The Influence of Vehicle Speed Changes at Mechanistic Performance of Asphalt Mixture

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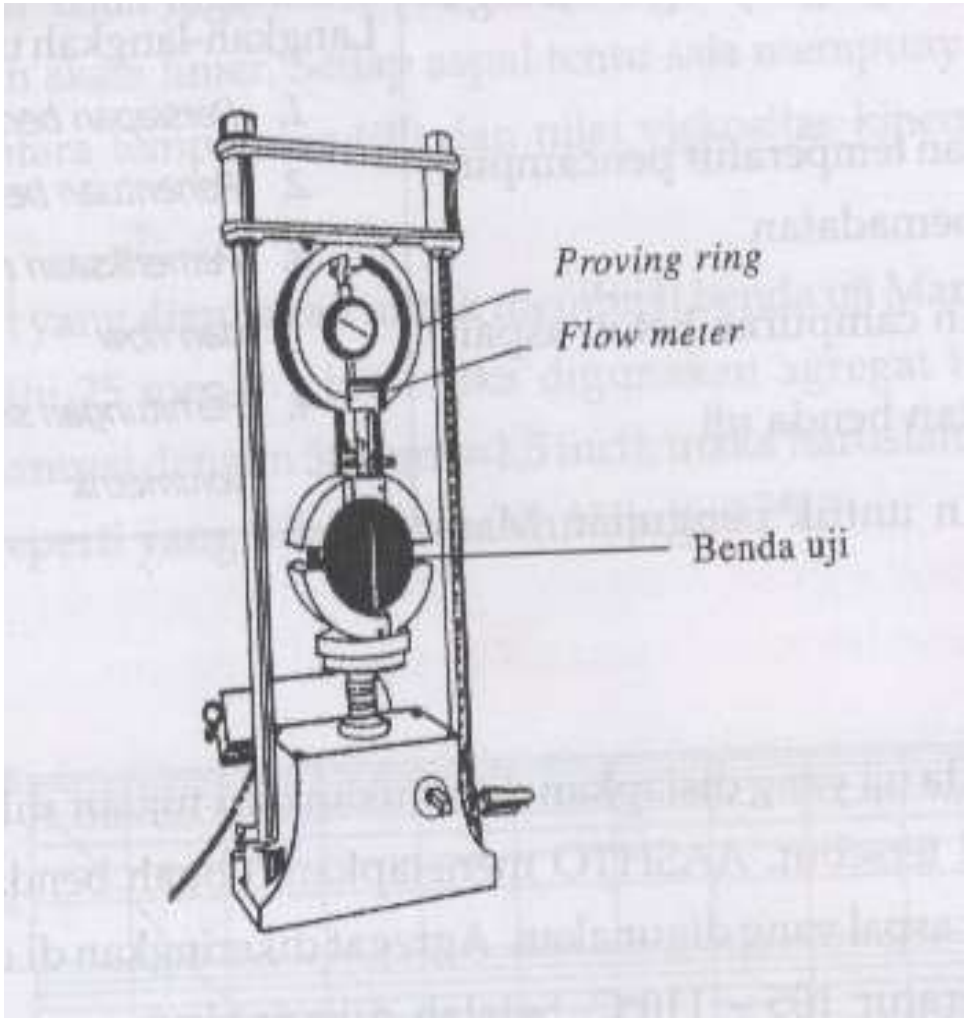
AIMS OF RESEARCH

This aim of research : to determine mechanistic performance of bitumen (for example : bitumen stiffness) and hotmix asphalt (such as asphalt mix stiffness and fatigue life asphalt mix) with different aggregate gradation types, namely dense graded and gap graded, influenced by vehicle speed changes, based on empirical tests data (bitumen penetration, bitumen softening point, and Marshall test : volume of bitumen, volume of aggregate and volume of voids)

