DETERMINATION OF DESIGN PARAMETERS OF ASPHALT PAVEMENT BASED ON PG TECHNOLOGY

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ABSTRACT

The design parameters are one of the important factors to ensure the quality of asphalt pavement design. In “Highway Asphalt Pavement Design Specification” (JTGD50-2017), the stander of China, used the asphalt mixture anti-pressure resilience modulus at a single temperature of 20 ℃ as the design metrics. However, asphalt mixture, as a sticky-bullet plastic material, shows different mechanical properties at different temperatures. China is a vast territory, and there are great differences between the high and low temperature value (m and n) of each region. Therefore, it is unreasonable to design asphalt pavement only with the asphalt mixture anti-pressure resilience modulus value at 20 ℃. Studies show that the design parameters using PG technology can improve the high temperature anti-rutting and low temperature cracking performance of asphalt pavement.

KEYWORDS

Road engineering, Asphalt mixture, Design parameters, Resilience modulus, PG technology

INTRODUCTION

Some modern asphalt pavement designs (for example, in China) use the asphalt mixture's anti-pressure resilience modulus (20°C) as a criterion. The anti-pressure resilience modulus is one of the most important parameters for the mechanical properties of pavements [1-2]. A reasonable pavement thickness can be calculated from the anti-pressure resilience modulus [3]. The index of anti-pressure resilience modulus can also be used to evaluate the long-term service performance of asphalt pavements in terms of fatigue life [4], permanent deformation [5] and thermal cracking [6]. The anti-pressure rebound modulus of asphalt mixtures is therefore widely used as a parameter in the design of pavements. For example, Elliott R P et al. in the 1986 AASHTO Guide to Structural Design of Pavements stated that modulus of elasticity was one of the basic and reasonable indicators to be included in pavement design [7] Maher A et al. also used parameters such as dynamic modulus, elastic modulus and Poisson's ratio for flexible pavement design [8]; The effect of different factors on pavement performance was investigated by Su N et al. The study showed that the modulus of elasticity, load and temperature have a large effect on the variation in the performance of asphalt pavements. [9] According to Hossain Z et al., the modulus of elasticity is an important design element in the pavement design process. [10] The design parameters at a single temperature, on the other hand, are not reflective of the mechanical characteristics of the asphalt mixture at varied temperatures. This is due to the fact that both asphalt and asphalt mixtures have viscoelastic material qualities. [11-12] The material's mechanical characteristics change with temperature [13-14], resulting in totally distinct states and moduli at high and low temperatures [15-16]. The pavement performance of asphalt mixtures is clearly influenced by temperature. Therefore, in order to avoid the influence of temperature changes on asphalt pavement design, many countries and regions have started to adopt PG technology for asphalt pavement design. Based on the PG rated climate zones for road asphalt pavements, the high and low temperature design parameter

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values for each region are selected for road design. For example: Salem H A et al. found that the PG method was more reasonable for the design of Libyan desert roads and classified Libyan desert roads as PG70-10, PG76-10 and PG82-10. [17] Tan Y et al. used digital image correlation (DIC) analysis to obtain design parameters capable of characterizing the low-temperature performance of asphalt mixtures in cold regions, based on the theory of PG techniques. And they found that the low temperature performance of asphalt mixes was better when designed using this method. [18] Copeland A et al. also used PG technology to design the Florida Highly Recycled Asphalt Pavement - Warm Mix Asphalt project.[19] It can therefore be seen that the use of PG technology for asphalt pavement design allows for a range of high and low temperature variations in asphalt pavement design compared to the use of indicators such as anti-pressure resilience modulus at a single temperature for asphalt pavement design. This avoids the impact of temperature changes on the design of the pavement.

This study is an exploratory study of the design method for asphalt pavements with PG technology in the USA, based on the standard design method for road asphalt pavement design with parameters such as anti-pressure rebound modulus. On the basis of the climatic zones of China and the PG classification of asphalt pavements, asphalt pavement design parameters corresponding to the high and low temperature values (m and n) for each climatic zone were established. Refinement of asphalt pavement design parameters determined by a single temperature of 20°C in China. Design parameters using PG technology can improve the high temperature rutting resistance and low temperature cracking resistance of asphalt pavements.

ASPHALT MIXING MATERIAL COMPOSITION DESIGN

Asphalt

The experiment selected four kinds (70# base asphalt, SBS modified asphalt (70#), 90# base asphalt, SBS modified asphalt (90#)) asphalt as the binding material, asphalt technical indicators as shown in Table 1.

