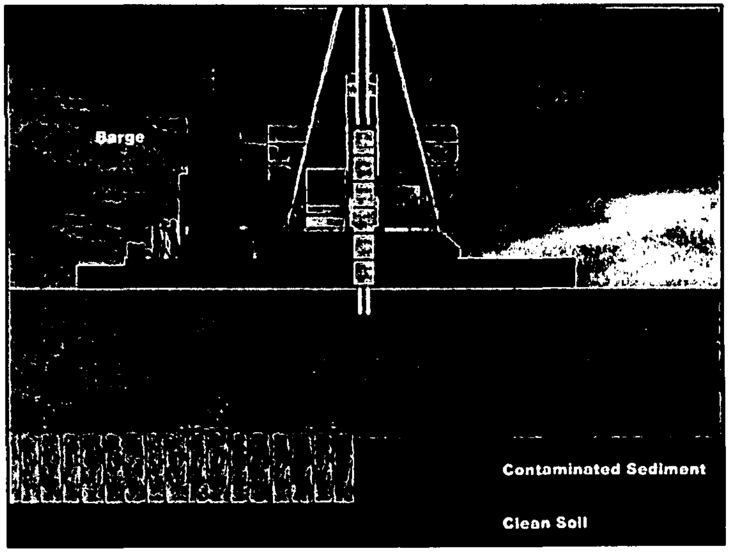
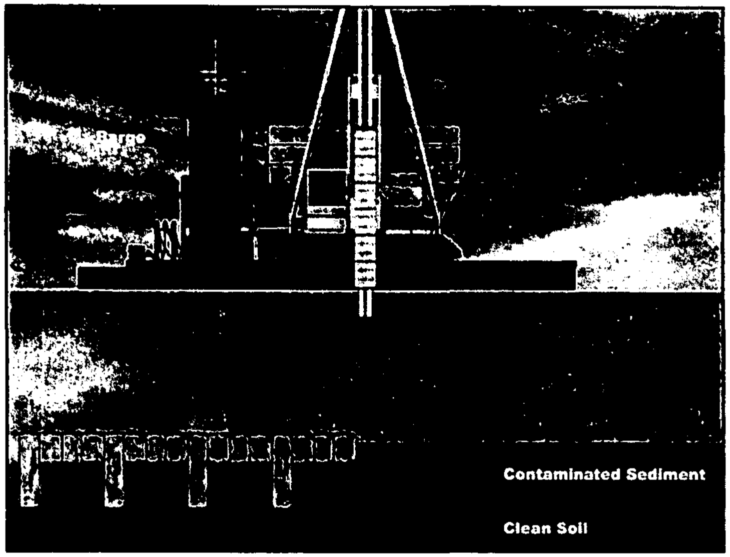
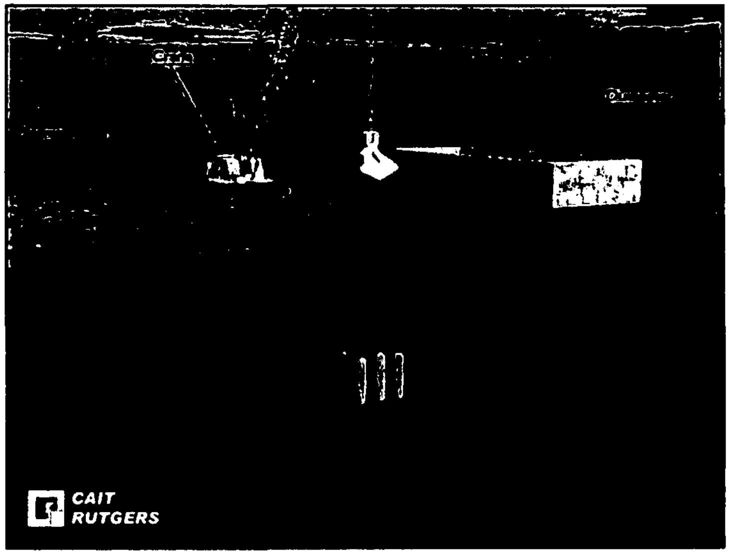
In-Situ Solidification and Stabilization of Contaminated Sediments (CDSM approach)

- Intermediate and Long-Term Remedial Measure for Contaminated River Sediments
- Concept
- Background
- Pilot-Study Phase I (2004-2005)
- Pilot Study Phase II

Concept!




