Dry Soil Mixing - Current US Practices

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Mass Stabilization
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Geotechnical Construction
KELLER
www.HaywardBaker.com

Presentation Outline

- History of Dry Mixing
  - USA Experience
- Dry Mixing Design/Applications
- Equipment and Tooling
- Case Histories
- QC

What is the experience in the USA with dry mixing?

- Woodrow Wilson Test embankment installed by Underpinning and Foundations/Skanska in mid 2000.
- IHNC test program by Underpinning and Foundations in 2003 for the COE – New Orleans district
- Other uses by UAF/Skanska on the I-4 project in Salt Lake City in 2004-2005
- Mixing done in upstate NY and Nebraska by Hayward Baker and UAF for COE and NBDOT - 2006

US History with Deep Mixing continues to grow through various uses…

- 2003 – Large scale dry mixing project performed for US1 in Florida
- 2006 following Katrina mixing in COE – NOLA district continued to grow, some 7 jobs completed
- Regularly used in the Oil and Gas industry as well as still evaluated for use and compared to Wet mixing methods for COE Projects

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What limitations in regards to soil strength should we consider before using Dry Mixing

- Shear strength of soil has to be low enough to allow mixing
- Binder requirement has to be in line with output
- Moisture content has to be high enough to allow complete hydration
- Compute $I_C \geq 0$ and $I_L > 1$

Binder Types and Dosage

- Lime
- Cement
- Lime-cement blends
- Slag-cement blends
- Typical dosage is 10% by weight of soil
  - 50 to 200 kg/m^3
- Lab testing with site soil and binder

Mixing energy or Blade Rotation Number (BRN) a function of the tool type and installation speed

BRN (Blade Rotation Number)= Σ[(no. blades x rotation speed x penetration rate) + (no. blades x rotation speed x withdraw rate)] per 1 meter length of column

Example:

Number of blades=4-8

Retrieval rate= 10-30mm/rev

Rotation speed= 100-200 rpm

$$BRN = \frac{6}{0.025} = 240$$

- Organic soils, peat = BRN>400
- Organic clay, Sandy clays = BRN>300
- Clay, Silty clay = BRN>200

Embankment built on soft soil/peat can be designed using block/column treatment

Application: Sheet Pile Stabilization – Working over Water

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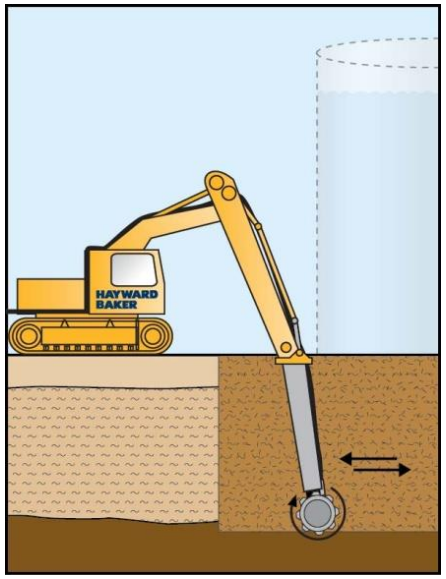
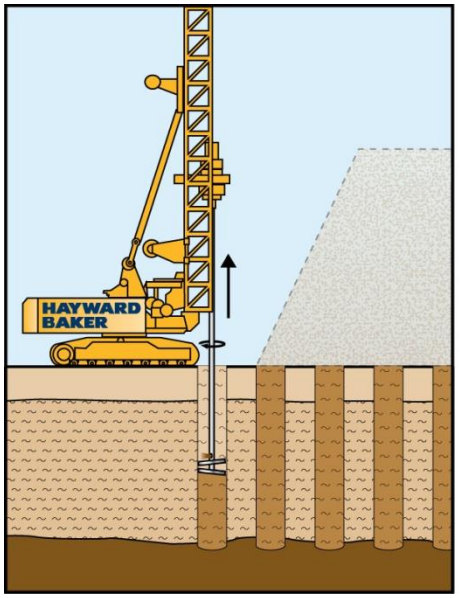
Dry Soil Mixing installation techniques include Columns and Blocks to meet design needs



Mass Mixing to form blocks

Column Mixing to form panels or single columns



Dry Deep mixing methods are utilized in wetter softer soils or where REM is a problem

Dry binder materials are pneumatically injected into the soil during the dry mixing process

Bottom up method of soil mixing

There must be adequate soil moisture for the binders to fully hydrate often limiting design strengths

Mass Soil Mixing Movie

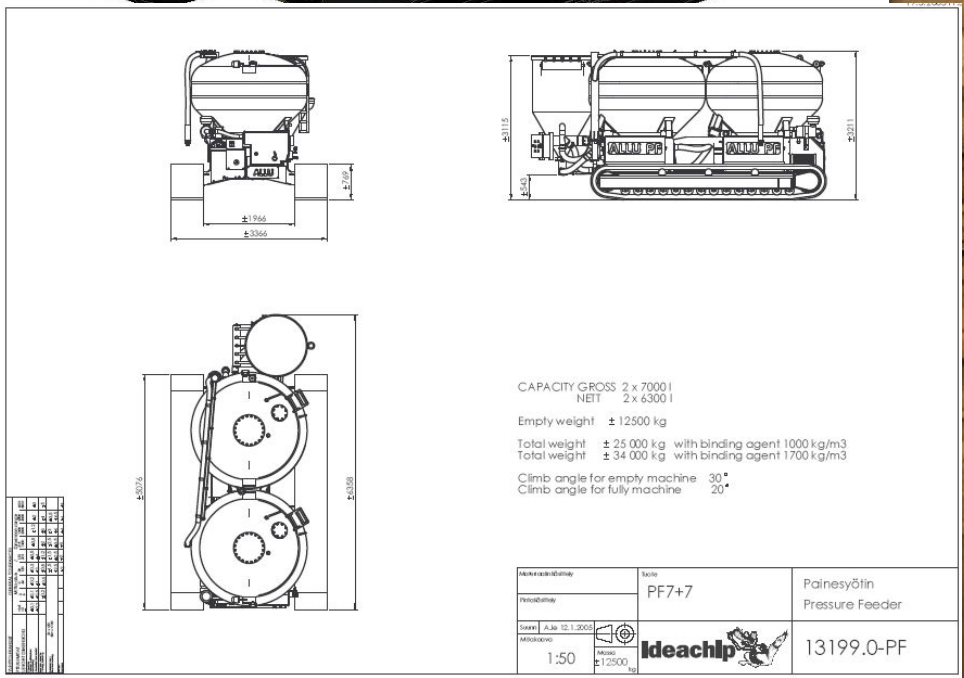
Dry Mixed Columns

Mass Mixing Tool

Binder Handling

Keller – Shuttle Type S1010	
Operating Weight:	20 tons
Volume Storage Vessel:	10 m³
Operating Pressure Max:	10 bar