Tab. 1 - Indexes of asphalt

Asphalt	Penetration (25℃)/ 0.1mm	Penetration index (PI)	Ductility		Softening point/℃	Viscosity (135℃)/Pa.s
			5℃	15℃		
70# base asphalt	66	-1.3	8.7	132	46.5	0.403
SBS modified asphalt (70#)	48	1.0	30.5	126.5	78.9	2.226
90# base asphalt	93	-0.77	9	165	44.5	0.328
SBS modified asphalt (90#)	68	-0.29	35	86	72.8	1.895

Aggregate

Three common aggregate gradations of AC-13, AC-16 and AC-20 were selected for the test. The detailed aggregate gradation parameters are shown in Table 2.

Tab. 2 - Gradations of aggregates

Mixture type	Percentage of mass passing through sieve hole (mm) / (%)											
	26.5	19	16	13.2	9.5	4.75	2.36	1.18	0.6	0.3	0.15	0.075
AC-13			100	97.5	75	50	35	27	20	14	8.5	6
AC-16		100	95	85	75	50	40	25	18	13	12.5	9.5
AC-20	100	95	82.5	71	62	48	37	27	20	15	10	6

Asphalt mixture design

The optimal asphalt content of different asphalt mixtures is obtained through the Mashall mix ratio design (Table 3). The static pressure method and the compaction method were used to form the test specimens (100 mm in diameter and 160 mm in height), and two ends of the two test specimens were cut by 30 mm to form a standard test specimen. Then the compressive resilience modulus of the two test pieces was tested in the temperature range of -30 ℃ - 60 ℃.

Tab. 3 - Optimum asphalt content

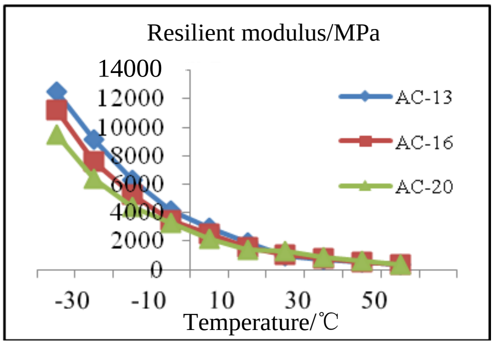
Type of asphalt	Asphalt mixture gradation		
	AC-13	AC-16	AC-20
70# base/ modified asphalt	5.30	4.40	4.10
90# base/ modified asphalt	5.60	4.70	4.40

RELATIONSHIP BETWEEN DYNAMIC MODULUS AND STATIC MODULUS OF ASPHALT MIXTURE

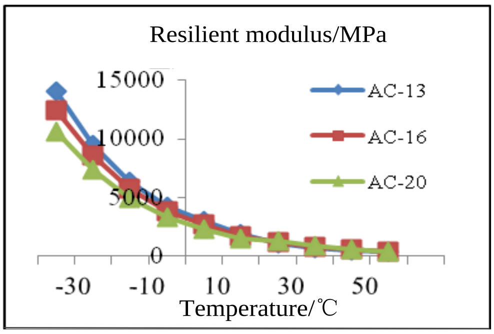
The "Testing Rules for Asphalt and Asphalt Mixtures of Highway Engineering" (JTG E20-2011) stipulates that the specimens used in the single-axis compression anti-pressure resilience molding of asphalt mixtures shall be formed by static pressure method or by using a core drill from the molding plate. The "Specifications for Design of Highway Asphalt Pavements" (JTG D50-2017) stipulates that test specimens formed by impact compaction, static compaction, vibration compaction and other methods can be used to perform dynamic compression resilience modulus tests of asphalt mixtures.

Relationship between static compressive resilience modulus of asphalt mixture and temperature

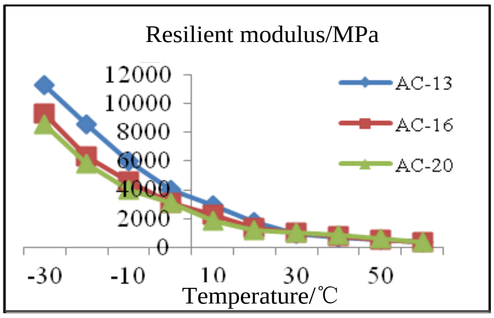
The test results are shown in Figure 1. The regression relationship and suggested values at different temperatures were obtained by fitting the curve of the relationship between the static modulus and the temperature (Table 4).



