Dynamic pile testing in Alabama

ASCE TUSCALOOSA BRANCH

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BUILDING & EARTH

Geotechnical, Environmental, and Materials Engineers

Alabama DOT Transitioning to LRFD from ASD

Alabama bridges will be subject to LRFD

Alabama uses a combination of static and dynamic load tests

Nominal Resistance Verification Program (NRVP)	Minimum Testing Requirements	Resistance Factor, φ	Resistance Factor for Small Pile Groups (<5 piles/group)
NRVP-A	Driving criteria established by successful static load test of at least one pile per Geotechnical Site, quality control by dynamic testing of at least two production piles per Geotechnical Site, but no less than 2 percent of the production piles.	0.80	0.64
NRVP-B	Driving criteria established by successful static load test of at least one pile per Geotechnical Site without dynamic testing.	0.75	0.60
NRVP-C	Driving criteria established by dynamic testing conducted on 100 percent of production piles	0.75	0.60
NRVP-D	Driving criteria established by dynamic load test, quality control by dynamic testing of at least two production piles per Geotechnical Site, but no less than 2 percent of production piles.	0.65	0.52
NRVP-E	Driving criteria established by wave equation analysis, without pile dynamic measurements but with field confirmation of hammer performance by driving to refusal.	0.50	0.40

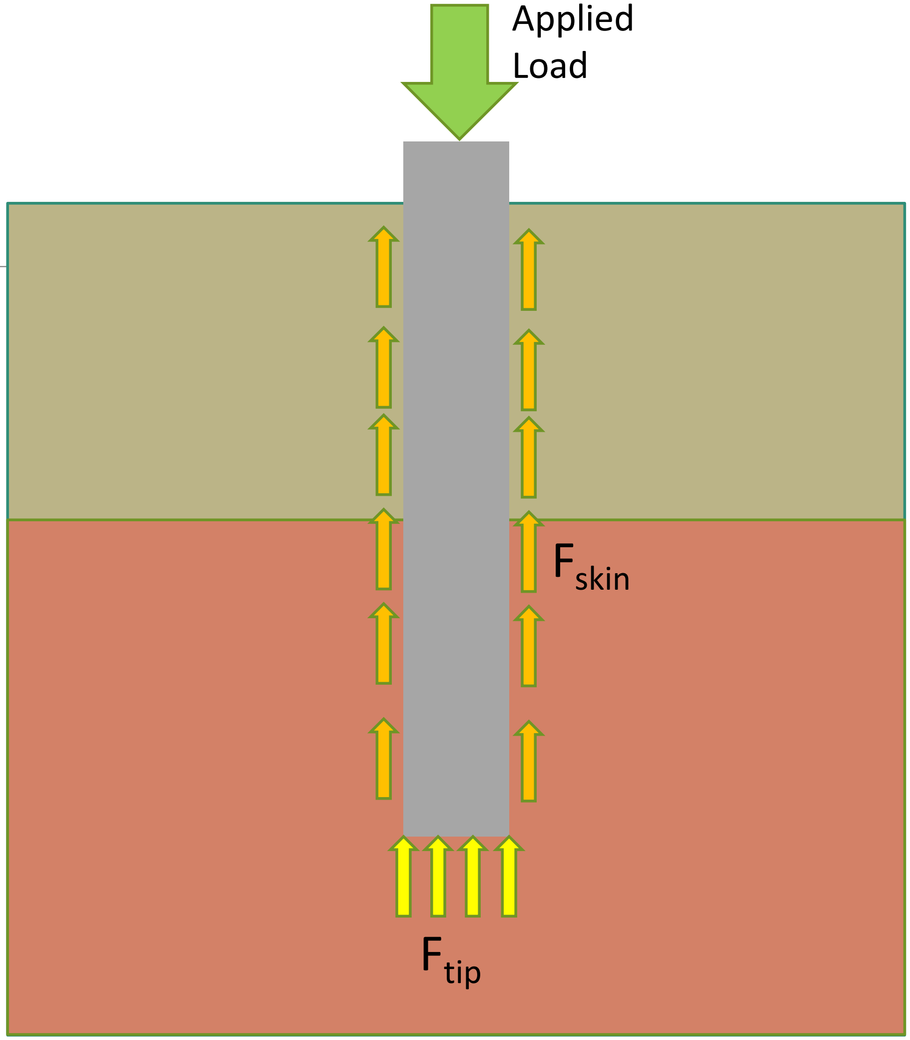
Driven Pile Overview

Deep foundation typically used in very heavy structures (bridges, multi-story buildings, etc.)

