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Assessing dynamic modulus properties for typical asphalt mixtures in Jiangsu

Wang Haopeng Yang Jun Zhou Wenzhang Chen Xianhua

(School of Transportation, Southeast University, Nanjing 210096, China)

Abstract: To investigate the validity of two dynamic modulus predictive models (Witczak 1-37A viscosity-based model and Witczak 1-40D shear modulus-based model) in the context of Jiangsu, and evaluate the effect of different mixture design variables (aggregate gradations, binder type, and volumetric properties) on dynamic modulus E^*, asphalt mixtures commonly used in the local surface layer, including Sup-13 and AC-13, are prepared in the laboratory and their dynamic modulus E^* values are predicted based on the above mentioned models. The corresponding asphalt tests, including viscosity and dynamic shear modulus tests, are also carried out to obtain the prediction model parameters. The test results show that binder type and asphalt content have a significant impact on dynamic modulus. There is a good correlation between the E^* values based on above two predictive models and the measured E^*, while a relatively lower bias can be expected from Witczak 1-37A model. The test results can be used for the calibration of dynamic modulus with higher accuracy.

Key words: dynamic modulus; prediction models; asphalt pavement; Witczak 1-37A; Witczak 1-40D; mechanistic empirical pavement design guide

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Dynamic modulus is one of the fundamental properties defining the response of asphalt mixtures in flexible pavement systems. The mechanistic empirical pavement design guide (MEPDG) computes stresses, strains, and deflections within a pavement system and then predicts various distresses in the pavement through empirical models[1]. These empirical models are related to dynamic modulus, which is a fundamental property for time-temperature-dependent hot-mixture asphalt (HMA). Hence, dynamic modulus is proposed by MEPDG as a primary input parameter required to perform the analysis and design. Moreover, it is a leading candidate for the asphalt materials performance tester (AMPT), recommended by the NCHRP projects 9-19 and 9-29 and it has been proposed as a potential quality control (QC)-quality assurance (QA) parameter.

The MEPDG software adopts three different hierarchical input levels, depending on the available data to characterize both asphalt binders and mixtures. For Level 1 HMA characterization, direct laboratory-measured dynamic modulus values are required. The inputs of E^* at Levels 2 and 3 are estimated from regression-based E^* predictive models. Similarly, both Levels 1 and 2 inputs for binder characterization require laboratory measurements. For Level 3 binder inputs, users are only required to select the binder grade based on the superpave performance grade, conventional penetration grade, or conventional viscosity grade systems. However, dynamic modulus testing and master curve development can be time consuming and costly and they require trained staff for specimen preparation, testing and data analysis[2]. It is not practical to require Level 1 HMA input parameters for all mechanistic-empirical based pavement designs. Consequently, a number of database of dynamic modulus for US asphalt mixtures have been established and several E^* predictive models (Witczak 1-37A, Witczak 1-40D, Hirsh and Al-Khateeb)[3] have been developed from various intrinsic characteristics of the mixture, such as volumetric properties, aggregate gradation, and binder properties, for pavement design purposes. The two Witczak E^* predictive models were also implemented in MEPDG. Both the Witczak 1-37A and 1-40D models predict E^* of HMA mixtures as a sigmoidal function of mixture volumetric properties, mixture aggregate gradation, and a binder stiffness parameter.

Several researchers[4–10] investigated the strengths and weakness of available empirical models, and found that both Witczak models showed different performances based on the type of HMA and temperature. A recent study by Shen et al.[4] reported that, the Witczak 1-37A model under-predicted E^* at low temperatures and over-predicted E^* at high temperatures for Washington State mixtures. The study also showed that the Witczak 1-40D model has better prediction of dynamic modulus at higher and lower temperatures compared to the Witczak 1-37A model, while under-predicting E^* at medium temperatures. Several other studies[5–7] reported that the Witczak 1-37A model over-predicted E^*, particularly at high temperatures. In addition, research by Azari et al.[8] and Ceylan et al.[9] found better E^* predictions with the Witczak 1-40D model than the Witczak 1-37A model. However, according to El-Badawy et al.[10], the Witczak 1-37A

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Biographies: Wang Haopeng (1991—), male, graduate; Yang Jun (corresponding author), female, doctor, professor, yangjun@seu.edu.cn.

