GAS TECHNOLOGY INSTITUTE

Cement-Lock Demo Plant

Ecomelt - Passaic River Sediment

Cement-Lock® Technology for Decontaminating Dredged Estuarine Sediments

Topical Report on Beneficial Use of Ecomelt from Passaic River Sediment at Montclair State University, New Jersey

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Submitted to:

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April 2008

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213389

EXECUTIVE SUMMARY

This topical report on "Beneficial Use of Ecomelt from Passaic River Sediment at Montclair State University, New Jersey" describes the work conducted as part of the overall program "Cement-Lock®[1] Technology for Decontaminating Dredged Estuarine Sediments." The work was performed by the Gas Technology Institute (GTI, Des Plaines, IL) and its wholly owned subsidiary, ENDESCO Clean Harbors (ECH, Des Plaines, IL) for the U.S. Environmental Protection Agency Region 2 and the U.S. Army Corps of Engineers (New York District) with technical and contractual support through Brookhaven National Laboratory (BNL, Contract No. 725043). Funding for the beneficial use task was provided to GTI from BNL through the federal Water Resources Development Act.

Beneficial Use Project: CTLGroup (formerly Construction Technology laboratories, Skokie, IL) conducted tests on a small sample of Ecomelt from Passaic River sediment to determine its suitability as a partial replacement for Portland cement in concrete. CTLGroup also prepared a batch of concrete made with Ecomelt (40% replacement of Portland cement) and conducted specific concrete-related tests on the concrete produced. The objective of these tests was to characterize the concrete and establish a mix design for the beneficial use project at Montclair State University (MSU), Montclair, New Jersey. For the beneficial use project, a length of sidewalk (165 feet long by 6 feet wide) will be poured on the MSU campus. The results of tests conducted by CTLGroup are summarized below.

CTLGroup also ground about one ton of Ecomelt to cement fineness (<50 μm) using a batch ball mill. The ground Ecomelt will be used for producing a batch of concrete for pouring a length of sidewalk (165 feet long by 6 feet wide) at MSU. An Acceptable Use Determination (AUD) was issued by the New Jersey Department of Environmental Protection (NJ-DEP) to ECH for the beneficial use project. The one ton of Ecomelt in five 55-gallon drums was shipped to MSU on May 1, 2008.

[1] Inquiries regarding commercial application of Cement-Lock® Technology may be directed to the technology owner, Volcano Group LLC, 557 North Wymore Road, Suite 100, Maitland, FL 32751, phone (877) 326-6358 / (877) ECOMELT.

Characterization of Ecomelt from Passaic River Sediment: The sample of Ecomelt was finely ground and blended with ordinary Portland cement at a 40:60 Ecomelt/Portland cement weight ratio. The blended cement was subjected to compressive strength tests according to ASTM C 595 specifications for blended cements. The results (Table ES-1) showed that after 7 and 28 days of curing, the mortar samples made with 40:60 Ecomelt/Portland cement blend exceeded the compressive strength of the control mortar specimens.

Based on the results, CTLGroup concluded that "the Ecomelt appears to be potentially suitable as a 40% replacement for Portland cement in concrete for use in general construction and/or where high early strength is required." CTLGroup further recommended that additional tests be conducted on a larger batch of Ecomelt so that an appropriate concrete mix design could be developed for a specific application.

Table ES-1. Results of Compressive Strength Tests Conducted on Mortar Samples Made with Ecomelt/Portland Cement Blend (40:60 wt %) and Control Cement

Days of Curing	Ecomelt/Portland Cement Blend Mortar	Control Mortar
	Compressive Strength, psi (MPa)	
1	1,800 (12.4)	--
3	3,680 (25.4)	3,690 (25.5)
7	5,300 (36.5)	4,860 (33.6)
28	7,550 (52.1)	6,900 (47.8)

Subsequently, ECH provided several hundred pounds of Ecomelt from Passaic River sediment to CTLGroup to conduct the recommended tests, including compressive strength, flexural strength, drying shrinkage, freeze-thaw testing, deicing-scaling, and chloride permeability. The compressive strength tests results (Table ES-2) showed that after 28 and 56 days of curing, the Ecomelt/Portland cement blend achieved 5,700 psi; while the control achieved 5,950 psi. After 56 days of curing, the compressive strength results were the same. These results show that concrete made with the 40:60 Ecomelt/Portland cement blend may require an accelerator for high early strength applications.