Relies on a combination of skin friction and tip resistance

Pile capacity function of:

- Material driven through
- Depth driven
- Material bearing on pile tip



Driven Pile Analysis

Hand calculations for skin friction

- Total Stress method (alpha)
- Effective Stress method (beta)

GRLWEAP

PDA Analysis

CAPWAP

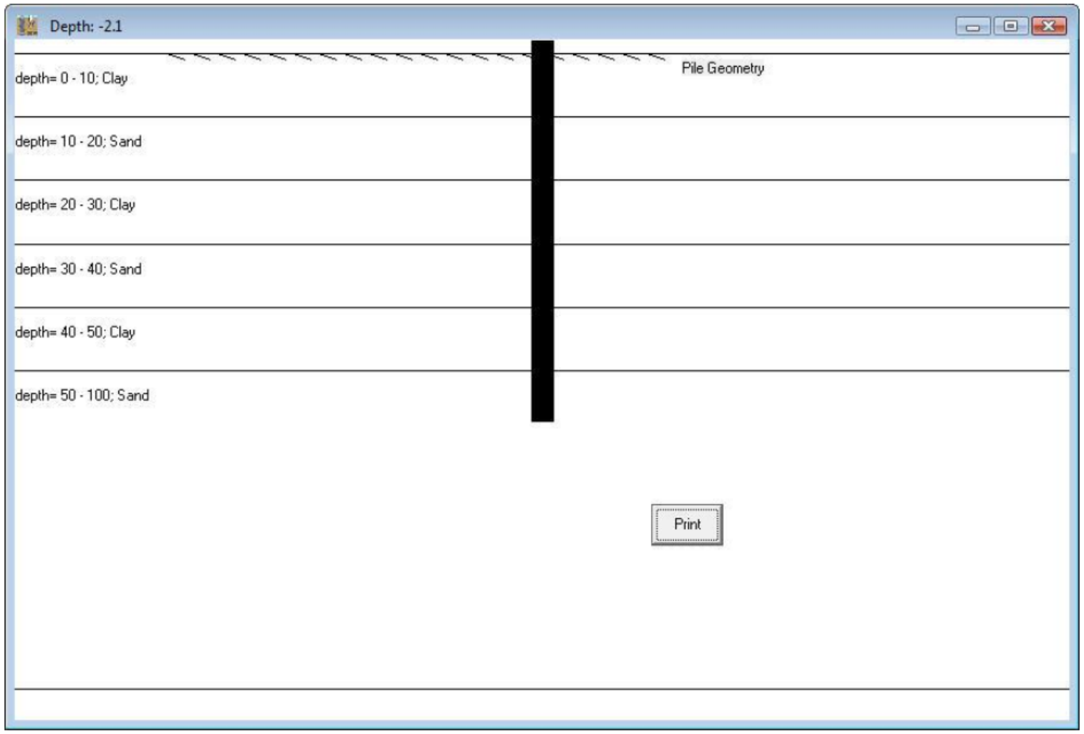
APILE

APILE used to estimate axial pile capacity