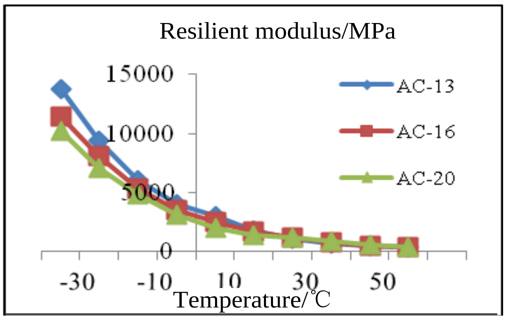
(a) 70# base asphalt mixture



(b) SBS modified asphalt mixture(70#)



(c) 90# base asphalt mixture



(d) SBS modified asphalt mixture (90#)

Fig. 1 - Curve of static compression modulus and temperature of asphalt mixture

Tab. 4 - Static Resilience Modulus Suggested Values

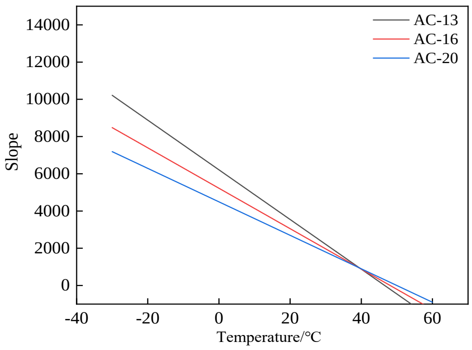
Type of mixture		Regression relation	Suggested static modulus at different temperatures (℃)/ Mpa					
			-30	-10	0	20	40	60
70# base asphalt	AC-13	y = 3999.5e-0.041x R² = 0.9948	13678.3	6039.2	3999.5	1759.8	759.9	360.1
	AC-16	y = 3550.2e-0.038x R² = 0.9987	11101	5191	3550.2	1660	777	363.1
	AC-20	y = 3215.9e-0.035x R²=0.9938	9189.9	4563.6	3215.9	1597.1	793	393.8
SBS modified asphalt (70#)	AC-13	y = 4218.7e-0.041x R² = 0.9977	14433.1	6356.8	4218.7	1858	818.3	360.4
	AC-16	y = 3890.8e-0.039x R² = 0.9998	12563	5747	3890.8	1784	818	374.8
	AC-20	y = 3506.1e-0.035x R² = 0.9965	10019.2	4975.4	3506.1	1741.1	864.6	429.3
90# base asphalt	AC-13	y = 3792.9e-0.04x R² = 0.9938	12592.9	5658.3	3792.9	1704.3	765.8	344.1
	AC-16	y = 3161e-0.036x R² = 0.9959	9308.1	4530.8	3161	1538.6	748.9	364.5

	AC-20	y = 2897.9e-0.034x R^2 = 0.9899	8036.4	4071.4	2897.9	1468.1	743.8	376.8
SBS modified asphalt (90#)	AC-13	y = 4104.7e-0.041x R^2 = 0.9976	14043.1	6185	4104.7	1807.8	796.2	350.7
	AC-16	y = 3661.7e-0.038x R^2 = 0.9996	11449.3	5354.4	3661.7	1712.5	800.9	374.5
	AC-20	y = 3295.7e-0.035x R^2 = 0.9938	9418.1	4676.8	3295.7	1636.6	812.7	403.6

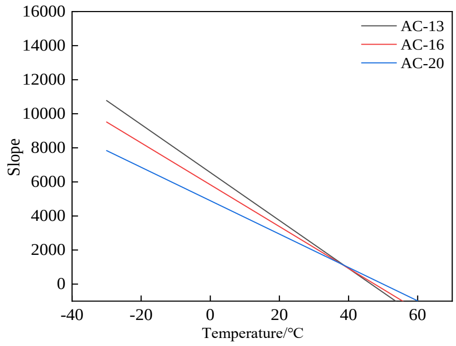
Establishment of the relationship between dynamic modulus and static modulus of asphalt mixture

Studies have shown that the dynamic modulus of asphalt mixtures is approximately two to three times the static modulus. The resilience modulus value of asphalt mixture is greatly affected by temperature and loading frequency. Under different temperatures and loading frequencies it will be several times different. There is usually a large multiple relationship between the dynamic and static modulus at low temperature and high frequency, but the difference is not large at room temperature and low frequency; and a slightly larger at the general temperature and frequency compared with room temperature and low frequency. Different loading frequencies represent vehicles of different speeds on the road. The speed range specified by the “Technical Standards for Highway Engineering” of China is 30-120 Km/ h. China's current stander "Code for Design of Highway Asphalt Pavements" (JTG D50-2017) stipulates that the loading frequency of the asphalt surface layer modulus is 10Hz (translates to a driving speed of approximately 67Km/ h), which can truly reflect the most actual speed of road vehicles in China.

