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IN-SITU STABILIZATION USING SHALLOW SOIL MIXING AND DEEP SOIL MIXING

by
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Of the currently emerging technologies for site remediation, one of the most attractive and economical is in-situ stabilization and/or in-situ fixation of contaminated soils by Shallow Soil Mixing (SSM) or Deep Soil Mixing (DSM). Actually, the soil mixing process is not new. It has been in use as a geotechnical construction process for over two decades. However, its use as a treatment for hazardous waste is a recent development.

Although the process of soil mixing originated in the United States in the 1950s (1), its major development occurred over the last twenty years in Japan. Several Japanese companies have developed different types of soil mixing methods and built large geotechnical construction divisions of their businesses based on the use of these processes. To date, there have been thousands of projects performed in Japan using some form of soil mixing. However, the first use for environmental cleanups was in the United States.

Soil mixing for in-situ stabilization of contaminated soils offers a methodology which allows soils to be treated above and below the water table without removal. There is no environmental impact and no special preparation required.

Soil mixing is divided into two categories, Shallow /soil Mixing (SSM) and Deep Soil Mixing (DSM). The SSM system utilizes a crane mounted mixing system. The mixing auger, three feet to twelve feet (1 meter to 3.7 meters) in diameter, is driven by a high torque turntable. /The mixing head can be enclosed in a bottom-opened cylinder, as depicted in Figure 1, to allow for closed system mixing of the waste and treatment chemicals.

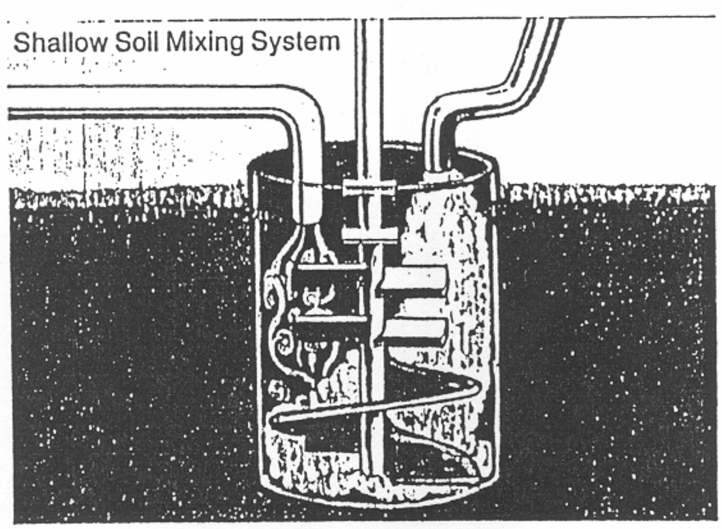


Figure 1

Treatment chemicals are transferred pneumatically for dry chemicals, as shown in Figure 2, or pumped in cases where fluid chemicals would be utilized. Treatment chemicals are precisely weighed (for dry systems), or volumetrically measured (for fluid systems), to allow the correct proportions to be mixed with the untreated waste sludge or soil. The bottom-opened cylinder described in figure 1, is lowered into the waste and the mixing blades are started while chemicals are introduced. The mixing blades mix through the total depth of the waste in an up and down motion. A negative pressure is kept on the head space of the bottom-opened cylinder to pull any vapors or dust to the vapor treatment system. At the completion of a mixed cylinder of waste, the blades are retracted inside the bottom-opened cylinder and the cylinder removed. The cylinder is then placed adjacent, and overlapping, to the previous cylinder and the process is repeated until all waste has been treated, as shown in Figure 3.

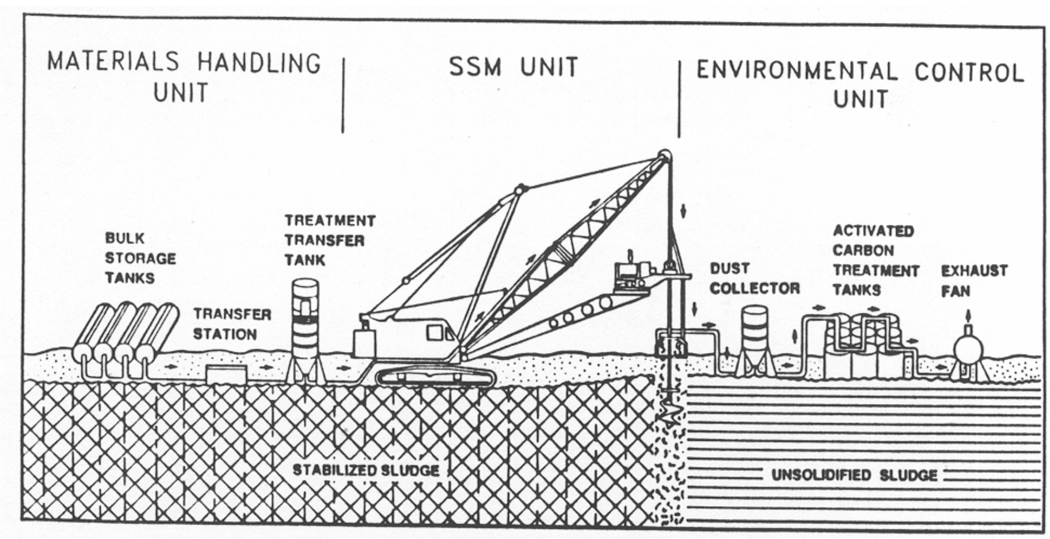


Figure 2

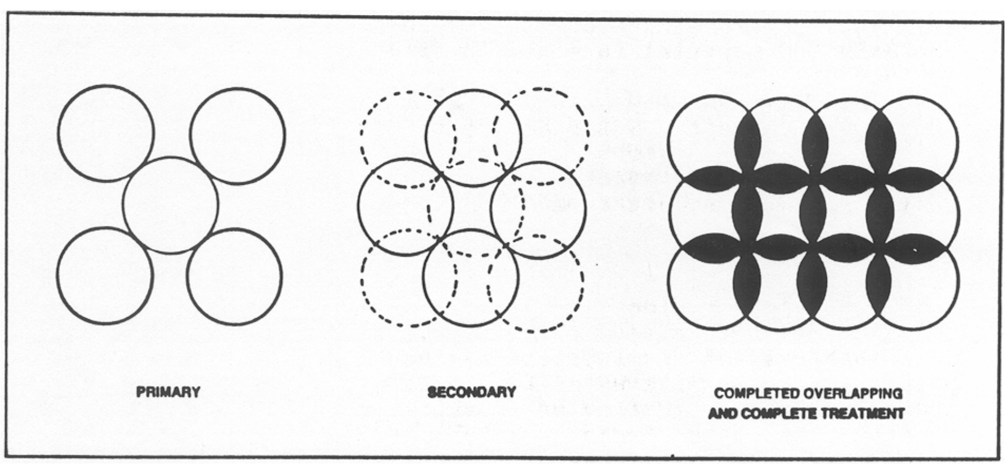


Figure 3

The SSM mixing auger can also be used without the cylinder. This method would be utilized when the soils are not in a flowing state or there are no emissions from the process.

