

# **Modified Dry Method (MDM)**

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## **Field test, MDM columns**

**Performed by**

**LCT/Hercules**

**Testing & evaluation**

**by SGI**

**October/November, 2003**

**Stockholm, Sweden**

# Purpose of Test

- Show possible improvements to dry mixing, using the MDM technology
- Determine new range of applications of the MDM equipped installer, from low to very high strength columns, using the same equipment
- Evaluate installation efficiency of the MDM method
- Evaluate MDM equipment (design & function)

# Test Criteria

## Existing Applications

Improvements to installations in clay

- Produce columns in layered soils
- Improve mixing ability/efficiency
- Alter Liquidity Index
- Compare to LIMIX (dry mix)

## New Applications

Installations in hard, sandy & dry conditions

- Create medium strength columns
- Create high strength columns
- Facilitate penetration in hard soils

# Test Criteria, cont.

- Two sites chosen, one clayey and one sandy
- Perform excavation and visual inspection at clayey site
- Perform excavation and core sampling at sandy site
- Perform permeability tests at sandy site
- All columns to be tested after 30 days

# Equipment Specifications:

- Hercules KC 4 dry mix installer with separate carrier
- 800 mm MDM tool
- 20 meters capacity
- Standard dry mixing blade configuration
- 1.5” water swivel
- 15 bar pump capacity



# Site Specifications

## Bro site

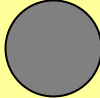
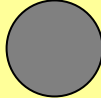

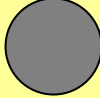
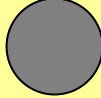
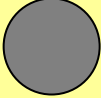

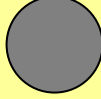
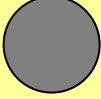
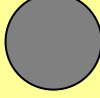
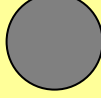
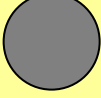
- Clay
- Dry crust, 2 meters thick, overlaying the clay
- Water content: 35 – 88 %
- Liquidity Index: -0.5 - 1.3 (see graph)
- Binder used: 100 % cement

## Tullinge site

- Sand, silty sand
- Silt layer between 2-2.5 meters
- SPT between 25 and 50
- Binder used: 100 % cement

# Bro test site (clay)

## Column specifications

<b>MDM</b>	Binder: 100 kg/cu.meter Penetration: 25 mm/rev, 100 revs Withdrawal: 25 mm/rev, 200 revs	<b>1.1.1</b> 	<b>1.1.2</b> 	<b>1.1.3</b> 
<b>MDM</b>	Binder: 300 kg/cu.meter Penetration: 25 mm/rev, 100 revs Withdrawal: 10 mm/rev, 200 revs	<b>1.2.1</b> 	<b>1.2.2</b> 	<b>1.2.3</b> 
<b>Limix</b>	Binder: 100 kg/cu.meter Penetration: Normal Withdrawal: 25 mm/rev, 200 revs	<b>1.3.1</b> 	<b>1.3.2</b> 	<b>1.3.3</b> 
<b>Limix</b>	Binder: 300 kg/cu.meter Penetration: Normal Withdrawal: 10 mm/rev, 200 revs	<b>1.4.1</b> 	<b>1.4.2</b> 	<b>1.4.3</b> 



