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Creep Compliance Characteristics of Cement Dust Asphalt Concrete Mixtures

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***Abstract*— The current research is directed towards studying the creep compliance characteristics of asphalt concrete mixtures modified with cement dust. This study can aid in assessing the permanent deformation potential of asphalt concrete mixtures. Cement dust was added to the mixture as mineral filler and compared with regular lime stone filler. A power law model was used to characterize the creep compliance behavior of the studied mixtures. Creep testing results have revealed that the creep compliance power law parameters have a strong relationship with mixture type. Testing results of the studied mixtures, as indicated by the creep compliance parameters revealed an enhancement in the creep resistance, Marshall stability, indirect tensile strength and compressive strength for cement dust mixtures as compared to mixtures with traditional lime stone filler.**

Keywords—Cement dust; Asphalt Concrete Mixtures; Creep Compliance; Marshall stability; Indirect Tensile Strength; Compressive Strength.

I. Introduction

Nowadays, environmental problems were incorporated due the successive increase of the generated waste by product materials. An important example of such material is cement dust that is formed in large quantities by Portland cement factories. It is generated during the calcining process in cement production. of cement kiln and cooling towers. This huge quantity of dust generates continuous problems for both cement makers and governments. Cement dust causes lung function impairment, chronic obstructive lung disease, restrictive lung disease, pneumoconiosis and affect the humans micro-structure and physiological performance. One of the possible solutions of these environmental pollution problems is to use cement dust as a non-conventional raw material for road construction.

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Lime (CaO) constitutes more than 60% of CBPD composition. Other compounds include SiO2, Al2O3, Fe2O3, K2O, Na2O, Cl, etc.. In Egypt, cement industry discard about 3 million tons per year of cement dust that are collected from exhaust gases

Previous studies on utilization of cement dust on asphalt mixtures indicated that cement dust has a considerable effect on the asphalt cement making it act as a much stiffer grade of asphalt cement compared to the neat asphalt cement grade [1-3]. Other studies have shown that cement dust can improve the HMA pavement performance including its fracture behavior [4-5]. It was also shown that the components of cement dust can assist in promoting stripping resistance and thus can replace hydrated lime or liquid antistripping agents [6-7].

Due to its very fine nature it causes air pollution which affects negatively on the environment and causes serious problems to humans health, animals and plants. Therefore, the use of such waste as non-conventional raw material in highway construction can have beneficial economical and environmental impact. Using of Cement dust as a mineral filler in highway asphalt concrete has been reported by many researchers. A recent study made by Othman [8] indicated through Marshall testing that cement dust can be used as a substitution for lime stone mineral filler in asphalt paving mixtures. It was also shown that the components of cement dust can assist in promoting stripping resistance and thus can replace hydrated lime or liquid antistripping agents [9,10].

Although many studies have shown the feasibility of using cement dust in asphalt mixtures as mineral filler, few research have been involved in testing the creep resistance of cement dust asphalt mixtures. Creep testing allows studying the viscoelastic behavior of the studied mixtures and to predict their potential to permanent deformation. Within this research, Creep compliance characteristics of asphalt mixtures modified with cement dust filler were evaluated based on static creep test and compared with mixtures have traditional lime stone mineral filler. Creep test results were compared with the results of traditional mechanical testing as Marshall Stability, indirect tensile strength and unconfined compressive strength.

II. CREEP COMPLIANCE CHARACTERISTICS

Permanent deformation and rutting are among the major load-associated distress types affecting the performance of asphalt concrete pavements. The static creep test has been widely used [11] to assess the rutting or permanent deformation potential of asphaltic mixtures. Since creep is a time-dependent function, it can provide extremely important practical information about long term performance of asphaltic mixtures. The static creep test is normally conducted by applying a static load to an asphalt concrete specimen and measure the resulting deformation with time. In creep testing, several unique moduli can be defined to describe the material behavior. In particular, the "creep" or time dependent modulus can be defined as the ratio between applied creep stress to resulting creep strain at any time ($E(t) = \sigma_{0/}\ \varepsilon_{(t)}$). The "modulus" of a material is a very important property that relates stress to strain. However, for viscoelastic materials, it is more advantageous to use the term "compliance" or D(t). Compliance is the reciprocal of the modulus and is expressed as;

$$D(t) = \varepsilon_{(t)}/\sigma_0 \qquad (1)$$

Where $\varepsilon_{(t)}$ is the creep strain at time (t) and σ_0 is the applied creep stress. A typical creep compliance – stress – time behavior of a material under static creep test is shown in **Figure 1**.