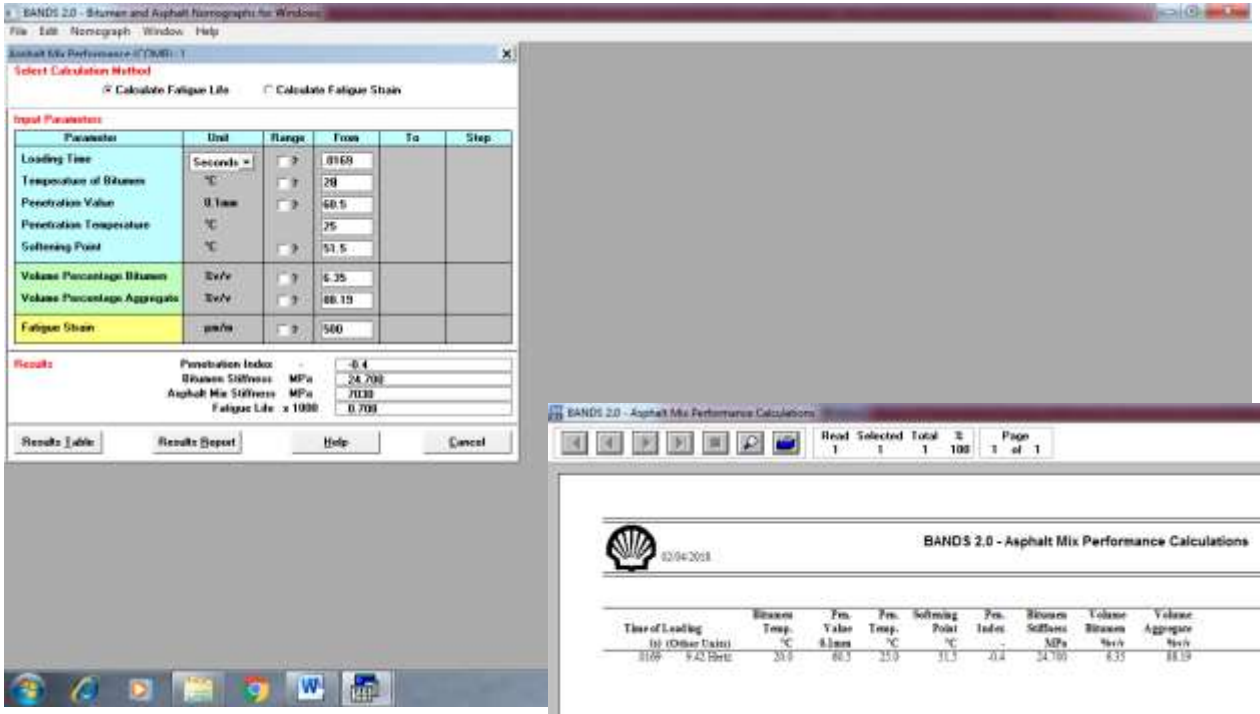
BACKGROUND

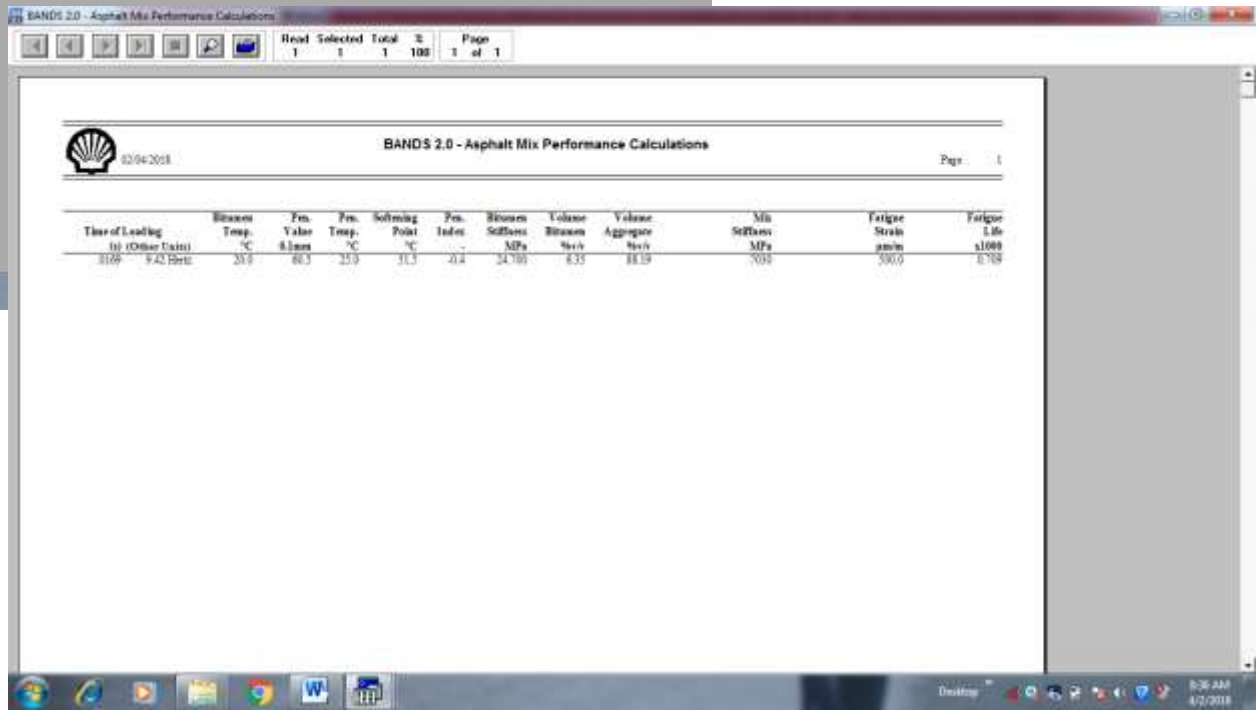
- Asphalt mixture is a viscoelastic material. Several factors affect the behavior of a viscoelastic material. Temperature and loading time are the most critical of these parameters. Vehicle speed affects time loading, therefore it's very important to know the influence of vehicle speed changes in mechanistic performance of bitumen (for example : bitumen stiffness) and asphalt mixture (such as asphalt mix stiffness and fatigue life asphalt mix) with different aggregate gradation types.
- In this case using : Asphalt Concrete-Wearing Course (AC-WC) AND Hot Rolled Sheet-Wearing Course (HRS-WC) because these asphalt mixtures have different gradation and frequently used for wearing course in Indonesia (Bina Marga, 2013)

