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EFFECT OF USING WASTE CEMENT DUST AS A MINERAL FILLER ON THE MECHANICAL PROPERTIES OF HOT MIX ASPHALT

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ABSTRACT:

By pass cement dust is proposed within this research as an alternative to traditional limestone mineral filler in hot mix asphalt (HMA). The effect of using waste cement dust as a mineral filler on the mechanical properties of hot mix asphalt was investigated. The optimum cement dust content was determined. The studied mechanical properties include Marshall properties, indirect tensile strength, and unconfined compressive strength. Five asphalt concrete mixtures with various cement dust contents, namely; 0%, 25%, 50%, 75% and 100% by weight of the limestone mineral filler were studied. Laboratory testing has revealed an enhancement in Marshall and mechanical properties of asphalt concrete mixtures when cement dust was used. Marshall testing results have indicated an increase in the stability, unit weight and a decrease in the flow, voids ratio and voids in mineral aggregates when the percentage of cement dust content increases. The indirect tensile strength and unconfined compressive strength have also increased as the ratio of cement dust increased. The optimum cement dust ratio was found to be 100% of the used mineral filler. Hence, cement dust can totally replace lime stone mineral filler in asphalt paving mixtures.

INTRODUCTION:

Waste materials can broadly be categorized as industrial wastes such as cement dust, wood lignins, bottom ash and fly ash; and municipal/domestic wastes such as incinerator residue, scrap rubber, waste glass and roofing shingles. Waste cement dust or cement kiln dust is the by-product of the manufacture of portland cement. It is generated during the calcining process in the kiln. Lime (CaO) constitutes more than 60% of CBPD composition. Other compounds include SiO_2, Al_2O_3, Fe_2O_3, K_2O, Na_2O, Cl, etc. Most of Cement Company generates huge quantities of CBPD every year. Some CBPD is recycled back again with the clinker. However, most of the material is disposed of on-site without any further reuse or reclamation.

Waste material recycling into useful products has become a main solution to waste disposal problems. Many highway agencies are conducting wide variety of studies and research projects concerning the feasibility, environmental suitability, and performance of using recycled products in highway construction[1]. Major environmental problems arise from the disposal of kiln dust. This dust production is not only unpleasant for the worker, but also create equipment failures, decrease efficiency and produce maintenance problems. Therefore, the

design of the plant includes different types of filters and dust collectors which investment up to 12% of the entire cost of the plant. The cement industry usually uses mechanical, electrostatic precipitators bughouse dust collectors, or combinations in order to control the emission of dust particle. These studies try to match society's need for safe and economic disposal of waste materials with the highway industry's need for better and more cost-effective construction materials.

Recently, many environmental and highway agencies are using waste material in highway construction. Some fines have 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[2-5], and thereby affect the HMA pavement performance including its fracture behavior[6-7]. Study made by Taha[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].

The current study is performed to study the effect of using waste cement dust obtained form white cement industry in asphalt concrete mixtures as a part of the fine aggregate. The effect of cement dust content on the mechanical properties of asphalt concrete mixtures was also evaluated. A laboratory study was conducted on five asphalt mixtures with various cement dust contents, namely; 0%, 25%, 50%, 75% and 100% by weight of mineral filler. Mechanical testing used includes; Marshall properties, indirect tensile strength and unconfined compressive strength.

MATERIAL CHARACTERIZATION:

1-Asphalt Binder:

Asphalt binder 60/70 supplied by Suez Bitumen Supply Company was used within this research. The used asphalt binder was subjected to a series of standard laboratory tests to determine its physical properties. Results of those tests are shown in Table (1).

2-Aggregate:

Coarse aggregate and fine aggregate (Bulk specific gravity of 2.72 and 2.67 respectively) were used in the preparation of the asphalt concrete mixtures. Limestone was used as mineral filler. 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. Table (2) presents the selected mix gradation (including Cement dust).

3-Mineral filler:

Cement dust was used as a percent of 0%, 25%, 50%, 75%, and 100% of limestone The properties (Gradation, Specific Gravity, and Absorption) of the cement dust and lime stone are given in Table (3).