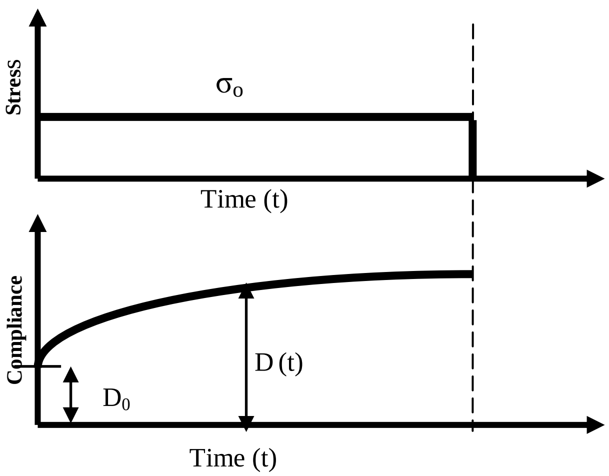

Figure 1: Typical Creep Compliance – Stress- Time Relationship

The creep compliance D(t), as measured by the static creep test can be divided into two components. The first component is D_0, which represents the instantaneous compliance at the beginning of the test. The second component is the viscoelastic compliance component ($D_{ve}(t)$) at any time during the test. The viscoelastic compliance component can be represented by a power law model [11]. Based on this model the viscoelastic compliance component at any time within the stable loading stage and before failure occurs, can be expressed as;

$$D_{ve}(t) = D(t) - D_0 = a\,t^m \qquad (2)$$

Where;

$D_{ve}(t)$	= Viscoelastic compliance component at time (t)
D(t)	= Total creep compliance at time (t)
D_0	= Instantaneous compliance
t	= Loading time
a, m	= Material regression coefficients

In the above model, the regression coefficients "a" and "m" are generally referred to as the creep compliance parameters. These parameters are the general indicators of the permanent deformation behavior of the materials. In general, the larger the value of "a", the larger the Dve(t) value, and hence the larger the potential of the material for permanent deformation. In addition, for a constant "a" value, as the slope parameter "m" increases, the Dve(t) value increases as well and the potential for permanent deformation becomes larger. The creep compliance parameters (a, m) are used within this research for characterizing the asphaltic mixtures creep resistance and to assess their potential to rutting or permanent deformation.

III. MATERIAL CHARACTERIZATION

Asphalt binder 60/70 was used within this research. Coarse aggregate and fine aggregate (Bulk specific gravity of 2.77 and 2.68 respectively) were used in the preparation of the asphalt concrete mixtures. The selected gradation of aggregate incorporated in all asphalt concrete specimens confirms to the mid point of the standard 4-c aggregate gradation specified in the Egyptian highway standard specifications. White cement dust was incorporated in the mixture as mineral filler and compared with traditional lime stone filler. Cement dust is a waste material that is generated as a by-product of the manufacture of Portland white cement. It is generated during the calcining process in the kiln. Table (1) shows the compositions of cement dust.

TABLE 1: COMPONENTS OF CEMENT DUST

Component	Percentage
Al_2O_3	5.5
SiO_2	20.5
Fe_2O_3	1.5
CaO	62.5
MgO	2
SO_3	8

Mechanical properties of cement dust and lime stone mineral filler are shown in **Table (2)**.

TABLE 2: PROPERTIES OF USED MINERAL FILLER MATERIALS

Properties	Cement Dust	Lime Stone
% Passing sieve No. 30	100	100
% Passing sieve No. 50	100	95
% Passing sieve No. 200	85	78
Plasticity Index	2	3
Specific Gravity	2.8	2.55

IV. LABORATORY TESTING PROGRAM

A. *Sample preparation*

Two different mixtures with two different mineral filler types were prepared within this study. The two selected mineral fillers types include cement dust and lime stone. Mineral fillers were blended with the natural aggregate to obtain a uniform natural aggregate mix before mixing with the asphalt binder. All examined asphalt concrete mixtures were prepared in accordance with the Standard 75-blow Marshall design method for designing hot asphalt concrete mixtures, designated as (ASTM Designation: D 1559-89) using automatic compaction. Constant bitumen content of 5% was used. Marshall specimens (2.5 inches thick and 4 inches diameter) were produced for each mixture. To provide adequate data three samples were prepared from each mixture for each test.

B. *Creep Test*

Creep tests were performed on the moisture conditioned Marshall specimens using a standard consolidation-testing machine. The cylindrical specimens were loaded in the axial direction at a pressure of 6.25 kg/cm^2 for 60 minutes and before failure occurs. The static creep test was performed at room temperature that ranged between 27-30^{o}C. Strain was recorded during the test at 1, 2, 3, 4, 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55 and 60 minutes so that a creep plot (compliance vs. time) could be obtained.

C. *Mechanical Testing Procedure*

Mechanical testing program was conducted to evaluate the effect of moisture conditioning on the mechanical behavior of the two studied mixtures. The testing program include running Marshall stability, indirect tensile strength and unconfined compressive strength tests. The results can be used to assess the long-term stripping susceptibility of the bituminous mixtures. The Marshall stability test was conducted according to *ASTM Designation (D 1559-82)*, while the indirect tensile tests was conducted in accordance with (ASTM D4123). The unconfined compression tests were performed using a 15-ton capacity universal testing machine. Marshall specimens were placed on the lower fixed platen of the testing machine. Load was applied with a uniform rate of 2 mm/min on the circular face of the testing samples until failure occurred. The maximum load to failure was recorded and hence the compressive strength was calculated.