DSM is a relatively simple process involving standard construction equipment rearranged for the DSM process. The equipment is a crane-supported set of leads which guides a series of one to four hydraulically driven, overlapping mixing paddles and auger flights (Figure 4). The auger flights are twenty-four inches to thirty-six inches (600 mm to 900 mm) in diameter. As penetration occurs, a slurry is injected into the soil through the tip of the hollow-stemmed augers. The augher flights penetrate and break loose the soil and lift it to the mixing paddles which blend the slurry and soil.

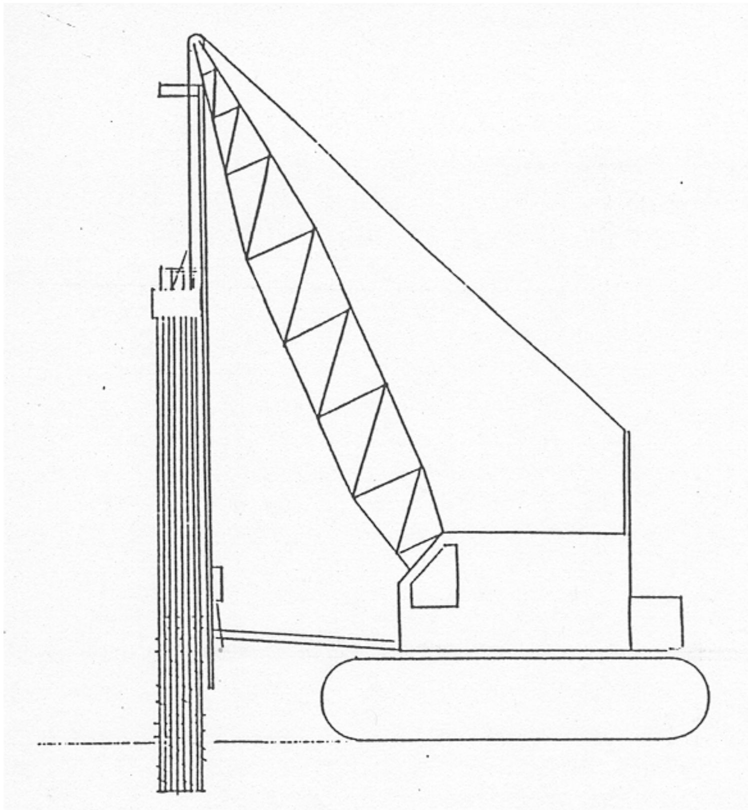


Figure 4

As the auger continues to advance, the soil and slurry are remixed by additional paddles attached to the shaft. Generally, about sixty percent to eighty percent of the slurry is injected as the augers penetrate downward and the remainder is injected as they are withdrawn so that the mixing process is repeated on the way out.

An overlapping pattern of primary and secondary strokes is used (Figure 5) so that an entire block of soil is treated.

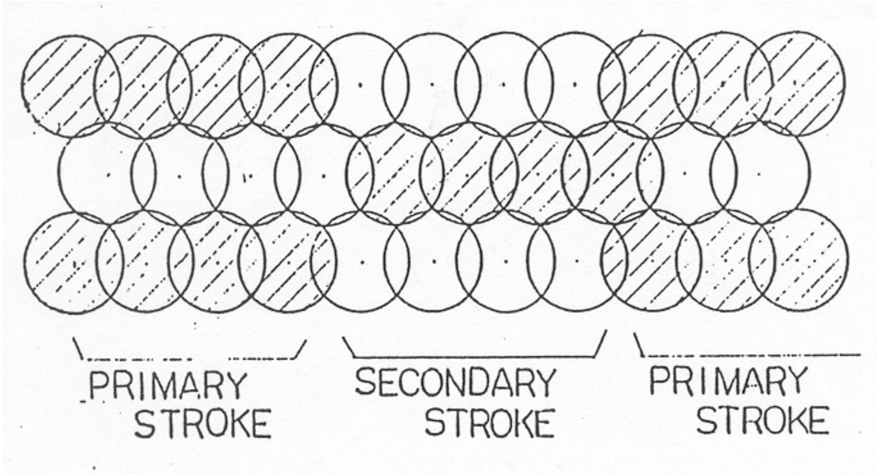


Figure 5

SSM is utilized o loose soils and sludges to depths up to thirty feet (9 meters). Because of the soft material to be treated, a very large diameter mixing shaft can be utilized without torque requirements exceeding the torque available with the turntable. By using the large mixing shaft, much more soil is mixed at once, greatly improving the economics over DSM.

DSM is utilized on harder or deeper soils by using smaller augers which do not require as much torque. Depending on soil conditions, DSM can extend down up to 150 feet (46 meters).

Soil mixing is a proven technology for mixing materials into soils. The key questions to be answered for site remediation applications are what type of chemical or other reagent should be injected and mixed into the contaminated soil and in what quantities.

The answer to both questions is determined with bench scale testing. Actual soil samples are taken from a site, analyzed for pollutants and soil properties, and tested for pretreatment data to be compared with post treatment data. Soil samples are then mixed with varying amounts of one or more reagents and tested to obtain post treatment data.

If solidification is the desired result, many common materials such as cement, lime, kiln dust and flyash can be batched into slurry form and mixed into the soil. If fixation is desired, there are several proprietary materials available which produce chemical reactions with different pollutants producing various degrees of fixation.

Recently, an EPA Superfund Innovative Technology Evaluation (SITE) program was performed using DSM and a proprietary chemical to effect in-situ fixation of PCB contaminated soils. The project report is still in draft form but preliminary results indicate that fixation of the PCBs was achieved.

SSM and DSM appear to be an economical and practical way to perform in-situ solidification and/or-in-situ fixation of contaminated soils and sludges. As the processes evolve, other uses in the site remediation field should develop.