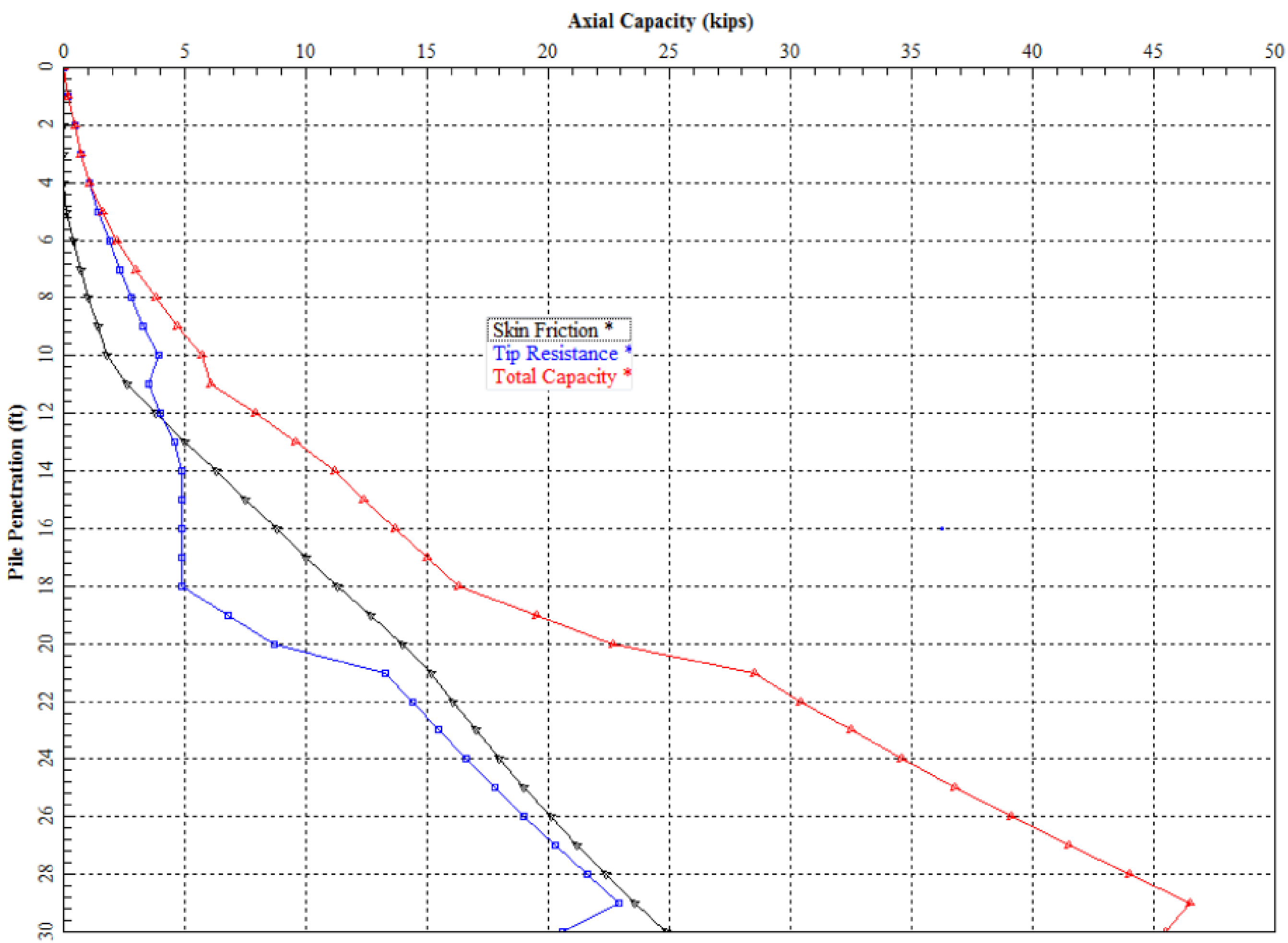
Difficult to predict end bearing in hard rock

Four methods can be used to determine axial capacity

- FHWA
- USACE
- API
- Lambda Method



Plot Pile Capacity



In-Situ Pile Testing

Performed to understand actual stresses in strains in *piles*, *resisting medium* and pile capacity

Static load test

PDA (pile driving analyzer)