Technical Data Sheet



Keller – Shuttle Type S1010
Status: Dec.07
Originator: Wolber/Kimmig
Subject to technical modifications

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Levee Stability enhancements made possible using Soil Mixing

17th Street Canal New Orleans

800 mm diameter soil mixed columns installed from a barge

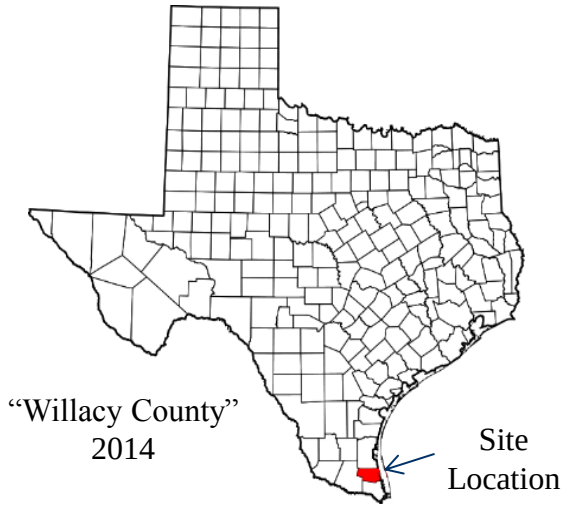
Dry mass mixing is working in block cell arrangement working from platform for a Tank