The results of the drying shrinkage test showed that the concrete made with the Ecomelt/Portland cement blend had a slightly lower shrinkage than the control.

Table ES-2. Results of Compressive Strength Tests Conducted on Concrete Samples Made with Ecomelt/Portland Cement Blend (40:60 wt %) and Control Cement

Days of Curing	Ecomelt/Portland Cement Blend Concrete	Control Concrete
	Compressive Strength, psi (MPa)	
4	2,850	4,500
7	3,450	4,800
28	5,700	5,950
56	6,650	6,650

Also, after 301 freeze-thaw cycles, the Ecomelt/Portland blend specimens had a slightly higher relative dynamic modulus of elasticity of 91 percent compared to 90 percent for the control.

The Ecomelt/Portland blend specimens showed lower resistance to deicer scaling than the control.

The Ecomelt/Portland blend specimens showed "Very Low" chloride permeability compared to "Moderate" chloride permeability for the control, where a lower result is preferred.

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I. BENEFICIAL USE DEMONSTRATION OF CEMENT-LOCK® ECOMELT®

The beneficial use project with Ecomelt produced from Passaic River sediment at the Cement-Lock demonstration plant (Bayonne, NJ), and chemical and physical characterization of Ecomelt for the beneficial use project are described below.

Beneficial Use Project

The objective of the beneficial use project is to demonstrate that the Ecomelt produced from Passaic River sediment can be used successfully and in an environmentally acceptable manner in a general construction project. For this beneficial use project, Ecomelt will be used as a partial replacement for Portland cement in the production of a batch of concrete. The concrete will be used to pour a length of sidewalk (165 feet long by 6 feet wide) at Montclair State University, Montclair, New Jersey. The concrete pouring/placement is tentatively planned for June/July 2008.

To this end, about one ton of Ecomelt from Passaic River sediment was dried and ground to cement fineness (<50 μm) in a batch ball mill. The batch grinding work was performed at the laboratories of CTLGroup (formerly Construction Technology Laboratories, Skokie, IL). CTLGroup also conducted the Ecomelt characterization testing described below. The two reports prepared by CTLGroup for this work are included in Appendix A.

As part of their work, CTLGroup developed a mix design for the Ecomelt that can be used for the beneficial use project. The mix design (Table 1) specifies the amounts of Ecomelt, Portland cement, sand, gravel, water, and admixtures that must be mixed together to yield concrete with the desired properties for the beneficial use application. Ecomelt is used as a 40 percent (by weight) replacement for Portland cement in the mix design.

A formal application for Acceptable Use Determination (AUD) was submitted to New Jersey Department of Environmental Protection (NJ-DEP) for the beneficial use project. The AUD application, supporting documentation, and AUD issued by NJ-DEP are included in Appendix B. The one ton of Ecomelt in five 55-gallon drums was shipped to MSU on May 1, 2008.

Characterization of Ecomelt from Passaic River Sediment

CTLGroup conducted tests on samples of Ecomelt from Passaic River sediment to determine suitability as a partial replacement for Portland cement in concrete. The objective of these tests was to characterize the concrete and establish a mix design for the beneficial use project at Montclair State University. The results of these tests are summarized below.

Table 1. Mix Design for Ecomelt/Portland Cement Concrete Batching

Mixes	**Control**	**Ecomelt/Portland**
Type I cement (Portland), wt %	100	60
Ecomelt, wt %	0	40
Mix Design		
Cement (Continental), lb	564	338.4
Ecomelt (GTI), lb	0	225.6
1" Coarse Aggregate (Vulcan), lb	1875	1875
Fine Aggregate (McHenry Sand), lb	1256	1222
Water (City), lb	255	255
Air Entraining Agent (Daravair), oz/cwt	1.00	2.55
Water Reducing Agent (WRDA 64), oz/cwt	4.25	5.00
Fresh Properties		
Fresh Density, lb/ft^3	145.4	145.4
Slump, inches	4.00	4.00
Air content, %	6.2	5.7
Yield, ft^3/yd^3	27.2	26.9
Time of Setting		
Initial, hr:min	6:21	6:33
Final, hr:min	7:37	8:19

The initial sample of Ecomelt was finely ground and blended with ordinary Portland cement at a 40:60 Ecomelt/Portland cement weight ratio. Forty percent was selected because it represents the maximum replacement of Portland cement by a pozzolanic material allowed under ASTM C 595 (Standard Specification for Blended Hydraulic Cements). The blended cement was subjected to compressive strength tests according to ASTM C 109 (mortar samples) and the results compared with C 595 specifications. The results (Table 2) showed that after 7 and 28 days of curing, the mortar samples made with 40:60 Ecomelt/Portland cement blend exceeded the compressive strength of the control mortar specimens as well as the ASTM C 595 specifications for blended cement.

