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Crushed Glass For Use In Asphalt Concrete Or Cement
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Broken glass for the project was supplied by the Glass Container Corporation of Vernon, California, and was received crushed to a size of approximately 3/4 x 1/2". In order to provide the various size fractions of glass needed for asphalt concrete grading requirements, the glass was further crushed and separated by size down to and including the passing No. 200 sieve.

It was decided that, in addition to testing specimens utilizing all glass aggregate, it would be appropriate to test specimens fabricated with glass coarse (retained No. 4) and mineral aggregate fines (passing No. 4). Specimens with mineral aggregate coarse (retained No. 4) and glass fines (passing No. 4) were also fabricated and tested. Specimens fabricated from all mineral aggregates were also tested for control purposes. A 3/4" maximum medium grading was used in all specimens to minimize any possible influence that may be due to different gradations (see Table 1). This particular gradation is the one most often used in asphalt concrete mixture in California.

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FINAL REPORT

Crushed Glass for Use in Asphalt
Concrete or Cement Treated Base

71-27

Introduction

The amount of waste glass created by nonreturnable bottles is rapidly becoming a disposal problem in the United States. A paper written by Ward R. Malisch, Delbert E. Day, and Bobby G. Wixson of the University of Missouri on the use of waste glass as an aggregate in asphalt concrete, appeared to have merit of sufficient magnitude to warrant a preliminary laboratory research project.

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Evaluation of these various asphalt concrete mixes was carried out by means of a routine method of design and evaluation utilizing the stabilometer, cohesiometer and surface abrasion equipment. The use of glass as an aggregate for cement treated base was also explored. The glass again was crushed to various sizes and typical gradation for a Type 3 cement treated base was prepared and tested for compressive strength.

An asphalt pavement utilizing glass as an aggregate was placed, by the Glass Container Corporation, on a city street in Fullerton, California. This pavement was visually inspected and skid resistance tests were performed on it, as part of this study.

Conclusions

Based on the results of the laboratory tests performed in this study and the field observations of the glasphalt street, the following conclusions are drawn:

1. More experimentation is necessary before glass can be accepted as an aggregate for asphalt concrete used on high speed, heavily traveled highways.
2. Glass may have some possibilities as an aggregate for base or subbase, but the problems of using the material should be investigated by field trials.

Discussion and Test Results

Glass

Samples of crushed glass were provided for this study by the Glass Container Corporation. The glass had been crushed to approximately 3/4", and was noticeably free from sharp razor-like edges. The edges were rounded and could be handled quite easily without any danger of lacerations. Microscopic examination of the glass dust particles did, however, show that they are flat, sharp or slivery. The majority of glass received appeared to be crushed bottles and was clear with a sprinkling of colored pieces. A small sample of glass was also received which appeared to have been heated and rapidly cooled. It had a crystalline formation similar to a lava rock in shape, and was green in color. This glass has a tendency to be highly friable and was not used in the testing. (Apparently this material is a waste product of the manufacturer.)

Asphalt Concrete

In this study, a very comprehensive effort was made in the laboratory to examine every physical property that might conceivably cause distress in the roadway. For comparison purposes in the test results of this study each type of aggregate, or blend of aggregates, is referred to as a series (see Table 2).

The compaction of glass asphalt mixtures became an immediate problem. Mixtures of all glass aggregate and those with glass only in the passing No. 4 fraction would not consolidate under the laboratory kneading compactor and a method of static compaction had to be used to properly compact specimens for testing.

It was apparent after compaction that glass mixtures resulted in bleeding or flushing surfaces at asphalt contents lower than with mineral aggregates (see Table 3).

Various tests were performed on specimens fabricated with the optimum asphalt content and the results are shown in Table No. 4. Lower stabilometer values, with glass aggregate, are quite evident. The cohesion recorded for glass aggregates, when coarser sizes were used, however, was higher. This was attributed to the fact that the glass oriented itself in a horizontal plane throughout the test specimens.

One of the very first studies made using glass aggregate was to observe the effect of compaction on degradation (see Table 5). It was noted that when degradation did occur it was primarily in the retained No. 4 fraction. Degradation was insignificant in glass passing the No. 4 sieve. The degradation was never considered excessive.