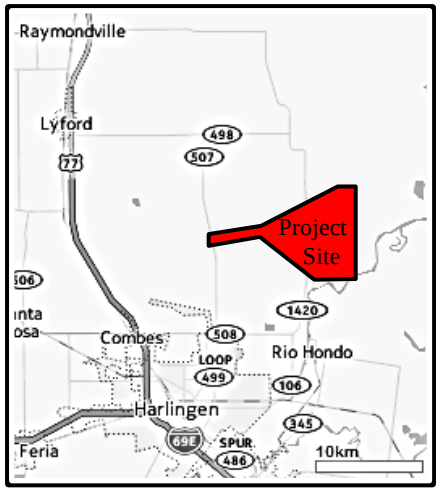

LCM
HAYWARD BAKER
OCT 10 2005


ICM

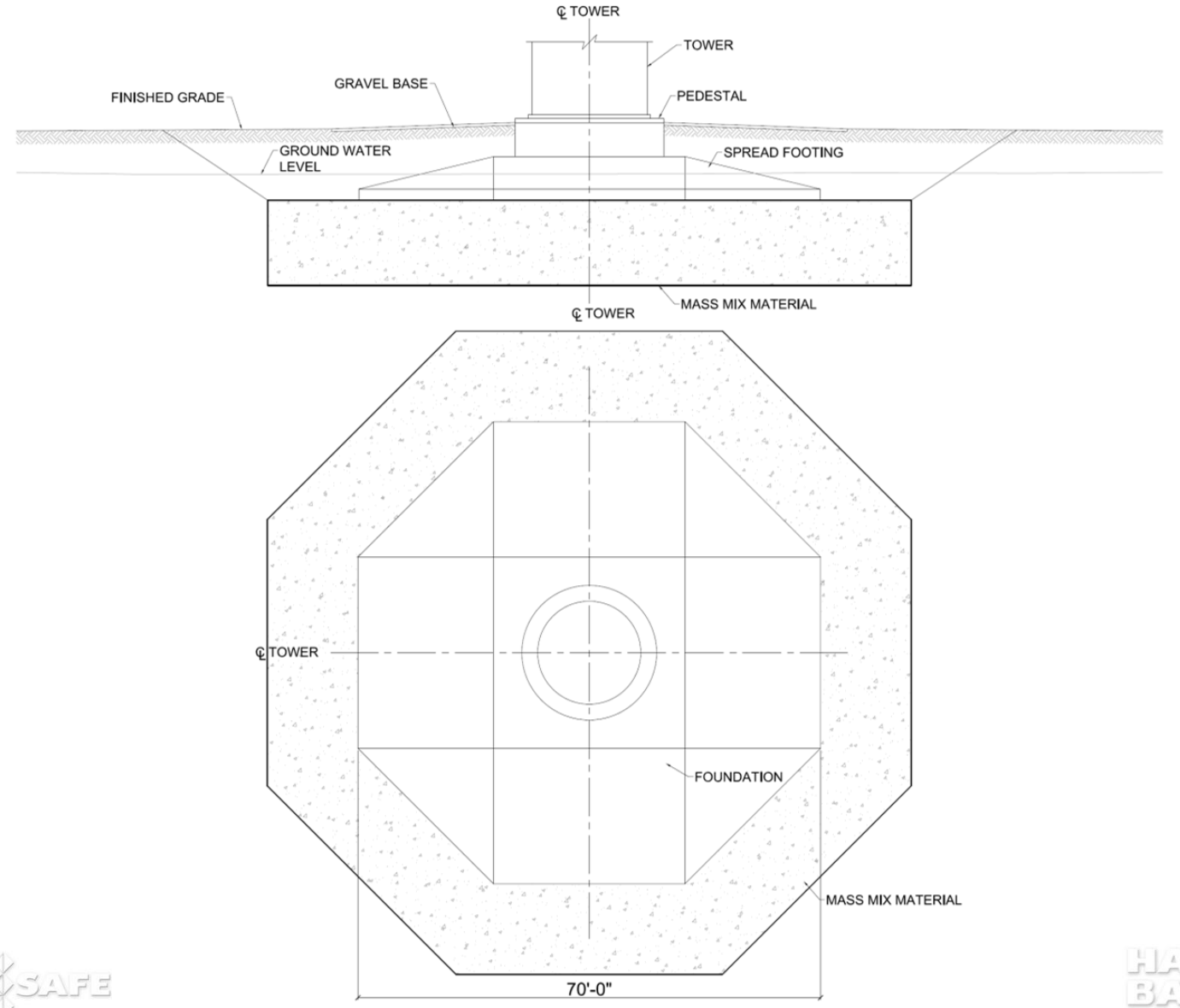
Los Vientos

- Los Vientos I and II
  - 180 Wind turbines
  - 402 MW total capacity
  - Both Built in 2012
- Rio Grande Valley
  - Willacy County, TX
- Dry Mass Soil Mixing (DMSM)
  - 26 foundation locations