In their report, CTLGroup concluded that "the Ecomelt appears to be potentially suitable as a 40% replacement for Portland cement in concrete for use in general construction and/or where high early strength is required." CTLGroup further recommended that additional tests be conducted on a larger batch of Ecomelt so that an appropriate concrete mix design can be developed for a specific application.

Table 2. Results of Compressive Strengths Tests Conducted on Mortar Samples Made with Ecomelt/Portland Cement Blend (40:60 wt %) and Control Cement

Days of Curing	Ecomelt/Portland Blended Cement Mortar	Control Mortar	ASTM C 595 Specification
	Compressive Strength, psi (MPa)		
1	1,800 (12.4)	--	--
3	3,680 (25.4)	3,690 (25.5)	1,890 (13.0)
7	5,300 (36.5)	4,860 (33.6)	2,900 (20.0)
28	7,550 (52.1)	6,900 (47.8)	3,620 (25.0)

Subsequently, ECH provided several hundred pounds of Ecomelt from Passaic River sediment to CTLGroup to conduct the recommended larger-scale tests. The tests are standard methods from the American Society for Testing and Materials (ASTM) and include:

- Standard Test Method for Time of Setting of Concrete Mixtures by Penetration Resistance (ASTM C-403)
- Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens (ASTM C-39)
- Standard Test Method for Flexural Strength of Concrete (Using Simple Beam with Third-Point Loading) (ASTM C-78)
- Standard Test Method for Length Change of Hardened Hydraulic-Cement Mortar and Concrete (AST C-157)
- Standard Test Method for Resistance of Concrete to Rapid Freezing and Thawing (ASTM C-666)
- Standard Test Method for Scaling Resistance of Concrete Surfaces Exposed to Deicing Chemicals (ASTM C-672)
- Standard Test Method for Electrical Indication of Concrete's Ability to Resist Chloride Ion Penetration [ASTM C-1202 (AASHTO T 277)]

The results of these tests are discussed in detail below. As mentioned above, the complete reports prepared by CTLGroup are included in Appendix A.

Time of Setting of Concrete: The initial and final setting times for the Ecomelt/Portland cement blend concrete and Portland cement concrete control samples were determined according to ASTM C 403. The initial setting times (refer to Table 1) were similar for the control and test mix at 6:21 and 6:33 (hr:min), respectively. The final setting times were 7:37 and 8:19 (hr:min) for the control and test mix, respectively. Pozzolanic materials such as Ecomelt are typically slow to react, but eventually achieve characteristics similar to those of ordinary Portland cement. In the event that a quicker setting time is required, an accelerator such as calcium chloride could be added to the concrete mix.

Compressive Strength: The compressive strengths of cylindrical concrete specimens (4 inches in diameter by 8 inches long) were determined after 4, 7, 28, and 56 days of curing. The results presented in Table 3, show that the compressive strengths of the Ecomelt/Portland cement blend specimens were 2,850 psi, 3,450 psi, 5,700 psi, and 6,650 psi, respectively. The compressive strengths measured were 63 percent, 72 percent, 96, and 100 percent of the control after 4, 7, 28, and 56 days, respectively. The Ecomelt-based blended cement achieved compressive strength at a slower rate than the control. However, it does gain strength with time. Figure 1 shows a specimen of Ecomelt-based blended cement concrete ready for compressive strength testing. Figure 2 shows the specimen after testing. It showed a typical conical break.

Table 3. Results of Compressive Strengths Tests Conducted on Concrete Samples Made with Ecomelt/Portland Cement Blend (40:60 wt %) and Control Cement

Days of Curing	Ecomelt/Portland Blended Cement Concrete	Control Concrete
	Compressive Strength, psi (MPa)	
4	2,850	4,500
7	3,450	4,800
28	5,700	5,950
56	6,650	6,650

Flexural Strength: The flexural strengths (modulus of rupture) of concrete block specimens were determined after 4, 7, and 28 days of curing to be 510 psi, 660 psi, and 910 psi, respectively. The flexural strengths measured were 74 percent, 89 percent, and 99 percent of the control after 4, 7, and 28 days, respectively. Figure 3 shows a specimen of Ecomelt-based blended cement concrete ready for flexural strength testing. Figure 4 shows the specimen after testing. The specimen fractured at the tension surface within the middle one-third of the span length.