- Pile instrumented with strain gauge and accelerometer

Static Load Testing

Time Consuming

Expensive

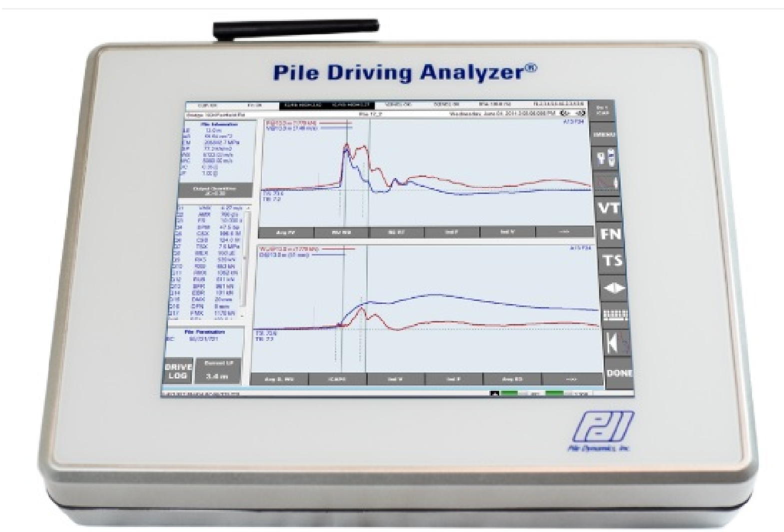
Potential for danger

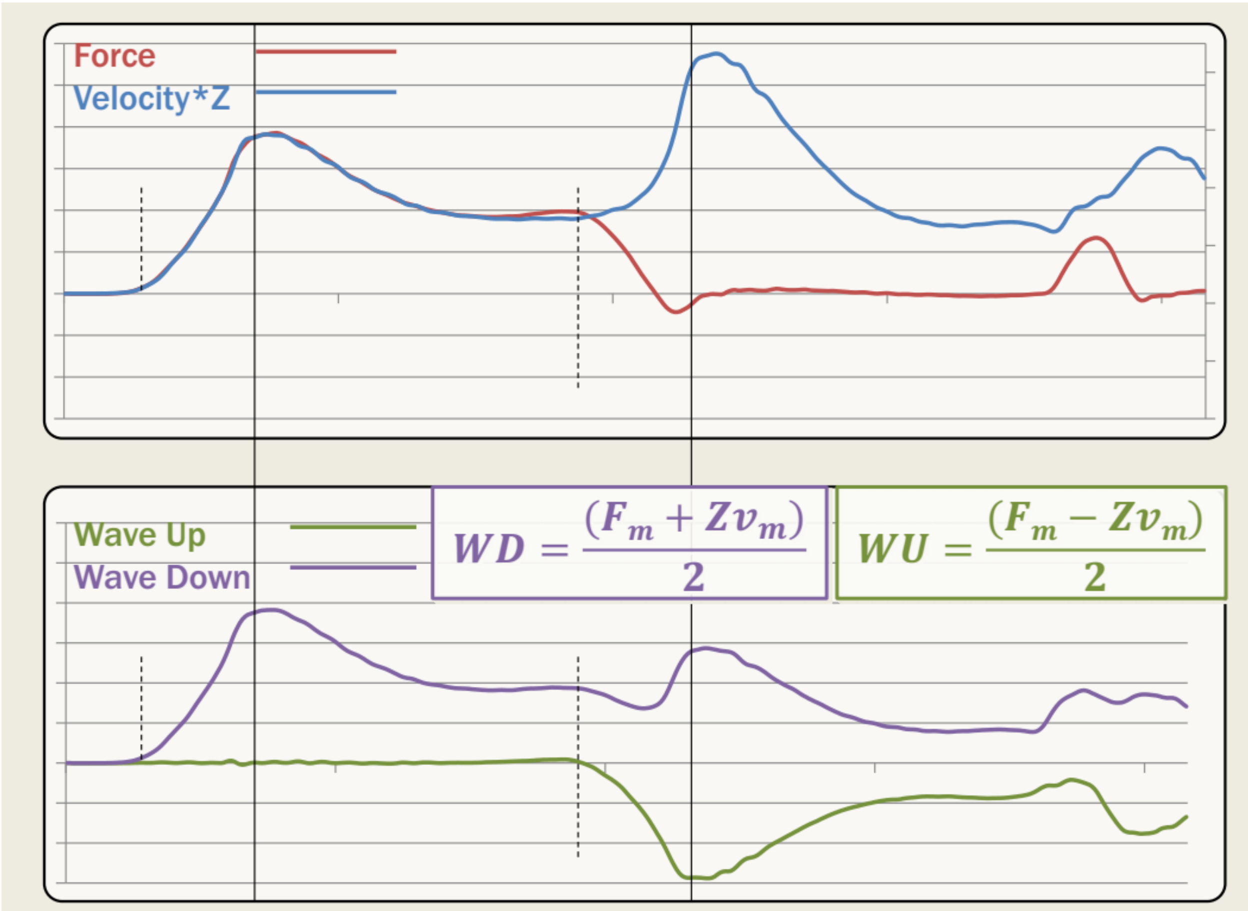
$$\rho\frac{\partial^2 u}{\partial t^2} = E\frac{\partial^2 u}{\partial x^2}$$

PDA Analysis

PDA based on one dimensional wave equation

Piles instrumented with strain gauge and accelerometer




Force
Velocity*Z
Wave Up
Wave Down
$WD = \frac{(F_m + Zv_m)}{2}$
$WU = \frac{(F_m - Zv_m)}{2}$

Wave Equation Analysis of Pile Driving (WEAP)