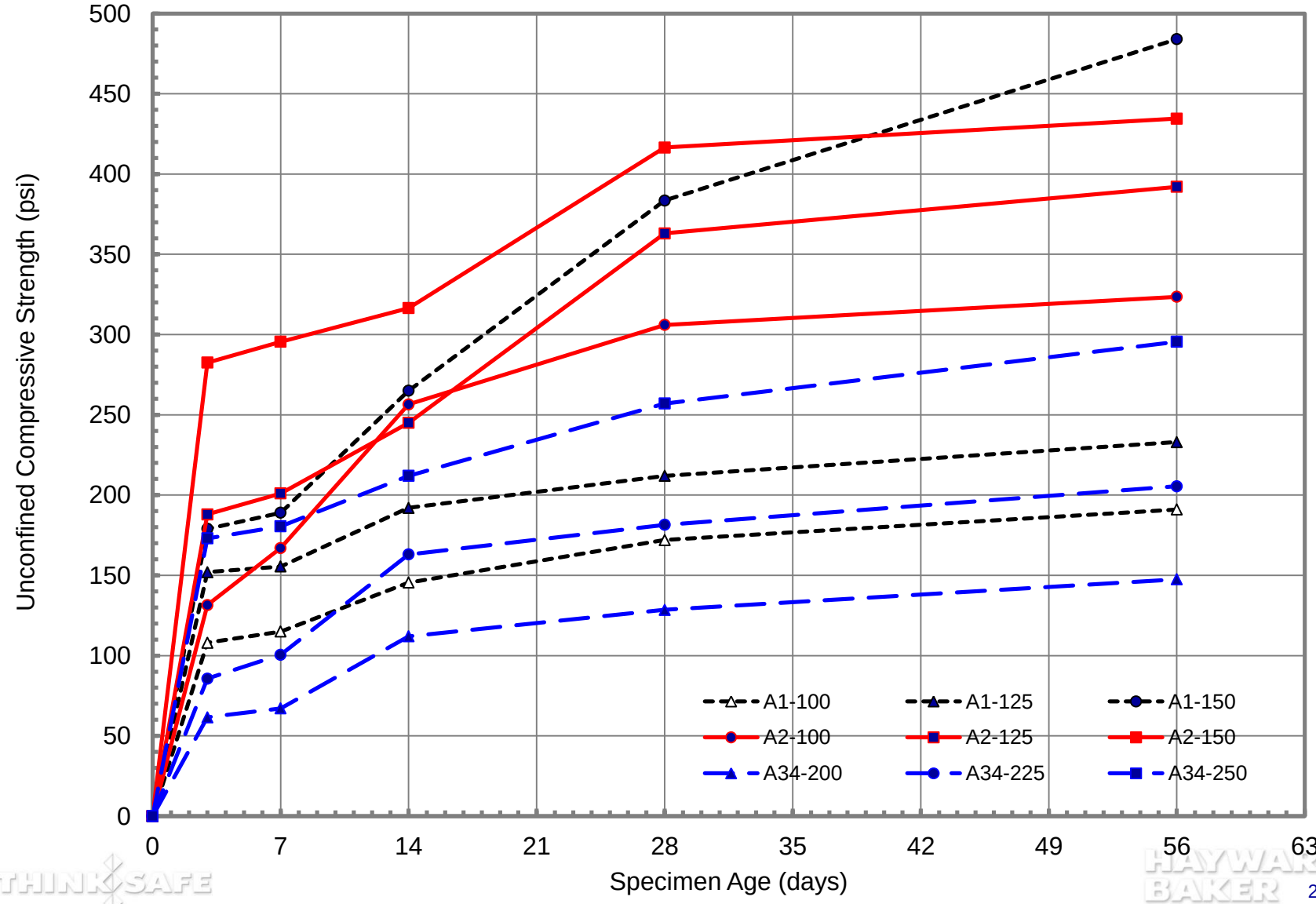




Foundation Design



Mass Stabilization Design

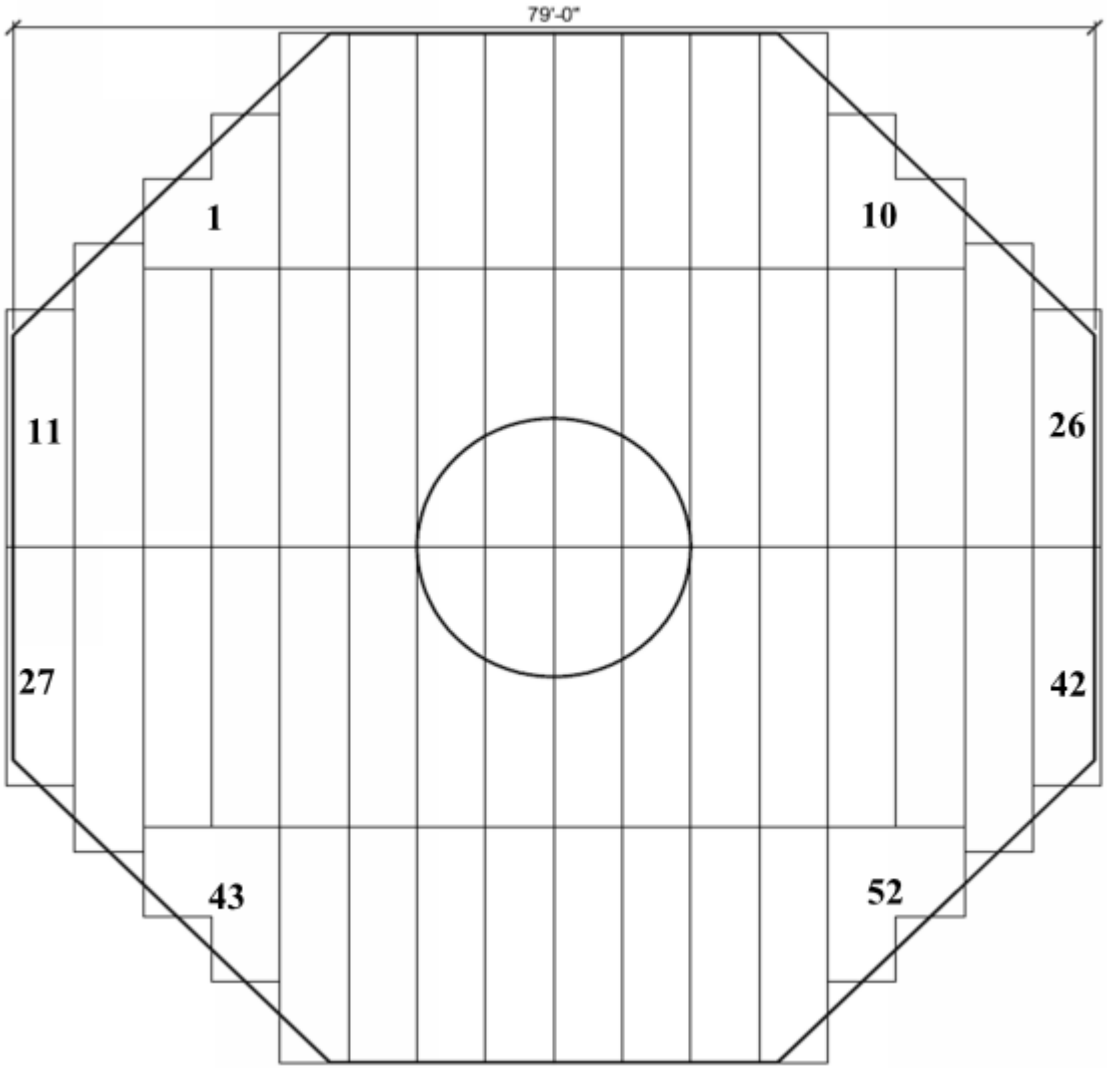


Mass Stabilization Construction

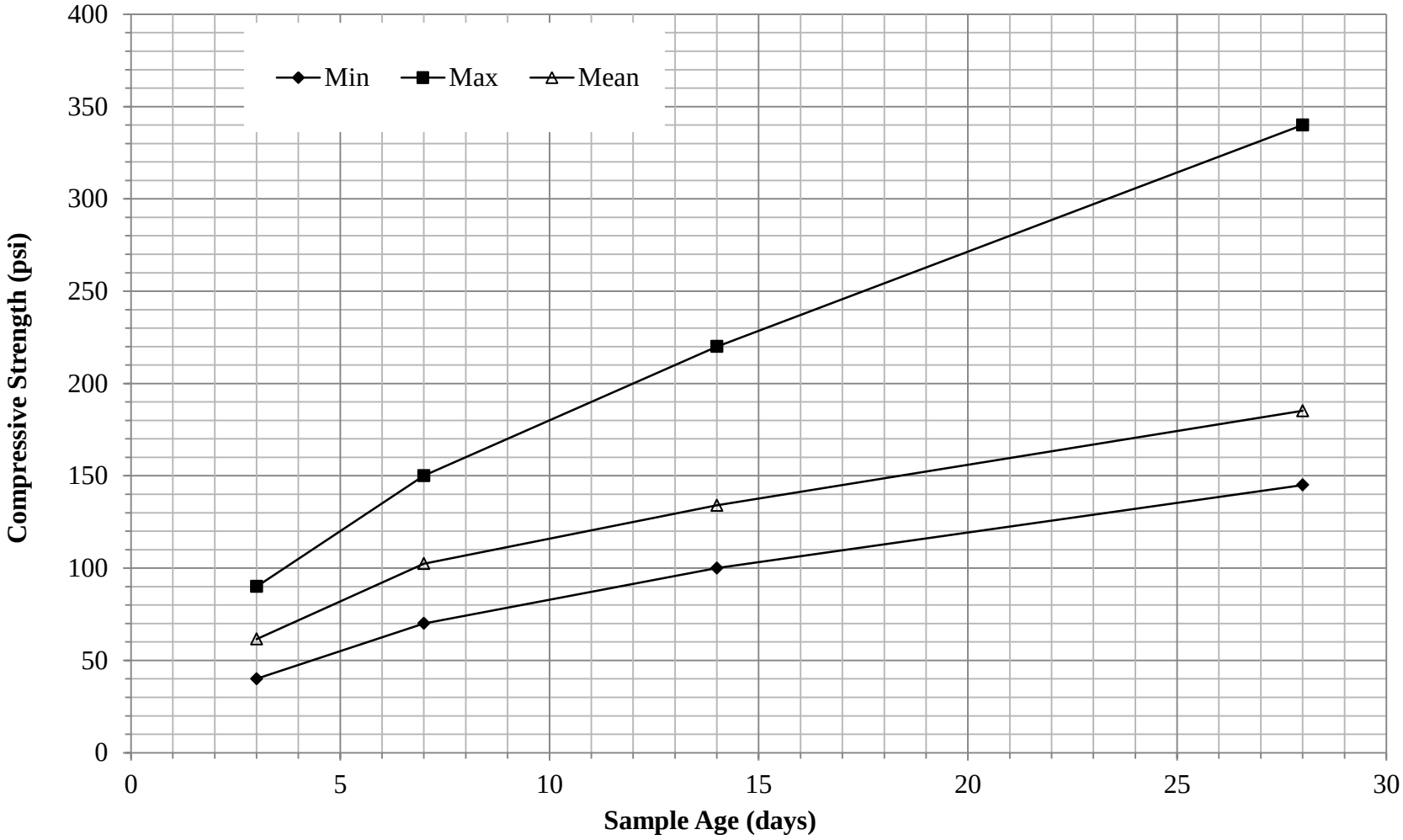
- 26 foundation sites
- Construction process
  - Strip topsoil
  - Pre-excavate 8.5 ft
  - Perform DMSM
    - Outside excavation
    - Within excavation
  - Grading
  - Form and pour foundation

