



# Pile Foundations



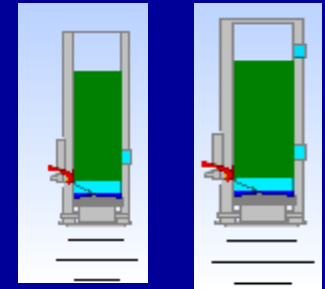
Joe Carte

# Overview

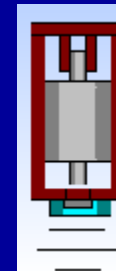
- **Introduction**
- **Specifications**
- **Pile Problems and Solutions**

# Hammers Types

- Internal Combustion
  - open end diesels
  - closed end diesels

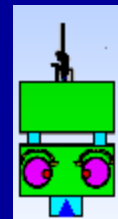


- External Combustion
  - steam hammers
  - air hammers



Single Acting &  
Double Acting

- Vibratory hydraulic hammers
- Gravity Hammers
- New Hammers – The Resonant Driver



# Pile Types

- Steel H-Piles
- Prestressed Concrete Piles
- Precast Concrete Piles
- **Cast-In-Place Pipe Piles**
- Timber Piles
- Shell & Fluted Piles



# Specifications



# WVDOH Specifications

Steel Piles: Steam /Air Hammer ~ 12,000 ft-lb

Concrete Piles :Steam /Air Hammer ~15,000 ft-lb

“Gravity hammer for driving steel [and concrete] piles shall weight not less than 2,000 and 3,000 lb respectively ....”

“Refusal is defined as the equivalent of 20 BPI with a power hammer developing the minimum designated foot pounds per blow”

Diesel Hammers are mentioned

# LRFD Specifications

- **10.7.3.2.2 Piles Driven to Soft Rock**

Soft rock that can be penetrated by pile driving shall be treated in the same manner as soil for the purpose design for axial resistance

- **10.7.3.2.3 Piles Driven to Hard Rock**

The nominal resistance of piles driven to **point bearing on hard rock** where pile penetration into the rock formation is minimal is **controlled by the structural limit state**. (This is the normal case in WV)

- The resistance factors for the compression limit state are specified in Article 6.5.4.2. - 0.6 for easy driving and **0.5 for hard driving**

# WVDOH Specifications

- Plumbness  
~ 2% from vertical or batter
- Alignment ~  
6-inches for group  
3-inches for a  
single line of  
piles *Why?*





# LRFD Specifications

- Resistance Factor for Wave equation analysis, without pile dynamic measurements or load test, at end of drive conditions only is 0.40 (**Table 10.5.5.2.3-1**)
- We used 0.5 for point bearing piles on rock when using the end of driving analysis
- We include a skin friction estimate for our analysis purposes only