Should be used during design phase

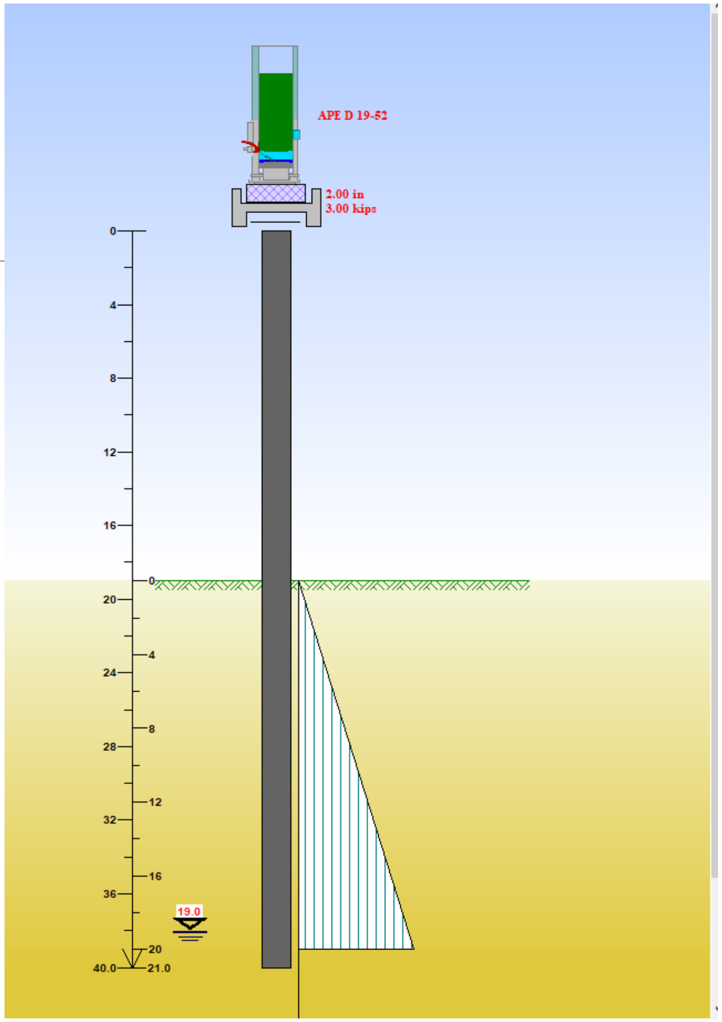
Uses 1-D wave equation

Calculates soil resistance, dynamic pile stresses, and estimated capacities based on field data, hammer and pile type.

Can be used to help select appropriate hammer and driving system

Can help determine if a pile will become overstressed at certain depth or if refusal is likely prior to desired penetration depth

Estimates driving time



Bearing Graph - HP12x53

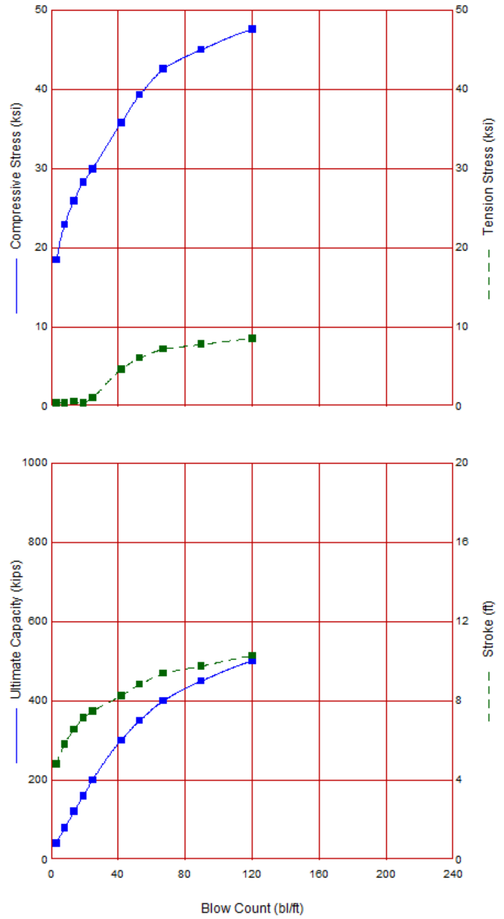
File View Window Help

English | blows/ft

HP12x53

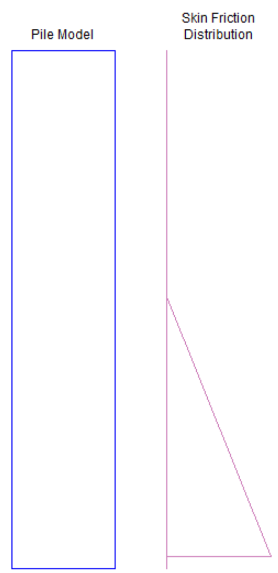
Pile Dynamics, Inc.-DEMO
HP12x53 Pile

29-Jan-2020
GRLWEAP Version 2010



APE D 19-52

Ram Weight	4.19	kips
Efficiency	0.800	
Pressure	1710 (100%)	psi
Helmet Weight	3.00	kips
Hammer Cushion	56715	kips/in
COR of H.C.	0.800	
Skin Quake	0.100	in
Toe Quake	0.100	in
Skin Damping	0.200	s/ft
Toe Damping	0.150	s/ft
Pile Length	40.00	ft
Pile Penetration	21.00	ft
Pile Top Area	15.50	in2