REFERENCE

1. N. L. Liver, Mixed In Place Pile Patent, U. S. Patent No. 3,023,585, Filed November 26,1956

March 6, 1962 N. L. LIVER 3,023,585

MIXED IN PLACE PILE

Filed Nov. 26, 1956 2 Sheets-Sheet 1

FIG. 2

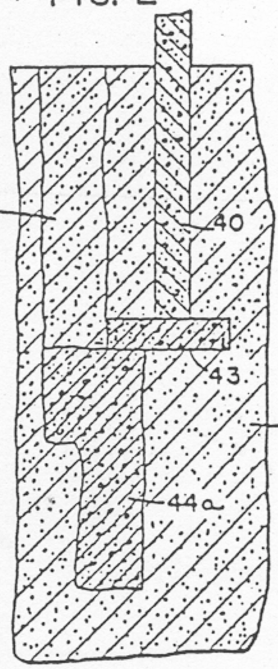


FIG. 1

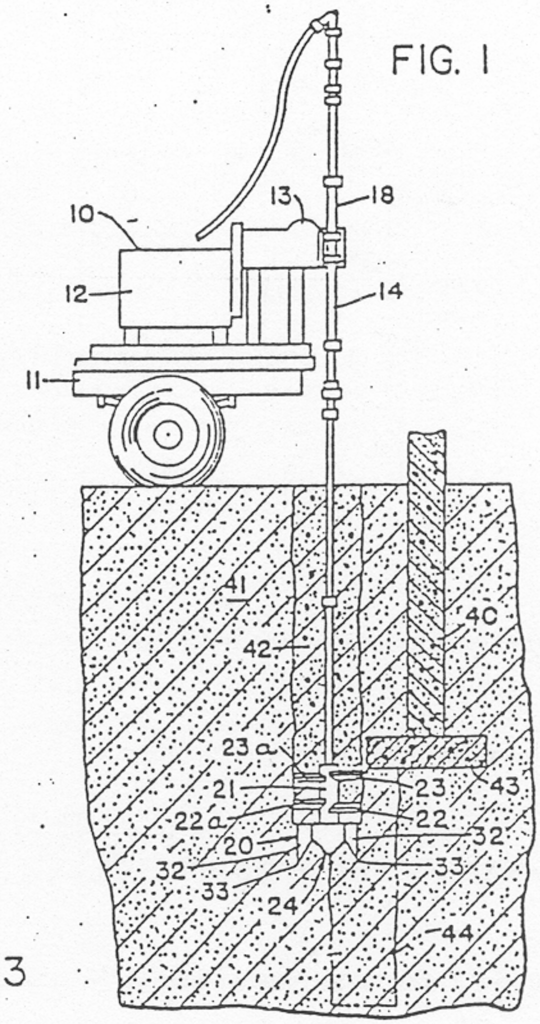
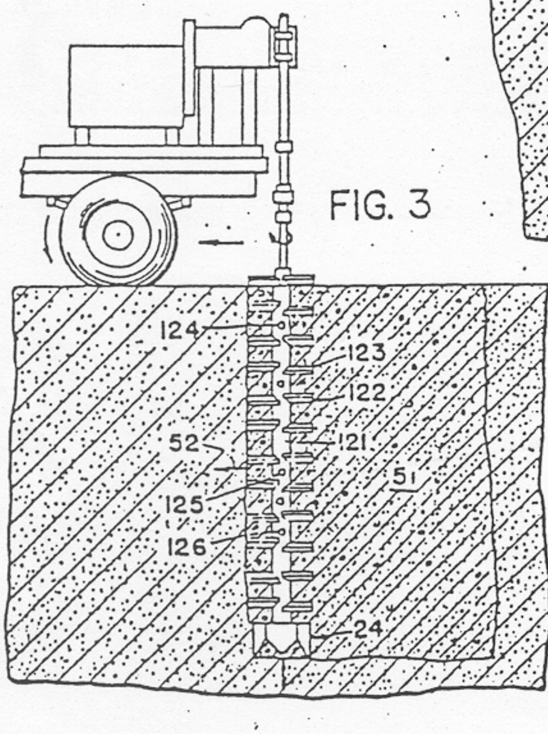