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model produced better E^* predictions than the Witczak 1-40D model for HMA plant-produced mixtures placed on the NCAT test track.

Asphalt pavements constructed in Jiangsu Province have always been in the leading status among different regions in China. The Department of Transportation of Jiangsu Province is the first department that applied and generalized superpave technology in pavement design and construction. There has been growing interest among road authorities in China, particularly in Jiangsu Province, in adopting dynamic modulus as a more rational and realistic representative of material properties than the currently used resilient modulus in pavement design procedure. Nevertheless, there is concern about whether the MEPDG dynamic modulus predictive models are appropriate for asphalt mixtures using local material in Jiangsu Province. The results in the literature conclusively demonstrated that these E^* predictive models may not be able to predict accurate and consistent E^* values among different HMA mixtures under a given set of specific environmental conditions and design traffic. Therefore, it becomes important to evaluate the performance of empirical models for local materials and conditions.

This paper aims to evaluate the influence of mixture properties (binder type and asphalt content) on dynamic modulus, and to evaluate the performance of MEPDG empirical models (Witczak 1-37A and Witczak 1-40D) for estimation of E^* of local HMA mixtures commonly used in Jiangsu Province.

1 Review of Dynamic Modulus Predictive Models in MEPDG

1.1 Witczak 1-37A model

The Witczak 1-37A model is based on nonlinear regression analysis and is currently utilized to predict the dynamic modulus in Levels 2 and 3 designs of the MEPDG shown as

$$\log E^* = -1.249\,937 + 0.029\,232\rho_{200} - 0.001\,767(\rho_{200})^2 - 0.002\,841\rho_4 - 0.058\,097V_a - 0.802\,208\frac{V_{beff}}{V_{beff}+V_a} + \frac{3.871\,977 - 0.002\,1\rho_4 + 0.003\,958\rho_{38} - 0.000\,017(\rho_{38})^2 + 0.005\,47\rho_{34}}{1+e^{-0.603\,313-0.313\,551\log f-0.393\,532\log\eta}} \tag{1}$$

where E^* is the dynamic modulus of the asphalt mixture, MPa; η is the viscosity of the binder, Pa · s; f is the loading frequency, Hz; V_{beff} is the effective binder content in volume, %; V_a is the air voids in the mixture, %; ρ_{200} is the percentage of passing No. 200 sieve (0.075 mm); ρ_4 is the percentage of cumulative retained on No. 4 sieve (4.75 mm); ρ_{38} is the percentage of cumulative retained on the 3/8 inch sieve (9.5 mm); ρ_{34} is the percentage of cumulative retained on the 3/4 inch sieve (19 mm).

It incorporates rudimentary volumetric properties and gradations of the mixture, binder viscosity η and loading frequency into a sigmoidal function to predict E^* over a range of temperatures and frequency. The Witczak 1-37A model requires an established linear viscosity-temperature relationship to calculate the viscosity of the binder at the desired temperature shown as

$$\log\log\eta = A + S_{vt}\log T \tag{2}$$

where A is the regression intercept; S_{vt} is the regression slope of the viscosity-temperature relationship; T is the temperature, ℃. In this paper, A and S_{vt} are calculated by establishing a linear regression for laboratory measured viscosities of binders at 15, 30, 45, and 55 ℃ to comply with the planned dynamic modulus testing temperature scheme.