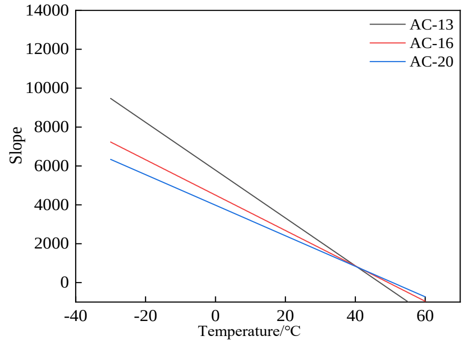
Through experiments, this study found that the main factors affecting the resilience modulus of asphalt mixtures are temperature and frequency, while the gradation, the amount of asphalt, and the type of asphalt have little effect. And there are different multiples gap between the dynamic modulus and the static modulus of the asphalt mixture at different temperatures and loading frequencies. Therefore, this study mainly considers the two influencing factors of temperature and frequency. Based on the "Code for Design of Highway Asphalt Pavements" (JTG D50-2017), the relationship between the dynamic and static modulus of asphalt mixtures at 10 Hz and different temperatures is established. It can be found in Figure 1 that the decrease rate of the resilience mode value is larger at -30-0 ℃. In this temperature interval, the resilience mode value of 70# asphalt mixes with three grades decreased by an average of 7266.67Mpa. The resilience mode value of SBS modified asphalt decreased by 9666.81Mpa on average. The resilience mode value of 90# matrix asphalt mix decreased by 6783.33Mpa on average, The resilience mode value of SBS modified asphalt mix (90#) decreased by 9133.46Mpa on average. But the rate is reduced at 0-30 ℃, and the change of the modulus value slows down at 30-60 ℃.Compared with 0°C, the resilience mode value of the four asphalt mixes with different grades at 30°C decreased by 2373.41 MPa, 1675.21 MPa, 2276.69 MPa, and 1800.04 MPa on average, respectively. The average variation of the resilience mode value is lower in the 30-60 °C range. The slope change curve is shown in Figure 2.



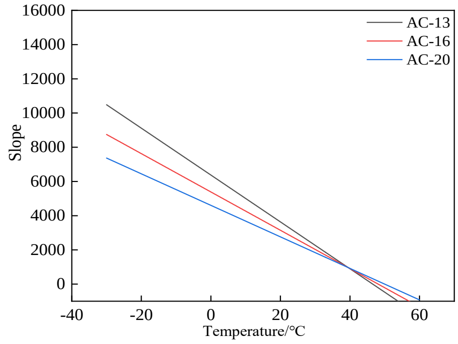
(a) 70# base asphalt mixture



(b) SBS modified asphalt mixture(70#)



(c) 90# base asphalt mixture



(d) SBS modified asphalt mixture (90#)

Fig.2 - Slope change curves at different temperatures

Therefore, this study divided the range of -30-60 ℃ into three temperature ranges of -30-0 ℃, 0-30 ℃, and 30-60 ℃. And the three temperatures of -20 ℃, 20 ℃ and 40 ℃ were taken as the representative to obtain the multiple relationships between the dynamic and static modulus. Because the impact of gradation and asphalt type on the resilience modulus value of asphalt mixtures was not obvious, the average values of the static modulus of different grades and asphalt types at -20 ℃, 20 ℃, and 40 ℃ were used as modulus value at this temperature, respectively (Table 5).

Tab. 5 - Test results of resilient modulus of asphalt mixture

Test temperature /℃	Static modulus of Asphalt mixture (MPa)				Average value (Mpa)
	70# base asphalt	Modified asphalt (70#)	90# base asphalt	Modified asphalt (90#)	
-20	8044.1	8463.5	6919.9	8183.1	7902.7
20	1607.3	1739.8	1423.2	1650.9	1605.3
40	799.5	820.3	776.4	804.4	800.2

Relevant research shows that the dynamic modulus of the asphalt mixture obtained at 10 Hz loading frequency and 20 ℃ is 16507 Mpa[20], which is 10.3 times the static modulus value of this research. The average resilience modulus of different grades obtained at 40 ℃ is 5637.3 MPa, which is 7.1 times the static modulus value of this study. The dynamic modulus of the asphalt mixture obtained at the loading frequency of 10Hz at 21.1 and 39.2 ℃ is 7164.7 and 2508.3 MPa, which are

4.5 and 3.2 times the static modulus values of this study, respectively. The dynamic moduli obtained at -20 ℃ and 20 ℃ are 31308.5 and 5622.7MPa, which are 3.97 and 3.5 times the static modulus of the same temperature in this study, respectively.