Res. Toe = 39.6 kips
(Constant Res. Toe)

HP12x53

Pile Dynamics, Inc.-DEMO
HP12x53 Pile

29-Jan-2020
GRLWEAP Version 2010

Ultimate Capacity kips	Maximum Compression Stress ksi	Maximum Tension Stress ksi	Blow Count bl/ft	Stroke ft	Energy kips-ft
40.0	18.45	0.36	3.3	4.80	26.79
80.0	22.89	0.38	8.1	5.81	23.10
120.0	25.90	0.55	13.6	6.55	21.64
160.0	28.26	0.38	19.4	7.12	21.21
200.0	29.93	1.05	24.8	7.47	21.04
300.0	35.71	4.64	41.8	8.24	21.79
350.0	39.24	6.13	52.9	8.82	23.04
400.0	42.50	7.20	67.1	9.37	24.35
450.0	44.97	7.80	89.7	9.75	25.08
500.0	47.52	8.57	120.0	10.27	26.28

CAPWAP

- Matches field data to soil data
- Best method for determination of pile capacity
- Can be used to determine internal pile properties
- Performed in the office after collection of field data
- Should pick blow count with high energy

CLIP: OK | FV: OK | F1/F2: OK 1.11 | V3/V4: OK 0.93 | V[END]: OK: | D[END]: OK | BTA: 100.0 % | Balance

fbi admin | pda pile 348 | 12/3/2019 11:48:36.478 AM

LE	30.90 ft
AR	15.50 in^2
EM	30000 ksi
SP	0.492 k/ft3
WS	16807.9 ft/s
WC	16702.7 ft/s
JC	0.90
JF	1.00

Output Quantities
JC=0.90

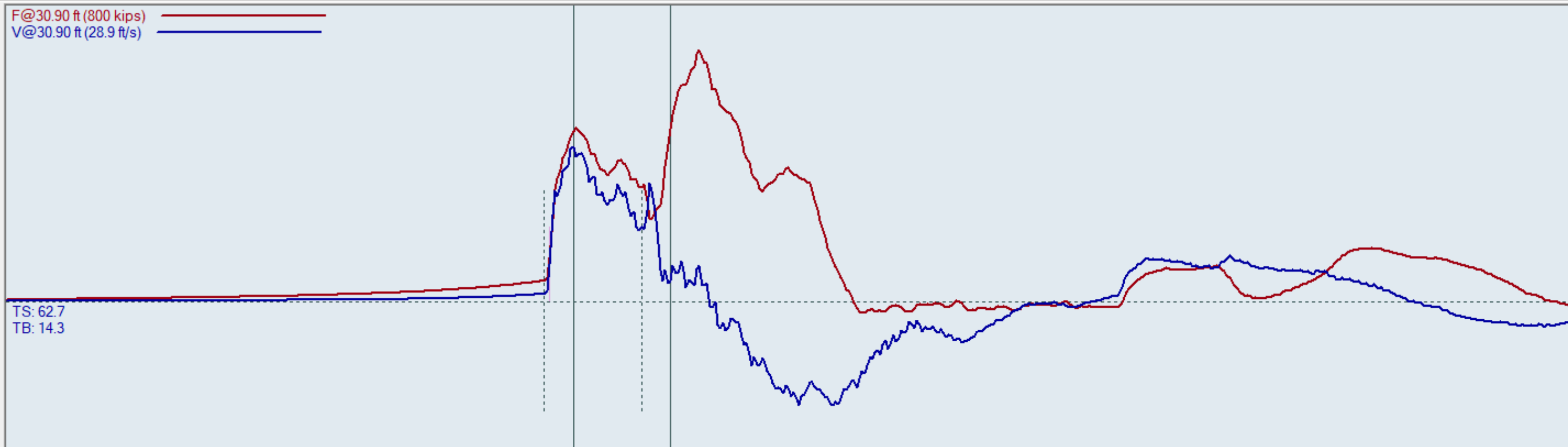
CSI	48.4 ksi
CSX	43.8 ksi
CSB	40.2 ksi
EMX	18.9 k-ft
ETR	43.7 %
STK	7.53 ft
FMX	679 kips
RX5	646 kips
RX7	630 kips
RX9	625 kips
RUC	0 kips
SFC	0 kips
MQ	0.00