Drying Shrinkage: The drying shrinkage characteristics of the control and test mix concrete specimens were determined according to ASTM C 157. After 56 days of curing, the control

Figure 1. Concrete Cylinder of Ecomelt-Based Blended Cement in Position for Compressive Strength Testing at CTLGroup Laboratories


Figure 2. Concrete Cylinder of Ecomelt-Based Blended Cement After Compressive Strength Testing at CTLGroup Laboratories

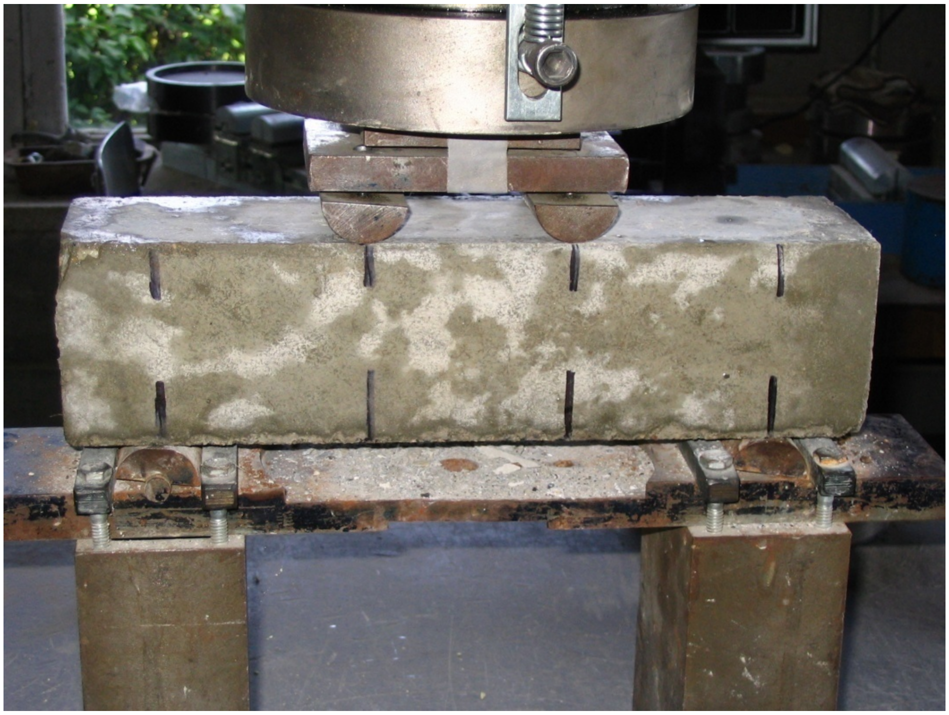

Figure 3. Concrete Block of Ecomelt-Based Blended Cement in Position
for Flexural Strength Testing at CTLGroup Laboratories

Figure 4. Concrete Block of Ecomelt-Based Blended Cement After
Flexural Strength Testing at CTLGroup Laboratories

specimen showed a shrinkage value of -0.038 percent. The Ecomelt test specimen showed a shrinkage value of -0.031 percent. As less shrinkage is preferred, this indicates that the Ecomelt-based specimen has a slightly lower shrinkage characteristic than that of the control.

Freeze-Thaw Testing: In the freeze-thaw test (ASTM C 666), concrete block samples are cyclically cooled from 40° to 0°F and then heated to 40°F over the course of 2 to 5 hours (1 cycle). The freeze-thaw apparatus is usually automated and can be operated around the clock. The test samples are subjected to up 300 freeze-thaw cycles or until the relative dynamic modulus of elasticity falls below 60 percent. The test samples are periodically weighed and measured. After 301 freeze-thaw cycles, the concrete blocks made with Ecomelt/Portland cement showed a relative dynamic modulus of elasticity of 91 percent; whereas the control specimens showed a relative dynamic modulus of elasticity of 90 percent. The freeze-thaw resistance characteristic of the Ecomelt-based blended cement was similar to that of the control. Figure 5 shows the concrete test specimens in the freeze-thaw apparatus (cover open).