FIG. 3



INVENTOR.
NORMAN L. LIVER
BY

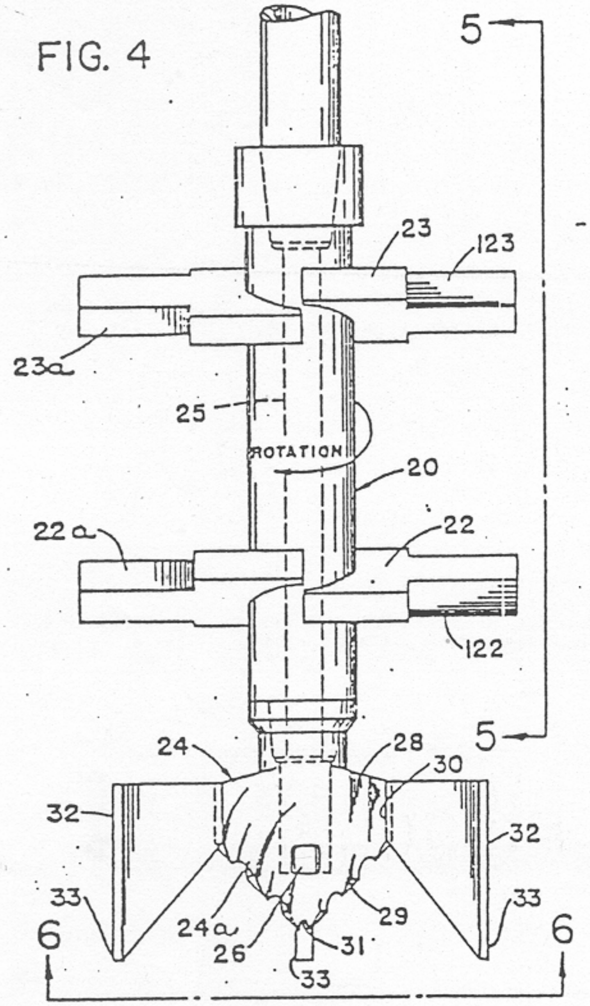
ATTORNEY

March 6, 1962 N. L. LIVER 3,023,585

MIXED IN PLACE PILE

Filed Nov. 26, 1956 2 Sheets-Sheet 2

FIG. 4



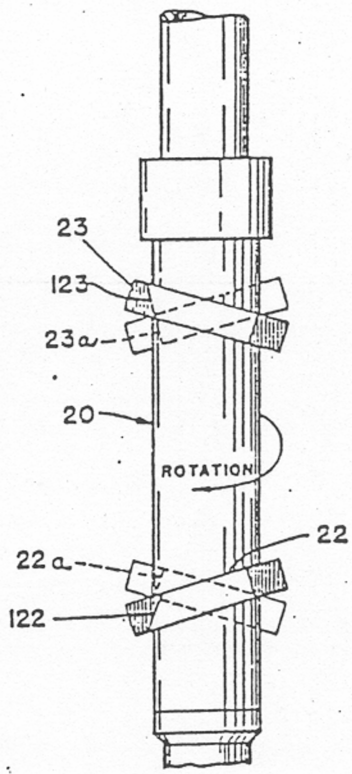


FIG. 5

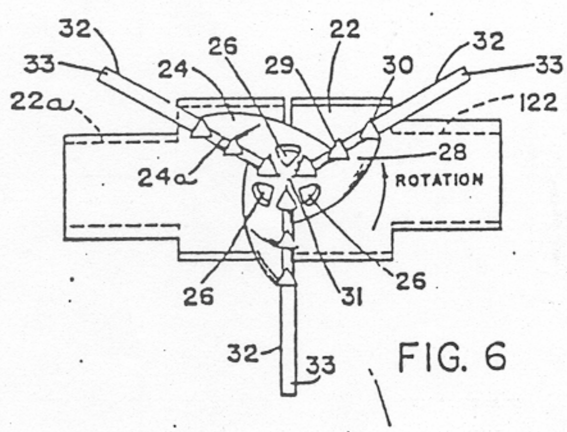


FIG. 6

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NORMAN L. LIVER
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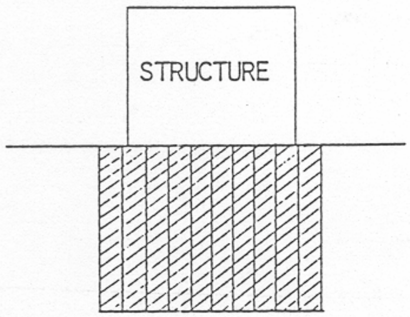
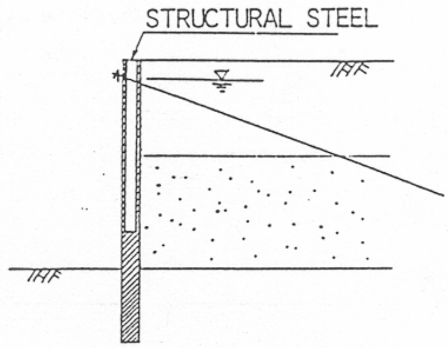
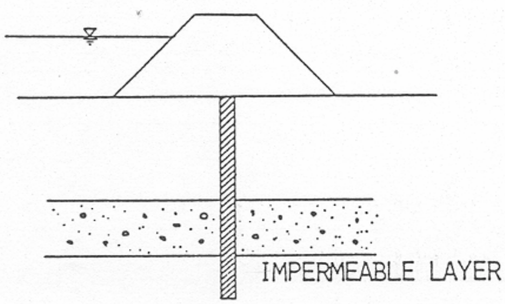
Alfred C. Body
ATTORNEY