# WVDOH Specifications



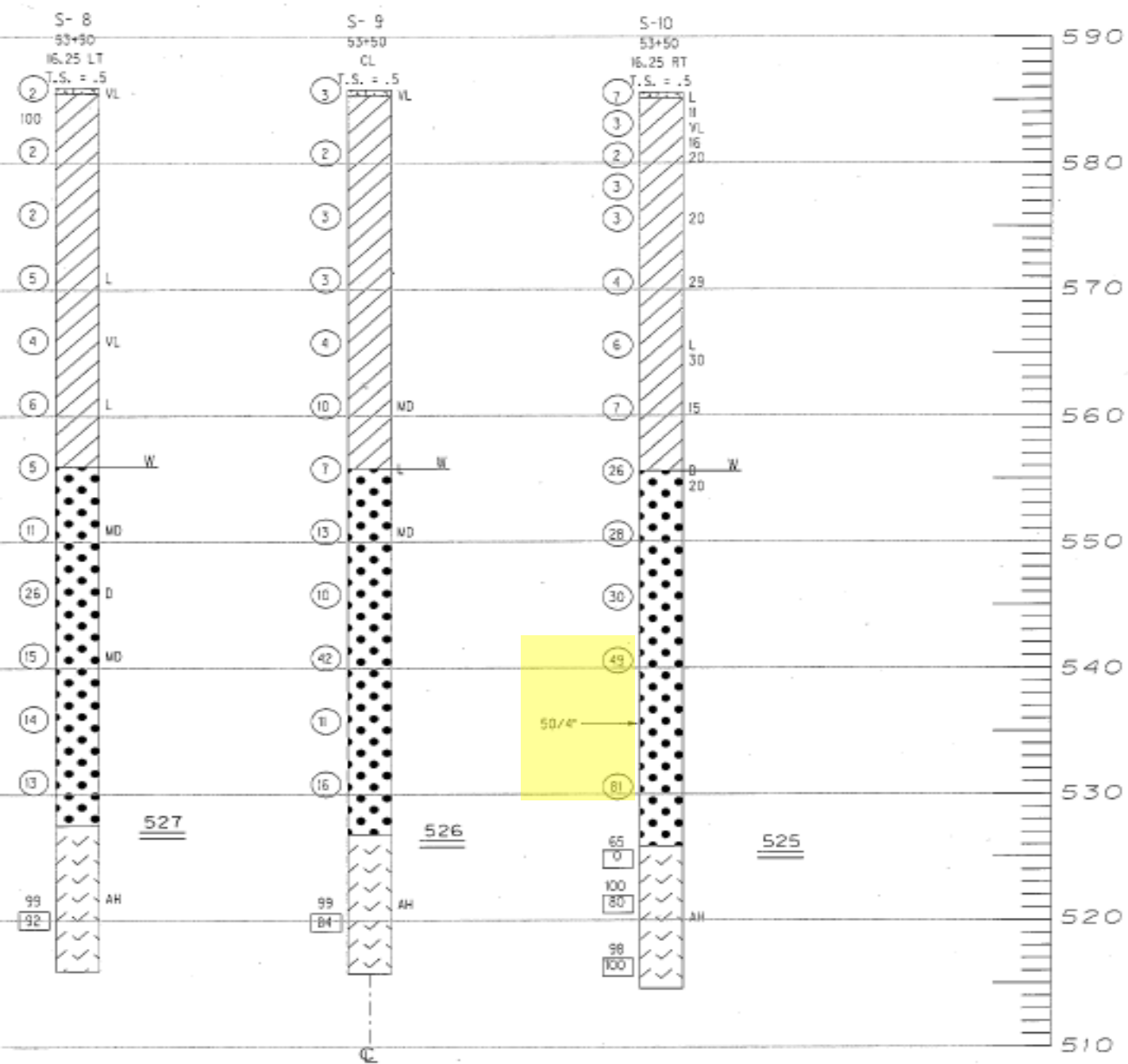
# LRFD Specifications

## *10.7.3.8.4—Wave Equation Analysis*

A wave equation analysis may be used to establish the driving criteria.