Asphalt film stripping in the presence of water was very severe with glass aggregate. Various methods of analysing the film stripping phenomena were studied using primarily the routine tests established by the State of California such as the Film Strip Test, the Surface Abrasion Test and the Moisture Vapor Susceptibility Test.

In the regular film strip test, glass aggregates had a tendency to strip or lose their asphalt film rather rapidly in the presence of water. It is estimated that 25-30% of the asphalt film was removed after shaking in water. The addition of various commercial admixtures, and a lime slurry helped to retain the asphalt film (see Table 6).

The analysis of stripping using the Moisture Vapor Test did not indicate stripping of any great degree.

The analysis of stripping using the Surface Abrasion Test, however, was quite revealing (see Table 6). Without an additive the glass aggregate virtually disintegrated, and with the use of commercial additives, including dry lime, the degree of disintegration was still such that the material would have to be classified as a failure (50% or more disintegrated). The glass treated with a lime slurry, on the other hand, performed quite well. Glass aggregate so coated had very little stripping as indicated by an abrasion loss.

The expansion test was also explored to determine the effect of glass aggregate. In this test a bar about 11 inches long, 3 inches square was measured for expansion and contraction when subjected to a wet and dry cycle. Glass without additives expanded, stripped and began to disintegrate with this test (see Table 7). No additional tests were made with additives because of the amount of material required and the long testing period.

Glass was also tested as a substitute for filler dust in AC (see Table 8). A regular gradation of rounded streambed gravel, without the passing 200 fraction, had glass added as a filler (-200 fraction only) to see what effect it would have on the physical properties of the mixture. There appeared to be no measurable result, good or bad, noted when glass is used in this particular way.

"Glasphalt" Street

Glass was used in an asphalt pavement placed by the Glass Containers Corporation, in October 1970, on a city street in Fullerton, California. This glasphalt pavement was placed with regular asphalt spreaders and rolled with an 8-ton Essex Vibratory Roller. No special pavement equipment was used. Lime was added to the mix to improve adhesion. No information on the cost of the material or placing of the glasphalt was received. Skid resistance measurements were performed shortly after construction. These tests were performed in accordance with ASTM Test Method 274 and the average SN₄₀ was 57 with a ribbed tire. This value would be considered very good.

The glasphalt pavement was visually inspected in January 1971, three months after construction. At this time, there was evidence of some raveling of glass from the mix by the presence of loose glass particles on the shoulders and in the gutters.

The glasphalt pavement was again visually inspected in April 1971. Prior to this inspection, the street had been hosed down and swept off. At the time of this inspection (about 5 P.M.) the street exhibited a definite glare (see attached photos). Close inspection showed that the asphalt had been removed from the top surface of the coarse glass asphalt. This removal apparently occurred during the aforementioned cleaning operation. A close inspection of the pavement also revealed that the coarse glass aggregate was fracturing and raveling in areas where vehicles were turning onto or off of the glasphalt. This would indicate that the glasphalt has low resistance to forces associated with turning and braking actions. This particular glasphalt street has had very little traffic and it is felt that considerable raveling might have occurred under even moderate traffic conditions. The portion of the street where glasphalt was only used in the base course is performing in a satisfactory manner and no distress is evident.

Cement Treated Base

Test specimens using glass were also prepared and tested after cement treatment. The gradings used were in compliance with requirements for cement treated base as given in the 1969 Standard Specifications. The portion of the mineral aggregate passing the No. 4 sieve when adjusted to 55% on the No. 4 sieve conformed very closely to a grading "right down the middle" of the CTB grading specifications. All additional blends of glass and aggregates had identical gradings.

Test specimens were fabricated using 3, 5, 7 and 9% cement (amounts arbitrarily selected). The water content and curing time were the same for all briquettes and they were prepared and tested using Test Method No. Calif. 212-E.

During compaction it was noted that the glass would not consolidate readily and was fairly hard to compact (kneading compaction).

After the briquettes were tested, they were broken to see the particle arrangement. It was found that the glass and aggregate particles were arranged randomly.

Except for the specimen blended with glass (in the retained No. 4 fraction), all specimens broke above the required minimum compressive strength of 750 psi (see Table 9).

