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Utilization of a Pneumatic Tube Mixing Technique for Processing and Stabilization of Contaminated Dredged Material

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Ali Maher[1]
Professor

Masaki Kitazume[2]
Professor

Masoud Janbaz[1]
Ph.D. Candidate

Robert Miskewitz[1]
Associate Research Professor

Scott Douglas[3]

David Yang[4]
Professional Engineer

Center for Advanced Infrastructure and Transportation[1]
Rutgers, The State University of New Jersey
100 Brett Road, Piscataway, NJ 08854

Tokyo Institute of Technology[2]

Office of Marine Resources[3]
New Jersey Department of Transportation
1035 Parkway Avenue, Trenton, NJ 08625

JAFEC Group[4]
San Jose, California

External Project Manager
Scott Douglas
Office of Marine Resources
New Jersey Department of Transportation

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16. Abstract

The following progress report describes the laboratory activities completed for the development of the experimental field program designed to evaluate sediment amendment using the Pneumatic Flow Tube Mixing Apparatus (PFTM) in NY/NJ Harbor. These activities were completed to determine the appropriate field mixing conditions during the July- August 2015 pilot demonstration of the PTFM. It is a novel technology originally developed in Japan for high rate amendment of dredged material for use in man-made islands. The increased rate of processing and uniformity of the stabilized sediment mixture led the New Jersey Department of Transportation (NJDOT) to support a Rutgers University CAIT pilot scale field demonstration of the PFTM system in Newark Bay. This effort will evaluate the applicability of PTFM for stabilization of the loose and contaminated sediments native to the Bay for later beneficial use in structural and fill applications.

In April 2015 100 gallons of raw dredge material was acquired from the Arthur Kill adjacent to the CME Inc. waterfront. The location is the site of the subsequent dredging operation that will provide sediment for the field scale pilot test. The material was allowed to settle and then was decanted to approximately the water content that will present during PTFM operations. The material was then stabilized with Portland cement at 5 different dosages and 3 different initial moisture contents. The samples were then tested for flowability, short term strength gain using the laboratory vane shear apparatus, and long term strength gain using the Unconfined Compressive Strength Test and the Needle Penetration Test. Cured samples of both the raw and amended material were sent to Precision Testing Laboratory Inc. (Toms River, NJ) for chemical analysis of both raw sediment and leachate via the Synthetic Precipitation Leaching Procedure (SPLP).

The preliminary laboratory study has indicated that the primary NJDOT guidance criteria for the July- August 2015 pilot demonstration project will be met using the standard mix of 8% cement by wet weight. Results indicate that:

1. Leachability of potential contaminants is restricted by the stabilization procedure.
2. The raw material will be sufficiently flowable to be processed in the tube mixing system.
3. The stabilized material is predicted to have the minimum required bearing capacity of 3000 lbs/ square foot or 145 kPa.

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Executive Summary

The following progress report describes the laboratory activities completed for the development of the experimental field program designed to evaluate sediment amendment using the Pneumatic Flow Tube Mixing Apparatus (PFTM) in NY/NJ Harbor. These activities were completed to determine the appropriate field mixing conditions during the July- August 2015 pilot demonstration of the PTFM. It is a novel technology originally developed in Japan for high rate amendment of dredged material for use in man-made islands. The increased rate of processing and uniformity of the stabilized sediment mixture led the New Jersey Department of Transportation (NJDOT) to support a Rutgers University CAIT pilot scale field demonstration of the PFTM system in Newark Bay. This effort will evaluate the applicability of PTFM for stabilization of the loose and contaminated sediments native to the Bay for later beneficial use in structural and fill applications.

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Laboratory Mixing Tests

Sediment Characteristics

The soil used in the study was excavated from Pralls Creek, New Jersey. The sediment was a black-colored contaminated organic soil, depicted in Figure 1. It had the physical properties and chemical composition summarized in Tables 1 and 2.

Fig. 1. Organic soil used in the study

Table 1. Physical properties of sediment

Soil	Liquid limit, w_L (%)	Plastic limit, w_P (%)	Plasticity index, I_p	Soil particle density, G_s	Natural water content, w_n (%)	Organic content (%)
NJ clay	91.9	48.7	43.2	2.2	138.58	9.3