Foundation Construction

QAQC and Verification Testing



QAQC and Verification Testing



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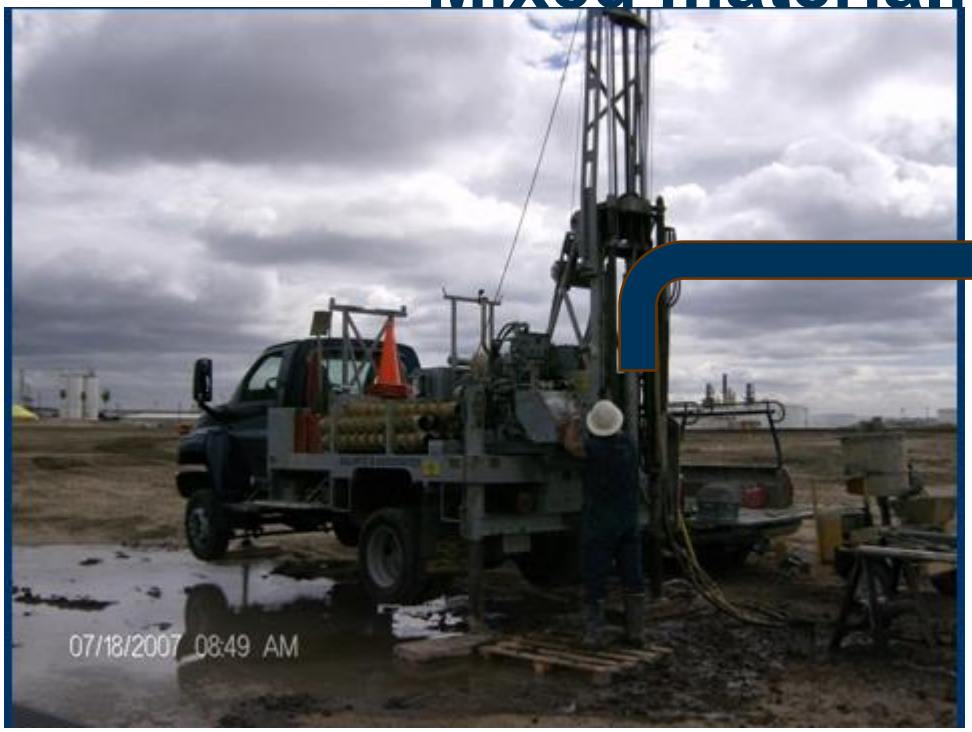
How do you measure the quality of the Dry Mixed material…CORE it



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SOILCRETE CORE LOG

DATE 7/18/07

CORE I.D. 1550

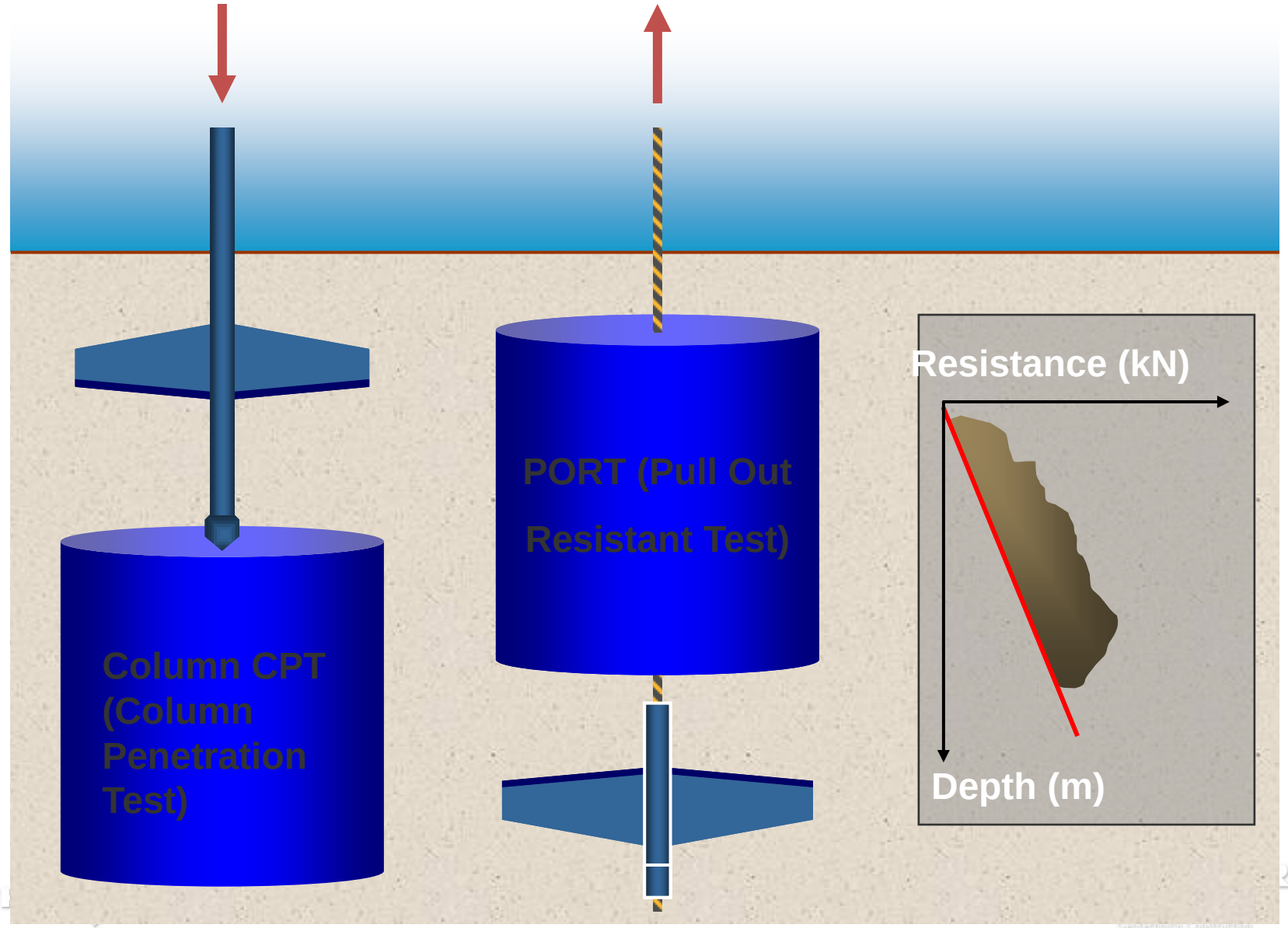
JOB No. 53850 Surface Elevation +17.0 DRILLER Gularte Assoc.