The suggested static modulus of the original code “Design Code for Highway Asphalt Pavement JTG D50-2006” at 20 ℃ is between 800-1600MPa, while the new specification “Code for Design of Highway Asphalt Pavement Design JTG D50-2017” is shown as Table 6.

Tab. 6 - Range of dynamic compression resilient modulus of asphalt mixture at 20 ℃ (MPa)

Mixture Gradation	Asphalt type			
	70# base asphalt	90# base asphalt	110# base asphalt	SBS modified asphalt
AC10、AC13	8000~12000	7500~11500	7000~10500	8500~12500
AC16 、 AC20 、 AC25	9000~13500	8500~13000	7500~12000	9000~13500

It can be seen from Tables 5 and 7 that the dynamic compression resilience modulus is 5 to 10 times the static modulus, and the suggested value for the dynamic compression resilience modulus is 5-8 times. In this study, the top surface method was be used to test the spring deformation of the specimen at all heights, so the obtained resilience modulus value will be small. In order to obtain a more accurate relationship between dynamic and static modulus, combined with domestic and foreign research results, standard recommended values, measured data of this study, etc., it is concluded that that there is 4 times, 5 times, 7 times of the relationship between asphalt mixture dynamics and static modulus in the three temperature ranges (-30-0 ℃, 0-30 ℃ and 40-60 ℃), respectively.

Conversion of static-dynamic anti-pressure resilience modulus of asphalt mixture

The static modulus of asphalt mixture is converted to dynamic modulus according to the resulting multiple relationship in different temperature intervals. The conversion results are shown in Table 7.

Tab. 7 - Dynamic compression resilient modulus of asphalt mixture (MPa)

Type	Gradation	Test temperature/ ℃									
		-30	-20	-10	0	10	20	30	40	50	60
70# base asphalt	AC-13	50038	36442	25094	20589	14945	9408	4963	4865	3678	2679
	AC-16	44823	30462	21203	17230	12675	7765	5349	5303	3827	2561
	AC-20	38142	25624	17484	16449	10890	6935	6367	5985	4348	2556
SBS modified asphalt (70#)	AC-13	56068	37909	25543	21330	15370	9607	5747	5229	3816	2768
	AC-16	49870	34320	22965	19141	13468	8780	5940	5772	3950	2687

	AC-20	42323	29332	19964	16905	11484	7560	6621	6224	4414	2801
90# base asphalt	AC-13	45158	34200	24004	20081	14521	8752	4822	4574	3616	2650
	AC-16	37200	25467	20384	15545	11327	6670	4981	4844	3723	2570
	AC-20	34412	23250	16103	15454	9304	5942	5129	4991	4230	2529
SBS modified asphalt (90#)	AC-13	55152	37439	24152	20361	15298	9108	5663	5191	2697	2723
	AC-16	45776	32548	21600	17427	12582	8450	5772	5699	3777	2647
	AC-20	40758	28211	19242	15712	9892	7205	5928	5583	4316	2693

Through the conversion, it can be found that the modulus value of asphalt mixture at 20 ℃ is in the range of 6670-9607 MPa, which is in the dynamic modulus value of the new specification recommends at the loading frequency of 10Hz and 20 ℃. This shows that the conversion relationship between the static module of asphalt mixture and the dynamic modulus is reasonable.

RELATIONSHIP BETWEEN ASPHALT MIXTURE DESIGN PARAMETERS AND TEMPERATURE

Relationship between dynamic resilience modulus and temperature of asphalt mixture

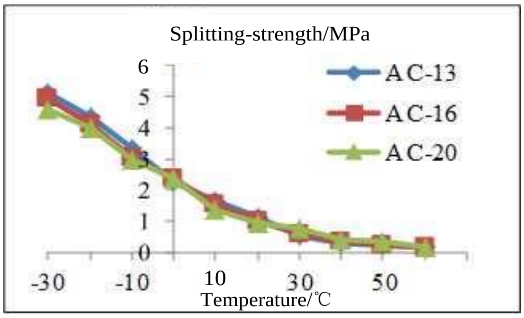
The relationship between the dynamic anti-pressure resilience modulus and the temperature regression of asphalt mixture is shown in Table 8.