- **10.7.8—Drivability Analysis**

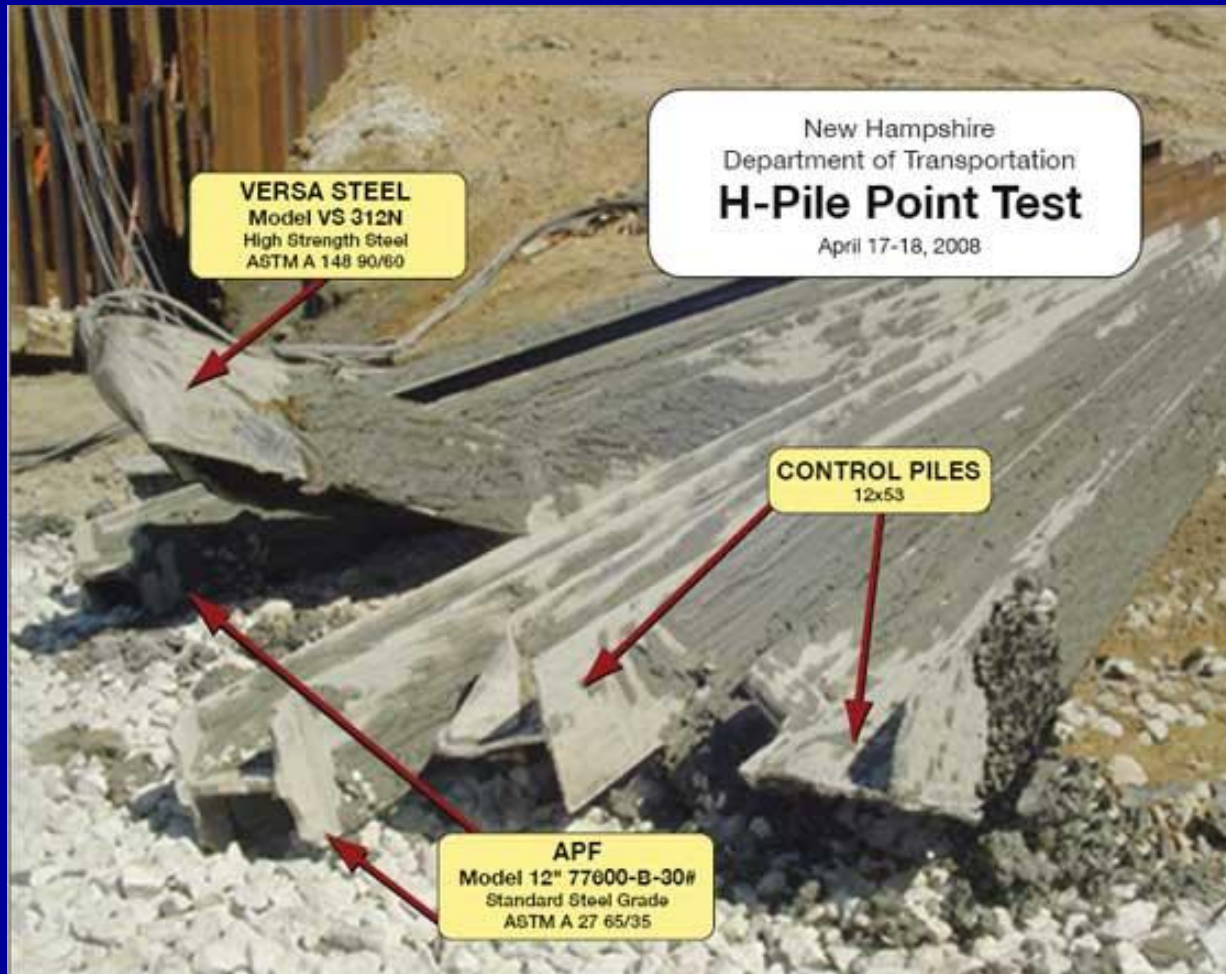
The establishment of the installation criteria for driven piles should include a drivability analysis.