V. RESULTS AND DISCUSSION

A. *Creep Test Results*

The creep compliance was calculated from the applied creep stress and the measured strain over time based on Equation (1) and presented on **Table (3).** Relationships between the creep compliance and time for each of the lime and cement dust specimens are shown in **Figures (2)**. It could be noted from this figure that, mixtures with cement dust exhibit lower initial and lower total compliance. The creep compliance regression coefficients "a" and "m" can be obtained by applying the power law model given in Equation 2 on the creep compliance measurement shown in **Figure (2)**. **Table (4)** presents the regression coefficients "a" and "m" for the lime stone and cement dust mixtures. The values of "a" and "m" given in **Table (4)** are obtained considering the compliance values in mm^2/N and time values are in minutes.

TABLE3: CREEP TESTING RESULTS FOR THE TESTED MIXTURES

Time (Minutes)	Creep Compliance mm2/N	
	Lime Stone	*Cement Dust*
0	3.33	1.54
1	4.15	1.96
2	4.33	2.22
3	4.40	2.28
4	4.52	2.42
5	4.63	2.54
10	4.93	2.61
15	5.25	2.68
20	5.53	2.74
25	5.64	2.77
30	5.74	2.81
35	5.95	2.84
40	5.99	2.87
45	6.05	2.87
50	6.10	2.89
55	6.17	2.90
60	6.27	2.90

As mentioned earlier, the coefficients "a" and "m" are indicators of the permanent deformation behavior of asphaltic mixtures. The larger the value of "a" and "m" the larger the mixture compliance and the larger is the potential to permanent deformation.

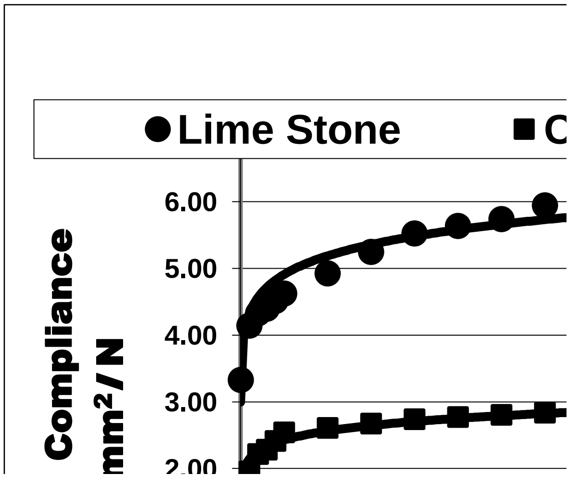

Figure 2: Creep Compliance Vs. Time for Tested Asphalt Mixture

TABLE 4: CREEP COMPLIANCE COEFFICIENTS OF LIME AND CEMENT DUST MIXTURES AT DIFFERENT MOISTURE CONDITIONING PERIODS

a		m	
Lime Stone	***Cement Dust***	***Lime Stone***	***Cement Dust***
0.44	0.32	0.47	0.42

It is indicated from Table 4 that the cement dust mixture displayed lower values of the coefficients "a" and "m" as compared to the lime stone mixture. Hence, cement dust mixture is considered more superior in resisting permanent deformation in both dry and wet conditions. This enhancement can be related to the modification of the surface chemistry at the aggregate-asphalt interface to promote better adhesion.

B. *Mechanical Properties Results*

Relationships between Marshall stability, indirect tensile and unconfined compressive strength values and moisture conditioning period for the two studied mixtures are presented in **Table (5)**.

TABLE 5: RESULTS OF MECHANICAL PROPERTIES OF TESTED MIXTURES

Properties	Cement Dust	Lime Stone
Marshall stability (KN)	9.9	7.8
Indirect tensile strength (N/cm^2)	27.4	18.5
Unconfined compressive strength (N/cm^2)	135.6	95.2

It is evident from Table 5 that, the cement dust mixture exhibits higher values of Marshall stability, indirect tensile and unconfined compressive strength as compared to the lime mixture. This indicates that adding cement dust as mineral filler for asphalt concrete mixtures can produce mixtures that are more superior in resisting various distresses. These findings agree with the creep results shown previously.

VI. CONCLUSION

A power law model has been successfully used to characterize the creep compliance behavior of asphaltic mixtures. Mixtures include white cement dust as a mineral filler was studied and compared with mixtures containing traditional lime stone mineral filler. The current study reveals that, creep compliance parameters (a, m) have a strong relationship with mixture type. Mixtures with cement dust mineral filler experienced higher creep resistance when compared to traditional lime stone mixtures. Mechanical testing results as indicated by Marshall stiffness, indirect tensile and unconfined compressive strength were found to be consistent with creep testing results. Thus it can be concluded that, the creep compliance parameters have been successfully used to characterize the potential of asphalt concrete mixtures to permanent deformation. It is also concluded that cement dust can be successfully used to decrease the potential of asphalt concrete mixture to permanent deformation and improve its mechanical properties. This is in addition to the environmental benefits that can be gained when using cement dust in asphalt paving technology.

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