Tab. 8 - Regression relationship of dynamic resilient modulus and temperature of asphalt mixtures

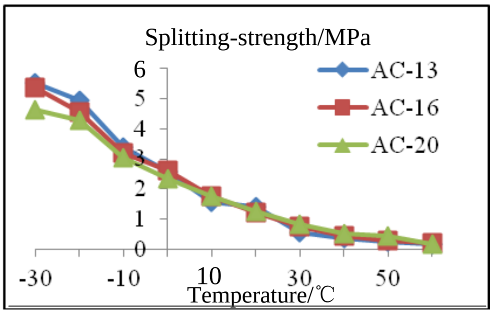
Type of asphalt	Gradation	Regression relation	
70# base asphalt	AC-13	y=20250.57-709.15x+7.29x2	R2=0.9916
	AC-16	y=17343.97-617.28x+6.7x2	R2=0.9825
	AC-20	y=15370-496.31x+5.28x2	R2=0.9664
SBS modified asphalt (70#)	AC-13	y=21166.38-783.92x+8.51x2	R2=0.9826
	AC-16	y=19145.83-691.18x+7.53x2	R2=0.9819
	AC-20	y=16766.12-571.83x+6.26x2	R2=0.9780
90# base asphalt	AC-13	y=19238.74-640.48x+6.29x2	R2=0.9943
	AC-16	y=15383.94-507.31x+5.24x2	R2=0.9889
	AC-20	y=13752.91-459.97x+5.03x2	R2=0.9724
SBS modified asphalt (90#)	AC-13	y=20541.46-774.12x+8.43x2	R2=0.9797
	AC-16	y=17926.13-636.18x+6.90x2	R2=0.9842
	AC-20	y=15691.42-560.29x+6.35x2	R2=0.9796

Relationship between splitting strength of asphalt mixture and temperature

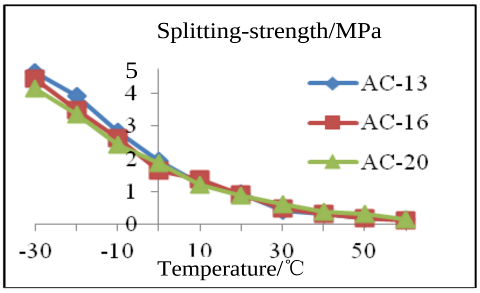
The relationship between the asphalt mixture splitting strength and temperature is shown in Figure 2. According to the relationship curve fitting of Figure 3, the regression relationship formula and the suggested values at different temperatures (Table 9) are obtained.



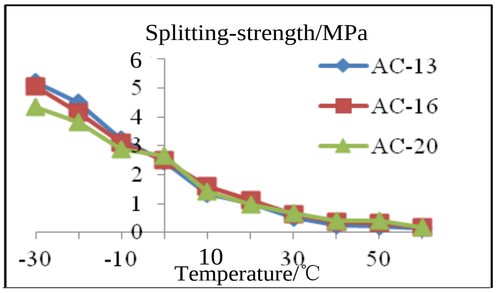
(a) 70# base asphalt mixture



(b) SBS modified asphalt (70#)



(c) 90# base asphalt mixture



(d) SBS modified asphalt (90#)

Fig. 3 - Curves of splitting tensile strength with temperature of asphalt mixture

Tab. 9 - Recommended values for split tensile strength

Type of mixture		Regression relation	Suggested value of split tensile strength at different temperatures (℃)/ Mpa					
			-30	-10	0	20	40	60
70# asphalt	AC-13	y =2.19-0.11x+0.001x2 R² = 0.9804	6.85	2.96	1.94	0.84	0.36	0.16
	AC-16	y= 2.17-0.10x+0.001x2 R² = 0.9815	6.64	2.92	1.94	0.85	0.38	0.17
	AC-20	y=2.10-0.09x+9.85Ex2 R² = 0.9865	5.82	2.78	1.92	0.92	0.44	0.21
70# SBS	AC-13	y =2.36-0.11x+0.00138x2 R² = 0.9805	7.36	3.18	2.09	0.9	0.39	0.17
	AC-16	y =2.40-0.103x+0.00118x2 R² = 0.9852	6.83	3.19	2.18	1.02	0.48	0.22
	AC-20	y =2.29-0.09x+9.78E-4x2 R² = 0.9889	6.05	3.01	2.12	1.05	0.52	0.26

90# asphalt	AC-13	y = 1.89-0.09x+0.00106x2 R^2 = 0.9818	5.78	2.55	1.69	0.74	0.33	0.14
	AC-16	y=1.82-0.083x+9.82931E-4x2 R^2 = 0.983	5.43	2.44	1.63	0.73	0.33	0.15
	AC-20	y=1.81-0.073x+8.14556E-4x2 R^2 = 0.9870	4.92	2.39	1.67	0.81	0.41	0.19
90# SBS	AC-13	y = 2.19-0.112x+0.00139x2 R^2 = 0.9778	7.15	2.97	1.91	0.79	0.33	0.14
	AC-16	y = 2.24-0.096x+0.0011x2 R^2 = 0.9855	6.36	2.98	2.04	0.95	0.45	0.21
	AC-20	y = 2.038-0.083x+9.17521E-4x2 R^2 = 0.9798	5.53	2.69	1.88	0.91	0.45	0.22

