PERFORMANCE EVALUATION OF WASTE TILES IN FLEXIBLE PAVEMENT CONSTRUCTION

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ABSTRACT

Huge vloume of tiles dust are produced from building construction and ceramic industries. Basically Waste Tiles Aggregates (WTA) are being produced by crushing ceramic tiles during the process of transport and installation of roof, wall and floor. Present society are progressively moving forward to be more environment friendly. To meet up this purposes, recycling and reuse of this waste material can be the best alternatives than landfill disposal in respect of environment conservation and economy. To increase the usage of wastes tiles in pavement construction, different percentage of wastes tiles can be used with the natural aggreegate. The technical feasibility of using waste tiles aggregates as partial replacement of natural aggregates in bituminous mixes can be evaluated. This research work presents some of the laboratory investigation on the possible application of waste tiles aggregates in bituminous mixes. The physical properties of coarse aggregates, fine aggregates, filler and bitumen are determined according to standard test. Marshall test specimens are prepared for testing to measuere the Marshall properties. Three specimens are prepared with bitumen content 4.5%. For Mix Type A, black stone chips, coarse sand and stone dust filler are used. Mix Type B is preared by black stone chips with some percentage of WTA, coarse sand and stone dust filler and Mix Type C is prepared by black stone chips with some percentage of WTA, fine waste tiles and stone dust filler. Five bitumen content are used with increment of 0.5% for Mix Type A, B and C. The strength properties are measuered for both coarse and fine aggregates produced from waste tiles. Marshall stability value 13.0 kN, 12.9 kN and 13.4 kN at optimum bitumen content 5.65%, 5.70% and 5.80% for Mix Type A, B and C respectively are determined. Acording to AASHTO, Marshall stability test properties of mixes of waste tiles aggregates are satisfactory. The required bitumen content is higher for mix type C and it is 1.02 times of mix type A. Mix type B needs comparitively less amount of bitumen than mix type C and it is 1.04 times of mix type A. The investigated results indicate that the bituminous mixes with waste tiles aggregates give satisfactory results for construction of medium traffic road.

Keywords: *Waste Tiles Aggregates, Marshall Mix Design, Flexible Pavement Construction.*

1. INTRODUCTION

The recycling of waste aggregates has long been recognized to have the potential to conserve the natural resources and to reduce energy used in production. It is a standard alternative for both construction and maintenance, practically where there is a shortage of aggregate. Generally, the term 'waste aggregate' refers to aggregates that have been used previously in construction which comprise construction and demolition waste, deteriorated asphalt pavement material, used railway ballast and so on. Ceramic materials, which include ceramic tiles and other ceramic products, contribute one of the highest content of wastes in the construction and demolition wastes. Actually, ceramic tile, being one of the most widely used construction materials, having its consumption rising with the growth of population and urbanization in many countries. Not only for walls and flooring in the buildings but also in many kinds of industrial and commercial structures, we use them in decoration, protection, or other improvement applications. During the process of wide range of manufacturing, transport and installation, a large number of tiles wastes are generated in an increasing amount day by day. However, with the large number of wastes comprising ceramic tiles and assured increase of it in the future, land filling has also become a major problem, particularly in countries where land is scarce. So apart from putting more effort in minimizing its generation and the setting up of temporary fill banks, recycle is one of the most effective means to alleviate the growing problem. On the other hand, many highway agencies, service providers, private organizations and individuals have completed or are in the process of completing a wide variety of studies and research projects concerning the feasibility, environmental suitability and performance of using recycled products in highway construction. The ever-increasing economic cost and lack of availability of natural material have opened the opportunity to explore locally available waste materials like waste tiles. Thus, recycling has been gaining wider attention as a variable option for the handling of waste tiles. As per the studies, recycled aggregate utilization from the ceramic industry wastes was largely considered in road construction as: landfills, sub-base courses on low volume roads, concrete blocks and manufacture of concrete (Koyuncu H. *et al.,* 2004, Huang B. *et al.,* 2009). Krüger and Solas., (2008) investigated the use of sanitary ceramic wastes as recycled aggregates for road surface courses. High whiteness and hardness of recycled aggregates from sanitary ceramic wastes improved sunlight reflection, avoiding heating during summer months and increased pavement stability, further improving the visual contrast in the roadway. Silvestre *et. al.,* (2013) reclaimed that recycled ceramic wastes are considered technically feasible to be incorporated as aggregates into asphalt concrete mixtures for open graded wearing courses. The mixture with 30% of recycled ceramic aggregates by aggregates weight meet most of the mechanical and superficial characteristics to be used as road surface layer for medium–low traffic volumes, with exception of water sensibility. In this study, investigation and experiments were performed to attain and compare the physical properties of stone aggregates and waste tiles aggregates primarily. Thus, the behaviour of bituminous mixes with respect to stone aggregates and waste tiles aggregate was evaluated to suggest a design criterion for the construction of flexible pavements with waste tiles aggregate.