MARSHALL TEST



software BANDS 2.0





MATERIAL

- bitumen penetration 60/70 (penetration = 60,5 (in 0,1 mm) , softening point = 51,5°C),
- coarse aggregate and fine aggregate based on the Bina Marga specification (2010).
- the dense graded asphalt concrete-wearing course (AC-WC) and gap graded hot rolled sheet-wearing course (HRS-WC) specifications also refer to Bina Marga (2010)

TABLE Gradation Envelop of AC-WC and HRS-WC based on Bina Marga (2010) Specification

Ø sieve	AC-WC			HRS-WC		
	Specification	Medium specification	actual	Specification	Medium specification	actual
3/4 "	100	100	100	100,00	100	100
1/2 "	90-100	95	92.31	90-100	95	90.07
3/8 "	77-90	83.5	83.53	75-85	80	79.85
No. 4	53-69	61	60.85	-	-	-
No. 8	33-53	43	41.92	50-72	61	61.20
No. 16	21-40	30.5	30.05	-	-	-
No. 30	14-30	22	21.30	35-60	47.5	35.31
No. 50	9-22	15.5	14.62	-	-	-
No. 100	6-15	10.5	10.19	-	-	-
No. 200	4-9	6.5	6.50	6-10	8	8.52
Pan	0	0	0	0	0	0

METHOD

1. **Determine : penetration and softening point bitumen**
2. **Determine : Optimum Bitumen Content**
3. **Determine : Marshall Properties**
4. **Measure mechanistic performance of hotmix asphalt influenced by vehicle speed changes, simulated by software BANDS 2.0**
5. **Vehicle speeds are 40, 50, 60, 70, 80, 90, 100 km/h. Time loading is determined based on the Groenendijk formula:** log t_b=0,5h-0,2-0,94logv, where tb : *loading time (s)*, h: surface course thickness (m), and v: vehicle speed (km/h).

Optimum Bitumen Content

TABLE . The results of AC-WC testing to determine optimum bitumen content from Marshall test

Bitumen content (%)	Stabillity (Kg)	Flow (mm)	VIM (%)	VMA (%)	VFWA (%)	MQ (Kg/mm)	Density	Porosity (%)
Spec	**≥ 800**	**2≤4**	**3≤5**	**≥14**	**≥65%**	**≥250**	**-**	**-**
4.5	1325.38	3.25	8.20	18.04	54.53	410.70	2.27	8.20
5.0	1426.98	3.35	7.80	18.76	58.45	442.06	2.26	7.80
5.5	1577.06	3.60	4.86	17.25	71.81	437.48	2.32	4.86
6.0	1685.40	3.85	3.11	16.78	81.49	439.13	2.34	3.11
6.5	1436.12	4.70	2.35	17.26	86.46	306.39	2.34	2.35

optimum bitumen content AC-WC = 5,8%

Optimum Bitumen Content

TABLE . The results of HRS-WC testing to determine optimum bitumen content from Marshall test