Pile Penetration

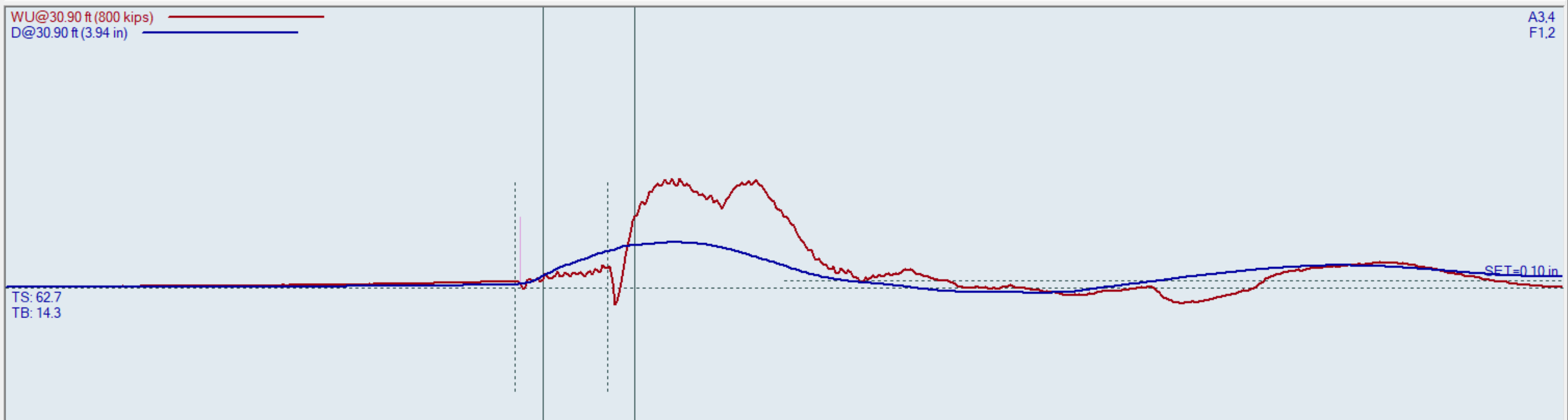
BC	0/206/204
SL	203/205
BN	204

DRIVE LOG

Current LP (ft)
29.70



Avg FV | Avg D, WU | Ind F | Ind V | Ind S | -->>



Avg D, WU | Ind V | Ind F | iCAP® | Ind A | -->>

Do 1 iCAP | iMENU | VT | FN | TS | Report

SL:203/205 BN:204 BC:0/206/204

CAPWAP(R) 2014-3-Building & Earth Sciences, Inc. - [pda pile 348_204-RWC]

File Edit View Input Update Tools Analysis Window Help

JSkn - Case Skin Damping, dimensionless. Suggested: 0.000 to 2.728.

fbi admin; pda pile 348; reaction pile

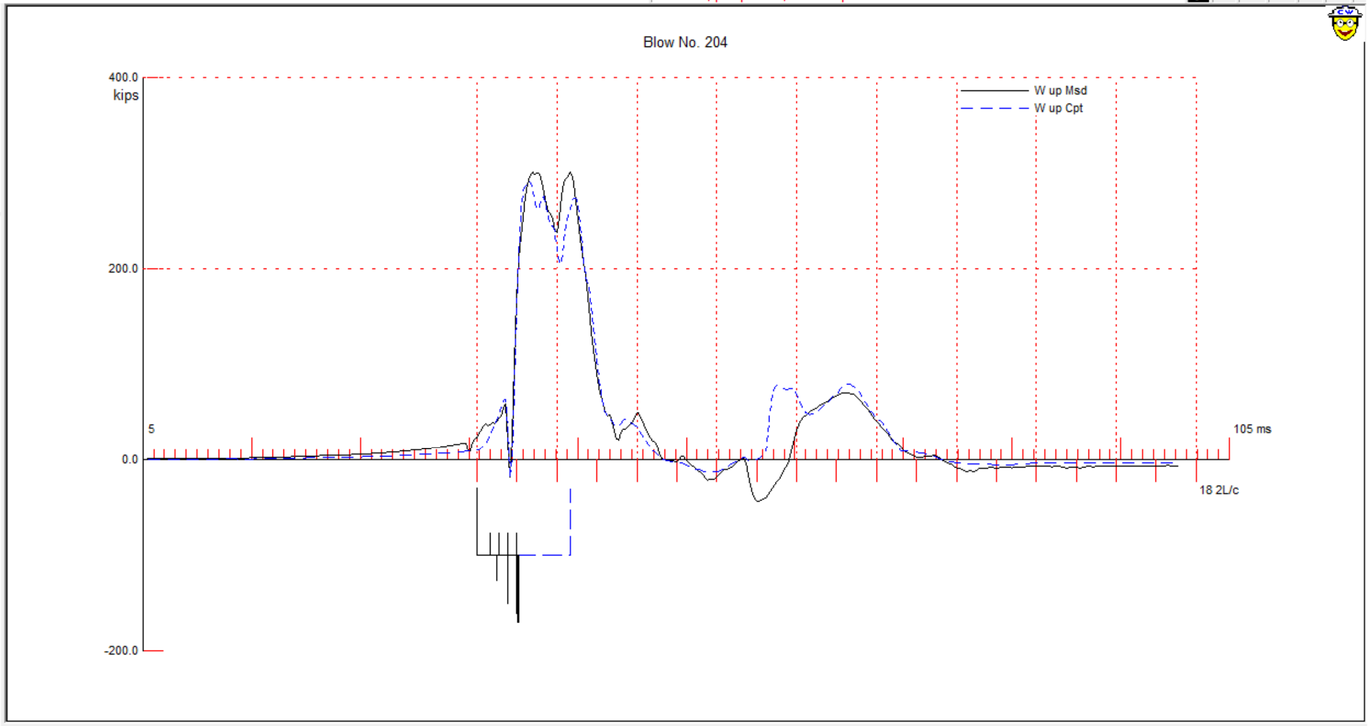
Blow Ct.(b/ft)		Match Quality		Mult. Blow	
Msd	120.	AN #	14036	RSA	0
Cpt	177.1	Now	3.82	Start	
Match	✓	Best	3.82	End	

