BEVAVIOR OF ASPHALT CONCRETE MIXTURES UNDER REPEATED LOADS

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1.INTRODUCTION

The rational design of pavements should take into account the mechanical behavior of the pavement materials under various loading conditions,through the studying the dynamic elastic modulus(DEM) or creep and relaxation functions of these materials.The DEM was selected in this investigation as it permits the evaluation of the relative effect of rate and duration of loading,also,deflection and rut depth of pavements as well as stresses through the pavement can be calculated using it.In the exprimental phase,the DEM of the asphaltic concrete mixtures has been determined by transforming the response of these mixtures from the time domain(creep test using triaxial apparatus) to the frequency domain.The influence of the main mix components(aggregate gradation,asphalt content,and asphalt type) and test temperature on the DEM was invesstigated.Finally,a predective equation relating the DEM and the afforementioned variables was derived.

2.DEFINITION

The asphaltic concrete mix is a viscoelastic and therefore,its mechanical properties depend on stress duration as well as the temperature at which this stress takes place.Many investigators indicated that,by applaying stress(σ) to the concrete mix by the form

$$\sigma = \sigma_o e^{i\omega t}$$

where:

σ_o = stress amplitude,psi or kg/cm^2

i = $\sqrt{-1}$

ω = angular frequency,rad/sec

t = time,sec

The resulting strain has the same frequency as the stress but out of phase by an angle$\phi$and is expressed

$$\epsilon = \epsilon_o e^{i(\omega t-\phi)}$$

where:

ϵ_o= recoverable strain amplitude,in./in. or cm/cm

ϕ = phase lag, degress

Under these conditions,stress and strain are related by a complex number expressed by

$$E^* = \frac{\sigma}{\epsilon_o} . e^{i\phi}$$

where E^* is defined as the complex modulus of the asphalt concrete mix.

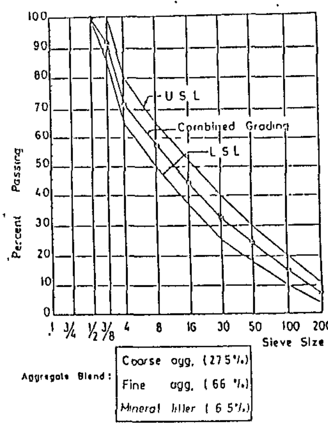

FIG 1: Gradation Curve (5-A)

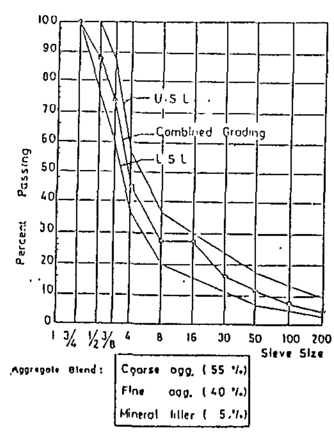

FIG.2 Gradation Curve (3-B)

3.MATERIALS AND TESTING PROGRAM

To investigate the asphaltic concrete mix components and temperature changes effect on the DEM,cylindrical asphalt concrete specimens 7 cm by 15 cm were prepared for the creep test with an average density 2.4 gm/cm^3.

One aggregate type(silicious sand,crushed limestone,and limestone filler) was used with two gradations one with a maximum size 9.53mm and the other with a maximum size of 12.7mm[5-A(dense) and 3-B(open),respectively according to the Asphalt Institute specifications].Sieve analysis results are given in Figures (1 and 2).

Two asphalt cements obtained from Suez and Alexandria refineries in Egypt were used.The physical properties for the asphalts are given in Table(1).Also,the asphalt content varies between 4.5% and 6.5%.

Test temperatures in the range of 10^{o}c to 40^{o}c according to typical ambient temperature in Egypt.

Test specimens were classified to three groups A,B,and C as shown in Table(2) and a total of 54 spcimens were molded for testing Table (3) illustrates the various combinations in the experimental design of the laboratory testing program.

Test	Designation Number	Test Results Suez	Test Results Alex.
Specific gravity at 22/25°C	AASHO T-63	1.02	1.10
	ASTM D-70		
Penetration,25°C,100 gm,5 sec	AASHO T-49	65	65
	ASTM D-5		
Kinematic viscosity,centis	.	352	287
tokes softening Point, °C	ASTM D-36	52	50

Table 1. Physical Properties of the Asphalt Cements.