Bitumen content (%)	Stabillity (Kg)	Flow (mm)	VIM (%)	VMA (%)	VFWA (%)	MQ (Kg/mm)	Density	Porosity (%)
Spec	≥ 800	≥ 3	4 ≤ 6	≥ 18	≥ 68%	≥ 250	-	-
5.0	1258.45	3.55	9.70	20.44	52.70	354.92	2.24	9.70
5.5	1497.30	3.65	8.33	20.28	59.02	423.53	2.26	8.33
6.0	1652.37	3.88	5.43	18.85	71.22	434.73	2.31	5.43
6.5	1696.81	4.00	4.75	19.34	75.44	426.97	2.31	4.75
7.0	1224.49	4.70	3.47	19.18	82.00	261.52	2.33	3.47

optimum bitumen content HRS-WC = 6,35%

MARSHALL PROPERTIES

- Based on the optimum bitumen content of several AC-WC and HRS-WC asphalt mixture, specimens are made to reveal the Marshall properties.
- **TABLE** Marshall Properties of AC-WC and HRS-WC asphalt mixture from Marshall test

Marshall Properties	Unit	AC-WC		HRS-WC	
		specification	actual	specification	actual
Marshall Stability	Kg	≥ 800	1412.31	≥ 800	1319.51
Flow	mm	2≤4	3.57	≥ 3	3.77
VIM (Void in the mix)	%	3≤5	4.54	4 ≤ 6	5.46
VMA (Void in mineral aggregate)	%	≥14	17.53	≥ 18	19.61
VFWA (Void filled with asphalt)	%	≥65	74.14	≥ 68	72.25
Marshall Quotient (MQ)	Kg/mm	≥250	402.03	≥ 250	356.37

The Influence of Vehicle Speed Changes at Mechanistic Performance of Asphalt Mixture

- The influence of vehicle speed changes at mechanistic performance of asphalt mixture are simulated by software BANDS 2.0.
- Bitumen stiffness (Sbit) is obtained by input data bitumen penetration and bitumen softening point.
- Asphalt mix stiffness (Smix) is derived from data Sbit, volume of bitumen, volume of aggregate and volume of voids hotmix asphalt, while fatigue life asphalt mix (NFAT) from data Smix and volume of bitumen each hotmix asphalt mixture.
- The results from simulation of software BAND 2.0 are shown in these Tables and Figures :

