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Evaluation of Maximum Usage Potential of Coarse Aggregate and Filler in Bituminous Mixes

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Abstract: - These days dealing with waste is a major problem which is generated from industries and residential areas. This work presents the use of industrial glass waste in dense bituminous macadam (DBM) of flexible pavement in the form of coarse aggregates and filler. In this work, 25% of glass aggregates and 4% - 8% fillers used to replace the natural aggregates and stone dust respectively. Various Experiments were performed like impact value, specific gravity, water absorption, elongation and flakiness, ductility, softening point, viscosity and Marshall Stability. Impact test was performed on glass and natural aggregates individually to check their impact values. Then after glass was mixed with natural aggregates in various percentages (5%, 10%, 15%, 20%, 25%) and impact test was performed for every percentage of glass in aggregate to obtain the maximum amount of glass aggregates that can be used with natural aggregates without exceeding the permissible value of impact for dense bituminous macadam. Tests like specific gravity, water absorption, elongation and flakiness, ductility, softening point and viscosity were performed to check the properties of individual material (glass aggregates, natural aggregates and bitumen). Marshall Stability test was performed to find out optimum bitumen content of mix which consist natural aggregates (75%) and glass aggregates (25%) by using 3.5%, 4%, 4.5% and 5% bitumen content. This test also performed to determine the optimum percentage of glass filler in which mixture involved natural aggregates (75%), glass aggregates (25%) and varying percentage of glass filler (i.e. 4%, 6% and 8%).

Key words: Natural Aggregate, Glass, softening point, viscosity and Marshall Stability.

1. Introduction

Numerous waste materials result from manufacturing operations, service industries, sewage treatment plants, households and mining. Performance of building materials is one of the most important aspects that engineers must consider. Glass is a non-metallic and inorganic material made by sintering selected raw materials, so it can be neither incinerated nor decomposed. Glass recycling can save energy and decrease environmental waste. A focus on glass recycling technology will widen the application domain of waste glass and promote further development of glass techniques. Nearly ten million tons of waste glass is generated in metropolises every year, about 3–5 wt% of the domestic waste. A study on the dynamic characteristics of asphalt mixtures containing waste glass aggregates and conventional asphalt concrete mixtures showed an increase in the stiffness modulus of glass–asphalt pavements in comparison with conventional asphalt-mix. Four percent of hydrated lime was used as an anti-stripping agent additive, and the results were compared with those of a specimen without anti-stripping.

2. Experimental procedures

The aggregates used in this study were graded using the continuous type III scale of the AASHTO standard, which is presented in Table 1

Table 1: Continuous type gradation for HMA, Topka layer.

Sieve size	1″	3/4″	1/2″	3/8″	#4	#8	#50	#200
Percent passing	–	100	95	–	59	43	13	6

Pure bitumen 60–70 was used in the preparation of the samples. The characteristics of the bitumen were controlled and presented in table. The crushed glass used in this research was supplied from the waste glass of a glassmaking company. The maximum size of the glass aggregates was 4.75 mm. The lime-mixed aggregates were retained for a period of time for preparation and drying. This method permits increased certainty about the equal distribution of lime over the aggregates.

The fatigue life of the samples was determined by the Indirect Tensile Method using a Nottingham Asphalt Testing (NAT) apparatus. The Marshall test was carried out to determine the optimum bitumen content of asphalt concrete mixtures containing different percents of waste glass cullet aggregates.

Specimens were prepared with crushed glass contents of 0%, 5%, 10%, 15% and 20%wt. The optimum content of hydrated lime was also determined by the Marshall test on glass asphalt mixture specimens with optimum bitumen content containing various proportions of glass.

The fatigue life of the specimens was identified by using the indirect tensile fatigue test (ITFT) method on samples with 100 mm diameter and 40 mm thickness. This loading was accomplished by applying repeated loads at a frequency of 1 Hz until the failure point of the specimen. The failure was also characterised by measuring the vertical deformation of the samples. Fatigue life tests are usually carried out via two methods: loading with constant stress and loading with constant strain. In the constant stress test, strain increases with the number of pulses of loading, while in the constant strain test, stress decreases with the number of pulses of loading.

Table 2: Properties of bitumen used in this study

Total bitumen Content	Weight drop	Inflammation point	Ductility	Softening point	Specific gravity
%	%	°C	Cm	°C	25 °C
99	0.75	262	112	51	1.02

Table 3: Chemical properties of the used crushed glass aggregates

Sodium oxide %	Calcium oxide %	Magnesium oxide%	Aluminum oxide%	Bur oxide%	Potassium oxide%
15	5.55	3.6	1.5	0.4	0.4

3. Methods

3.1 Ground waste glass

The waste glass used in this study was obtained from recycled fluorescent lamps supplied by RLF Canada in Quebec. It was a typical soda lime glass. The chemical composition of the glass was analyzed using an X-ray microprobe analyzer and is listed in Table 1 together with that of Class F fly ash and silica fume for comparison. Al- though the silica content of glass is higher than fly ash, the equivalent reactive components (SiO_2 + Al_2O_3 + Fe_2O_3) is relatively low in glass. The silica fume had the highest percentage of reactive silica among the three. In accordance to ASTM C618, the glass satisfies the basic chemical requirements for a pozzolan and exhibited a favored white color. However, it does not meet the optional requirement for the alkali content because of the high percentage of Na_2O in glass. To satisfy the physical requirement for fineness, the glass has to be ground to pass a 45-μm sieve. This was accomplished by crushing and grinding the glass in a jar mill in the laboratory, and by sieving the ground glass to the desired particle size. According to ASTM C618, the 150-μm glass did not qualify as a pozzolan due to the coarse particle size. The 75-μm glass was marginal, depending on the percent passing the 45-μm sieve. Consequently, only the 38μm glass satisfied the fineness requirement. The purpose of the study was to examine if the coarse ground glass could still depict certain levels of pozzolanic behavior.