DETERMINATION OF ASPHALT PAVEMENT DESIGN PARAMETERS BASED ON PG TECHNOLOGY (HEILONGJIANG PROVINCE, CHINA)

Based on the asphalt pavement design specification, the dynamic rebound modulus and the relationship between crack strength and temperature of asphalt mixtures, as well as the classification of PGm-n grades of asphalt pavements, were investigated by combining the PGm-n technology while retaining the design parameters of the specification. Based on the results of the previous study, this paper takes asphalt pavement in Heilongjiang Province, China, as an example to verify the validity of the results of the previous study.

Asphalt pavement PGm-n grade climate partition

Through the PGm-n grade analysis of asphalt pavement climate zoning in Heilongjiang Province, the PGm-n grade and the corresponding representative city (Table 10) are obtained. Based on the above research data, the design parameters of asphalt pavement in Heilongjiang province based on PG technology (Table 11 and 12) are obtained.

Tab. 10 - Climate zones and PGm-n of asphalt pavement in Heilongjiang province

Climate zoning	PGm-n grade	Representative city
2-1	PG52-46	Mohe
2-1	PG58-40	Nenjiang
2-1	PG58-34	Mudanjiang
2-2	PG58-34	Harbin

Tab. 11 - Parameter of resilient modulus of asphalt mixture（Heilongjiang province）

Climate zoning	City	PGm-n	Asphalt	Gradation	Static resilience modulus /MPa			Dynamic resilience modulus /MPa		
					m ℃	20 ℃	-n ℃	m ℃	20 ℃	-n ℃
2-1	Mohe	PG52-46	90#	AC-13	474	1704.3	23882.1	3316.6	8521.5	95528.4
				AC-16	486	1538	16558.3	3403.4	7690	66233.2
				AC-20	495	1468.1	13845.9	3462.2	7340.5	55383.6
			90#	AC-13	487	1451.5	27062.1	3407.6	7257.5	108248.2

			modified	AC-16	508	1712.5	21029.5	3553.2	8562.5	84118
				AC-20	534	1636.6	16487.8	3738.7	8183	65951.2
2-2	Harbin	PG58-34	90#	AC-13	373	1704.3	14777.9	2608.9	8521.5	59111.6
				AC-16	392	1538	10749.8	2742.6	7690	42999.2
				AC-20	403	1468.1	9207.2	2823.1	7340.5	36828.8
			90# modified	AC-13	381	1451.5	16545.8	2664.9	7257.5	66183.2
				AC-16	404	1712.5	13328.8	2828.7	8562.5	53315.2
				AC-20	433	1636.6	10833.2	3029.6	8183	43332.8

Tab. 12 - Parameter of split strength of asphalt mixtures（Heilongjiang province）

Climate zoning	City	PGm-n	Asphalt	Gradation	Split tensile strength /MPa		
					m ℃	20 ℃	-n ℃
2-1	Mohe	PG52-46	90#	AC-13	0.2	0.74	11.14
				AC-16	0.2	0.73	10.29
				AC-20	0.26	0.81	8.75
			90# modified	AC-13	0.19	0.79	14.46
				AC-16	0.28	0.95	11.69
				AC-20	0.29	0.91	9.84
2-2	Harbin	PG58-34	90#	AC-13	0.16	0.74	6.82
				AC-16	0.16	0.73	6.38
				AC-20	0.21	0.81	5.68
			90# modified	AC-13	0.15	0.79	8.53
				AC-16	0.22	0.95	7.41
				AC-20	0.23	0.91	6.39

CONCLUSIONS

(1) The resilience modulus and splitting strength of the asphalt mixture decrease with increasing temperature. When the temperature is between -30-0 ℃, these indicators are maintained at a high level; when the temperature is between 0-60 ℃, the mechanical index values are small and when the temperature is between -30-30 ℃, the drop of asphalt mixture indicators is large. In the range of 30-60 ℃, the downward trend of the mechanical index of the same class and different combination material types slows down, and the change of the mechanical index of asphalt mixture is not obvious.

(2) The asphalt mixture dynamics and static modulus have differences in terms of moulding method and loading method, and the test specimen preparation method has unevenness between static pressure and hard-hitting. Asphalt blend springing modulus is greatly influenced by temperature and loading frequency, and there are different multiplier relationships between dynamic and static module at different temperatures and loading frequencies. By dividing the entire temperature range (-30-60 ℃), combined with test data, domestic and foreign research results and specification recommendations, this study obtained 4 times, 5 times and 7 times relationship

between dynamic and static modules in different temperature ranges (-30-0 ℃, 0-30 ℃ and 40-60 ℃), respectively.