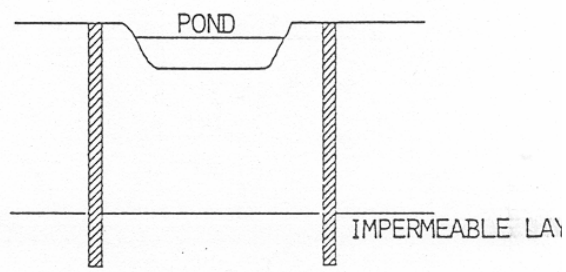
FOUNDATION & SOIL IMPROVEMENT



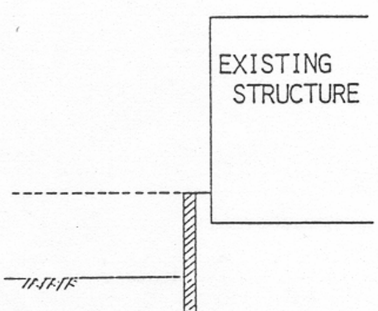
RETAINING & CUT-OFF WALL



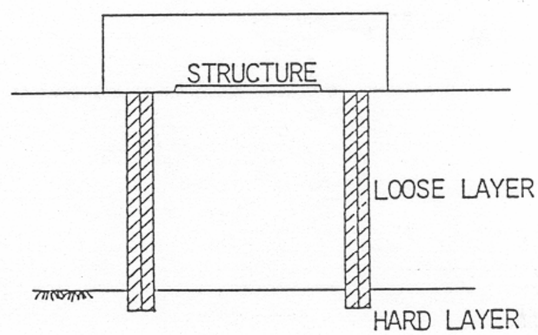
CUT-OFF WALL



SEEPAGE BARRIER

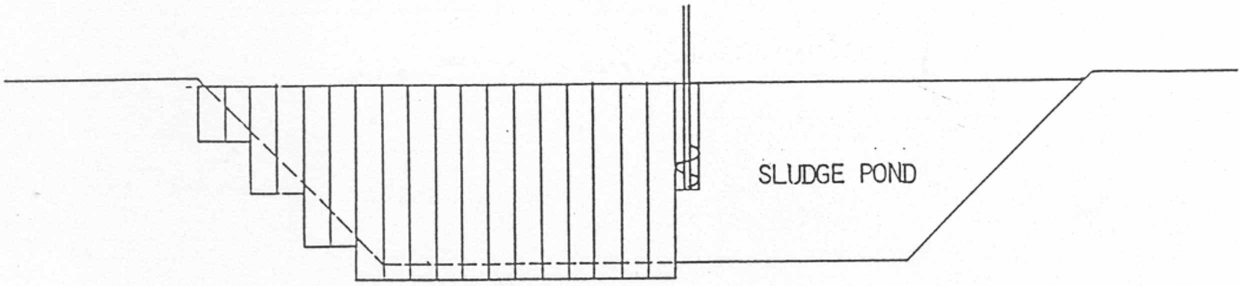


ANY WALLS ADJACENT TO EXISTING STRUCTURE

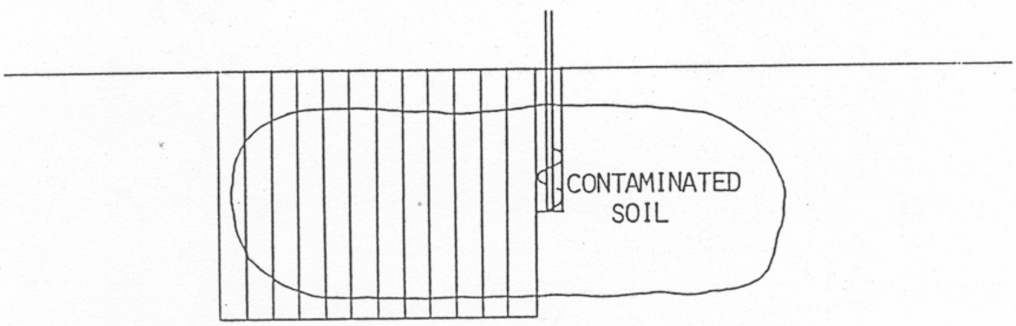


LOW STRENGTH PILES

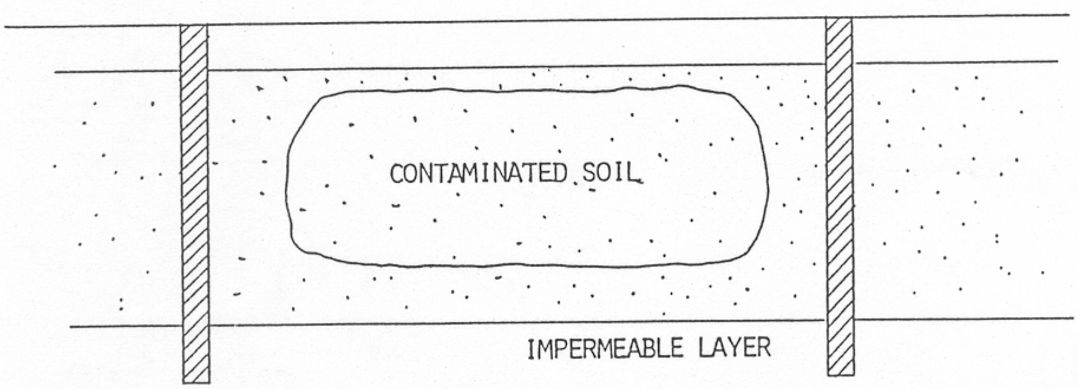
GEOTECHNICAL APPLICATIONS OF DEEP SOIL MIXING



SOLIDIFICATION



FIXATION



CONTAINMENT

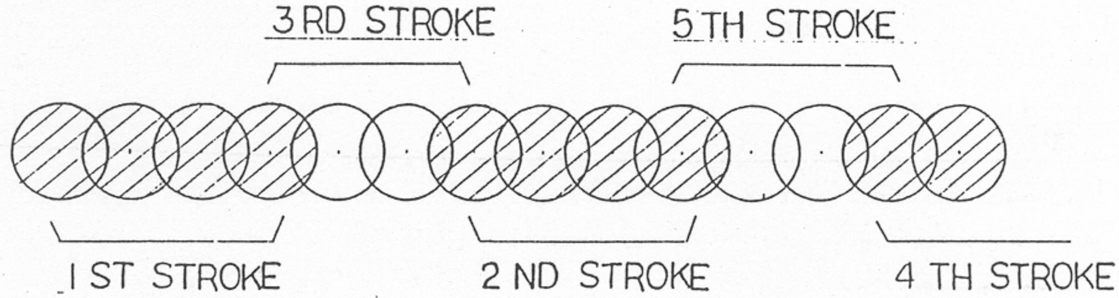
ENVIRONMENTAL APPLICATIONS
OF DEEP SOIL MIXING

	W/C = 1.5	W/C = 1.0	COMPRESSIVE STRENGTH
	LB/CY	LB/CY	PSI
LOOSE SAND	500	450	500 - 1000
DENSE SAND	450	400	500 - 1000
CLAY	600	500	200 - 400

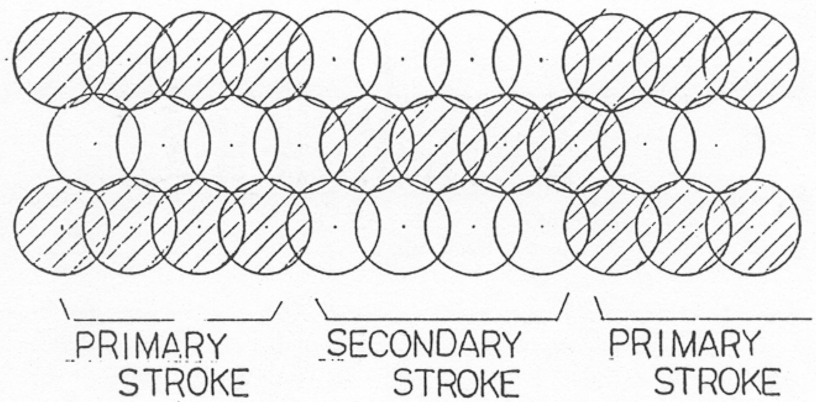
TYPICAL INJECTION RATE (CEMENT)