Table (1): Properties of Used Asphalt Binder

Test	Results
Penetration at 25 C^o	67
Kinematics Viscosity (centistokes at135 C ^{o})	420
Ring and Ball Softening Point	50.5 ^{o}C
Specific Gravity	1.02
Flash Point	265 ^{o}C

Table (2): Selected Mix Gradation

Sieve	% Passing	
	Used Gradation	Gradation Limits [Egyptian Specs. (4 C)]
1″	100	100
3/4″	100	80-100
3/8″	75	60-80
3/16″	52	48-65
No.10	43	35-50
No. 30	23	19-30
No. 50	20	13-23
No. 100	10	7-15
No. 200	5	3-8

Table (3): Physical Properties of Used mineral filler

Sieve	% Passing	
	Cement Dust	Lime Stone
No. 30	100	100
No. 50	100	95
No. 200	85	78
Plasticity Index	2	3
Specific Gravity	2.7	2.55
Absorption	1%	1.5 %

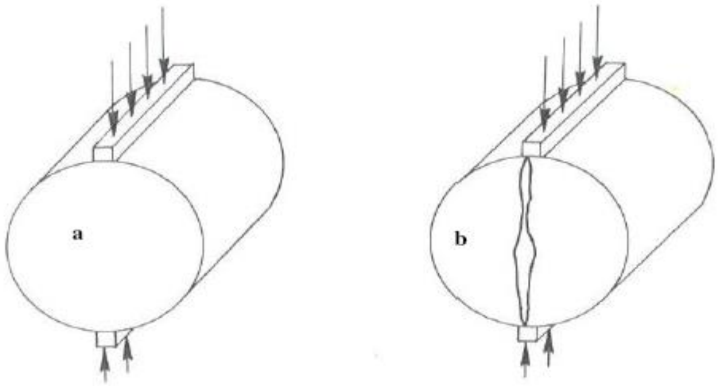
EXPERIMENTAL PROCEDURE:

1-Marshall Testing:

Laboratory investigations on the mechanical performance of asphalt concrete mixtures have been conducted by using varying specimen bitumen content. The Marshall stability test (*ASTM Designation: D 1559-82*), is used in highway engineering for both mix design and evaluation. Although Marshall method is essentially empirical, it is useful in comparing mixtures under specific conditions. Therefore it was selected within this research to study the effect of adding cement dust as a mineral fillers in hot mix asphalt. Constant asphalt content of 5% was considered in mixtures preparation.

2-Indirect Tensile Strength Test (ITS):

A mechanical displacement control testing frame was used to conduct the indirect tensile tests in accordance with (ASTM D4123) to evaluate the tensile strength of asphalt concrete mixtures. Test specimens 2.5 inches thick and 4 inches diameter were compacted and then tested using curved steel loading strips 0.5 inch wide. The load was applied at a vertical deformation rate of 4 mm/min. The indirect tensile strength is the maximum stress developed at the center of the specimen in the radial direction during loading. The specimen failed by splitting along the vertical diameter as shown in Figure (1). Indirect tensile strength testing was made at a room temperature of around 25 ^{o}C.



a) loading mode **b) failure plane**

Figure (1): Laboratory test setup for the ITS strength test

3-Unconfined Compressive Strength Test:

The unconfined compression tests were performed using a 15-ton capacity universal testing machine in the a room temperature of around 25°C. Test specimens 2.5 inches thick and 4 inches diameter were placed on the lower fixed plate 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.

RESULTS AND DISCUSSION:

1-Marshall Properties:

The results of all Marshall Stability tests using the designed asphalt ratio of 5% are summarized in Table (4) for mixtures with different cement dust content. All results shown for each specimen are the average value of three tests.

From table (4) and figures (2-6) it is found that specific gravity and Marshall Stability value increases as the cement dust content increases. While, the flow, % of VMA and % of VTM values decrease as the percentage of cement dust increases. Thus it can be concluded that there is a marked improvement in the Marshall properties of the asphalt concrete mixtures when cement dust is used.

