.30	101.5	1264	766						
Average			61.78	101.7	1262	765						

II. RESULT AND DISCUSSION

A. Test Results On Modified Binder

S NO.	CHARACTERISTICS	PAVING GRADES REQUIREMENT (VG 10)	VG – 10	OBSERVED VALUES AFTER ADDITION OF ZYCOTHERM		
				VG10+0.1%	VG10 +0.125%	VG10+0.15%
1	Penetration at 25 C,100 g, 50 s, 0.1 mm, Min	80	70	68	67	65
2	Absolute viscosity at 60 C , Poises	800-1200	1072.3	1092.3	1100.7	1109.8
3	Kinematic viscosity at 135 C, cSt, Min	250	265.27	270.3	273.2	283.5
4	Flash point(open cup), C, Min	220	240	235	230	231
5	Softening point, C, Min	40	48	49	51	53
6	Specific gravity	0.97-1.02	1.01	1.01	1.031	1.029
7	Test on residue from rolling thin film oven test: a) Viscosity ratio at 60 C, Max b) Ductility at 25 C, cm, Min	4.0 75	1.029 Above 100	1.02 Above 100	1.031 Above 100	1.041 Above 100

B. Test Results Of Modified Design Mix Samples

As per **MORTH** the requirements and the observed values for the dense bituminous concrete mix are for **5.5% bitumen content** and **0% , 0.1% , 0.125 and 0.15% zycotherm content :**

Properties	**Viscosity grading paving bitumen**	**Test method**	**OBSERVED VALUES AFTER ADDITION OF ZYCOTHERM**			
Compaction level	75 blows on each face of specimen		**0%**	**0.1%**	**0.125%**	**0.15%**
Minimum stability (KN at 600 C)	9.0	**AASHTO T245**	12.00	10.19	11.20	12.20
Marshall flow (mm)	2 – 4	**AASHTO T245**	3.0	3.10	3.30	3.10
Marshall quotient (stability/flow)	2 – 5	**MS-2 and ASTM D2041**	4.03	3.28	3.39	3.93
% air voids Vv	3 – 5		3.80	4.40	4.20	3.90
% Voids filled with bitumen (VFB)	65 – 75		68.58	66.50	65.30	68.50
Coating of aggregate particle	95% minimum	**IS : 6241**	98%	99% above	Almost 100%	Almost 100%
% Voids in mineral aggregate (VMA)	For Vv 3% = 11 For Vv 4% = 12 For Vv 5% = 12		11.10	11.70	11.40	11.60

As per **MORTH** the requirements and the observed values for the dense bituminous concrete mix are for **6% bitumen content** and **0% , 0.1% , 0.125 and 0.15% zycotherm content :**

Properties	**Viscosity grading paving bitumen**	**Test method**	**OBSERVED VALUES AFTER ADDITION OF ZYCOTHERM**			
Compaction level	75 blows on each face of specimen		**0%**	**0.1%**	**0.125%**	**0.15%**
Minimum stability (KN at 600 C)	9.0	**AASHTO T245**	13.00	12.03	12.10	13.10
Marshall flow (mm)	2 – 4	**AASHTO T245**	3.70	3.69	3.60	3.50
Marshall quotient (stability/flow)	2 – 5	**MS-2 and ASTM D2041**	3.56	3.99	3.10	3.74
% air voids Vv	3 – 5		4.0	4.50	4.30	4.10
% Voids filled with bitumen (VFB)	65 – 75					
Coating of aggregate particle	95% minimum	**IS : 6241**	98%	99% above	Almost 100%	Almost 100%
% Voids in mineral aggregate (VMA)	For Vv 3% = 11 For Vv 4% = 12 For Vv 5% = 12		11.71	11.92	11.80	11.60

As per **MORTH** the requirements and the observed values for the dense bituminous concrete mix are for **6.5% bitumen content** and **0% , 0.1% , 0.125 and 0.15% zycotherm content :**