PROJECT Pacific Ethanol Plant SOILCRETE AGE 15 days Engineer DEA

RUN #	DEPTH FROM	DEPTH TO	RUN LENGTH	RCOVRD LENGTH	RECOVERY %	TOTAL LENGTH of PCC > DIAMETER	SOD	DESCRIPTION / REMARKS
1	0'	5'	5'	3.50	70%			Top 2.0' fill - bottom 1.5' soilcrete
2	5'	10'	5'	5'	100%			soilcrete - (5-10')
3	10'	15'	5'	5'	100%			soilcrete (10-15)
4	15'	20'	5'	5'	100%			soilcrete (15-19)
5	21'	25'	5'	5'	100%			soilcrete; end of 4th run (19-20'); beginning of 5th run (20-23'); bottom piece (23-25')

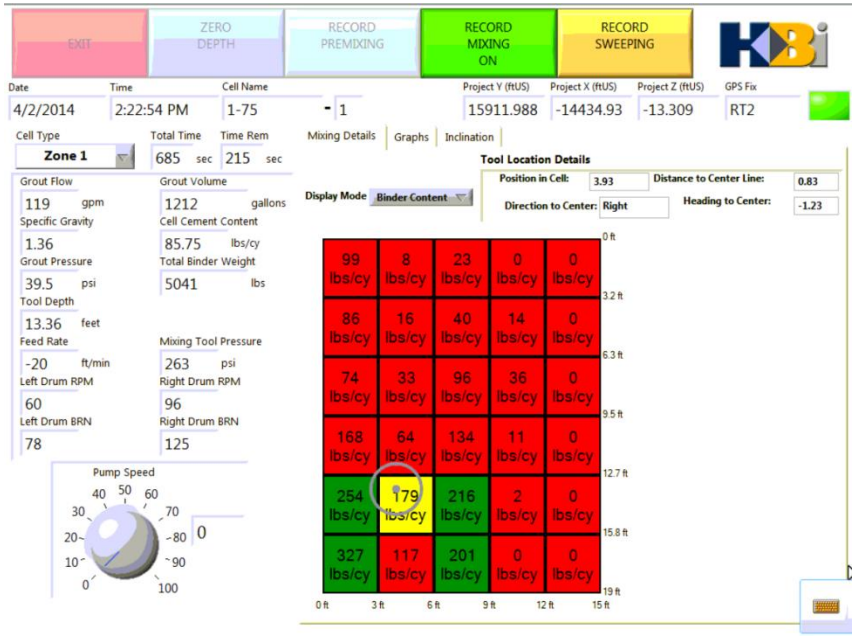
Core the columns and check continuity…destructive testing