Table (4): Marshall Stability test results for Mixtures with different cement dust content at 5% bitumen content

Mineral Filler Type		Unit Weight (lb/ft^3)	Stability (lb)	Flow (0.01 in.)	% of VMA	% of VTM
% of limestone	% of cement dust.					
100%	0 %	142	1800	14	15.1	4.2
75%	25%	149	2050	13	15.0	3.7
50%	50%	150	2180	13	14.8	3.7
25%	75%	151	2200	11	14.8	3.6
0%	100%	153	2318	11	14.7	3.5

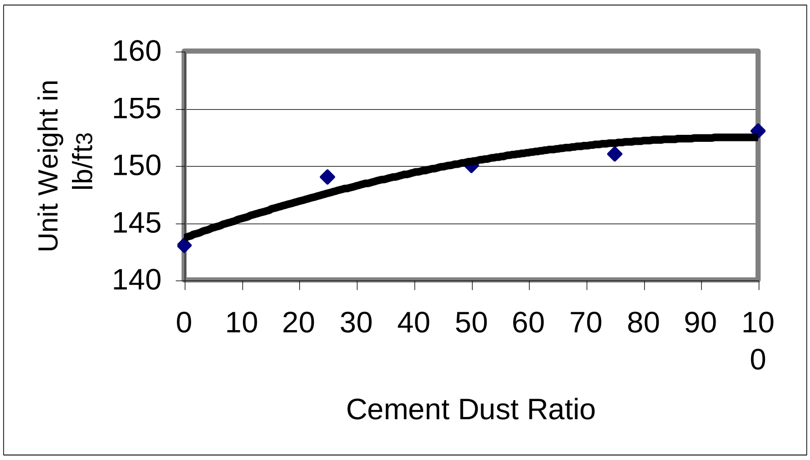


Fig. (2): Unit Weight for Mixtures with Different Cement Dust Content

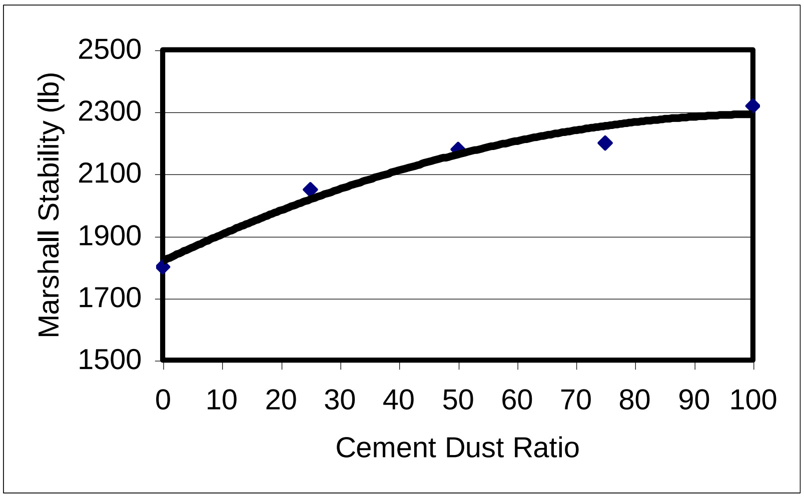


Fig. (3): Marshall Stability for Mixtures with Different Cement Dust Content

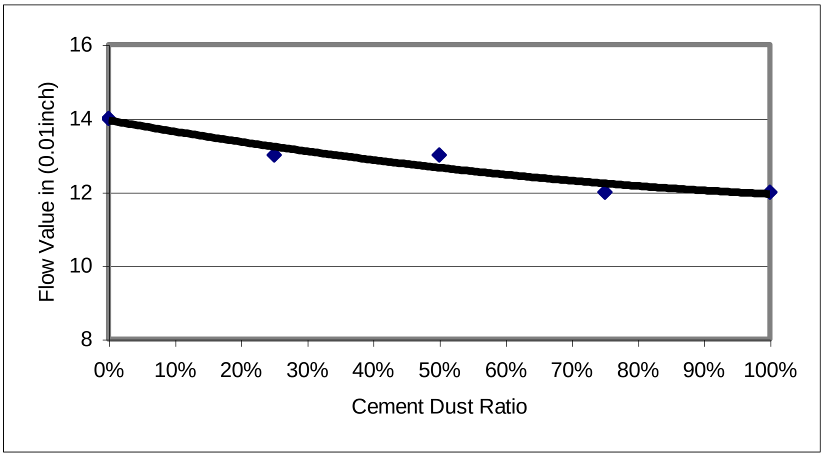


Fig. (4): Flow Values for Mixtures with Different Cement Dust Content

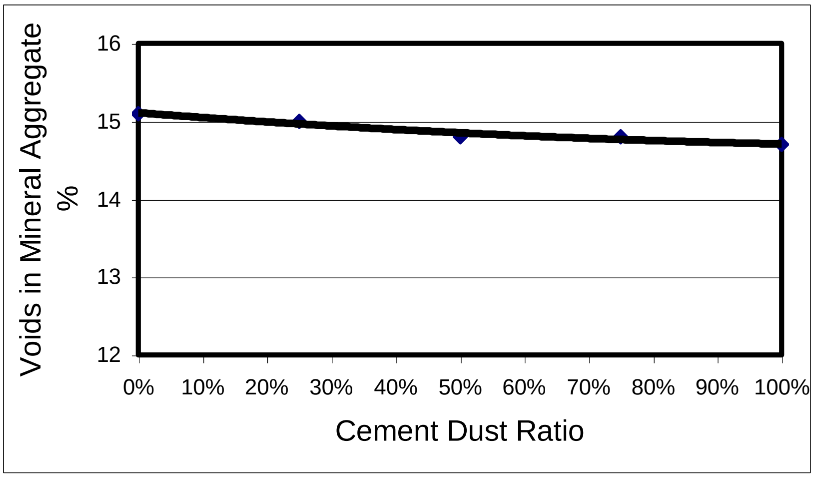


Fig. (5): Voids in Mineral Aggregate for Mixtures with