1.2 Witczak 1-40D model

The Witczak 1-37A model is revised with an expanded database of 7 400 data points from 346 different HMA mixtures, and it has been refined using the dynamic shear modulus G_b^*. The phase angle δ_b is used to characterize the binder stiffness rather than the viscosity, which is to be partly consistent with superpave performance graded (PG) binder specifications. The revised Witczak 1-40D model is

$$\log E^* = -0.349 + 0.754 G_b^{*\,-0.005\,2}\left(6.65 - 0.032\rho_{200} + 0.002\,7(\rho_{200})^2 + 0.011\rho_4 - 0.000\,1(\rho_4)^2 + 0.006\rho_{38} - 0.000\,14(\rho_{200})^2 - 0.08V_a - 1.06\frac{V_{beff}}{V_a+V_{beff}}\right) + \frac{2.56 + 0.03V_a + 0.71V_{beff}/(V_a+V_{beff}) + 0.012\rho_{38} - 0.000\,1(\rho_{38})^2 - 0.01\rho_{34}}{1+e^{-0.781\,4-0.578\,5\log|G_b^*|+0.883\,4\log\delta_b}} \tag{3}$$

where G_b^* is the complex shear modulus of the binder, Pa; δ_b is the phase angle of the binder associated with G_b^*, °.

Similar to the Witczak 1-37A model, the sigmoidal structural form is maintained and the same inputs of volumetric and gradation properties of the mixture are used in the Witczak 1-40D model. According to Bari and Witczak[7], it should be noted that the loading frequency used in the dynamic shear mode is not equivalent to the loading frequency used in dynamic compression mode, but rather, is related to

$$f_c = 2\pi f_s \tag{4}$$

where f_c is the frequency in the compression mode, Hz; f_s is the frequency in the shear mode, Hz. Therefore, in this paper, the loading frequencies of 3.979, 3.184, 1.592, 0.796, 0.159, 0.080, 0.032 and 0.016 Hz (equivalent to 25, 20, 10, 5, 1, 0.5, 0.2, and 0.1 Hz in the compression mode) are used to estimate shear modulus and phase angle values based on the established G_b^* master curve. The temperatures of 15, 30, 45, and 55 ℃ are used in E^* and G_b^* tests.

2 Experiment Design

The experimental work conducted in this research involves laboratory testing for both binders and mixtures. To meet the aims of this study, dynamic modulus testing was conducted on all mixtures. Dynamic shear rheometer (DSR) testing and Brookfield viscosity testing were also conducted on the corresponding binders.

2.1 Materials and sample preparation

Three types of asphalt binders, including the conventional base binder namely SHELL-70 (PG64-22), SBS modified binder (PG76-28), and carbon nano-tubes (CNTs) modified binder, are used in this paper. The conventional base binder and styrene-butadiene-styrene (SBS) modified binder are the typical asphalt binders used in Jiangsu Province based on local climate and traffic conditions[11]. CNTs, a promising nano-structure material, are also included in this study to evaluate the dynamic modulus properties of CNTs modified asphalt mixtures. The dosage of CNTs blended with the mixture is 1% by weight of the base binder. Local basalt aggregates and limestone fillers are used in this study. The technical performance of the local basalt aggregates and limestone fillers are shown in Tab. 1 and Tab. 2.

Two surface mixtures (AC-13 and Sup-13) with a nominal maximum aggregate size (NMAS) of 13.2 mm, commonly used in Jiangsu Province, are included in this study. The AC-13 mixtures are designed based on the Marshall mixture design method, while Sup-13 mixtures are based on the superpave volumetric mixture design method. Each mixture is preheated in an oven, and samples are compacted with a superpave gyratory compactor into a 150-mm-diameter mold to approximately 160 mm in height. Test specimens are then cored from the center of the gyratory compacted samples into 100 mm in diameter by 150 mm in height. The gradations of the two surface mixtures are shown in Tab. 3. A total of ten asphalt mixtures with various asphalt binder types, asphalt contents and gradations are designed to meet the objectives of this study, detailed information and volumetric properties of all the mixtures are summarized in Tab. 4. Two replicates were prepared for each mixture.