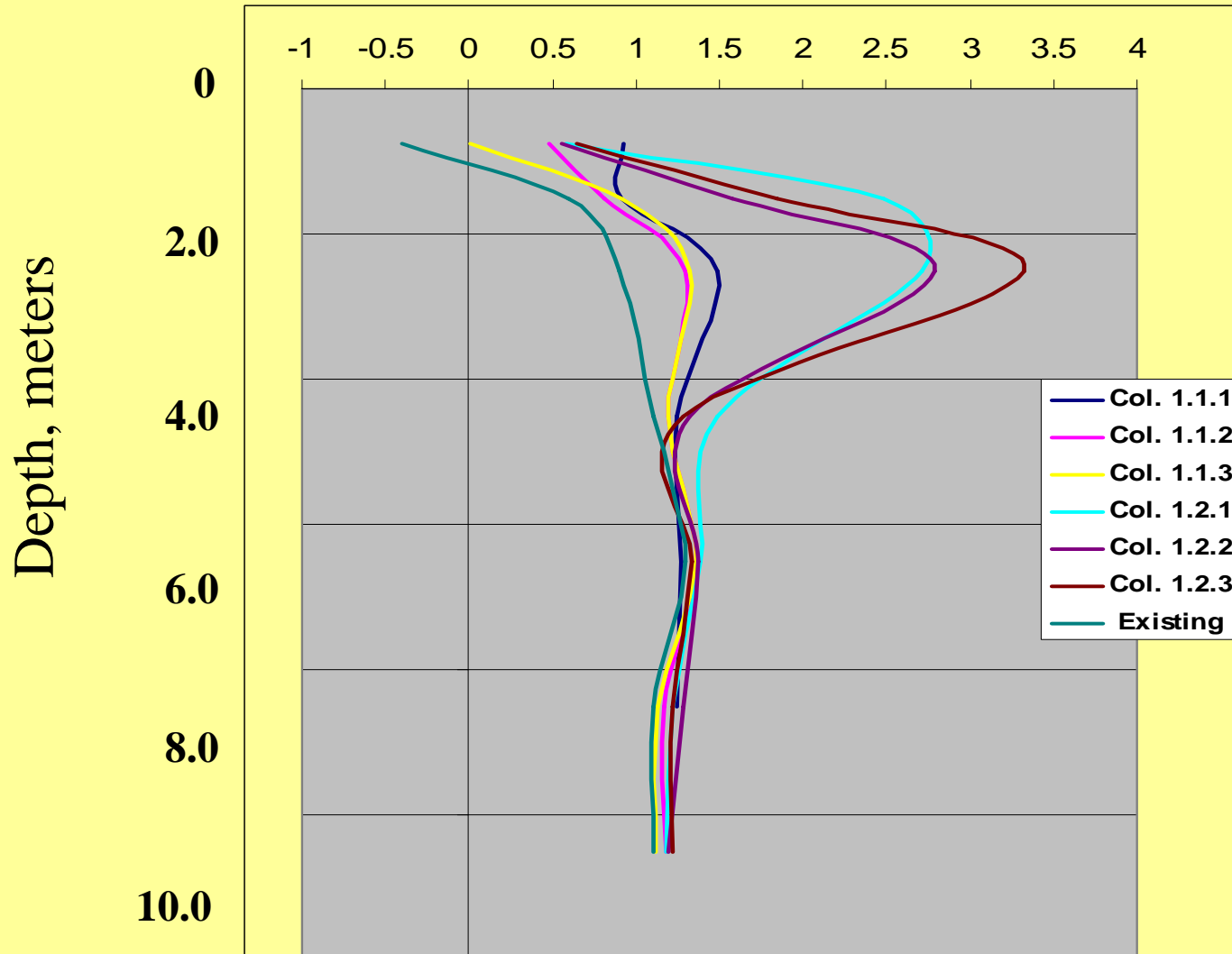
# Installation, Bro (Clay)