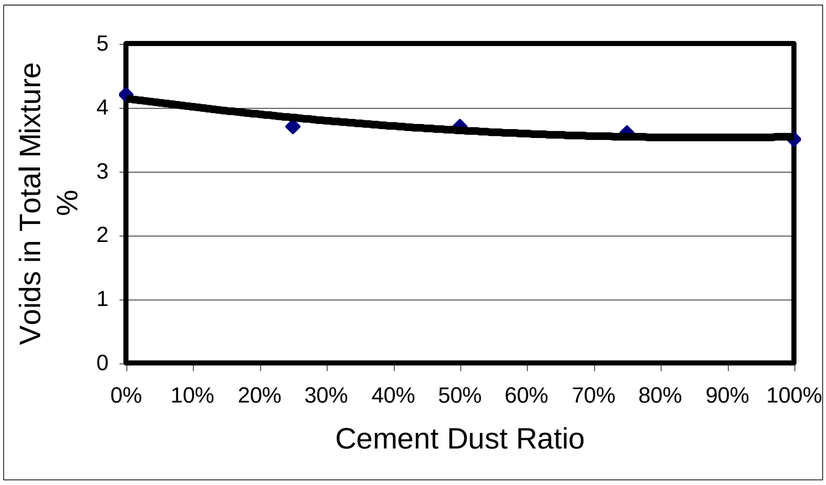


Fig. (6): Voids in Total Mixture for Mixtures with Different Cement Dust Content

2-Indirect Tensile Strength:

The indirect tensile test was developed to determine the tensile properties of cylindrical concrete and asphalt concrete specimens through the application of a compression load along a diametrical plane through two opposite loading heads. It was shown[10] that this type of loading produces a relatively uniform stress acting perpendicular to the applied load plane, causing the specimen to fail by splitting along the loaded plane. The maximum load carried by the specimen was found, and the indirect tensile stress at failure was determined and presented in Table (7). It can be seen from Table (7) that the indirect tensile strength increases as the cement dust content increases.

