DECONTAMINATION AND BENEFICIAL REUSE OF DREDGED MATERIAL USING EXISTING INFRASTRUCTURE FOR THE MANUFACTURE OF LIGHTWEIGHT AGGREGATE

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ABSTRACT

The need to achieve an environmentally acceptable and economically beneficial reuse option for the management of dredged material is self-evident in order to retain and enhance the economic viability of America's waterways and harbors.

JCI/UPCYCLE Associates' technological and commercial approach focuses on the utilization of dredged material as a feedstock in the manufacture of a value added building material, lightweight aggregate (LWA). Our approach, based on proven unit operations, is capable of yielding an "upcycled" product with a demonstrated market demand. Key to the success of the approach is the incorporation of existing infrastructure and capital assets. Beneficial reuse and thermal decontamination are accomplished employing a high temperature rotary kiln process traditionally used in the LWA manufacturing process at a plant that has been in continuous operation in the State of New York since the mid-1950's.

Keywords: Dewatering, Thermal Processing, Rotary Kiln, Building Material, Geotechnical Fill

INTRODUCTION

In order to remain as viable port facilities, the harbors and waterways of the United States require periodic dredging to provide adequate draft for large ocean going vessels. Further, dredging is often required in order that draft can be maintained for barge movement. Historically, the dredged material has either been deposited in borrow pits at sea or on land (upland disposal) near the site of the dredging activity. In recent times, the ability to utilize these management options has been significantly limited due to environmental concerns surrounding the potential impact of contaminants, both organic and inorganic, on the environment. (5)

Disposal at sea continues to be an option, but only for a limited volume of material that has been deemed "clean" from a contamination perspective. The remaining materials must be managed on land and are subject to strict environmental regulation. Briefly, the materials managed on land must be either decontaminated, stabilized or placed into an approved landfill.

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A considerable effort has been undertaken by both public and private interests to develop a recycling approach, but to this point that effort has been unsuccessful either due to high operating/capital costs of the proposed method or lack of market for the resultant product.

The Port of New York/New Jersey serves as a prime example of this problem. While the Port would appear to be prosperous and growing, its rate of growth was substantially behind its major U.S. and international competitors. The world-wide trend for shipping is for increased containerization in larger ships. As other ports deepen their harbors to accommodate these new generation vessels, the Port of NY/NJ is faced with serious challenges to maintain the current depths of its channels and berthing areas, let alone to increase them.

The major obstacle facing the Port and potentially impacting its future viability is the lack of an acceptable and reliable means of disposing of the millions of cubic yards of material that must be dredged to both maintain the current depth and provide additional depth for the new generation of container vessels.

The many years of industrial activity in the Port area have caused pollution and contamination of the sediment with the result being concern over the impact on the ecology of the Bight and its adjacent estuary. Due to the concern over these pollutants and their long-term potential degradation, the criteria for ocean disposal of dredged material were revised in 1992. These revisions include increased sensitivity in detection limits and more stringent criteria for assessing chronic impacts. Under this new testing regime, more of the dredged material (estimated at 75%) (5) fails the ocean disposal test. The immediate result to the Port of NY/NJ is a situation where there is a lack of environmentally acceptable disposal sites for the vast majority of material requiring dredging.

Publicly available information shows that the Port Authority of NY/NJ paid $118 per cubic yard to stabilize dredge material, barge it to Texas and then rail the material to Utah for landfill cover. Material dredged from Port Newark Reach A was stabilized and used as a fill sub-base for a parking lot at a cost of $57 per cubic yard. The Pennsylvania Mine Reclamation Project has been reported at $84 per cubic yard. Other disposal options without the benefit of beneficial reuse range from $35 to $60 per cubic yard. (2) With an estimated 4-5 million cubic yards per annum of dredged material needing proper handling, cost effective and environmentally acceptable management options are imperative if the Port of NY/NJ is to remain open and viable.