# Test data Bro (clay)

## Existing & Modified Liquidity Index



# Evaluation Bro (clay)



Excavation

Visual inspection



# Tullinge site, column locations

Upper plateau

3 x MDM 300

3 x MDM 300

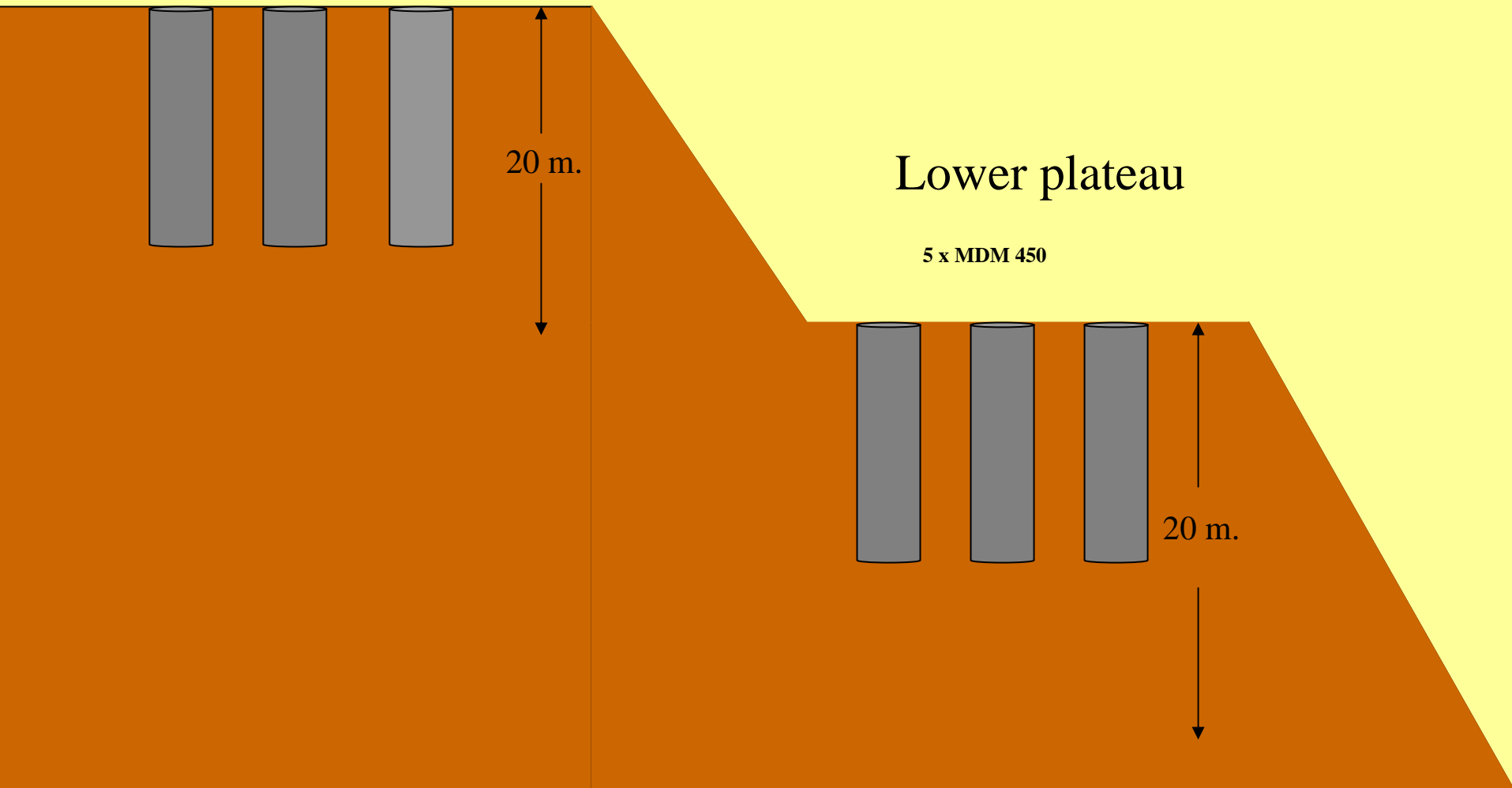
3 x MDM 100

20 m.

Lower plateau


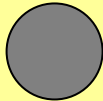
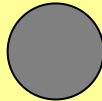


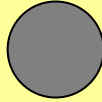


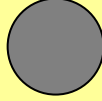
5 x MDM 450

20 m.



