DEVELOPMENT OF A GLASS POLYMER COMPOSITE SEWER PIPE FROM WASTE GLASS

PROGRESS REPORT NO. 5
JULY - SEPTEMBER 1977

MASTER

PROCESS SCIENCES DIVISION
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Abstract

Large quantities of energy can be conserved by recycling municipal solid waste. Reductions in the costs associated with waste disposal such as by landfilling can also be accrued. While uses for recycled ferrous and non-ferrous metals are apparent, uses for the glass fraction which constitutes $\sim 10\%$ of municipal solid waste, have not been developed. 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 the properties of glass polymer composite (GPC) sewer pipe have been measured, field testing of full-scale specimens has been initiated, and calculations made to determine the energy requirements and costs. Compared to vitrified clay pipe, the use of GPC can result in energy and cost savings of up to 16% and 44%, respectively. Work accomplished during the period July 1 - September 30, 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 and economic benefit. As the initial phase of this work, the properties of GPC were measured to a degree that they are statistically acceptable with respect to relevant ASTM methods and standards. 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 reduces the wall thickness from 30 to 50%.

Calculations have been made to determine the energy requirements to produce GPC and vitrified clay pipe. Conservative estimates indicate that the use of GPC can result in energy savings of up to 16%.

The cost of producing GPC utilizing glass from a 1,200 ton/day waste separation plant has been estimated. These calculations indicate that 6 to 48-in. GPC pipe can be produced at a cost from 11 to 44% less than the 1974 selling price of vitrified clay when a value of \$20/ton is assumed for the waste glass fraction. Substitution of GPC for reinforced concrete pipe up to a diameter of 36-in. will result in similar cost reductions.

Additional reductions in energy consumption and cost are anticipated as work to optimize the glass particle size distribution and resin content is performed.

Development of a Glass Polymer Composite Sewer Pipe from Waste Glass

Progress Report No. 5
July-September 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.

The particular application of GPC sewer pipe appeared quite attractive because of its high strength and durability to acids which exist in municipal sewage. GPC is far superior to concrete in these properties and potentially less energy intensive and less costly than vitrified clay and asbestos cement which are presently specified for sewage systems. Furthermore, this application takes a waste material generated by a municipality and converts it to a product which can readily be used by that same municipality.

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 are being achieved by performance of 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 four progress reports on the program have been issued.⁵⁻⁸ Accomplishments during the period July-September 1977 are summarized in the current report.

Task 1. GPC Property Measurements

Work scheduled for FY 1977 to determine the minimum wall thickness of 8-in.-i.d. GPC sewer pipe required to meet the ASTM Standard C-76 was completed.

The formulation used to produce the GPC consisted of 88.25 wt % glass and 11.75 wt % of a polyester-styrene mixture. The glass fraction was obtained from the Cockeysville, Maryland solid waste separation plant and contained small quantities of organics, metal, and stones. A typical analysis is given in Table 1. The glass was then dried and ground.

A monomer mixture consisting of 81 wt % inhibitor-free styrene, 14.9 wt % of low viscosity polyester resin, and 4.1 wt % of a low shrinkage polyester was then mixed with the glass fraction. Prior to mixing, a silane coupling agent, an internal release agent, and a polymerization initiator, each at a concentration of 1% by weight of monomer were added to the monomer.

The PC formulation was mixed in a conventional concrete mixer until all of the glass aggregate was wetted with monomer. It was then placed in the pipe forms and compacted using air-operated vibrators. A description of the forms is given in Ref. 6. The pipes were then cured in an oven at a temperature of 82°C for 4 hr.

Table 1

Composition of Glass Fraction
Separated from Munciple Waste

Source: Cockeysville, Maryland

<u>Material</u>	<u>Amount, %</u>
Glass	95.62
Ceramics	1.03
Metals	0.21
Organics	0.21
Plastics	0.06
Stones	2.87

In Progress Report No. 3,⁷ it was reported that increases in the compressive strength and three-edge bearing strength of GPC occurred as the percentage of glass fines in the mix was increased. This also resulted in a decreased concentration of monomer in the formulation. Since both effects significantly reduce the energy input requirements and cost of GPC pipe, it was decided to repeat some of the earlier work using the improved glass mixture. The work was started during the previous report period⁸ and completed during the current quarter. All of these results are summarized in Table 2 and in Figure 1. The curve in Figure 1 represents the lower limit of the data at the 90% confidence level $(\bar{x} - \frac{2\sigma}{\sqrt{n}})$ for wall thicknesses of 0.625 and 1.50-in. These data were then utilized in cost and energy estimates which are summarized in Task 3.