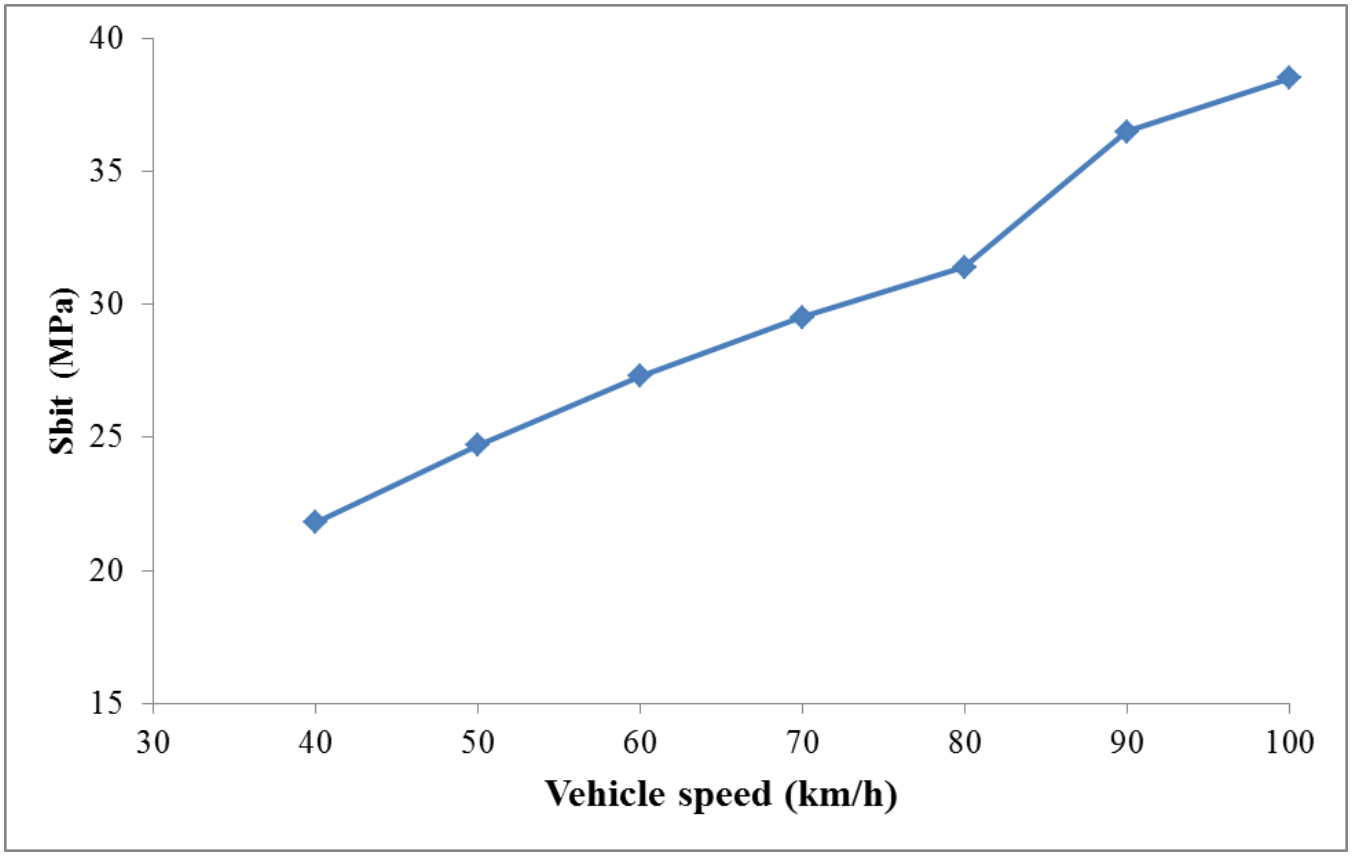
Bitumen Stiffness (Sbit), Asphalt mix stiffness (Smix) and Fatigue life asphalt mix (NFAT) at variation of vehicle speed from BANDS 2.0 simulation.

No.	V (km/h)	Loading		Sbit (MPa)		Smix (MPa)		Nfat (x1000)	
		Time (s)	Temperature (°C)	AC-WC	HRS-WC	AC-WC	HRS-WC	AC-WC	HRS-WC
1	40	0.0208	20	21.8	21.8	7890	6590	0.396	0.797
2	50	0.0169	20	24.7	24.7	8400	7030	0.354	0.709
3	60	0.0143	20	27.3	27.3	8830	7410	0.323	0.645
4	70	0.0123	20	29.5	29.5	9170	7710	0.302	0.600
5	80	0.0108	20	31.4	31.4	9470	7970	0.285	0.565
6	90	0.0079	20	36.5	36.5	10200	8610	0.249	0.492
7	100	0.0071	20	38.5	38.5	10500	8850	0.238	0.464