Set (in)			
Msd	0.1	Cpt	0.068

Prev/Best | Interp-F8 | Replace | Toe Hold

Rult	Rs	Unresolv.	
627.6	188.6	0.	Menu

Res	Modi.	Curr.	Prev.	Depth
	kips	kips	kips	ft
1	24.6	24.6	24.6	9.1
2	46.5	46.5	46.5	16.0
3	55.2	55.2	55.2	22.8
4	62.3	62.3	62.3	29.7
Toe	439.0	439.0	439.0	29.7
Extra	R	Quake	Smith D	
Toes		in	s/ft	
#1	0.0	0.000	0.000	0.0
#2	0.0	0.000	0.000	0.0



JS/JT	SS/ST	QS/QT	UN/TG	CS/CT	PS/PL	SK/BT	SO/OP	PI	RU/Rt
0.3283	0.048	0.295	0.98	1.454	0.	2.41	0	0.01	627.6
0.6207	0.039	0.136	0.071	0.497	0.	10.	2	Modi.	439.
	s/ft	in	in		kips				kips
0.3283	0.048	0.295	0.98	1.454	0.	2.41	0	0.01	627.5
0.6207	0.039	0.136	0.071	0.497	0.	10.	2	Previous	439.

Red means out of suggested range. Blue means change since last try.

PDA Experiences on Alabama Projects

Pile	Maximum Allowable Driving Stress (ksi)	Average Max Compressive Stress (ksi)	Average Max Bottom Stress (ksi)
HP 12 x 53	45	35.5	39.8
HP 12 x 53	45	25.2	17.0
HP 14 x 89	45	32.4	25.4
HP 12 x 53	45	26.8	20.4

Experience shows measured pile capacity typically exceeds predicted capacity

Specified depths for driving typically conservative

Stresses measured in piles show us piles capable of supporting additional loading

University of Alabama Water Tower

- HP 12x53 piles driven using a Junttan Model PM16 Hydraulic Hammer
- Designed with 400 kip ultimate capacity
- Estimated blow count at termination of 65 blows per foot, based on GRLWEAP
- 4 piles tested using PDA

Pile #	Case Ultimate Capacity (kips)	Max Compressive Stress (ksi)	Max Bottom Stress (ksi)
9A	489.7	36.4	36.8
20A	483.7	34.6	31.2
2A	481.6	35.8	30.4
14A	491	35.4	30.6

Concrete Piles

- 14 in. square prestressed concrete piles (6000psi) driven with a ICE I30 Diesel Hammer
- 75 foot piles (240 kip capacity)
- 96 foot piles (440 kip capacity)
- 6 piles tested using PDA

Pile #	Required Ultimate Capacity (kips)	Ultimate Capacity at End of Initial Drive (kips)	Ultimate Capacity after 72 hours (kips)
35	440	366.4	737.5
147	440	385.4	665.6
199	440	360.2	663.4
116	240	178	365.9
75	240	-	306.1
35	240	113.9	412.5

Questions