Tab. 1 Properties of basalt aggregates used in the surface layer

Indices	1#	2#	3#	4#	Specification
Specific gravity	2.972	2.813	2.953	2.942	≥2.60
Moisture absorption/%	0.3	0.6			≤2.0
Flakiness index/%	2.8	2.1			≤15
Content of granules (<0.075 mm)/%	0.02	0.06	0.16		≤1.0
Sand equivalency	93	≥60			
Hardness value/%	2.6	≤12			
Crushed stone value/%	15	≤26			
L. A. abrasion value/%	16.5	≤28			

Tab. 2 Properties of limestone filler

Indices		Test results	Specification
Specific gravity		2.78	≥2.50
Hydrophile coefficient		0.65	≤1.0
Moisture content		0.25	≤1.0
Heating invariability		Invariable	Invariable
Passing percentage/%	0.6 mm	100	100
	0.15 mm	98.9	90 to 100
	0.075 mm	97.5	75 to 100

Tab. 3 Gradations of two surface asphalt mixtures %

Gradation	Passing sieve size/mm									
	16	13.2	9.5	4.75	2.36	1.18	0.6	0.3	0.15	0.075
AC-13	100	96.0	75.7	52.0	38.6	25.8	16.8	11.2	8.9	6.9
Sup-13	100	99.1	91.9	66.3	45.7	31.0	21.1	14.9	12.3	9.8

Tab. 4 Properties of investigated mixtures

Mix ID	Gradation	Binder type	Volumetric properties/%			
			P_b	VMA	V_a	VFA
Mix 1	AC-13	Base	4.85*	13.84	3.6	74.0
Mix 2	Sup-13	Base	4.71*	14.32	4.0	72.1
Mix 3	AC-13	CNTs	4.85*	13.84	3.6	74.0
Mix 4	Sup-13	CNTs	4.71*	14.32	4.0	72.1
Mix 5	AC-13	SBS	4.85*	13.84	3.6	74.0
Mix 6	AC-13	SBS	5.35	13.19	3.6	72.7
Mix 7	AC-13	SBS	4.35	13.67	3.6	73.7
Mix 8	Sup-13	SBS	4.71*	14.32	4.0	72.1
Mix 9	Sup-13	SBS	5.21	13.71	4.0	70.8
Mix 10	Sup-13	SBS	4.21	14.14	4.0	71.7

Note: P_b is the asphalt content by mixture weight; VMA represents voids in mineral aggregate; V_a represents air voids; VFA represents voids filled with asphalt; * means optimum asphalt content (OAC).

2.2 Test methods

The viscosity of binder was determined for rolling thin film oven (RTFO) aged binders using the Brookfield rotational viscometer following AASHTO D4402-06 at 135 and 175 ℃. DSR testing was also conducted on the RTFO aged binders to measure the dynamic shear modulus and phase angle in accordance with AASHTO T315-12. Testing was conducted at four temperatures of 15, 30, 45 and 55 ℃. A frequency sweep test including 20 frequencies ranging from 0.1 to 25 Hz was applied at each of the four temperatures.

The dynamic modulus test was conducted in accordance with AASHTO TP 79-10 using the asphalt mixture performance tester (AMPT), also called the simple performance tester (SPT). Testing was conducted at four temperatures of 14, 30, 45, 55 ℃ and nine frequencies of 25, 20, 10, 5, 2, 1, 0.5, 0.2 and 0.1 Hz.

3 Results and Discussion

3.1 Effect of material properties on E^* master curve

E^* master curve was constructed following the time-temperature superposition (TTS) principle. The dynamic moduli at various temperatures were shifted in line with frequency until the curve merges into a single sigmoidal function, representing the master curve, using a second-order polynomial relationship between the shift factor and temperature. The reference temperature in this study was selected to be 30 ℃.