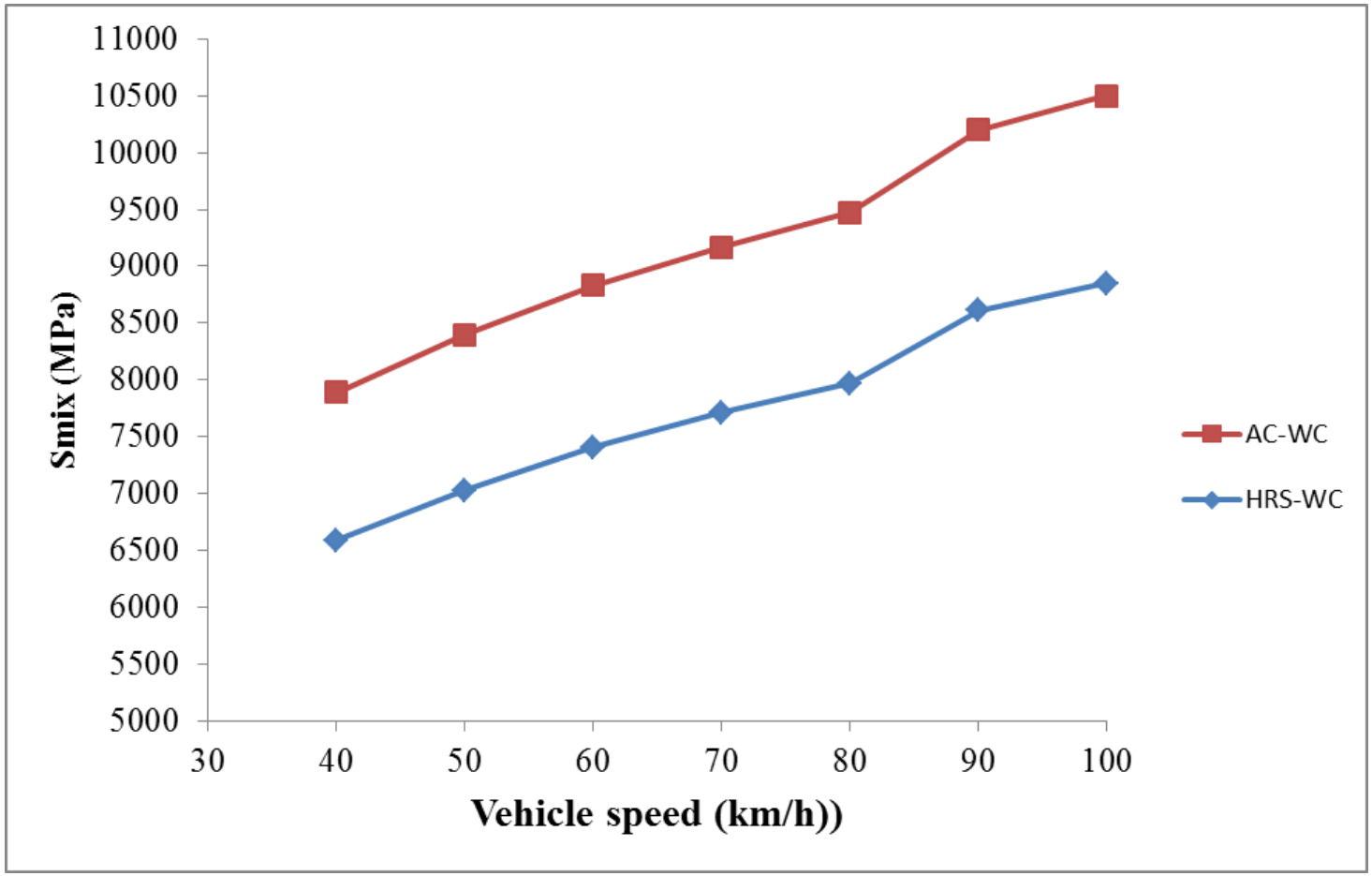
Bitumen Stiffness (Sbit), Asphalt mix stiffness (Smix) and Fatigue life asphalt mix (NFAT) at variation of temperature and V= 50 km/h from BANDS 2.0 simulation

No.	V (km/h)	Loading		Sbit (MPa)		Smix (MPa)		Nfat (x1000)	
		Time (s)	Temperature (°C)	AC-WC	HRS-WC	AC-WC	HRS-WC	AC-WC	HRS-WC
1	50	0.0169	15	49.5	49.5	11900	10100	0.190	0.371
2	50	0.0169	20	24.7	24.7	8400	7030	0.354	0.709
3	50	0.0169	25	11.3	11.3	5710	4700	0.709	1.460
4	50	0.0169	27	8.1	8.1	4830	3950	0.957	2.000

