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PROGRESS REPORT NO. 3
JANUARY - MARCH 1977

MASTER

PROCESS TECHNOLOGY DIVISION
DEPARTMENT OF APPLIED SCIENCE

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Abstract

Large quantities of energy and money can be conserved by recycling solid urban waste. While uses for recycled ferrous and non-ferrous metals are apparent, uses for the glass fraction have not been identified. As a result, a program to develop methods for incorporating waste glass into composites which can be used for construction materials was started in July 1976. Since that time tests to measure the properties of glass-polymer sewer pipe have been started. Field testing of full-scale specimens is also in progress. To date the results from compressive strength and three-edge bearing strength measurements indicate that the high strength properties are reproducible. The coefficient of variation is generally <10%. Hydrostatic test requirements can also be attained. Energy budgets and cost estimates are currently being made. Work accomplished during the period January 1-March 31, 1977 is described in the current report.

Summary

Tests are in progress to determine if the use of glass polymer composite (GPC) pipe as a replacement for vitrified clay, asbestos cement, and concrete pipe in sewage systems can result in energy conservation. As the initial phase of this work, the properties of GPC are being measured to a degree that they are statistically acceptable with respect to relevant ASTM methods and standards. To date the results from compressive strength, three-edge bearing strength, and hydrostatic tests indicate that when compared to several ASTM classes of steel reinforced concrete pipe, the use of GPC pipe reduces the wall thickness from 30 to 50%. Improved durability would also be expected. Greater reductions appear possible if the fraction of fines in the glass aggregate is increased.

Development of a Glass Polymer Composite Sewer Pipe from Waste Glass

Progress Report No. 3
January-March 1977

Introduction

The utilization of solid urban waste could result in many benefits. In addition to the production of substantial quantities of energy and the recovery of valuable materials, the costs associated with landfilling wastes would be lowered considerably. At the present time uses for recycled ferrous and non-ferrous metals are apparent. Efficient uses for recycled glass which constitutes ~ 10 wt% of the urban waste in the US, need to be developed.

The Brookhaven National Laboratory (BNL) program for the utilization of waste glass in construction materials is an outgrowth of previous work on concrete-polymer materials.¹ One of the materials developed in that program is polymer concrete (PC) which consists of a mixture of fine and coarse aggregate and a polymeric binder. The material can be mixed and placed using conventional equipment, cures rapidly at ambient temperature, and has strength and durability properties that exceed those of portland cement concrete.

In 1973 experiments were performed at BNL which indicated that glass and paper could be used as aggregate in PC formulations.² Potential applications as construction materials for sewer pipe, building block, chemical storage tanks, and insulating panels for use in energy storage systems were identified. Several pieces of glass polymer composite (GPC) sewer pipe were produced and installed in the Town of Huntington, on

Long Island and in Newark, New Jersey.

Based upon the above work, a preliminary cost analysis was performed³ and a technology transfer program was initiated.⁴ The latter resulted in the establishment of a cooperative program with an industrial company (Teledyne National) to utilize the glass fraction from a large urban waste plant in operation in Maryland.

In June 1976 the Office of Conservation of ERDA initiated support of the program. The goals for the program are as follows:

1. To provide the technical basis for energy conservation by the development, testing and practical demonstration of products made from industrial waste materials.

2. Rapid transfer and implementation of the technology in the private sector.

The program goals will be achieved by performing the following tasks:

1. Determine the properties of GPC sewer pipe to a degree that they are statistically acceptable with respect to relevant ASTM methods and standards.
2. Perform field testing of prototype and full-scale specimens.
3. Prepare energy budgets and cost analyses.
4. Involve the solid waste utilization industry in all phases of the program in order to provide a technical basis for the rapid implementation of the technology.

To date two progress reports on the program have been issued.^{5, 6} Accomplishments during the period January-March 1977 are summarized in

this report.

Task 1. GPC Property Measurements

Work to determine the minimum wall thickness of 8-in.-i.d. GPC sewer pipe required to meet the ASTM standard C-76 was continued.

In the previous report⁶ data from 4 batches of 8-in.-i.d. pipe specimens with a wall thickness of 1.50-in. were given. Each batch consisted of 3 sections of pipe and companion test cylinders. The GPC formulation used to fabricate the test specimens consisted of 88.25 wt% glass (see Table 1) and 11.75 wt% of a polyester-styrene mixture. The composition of the monomer was 9.5 wt% styrene from which the tert butyl pyrocatechol inhibitor had been removed, 1.75 wt% of a low viscosity polyester resin (Selectron 50293^a) and 0.5 wt% of a low shrinkage polyester resin (Grace 13024^b). A silane coupling agent, an internal release agent, and benzoyl peroxide -98, each at a concentration of 1% by weight of monomer were also included in the mix.

All of the samples for a batch were fabricated from a single GPC mix. After mixing in a conventional cement mixer until all of the aggregate was wetted with monomer (~ 3 min), the GPC was placed in the forms and compacted using an air-operated vibrator. The samples were then cured in an oven at a temperature of 82°C (180°F) for a minimum of 4 hrs.

