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USING INDUSTRIAL WASTES IN HIGHWAY ENGINEERING*

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ABSTRACT

This study is an attempt to contribute to environmental protection by glass waste recycling. The idea is to crush waste glass to powder form and add it to hot mix asphalt (HMA) with different percentages (5, 10, 15 and 20) % as a fine portion. To evaluate using waste glass in HMA, two approaches were carried out based on previous studies. The first approach was to try to improve the mix containing powder glass by adding hydrated lime as anti-stripping agent and that due to stripping problems occurring when powder glass is added to HMA. Hydrated lime was added with different percentages (1.5, 2, and 2.5) % as mineral filler. The second approach was to try to improve the mix containing powder glass by adding cement dust with a percentage of 6% instead of stone powder in the conventional mix. Both approaches try to verify good bond for all mix components. After carrying out necessary tests such as Marshall test and Loss–of stability test, and by analysis of results important conclusions were obtained. These conclusions indicated the possibility of using glass powder in hot mix asphalt with a percentage of 11.25% and hydrated lime with a percentage of 1.375%. Also, improvement of HMA is indicated when glass powder is used with 10% and cement dust by 6%.

KEY WORDS: Environmental protection, Recycling, Waste glass, paving mix, Marshall Test

L'UTILISATION DES DECHÉTS INDUSTRIES EN GÉNIE ROUTIER

RÉSUMÉ

Cette étude est une tentative pour contribuer à la protection de l'environnement par le recyclage des déchets de verre. L'idée est d'écraser les déchets de verre sous forme de poudre et l'ajouter à chaud enrobés (HMA) avec des pourcentages différents (5, 10,15 et 20) % comme une partie bien. Pour évaluer l'aide de déchets de verre HMA, deux approches ont été effectués sur la base des études antérieures. La première approche a consisté à essayer d'améliorer le mélange contenant du verre en poudre en ajoutant de la chaux hydratée comme agent anti -froid et qu'en raison de décapage problèmes survenant quand le verre en poudre est ajouté à HMA. La chaux hydratée a été ajouté avec des pourcentages différents (1,5, 2, et 2,5) % en tant que charge minérale. La seconde approche a consisté à essayer d'améliorer le mélange contenant du verre en poudre en ajoutant la poussière de ciment avec un pourcentage de 6 % au lieu de poudre de pierre dans le mélange classique. Les deux approches tentent de vérifier la bonne liaison pour tous les composants de mélange. Après avoir effectué les tests nécessaires, tels que Marshall essai et Pertes de test de stabilité, et par l'analyse des résultats des conclusions importantes ont été obtenues. Ces conclusions indiquent la possibilité d'utiliser une poudre de verre à l'asphalte mélangé à chaud avec un pourcentage de 11,25 % et la chaux éteinte avec un pourcentage de 1,375 %. En outre, l'amélioration de HMA est indiquée lorsque la poudre de verre est utilisée avec 10% de ciment et la poussière de 6%.

MOTS CLÉS: protection de l'environnement, recyclage, déchets de verre, ouvrant mélange, Marshall essai

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1. INTRODUCTION AND BACKGROUND