Barge
Contaminated Sediment
Clean Soil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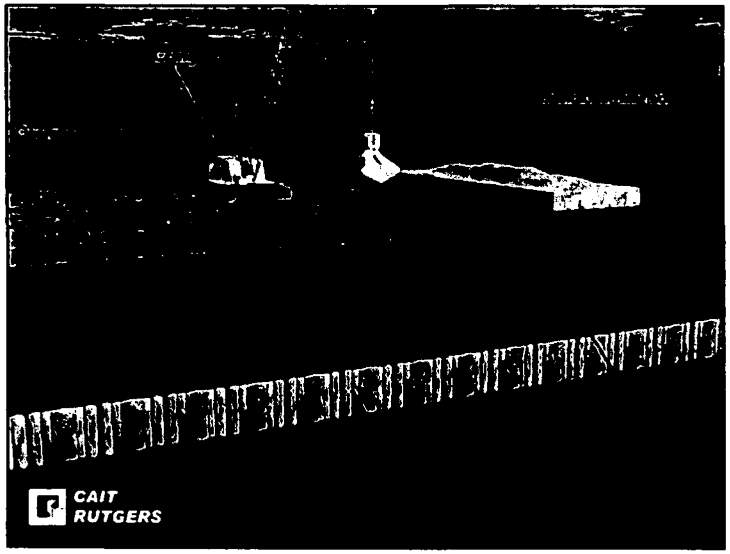
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Background

Solidification and Stabilization of Contaminated Sediments

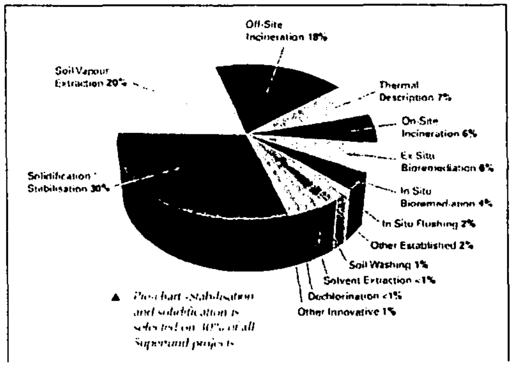
- ***Chemical fixation and solidification*** **or Solidification/Stabilization Treatment, S/S is widely used for the management and disposal of a broad range of wastes, especially those classified as hazardous.**
- ***The USEPA considers S/S an established treatment technology*, and has identified it as the best demonstrated available technology, BDTA, for 57 RCRA-listed wastes.**

Types of Remediation Methods

- Encapsulation
- Solidification
- Chemical Fixation
- Chemical reaction
- Pathway Interception

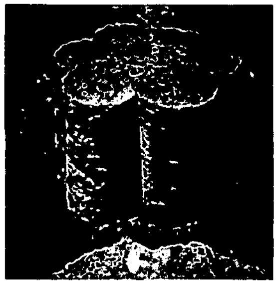
Solidification and Stabilization of Contaminated Solis

Distribution (in percent) of methods for treatment of contaminated soil within the Superfund project, USA (US, EPA, 1997)



Deep Soil Mixing as a part of Remediation Strategy for Contaminated Sites (Method of Delivery!)

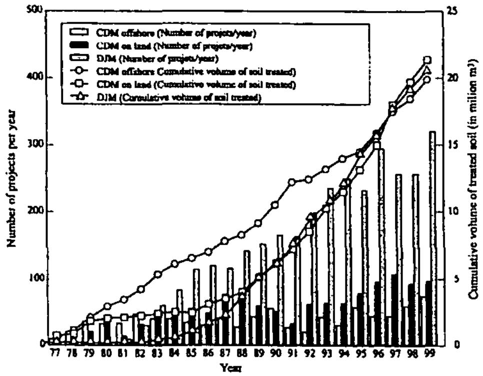
- In the U.S., significant amount of DSM was carried out in the early 1990s as a part of EPA's Superfund campaign.
- DSM has been used in the U.S. for encapsulation, stabilization and chemical fixation on a large number of successful projects.
- The lack of continuation of Superfund resources has slowed significant growth in soil mixing in the U.S.
- Growing use of DSM for remediation work in Europe (particularly Scandinavia)