The above procedure was continued during the current report period when pipe with wall thicknesses of 1.5, 1.0 and 0.625-in. were fabricated. The results from compressive and three-edge bearing

a, Supplier, PPG Industries, Inc.

b, Supplier, W. R. Grace Company

Table 1

Particle Size Distribution of Glass Used to
Produce GPC Pipe, Series No. 1

<u>U. S. Sieve Size</u>	<u>Experimental quantity retained, %</u>
No. 8	3.64
No. 20	19.33
No. 40	32.95
No. 60	20.16
No. 80	8.69
No. 100	2.57
Pan	12.66

strength measurements made on these samples are summarized in Tables 2 and 3, respectively. Included in the Tables are data (batches 258-261) which were given in the previous progress report. The results from earlier preliminary work with 0.9-in. wall pipe are also summarized in Table 3. The mean, standard deviation, and coefficient of variation for each wall size are listed. Good reproducibility is indicated. All of the data are being used in Task 3, Materials and Energy Estimate.

During the preparation of the 0.625-in. wall pipe, it became necessary to prepare additional glass of the desired particle size distribution. Rather than performing the time consuming effort of screening large quantities of Cockeysville and Bureau of Mines glass⁶ and blending the required amount of each fraction, tests were performed at the Sturtevant Mill Company to determine if the desired size distribution could be obtained by use of a roller mill. This information was also needed for cost and energy calculations. Preliminary tests indicated that this was feasible. However, when large quantities of waste glass containing metals and stones, were passed through the mill, unacceptably large variations in the particle size distribution were obtained.

As a possible alternate, glass was ground in a hinged-hammer pulverizer. Particle size distributions obtained are given in Table 4. Comparing these results with those used earlier (see Table 1), the glass contains a much higher percentage of fines. Using this glass in the GPC formulation described earlier, resulted in increases in compressive and three-edge bearing strengths of ~ 107% and 35%,

Table 2

Compressive Strength of GPC
Summary of Results, Series No. 1

Specimen size, 3-in.-diam. x 6-in.-long
Test procedure, ASTM C-39

<u>Batch No.</u>	<u>Compressive strength, psi</u>	<u>Mean</u>	<u>Standard deviation</u>	<u>Coefficient of variation</u>
258	6930 6620 6803 5254 6634 6120	6930	1052	0.164
259	5888 6610 6663	6387	451	0.071
260	8343 8473 8260 9012	8522	433	0.051
261	7680 7633 7763	7692	66	0.009
262	7610 7639 8473 8704 8929 9148	8417	654	0.078
263	9178 9325 7899 7941 9030	8675	697	0.080
264	8722	8722		
269	8243 7553 7787 7056	7660	494	0.064
Entire Series		7876	1062	0.135

Table 3

Three-Edge Bearing Strength of GPC Pipe
Summary of Results, Series No. 1

Specimen size, 12-in.-long x 8-in.-i.d.

Test procedure, ASTM C-497

Batch No.	Wall thickness, in.	Three-edge bearing strength lb/ftL - ft i.d.	Mean	Standard deviation	Coefficient of variation
258	1.50	10500 10039 9139	9893	692	0.070
259	1.50	10044 9591 9457	9697	308	0.032
260	1.50	10725 10800 11850	11125	628	0.056
261	1.50	9750 8325 9495	9190	760	0.083
262	1.50	10688 8859 9480	9676	930	0.096
263	1.50	12642 11435 10280	11452	1181	0.103
Entire Series			10170	1079	0.106
264	1.0	7717 7474 8866	8019	743	0.093
268	1.0	5401 6361 5218	5660	614	0.108
Entire Series			6839	1428	0.209
207	0.9	6643			
224	0.9	6747 5880	6313	613	0.097
227	0.9	5697			
228	0.9	6807			
Entire Series			6355	524	0.082
269	0.625	2783 2232 2663	2559	298	0.113
271	0.625	2418 2256	2337	114	0.049
Entire Series			2471	245	0.099

Table 4

Particle Size Distribution of Glass Used to
Produce GPC Pipe, Series No. 2

U. S. Sieve size	Experimental quantity retained, %		
	Batch No. 275	Batch No. 276	Batch No. 278
No. 20	6.34	4.04	9.13
No. 30	10.47	6.34	10.48
No. 40	16.03	11.62	13.33
No. 80	35.08	39.50	31.58
No. 100	3.78	3.48	3.02
No. 140	7.12	10.62	8.76
Pan	21.18	24.50	24.08

respectively. These data are summarized in Tables 5 and 6.

Tensile splitting strengths were also determined. The results, given in Table 7, indicate an average value of 2067 psi. A high quality concrete has a tensile splitting strength ~ 500 psi.

In addition to the strength improvements, reductions in polymer content are also obtained when the finer mix is used. Both effects will significantly reduce the energy-input requirements and cost of GPC pipe. As a result, some of the work in Task 1 will be repeated using the improved glass mixture. Pipe will be made at each of the wall sizes so that the properties can be computed on an acceptable basis. The results will then be used in calculations performed in Task 3.