Task 2. Field Test and Inspection

Monitoring of the performance of GPC currently in test at Huntington, New York and Newark, New Jersey is continuing. At Huntington, a total of 35 ft of 8-in.-diam sewer pipe has been in test since October 1972. Two sections of pipe contain methyl methacrylate and 8 others contain polyester-styrene. To date no problems with the pipe have been reported. A visual inspection of the pipe was made in 1974. A second inspection, originally scheduled for the current report period, has been rescheduled to FY 1978.

Twelve feet of 12-in.-diam pipe has been in test in Newark since November 1975. 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 2

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

Batch No.	Wall thickness, in.	Three-edge bearing strength, lb/ft _L -ft _{id}	Mean	Standard deviation	Coefficient of variation
276	0.625	3510 3582			
278		3010 2870 2770			
298		2051 2670			
Entire Series			2923	522	0.18
283	1.0	4656 4808 5349			
286		6159 6036 6609			
292		6810 7011			
296		5727 5602 6356			
Entire Series			5920	776	0.13
279	1.5	14703 14587 14340			
282		14714 13915 14370 15341 14153 14308			
Entire Series			14492	410	0.03

Figure 1. Three-edge bearing strength of Glass Polymer Pipe.

A TV inspection of the pipe was made during September 1976. No deterioration was apparent. A second inspection, originally scheduled for the current report period, has been rescheduled to FY 1978.

Arrangements have been made to initiate a second test at Newark. In this test, three 5 ft lengths of 12-in.-diam pipe will be installed at a location where the pH in steady operation is 2.4. The fabrication and hopefully the installation of the specimens will take place during the next report period.

Task 3. Materials, Cost, and Energy Estimates

During the report period revisions to preliminary estimates⁸ of the energy requirements to produce GPC pipe were initiated and cost calculations were made. Comparisons with vitrified clay and concrete sewer pipe were also prepared.

Energy Consumption

In the previous report⁸ results were given from preliminary estimates for the energy requirements to produce GPC and vitrified clay pipe. These calculations were based upon literature values for the ultimate energy consumption for polystyrene resin ranging between 116×10^6 BTU/ton⁹ and 50×10^6 BTU/ton.¹⁰ When the former was used, the calculations indicated energy savings up to 16% could be accrued by the use of GPC as a replacement for vitrified clay. At 50×10^6 BTU/ton the energy savings is 64%. These calculations are currently being revised to reflect the latest series of three-edge bearing strength measurements (Figure 1). The use of these data will result in additional savings in energy due to the reduced wall thickness requirements.

Cost Estimates

The cost of producing GPC sewer pipe utilizing the waste glass from the Cockeysville, Maryland 1,200 ton/day waste separation plant, operated for Maryland Environmental Services by Teledyne National, was estimated. The basis for the calculations and a process flow sheet are given in Table 3 and Figure 2, respectively.

The plant was designed to produce pipe of size ranging between 6 and 48-in. The quantity and size distribution of sewer pipe to be produced was estimated from the quantities utilized by the City of Baltimore during the period 1971-72, adjusted at an assumed annual growth rate of 10%. Based upon this assumption, the required GPC output from the plant would be ~ 7825 ton/yr.

Each of the process components listed on Figure 2 were sized and an installed cost based upon mid 1977 prices determined. These costs are summarized in Table 4. Based upon an installed equipment cost of \$327,000, a capital cost for the plant of \$1,308,000 was calculated (see Table 5).

Estimates of the annual operating expenses were also made. These results, summarized in Table 6, indicate a GPC production cost of 9.7¢/lb.

A comparison of the estimated production cost of GPC with the October 1974 cost of reinforced concrete and vitrified clay sewer pipe is given in Table 7. Since the separated glass fraction may have value in other processes (cullet, insulation, etc.), three assumed values for the glass (0, 10, and \$20/ton) have been considered.

As indicated in Table 7, the production cost of GPC sewer pipe of diameter 6 to 48-in. is from 11 to 44% less than the 1974 selling price of vitrified clay when a value of \$20/ton is assumed for the waste glass

Table 3

GPC Sewer Pipe Plant Design Data

Basis for Design

Solid Waste Separation Plant

Waste input	1200 ton/day
Operating time	10 hr/day, 300 day/yr
Primary ferrous metal recovery	5.9%
Primary non-metallic recovery	37.5%
Recovery of glass fraction from non-metallic recovery	5.3%

GPC Plant

Operating time	24 hr/day, 350 day/yr
Operating factor	90%
GPC mix composition	
glass	87.49%
styrene	9.82%
polyester-styrene	2.33%
coupling agent	0.12%
release agent	0.12%
initiator (benzoyl peroxide)	0.12%
Curing cycle	4 hr at 82°C
Loss of GPC components during processing	5%

Figure 2. Process flow sheet for the production of GPC sewer pipe.