3.1.1 Effect of asphalt binder types on E^* master curve

The properties of asphalt binder are directly related to the mechanical performance of the mixture. Three different asphalt binders (base binder, CNTs modified binder, and the SBS modified binder) were investigated in this study to evaluate the effect of binder type on the E^* master curve. According to the TTS principle, high and low temperatures correspond to low and high frequencies, respectively. As shown in Fig. 1, for both AC-13 and Sup-13 aggregate gradations, the E^* master curve of the SBS modified asphalt mixture is higher compared to CNTs modified and base asphalt mixtures at higher temperatures. As expected, SBS modified asphalt binder with higher PG can significantly increase the high temperature performance (rutting resistance) due to its absorption effect between its base asphalt and SBS particles, and the reinforcing effect of polymer networks. It is also observed that CNTs modified asphalt mixture E^* master curve is higher than those of both SBS modified and base binders at low temperatures. The reason may be that the high surface area of CNTs results in a strong interaction between the asphalt binder and nanoparticles. When the temperature continuously decreases to a low level, E^* master curves are overlapped with no specific trend. It is implied that CNTs make asphalt mixture stiff, which decreases the low temperature deformation flexibility to make it more vulnerable to low temperature cracking. Moreover, CNTs can benefit from the high temperature performance compared to base asphalt, in spite of being inferior to SBS.

3.1.2 Effect of asphalt content on E^* master curve

Asphalt content is a very important parameter for QA/QC control asphalt pavement. To evaluate the effect of

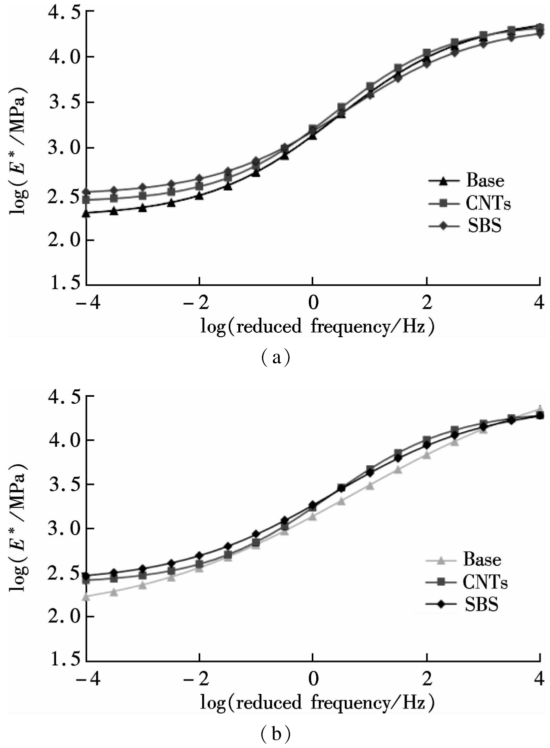

Fig. 1 Effect of asphalt binder types on E^* master curve. (a) AC-13 mix; (b) Sup-13 mix

asphalt content on the E^* master curve, three different asphalt contents (OAC, OAC ±0.5) were studied on both AC-13 and Sup-13 mixtures, as shown in Fig. 2. It was noted that there was no regular pattern regarding the effect of asphalt content on E^* master curves. However, it is obvious that the master curves with higher asphalt content (OAC +0.5) exhibit lower E^* values compared to those

