EFFECTS OF PORE WATER PRESSURE VARIATION UNDER DYNAMIC LOADS

A Case Study

PDA Users Day, 1990

By: C. Michael Morgano

In the field of dynamic testing, we realize the importance of restrike tests to verify time dependent soil strength changes. As we know, some of the most common strength changes include relaxation (weathered shales), set-up (fine grained soils) and pore water pressure changes (sands). The paper by Frank Rausche titled "Reasons for CAPWAPC Underprediction and Overprediction" discusses other less common soil behavior which may effect the soil strength.

This case study involved the testing of 12 inch O.D. closed end steel pipe piles driven directly under a creek by a Vulcan 06 hammer. The soil conditions consist mostly of wet, loose silt and medium loose to medium compact silty sand. A boring is included in the following pages. At this point your probably thinking, ahaaaa!!, prime soil conditions for pore pressure effects, right? right.

During the pile driving process, pore water pressure changes in fine (silty) sands can effect the soil strength in two ways. In dense soils, the shearing (failure) action causes "dilation" leading to a reduction in pore pressure (*i.e.*, negative pore pressure). This reduction in pore water pressure produces increased effective stresses and therefore a higher strength. After pile driving is stopped, the process described above is reversed. The pore water pressure will equalize to the static condition resulting in a reduced soil strength. The time it takes for the pore pressure to equalize is dependent on the soil permeability. If a pile is dynamically tested in this type of soil, the results would indicate higher resistance during the initial driving and a lower resistance during a restrike test.

Pore pressure changes can also effect soil strength in loose soils. In this case, dynamic soil motions caused by pile driving may result in soil densification and also in increased the pore water pressures possibly to the point of liquefaction. If this occurs, the soil strength would decrease during pile driving. After the pile driving process is stopped, the pore pressure would again equalize to the static condition, causing an increase in effective stresses and therefore and increase in the soil strength. A restrike test on the pile would confirm the additional soil resistance.

The case study presented here is an example of the latter case. Figure 1 shows two records representing the end of inial drive (a) and the beginning of restrike (b). Each plot shows force and velocity along with wave up and wave down curves. The restrike test was performed approximately three minutes after the initial drive was stopped (I have to admit that was not meant to be a three minute restrike test; driving was temporarily stopped to put some inch marks on the pile for blow counting.

The records indicate a significant increase in capacity over the three minutes waiting. Though the records indicate some set-up, the majority of the increased capacity seems to come from end bearing. This was confirmed by the results of CAPWAPC analyses performed both at EOD and BOR. These results are shown in Figures 2 and 3. Note that the end bearing increased from 105 to 180 kips. Also note the unusually large toe quakes. In this case, it is obvious that three minutes was sufficient time for the pore pressure to dissipate significantly, though further dissipation is still possible.

Whether in dense or loose soils, one can see the importance of restrike tests to monitor soil strength changes due to pore pressure variations. Depending on the soil denseness, the pile capacity may either be overpredicted or underpredicted if tested during initial drive only. Restrike tests, assuming that sufficient time has been given for the pore water pressures to equalize, are effective and necessary tests to monitor soil strength changes.