Environmental protection and resource conservation are one of the most very important world issues pursed by every country all over the world. So the main primary objective of this research is try to contribute in the protection of the environment by trying to reduce the volume of solid waste, which has become a source of constant danger to communities and relevant agencies, especially in Egypt. The rate of increase in the amount of solid waste in Egypt reaches to 16.2 million tons annually. Due to the solid waste contains of many materials resistant to degradation or decompose very slowly (such as auto body parts and used tires and waste plastic and glass ... etc.).[1] In this sense, the idea of this research is the possibility of contributing to reduce the size of solid waste disposal by reducing one of its kinds which is a waste glass. The amount of waste glass ratio is 1% - 5% of the amount of solid waste [1]. Therefore there is an attempt by using crushed waste glass which sometimes called cullet as aggregate into hot mix asphalt and in roadway construction. Review of previous work revealed that the hot mix asphalt HMA industry, has been pressured in recent years to incorporate wide variety of waste materials into HMA .So in the late of 1960'sand early of 1970's many studies carried out to evaluate the feasibility of using waste glass to modify HMA properties [2,3,4,5,6] this type of asphalt concrete which contain waste glass as an aggregate substitute in HMA knew as glasphalt [5,7] .Many researches carried out on properties of glasphalt to evaluate its using [8,9]. Airey et al 2004 [10] were measured the mechanical properties of the asphalt mixture with glass cullet .also West et al 2007 [11] showed that the asphalt mixtures containing glass aggregate as a replacement for primary aggregate have tended to perform slightly worse than conventional materials, depending on the replacement ratio of glass aggregate and in terms of its mechanical performance. In addition, that some improvement was affected by the anti-stripping additive. Also he indicated that the coarse glass stripped more fine glass. Recently another studies carried out on the dynamic behavior of glasphalt. Especially on fatigue stress [12,13]. Finally using of waste glass into HMA in some studies all over the world has been studied and done such as in United States, United Kingdom, Taiwan and China [14].

2. EXPERIMENTAL DESIGN AND STUDY PROGRAM.

As we mentioned previously the main objective of this study can be summarized to evaluate of using industrial or natural waste materials such as waste glass after crushing and turning it to its powder shape and adding to hot mix asphalt HMA and study its effect on HMA properties. To achieve the main objective an experimental design was set up including:

a- **pilot study**: which shows the conventional mix and the mixes contain different percentages of crushed waste glass(as it is) and two approaches are investigated
b- **The first approach** is to improve the mixes containing crushed waste glass by adding anti-stripping agent (hydrated lime)
c- **The second approach** is improving mixes containing crushed waste glass by adding cement dust instead of lime stone powder.
Pilot study and two approaches illustrated in Figure (1). All the mixes will be tested using Marshall test and loss of stability test to check the improvement in their characteristics. Figure (2) shows the required and appropriate tests for materials and mix design.

2.1 Marshall Test

In order to determine the Optimum Asphalt Contents (OAC's) and the routine mix properties for the investigated mixes, to evaluate the characteristics of asphalt mixtures which used to compare properties of conventional mixtures with that of mixtures with additives Marshall mix design procedure was performed. The test criterion selected was for a 75-blow Marshall compaction according to ASTM D1559 and AASHTO T-245. Using the optimum asphalt percentage to prepare mixes with different percentages (0, 5, 10, 15, 20) % of waste glass as a percentage of fine portion of the mix, and different percentages (1.5, 2.5, 3.5) % of hydrated lime as a percentage of the lime stone dust, and at 6% of dust cement which will be added instead of lime stone dust in conventional mix. The properties (stability, density, flow, AV, VMA) will be measured for all the mixes studied and the data of the results will be collected and analyzed.

2.2 Loss-of-Stability Test

Loss of stability test, which is simplified version of AASHTO-T165 was used to measure mix durability by evaluating the resistance of the investigated mixes to moisture damage. This test is intended to measure the loss of stability resulting from the action of water on compacted asphalt mixtures by comparing the stability of dry specimens to the stability of specimens which have been immersed in water bath at 60oC for certain times; 1, 2 and 3 days .