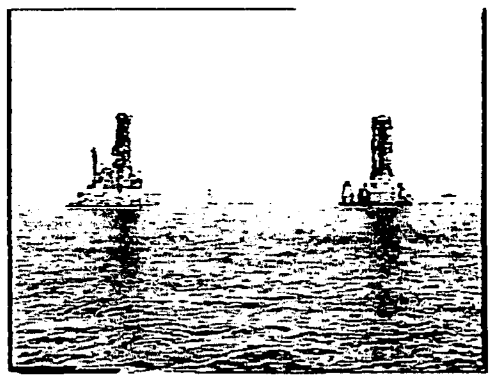
Application of DSM in Solidification and Stabilization S/S of Contaminated Sediments

- **Used primarily in upland contaminated sites**
- **Majority of S/S applications in Sweden, Norway and Japan**
- **Target contaminants include: hydrocarbons, heavy metals and PCBs**
- **Site specific mix design needed to address specific S/S needs**
- **Operation on many upland sites conducted under ground water level**

DSM in marine environments

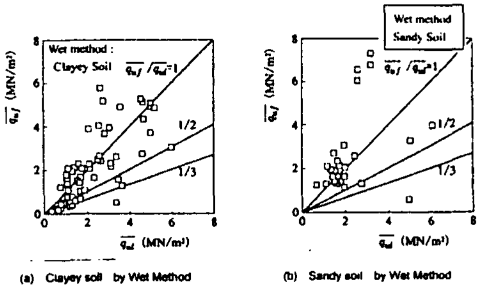


Cumulative volume of soil treated by deep mixing and number of Projects on annual basis in Japan (CDIT 2002)



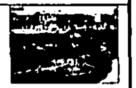
Exposed sea bottom improved by Wet type Deep Mixing Method at the intake of Aioi thermoelectric power station

(CDIT 2002)



Relationship between q_{uf} and q_{ul} for marine works by CDM Method Used to improve sea-bottom sediments. Note that in marine construction $q_{uf}/q_{ul}>1.0$ (Terashi, 2005)

DEEP SOIL MIXING APPLICATIONS IN SOLIDIFICATION AND STABILIZATION (S/S) OF CONTAMINATED SOILS

Project	Contaminants	Upland U, Near shore (N) or off shore (O)	Additive	Mix Method	Note
USA - In-situ Solidification/Stabilization of Hazardous Acid Waste Oil Sludge and Lessons Learned (Bates and Mallot, 2005)	Hydrocarbons Sulfuric acid lead	Wetland Miss River EPA's NPL	C, F and L	CDM (wet)	Pretreatment of 23500 yd³ with lime to increase PH of acidic oily sludge added to initial cost estimate. Developed performance specifications. Remediation met clean-up objectives. The groundwater monitoring program demonstrated that the combination of source area treatment and natural attenuation processes was effective in achieving the cleanup goals for the groundwater operable unit. Initial cost estimate at $135/yd3 but increased to $212 after pretreatment with lime
England - The Use of Deep Soil Mixing as part of the Remediation Strategy for Contaminated Sites (Essler and Kalin, 2005)	Acidic waste Hydrocarbons DNAPL		C, F and ZVI	CDM	Report on 3 case histories from England in the period from 1996 to 2004. The use of soil mixing as part of a remediation strategy can provide significant benefits. In particular the concept of creating a cellular treatment reduces cost and allow additives, introduced during soil mixing, to enhance natural attenuation. Soil mixing not only provides vertical barriers to groundwater flow but also acts as a delivery method for the introduction of contamination degradation acceleration.
Japan – Remediation of ground contaminated with VOCs based on dry mixing (DJM) technique in Japan	VOCs	Upland	Quick Lime	DJM (Dry)	With regards to soil contamination countermeasures, vapor extraction method is one of the most economical techniques for remediation areas contaminated by volatile organic compounds (VOCs). However, this method is not suitable for cohesive soils because of low permeability and long-term treatment. To address this problem, new remediation technology based on dry mixing (DJM) method using quicklime was developed. In this paper, in-situ field tests and some remediation works on sites contaminated by VOCs are introduced.
USA - In situ Soil Treatment Using Deep Mixing for a Waterfront Site Contaminated with VOC and PAH (Flori, et. al. 2005)	VOCs PAHs	Waterfront	C	CDM	This paper presents the challenging process to remediate a waterfront site contaminated with volatile organic compounds (VOCs) and polynuclear aromatic hydrocarbons (PAHs) using deep mixing technology. Cement was used as the main binder to stabilize 80,000 cubic yards of contaminated soil to a maximum depth of 38 ft. The performance criteria, details of treatment and treatability tests, excavation, site remediation and post treatment monitoring in the field are discussed in detail. 
Sweden - Stabilization and solidification of contaminated ground - A preliminary study (Holm et. al., 2005)	Hydrocarbons Mercury PCBs	NS U Waterfront	C and F	CDM	Six case studies are reviewed in Sweden, Finland and the U.S. A river sediment in Hammarby Sjostad contaminated Mercury where dredging and transport of the contaminated sediments deemed detrimental to the environment was successfully treated with CDM with mix of 125 Kg/m3 of cement. There is a need for methods to forecast the long-term function of the strength and leakage for S/S treated soils. Well-documented follow-ups of S/S treated areas are essential, preferably in a database. An increased knowledge on different stabilization binder suitability for use in contaminated soils is necessary