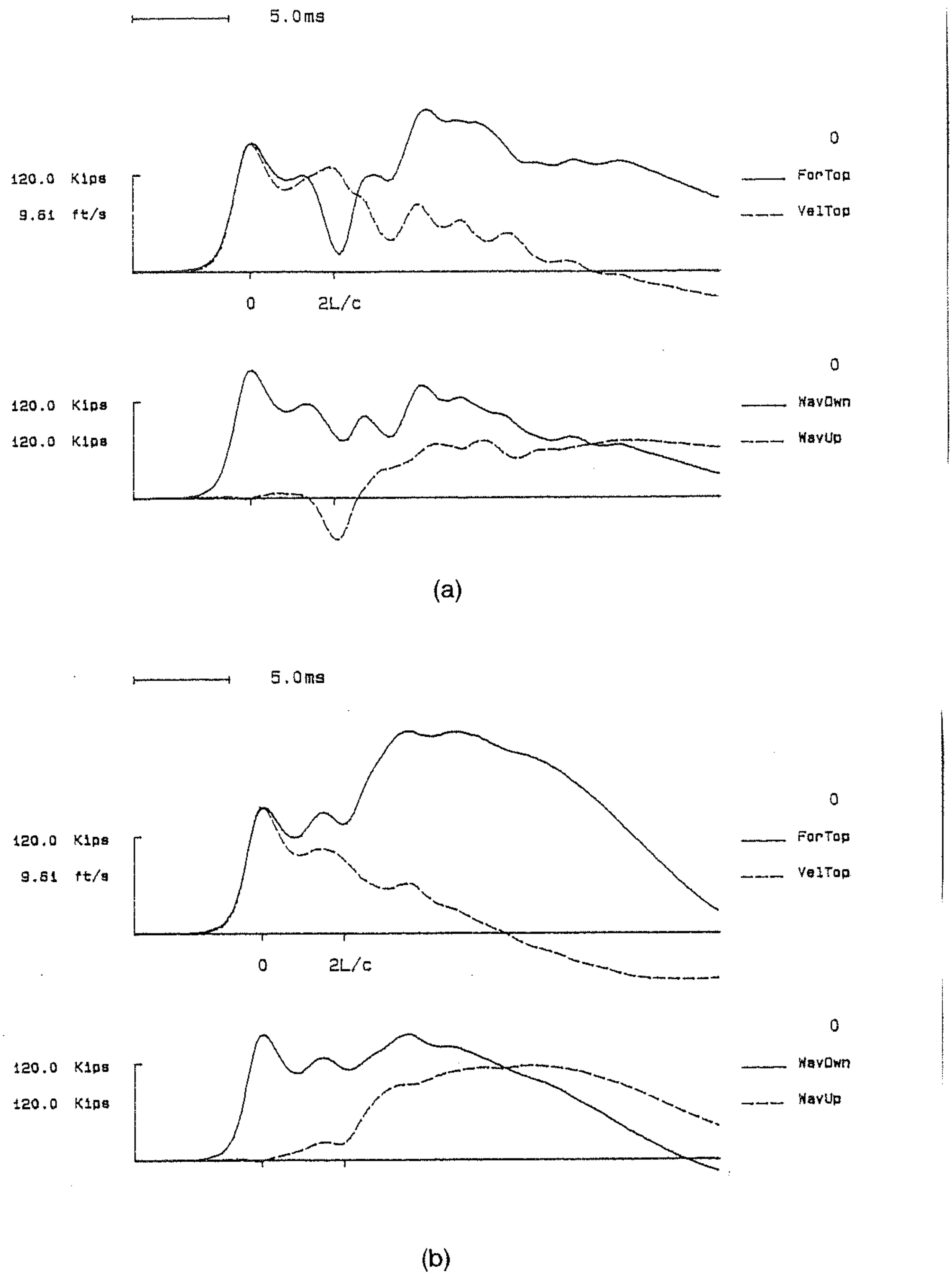


Figure 1: Force-Velocity and Wave Up-Wave Down records for (a) EOD and (b) BOR.

CAPWAPC - GRL & Associates, Inc.
pile no 16 vulcan 06 * 23 ft pen 06/27/90

Final CAPWAPC Capacity: Ru 145.7, Skin 40.2, Toe 105.5 Kips

Soil Sgmnt No.	Depth Below Gages ft	Depth Below Grade ft	Ru Kips	Sum of Ru Up Kips	Sum of Ru Down Kips	Unit Resist. w. Respect to Depth Kips/ft	Unit Resist. w. Respect to Area Kips/f2	Smith Damping s/ft	Quake inch
				145.7					
1	16.8	7.8	10.0	135.7	10.0	1.49	.48	.011	.100
2	23.5	14.5	10.0	125.6	20.1	1.49	.48	.011	.100
3	30.3	21.3	10.0	115.6	30.1	1.49	.48	.011	.100
4	37.0	28.0	10.0	105.5	40.2	1.49	.48	.011	.100
Average Skin Values			10.0			1.44	.48	.011	.100
Toe			105.5				98.60	.038	.660

Soil Model Parameters/Extensions		Skin	Toe
Case Damping		.035	.321-Smith Type
Unloading Quake	(% of loading quake)	20	20
Unloading Level	(% of Ru)	20	
Soil Plug Weight	(Kips)		.08