Table 4

Installed Cost of Equipment for GPC Sewer Pipe Plant

Item No. (a)	Equipment	Installed cost, (b) \$
1	raw glass conveyor	12,600
2	raw glass silo	20,500
3	transfer conveyor	2,100
4	dryer feed elevator	3,900
5	raw glass dryer	46,000
6	dry glass elevator	5,600
7	sump pump	1,500
8	dry glass mill	6,900
9	milled glass hopper	400
10	change can mixer	41,400
11	molds and vibrators	84,600
12	curing oven	21,400
13	mold storage	16,000
14	fork lift truck	14,900
18	external release agent tank	100
19	external release agent pump	480
20	trolley hoist	2,030
21	styrene tank	12,900
22	styrene pump	950
23	polyester resin No. 1 tank	4,100
24	polyester resin No. 1 pump	900
25	polyester resin No. 2 tank	4,100
26	polyester resin No. 2 pump	900
27	catalyst solution tank	1,900
28	catalyst solution pump	900
29	internal release agent tank	4,100
30	internal release agent pump	900
31	bonding agent tank	150
32	bonding agent pump	900
33	solvent tank	3,600
34	solvent pump	1,710
35	dust collector and blower	8,400
40	static mixer	540
Total		\$327,000

a, refers to Figure 2.

b, mid 1977 prices.

Table 5

Capital Cost of GPC Sewer Pipe Plant

Component	Fraction of capital cost (a)	Cost, (b) \$
installed process equipment	25.0	327,000
site preparation	1.1	14,388
concrete	2.0	26,160
structural steel	1.6	20,928
building	1.0	13,080
pipng	8.0	104,640
electrical	5.8	75,864
instrumentation	2.0	26,160
insulation	1.0	13,080
fire loop and hydrants	0.5	6,540
painting	0.5	6,540
spares	0.5	6,540
project indirects	15.0	196,200
home office	15.0	196,200
field expenses	8.0	104,640
working capital	3.0	39,240
contingency	10.0	130,800
Total	100.0	1,308,000

a, based upon data given in Perry's Chemical Engineering Handbook, Vol. V, pages 16-25.

b, mid 1977 costs.

Table 6

Operating Costs for GPC Sewer Pipe Plant

<u>Item</u>	<u>Cost, \$/yr</u>
raw materials	795,686
utilities	30,608
direct labor and supervision	231,840
fringe benefits	57,960
maintenance	81,946
insurance	6,540
subtotal	1,204,580
G & A (assume 15%)	180,687
Amortization (assume 10%/yr)	130,800
total	1,516,067
GPC output, lb/yr	15,651,249
Unit production cost, ¢/lb	9.69

Table 7

Comparison of Cost of GPC, Reinforced Concrete, and Vitrified Clay Sewer Pipe

Size, in.	GPC at assumed value of glass, \$/ton			RC, ^a	Difference, ^b	VC, ^a	Difference, ^c
	0	10	20	\$/ft	%	\$/ft	%
6	1.04 ^d	1.10	1.16	--	--	1.55	25
8	1.64	1.74	1.83	--	--	2.14	14
10	2.38	2.52	2.66	--	--	3.55	25
12	3.25	3.44	3.63	5.60	35	4.78	24
15	5.08	5.38	5.67	6.89	18	6.92	18
15R	3.48	3.68	3.88	6.89	44	6.92	44
18	5.38	5.70	6.01	8.30	27	9.43	36
21	6.96	7.36	7.77	11.34	31	12.32	37
24	9.57	10.13	10.68	12.89	17	15.60	31
27	11.64	12.32	12.99	14.45	10	20.30	36
30	13.91	14.71	15.52	18.63	17	23.80	35
33	17.52	18.53	19.55	21.26	8	28.66	32
36	20.28	21.45	22.63	23.09	2	33.19	32
42	27.84	29.45	31.08	27.68	-12	38.75	20
48	36.61	38.72	40.86	30.04	-36	45.76	11

RC, reinforced concrete

VC, vitrified clay

a, selling price 10/4/74

b, $\left(\frac{\text{RC-GPC at } \$20/\text{ton}}{\text{RC}} \right) 100\%$ c, $\left(\frac{\text{VC-GPC at } \$20/\text{ton}}{\text{VC}} \right) 100\%$

d, \$/ft

fraction. Substitution of GPC for reinforced concrete pipe up to 36-in. diam will yield similar cost reductions. For larger diameters, GPC is more expensive than concrete pipe even when the value of the glass fraction is assumed to be zero.

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