Finland - Remediation of contaminated land of Sörnäinen, Helsinki, by using the mass stabilization (Jelinic and Neppalen, et. al., 2005)	Hydrocarbons Heavy metals	Waterfront U	C	CDM	The first use of mass stabilization to stabilize and remediate contaminated soils took place in a former industrial area of Sörnäinen in Helsinki, Finland 1999. A PCB and oil contaminated clay layer was stabilized in-situ with cement
Brazil - Solidification stabilization of a residual soil contaminated by diesel oil (Crap et. al., 2005)	Diesel oil	Laboratory investigation	C		Unconfined compressive strength (UCS) and column leaching (ASTM D4874) tests were carried out to evaluate the efficiency of remediation of a residual soil contaminated by diesel oil, through stabilization/solidification (S/S) method by means of Portland cement addition. The results showed that UCS is dependent of cement and oil amounts and time of cure. According to column test results, the S/S method showed to be efficient to immobilize diesel oil in the studied soil just for small oil amounts. For high oil amounts, a major part of the leachate is released independently of cement amount
USA - Use of DSM for Remediation of a Metal Site (Yang, 1995)	Arsenic Pesticides	Upland	C	CDM	USA

1. 540SSR9XXM
Technology Demonstration Summary: International Waste Technologies In Situ Stabilization/Solidification, Hialeah, Florida
pages: 8
2. 540MS89004
Site Superfund Innovative Technology Evaluation - Demonstration Bulletin: In-Situ Soil Stabilization
pages: 2
3. 5405R9004A
Technology Evaluation Report: SITE Program Demonstration Test International Waste Technologies In Situ Stabilization/Solidification Hialeah, Florida, Volume I
pages: 166
4. 542R98008
Field Applications of In Situ Remediation Technologies: Chemical Oxidation
pages: 40
5. 540AS89004
International Waste Technologies/Geo-Con In Situ Stabilization / Solidification: Applications Analysis Report
pages: 96
6. 542R01004
Treatment Technologies for Site Cleanup: Annual Status Report (Tenth Edition)
pages: 80
7. 542B00004
Innovative Remediation Technologies: Field Scale Demonstration Projects in North America, 2nd Edition, Year 2000 Report
pages: 142

Coastal Development Institute Of Technology Japan 2006

Figure 1.1 Distribution of Water Areas with Mercury Sludge Cleanup

Note: Water areas include Harbors and Rivers

Coastal Development Institute Of Technology Japan 2006

Table 4.2 Leaching Test Results of Sludges Treated by Solidifications (by Takenaka Research Institute)

[illegible]

Bates and Mallot, 2005

Table 2 Performance Standards for Solidification/Stabilization of Waste Material (all values after 28 days cure time)

Test	Method	Design Criteria
Leachate Toxicity[1,2]	EPA SW846 1312	Pb <15 μg/L As <50 μg/L Ba <2,000 μg/L Be <4 μg/L Mn <4,088 μg/L Average of all samples tested
pH	EPA SW846 9045	7.0 <pH <11.5
Unconfined Compressive Strength[3]	ASTM D2166	Average of all samples 345 kPa (50 psi) @ 28 days Minimum of any sample 276 kPa (40 psi) @ 28 days Average of all samples 172 kPa (25 psi) @ 3 days
Hydraulic Conductivity	ASTM D5084	$1x10^{-5}$ cm/sec @ 28 days Average of all samples $1x10^{-4}$ cm/sec @ 28 days Maximum of any sample
Volume Expansion		Not to Exceed 65%

(1) Lead was the primary contaminant of concern. However, other metals and some organics present in the waste were initially tracked to assure that they were not occurring in SPLP leachate in concentrations approaching drinking water criteria.
(2) Allowance was included for 20% of samples to exceed these numbers by twice and for 10% of samples to exceed these numbers by a factor of five, provided that the average of all samples tested met these numbers.
(3) psi - pounds per square inch.