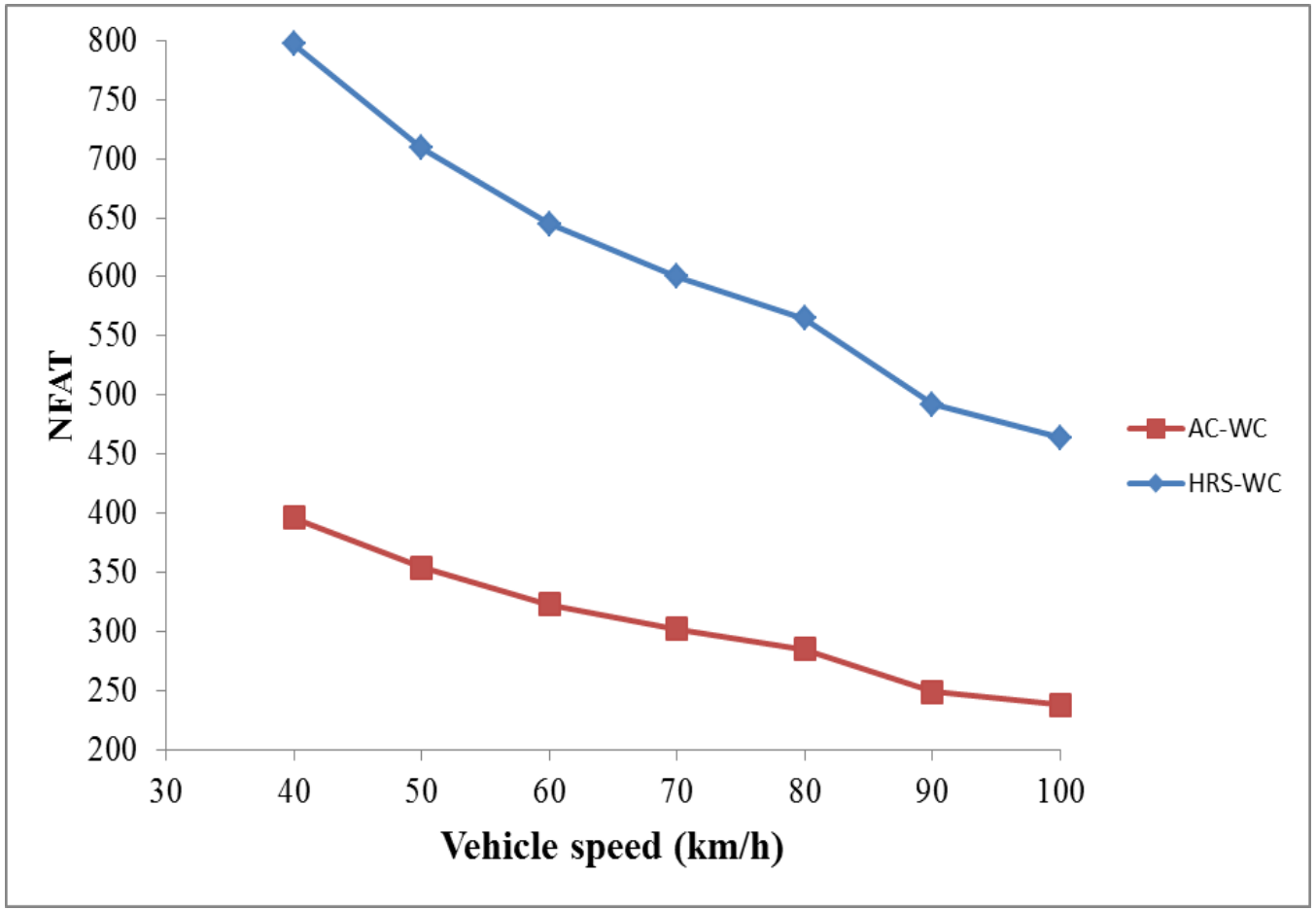
Graph of relation between vehicle speed and bitumen stiffness (Sbit) from BANDS 2.0 simulation



Graph of relation between vehicle speed and asphalt mix stiffness (Smix) from BANDS 2.0 simulation



Graph of relation between vehicle speed and fatigue life asphalt mix (NFAT) from BANDS 2.0 simulation



CONCLUSIONS

1. Mechanistic performance of bitumen and hotmix asphalt are influenced by vehicle speed changes, sensitively.
2. The higher vehicle speed the higher bitumen stiffness (Sbit). The higher vehicle speed the higher asphalt mix stiffness (Smix), on the contrary for fatigue life asphalt mix (NFAT).
3. At the same temperature, dense graded mixture has higher value of bitumen stiffness (Sbit) and lower value of fatigue life asphalt mix (NFAT).