Figure (7) also presents the relation between indirect tensile strength and cement dust content. It is indicated that the indirect tensile strength of the mixtures increases as the cement dust content increases.

Table (7): Indirect Tensile Strength of Mixtures with Different Cement Dust Content

Limestone %	Cement Dust %	Indirect Tensile Strength (psi)
100%	0%	207
75%	25%	370
50%	50%	458
25%	75%	523
0%	100%	535

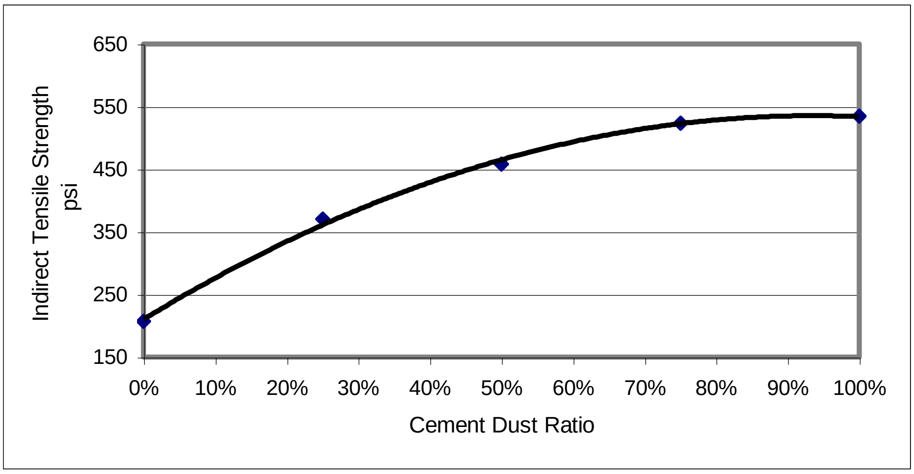


Fig. (7): Indirect Tensile Strength of Mixtures with Different cement dust Content

3-Unconfined Compressive Strength:

The unconfined compressive strength test was performed to determine the compressive properties of the five studied mixtures. A compression load is applied on the circular face of the specimens. The load is increased until failure occurs. The compressive strength can be calculated by dividing the failure load by the specimen cross sectional area. The average unconfined compressive strength for various mixtures is listed in Table (8).

As seen in Table (8), the mixture with 100% cement dust has the highest compressive strength as compared to other mixtures. The mean compressive strength of the 100% cement dust mixture was determined to be almost 1.5 times that of the control mixture (0% cement dust). Figure (8) presents the relation between compressive strength and cement dust content. The figure indicates that as the cement dust content increases the compressive strength increases. Thus it can be concluded that, cement dust enhances the compressive strength characteristics of asphalt concrete mixtures.

Table (8): Failure Compressive Load and Unconfined Compressive Strength for Mixtures with Different Cement dust Content

Limestone Percent of Mineral Filler	Cement Dust Percent of Mineral Filler	Unconfined Compressive Strength (psi)
100%	0%	526
75%	25%	619
50%	50%	747
25%	75%	782
0%	100%	815