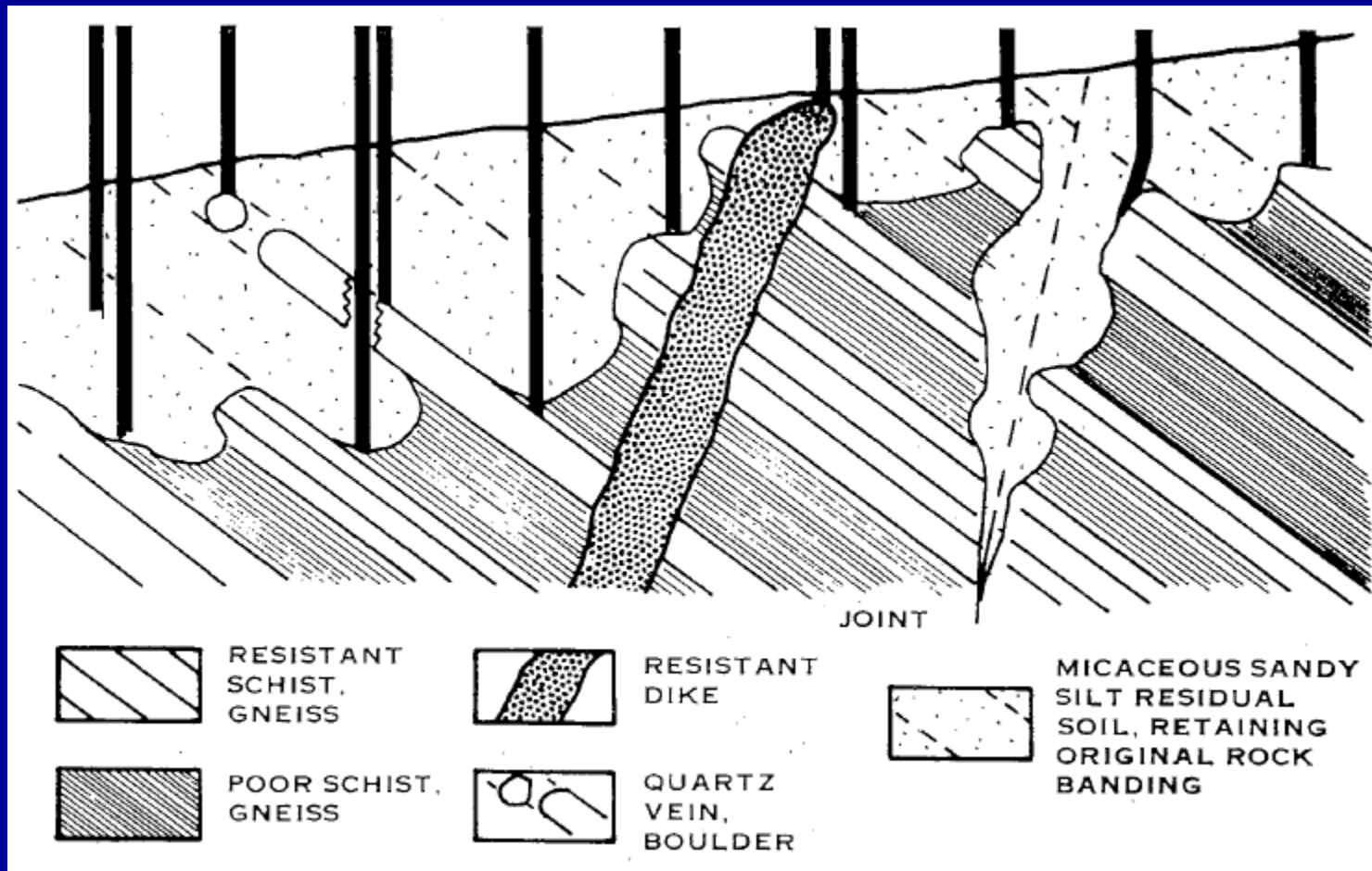
# Problems

GEOLOGIC CROSS SECTIONS

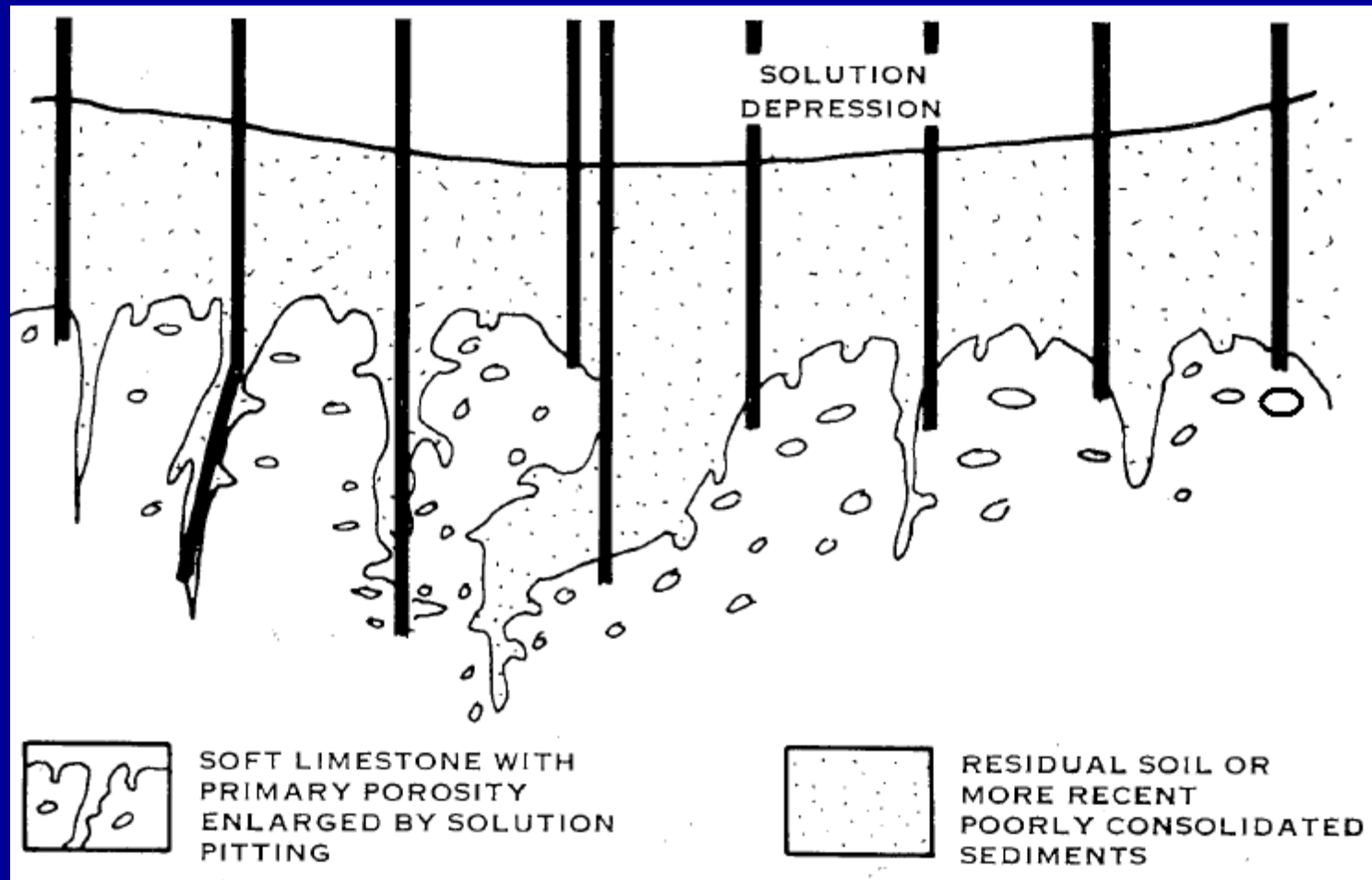
# Problems



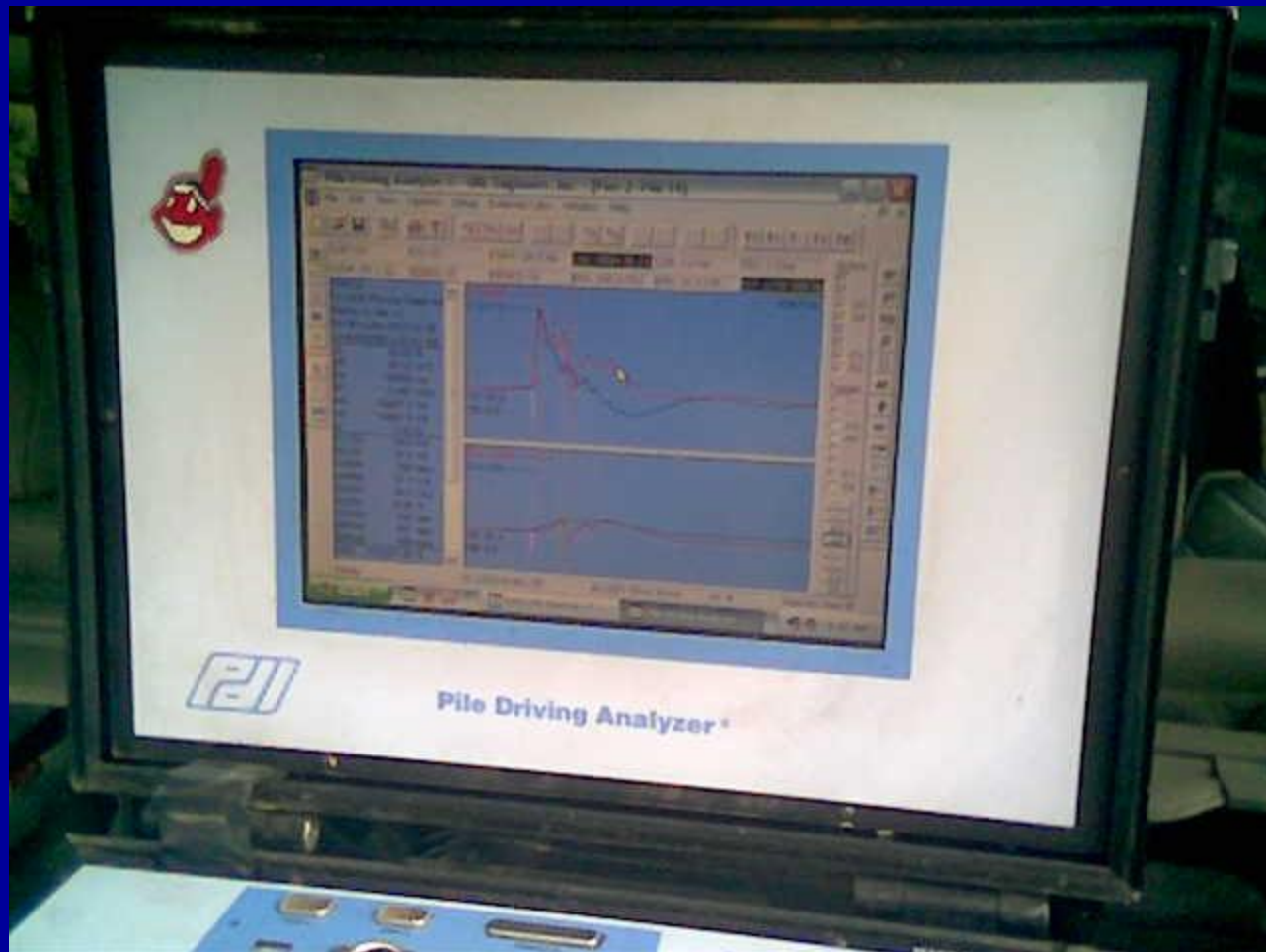
# Problems



# Problems



# Solutions





# Solutions

Project: US35 Flyover Ramp

Date: April 17<sup>th</sup>-19<sup>th</sup>, 28<sup>th</sup>, May 8<sup>th</sup>-9<sup>th</sup>, 15<sup>th</sup>, 25<sup>th</sup>, and June 13<sup>th</sup>, 2006

Hammer: APE D30-32