2.3 Materials

To achieve the objective of this study asphalt concrete mixes was made and composed of

coarse portion which consist of two types of aggregate. They are crushed dolomite of grade (I) as a first type and crushed dolomite of grade (Π) as a second type.The two types were obtained from "ATAKA" quarry, Suez Governorate. The engineering properties of both types are presented in Table (1), fine portion which consist of natural siliceous sand obtained from "Elrehab" quarry, Cairo governorate, with bulk specific gravity 2.65. Lime stone dust as a mineral filler with bulk specific gravity 2.85. Gradations of two types are presented in Table (2). , bituminous material (Suez asphalt cement with 60-70 penetration grades) is used as a binder and its engineering properties are presented in Table (3), and additives which consist of the following:

- Crushed glass: Waste glass or cullet used as a portion of fine aggregate in asphalt paving mixes. Table (4) shows gradation and specific gravity of crushed glass.
- Hydrated lime: Is a fine portion using as anti-stripping agent due to stripping problems. Its gradation and specific gravity are shown in Table (4).
- Cement dust:Is a fine portion (dust) using as mineral filler. Its gradation and specific gravity are shown in Table (4).

2.4 Mix Gradation

The asphaltic concrete mixes, tested in this study, are composed of 28 % coarse aggregate of first type, 24 % coarse aggregate of second type, 42 % of natural sand, and 6 % of limestone dust as a mineral filler. Different percentages were added to the investigated mixes from crushed glass, hydrate lime and cement dust to form different types of mixtures. The gradations of these mixtures lie within the limits of Egyptians standard specifications for dense graded surface course mix (Mix 4-c). Table (5) shows the different gradations of the asphalt concrete mixes investigated the study.

3. RESULTS AND DISCUSSION

The routine mix characteristics (OAC, unit weight, stability, flow, AV and VMA) according to Marshall test are carried out to investigated mixes to evaluate the feasibility of using crushed waste glass (CWG) in HMA. So the methodology of the study is concerned with following tasks:

3.1 Evaluation of HMA with CWG added as is (without any other additives).

The results of Marshall test of mixes having different percentages of CWG (at o% additives) is shown in Table (6). Results indicated that generally the maximum density value has maximum slightly increase from 2.322 to 2.336 occurs at 15% CWG added to conventional mix. %air voids decrease generally from 4.2 to 3.93at best case when added 5%CWG.the flow is increased from 2.2 to 2.8 at 15%CWG .the stability generally decreased from 968 to 843 at best case when added 5%CWG.

3.2 Evaluation of HMA with CWG Improved by Anti-stripping Agent (hydrated lime)

The results of Marshall test of mixes having a combination of different percentages of CWG and HL at OAC is shown in Table (7). Results indicated that the density increased from 2.322 to 2.341when added 20%CWG and 1.5%HL to the conventional mix. % air voids generally decreased when added any percentage of (CWG and HL) except when added (10%CWG and 2.5%HL)it increased from 4 to 4.22.Flow value increased from 2.2 to 2.6 when added 15% CWG and 1.5% HL. Stability decreased generally from 968 to 843 at best case when added (5%CWGand 2.5HL).

3.3 Evaluation of HMA with CWG Improved by Cement Dust.

The results of Marshall test of mixes having a combination of different percentages of CWG and 6%DC at OAC is shown in Table (8). Results indicated that the density increased from 2.322 to 2.341when added 15%CWG and 6%DC. % air voids generally decreased from 4.2 to 3.84 at best case when added 5%CWG and 6%DC.the flow is increased slightly from 2.2 to 2.4 when added 15 %CWG or 20% CWGAND 6% DC. The stability is increased from 968 to1040 when added 5% CWG and 6% DC.

3.4 Performance of HMA Containing CWG (based on loss-of-stability test).

The percent loss of stability was used as indicator to mix durability under different conditions .Table (9) presents the results of loss of stability test performed on the investigated mixes. Figures (7) show the loss of stability percents versus immersion time for the 25 mixes from conventional mix M0 to Mg & c. from the figure it can be noted that for all mixes the loss of stability increases as immersion time increases with decreasing rate. The mixes contains higher stability value (mixes contains cement dust only and mixes contains a combination of cement dust and waste glass followed by the mix contains of hydrated lime only) .They have superiority in resisting moisture damage, they have the stability loss with acceptable range (<20%).On the other hand the mixes with few lower stability value (mixes contains a combination of waste glass and hydrated lime followed by mixes contains waste glass only) are suffering higher loss of stability values variance from 22% to 40.5% .Generally based on these results it can be concluded that the use of cement dust by 6% instead of lime stone powder in conventional mix or using a mixes contains a combination of cement dust and waste glass at different percentages may be achieved some improvement for durability than conventional mix by 0.05% to 0.2% and it can be noted that in the mix which contains a 5% waste glass as a portion of fine aggregate and 2% hydrated lime as anti-stripping agent .the loss of stability percents are in the allowable range.