JCI/UPCYCLE Associates provides a technologically and economically viable approach for commercial quantities of dredged material, i.e., 500,000 cubic yards per year, that is highly competitive and offers an environmental benefit in the ability to reuse the dredged material and thus to conserving precious natural resources.

PROCESS OVERVIEW

Succinctly, the process technology encompasses dewatering, pelletizing and extrusion of the dredged material coupled with thermal treatment via a rotary kiln to achieve dredged material decontamination and coincidentally, beneficial reuse. After dredging, the pre-kiln processing steps including initial sizing and debris removal, dewatering and pelletizing are envisioned to occur at a central or "merchant" commercial facility operated by JCI/UPCYCLE. The dewatered pellets will then be transported to Norlite Corporation's existing lightweight aggregate plant where they will undergo extrusion prior to final processing in Norlite's rotary kilns. Figure 1 depicts the process flow.

Norlite's lightweight aggregate manufacturing site is anchored by two (2) 11 foot diameter by 175 foot long refractory lined rotary kilns supported by a full complement of monitored air and water pollution control systems. Ancillary equipment includes a full array of crushing, screening and sizing equipment.

JCI/UPCYCLE Associates developed its concept after close examination of the mineralogical nature of dredged material within the Port of NY/NJ. This examination revealed that the mineralogical components are essentially the same as those in building materials produced and sold in commerce today. Table 1 presents a chemical analysis comparison of typical feedstock for lightweight aggregate production versus dredged material.

The beneficial reuse and decontamination technology being offered maximizes the contaminants that will be removed and destroyed while minimizing those that are left untreated. By exposing the extruded dredged material to the temperatures within the kiln's burning zone of 2100 - 2200° F, thermal desorption and destruction of organic constituents is obtained. The manufacture of lightweight aggregate is based on the conversion of the solids into a pyro-plastic (partially molten) state at the same temperature that the bloating gases begin to evolve. The plasticity of the substance is controlled by the amount and ratio of flux compounds (used to promote fusion) within the solids. These various flux compound oxides react with the SiO_2 (the predominant mineralogical component of dredged material) to form the complex compound matrix that further binds and immobilizes the various metal constituents and contaminants. The lightweight aggregate product, with the millions of minute separated air cells, provides greatly enhanced thermal resistance and more than double the thermal insulation value to the final concrete end-product. Additionally, the LWA pyro-manufacturing process improves the fire resistance of the resulting concrete since any combustible components are removed within the kiln.

The dewatered dredged material pellets that will subsequently be thermally converted into LWA yield an end product in conformance with applicable ASTM and construction industry specifications with additional potential use in Brownfields' remediation and/or as landfill cover. From an environmental standpoint, dredged material provides a benefit from its ability to be reused and from conserving precious natural resources, e.g., shale or clay. From a commercial perspective, the markets for "upcycled" aggregate are well established and of such size that they can easily accommodate the introduction of additional sources. From an economic viewpoint, the process utilizes existing infrastructure, commercially available equipment and proven technology to create a viable dredged material management option.

OVERVIEW OF PROGRESS TO DATE

JCI/UPCYCLE Associates, LLC in conjunction with its team members has self-funded a comprehensive pilot scale program to demonstrate the feasibility of its technology. Complementing and supporting JCI/UPCYCLE are Norlite Corporation, Fuller Company, Solomon Technologies, Inc., Komline-Sanderson and GZA GeoEnvironmental, Inc.

JCI/UPCYCLE Associates, LLC in conjunction with Fuller Company, GZA GeoEnvironmental, Inc., Komline-Sanderson, and Solomon Technologies, Inc. has conducted bench scale testing to confirm the suitability of dredged material to dewater and subsequently, to bloat and create lightweight aggregate.

JCI/UPCYCLE Associates, LLC used material supplied by the USACE from the Arthur Kill for its preliminary analysis performed by Fuller. While detailed analytical results are not available on the Arthur Kill material, these tests did produce actual quantities, albeit small amounts, of acceptable LWA. Most importantly, Fuller stated on January 8, 1998, that these "preliminary tests have indicated that the dredged material has very good potential for the production of lightweight aggregate".