File No.	Substructure	Test Date	Test <sup>1</sup> Type	Penetration <sup>2</sup> Depth (ft)	Blow <sup>3</sup> Count (blows/in)	Transf'd Energy (kip-ft)	Hammer <sup>4</sup> Stroke (ft)	Max. Compressive Force (kips)	Compressive Stress (ksi)	CASE <sup>5</sup> Method Capacity (kips)	CAPWAP Mobilized Capacity (kips)
4	Abut 1	28-Apr-06	EOID	13.6	20	40.9	10.7	997	38.2	1111	1108
		9-May-06	BOR	13.6	7 <sup>7</sup>	4.8	11.9	538	20.6	228	215
			EOR	16.6	17	47.6	11.4	1065	40.8	1180	-
		13-Jun-06	BOR2	16.6	20/0.5"	34.5	9.2	902	34.6	672	670
			EOR2	16.6	20/0.5"	30.3	8.7	950	36.4	879	-
1	Wing Wall A	9-May-06	BOR	12.5	11	21.2	7.9	797	30.5	614	560
8	Wing Wall A	13-Jun-06	BOR	15.0	14	23.5	8.0	832	31.9	787	-
			EOR	15.1	7/0.5"	24.8	7.9	873	33.4	822	-
12	Pier 1	18-Apr-06	EOID	27.5	20	27.1	8.6	821	31.5	848	844
		8-May-06	BOR	29.3	8	26.5	8.6	803	30.3	690	650
			EOR	29.6	16	26.0	8.5	835	32.0	890	-