Task 2. Field Test and Inspection

Monitoring of the performance of GPC pipe currently in test in Huntington, N.Y. and Newark, N.J. is being continued. At Huntington, a total of 35 ft of 8-in.-diam. pipe was installed during October 1972. Two pieces of pipe contained methyl methacrylate and 8 contained polyester-styrene. To date no problems with the pipe have been reported. A visual inspection was made in 1974 and another will be made during the latter half of FY 1977.

In November 1975 ~ 12 ft of 12-in.-diam. pipe was installed in a sewer line in Newark, N.J. The pipe is in an industrial part of the city and is exposed to acid-type waste from several chemical plants. Prior to installation the pipe was shown to conform to the ASTM strength and hydrostatic test specifications. The leakage rate at the joints was also measured as well below that specified by the City

Table 5

Compressive Strength of GPC
Summary of Results, Series No. 2

Specimen size, 3-in.-diam. x 6-in.-long
Test procedure, ASTM C-39

<u>Batch No.</u>	<u>Compressive strength, psi</u>	<u>Mean</u>	<u>Standard deviation</u>	<u>Coefficient of variation</u>
275	16845 16676 18662	17394	1101	0.063
276	19113 19197	19155	59	0.003
278	14254 15778	15016	1077	0.072
279	12901 14507	13704	1136	0.083
Entire Series		16317	2278	0.140

Table 6

Three-Edge Bearing Strength of GPC Pipe
Summary of Results, Series No. 2

Specimen size, 12-in.-long x 8-in.-i.d.
Test procedure, ASTM C-497

<u>Batch No.</u>	<u>Wall thickness, in.</u>	<u>Three-edge bearing strength lb/ftL - ft i.d.</u>	<u>Mean</u>	<u>Standard deviation</u>	<u>Coefficient of variation</u>
276	0.625	3582 3510	3544	51	0.014
278	0.625	3009 2868 2769	2882 3213	121 381	0.042 0.118
Entire Series					
279	1.50	14696 14580 14332	14536	186	0.013.

Table 7

Tensile Splitting Strength of GPC
Summary of Results, Series No. 2

Specimen size, 3-in.-diam. x 6-in.-long

<u>Batch No.</u>	<u>Tensile splitting strength, psi</u>	<u>Mean</u>	<u>Standard deviation</u>	<u>Coefficient of variation</u>
276	2471 2255 2587	2438	168	0.069
278	1904 2088 2024	2005	93	0.047
279	2017 1501	1759	365	0.207
Entire Series		2067	342	0.165

of Newark.

A T.V. inspection of the pipe was made during September 1976. No deterioration was apparent. Another inspection will be made in September 1977.

Task 3. Materials and Energy Estimate

Estimates of the materials and energy trade-offs of GPC pipe vis-a-vis replacing vitrified clay pipe or other sewer pipe, are being made. Production cost estimates will also be made.

Work in this task was started during the current report period. The data given in Table 3 were used to calculate the three-edge bearing strength as a function of wall thickness at a confidence level of 90%. The lower limit of the resultant envelope ($\bar{x} - \frac{z\sigma}{\sqrt{n}}$) was used to calculate the minimum failure stress. This value (1839 psi) was then used to calculate the GPC wall thickness required to meet the desired ASTM specification. A partial summary of results for GPC pipe and concrete sewer pipe meeting ASTM requirements is given in Table 8. As noted in the table, reductions in wall thickness generally ranging between 30 and 50% were calculated. At larger pipe diameters and for high strength pipe (Class VB), the differences between concrete and GPC become smaller, due primarily to the effect of the steel reinforcement in the concrete.

As a result of the higher strengths obtained by the use of finer-ground glass in Series No. 2, the above calculations will be revised during the next report period. Greater reductions in wall size are anticipated. Energy input calculations comparing GPC with vitrified clay, asbestos cement, and concrete pipe will also be made.

Table 8

Comparison of Wall Thickness Requirements for
Concrete and GPC Sewer Pipe

Test Series No. 1

ASTM specification	Required three-edge bearing strength, lb/ft ² - ft ² /d.	Diameter, in.	Wall thickness, in.		Reduction, %
			Concrete ^a	GPC	
C-14 Class 3	2400	6	0.875	0.558	36
		8	1.125	0.744	34
		10	1.25	0.930	26
		12	1.75	1.162	34
C-76 and C-14 Class IIA	1500	12	1.75	0.883	50
		18	2.0	1.324	34
		24	2.5	1.765	29
		30	2.75	2.206	20
		48	4.0	3.530	12
		72	6.0	5.295	12
		96	8.0	7.060	12
C-76 and C-14 Class IIB	1500	12	2.0	0.883	56
		18	2.5	1.324	47
		24	3.0	1.765	41
		30	3.5	2.206	37
C-76 and C-14 Class IIC	1500	36	4.75	2.648	44
		48	5.75	3.530	39
		60	6.75	4.413	35
		72	7.75	5.295	32
		96	9.75	7.060	28
C-76 and C-14 Class VB	3750	12	2.0	1.395	30
		18	2.5	2.093	16
		24	3.0	2.791	7
		30	3.5	3.489	0.3
		36	4.0	4.186	-4.7
		48	5.0	5.582	-12

a, contains steel reinforcement

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