Table 4. Remedy Cost Comparison

Description of Capital Costs	ROD Estimated Cost	Original Bid	Final Estimated Cost
Administrative Requirements	$255,000	$225,125	$228,128
Health & Safety (Includes air monitoring)	$130,020	$72,492	$129,085
Temporary Facilities & Control	$87,200	$95,260	$175,967
Execution Requirements	$63,900	$81,246	$81,246
Wastewater Treatment Systems	$351,250	$5,370	$13,000
Solidification & Stabilization	$1,420,000	$1,776,601	$3,121,529
Site Preparation	$10,000	$12,836	$12,836
Soil Cover-Placement & Compaction	$70,000	$22,800	$68,350
Excavation – On-site Borrow Area	$40,000	$27,240	$23,835
Soil Erosion & Sediment Control	$4,000	$8,775	$2,010
Constructed Wetlands	$63,800	$73,839	$5,000
Security Gate	$1,250	$2,150	$2,150
Hydraulic Seeding	$4,950	$9,000	$9,000
Sample Analyses	$420,000	NA	$200,000
Contingency (25%)	$731,592	NA	NA
Engineering (20%)	$585,274	NA	$575,000
Total Capital Costs	$4,238,236	$2,415,737	$4,947,136

Bates and Mallot, 2005

Solidification and Stabilization of Contaminated Sediments

- **Target contaminants in the Passaic River**
  - **PCBs**
  - **Dioxins**
  - **Polyaromatic Hydrocarbons, PAH**

Advantages

- **Uses established technologies**
- **Reduces off-site disposal problems**
- **Relatively fast**
- **Reduces surface exposure**
- **Cost effective**
- **Low noise and vibration level**
- **Enables rapid redevelopment of sites**
- **Additional ground improvement of contaminated soils**

Pilot Study – Phase I 2004-2005

Location: Newark Bay Volume Treated: 1000 Yd^3

PILOT STUDY on NEWARK BAY (NJ)

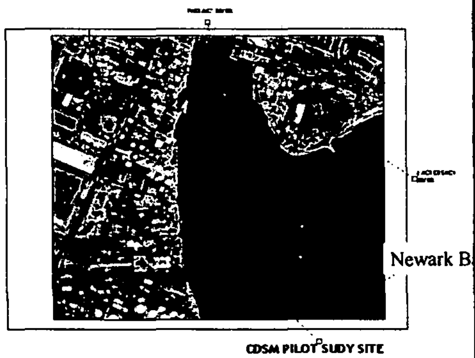
- **PROJECT TASKS**
  - **Site designation and investigation**
  - **Laboratory testing and evaluation**
  - **Field design (column layouts)**
  - **Field operation**
  - **Monitoring program**
    - **SPT survey**
    - **Turbidity**

PROJECT TEAM

- **Sponsors**
  - **NJ OMR (Lisa Baron, PM)**
  - **CAIT (USDOT), Rutgers University**
- **Industrial Partner**
  - **Raito, Inc. Baltimore, MA**
- **Advisor**
  - **Scott Nicholson, Army COE**

Site Designation / Investigation

- **Location**
  - **Darling International site waterfront**
  - **The mouth of Newark Bay**