2. MATERIALS AND METHODOLOGY

Two types of coarse aggregates were used in this study which consist of black stone chips to the size of 19 mm and less were collected from the construction site of Architecture Building of Rajshahi University of Engineering and Technology (RUET), Rajshahi, Bangladesh. Waste tiles were obtained from different waste disposal sites of Rajshahi, Bangladesh. Tiles pieces were crushed manually to bring the size of 12.5 mm and down grade as coarse aggregates.

Figure 1 and Figure 2 indicate the appearances of these two types of coarse aggregates respectively.

Figure 1: Appearance of Stone Aggregate

Figure 2: Appearance of Waste Tiles Aggregate

Coarse sand, collected from Domar, Panchagar, passing through 2.36 mm sieve and retained on 0.075 mm sieve was used as fine aggregate. Particles of waste tiles were obtained after collection of tiles pieces from different waste disposal sites of Rajshahi, Bangladesh. They were crushed manually to bring the size of 2.36 mm and retained on 0.075 mm sieve as fine aggregate. Stone dust finer than 0.075 mm (No.200) was used as filler in all bituminous mixes. The appearances of two types of fine aggregates are shown in Figure 3 and Figure 4 respectively.

Figure 3: Appearance of Coarse Sand

Figure 4: Appearance of Fine Aggregate from Waste Tiles

Bitumen used in this study was of 60-80 penetration grade asphalt collected from Eastern refinery, Chittagong. This was used for all the mixes so that the type and grade of binder would be constant.
The engineering properties of materials were determined according to the procedure specified by AASHTO, ASTM and BS standards. In order to study the effect of aggregates on the behavior of bituminous mixes, Marshall Test specimens were prepared for three types of aggregate mixes with 50 blows for medium traffic road according to the standard procedure specified by AASHTO.

2.1 Physical Properties of Aggregates

Table 1: Properties of Coarse Aggregates

Properties	**Methods (AASHTO/BS)**	**Coarse Aggregates**	
		Crushed Stone	**Waste Tiles**
Unit weight(loose), kg/m^3	T19	1520	1230
Unit weight(dense), kg/m^3	T19	1610	1240
Bulk specific gravity	T85	2.63	2.35
Apparent specific gravity	T85	2.78	2.43
Absorption of water, percent	T85	0.7	1.20
Abrasion(Grade-B),percent	T96	12	19
Soundness(Na_2SO_4),percent	T104	3	7
AIV, percent	BS812	8	16
ACV, percent	BS812	11	23
Ten percent fines value, kN	BS812	300	120
Flakiness Index, percent	BS812	12	15

Table 2: Properties of Fine Aggregates and Filler

Properties	Methods (AASHTO)	Fine Aggregates		Filler	
		Coarse sand	Waste Tiles	Stones Dust	Tiles Dust
Unit weight(loose),kg/m^3	T19	1440	1230	1160	1170
Unit weight(dense),kg/m^3	T19	1570	1350	1300	1347
Bulk specific gravity	T85	2.461	2.530	--	--
Apparent specific gravity	T85	2.647	2.960	2.513	2.642
Absorption of water	T85	3.125	2.327	--	--

2.2 Bituminous Mix Design

In order to study the effect of aggregates on the behavior of bituminous mixes, Marshall Test specimens were prepared with 50 blows for medium traffic road according to the standard procedure specified by AASHTO. Three types of mixes were studied and these were designated as mix types A, B and C.