The Concrete Section has cautioned that there may be an adverse reaction between glass and cement, and that this aspect should be further investigated. A report "Utilization of Waste Glass in Portland Cement Concrete," by Dartmouth College, has been sent for and will be reviewed before additional work is carried out.

Implementation

The results of this study have furnished information on the performance of glass as an aggregate in asphalt concrete surface courses. This preliminary study prevented the necessity of a field trial on a more highly traveled State highway.

May 1971

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Photos Showing Glare on Glasphalt

TABLE NO. 1

Aggregate Gradation Used

<u>Sieve</u>	<u>AC</u> <u>% Passing</u>	<u>CTB</u> <u>% Passing</u>
3/4	100	100
1/2	85	85
3/8	73	76
4	50	55
8	36	41
16	27	32
30	18	24
50	11	16
100	6	11
200	5	5

Specific Gravities

<u>Material</u>	<u>Coarse</u>	<u>Fine</u>	<u>Test No.</u>	<u>Source</u>
Min. Agg.	2.72	2.77	70-1174	Teichert-Perkins
Glass	2.50	2.50	70-1765	Glass Container Corp.
Min. Agg.	2.64	2.71	70-1989	Cache Creek

TABLE NO. 2

Series Identification

(All Series have the gradation (AC and CTB) indicated in Table No. 1)

Series

- | | |
|-----|---|
| 1* | Mineral aggregate* used in both coarse and fine portions. |
| 2 | Glass was used in the retained No. 4 fractions, mineral aggregate was used in the passing No. 4 fractions. |
| 3 | Glass was used in the passing No. 4 fraction and mineral aggregate was used in the retained No. 4 fraction. |
| 4 | Glass was used in the coarse and fine portions. |
| 5** | Glass was used in the passing 200 fraction only (filler dust) and compared with other fillers. |

*Mineral aggregate in Series 1 through 4 was from Teichert's Rock and Gravel located at Perkins. Series 5 used aggregate from Cache Creek in Woodland.

**Studied only for asphalt concrete.

TABLE NO. 3

AC

Selection of Optimum Asphalt

Series	Test	% Asphalt					
		3.5	4.0	4.5	5.0	5.5	6.0
(1)	Stabilometer	-	-	44	45	43	35
All	Voids	-	-	6.9	5.0	4.0	2.8
Min.	Surf. Flushing	None	None	None	None	Slight	Heavy
Agg.	Optimum					X	
(2)	Stabilometer	-	32	30	26	28	16
Glass (+4)	Voids	-	8.5	6.2	5.0	5.2	3.2
Min. Agg. (-4)	Surf. Flushing	None	None	Slight	Heavy	Heavy	Heavy
	Optimum			X			
(3)	Stabilometer	26	27	24	11	4	-
Glass (-4)	Voids	9.2	8.0	5.5	2.8	1.8	
Min. Agg. (+4)	Surf. Flushing	None	Slight	Slight	Heavy	Heavy	
	Optimum		X				
(4)	Stabilometer	13	13	11	7	-	-
All	Voids	6.6	6.0	4.5	3.5		
Glass	Surf. Flushing	None	Slight	Slight	Heavy		
	Optimum		X				

Note: Surface flushing characteristics were based on static compaction for Series 3 and 4.

Specimens may have flushed at lower contents with kneading compaction!

TABLE NO. 4

AC

Test Results with Optimum Asphalt Content

Series Description	Stab	Sp.Gr. Brq.	Voids	Coh.	M.V.S.		Swell	Surf.* Abrasion	F.S.	Asphalt		Method of Comp.
					Stab.	Moist.				Grade	% Used	
1 All mineral aggregate	43	2.40	4.0	330	36	0.4	.002	9.3	N.S.	85-100	5.5	(500 psi) Kneading Comp.
2 Glass (+4) Min. Agg. (-4) **	30	2.30	6.2	143	24	0.2	.003	12.8	0%	85-100	4.5	(500 psi) Kneading Comp.
3 Glass (-4) Min. Agg. (+4) **	26	2.25	8.0	192	40	1.1	.000	61.6	0%	85-100	4.0	40,000 lb. static load
4 All Glass ***	16	2.23	6.0	370	39	1.1	.000	1000 (Disintegrated)	0	85-100	4.0	40,000 lb. static load
5 Glass Filler - See Table 8												

* All specimens for the Surface Abrasion Test were compacted with a 40,000 lb. load.