Figure 5. Concrete Blocks of Ecomelt-Based Blended Cement Being
Subjected to Freeze-Thaw Cycles at CTLGroup Laboratories

Scaling Resistance to Deicer Chemicals: Concrete test specimens were subjected to ASTM C 672 to determine resistance of the concrete surface to scaling due to exposure to deicer chemicals, specifically calcium chloride ($CaCl_2$). The results showed that the deicer chemical attacked the Ecomelt/Portland cement concrete samples more aggressively than the control samples. After 50 cycles, the Ecomelt/Portland cement samples showed a cumulative mass loss of 0.4 lb/ft^2, while the control showed a cumulative mass loss of 0.04 lb/ft^2.

Chloride Ion Penetration: Concrete test specimens were subjected to ASTM C 1202 (AASHTO T 277) to determine the concrete ability to resist chloride ion penetration. The Ecomelt/Portland cement blend specimens showed "Very Low" chloride ion permeability compared to "Moderate" chloride ion permeability for the control, where a lower result is preferred.

Summary: A mix design for concrete using Ecomelt as a partial replacement for Portland cement was developed for the beneficial use project. The major chemical and physical characteristics of concrete made with Ecomelt/Portland cement blend have been determined.

The time of setting for the Ecomelt/Portland cement blend was slower than that of the control. The compressive and flexural strengths were similar to those of the control, but typical of pozzolanic materials took longer to achieve. Drying shrinkage and freeze-thaw results were similar to those of the control.

Resistance to deicer scaling was lower for the Ecomelt/Portland cement specimen compared to the control. CTLGroup offered several explanations for this result: The test sample may have lower entrained air content than the control, which would result in lower resistance to the deicer salt. Pore water bleeding to the concrete specimen surface may evaporate leaving calcium hydroxide [$Ca(OH)_2$] to react with CO_2 in the atmosphere generating calcium carbonate ($CaCO_3$), which is fairly weak. Also, finishing the concrete sample may have disturbed the air entrained at the surface. CTLGroup suggested that reducing the Ecomelt replacement from 40 to 30 percent of the Portland cement requirement could reduce scaling. They also suggested that using a curing compound on the concrete surface after pouring could reduce scaling.

Resistance to chloride ion penetration was better with the Ecomelt/Portland cement specimen than the control.

II. SUMMARY AND CONCLUSIONS

The beneficial use project with Ecomelt made from Passaic River sediment during the Extended Duration Test campaigns at the Cement-Lock demonstration plant (Bayonne, NJ) will be conducted at the campus of Montclair State University. A batch of concrete will be produced and poured for a length of sidewalk on the campus. Following are a summary of the results and conclusions from the beneficial use task:

- The physical and chemical properties of Ecomelt samples from Passaic River sediment have been evaluated by CTLGroup. The results show that Ecomelt can be used as a partial replacement (up to 40 wt %) for Portland cement in a general construction project.
- The Ecomelt/Portland cement blend achieved compressive strength at a lower rate than did the control sample. However, after 56 days of curing, the compressive strengths of both Ecomelt/Portland cement blend and control specimens were the same.
- Time of setting was longer for the Ecomelt/Portland cement blend than that of the control – typical of pozzolanic materials.
- CTLGroup prepared a mix design for the beneficial use of the dried and ground Ecomelt to be incorporated into a batch of concrete.
- About 1 ton of Ecomelt from Passaic River sediment was dried and ground to cement fineness (<50 µm) by CTLGroup. It has been shipped to Montclair State University for the beneficial use project.

There are areas of additional cement-related testing that would enhance the Cement-Lock Technology:

- Tests to evaluate the long-term endurance properties of concrete made with Ecomelt should be conducted (will be done by MSU under the Earth and Environmental Studies Department).
- Tests to determine the compressive strength of Ecomelt made outside the "target" composition (within the patent scope) should be conducted.
- Specific large-scale tests should be conducted with feedstock previously tested only as surrogates, i.e., PCB-contaminated soils or sediment.

APPENDIX A.

CTLGROUP REPORTS

TESTING AND EVALUATION OF ECOMELT (May 5, 2007)

EVALUATION OF ECOMELT IN CONCRETE TESTING (May 2008)

APPENDIX B.

ACCEPTABLE USE DETERMINATION FOR BENEFICIAL USE OF ECOMELT FROM PASSAIC RIVER SEDIMENT AT MONTCLAIR STATE UNIVERSITY, NEW JERSEY