Field control methods



Mass Mixing Grid Control

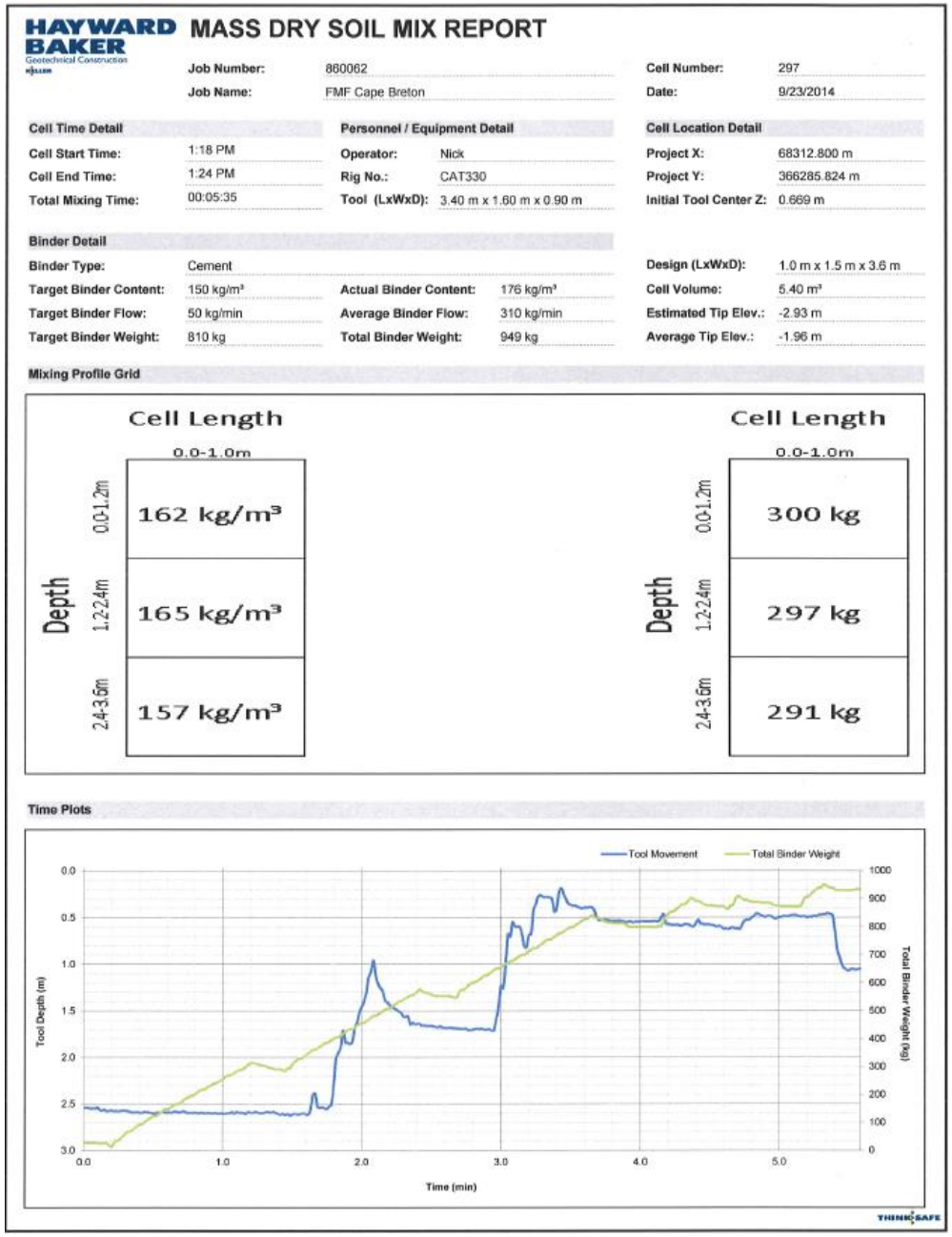
- Shows the real-time depth & position of the mixing tool along the length of the cell
- Grid sub-cells are drawn in red, yellow, or green to indicate when the target binder content or mixing time has been reached within each sub-cell
- Rig software also tracks the rig heading vs. cell center line & the tool distance from the center line to aid in proper positioning along the cell



- Binder and mixing time are proportionally assigned to sub-cells based on the position of the center of the tool
- For example, if the tool center is at the corner between 4 sub-cells each cell would receive 25% of the binder added

Mass Dry Mixing Report

- Profile grid shows binder distribution grid by depth and cell length
- Tool depth is tracked using elevation from rig GPS system
- System tracks binder content & time for each sub-cell within the design cell area



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MASS DRY SOIL MIX REPORT

Job Number:	860062	Cell Number:	297
Job Name:	FMF Cape Breton	Date:	9/23/2014

Cell Time Detail		Personnel / Equipment Detail		Cell Location Detail	
Cell Start Time:	1:18 PM	Operator:	Nick	Project X:	68312.800 m
Cell End Time:	1:24 PM	Rig No.:	CAT330	Project Y:	366285.824 m
Total Mixing Time:	00:05:35	Tool (LxWxD):	3.40 m x 1.60 m x 0.90 m	Initial Tool Center Z:	0.669 m

Binder Detail

Binder Type:	Cement			Design (LxWxD):	1.0 m x 1.5 m x 3.6 m
Target Binder Content:	150 kg/m³	Actual Binder Content:	176 kg/m³	Cell Volume:	5.40 m³
Target Binder Flow:	50 kg/min	Average Binder Flow:	310 kg/min	Estimated Tip Elev.:	-2.93 m
Target Binder Weight:	810 kg	Total Binder Weight:	949 kg	Average Tip Elev.:	-1.96 m

Mixing Profile Grid

Time Plots

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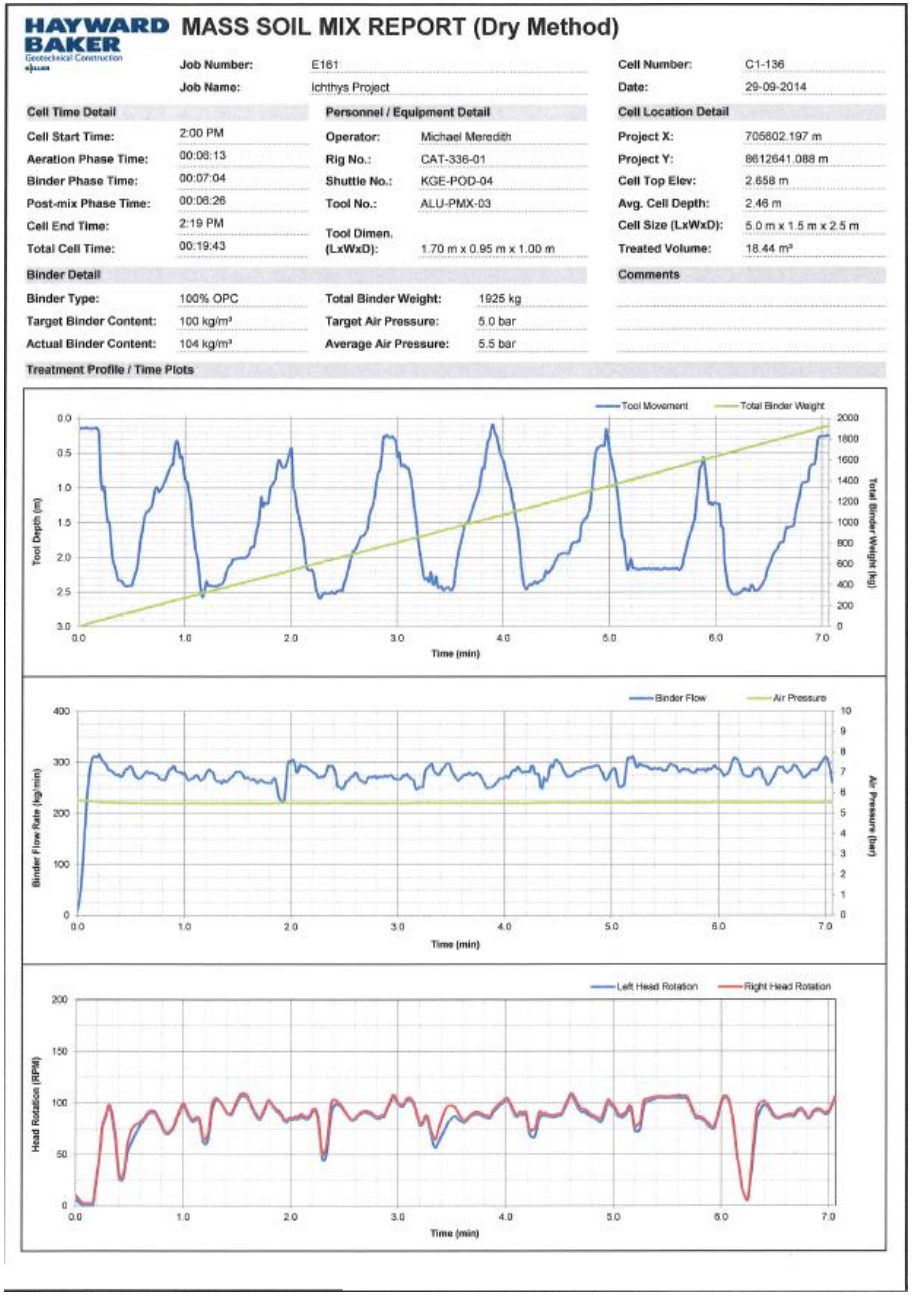
Mass Dry Mixing Report