REFERENCES

1. R. Jongepier, and B. Kuilman, Characteristics of The Rheology of Bitumens, *J. Assoc. Asph. Paving Technol.*, **38**, 98–121 (1968)
2. B. Rahimzadeh, *Linear and Non-Linear Viscoelastic Behavior of Binders and Asphalts*, School of Civil Engineering, University of Nottingham (2002)
3. J. Read, and D. Whiteoak, *The Shell Bitumen Handbook*, Fifth Edition, London: Thomas Telford (2003)
4. R. Lamperti, *Rheological and Energetic Characterization of Wax-Modified Asphalt Binders*, Engineering Faculty Universita Di Bologna (2011)
5. L.Davide, *Rheology and Curing of Tyre Rubber Modified Bitumen* (2011)
6. Y. H. Huang, *Pavement Analysis and Design* (2012)
7. N. S. Mashaan, *Investigating the Rheological Properties of Crumb Rubber Modified Bitumen and its Correlation with Temperature Susceptibility*, *Cent. Transp. Res. Fac. Eng. Univ. Malaya, 50603 Kuala Lumpur, Malaysia*, 116–127 (2013)
8 Bina Marga, *Design Manual of Road Pavement No. 02/M/BM/2013,* Jakarta: Bina Marga (2013)
9. S. Sukirman, *Asphalt Concrete Hotmix,* Jakarta: Granit (2003)
10. D. Utama, Influence of Aggregate Gradation in Rutting Depth of Asphalt Concrete, *J. Transp.*, **5**, 1, 87–98 (2005)
11. D.M. Mrawira, and J. Luca, Effect of aggregate type, gradation and compaction level on thermal properties of hot-mix asphalt, *Canada J. Civ. Eng.*, **1417**, 1976, 1410–1417 (2006)
12. W.S. Abdullah, M.T. Obaidat, and M.A. Nasem, Influence of Aggregate Type and Gradation on Voids of Asphalt Concrete Pavements, *J. Mater. Civ. Eng.*, May, 76–85 (1998)
13. J.A. Henrichsen and J. Heggen, *Minimum Voids in Mineral Aggregate in Hot-Mix Asphalt Ba*
Gradation and Volumetric Properties, *Transp. Res. Rec. 1545*, **4**, 75–79 (1995)

REFERENCES

14. M. Xing, S. Chen, B. Wang, and S. Wei, Research on Influence of Aggregate Aggregate Gradation on the Performance of Porous Asphalt Pavement, *ICCTP 2010 Integr. Transp. Syst. Green Intell. Reliab. @2010 ASCE*, 3738–3746 (2010)
15. C. Zhang, H. Wang, Z. You, and X. Yang, Compaction Characteristics of Asphalt Mixture with Different Gradation Type Through Superpave Gyratory Compaction and X-Ray CT Scannig, *J. Constr. Build. Mater.*, **129**, 243–255 (2016)
16. R. Collins, D. Watson, A. Johnson, and Y. Wu, *Effect of Aggregate Degradatin on Specimens Compacted by Superpave Gyratory Compactor* (1997)
17. F. Moavenzadeh, and W.H. Goetz, *Aggregate Degradation in Bbituminous Mixtures*, *Highw. Res. Rec. 24, HRB, Natl. Res. Counc. Washington, DC* (1963)
18. S.N. Amirkhanian, and D.B.J. Kaczmarek, *Effect of Los Angeles Abrasion Test Values on The Strengths of Laboratory Prepared Marshall Specimens* (1991)
19. J.W. Button, D.N. Little, and V. Jagadam, *Correlation of Select Laboratory Compaction Methods with Field Compaction* (1994)
20. G.D. Airey, A.E. Hunter, and A.C. Collop, The Effect of Asphalt Mixture Gradation and Compaction Energy on Aggregate Degradation, *J. Constr. Build. Mater.*, **22**, 972–980, (2008)
21. R.B.. Mallick, and T. El-korchi, *Pavement Engineering : Principle and Practice,* Boca Raton London New York: CRC Press (2013)
22. F. Bonnaure, G. Gest, A. Gravois, and P.A. Uge, *A New Method of Predicting The Stiffness of Asphalt Paving Mixture*, *Asph. Pavement Technol.* (1977)
23. Bina Marga, *General Specification of Bina Marga 2010 Divisi 6* (2010)
24. J. Groenendijk, *Accelerated Testing and Surface Cracking of Asphaltic Concrete Pavement*. Delft: Technische Universiteit Delft (1998)
25. Michael, *Fatigue Analysis on Surface Course with Dissipated Energy Approach*, Civil Enginee Universitas Sebelas Maret Surakarta (2016)

THANK YOU