	FT/MIN
LOOSE SAND	3 - 5
DENSE SAND	2 - 3
CLAY	2 - 3

TYPICAL PENETRATION RATE

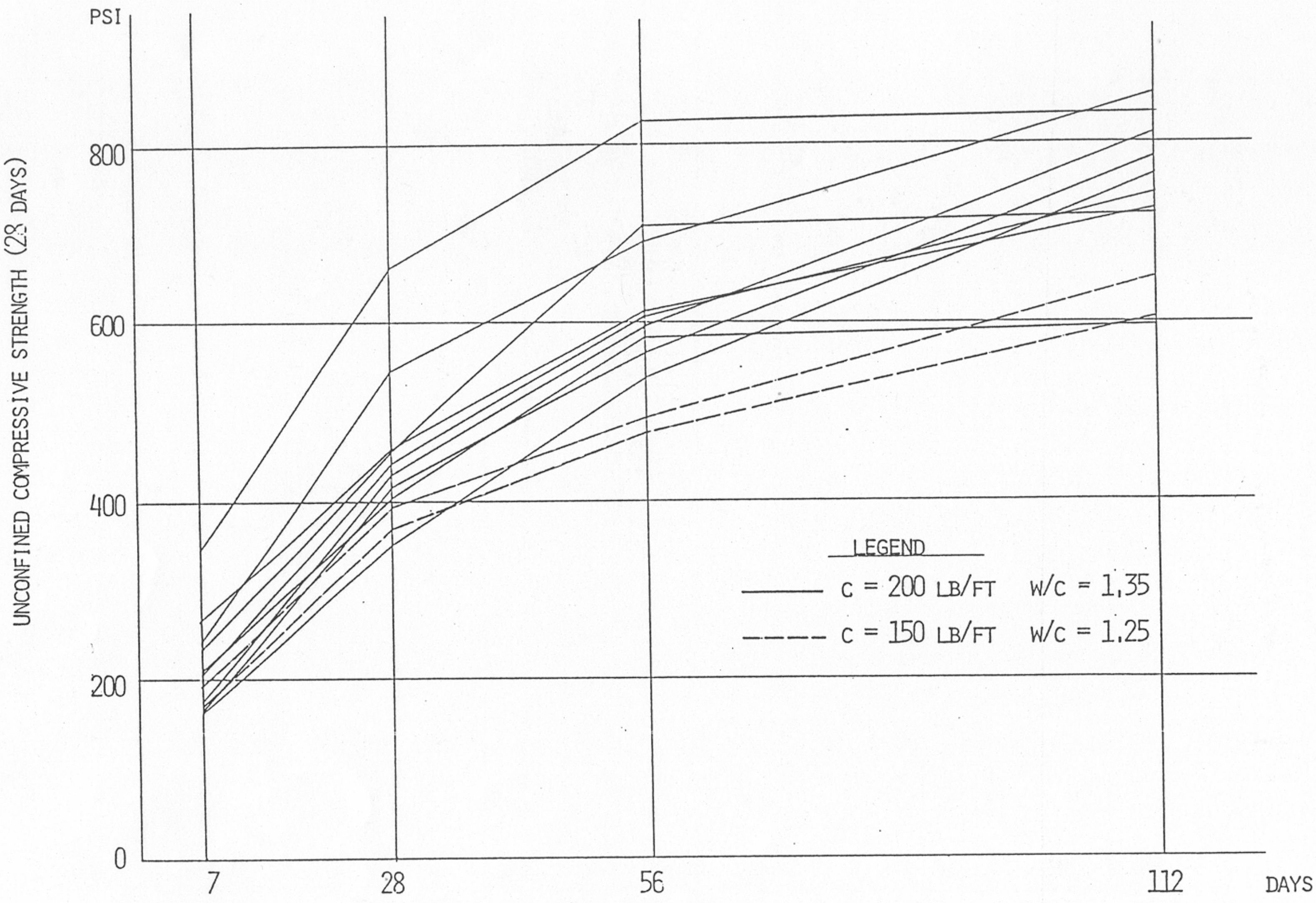


PATTERN A

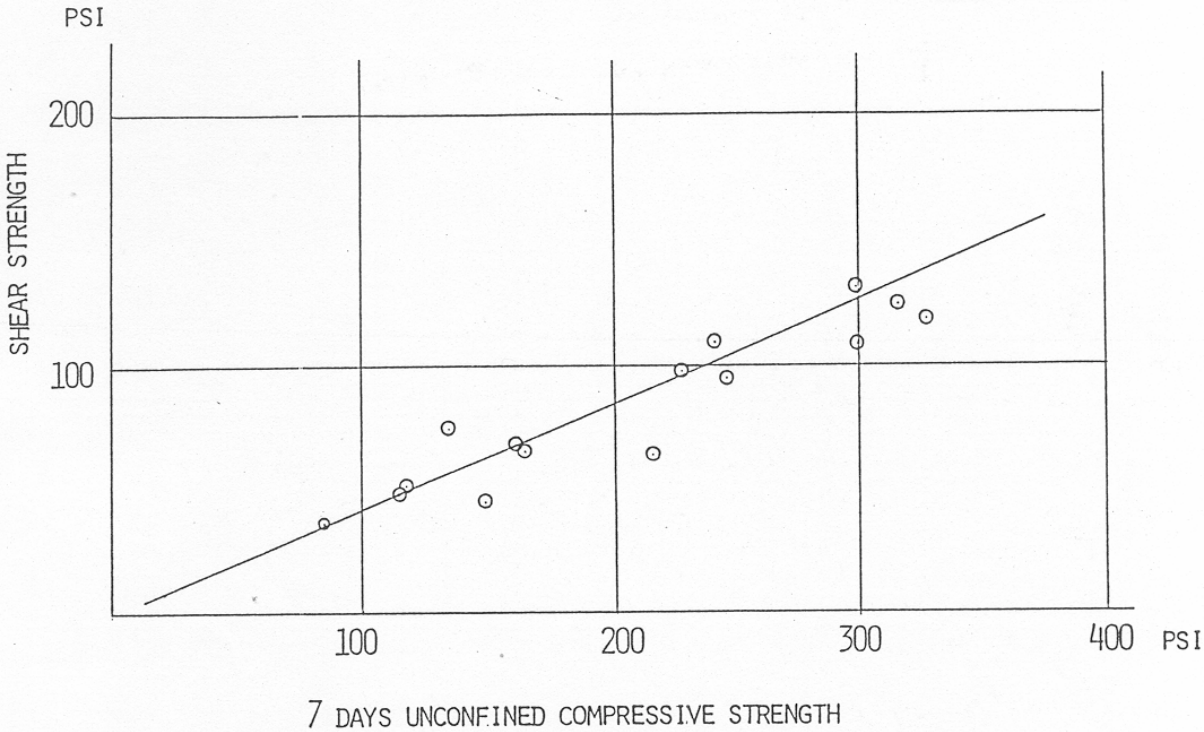


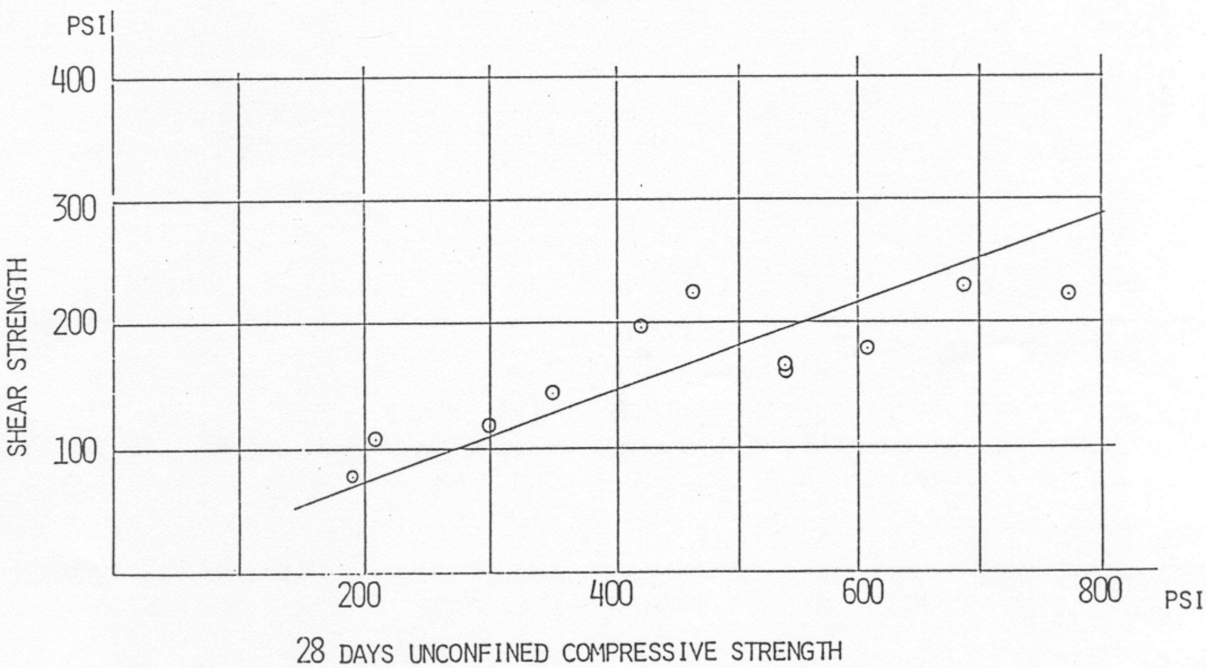
PATTERN B

CONTINUOUS DRILLING PATTERN

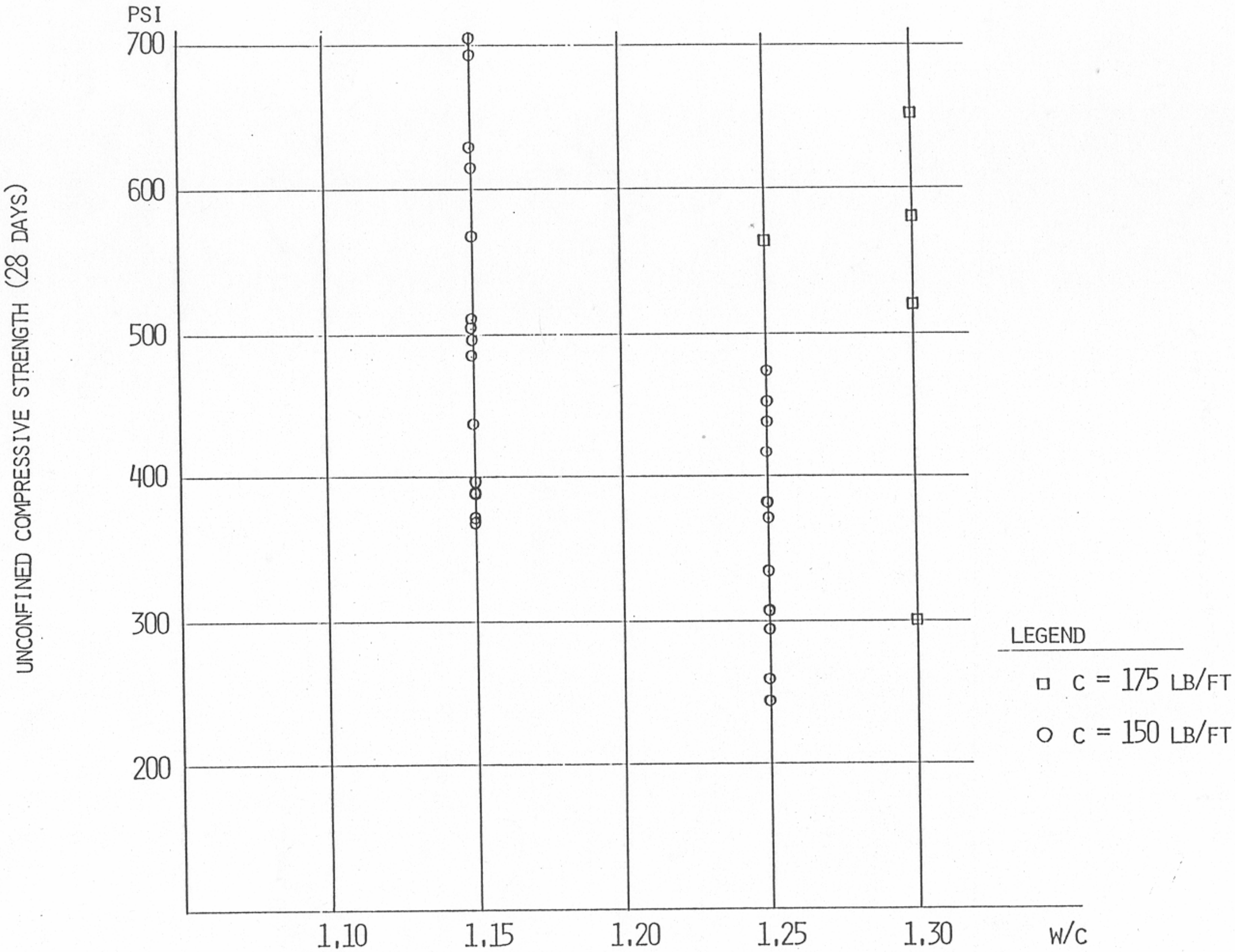


SOILCRETE STRENGTH VS. TIME

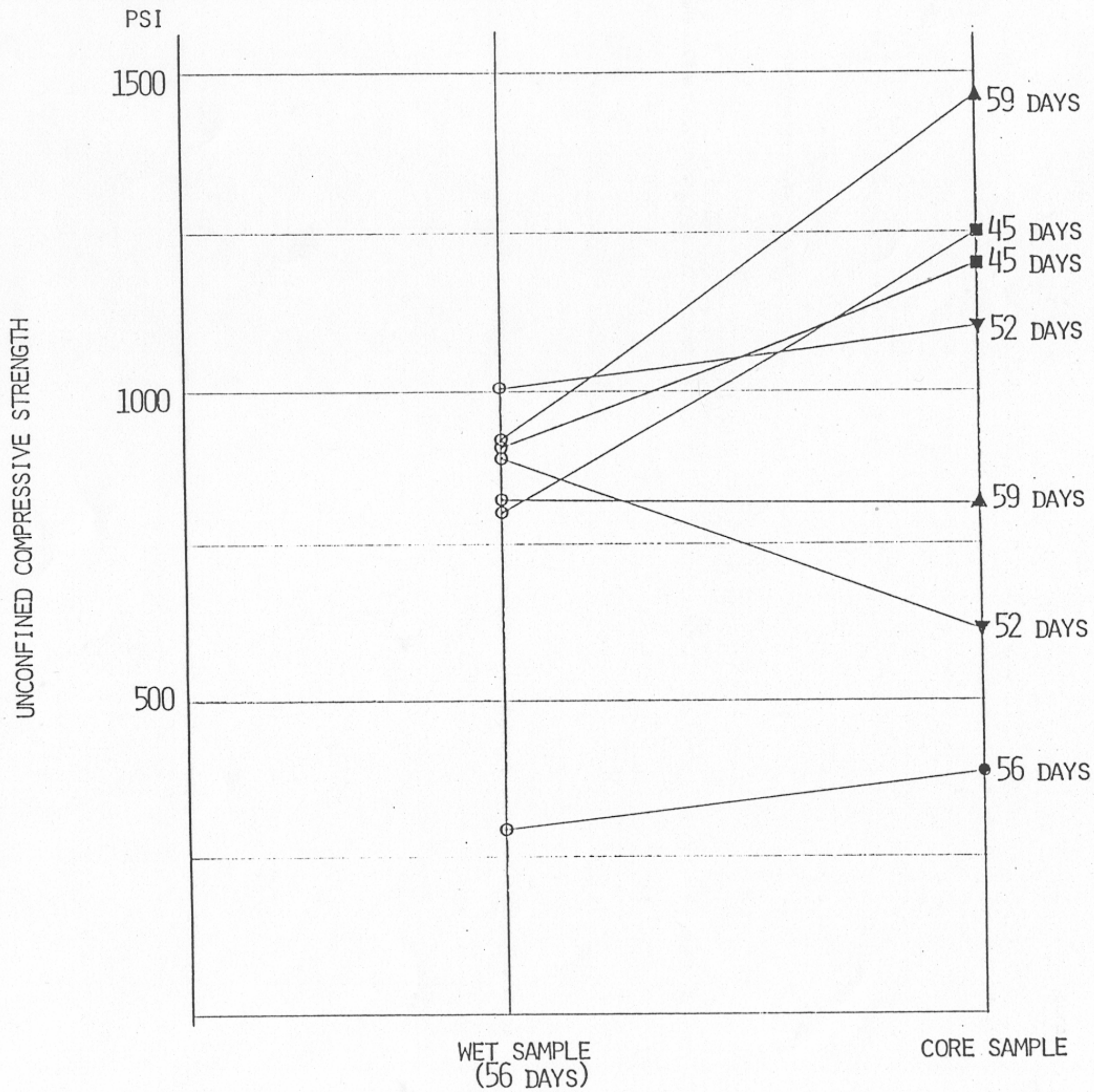




SOILCRETE UNCONFINED COMPRESSIVE STRENGTH vs. SHEAR STRENGTH



SOILCRETE STRENGTH VS. WATER CEMENT RATIO

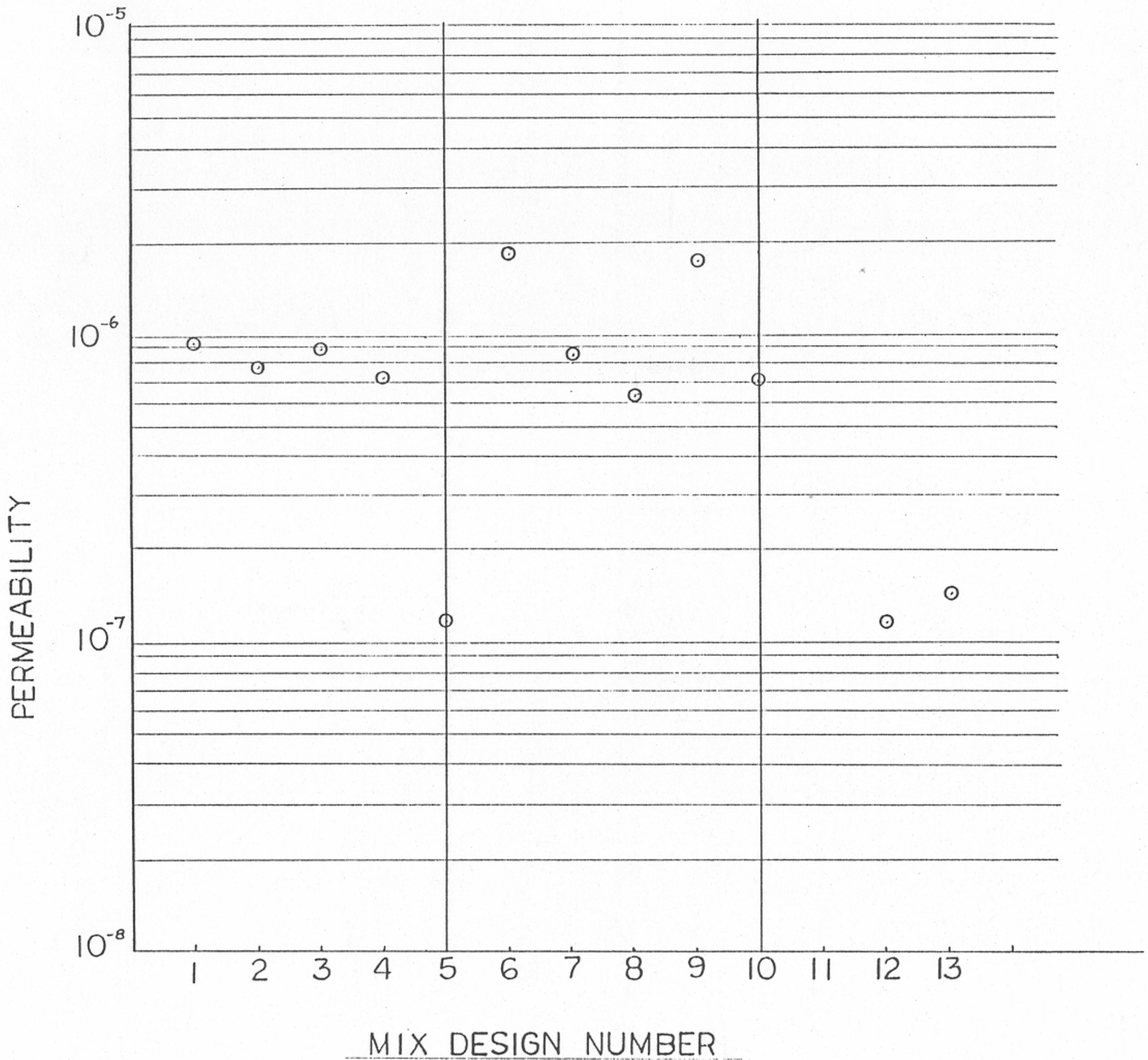


WET SAMPLE STRENGTH vs. CORE SAMPLE STRENGTH

COMPARISON OF TRIAL MIXES

Mix No.	Percent by Weight to Water: Cement	Percent by Weight to Water: Bentonite	Percent Addition of Slurry to Soil by Weight	K Permeability
1	10	4	19.4	9.17×10^{-7}
2	15	4	28.3	7.82×10^{-7}
3	10	10	21.6	8.91×10^{-7}
4	10	10	48.2	7.19×10^{-7}
5	15	4	48.8	1.17×10^{-7}
6	16	4	40.5	1.87×10^{-6}
7	10	8	45.0	8.40×10^{-7}
8	10	8	25.0	6.16×10^{-7}
9	7	4	25.0	1.76×10^{-6}
10	7	4	40.0	7.05×10^{-7}
11	0	8	17.0	DID NOT SET
12	4	11*	40.0	$1.16 \text{ X } 10^{-7}$