Fuller's ability to make the above statement is based on a variety of factors notwithstanding their 40 years in evaluating a multitude of potential raw materials for use in the manufacture of LWA. The first is the empirical relationships that predict the ability of a raw material to bloat based on its chemical analyses. The second is Fuller's knowledge and experience "that there is not much difference in producing LWA from dredged material, once it has been dried, then from conventional expandable clays or shales, particularly clays, which are a soil on land. Once dewatering is done on the dredge material, the material could be considered a sedimentary clay where it most likely originated from, based on the chemical analyses obtained in almost all cases."

With the understanding that LWA can be produced from dewatered dredged material and that Norlite's high temperature treatment is effective at handling most commonly found contaminants, JCI/UPCYCLE focused its efforts on consolidation/dewatering.

On January 13, 1998, JCI/UPCYCLE personnel in conjunction with the EPA and the USACE representatives, participated in a sampling program and obtained approximately 100 gallons of Category III material from Newark Bay. These samples were analyzed by GZA's Environmental Chemistry Laboratory to determine and to verify the physical and chemical nature of the dredged material as compared to data available from both the EPA and the USACE's Waterways Experiment Station.

In March, 1998, JCI/UPCYCLE commissioned GZA GeoEnvironmental, Inc. to conduct a library search and to perform bench scale testing on sediments to evaluate the effect of polymers to enhance water content reduction of dredged materials.

The library research concluded that polymers can and do play a key role in the dewatering operation. Also, the right polymer for a specific application can enhance the engineering behavior of dredged materials with regards to both free and consolidated drainage. However, the library search identified that the state of knowledge and experiences were inadequate to engineer an off-the-shelf process for dewatering dredged material.

A second phase of laboratory testing on about 70 gallons of a homogeneous sample was proposed. This phase included the selection of specific polymers/conditioners, free drainage dewatering tests and consolidated dewatering tests utilizing pre-selected polymers.

The following conclusions have been excerpted from GZA's test results. (4)

- The dredged soil can be dewatered to acceptable levels of water content by a one step consolidation dewatering process.

- Consolidation dewatering of this material without a polymer additive requires long dewatering times.

- The addition of polymers to the soil during the mixing of the soil simultaneously destroys the natural soil structures causing dramatic decreases in the time to consolidate the soil. The amounts of the decreases are systematically related to the concentration of the polymer. The equilibrium water contents of the soil at full consolidation are not significantly affected by the presence of the polymer.

- The processed data from the consolidation tests was used to develop design curves relating the time required for different amounts of consolidation as functions of drainage path distances, squeezing pressures and polymer concentrations.

In May, 1998, with this confirmatory information in hand, a laboratory test was undertaken at Komline-Sanderson to evaluate the effectiveness of a continuous belt filter press as a dewatering process for dredged material. The test program utilized bench scale filtration equipment and proprietary models to evaluate filtration properties, to define process relationships and to determine full scale equipment performance and sizing parameters. The technical goals of this test program included:

- Production of a friable cake suitable for transportation and further processing

- High processing rate

- Low operating and maintenance costs

- Small footprint

In summary, the test work confirmed that a belt filter press "will achieve significant volume reduction and produce a friable filter cake which easily passes the paint filter test." Additionally, it was determined that "operational costs are directly proportional to inlet concentration (rather than volume). Finally, the tests determined that the expected process efficiency, or solids capture rate, will range from 98.8% - 99.4% based on a total suspended solids mass balance and that filtrate and spent wash water are readily settleable at high processing rates." (6)