(3) There is an exponential function between the mechanical specifications of the asphalt mix and the temperature. According to the relationship between the indicators and temperature and the PGm-n grade of the asphalt pavement climate zone in China, the proposed value of asphalt pavement design parameters is established. The results of the study are of some theoretical and practical value to the design of asphalt pavement.

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REFERENCES

[1] Qian G, Shi C, Yu H, et al. Evaluation of different modulus input on the mechanical responses of asphalt pavement based on field measurements[J]. Construction and Building Materials, 2021, 312: 125299.

[2] Khasawneh M A, Al-jamal N F. Modeling resilient modulus of fine-grained materials using different statistical techniques[J]. Transportation Geotechnics, 2019, 21: 100263.

[3] Shafabakhsh G, Tanakizadeh A. Investigation of loading features effects on resilient modulus of asphalt mixtures using Adaptive Neuro-Fuzzy Inference System[J]. Construction and Building Materials, 2015, 76: 256-263.

[4] Ibrahim H, Wahhab A A, Hasnain J. Laboratory study of asphalt concrete durability in Jeddah[J]. Building and environment, 1998, 33(4): 219-230.

[5] Saberian M, Li J. Effect of freeze–thaw cycles on the resilient moduli and unconfined compressive strength of rubberized recycled concrete aggregate as pavement base/subbase[J]. Transportation Geotechnics, 2021, 27: 100477.

[6] Yousefi A, Behnood A, Nowruzi A, et al. Performance evaluation of asphalt mixtures containing warm mix asphalt (WMA) additives and reclaimed asphalt pavement (RAP)[J]. Construction and Building Materials, 2021, 268: 121200.

[7] Elliott R P, Thornton S I. Resilient modulus and AASHTO pavement design[J]. Transportation research record, 1988 (1196)

[8] Maher A, Bennert T A. Evaluation of Poisson's ratio for use in the mechanistic empirical pavement design guide (MEPDG)[R]. 2008.

[9] Su N, Xiao F, Wang J, et al. Characterizations of base and subbase layers for Mechanistic-Empirical Pavement Design[J]. Construction and Building Materials, 2017, 152: 731-745.

[10] Hossain Z, Zaman M, Doiron C, et al. Characterization of subgrade resilient modulus for pavement design[M]//Geo-Frontiers 2011: Advances in Geotechnical Engineering. 2011: 4823-4832.

[11] Zhang Y, Luo R, Lytton R L. Anisotropic viscoelastic properties of undamaged asphalt mixtures[J]. Journal of Transportation Engineering, 2012, 138(1): 75-89.

[12] Specht L P, Lucas F, Di Benedetto H, et al. Application of the theory of viscoelasticity to evaluate the resilient modulus test in asphalt mixes[J]. Construction and Building Materials, 2017, 149: 648-658.

[13] Guo M, Liang M, Jiao Y, et al. A review of phase change materials in asphalt binder and asphalt mixture[J]. Construction and Building Materials, 2020, 258: 119565.

[14] Si W, Li N, Ma B, et al. Temperature response to tensile characteristics of the hot asphalt mixtures[J]. KSCE Journal of Civil Engineering, 2016, 20(4): 1336-1346.

[15] Moreno-Navarro F, Sol-Sánchez M, Rubio-Gámez M C, et al. The use of additives for the improvement of the mechanical behavior of high modulus asphalt mixes[J]. Construction and Building Materials, 2014, 70: 65-70.

[16] Zhang J, Fan Z, Wang H, et al. Prediction of dynamic modulus of asphalt mixture using micromechanical method with radial distribution functions[J]. Materials and Structures, 2019, 52(2): 1-12.

[17] Salem H A, Uzelac D, Matic B. Temperature zoning of Libya desert for asphalt mix design[C]//Applied Mechanics and Materials. Trans Tech Publications Ltd, 2014, 638: 1414-1426.

[18] Tan Y, Sun Z, Gong X, et al. Design parameter of low-temperature performance for asphalt mixtures in cold regions[J]. Construction and Building Materials, 2017, 155: 1179-1187.

[19] Copeland A, D'Angelo J, Dongre R, et al. Field evaluation of high reclaimed asphalt pavement–warm-mix asphalt project in Florida: Case study[J]. Transportation Research Record, 2010, 2179(1): 93-101.
[20] Wu S, Ye Q, Li N. Investigation of rheological and fatigue properties of asphalt mixtures containing polyester fibers[J]. Construction and Building Materials, 2008, 22(10): 2111-2115.