- Time plot report
  - Tool Depth vs. Time
  - Binder Weight vs. Time
  - Binder Flow & Air Pressure vs. Time
  - Left & Right Tool RPM vs. Time
- Avg. Treatment Depth
- Avg. Air Pressure
- Avg. Binder Content



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MASS SOIL MIX REPORT (Dry Method)

Job Number:	E161			Cell Number:	C1-136
Job Name:	Ichthys Project			Date:	29-09-2014
Cell Time Detail		**Personnel / Equipment Detail**		**Cell Location Detail**	
Cell Start Time:	2:00 PM	Operator:	Michael Meredith	Project X:	705802.197 m
Aeration Phase Time:	00:06:13	Rig No.:	CAT-336-01	Project Y:	8612641.088 m
Binder Phase Time:	00:07:04	Shuttle No.:	KGE-POD-04	Cell Top Elev:	2.658 m
Post-mix Phase Time:	00:06:26	Tool No.:	ALU-PMX-03	Avg. Cell Depth:	2.46 m
Cell End Time:	2:19 PM	Tool Dimen. (LxWxD):	1.70 m x 0.95 m x 1.00 m	Cell Size (LxWxD):	5.0 m x 1.5 m x 2.5 m
Total Cell Time:	00:19:43			Treated Volume:	18.44 m³
Binder Detail				**Comments**	
Binder Type:	100% OPC	Total Binder Weight:	1925 kg		
Target Binder Content:	100 kg/m³	Target Air Pressure:	5.0 bar		
Actual Binder Content:	104 kg/m³	Average Air Pressure:	5.5 bar		

Treatment Profile / Time Plots

Mass Dry Mixing Report

- Grid report showing cell divided into several sub cells
- Grid dimensions (rows & columns) are specified in rig software
- Grid is adjustable based on cell type for projects with multiple cell sizes

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Binder Detail				Comments
Binder Type:	100% OPC	Total Binder Weight:	1925 kg	
Target Binder Content:	100 kg/m³	Target Air Pressure:	5.00 bar	
Actual Binder Content:	104 kg/m³	Average Air Pressure:	6 bar	

Treatment Profile / Time Plots

Cell Length

Depth							
	80 kg/m³	77 kg/m³	144 kg/m³	69 kg/m³	0 kg/m³	0 kg/m³	0 kg/m³
	170 kg/m³	104 kg/m³	156 kg/m³	67 kg/m³	6 kg/m³	0 kg/m³	0 kg/m³
	174 kg/m³	97 kg/m³	152 kg/m³	87 kg/m³	17 kg/m³	0 kg/m³	0 kg/m³
	168 kg/m³	82 kg/m³	188 kg/m³	181 kg/m³	77 kg/m³	1 kg/m³	0 kg/m³
	193 kg/m³	89 kg/m³	256 kg/m³	293 kg/m³	121 kg/m³	2 kg/m³	0 kg/m³
	71 kg/m³	40 kg/m³	139 kg/m³	124 kg/m³	29 kg/m³	0 kg/m³	0 kg/m³
	0 kg/m³	0 kg/m³	2 kg/m³	0 kg/m³	0 kg/m³	0 kg/m³	0 kg/m³

Cell Length

Depth							
	43 kg	41 kg	78 kg	37 kg	0 kg	0 kg	0 kg
	92 kg	56 kg	84 kg	36 kg	3 kg	0 kg	0 kg
	94 kg	52 kg	82 kg	47 kg	9 kg	0 kg	0 kg
	91 kg	44 kg	102 kg	98 kg	41 kg	1 kg	0 kg
	104 kg	48 kg	139 kg	159 kg	65 kg	1 kg	0 kg
	38 kg	21 kg	75 kg	67 kg	16 kg	0 kg	0 kg
	0 kg	0 kg	1 kg	0 kg	0 kg	0 kg	0 kg

Time Plots

QA/QC – Expose it if you can

Temporary excavation pit Clay – UK (2005)

Exposed DDM columns for permanent slope stability in Uppsala – Sweden (2005)

DDM columns supporting a temporary excavation for the railway link between Gothenburg and Malmö – Sweden (2003)

This is the Last Slide
Thank You!! *Questions?*

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