PCM composites can be made using residues "as received" from the source. However, the amount of residue which can be incorporated into the composite is significantly less than that which can be added to a PC composite. In addition, compressive strengths of the PCM composites were shown to decrease with increasing residue content.

Based upon the data presented, it is felt that much more research is required to properly determine the long-term characteristics of PC and PCM composites before they can be utilized as a means of stabilizing hazardous geothermal residues.

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TABLE 1--PIXE SPECTROSCOPY ANALYSIS OF GEOTHERMAL RESIDUES

ELEMENT[a]	CONCENTRATION, mg/liter			
	RESIDUE			
	BR1	BR2	BR3	BR4
Titanium (Ti)	12,870 ± 1,900	20,530 ± 2,300	12,500 ± 1,710	4,380 ± 160
Vanadium (V)	7,130 ± 1,430	13,090 ± 836	7,080 ± 1,080	2,380 ± 111
Chromium (Cr)	1,530 ± 390	1,870 ± 208	1,180 ± 202	1,070 ± 170
Manganese (Mn)	1,980 ± 440	3,300 ± 79	1,530 ± 220	1,370 ± 91
Iron (Fe)	31,310 ± 6,300	54,340 ± 9,490	22,680 ± 4,870	41,220 ± 3,390
Nickel (Ni)	——	——	——	——
Copper (Cu)	38 ± 6	373 ± 25	296 ± 8	635 ± 48
Zinc (Zn)	65 ± 19	131 ± 7	216 ± 86	1,070 ± 145
Arsenic (As)	——	——	——	774 ± 117
Bromine (Br)	——	——	26 ± 2	——
Rubidium (Rb)	79 ± 23	70 ± 14	118 ± 35	342 ± 10
Strontium (Sr)	4,950 ± 1,430	5,130 ± 92	3,540 ± 700	1,660 ± 165
Zirconium (Zr)	9,780 ± 480	1,210 ± 160	895 ± 280	340 ± 41
Lead (Pb)	124 ± 35	140 ± 19	52 ± 7	1,300 ± 124

[a] In addition to the elements listed, the residues also contained various levels of phosphorus, sulfur, chlorine, potassium and calcium.

TABLE 2--GAMMA PULSE HEIGHT ANALYSIS OF GEOTHERMAL RESIDUES, NATURAL PRODUCTS

NUCLIDE	Half Life, yr	ACTIVITY, μCi/gm			
		RESIDUE			
		BR1	BR2	BR3	BR4
K-40	20,000	3.80 E-5	4.13 E-5	5.79 E-5	2.34 E-5
Bi-211	70,000	1.06 E-3	9.42 E-4	1.15 E-3	3.07 E-4
Bi-212	14,000	1.30 E-4	4.07 E-5	5.16 E-5	1.70 E-5
Bi-214	1,602	2.97 E-4	2.75 E-4	3.49 E-4	8.76 E-5
Pb-212	14,000	1.58 E-4	4.90 E-5	6.63 E-5	2.20 E-5
Pb-214	70,000	4.26 E-4	3.66 E-4	4.46 E-4	1.19 E-4
Tl-208	14,000	1.25 E-4	4.07 E-5	5.16 E-5	1.71 E-5
Ra-224	14,000	9.89 E-4	5.70 E-4	9.76 E-4	2.57 E-4
Ra-226	1,602	3.63 E-4	2.68 E-4	3.40 E-4	8.52 E-5
Th-228	14,000	1.48 E-4	4.71 E-5	6.38 E-5	2.12 E-5
Th-234	70,000	2.04 E-5	2.11 E-5	4.08 E-5	4.89 E-6
Ac-228	14,000	3.26 E-4	3.98 E-4	4.70 E-4	1.22 E-4

TABLE 3--MOISTURE CONTENT AND pH OF GEOTHERMAL RESIDUES

	RESIDUE			
	BR1	BR2	BR3	BR4
Moisture content of solids, wt %	15	10	19	39
pH of excess fluid after settlement of solids	1.67	—[a]	3.35	5.10

[a] Residue contained no free moisture.

TABLE 4--48 HOUR WET ANALYSIS OF "AS RECEIVED" GEOTHERMAL RESIDUES

RESIDUE	ELEMENTAL CONCENTRATION,[a] mg/l													
	Sb	As	Ba	Cd	Cr	Co	Cu	Pb	Mo	Ni	Ag	V	Zn	Hg
BR1	3	ND[b]	27	0.2	<0.1	0.2	0.8	3.5	ND	0.5	<0.1	ND	18	<<0.01
BR2	0.7	ND	29	<0.1	ND	<0.1	0.4	0.3	ND	ND	ND	ND	1	<<0.01
BR3	40	13	24	0.2	0.5	0.5	20	9.3	ND	0.8	<0.1	ND	17	<<0.01
BR4	17	77	19	2.3	96	0.9	0.1	136	ND	1.2	<0.1	ND	215	<<0.01
STLC[c]	100	5	100	1	5	80	25	5	350	20	5	24	250	0.2

[a] Values reported are the highest concentration measured in three separate tests.

[b] ND = not determined.

[c] STLC = soluble threshold limit concentration.

TABLE 5--ENCAPSULATION OF RESIDUE BR1 USING ALTEK 78-50 EMULSIFIABLE POLYESTER

MIX DESIGN	CONDITION OF RESIDUE	COMPRESSIVE[a] STRENGTH, psi	48-hr WET Analysis				
			Elemental Concentration, mg/l				
			Ba	Cr	Cu	Pb	Zn
25 wt% resin 75 wt% BR1	As Received	3695	17.0	<0.1	0.5	1.9	18.0
30 wt% resin 70 wt% BR1	Dried	5475	20.0	<0.1	0.5	1.4	10.2
32 wt% resin 68 wt% BR1	Washed & Dried	12,900	23.0	<0.1	0.3	0.5	1.9
STLC[b]	——	——	100	5	25	5	250

[a] Average of three test specimens. 1 psi = 0.00689 MPa.