13	5	12*	40.0	$1.44 \text{ X } 10^{-7}$

* 1% Retarder



TRIAL MIX PERMEABILITIES

DSM QUALITY CONTROL

Daily Report No. 1
(Page ___ of ___)

Date: ____________________ Job Number: ____________________
Weather: ____________________ Job Name: ____________________

Stroke No.						
Station/No.						
Depth (ft.)						
Key (ft.)						
Primary/Secondary						
Wall Area (s.f.)						
Start Time						
Bottom						
Complete						
Time Down (min.)						
Time Up (min.)						
Total Time (min.)						
Slurry Take (gal.)						
Average Flow Rate (gal./min.)						
Cement (lb.)						
Bentonite (lb.)						
Water (gal.)						
Comments						

<u>EXHIBIT C</u>

Preliminary Materials QC/QA Outline
Deep Soil Mixing Wall

SUBJECT		STANDARD	TYPE OF TEST	MINIMUM FREQUENCY	SPECIFIED VALUES
MATERIALS:	Water	-	-pH -Total Hardness	One per source One per source	As required to properly hydrate bentonite with approved additives
	Cement	ASTM C150	Manufacturer certificate of compliance	One per truckload	Portland, Type I
	Bentonite	API Std 13A	Manufacturer certificate of compliance	One per truckload	Premium grade sodium montmorillonite clay
	Attapulgite	API Std 13A	Manufacturer certificate of compliance	One per truckload	Premium grade sodium-free attapulgite clay
SLURRY:	Clay Slurry	API Std 13B	-Viscosity -Unit Weight -pH -Filtrate	Two per shift Two per shift One per shift One per shift	TDB
	Grout	API Std 13B	-Cement Content -Clay Content -Water Content -Unit Weight	One per batch One per batch One per batch Two per shift	TBD
BACKFILL MIX:	Soil-Grout	EM-1110-2-1906 App VII App XI	-Triaxial Permeability -Unconfined /strength	One per 100 l.f. One per l.f.	TBD

PRECONSTRUCTION INVESTIGATION

A. SOIL SAMPLING REQUIREMENTS

EVALUATION OF SOIL TYPE

- GOVERNING SOIL TYPE (SAND OR CLAY)

- EXISTENCE OF ORGANICS

- EXISTENCE OF BOULDERS

WATER CONTENT

SPECIAL SOIL CONDITIONS

B. LABORATORY TESTING REQUIREMENTS

TO DECIDE THE MIXING PARAMETERS TO MEET THE SPECIFIED STRENGTH OR PERMEABILITY

PARAMETERS

- W/C RATIO

- INJECTION RATE (CEMENT CONTENT PER UNIT VOLUME SOIL)

- MIXING TIME