Mix Type A	:	consists of black stone chips as CA, coarse sand as FA and stone dust filler
Mix Type B	:	consists of black stone chips, partially replaced by 35% WTA(9.5mm down grade) as CA,coarse sand as FA and stone dust filler
Mix Type C	:	consists of black stone chips, partially replaced by with 35% WTA(9.5mm down grade) as CA, fine waste tiles as FA and stone dust filler

2.3 Marshall Mix Properties

The maximum load carried by a compacted specimen at a standard test temperature of 60°C can be defined as Marshall Stability of a mix. The deformation of the Marshall Test specimen that undergoes during the loading upto the maximum load in 0.25 mm units is called the flow value. Marshall properties like stability, flow value, unit weight, total voids in a mix, voids in mineral aggregates and voids filled with bitumen were determined for three mix types. The graphs were plotted for bitumen content with respect to Marshall Stability, unit weight and air voids. The bitumen content corresponding to maximum stability, maximum unit weight and 4% air voids were obtained from these graphs. The average value of bitumen content obtained from the 3 plotted graphs is treated as the optimum bitumen content (OBC). The graphical representations of Marshall Test Properties are illustrated as follows.

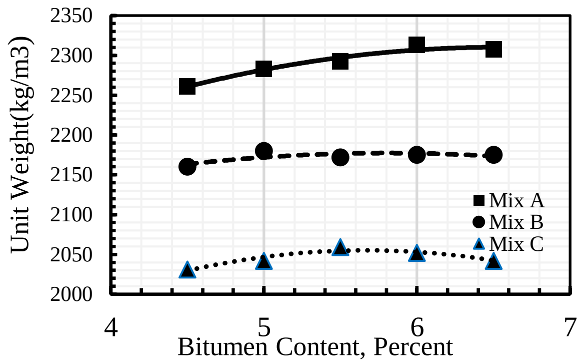

Figure 5: Relationship between Unit Weight and Bitumen Content for Mix Type A, B and C

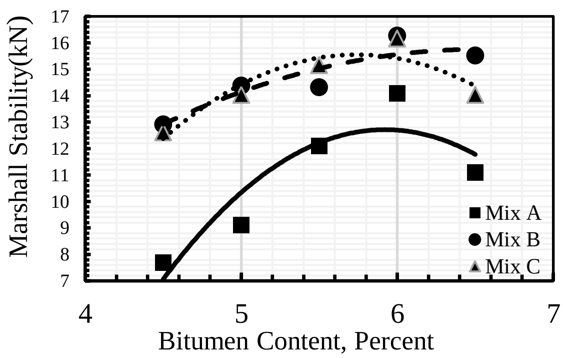

Figure 6: Relationship between Marshall Stability and Bitumen Content for Mix Type A, B and C

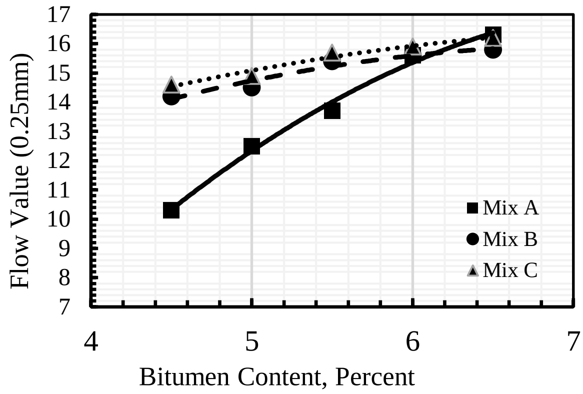

Figure 7: Relationship between Flow Value with and Bitumen Content for Mix Type A, B and C

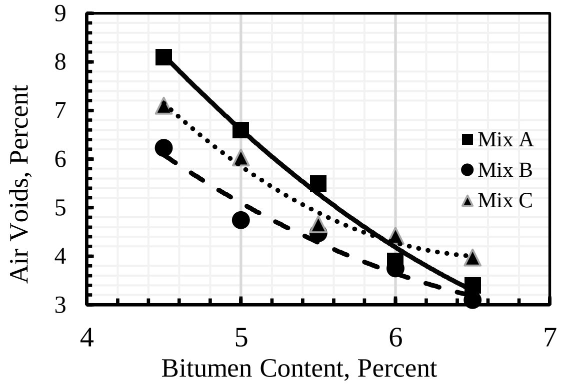

Figure 8: Relationship between Air Voids and Bitumen Content for Mix Type A, B and C