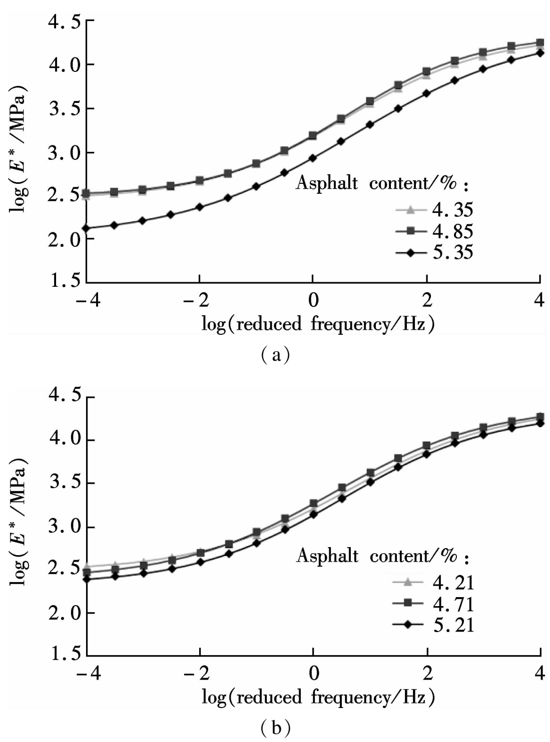

Fig. 2 Effect of asphalt content on E^* master curve. (a) AC-13 mix; (b) Sup-13 mix

with low asphalt content. With the same air voids, mixtures with high asphalt contents have more free asphalt, weakening the interlock of the aggregate skeleton as well as lowering cohesion strength. Therefore, mixtures with high asphalt content exhibit low E^* values and may decrease the rutting resistance.

3.2 Evaluation of existing E^* prediction models in MEPDG

Four approaches were adopted to assess the performance of each empirical model: goodness-of-fit statistics, comparison of measured and predicted values with line of equality (LOE) (visual inspection), overall bias statistics (slope, intercept, and average error), and the ranking ability of HMA mixtures.

The goodness-of-fit statistics, including standard error of estimated/standard deviation (S_e/S_y), and correlation coefficient R^2, are calculated as

$$S_y = \sqrt{\sum_{i=1}^{n} (E_{mi}^* - \bar{E}_m^*)^2/(n-1)} \tag{5}$$

$$e_i = E_{pi}^* - E_{mi}^* \tag{6}$$

$$S_e = \sqrt{\sum_{i=1}^{n} e_i^2/(n-k)} \tag{7}$$

$$R^2 = 1 - \frac{n-k}{n-1}\left(\frac{S_e}{S_y}\right)^2 \tag{8}$$

where n is the number of data points; k is the number of independent variables in the model; E_{mi}^* is the measured dynamic modulus; $\bar{E}_m^*$ is the mean value of measured dynamic modulus; E_{pi}^* is the predicted dynamic modulus; S_y is the standard deviation of the measured dynamic modulus; e_i is the error between the predicted and measured dynamic values; S_e is the standard error.

3.2.1 Laboratory measured vs. predicted E^*

A comparison of the laboratory measured vs. predicted dynamic modulus was conducted with both MEPDG E^* predictive models, as shown in Fig. 3. The LOE is plotted in the figure to examine the scattering of the data. A good predictive model will produce results following the LOE in an oval shape. The goodness-of-fit statistics of the model predictions are also listed in Fig. 3.

As can be seen from Fig. 3, both the Witczak 1-37A and 1-40D models yielded biased E^* estimations, particularly at high and/or low temperatures. The Witczak 1-37A model produced approximately half over-estimated and half under-estimated E^* values, while the Witczak 1-40D model over predicted E^* values at most temperature spectrums. Nevertheless, in terms of the good-of-fit statistics, the Witczak 1-37A model ($S_e/S_y = 0.409\ 8$, $R^2 = 0.894\ 4$) obtained more accurate and less biased E^* data than the Witczak 1-40D model ($S_e/S_y = 0.490\ 1$, $R^2 = 0.794\ 7$). According to the classification criteria[7], both Witczak models can be classified as a "Good" fit to laboratory measured data.