[b] STLC = soluble threshold limit concentration.

TABLE 6--ENCAPSULATION OF RESIDUES USING AN MMA-BASED MONOMER

MIX DESIGN[a]	CONDITION OF RESIDUE	COMPRESSIVE STRENGTH, psi[b]	48-hr WET Analysis				
			Elemental Concentration, mg/l				
			Ba	Cr	Cu	Pb	Zn
30 wt% MMA 70 wt% BR1	Dried	4165	33	0.4	0.3	0.1	1.0
30 wt% MMA 70 wt% BR2	Dried	16,500	30	ND[e]	0.3	0.1	0.6
30 wt% MMA 70 wt% BR3	Dried	5,400	23	0.1	9.5	2.1	—
30 wt% MMA 70 wt% BR4	Dried	0[c]	—	—	—	—	—
STLC[d]	——	——	100	5	25	5	250

[a] Monomer system = 75 wt% MMA - 25 wt% PMMA with 4 wt% BFF 50 benzoyl peroxide initiator and 1 wt% dimethyl-para-toluidine promoter.
[b] Average of 3 specimens. 1 psi = 0.00689 MPa.
[c] Unable to cure sample.
[d] STLC = soluble threshold limit concentration.
[e] ND = not detectable.

TABLE 7--COMPRESSIVE STRENGTHS OF PCM COMPOSITES CONTAINING GEOTHERMAL RESIDUES

PCM SYSTEM[a]	CONDITION OF RESIDUE	28-DAY COMPRESSIVE STRENGTH, psi[b]	CONDITION OF RESIDUE	28-DAY COMPRESSIVE STRENGTH, psi
Control - No Residue	--	4295	--	--
7 wt% BR1	Dried	4930	As Received	5160
18 wt% BR1	--	--	As Received	4700
7 wt% BR2	Dried	5530	As Received	5445
18 wt% BR2	--	--	As Received	2875
7 wt% BR3	Dried	4840	As Received	5265
18 wt% BR3	--	--	As Received	4450
7 wt% BR4	Dried	4135	As Received	4895
18 wt% BR4	--	--	As Received	3110

[a]Residue content is based on dry weight of the total solid content of mix.
[b]1psi = 0.00689 MPa.

TABLE 8--48 HOUR WET ANALYSIS OF PCM COMPOSITES CONTAINING GEOTHERMAL RESIDUES

PCM[a] SYSTEM	CONDITION OF RESIDUE	ELEMENTAL CONCENTRATION,[a] mg/l				
		Ba	Cr	Cu	Pb	Zn
Control - No Residue	--	1.4	0.1	0.2	ND[b]	0.1
7 wt% BR1	Dried	NT[c]	0.4	0.2	ND	0.1
7 wt% BR2		NT	0.4	0.3	0.1	0.2
7 wt% BR3		NT	0.5	0.8	0.1	0.1
7 wt% BR4		NT	1.2	2.7	1.8	0.8
7 wt% BR1	As Received	2.7	0.5	0.3	ND	0.1
18 wt% BR1		2.8	0.4	0.5	0.2	0.1
7 wt% BR2		2.6	0.6	0.2	ND	0.1
18 wt% BR2		3.1	0.4	0.4	0.2	0.1
7 wt% BR3		3.5	0.4	0.7	0.1	0.1
18 wt% BR3		2.5	0.4	2.6	0.3	0.1
7 wt% BR4		3.0	1.5	2.6	1.4	0.5
18 wt% BR4		1.8	5.0	9.0	5.4	2.5
STLC[d]		100	5	25	5	250

[a] Residue content is based on dry weight of the total solid content of mix.
[b] ND = not detectable.
[c] NT = no test.
[d] STLC = soluble threshold limit concentration.

Repair of Cracked Concrete with High Molecular Weight Methacrylate Monomers

by D.J. Rodler, D.P. Whitney,
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Synopsis: Three high molecular weight methacrylate monomer systems were tested to determine their effectiveness in repairing cracked portland cement concrete. Ultimate strains across repaired cracks, modulus of rupture, and percent of crack filled for slabs repaired with the monomers and stiffnesses of repaired beams were investigated. Tests on small, cracked slabs were also conducted under hot and wet conditions. One hundred thirty-five PCC slabs, 9 PCC beams, and 12 tension specimens were tested. The results varied with respect to the stiffnesses of the polymers. All monomer systems were shown to increase the stiffness of cracked flexural members and to fill cracks as small as 0.1 mm in width. The performance of the systems was adversely affected by moisture and heat. Minimum drying periods after saturation of the cracked concrete with water were determined.

Keywords: beams (supports); concrete slabs; cracking (fracturing); methacrylates; monomers; repairs; tests

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INTRODUCTION

Small cracks in bridge decks and reinforced pavements can allow water to infiltrate and corrode reinforcing steel. One simple solution to sealing cracks is the use of high molecular weight methacrylate (HMWM). HMWM refers to dicyclopentenyl methacrylate and its close relatives. This family of methacrylate monomers have been developed specifically for concrete repairs and all have viscosities in the range of 8 to 40 cps. The monomer system is poured or sprayed onto the concrete and brushed into the cracks. Research at The University of Texas at Austin (2,4) has shown HMWM monomers to be well suited for repair of narrow cracks in portland cement concrete.

The purpose of the research described in this paper was to evaluate the structural integrity of the repaired cracks as well as the capability of the material to fill the cracks. Adverse conditions, including moisture and heat, for applying the monomer were considered to determine the effects on the filling of cracks and the strength of the bond.