# Solutions

GRLWEAP 2005-2-West Virginia Dept of Transportation - [SmallestHammer.gww]

File Edit View Options Tools Window Help

English Simple Resistance Distr Uniform Pile Bearing Graph - prop. shaft resistance

Enter Project Title Here

Hammer Information  
Select from following list [10/24/2008-2003]: ID: **101**

ID	Name	Type	Ram Wt	Energy/Power
93	HITACHI HNC125	ECH	27.5573	108.493
101	KOBE K 13	OED	2.8700	25.428
103	KOBE K22-Est	OED	4.8500	45.347

Hammer parameters  
Efficiency: **0.8**  
Pressure: **1400.0** psi Fixed **100** %  
Stroke: **8.86** ft Variable of Max

Pile material  
 Concrete  Steel  Timber

Cushion Information

	Hammer	Pile
Area	<b>272</b>	<b>0.</b> in <sup>2</sup>
Elastic Modulus	<b>225</b>	<b>0.</b> ksi
Thickness	<b>3.5</b>	<b>0.</b> in
C.O.R.	<b>0.8</b>	<b>0.</b>
Stiffness	<b>0.</b>	<b>0.</b> kips/in
Helmet Weight	<b>1.687</b>	<b>0.</b> kips

Pile Information  
Length: **25** ft Auto Segments  
Penetration: **20** ft Auto. S-Length  
Section Area: **15.5** in<sup>2</sup> Auto. S-St. Wt  
Elast Modulus: **30000** ksi  
Spec Weight: **492.0** lb/ft<sup>3</sup>  
Toe Area: **144** in<sup>2</sup> 0 Splices  
Perimeter: **4** ft Pile Type:  
Pile Size: **12** in H Pile

Ultimate Capacities (up to 10)  
kips

1	<b>100.0</b>	6	<b>500.0</b>
2	<b>200.0</b>	7	<b>600.0</b>
3	<b>300.0</b>	8	<b>700.0</b>
4	<b>387.0</b>	9	<b>800.0</b>
5	<b>400.0</b>	10	<b>900.0</b>