Properties	**Viscosity grading paving bitumen**	**Test method**	**OBSERVED VALUES AFTER ADDITION OF ZYCOTHERM**			
Compaction level	75 blows on each face of specimen		**0%**	**0.1%**	**0.125%**	**0.15%**
Minimum stability (KN at 600 C)	9.0	**AASHTO T245**	12.6	11.10	11.70	12.70
Marshall flow (mm)	2 – 4	**AASHTO T245**	3.90	3.95	3.50	3.70
Marshall quotient (stability/flow)	2 – 5	**MS-2 and ASTM D2041**	3.30	2.81	3.34	3.43
% air voids Vv	3 – 5		4.20	4.60	4.40	4.10
% Voids filled with bitumen (VFB)	65 – 75		72.34	71.01	69.86	73.01
Coating of aggregate particle	95% minimum	**IS : 6241**	98%	Above 99%	Almost 100%	Almost 100%
% Voids in mineral aggregate (VMA)	For Vv 3% = 11 For Vv 4% = 12 For Vv 5% = 12		11.90	11.98	11.73	11.70

III. SUMMARY AND CONCLUSIONS

Zycotherm should be stored between 5 - 45º C (41 - 113º F) in a shaded, dry area away from sunlight, heat, ignition, sparks, rain, and standing water. The container lid should be securely fastened every time it is used. Shelf live is 24 months.

Zycotherm due to its nature, exert specific dimension properties. As a result, it exhibits specific characteristics, qualities and unique features compared to commonly used materials, making likewise feasible their integration as additives in asphalt pavements. Ordinary pavement materials can hardly meet the operational requirements for present and future highways as well as pavement construction technology.

Consequently, pavement materials of enhanced quality, increased safety, higher reliability and more environmental friendly features, are in high demand. The dispersion of zycotherm within asphalt materials may considerably enhance certain properties of asphalt constituents, e.g., visco-elasticity, high temperature effects, resistance to aging, fatigue and moisture). The zycotherm applied in asphalt pavement engineering with their specific properties are categorized in the next points:

1. The physical properties were conducted on the aggregates and the binder used in the present studies satisfies the requirements as per the MORT&H specifications.
2. Increasing percentage of additive dosage to rate of Marshall Properties also increases and satisfies the MORT&H specifications.
3. The Marshall properties of HMA in the present studies satisfy the MORT&H specifications.
4. The optimum bitumen content was found to be 6% for HMA mix at 160^0c temperature.
5. The maximum stability for 60/70 grade bitumen is achieved at 160^0c temperature with the additive dosage rate of 0.15% of Zycotherm by the weight of binder.
6. The addition of additive of zycotherm improves bulk density of the mix. The percentage air voids in the mix were found to decrease with the increase of HMA additive and 0.15% of zycotherm at 160^0c was lowest when compared to the conventional mix.
7. Residual water in aggregate at lower temperature helps to promote reactivity with the aggregate and can withstand boil tests lasting over six hours with an over 95% retained coating.
8. Captures sticky asphaltenes in nano cages of Zycotherm for improved free flow and reduced stickiness to trucks or paver and compaction rollers.
9. Wets & spreads even better at lower bitumen content to give a blacker looking mix
10. Captures all odorous compounds in nano cages of the Zycotherm Lowers mixing temperature by 95º C, saves fuel by 20-25% OR Helps in longer hauls OR Allows paving in cold conditions 32 - 41ºF.

REFERENCES

[1] Hurley GC, Prowell BD. Evaluation of Evotherm_ for the use in warm mix asphalt. National Center for Asphalt Technology. NCAT report 06-02, Auburn, 2006.

[2] Elsa Sanchez-Alonso(2012),”Evaluation of compactability and mechanical properties of bituminous mixes with warm additives Department of Transport, Projects and Process Technology, School of Civil Engineering (E.T.S.I.C.C.P.), University of Cantabria (UC), AvenidadelosCastross/n,39005Santander,Cantabria,Spain

[3] Kapil Kushwah, Harswaroop Goliya and Mayur Singi”EVALUATION OF SASOBIT WARM MIX ASPHALT” advanced in civil engineering andapplied mechanics,

[4] Liantong mo,Xun li ,Xing fang M.Huurman ,Shaopeng w(2012),” laboratory investigation of compaction characteristics and performance of warm mix asphalt containing chemical additives”, state key laboratory of silicate materials for architectures, wuhan university of technology,

wuhan 430070, chinab technology & development, bam wegen bv, utrecht 3500 gk, the netherlands

[5] Adriana, V., and David, H. T. (2012). “Rutting characterization of warm mix asphalt and high RAP mixtures.” Road Materials and Pavement Design, 13(1), 1-20.