With this ever increasing level of knowledge, in August, 1998, JCI/UPCYCLE Associates in conjunction with Norlite Corporation self funded a comprehensive pilot scale program at the laboratory facilities of the Fuller Company in Catasauqua, PA. The pilot program utilized approximately 600 gallons (3 yards) of dredged material from the Perth Amboy Marina to evaluate the rotary kiln production of lightweight aggregate. This work was performed utilizing the 1' diameter x 15' long pilot refractory lined rotary kiln system and was based on the previous successful laboratory study that demonstrated the feasibility of using dredged materials in the manufacture of lightweight aggregate. While the results from the Fuller pilot program are voluminous, the succinct outcome is that it is feasible to produce commercially acceptable lightweight aggregate from dredged materials. (3) This conclusion is supported by the product analysis and by the demonstrated excellent compressive strength levels observed as compared to several commercial aggregate samples. (See Table 2) The implication of the compressive strength levels achieved is that the product will be suitable for use in lightweight aggregate structural concrete and concrete masonry units.

To further support the Fuller results, JCI/UPCYCLE subjected the pilot aggregate produced to an independent testing effort conducted by Advance Testing Company, Inc. of West Stockbridge, MA. (1) This program consisted of making a 3000 psi concrete mix design incorporating the pilot aggregate and testing the resulting concrete cylinders for compressive and tensile strengths after various time periods. The conclusion reached by Fuller were completely validated in that the strengths achieved from the aggregate produced from dredged materials greatly exceeded those obtained from a control mix using commercially available aggregate.

Based on the above success, the Port Authority of NY/NJ agreed to test JCI/UPCYCLE pilot aggregate from the Fuller program to initiate and conduct its own material evaluation program. This work undertaken by the Port Authority's Materials Engineering Division at their Jersey City, NJ laboratories sought not only to replicate the evaluation performed by Advance Testing on behalf of JCI/UPCYCLE, but to subject the material to a battery of additional chemical and physical tests. The stated purpose of the Port Authority's efforts was to confirm the equivalence of lightweight aggregate manufactured from dredged material to that of commercially available aggregate in the concrete mixes routinely used by them, and of equal importance, to assure that there will not be adverse effects from the handling and use of dredged material produced LWA.

The Port Authority in their Laboratory Test Report on Upcycle Aggregate (8) concluded "... that the Upcycle aggregate exhibited physical characteristics desired for a construction grade lightweight aggregate." (See Table 3) Moreover, the Port Authority has indicated an interest in utilizing a substantial quantity of "upcycled" material in a demonstration engineering application.

JCI/UPCYCLE has continued to pursue innovative technologies for the fluid-sediment separation, i.e., dewatering, required prior to the initial pelletization step of our process. In this vein, we have been actively engaged with Solomon Technologies. Solomon has successfully undertaken and completed several bench scale tests utilizing their proprietary process equipment in conjunction with polymer chemistry and known mechanical means to produce a "dry" filter cake in the range of 70+% w/w solids. (7) These most promising results have marked beneficial environmental as well as economic impacts on the overall process.

CONCLUSIONS

JCI/UPCYCLE Associates, LLC has developed a concept capable of managing a minimum of 500,000 cubic yards per year of dredged material in a cost-effective and economically sound manner.

This technological and commercial approach focuses on the utilization of dredged material as a feedstock in the manufacture of a value added building material, lightweight aggregate. A central factor in the JCI/UPCYCLE approach is the utilization of existing infrastructure and capital assets coupled with the use of proven unit operations and readily available equipment. Beneficial reuse and decontamination of the dredged material is accomplished employing a high temperature rotary kiln process traditionally found in the LWA manufacturing process at a plant that has been in continuous operation in the State of New York since the mid-1950's.

JCI/UPCYCLE has self-funded extensive process pilot testing and coupled with thorough product testing conducted independently and by the Port Authority of NY/NJ that demonstrates that the aforementioned objective is achievable. Further, based on the Port Authority's test results, they have indicated an interest in utilizing "upcycled" aggregate in an upcoming engineering application.

JCI/UPCYCLE Associates, LLC offers a technologically and environmentally acceptable beneficial reuse and decontamination option for the management of dredged material that can serve to retain and enhance the economic viability of currently impaired waterways and harbors.