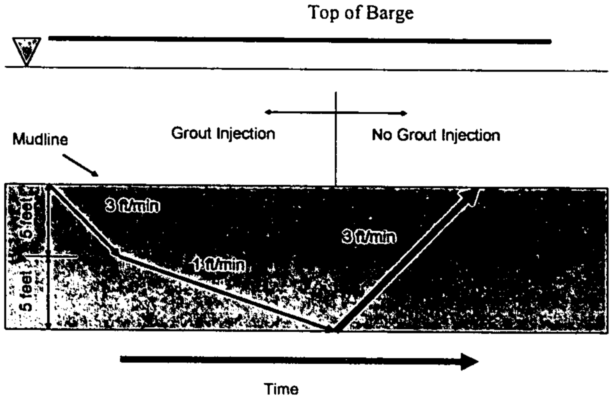


Laboratory Testing Program

- **Mixture design**

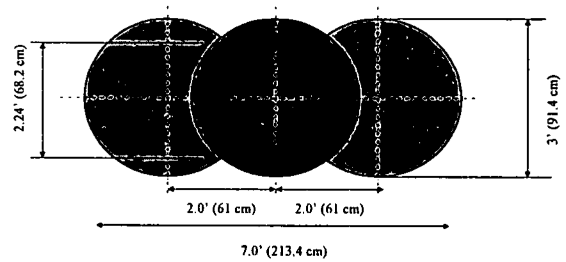
Item			Unit	Mix Design ID		
				MD-1	MD-2	MD-3
Mix Design	Dosage		kg/m³	100	150	200
			lb/cy	168.6	252.8	337.1
	Water - Cement Ratio of Slurry		%	80	80	80
Speed	Penetration Speed	Top 5.0 feet	feet/min	3.0		
		Bottom 5.0 feet		1.0		
	Withdrawal Speed	Top 5.0 feet		3.0		
		Bottom 5.0 feet		3.0		
[redacted]						
Injection Rate	Injection Rate During Penetration	Top 5.0 feet	gal/min/pump	15.1	22.7	30.3
		Bottom 5.0 feet		5.0	7.6	10.1
	Injection Rate During Withdrawal	Top 5.0 feet		0.0	0.0	0.0
		Bottom 5.0 feet		0.0	0.0	0.0

Laboratory Testing Program

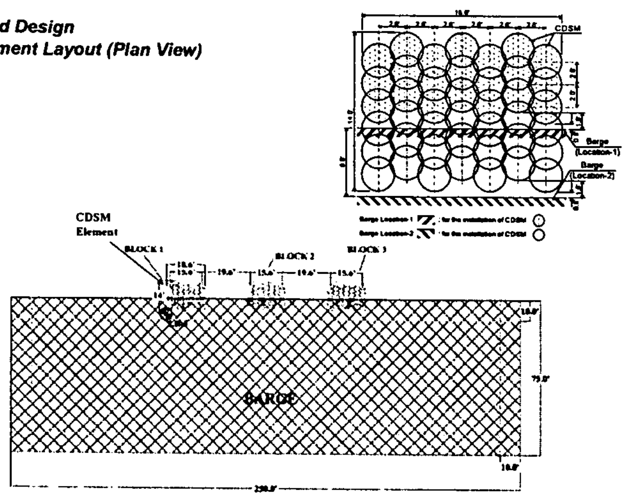


Field Design – Column Layouts

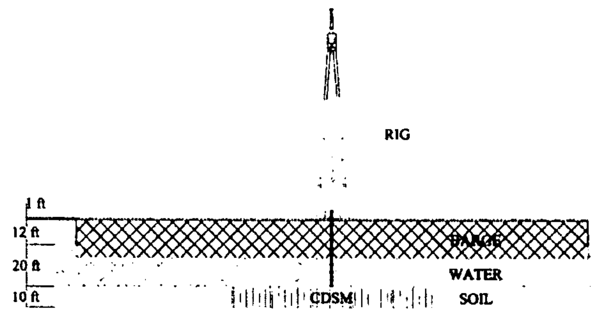
- **Work area was divided into individual elements (7' x 3') with specific identification numbers**



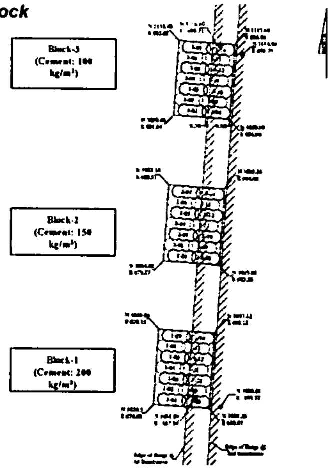
Field Design
Element Layout (Plan View)



Field Design
Element Layout (Cross Section)