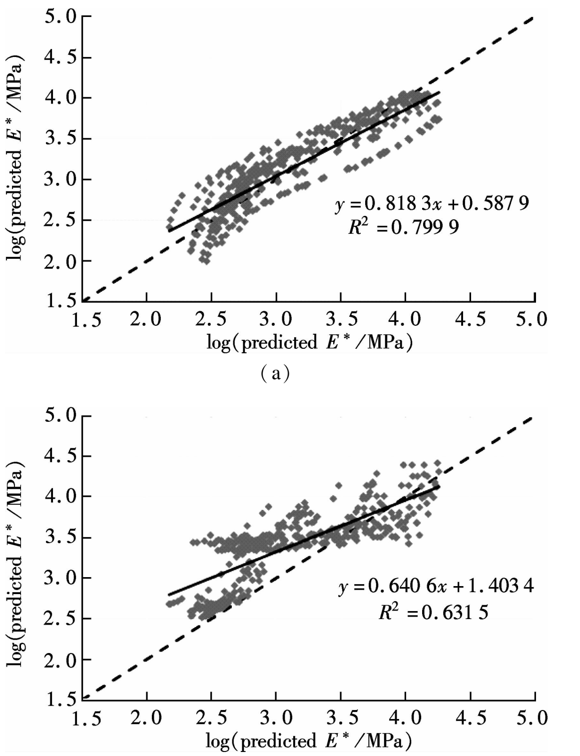

Fig. 3 Measured vs. predicted dynamic modulus on a log-log scale. (a) Witczak 1-37A model; (b) Witczak 1-40D model

3.2.2 Overall bias of the models

The results in Fig. 3 summarize the prediction accuracy of the models. However, overall good-of-fit statistics such as S_e/S_y and R^2 are only measures of the model accuracy (i. e., the degree of scatter with reference to the LOE). They do not tell the entire story regarding model accuracy, and they do not reflect the bias in the predictions. The overall bias in the prediction can be assessed by performing linear regression between the measured and predicted E^* values and evaluating the intercept and slope of these unconstrained regression lines. The divergence between slopes and unity suggests the reliability of prediction errors to actual values. The larger the intercepts, depending on their sign, the more the estimations are over- (for positive intercepts) or under- (for negative intercepts) predicted. The unconstrained regression lines are also shown in Fig. 3. Another measure of overall model bias is the average error. A nonzero average error indicates a consistent over-prediction or under-prediction by the model.

Tab. 5 summarizes the overall bias statistics for both Witczak models. The closer the intercept is to zero and the slope is to unity, the lower the bias is. As shown in Tab. 5, the intercept of the Witczak 1-37A model is lower compared to the Witczak 1-40D model, while the slope of the Witczak 1-37A model is closer to unity compared to the Witczak 1-40D model. The positive average error for both Witczak models indicates the over-predicted nature of the models, which can be visually observed from LOE plots (see Fig. 3). Moreover, the Witczak 1-40D model exhibits larger over-predicted magnitudes than the Witczak 1-37A model. It can be concluded that the Witczak 1-37A predictive model has better estimations in this study.

Tab. 5 Overall bias in model predictions

Parameter	Witczak 1-37A	Witczak 1-40D
Intercept in log(E^*/MPa)	0.59	1.40
Slope	0.82	0.64
Average error in log(E^*/MPa)	0.017	0.275

3.3 Practical implication of ranking HMA mixtures

Pavement and bituminous materials engineers often evaluate alternative HMA mixture designs in an effort to optimize pavement performance. In the MEPDG, this evaluation is done largely in terms of material inputs (i. e., dynamic modulus). Therefore, predictive models for E^* should rank mixtures in the same order as they would be ranked if E^* was actually measured in the laboratory. If this is not the case, the prediction model will give incorrect indications of the relative performance of the alternative mixtures[9]. For instance, several studies noted that E^* of asphalt layer(s) significantly affects the MEPDG predicted pavement performance in terms of rutting and longitudinal and alligator fatigue cracking[12-14]. If the measured E^* of mixture A is higher than that of mixture B at some given temperature and loading rate, and the predicted E^* of mixture A is lower than that of mixture B at the same temperature and loading rate, then the designed pavement structure with mixture B will be inadequate, which can cause premature rutting failure.