3.2 Lime-glass test

Lime-glass tests were conducted following ASTM C593 [7]. Five batches of samples with different mineral additives were prepared. Respectively, they contained the Class F fly ash, silica fume, 150-μm glass, 75-μm glass, and 38-μm glass. Both fly ash and silica fume batches were used as control for comparison. The chemical compositions of all additives are listed in Table 1, and the mixture proportions are given in Table 2. The hydrated lime, mineral additives, and graded standard sand were added up to 100% and water was adjusted to achieve a flow of 65 to 75% consistency through a flow table test. The mixture was cast in 50-mm cube molds, wrapped by wet burlap, sealed by plastic bag, and cured at 54°C in an oven. Compressive strength tests of all batches were carried out after 7 days curing at 54°C. At least three samples were tested and averaged for each batch. Cubes with 75-μm glass and 38-μm glass were also tested after an additional 21 days curing at 23°C in water to monitor the long-term strength gain. As recommended by ASTM C593, a satisfactory pozzolanic material should have a minimum compressive strength 4.1 MPa when mixed with lime after 7 days curing at 54°C, and after an additional 21 days curing at 23°C in water.

Glass filler (%)	Bitumen content (%)	stability	Flow (mm)	Unit weight	Air Void (%)	VMA	VFA
	3.5	1008	2.26	2.529	6.22	12.48	53.85
0	4	1273	2.71	2.552	5.1	12.26	61.54
	4.5	1162	3.14	2.545	3.45	13.49	74.42
	5	1079	3.33	2.538	2.59	13.7	81.1
	3.5	979	2.44	2.533	5.81	13.1	55.64
4	4	1237	2.78	2.555	4.58	12.78	64.18
	4.5	1147	3.17	2.548	3.69	13.71	73.07
	5	1021	3.4	2.54	2.96	14.04	78.87
	3.5	986	2.5	2.535	5.66	12.96	56.35
6	4	1266	2.83	2.556	4.37	12.59	65.31
	4.5	1105	3.19	2.549	3.76	13.77	72.67
	5	1027	3.42	2.542	3.15	14.2	77.82
	3.5	943	2.72	2.537	5.36	13.15	55.42
8	4	1174	3	2.558	4.6	12.8	64.08
	4.5	1081	3.28	2.551	3.49	13.53	74.19
	5	994	3.49	2.543	2.77	13.86	80.04

3.3 Compressive strength test

Compressive strength tests were conducted to study the strength development of concrete containing the ground glass

S. No.	Properties of glass	Value
1.	Water absorption	0%
2.	Specific gravity	2.28
3.	Impact value	37.83%

at early and late ages. The cement replacement by the ground waste glass in the concrete was targeted at 30% by volume. The concretes containing the ground glass were compared to the concretes having the same percent replacement of cement by fly ash and silica fume, as well as to the control concrete without any mineral additives.

3.4 Expansion test

Study of the expansion due to the possible reaction between the alkali in the cement and the silica in the glass was done in accordance with ASTM C1260 [7]. The 25 × 25 × 100-mm mortar bars were made of standard graded river sand, Type 10 Portland cement, and a mineral additive. The water to cementitious ratio was 0.47 and the cementitious- aggregate ratio was 1 to 2.25. For the five batches containing mineral additives, 30% by volume of the Portland cement was replaced by the silica fume, fly ash, 150-µm glass, 75-µm glass, and 38-µm glass, respectively. After 24 h of curing, the bars were placed in water at 80°C for another 24 h to gain a reference length. They were then transferred to a solution of 1 N of NaOH at 80°C. Readings were then taken every day for 14 days. The mortar bars without any additives were also tested as control. The comparison with the control is an indication of whether or not the silica in glass is re- active with the alkali in cement and from the solution. It also manifests if the mineral additives used are able to suppress the expansion by consuming more lime inconcrete.

4. Results and discussion

4.1 Properties of natural aggregates

S. No.	Properties	Value
1.	Impact value	14.14%
2.	Specific gravity	2.84
3.	Water absorption	0.25%

4.2 Properties of bitumen

S. No.	Properties	Values
1.	Ductility value	70 cm
2.	Softening point	51.5°C
3.	Viscosity	2650 poise

4.3 Impact test values

S.No.	Glass (%)	Impact value
1.	0%	14.14%
2.	5%	19%

3.	10%	23.33%
4.	15%	25.33%
5.	20%	27%
6.	25%	29.83%

4.4 Properties of aggregates and glass mix

S. No.	Properties (GLASS: AGGREGATE:: 25:75)	Value
1.	Specific gravity	2.703
2.	Water absorption	0.175%
3.	Impact value	29.83%

5. Conclusion

This paper has evaluated the influence of a fine glass powder on cement hydration. The pozzolanicity of the cement replacement materials, the alkali release characteristics from glass powder, and the non-evaporable water contents of the hydrated pastes were experimentally determined. A model has been developed to predict the degree of hydration of pastes containing supplementary cementing materials or hydration enhancing fillers.

The fine glass powder was found to exhibit pozzolanicity levels equal to or greater than that of fly ash at all the ages studied. The strength activity index of a coarser variety of glass powder was also investigated so as to bring out the changes in pozzolanic behavior of the glass powder with change in particle sizes.

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