Table 2. Chemical composition of sediment

Cas No.	Elements	Results (mg/kg)	DF	PQL (mg/kg)	MDL (mg/kg)
7440-22-4	Silver	3.49	1	0.389	0.16
7429-90-5	Aluminum	17400	5	58.4	6.35
7440-38-2	Arsenic	19.5	5	7.79	1.34
7440-39-3	Barium	301	5	3.89	0.14
7440-41-7	Beryllium	0.649	1	0.234	0.0148
7440-70-2	Calcium	11800	5	58.4	5.02
7440-43-9	Cadmium	3.21	1	0.156	0.0311
7440-48-4	Cobalt	10.3	1	3.89	0.208
7440-47-3	Chromium	139	5	1.95	0.346
7440-50-8	Copper	277	5	3.89	0.257
7439-89-6	Iron	33100	5	58.4	10.1
7439-97-6	Mercury	4.27	50	1.85	0.211
7440-09-7a	Potassium	3870	1	38.9	2.5
7439-95-4	Magnesium	8450	5	58.4	5.18
7439-96-5	Manganese	448	5	0.973	0.0934
7440-23-5	Sodium	10600	5	389	93.8
7440-02-0	Nickel	46.6	5	7.79	0.533
7440-36-0	Antimony	4.27	1	1.56	0.341
7782-49-2	Selenium	2.55	1	1.56	0.25
7439-92-1	Lead	240	5	7.79	0.393

7440-28-0	Thallium	ND	1	1.95	0.942
7440-62-2	Vanadium	50.1	5	3.89	0.646
7440-66-6	Zinc	409	5	5.84	0.911

Sediment Stabilization

The soil and site water were combined in a laboratory mixer mixed thoroughly to reach the targeted water content. Potland cement was added and mixed until the mixture was uniform. Soil-cement mixing continued for a total 10 minutes, with stoppage at the 5 minute mark to scrape off the mixture that built up on the inner surface of the mixer. Water content was measured upon the completion of mixing to confirm whether or not the target water content had been reached. After mixing, the soil-cement mixture was placed into molds of 50 mm diameter and 100 mm height. The molds were filled in three separate layer, and each layer was subjected to vibration by the table vibrator to remove any air bubbles that may have been entrapped in the soil during filling process. The molds were wrapped using a plastic bag and rubber band, then cured in an experiment room with a temperature of around 20 degrees Celsius.

Leachability

Cured samples of both the raw and amended material were sent to Precision Testing Laboratory Inc. (Toms River, NJ) for chemical analysis of both raw sediment and leachate via the Synthetic Precipitation Leaching Procedure (SPLP). These samples were analyzed for Base Neutral +15 TCL, TAL Metals, Pesticides, and PCBs. None of the samples were found to leach any compound in excess of the appropriate regulatory limits. The analytical reports for these samples are included in Appendix 1.

Flow Test

Immediately after mixing, sediment flow tests were conducted on the soil-cement mixture. The flow value is an essential property for the Pneumatic Flow Tube Mixing method. The standard test consisted of placing the soil mixture into a metal mold. The top surface of the soil mixture was flattened and then the mold was lifted up to release the soil mixture. The soil mixture was subjected to 10 times drop and its diameter was then measured. The measured flow values are shown in Figure 2, in which the water and cement ratio (*W/C)* is plotted on the horizontal axis. The flow value ranges from about 4 to 8 inches (10 to 20 cm) and increases slightly with increasing *W/C*. The required minimum flow value for the pneumatic flow tube mixing method is dependent on the transport distance, but is set at about 9 to 10 cm for many tube mixing sites in Japan. All of the measured flow values were larger than the required value, irrespective of mixing condition.

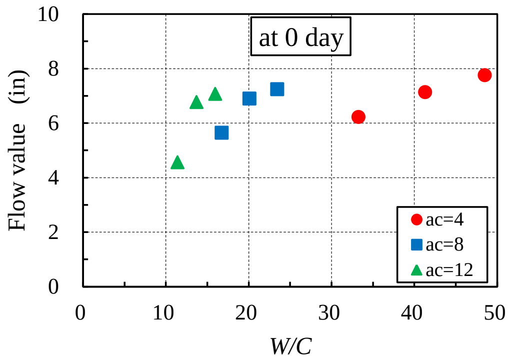

Figure 2. Soil mixture after removing the mold

Bearing Capacity

After being cured for various lengths of time (1, 3, 7, 14 and 28 days), the samples were subjected to the unconfined compression stress (UCS) test to measure their strengths and stress and strain properties. Samples that were not stable enough to conduct the UCS were subjected to vane shear or needle penetration tests to assess their strength.

Table 3. Bearing Capacity Test Experimental Design

Cement	Initial Moisture Content	Unconfined Compressive Strength (28 Days Curing)	Needle Penetration Test (28 Days Curing)	Vane Shear (3 & 7 Days Curing)	Unconfined Compressive Strength on Rehandled / Disturbed Samples
% Dry Weight	%	# of samples			
4	133	3	8	16	0
	165	0	6	20	0
	195	2	5	13	0
6	133	6	7	2	0
8	133	8	10	10	1
	165	22	10	8	3
	195	8	10	8	3
10	133	6	9	2	0
12	133	10	3	8	0
	165	10	8	8	0
	195	10	8	8	0

Figures 3,4 and 5 (4% show the unconfined compressive strengths of the stabilized soil, which were directly measured in the UCS tests and estimated in the needle penetration and laboratory vane shear tests. In these figures, "wi=1", "wi=1.2" and "wi=1.4" indicate that the initial water content of the soil is about the same as (about 133%), 1.2 times (about 165%), and 1.4 times (195%) that of the natural water content, respectively. The strength of the stabilized soil increases with curing time irrespective of the mixing condition.