Incr. **0** Action >>

Soil Parameters  
Quake  
Shaft: **0.1** in Const  
Toe: **0.04** in

Damping  
Shaft: **0.05** s/ft Const  
Toe: **0.15** s/ft Smith

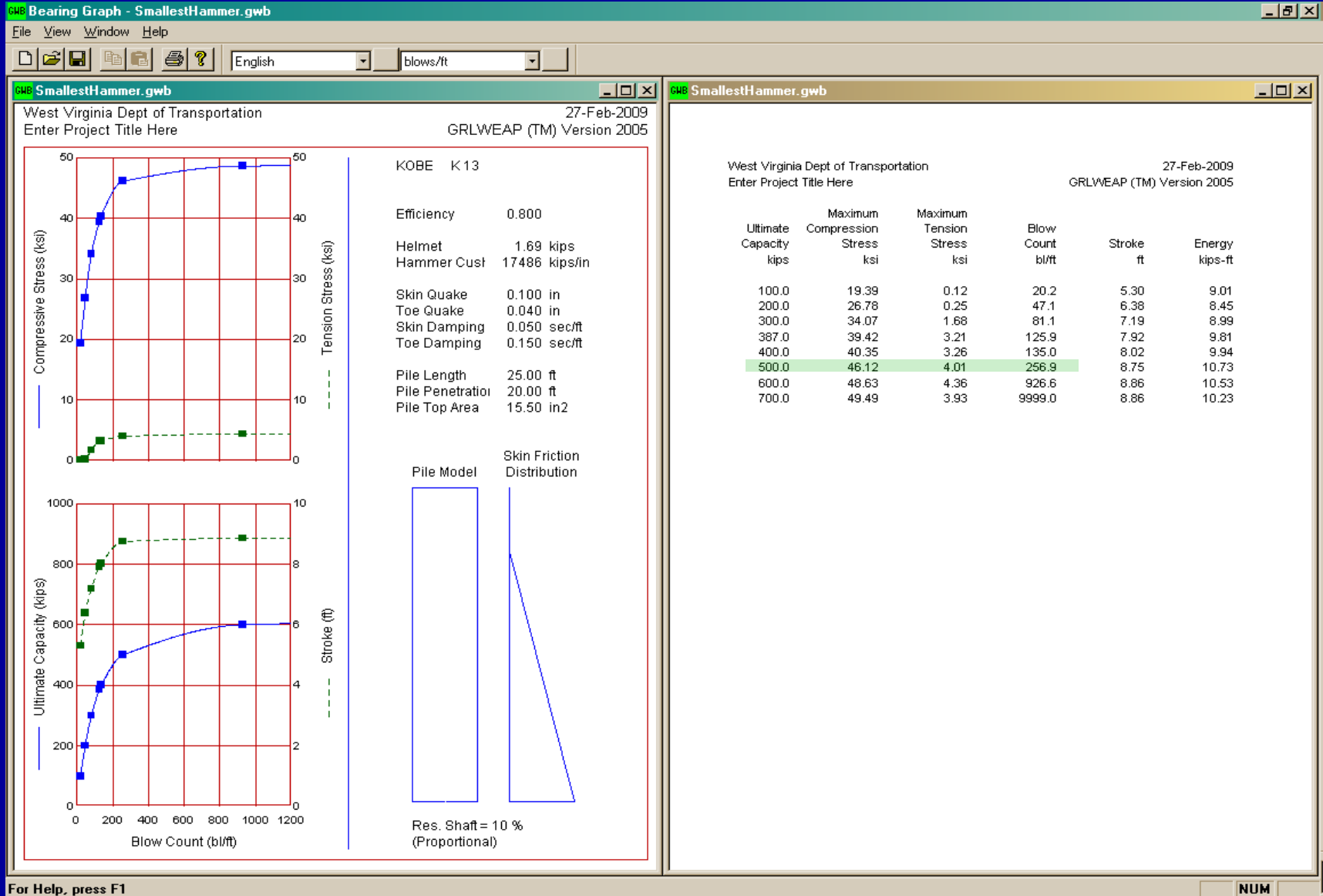
Shaft Resistance  
Percentage: **10** %  
Dist. Shape Num: **0.0**

Residual Stress Analysis: **No**

Press F1 for General Help Topics or F3 for Specific Help on Current Parameters

NUM

# Solutions



# Solutions

## Good Plan Notes

All steel piles shall be HP-----\_\_\_Steel Bearing Piles, Predrilled and Driven, and shall meet AASHTO M270, Grade 50, requirements. **Hardened steel pile points** shall be used. **The target capacity** is \_\_\_kips per pile [Insert **2x maximum factored load** per pile here] at refusal in bedrock. The Contractor shall predrill all the pile boreholes into [soft, medium hard, or hard rock\_\_\_ft. If **vary hard or extremely hard, provide additional warning to contractor**]

- All predrilled boreholes shall have a minimum diameter of \_\_\_ inches [Insert diameter **6-inches larger than the pile** diagonal dimension rounded up to the nearest size in 6-inch increment]. As a minimum, all predrilled boreholes shall be drilled to the tip elevations shown on the plans. **The holes shall be backfilled with dry sand prior to driving.**

# Solutions

- Refusal is defined as 20 blows for 1 inch of penetration, or the equivalent, using a power hammer with a minimum rated capacity of approximately 25,000 ft-lbs.
  - If a larger hammer is used, the Contractor shall submit new driving criteria using a wave equation analysis, such as GRLWEAP.
- Or
- A power hammer shall be sized by the Contractor to achieve the target capacity without exceeding 45 ksi maximum driving stress. The Contractor shall determine the hammer(s) rated energy, and pile driving criteria using a wave equation analysis such as GRLWEAP.

# Solutions



# QUESTIONS