**See Table No. 10 for cement treated base results.

TABLE NO. 5

AC
Degradation Study

Sieve	Series								
	1		2		3		4		*
	As Used	Ext. Grade	As Used	Ext. Grade	As Used	Ext. Grade	As Used	Ext. Grade	Ext. Grade
3/4	100	100	100	100	100	100	100	100	100
1/2	85	86	85	93	85	86	85	98	92
3/8	73	74	73	83	73	75	73	93	86
4	50	52	50	57	50	53	50	71	62
8	36	42	36	44	36	43	36	52	47
16	27	26	27	28	27	30	27	34	32
30	18	21	18	20	18	22	18	24	24
50	11	12	11	14	11	16	11	17	17
100	6	8	6	9	6	9	6	10	9
200	5	6	5	7	5	6	5	8	8
o/c Asphalt	5.5	5.1	4.5	4.2	4.0	3.8	4.0	3.6	3.7

Note: For Degradation Study only each series was compacted for the normal 5 minutes at 500 psi.

Series 3 and 4 did not consolidate after 5 minutes of tamping.

*Static compaction (40,000 lbs.)

TABLE NO. 6

AC

The effect of additives on Film Stripping & Surface Abrasion

Asphalt	Film Stripping			
	Additive	@ 15 hrs.	@ 24 hrs.	@ 48 hrs.
85-100	Control	0	0	5%
	Lime Slurry (2%)	0	0	0
	Com.*No. 1	0	0	0
	" " 2	0	0	0
	" " 3	0	0	0
	" " 4	0	0	0
MC-800	Control	15	25	75
	Lime Slurry (2%)	0	0	0
	Com. No. 1	0	0	0
	" " 2	0	0	0
	" " 3	0	0	0
	" " 4	0	0	0

Additive	Surface Abrasion (Gms Loss)			
	Asphalt			
	%	85-100	%	MC-800
Control	4.0	1000-Disintegrated	4.0	1000-Disintegrated
Lime Slurry (2%)	"	1.7	"	28.2
Dry Lime (2%)	"	202.0	"	466.4-Badly Abraded
Com. No. 1	"	1000-Disintegrated	"	1000-Disintegrated
" " 2	"	" "	"	" "
" " 3	"	" "	"	" "
" " 4	"	" "	"	" "

(Gradings consist of all glass aggregate)

*Commercial Admixture

TABLE NO. 7

AC

Expansion Study

Sieve		Expansion		Remarks
+4	-4	A	B	
Glass	Glass	.090	.109	Fell apart.
Glass	Teichert Mineral Aggregate	.008	.015	Appears satis- factory, slight surface stripping.

Note: 11x3x3" bars in 100°F water bath for 1 week.

TABLE NO. 8

AC

Using Glass As a Filler (-200 Fraction)
With Rounded Streambed Gravel

Test No.	Filler		Asphalt		Laboratory Tests			
	Type	% Used	Grade	% Used	Stab.	Coh.	Surf. Abr. ¹	M.V.S. ² Stab. Moist.
70-1989A	Control	3.0*	85-100	4.0	31	180	1.1 gms.	19 0.3
70-1989B	Glass	3.0	"	"	31	132	1.5 gms.	25 0.3
70-1989C	Lime-stone	3.0	"	"	31	95	0.4 gms.	21 0.2
70-1989D	Cement	3.0	"	"	30	100	0.2 gms.	20 0.4
70-1989E	Hydr. Lime	3.0	"	"	30	200	0.4 gms.	22 0.4

*(Natural -200 material)

R-No. of Filler: Glass = R-4627
Limestone = R-4568
Cement = Type II
Hydrated Lime = R-4650

¹ 15 gms. loss is considered maximum allowable.

² Moisture Vapor Susceptibility

TABLE NO. 9

Cement Treated Base Test Results
Compressive Strengths (psi)

Series Descrip.	Cement Content				Remarks
	3.0	5.0	7.0	9.0	
1. All mineral aggregate	948	1786	2241	2894	
2. Glass (+4) Mineral Agg. (-4)	672	924	1220	1910	
3. Glass (-4) Mineral Agg. (+4)	1114	1693	2070	2337	
4. All Glass	955	1218	1648	1979	