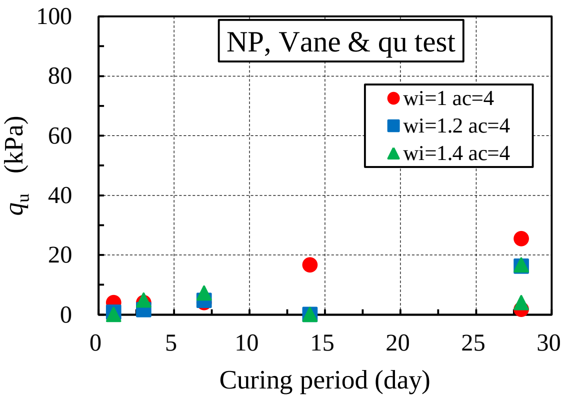

Figure 3. Compressive Strength of Stabilized Sediment (4% dry weight)

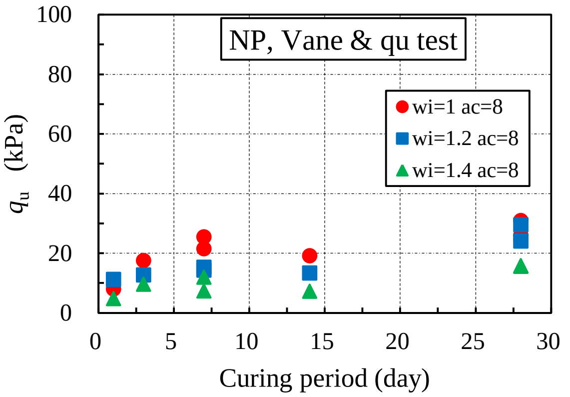

Figure 4. Compressive Strength of Stabilized Sediment (8% dry weight)

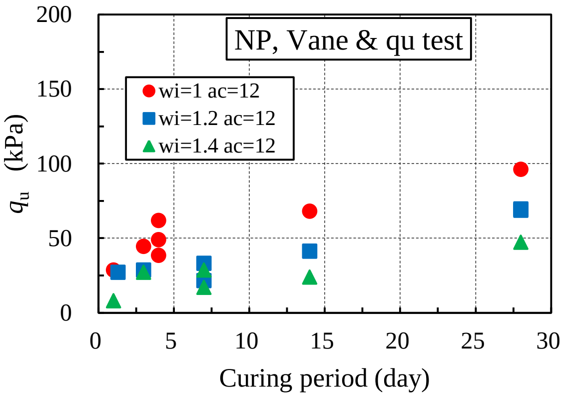

Figure 5. Compressive Strength of Stabilized Sediment (12% dry weight)

Subsequent to the performance of the strength tests it was determined that the cement ratio for stabilization is based upon "wet' weight instead of "dry" weight. Thus the amount of portland cement used for stabilization was lower than would be expected in the field. The 12% dry weight stabilization is approximately equal to 5% cement. It is apparent from the measured data that q_u value has a close relationship with the *W/C* ratio, the relationship was determined and used to estimate q_u at higher cement concentrations. A cement concentration of 20% dry weight is equivalent to 8% weight. The estimated soil strength is presented in Table 4.

Table 4. Estimation of stabilized soil strength at 20% Portland cement dry weight (8% wet weight)

	liquid limit			natural water content		
initial water content (%)	92.0	92.0	92.0	133.0	133.0	133.0
binder content (%)	20.0	20.0	20.0	20.0	20.0	20.0
water cement ratio (%)	60.0	80.0	100.0	60.0	80.0	100.0
W/C ratio	5.2	5.4	5.6	7.3	7.5	7.7
estimated qu (lab.)	241.8	233.4	225.3	168.2	162.4	156.7
estimated qu (field)	120.9	116.7	112.6	84.1	81.2	78.4

Conclusions and Continuing Activities

Based on the finding of the preliminary laboratory phase of this project, the primary NJDOT guidance criteria for the July- August 2015 pilot demonstration project will be met using the standard mix of 8% cement by wet weight. Results indicate that:

1. Leachability of potential contaminants is restricted by the stabilization procedure.
2. The raw material will be sufficiently flowable to be processed in the tube mixing system.
3. The stabilized material is predicted to have the minimum required bearing capacity of 3000 lbs/ square foot or 145 kPa.

Additional laboratory investigations will investigate the strength and flowability of sediment stabilized with 8% Portland cement by “wet” weight and attempt to determine the minimum degree of stabilization required to restrict leachability of contaminants. Finally, The field phase of this project will be completed during July and August of 2015.