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TABLE 1

CHEMICAL OXIDE ANALYSIS COMPARISONS (WT %)
LWA RAW MATERIALS

Chemical Compound	Typical LWA	Norlite Shale Fines	Upcycle DM	Upcycle #5 Mix	Brookhaven DM
SiO_2	50-80	59.51	53.56	53.13	75.23
Al_2O_3	10-25	16.40	12.66	13.06	10.25
Fe_2O_3	3-10	7.32	7.23	7.27	4.86
CaO	0-3	1.37	1.23	2.66	2.50
MgO	0-5	2.94	1.60	1.86	1.57
K_2O	1-10	3.55	2.19	2.51	2.19
Na_2O	0-5	1.24	1.87	1.83	2.30
P_2O_5		0.09	0.62	0.46	0.28
TiO_2		0.78	0.96	0.86	0.66
Mn_2O_3		0.18	0.12	0.13	0.061 (as MnO)
LOI @ 900°C	4-8	5.21	13.73	12.88	9.83

Typical LWA -	Data from Fuller	
Norlite Shale Fines - (Raw Shale)	Data from Upcycle Testing @Fuller - Table 11	(8/98)
Upcycle DM - (As-Dredged Material)	Data from Upcycle Testing @Fuller - Table 11	(8/98)
Upcycle #5 Mix -	Data from Upcycle Testing @Fuller - Table 13	(8/98)
Brookhaven -	Data from Spectochemical Labs - Composite	(12/97)

TABLE 2

COMPRESSIVE STRENGTH COMPARISON

LIGHTWEIGHT AGGREGATE PRODUCTS

PLANT	COMPRESSION lbs.	RANGE lbs.	COARSE BULK DENSITY lb/cf	END USES
A	131	103-169	55.0	Block & Limited Structural
B	177	138-236	50.7	Block
C	197	133-250+	41.0	Structural
D	128	70-180	34.1	Block
E	183	155-205	38.2	Block & Structural
F	165	110-205	35.0	Block
G	86	61-101	45.0	Fly Ash Block Product
UPCYCLE Mix #4	197+	175-230+	34.0	
UPCYCLE Mix #5	230+	230+	41.8	

Data from Fuller Company and UPCYCLE Testing @ Fuller - Table 7 (8/98)

TABLE 3

LABORATORY TEST RESULTS - UPCYCLE AGGREGATE

SUMMARY DATA OF THE MATRIX EVALUATION TESTING PROGRAM - 2/99
MATERIALS ENGINEERING DIVISION - ENGINEERING DEPARTMENT
THE PORT AUTHORITY OF NEW YORK AND NEW JERSEY

Control Material: Expanded Shale Lightweight Aggregate

ABSORPTION - Results are based on submerging the aggregate for 72 hours under 1/2 inch head of water at room temperature and atmospheric pressure.

	Total Absorption (Minimum)
Control Aggregate	**11.3%**
UPCYCLE Aggregate	**12.8%**

BULK SPECIFIC GRAVITY SSD & DRY RODDED UNIT WEIGHT - Results are determined after submerging the aggregate for 72 hours under 1/2 inch head of water at laboratory temperature and atmospheric pressure. Aggregate for Dry Rodded Unit Weight was oven dried for 24 hours and tested in accordance with ASTM C-29.

	Bulk Specific Gravity SSD	**Dry Rodded Unit Weight**
Control Aggregate	**1.25**	**44.8 lb/ft^3**
UPCYCLE Aggregate	**1.34**	**54.4 lb/ft^3**

SOUNDNESS (ASTM C-88) - Indicates how well an aggregate will hold up to weathering action. Five soaking and drying cycles were performed using Sodium Sulfate.

	Total Weighted Loss
Control Aggregate	**3.2%**
UPCYCLE Aggregate	**1.3%**

FREEZE & THAW ON AGGREGATE - Performed in accordance with AASHTO T-103 Procedure A with a total of ten freeze & thaw cycles.

	Total Weighted Loss
Control Aggregate	**3.1%**
UPCYCLE Aggregate	**0.7%**