4.ANALYSIS AND DISCUSSION OF RESULTS

4.1 Creep Test Results

Creep tests were performed on unconfined test cylinders using the traiaxial compression test.The exprimental

Mix Type	Asphalt Source	Aggregate Gradation	Asphalt Content	Number of Replicates	Number of Mix samples
			4.5%	6	
A	Suez	5 A	5.5%	6	18
			6.5%	6	
			4.5%	6	
B	Suez	3 B	5.5%	6	18
			6.5%	6	
			4.5%	6	
C	Alexandria	5 A	5.5%	6	18
			6.5%	6	

Table 2. Composition of tested mix specimens

Mix Type	Asphalt Type		Asphalt content	Aggregate Gradation		Test Temperature			Number of Replicates
	Suez	Alex.		5 A	3 B	20°C	30°C	40°C	
			4.5			x	x	x	6
A	x		5.5	x		x	x	x	6
			6.5			x	x	x	6
			4.5			x	x	x	6
B	x		5.5		x	x	x	x	6
			6.5			x	x	x	6
			4.5			x	x	x	6
C		x	5.5	x		x	x	x	6
			6.5			x	x	x	6

Table 3. Experimental program: Investigation of mix component and test temperature

stress levels used were selected to be sufficiently law (approximately in the range of 0.2 to 1.2 kg/cm^2).

4.2 Determination of DEM

The DEM was determined by transforming the response of the asphalt concrete mixtures from the time domain (creep test) to the frequency domain. This method depends on the equation of the 4-element model as well as the Laplace transformation. As DEM is a complex number it must be resolved into magnitude and phase as shown in Figure (4), or real and imaginary parts as shown in Figure (5). Figure (4) has the advantage of yielding directly the amplitude and phase angle of the material response and Figure (5) depicts the change in the degree of elasticity of the material due to change in frequency.

4.3 Factors Affecting DEM

The following are pertinent to the results and findings of this research :

1. The DEM increases by a factor of 2.5 as the frequency (time of loading) increases from 10^{-3} to 10^{-1} rad/sec. For frequency over 10^{-1} rad/sec, the change in DEM value is not appreciable.
2. For a constant temperature, asphalt type, aggregate gradation, the DEM decreases by nearly 65% as the asphalt content increases from 4.5% to 6.5%. 4.5% asphalt content could be considered as the limit at which the asphalt film reaches a critical thickness and consequently, any increase in the asphalt content tends to decrease the DEM
3. The DEM of dense asphalt mix is approximately 20% higher than the open mix
4. The DEM of Suez asphalt mix is approximately 50% higher than of Alexandria asphalt mix

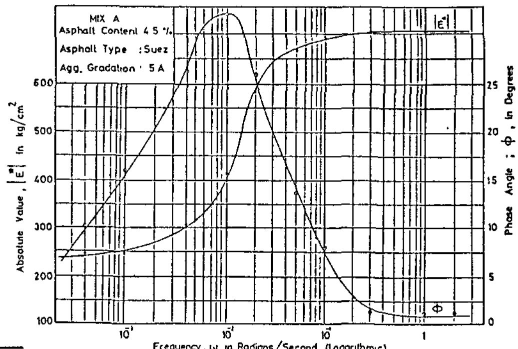

FIG 4 Magnitude and Phase Angle of Complex Elastic Modulus, E^*, at 20°C

5. The DEM decreases by nearly 40% as the temperature increases from 20°c to 40°c.

5. MATHEMATICAL RELATIONSHIP

The suggested equation is:

$$\log_{10}|E^*| = 2.13613 + 0.0722324\,X_1 - 0.0024956\,X_2 - 0.054983\,X_3 - 0.0204573\,X_4$$

$R^2 = 0.942$ S.E. = 0.0626791

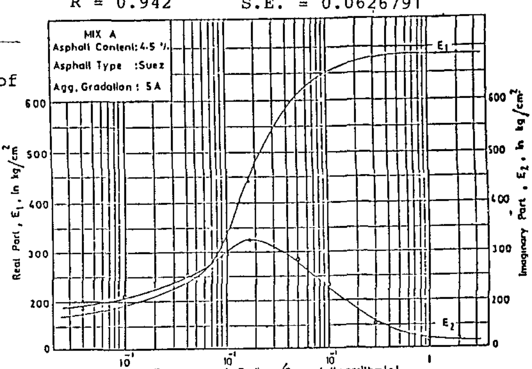

FIG 5 Real and Imaginary Parts of Complex Elastic Modulus, E^*, at 20°C

where :

$|E^*|$ = DEM in kg/cm^2

X_1 = percent passing sieve No. 200,

X_2 = asphalt viscosity, centistokes (at 135°C),

X_3 - percent asphalt by weight of mix,

X_4 = test temperature, °C,

R^2 = coefficient of multiple determination,

S.E. = standard error of estimate.

6. CONCLUSIONS

1. DEM is affected by the mix components (aggregate gradation, asphalt type and content) and test temperature.
2. The proposed equation relating DEM to the mix components and test temperatures may be used to estimate DEM using the results of routine tests.