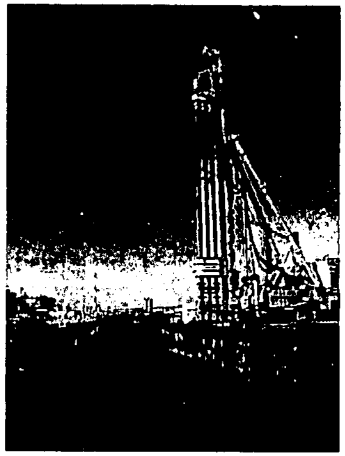


Field Design
As Built Coordinates for Each Block with Survey Points



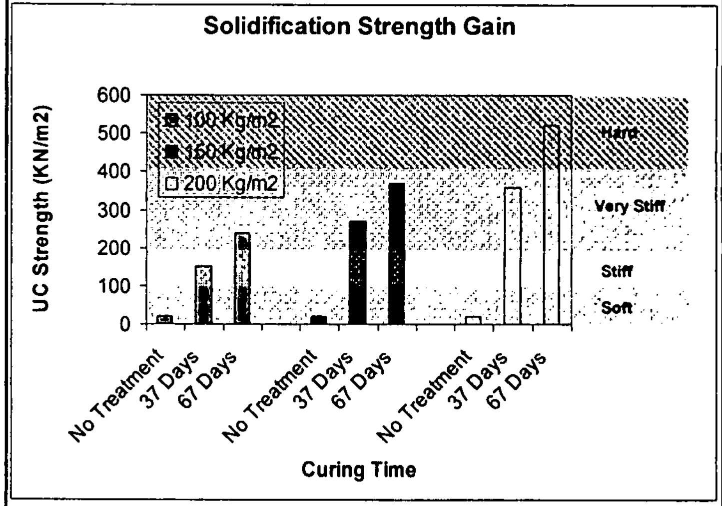
Equipment -3

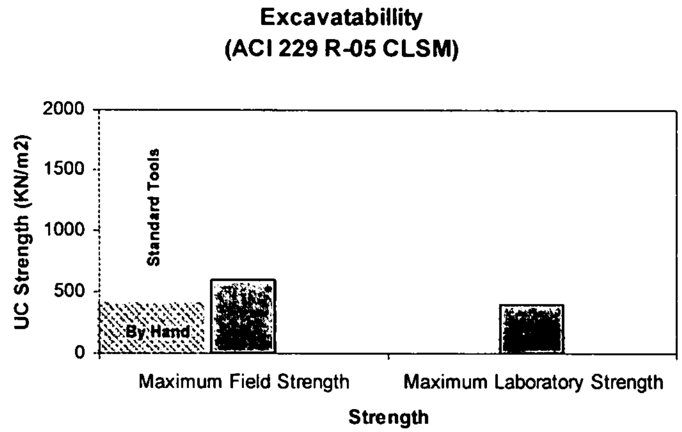
- Mixing rig
  - Crawler base machine and lead to support and guide the electric top driver motor
  - Inclinometers in the lead for left-right and fore-aft alignment
  - Sensors to monitor mixing tool penetration/withdrawal rates and mixing tool rotation speed.



Equipment -4

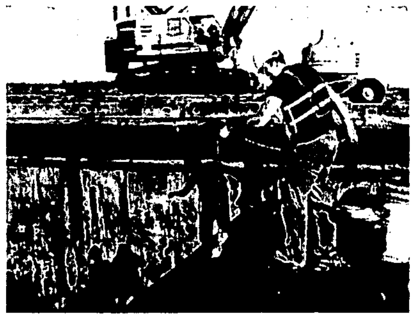
- Mixing tool
  - Triple shaft electric top drive motor with 3 axle mixing equipment
  - Mixing shafts with cutting augers and mixing blades (paddles) arranged to provide uniform mixing