In correlation analysis methods, Kendall's τ rank correlation coefficient is a standard statistic for quantifying the degree of correspondence between two rankings. Consider paired lists of measured and predicted E^* values for n HMA mixtures, with the paired items ranked in order of the first list (i. e., measured E^*) in descending order. Kendall's τ coefficient for the second list (predicted E^*) is defined as[15]

$$\tau = \frac{4P}{n(n-1)} - 1 \tag{9}$$

where P is the number of items in the second list that are also ranked correctly. A value for τ equal to 1 means that the ranking of the two lists is in a perfect agreement. A value of −1 means that the rankings are in a perfect disagreement (i. e., the second list is ranked in the reverse order of the first), and a value of 0 means that the rankings are completely independent. In other words, increasing positive values of τ corresponds to increasing agreement between the two rankings.

Kendall's τ values for the predicted E^* values are determined using two Witczak models for all of the data records. The τ values for the Witczak 1-37A model and Witczak 1-40D model are 0.733 and 0.645, respectively. As is hoped, the τ values are both high. This indicates that the rankings by predicted E^* values are approximately the same as the rankings by measured E^* values. However, the Witczak 1-37A model with a higher τ value performs better than the Witczak 1-40D model, which means that the mixture rankings based on E^* predictions from the Witczak 1-37A model are in better agreement with the rankings based on measured E^* values than the Witczak 1-40D model.

Part of the inaccuracy and errors developed in the model's prediction can be attributed to different databases, based on which the studied models were developed and calibrated, i. e., binder type and aging condition; aggregate type and gradation; mixture design and compaction method; and volumetric properties of the mixtures (air voids, VMA and VFA). Based on the results from evaluation of E^* predictive models, it can be concluded that both Witczak models can produce "good" E^* predictions for local HMA mixtures in Jiangsu Province in spite of the varying extents of bias. However, the Witczak 1-37A predictive model performs more accurately with lower bias than the Witczak 1-40D model.

4 Conclusion

1) Binder types or binder properties have a significant influence on the dynamic modulus. The SBS modified asphalt mixtures exhibit higher E^* values at a low level of E^* (high temperature and low frequency). CNTs modified asphalt mixtures exhibit higher E^* values at a high level of E^* (low temperature and high frequency).

2) There is no regular pattern regarding the effect of asphalt content on E^* master curves. However, higher asphalt content decreases the dynamic modulus of HMA mixtures.

3) Both MEPDG E^* predictive models yield biased E^* estimations, especially at high (higher than 45 ℃) and/or low temperatures (less than 5 ℃).

4) The Witczak 1-37A predictive model produces relatively lower biased and higher accurate estimations of the dynamic modulus than those of the Witczak 1-40D predictive model for local HMA mixtures.

5) The Witczak 1-37A model can better rank HMA mixtures in the same order as the measured dynamic modulus than the Witczak 1-40D model.

In future study, calibration factors for each E^* predictive model should be developed with more E^* data records of more kinds of HMA mixtures for use in Levels 2 and 3 designs in the MEPDG. Furthermore, within the context of mechanistic-empirical design, the significance of any errors in predicted E^* should be evaluated in terms of their impact on predicted pavement performance, i. e., rutting and cracking.

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江苏地区典型沥青混合料动态模量特性评价

王昊鹏　杨　军　周文章　陈先华

(东南大学交通学院,南京 210096)

摘要:为了研究2种动态模量预测模型(基于黏度的 Witczak 1-37A 模型和基于剪切复数模量的 Witczak 1-40D 模型)在江苏地区的适用性及不同混合料设计参数(级配类型、胶结料种类、体积参数)对动态模量的影响,进行了2种典型面层沥青混合料(Sup-13 和 AC-13)的动态模量试验研究,并将试验数据用于预测模型的分析.对不同沥青的黏度和动态剪切模量进行试验以获取预测模型的参数.试验结果表明:胶结料种类和沥青含量对动态模量有显著影响;2种预测模型与室内试验结果均有较好的相关度,Witczak 1-37A 动态模量的预测模型精度更高.试验结果可用于更高精度动态模量预测模型的修正.

关键词:动态模量;预测模型;沥青路面;Witczak 1-37A; Witczak 1-40D; 力学经验设计法

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