3.5 Statical Analysis

From all the above we can conclude the most suitable percentage of CWG when added to additives (HL or DC) which can improve Marshall properties as shown in table (10,11) and based on comparison between results which are presented in Figures(3) through(6). They illustrated the effect of additives on Marshall properties.
So we can calculate the most suitable percentage of a combination of (CWG and HL) as follow:

Average percent value of CWG

$$= \frac{20+0+15+10}{4} = 11.25\%$$

Average percent value of HL

$$= \frac{1.5+0+1.5+2.5}{4} = 1.375\%$$

So we can say that the most suitable percentage of CWG is 11.25% when added 1.375%HL as anti-stripping agent may be modify Marshall properties. Also we calculate the most suitable percentage of a combination of (CWG and DC) as follow:
Average percent value of CWG

$$= \frac{20+0+15+10}{4} = 10\%$$

So we can say that the most suitable percentage of CWG is 10% when added 6%DC instead of mineral filler limestone dust in conventional mix to modify Marshall properties. Table (12) showed the evaluation of using CWG on HMA at most suitable percentages added to conventional mixes as we illustrated previously.

4. CONCLUSIONS AND RECOMMENDATIONS

Based on the methodology and the analysis of results of this study, the following conclusions were drawn:

1. Using crushed waste glass up to 5% of fine aggregate portion in HMA manufacturing is allowed. This only

achieves stability 811kg > 600 kg (allowable stability value), and 657.54 kg > 600kg after immersion 3 days in water.

2. Crushed waste glass cannot be allowed to use in manufacturing HMA with a percentage more than 5% of fine aggregate portion. It exhibits grater loss of stability with time (stability loss > 20% ranges from 23.5%to 36.6% of its original stability values) after immersion time 3 days in water.
3. The enhancing of crushed waste glass by 1.5% of hydrated lime enables to use up to 15% of crushed waste glass in HMA safely. This achieves stability values more than allowable value (600 kg).It also achieves stability values ranges from 653.9 kg to 628.5 kg more than allowable value (600 kg) after immersion time 3 days in water.
4. Using HMA containing crushed waste glass with increasing percentages of hydrated lime more than 1.5% may worsen the stability. They are suffering higher loss of stability values varying from 23% to 40.5%. Hence it must be refused.
5. Using HMA containing crushed waste glass with increasing percentages of hydrated lime more than 1.5% may worsen the stability. They are suffering higher loss of stability values varying from 23% to 40.5%. Hence it must be refused.
6. Adding cement dust to HMA enable from valuable using of crushed waste glass in HMA**.** It increases the stability values higher than 600kg.
7. Using mixes containing cement dust with 6% and up to 10% of crushed waste glass achieved some improvement for stability values. It exhibits stability values ranges from 1044 kg to 977 kg more than reference mix stability (968kg). Using these percents also achieved some improvement for resisting moisture damage than conventional mix by 1.5% to 8%.fter immersion time 3 days in water.
8. Using of crushed waste glass in HMA save almost 20% of crushed sand (identical in gradation to crushed glass) used in conventional HMA.
9. The study should be carried out using other kinds of aggregates such as basalt and granite, to check the behavior of crushed waste glass with other types of coarse aggregates.
10. Complete economic evaluation must be carrying out to check using HMA containing crushed waste glass with hydrated lime or cement dust.

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