[6] Ahmed, T. A., Elie Y. H., Sebaaly, P. E., and Nate, M. (2013). “Influence of Aggregate Source and Warm-Mix Technologies on the Mechanical Properties of Asphalt Mixtures.” Advances in Civil Engineering Materials, 2(1), 400– 417.

[7] PROWELL B.D., HURLE G.C.: Warm-Mix Asphalt: Best Practices. Quality Improvement Series 125, NAPA, Lanham, United States, 2007. BEUVING E.: The use of Warm Mix Asphalt in Europe and the USA. Konference Asfaltové vozovky 2011, České Budějovice 2011 WILLIS J., ET AL.: Combining Warm Mix Asphalt Technologies with Mixtures Containing Reclaimed Asphalt Pavement. Proceedings 2nd International Warm-mix Conference (prezentace), St. Louis, 2011. EPPS A., ET AL.: Moisture Sensitivity of WMA – A review and look to the future. Proceedings 2nd International Warm-mix Conference (prezentace), St. Louis, 2011.OLARD F., ET AL.: Laboratory assessment of mechanical performance and fume emissions of LEA® HWMA (90°C) vs. traditional HMA (160°C). Proceedings 2nd International Warm-mix Conference, St. Louis, 2011.VALENTIN, J., SOUKUPOVA, L., MORAL, X., BENES, J., CÁPAYOVÁ, S.: Posouzení experimentálně vyrobených a průmyslově vyvíjených alternativ nízkoviskózních asfaltových pojiv - charakteristiky asfaltových pojiv, charakteristiky směsi ACO 11+. Dílčí výzkumná zpráva 1.1.5, Centrum CESTI, FSv

[8] ČVUT v Praze, 2013 (15 stran).ČSN EN 14023. Asfalty a asfaltová pojiva - Systém specifikace pro polymerem modifikované asfalty. Praha: Český normalizační institut, 2006.ČSN EN 14770. Asfalty a asfaltová pojiva- Stanovení komplexního modulu ve smyku a fázového úhlu - Dynamický smykový reometr (DSR). Praha: Český normalizační institut, 2006.ČSN EN 1427. Asfalty a asfaltová pojiva: Stanovení bodu měknutí - Metoda kroužek a kulička. Praha: Český normalizační institut, 2007.ČSN EN 1426. Asfalty a asfaltová pojiva: Stanovení penetrace jehlou. Praha: Český normalizační institut, 2007.

[9] ČSN EN 13302. Asfalty a asfaltová pojiva - Stanovení dynamické viskozity. Praha: Český normalizační institut, 2010. ČSN EN 13398. Asfalty a asfaltová pojiva - Stanovení vratné duktility modifikovaných asfaltů. Praha: Český normalizační institut, 2010.ČSN EN 13589. Asfalty a asfaltová pojiva - Stanovení tažných vlastností modifikovaných asfaltů metodou silové duktility. Praha: Český normalizační institut, 2004.AASHTO Designation: T 283-03. Standard Method of Test for: Resistance of Compacted Asphalt Mixtures to Moisture-Induced Damage. January 2007. Washington: American Association of State and Highway Transportation Officials, 2007. ČSN EN 12697-12.

[10] Asfaltové směsi – Zkušební metody pro asfaltové směsi za horka: Část 12: Stanovení odolnosti zkušebního tělesa vůči vodě. Březen 2005. Praha: Český normalizační institut, 2005. ČSN EN 12697-26. Asfaltové směsi – Zkušební metody pro asfaltové směsi za horka – Část 26:Tuhost. Praha: Český normalizační institut, 2012.ČSN EN 12697-44. Asfaltové směsi – Zkušební metody pro asfaltové směsi za horka – Část 44: Šíření trhliny zkouškou ohybem na půlválcovém zkušebním tělese. Praha: Český normalizační institut, 2011.TP 151. Asfaltové směsi s vysokým modulem tuhosti (VMT). Ministerstvo dopravy, odbor silniční infrastruktury, 2010.ČSN EN 12697-23. Asfaltové směsi – Zkušební metody pro asfaltové směsi za horka: Část 23: Stanovení pevnosti v příčném tahu. Březen 2005. Praha: Český normalizační institut, 2005.