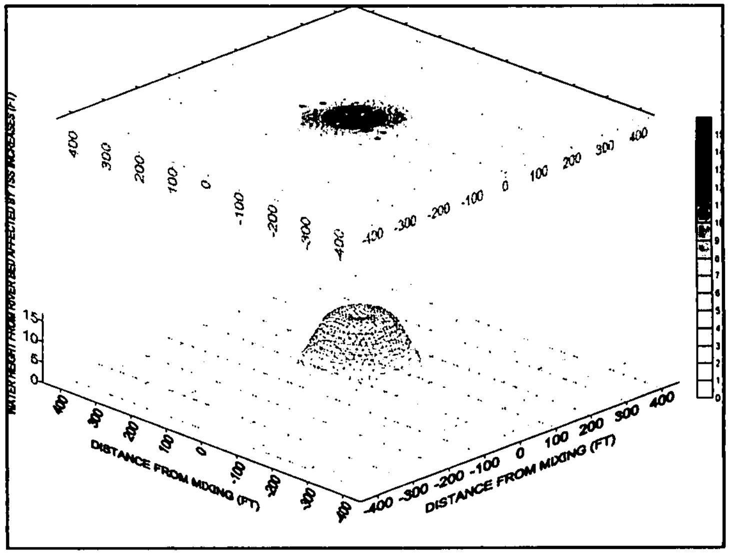
Monitoring Program

- Turbidity and resuspention evaluation



Turbidity Monitoring Program

1. To evaluate the effect of DSM process on the fate of potential contaminants within the sediments.
2. A component of the contaminant fate is the potential migration of polluted suspended solids within the water column.
3. A TSS survey study was implemented to evaluate the potential effects upon the water quality in the vicinity of the pilot CDSM site.



Phase I Conclusions

- DSM is highly effective in solidifying soft river sediments with material strength increasing significantly with additive contents as low as 100 Kg/m3
- The strength gain of solidified sediments is within allowable range for excavation with standard equipment
- Solidified sediments can either be removed en-mass or capped in place as an intermediate remedial measure

Phase I Conclusions

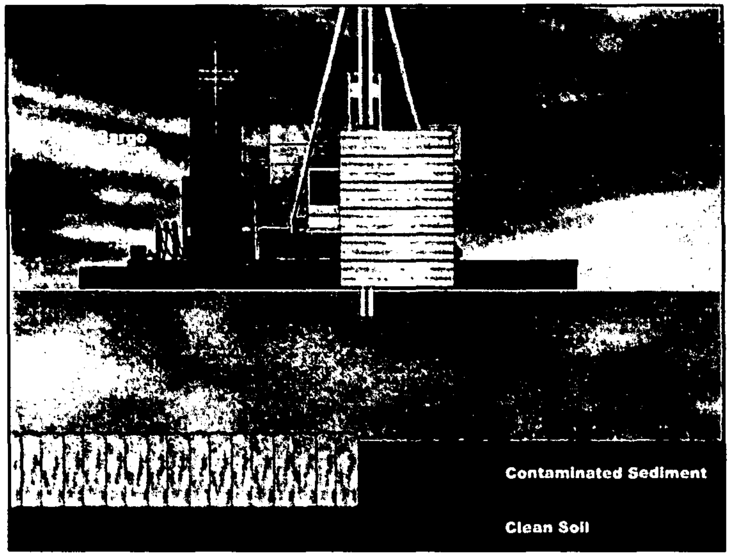
- Noticeable TSS increases (up to 450 ppm) over baseline results from 0 to 75 ft from mixing position and within 15 ft of depth.
- TSS was at baseline values at any depth at sampling points located > 125 ft from mixing.

Pilot Study – Phase II

Location: Passaic River
Volume Treated: TBD

PILOT STUDY on a Passaic River Site (Phase II)

- *The logistics and operational aspects* of DSM in a river environment, for example the optimal barge size and its maneuverability.
- *Perimeter containment during CDSM* operations to minimize potential migration of sediments during mixing and solidification (clip).
- *Addressing specific health and safety* measures during field operations.
- *Real-time monitoring of suspended solids* before, during, and after field operations in river environment. Once the results are available, determination could be made if perimeter containment is required or not.



PILOT STUDY on Passaic River (Phase II)

- *Validation of CDSM stabilization process* for improving leachate characteristics, which is of critical importance for in-situ stabilization.
- *Optimization of admixture recipe* for solidification and stabilization
- *Post treatment behavior of S/S mass* w/r to strength and leachate characteristics

PILOT STUDY on Passaic River

- *Assessment of potential volatilization* of contaminants during S/S operation.
- *Development of practical guidelines* and field specifications.

Frequently Asked Questions

- Expansion of soil mass due to addition of cement/water slurry (~20%).
- Fate of contaminants, e.g. contaminated pore water release into the water column or volatilization of organics.
- Health and Safety precautions.
- Elasticizer Chemistry.
- Production rates and associated costs.
- Containment requirements.
- Subsidence of solidified mass into the soft underlying sediments.