# Column specifications

## Tullinge test site, upper plateau

<b>MDM 300 Medium strength</b>	Binder: 300 kg/cu.meter Penetration: 25 mm/rev, 100 revs Withdrawal: 10 mm/rev, 200 revs	<b>TulM300.1</b> 	<b>TulM300.2</b> 	<b>TulM300.3</b> 
<b>MDM 300 Medium strength</b>	Binder: 300 kg/cu.meter Penetration: 25 mm/rev, 100 revs Withdrawal: 10 mm/rev, 200 revs	<b>TulM300.4</b> 	<b>TulM300.5</b> 	<b>TulM300.6</b> 
<b>MDM 100 Low strength</b>	Binder: 100 kg/cu.meter Penetration: 25 mm/rev, 100 revs Withdrawal: 10 mm/rev, 200 revs	<b>TulM100.1</b> 	<b>TulM100.2</b> 	<b>TulM100.3</b> 



**To lower plateau**



# Column specifications

## Tullinge test site, lower plateau



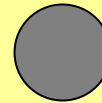
**To upper plateau**



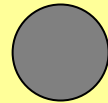
**MDM  
450  
High strength**

Binder: 450+ kg/cu.meter  
Penetration: 25 mm/rev, 100 revs  
Withdrawal: 10 mm/rev, 200 revs

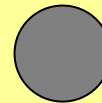
**TulM450.2**



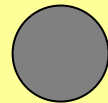
**TulM450.5**



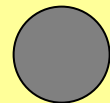
**TulM450.1**



**TulM450.3**



**TulM450.4**





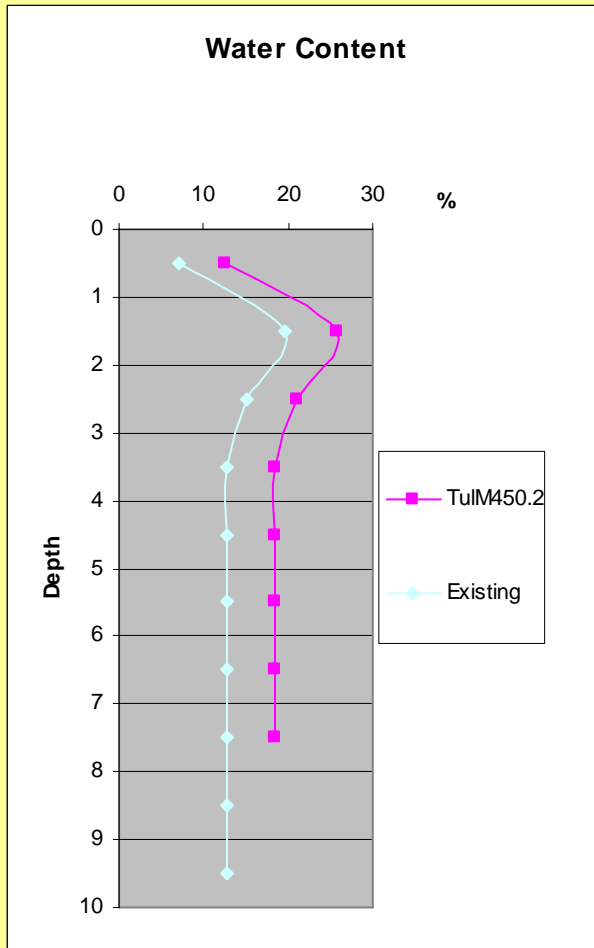
# Installation Tullinge (Sand)