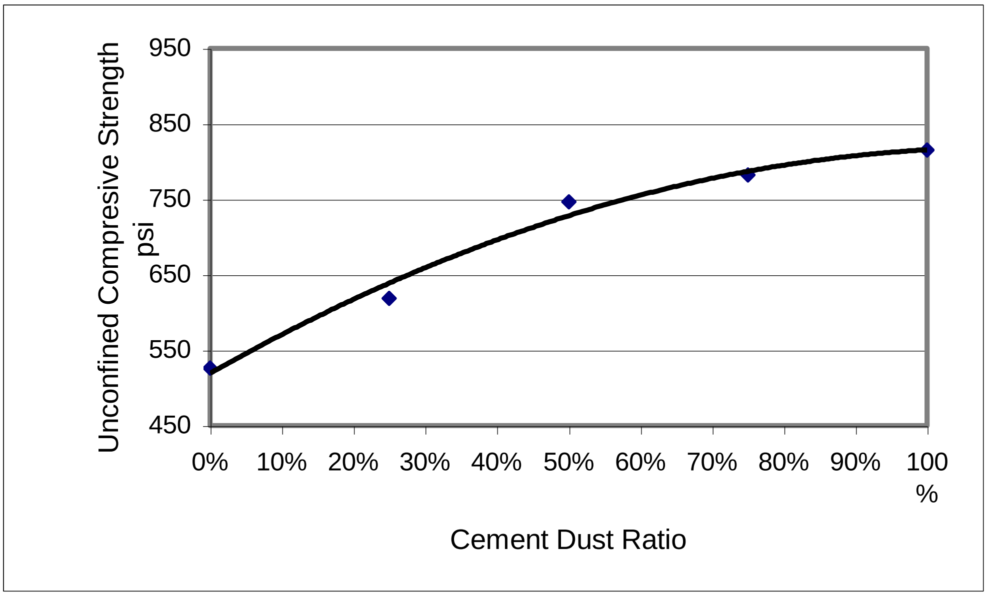


Figure (8): Unconfined Compressive Strength of Mixtures with Different Cement dust Content

CONCLUSION AND RECOMMENDATIONS:

By pass cement dust is proposed within this research as an alternative to traditional lime stone mineral filler. Evaluation of the mechanical properties of asphalt concrete mixtures has revealed an enhancement in their Marshall and mechanical properties when cement dust was used. It was found that each of Marshall stability, specific gravity, indirect tensile strength, and unconfined compressive strength increase as the cement dust increase. Flow values, void ratio and voids in mineral aggregates decreases as the cement dust content increases. Optimum cement dust content was found to be 100%. Thus cement dust can replace lime stone as a mineral filler in asphalt concrete mixtures. Using cement dust in asphalt mixing can also have many enviromental advantages. Before widely adapting cement dust in asphalt paving, trial sections and adequate provisions should be provided.

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تأثير استخدام بودرة تراب الأسمنت على الخواص الميكانيكية للخلطات الأسفلتية

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يعد تراب الأسمنت من المشاكل البيئية الضخمة لما يسببه من تلوث الهواء وتحجر الأراضي الزراعية. كما أن التخلص منه يمثل عبء اقتصادى ضخم نتيجة تكاليف نقله وضيق الأماكن التى يمكن تشوينه بها. وقد بدأ مؤخراً التفكير في استخدام تراب الأسمنت في أعمال رصف الطرق عوضا عن التخلص منه كنفايات. ويناقش هذا البحث إمكانية استخدام تراب الأسمنت الناتج من مصانع الأسمنت الأبيض كبديل عن بودرة الحجر الجيري في الخلطات الإسفلتية. وقد تم هذا من خلال تقييم الخواص الميكانيكية للخلطات الإسفلتية التي تحتوي على نسب مختلفة من تراب الأسمنت تمثل صفر%، ٢٥%، ٥٠%، ٧٥%، ١٠٠% من الوزن الكلي لبودرة الحجر الجيري الشائع استخدامها كإحدى المكونات الرئيسية للخلطة الأسفلتية. وتم تقييم الخواص الميكانيكية لهذه الخلطات عن طريق إجراء اختبارات مارشال، واختبار الشد غير المباشر، وكذلك اختبار الضغط الغير محصور.

وقد أظهرت نتائج اختبار مارشال زيادة قيمة الثبات والوزن النوعي ونقص في قيم الانسياب ونسب الفراغات للخلطات التي تمت دراستها بزيادة محتوى تراب الأسمنت. كما أظهرت نتائج الاختبارات الميكانيكية زيادة كل من مقاومتي الشد غير المباشر والضغط للخلطات الإسفلتية بزيادة المحتوى من تراب الأسمنت. وبناء عليه فإنه يمكن استخدام بودرة غبار الأسمنت في الخلطات الأسفلتية كبديل عن بودرة الحجر الجيري حيث أنها تحسن الخواص الميكانيكية للخلطات إضافة إلى المردود البيئي والاقتصادي المرجو من هذا الاستخدام.