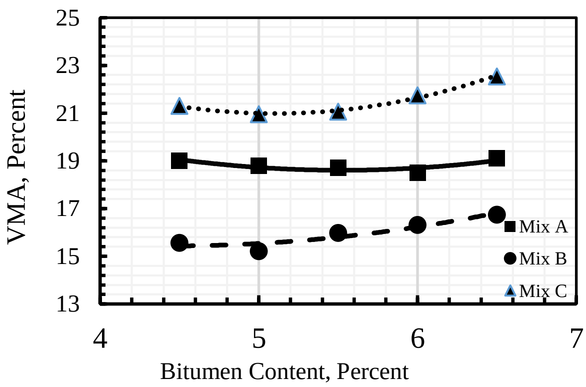

Figure 9: Relationship between VMA with and Bitumen Content for Mix Type A, B and C

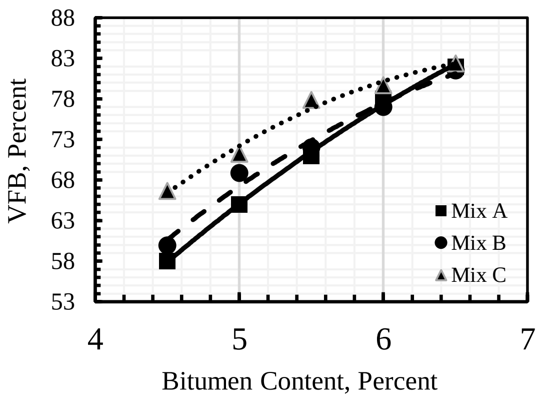

Figure 10: Relationship between VFB with and Bitumen Content for Mix Type A, B and C

Table 3: Characteristics of Bituminous Mixes for Mix type A, B and C

Aggregate Types	**O.B.C (%)**	**Unit weight (kg/m^3)**	**Marshall Stability (kN)**	**Flow (0.25 mm)**	**Air voids (%)**	**VMA (%)**	**VFB (%)**
A	5.65	2305	13.0	12.5	4.1	18.75	76
B	5.70	2178	12.9	12.8	4.1	15.80	74
C	5.80	2219	13.4	12.6	4.0	15.20	76

3. ANALYSIS OF RESULTS

As determination and comparison of the physical properties of natural aggregates and waste tiles aggregates are one of the main objectives of this study, Table 1 and Table 2 represents the experimental test results of physical properties of both types of aggregates. The experimental result shows that both types of aggregates satisfied the respective limiting value. Though tiles dust were not used in this study, we can use this as an alternative of stone dust filler regarding comparison of physical properties of both. Marshall Stability at optimum bitumen content for Mix types A, B and C are 13.0, 12.9 and 13.4 kN respectively. These three stability values satisfy the limiting value (3.336 kN) specified by The Asphalt Institute. The flow values are 12.5, 12.8 and 12.6 respectively. These values satisfy the limiting value 8-16 according to design criteria for medium traffic. From Table 3 it is found that at optimum bitumen content, %Va for mix type A, B and C are 4.1%, 4.1% and 4.0% respectively. These values satisfy the limiting value 3-5% specified by The Asphalt Institute. Table 5 shows that the %VMA at optimum bitumen content for mix types A, B and C are 18.75%, 15.80% and 15.20% respectively. These values are greater than the minimum value 12%. Table 4.5 shows that the %VFB at optimum bitumen content for mix types A, B and C are 76%, 74% and 76% respectively. These values satisfy the limiting value 65%- 78% specified by The Asphalt Institute. Marshall Stiffness value of Mix type A, B and C at optimum bitumen content are 4.16, 4.03 and 4.25 kN/mm respectively. All these values are above the required value of 2.1 kN/mm.

4. CONCLUSIONS

On the basis of experimental results of this study, the following conclusions are drawn:

a. Aggregates which are obtained by crushing waste tiles are suitable for the bituminous mixes from the consideration of aggregate strength properties.
b. Waste tiles aggregates as a partial replacement of black stone chips, coarse sand-bitumen mix with filler satisfies all the requirements of bituminous mixes for medium traffic road.
c. Waste tiles aggregates as a partial replacement of black stone chips, waste tiles fines-bitumen mix with filler satisfies all the requirements of bituminous mixes for medium traffic.
d. Marshall Test properties of mixes with waste tiles aggregates are satisfactory but required bitumen are 1.02 times and 1.04 times more for mix type B and C respectively than that of mix type A. Though the required amount of bitumen is more for mixes with WTA, it is considerable in the sense of utilization of a waste material.
e. The investigated results indicate that the bituminous mixes with waste tiles aggregates give satisfactory results when they are constructed using dense grading, good compaction and optimum bitumen content for medium traffic.

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