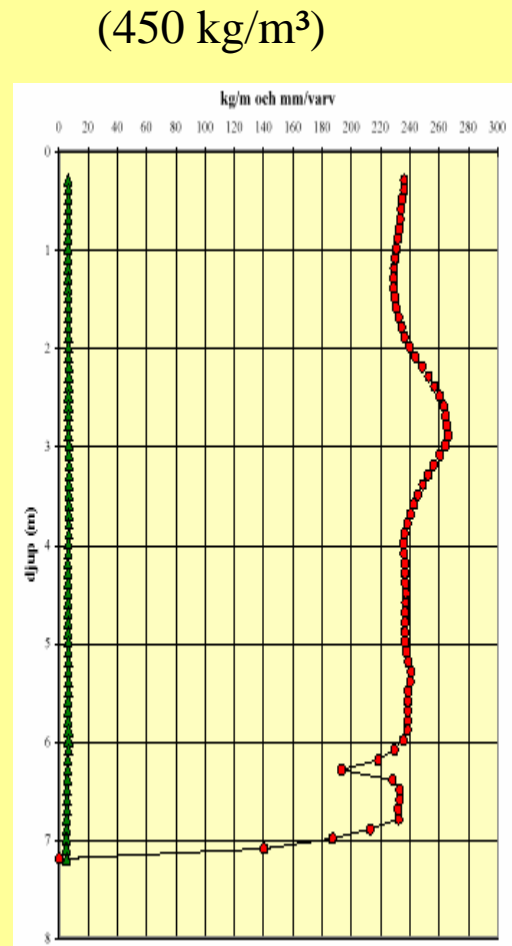


# Installation data, lower plateau Tullinge. TulM450.2

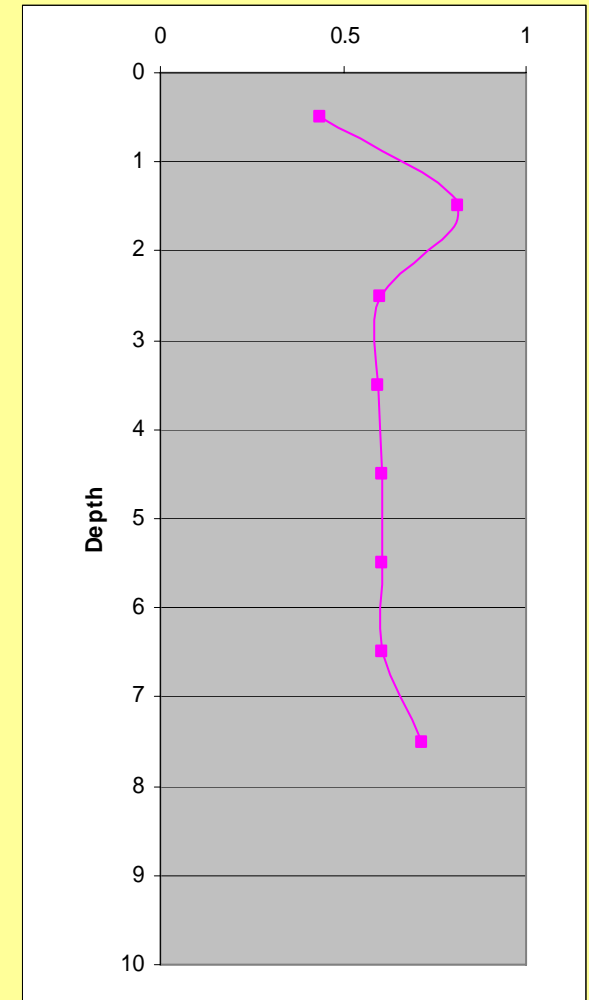
## Water content



## Binder added



## Water/Cement ratio



# Testing, Tullinge

**Curing: 30 days**

**Core drilling**



**Excavation**



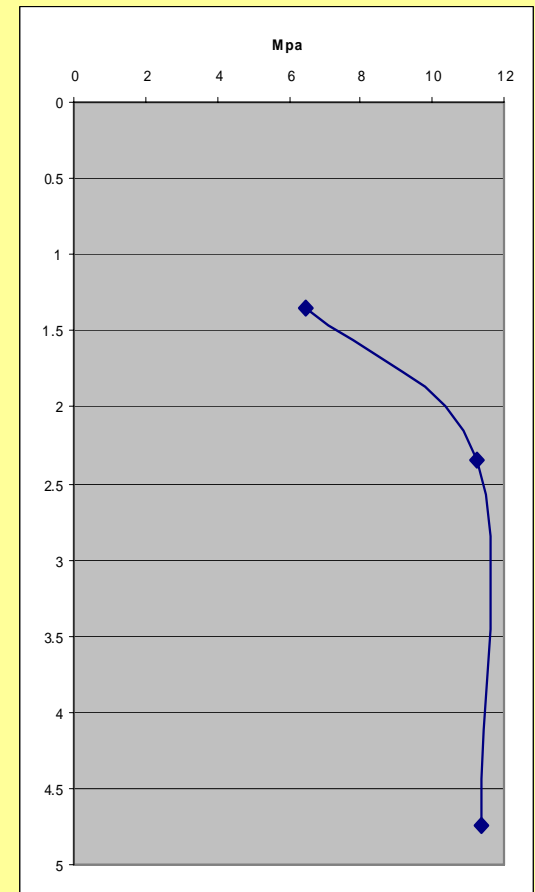
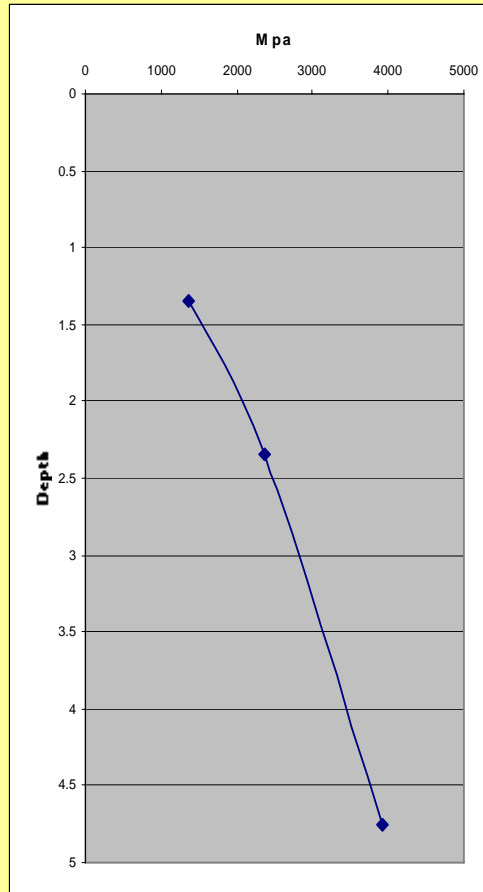
# UCT results, lower plateau.

## TuIM450.2

### E 50-modulus

### Compressive Strength

- Compressive strength: 1700 psi+
- Permeability: 0.8 l/min @ 4 bar, full length of column
- Installation time: 1 min/lin. meter



# Visual Evaluation Tullinge



Visual inspection

Live load test





# Conclusions

## Clayey Conditions

- MDM produced columns through a dry crust (layered conditions)
- More material could be fed without plugging of equipment
- Drastically reduced amount of airborne dry binder during installation
- Better mixing due to “sensitizing” of the clay
- Less load on equipment
- Larger diameter columns could be efficiently produced
- No spoil created
- The MDM method has the ability to raise L.I. to well over 3.0 in a stiff clay

# Conclusions

## Sandy Conditions

- Columns of very high strength can be produced (1700 psi)
- Reinforcements are possible
- MDM can compete with driven piles and wet method under these conditions
- Very high strength columns were installed at a rate of one linear meter/minute
- Large volumes of binder could be added (500 kg/m<sup>3</sup>)
- Installations could be made in very hard soils (where the dry methods could not be used)
- No spoil created



# Conclusions

## General

- MDM technology allows for installations of columns in vastly different conditions and of varying strengths using the same equipment without any modifications
- Installation parameters can be changed from station to station
- Material (binder) dust is diminished
- Wear on equipment is reduced
- Existing equipment can be employed where previously not strong enough to penetrate and mix soil properly
- The MDM equipment used worked without clogging of either water or material feed jets

# Acknowledgements:

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