CAPWAPC - GRL & Associates, Inc.
Pile No. 16 * Vulcan 06 * 23 Ft. Pen
06/27/90

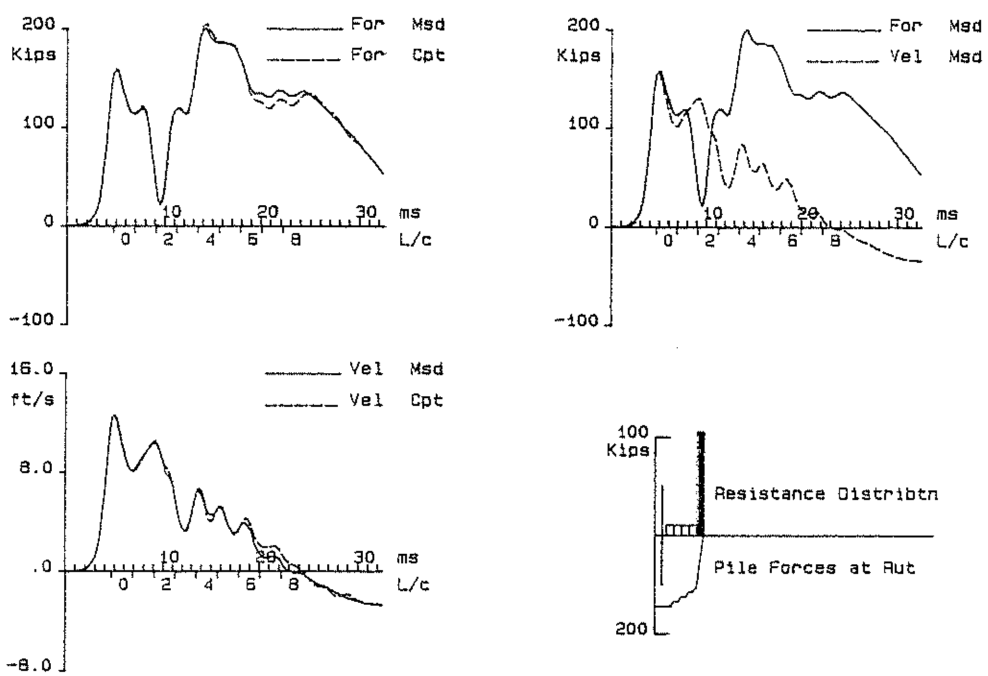


Figure 2: CAPWAPC Results for EOD record

CAPWAPC - GRL & Associates, Inc.
Pile No 16 * Vulcan 06 * 23 FT PEN * BOR 06/27/90

Final CAPWAPC Capacity: Ru 240.4, Skin 60.0, Toe 180.4 Kips

Soil Sgmnt No.	Depth Below Gages ft	Depth Below Grade ft	Ru Kips	Sum of Ru Up Kips	Sum of Ru Down Kips	Unit Resist. w. Respect to Depth Kips/ft	Unit Resist. w. Respect to Area Kips/f2	Smith Damping s/ft	Quake inch
				240.4					
1	16.8	7.8	11.0	229.4	11.0	1.64	.52	.046	.100
2	23.5	14.5	11.0	218.4	22.0	1.64	.52	.046	.100
3	30.3	21.3	16.9	201.4	39.0	2.52	.80	.046	.100
4	37.0	28.0	21.0	180.4	60.0	3.13	1.00	.046	.100
Average Skin Values			15.0			2.14	.71	.046	.100
Toe			180.4				168.57	.018	.380

Soil Model Parameters/Extensions		Skin	Toe
Case Damping		.223	.259
Unloading Quake	(% of loading quake)	45	45
Soil Plug Weight	(Kips)		.07

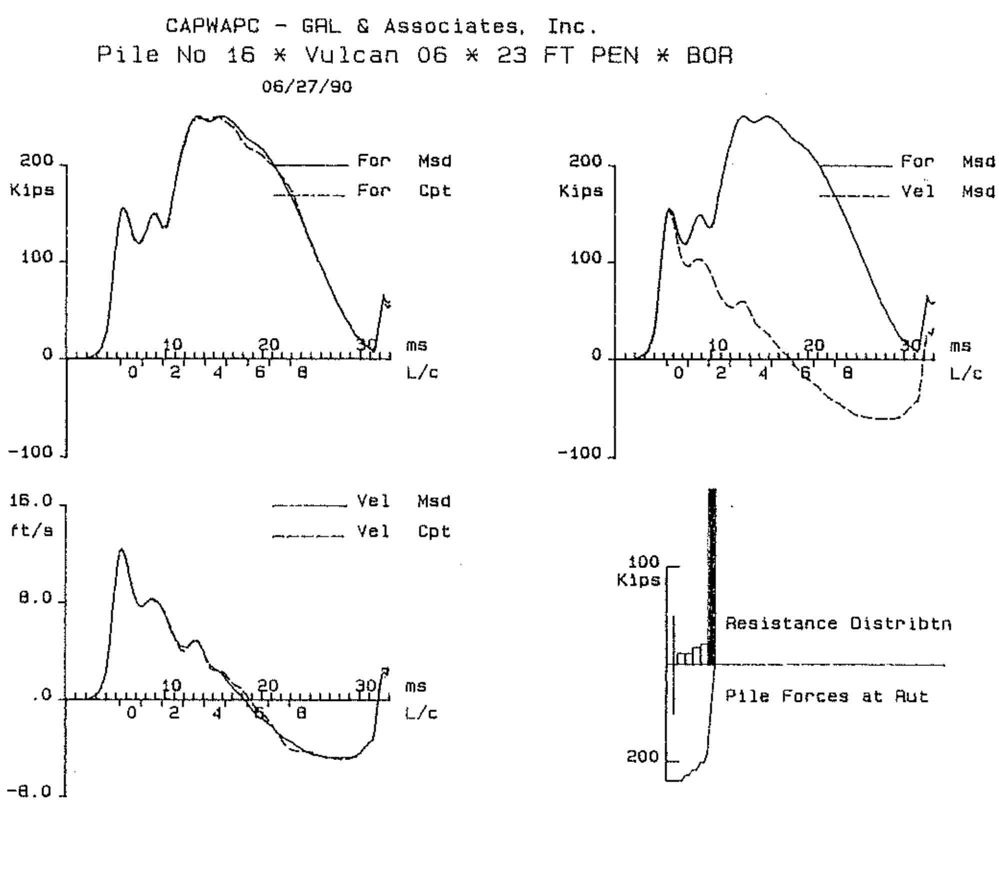


Figure 3: CAPWAPC Results for BOR record

PITTSBURGH TESTING LABORATORY

LOG OF BORING

Job No. CUE-2236

Client Cleveland Metro Park Systems

Project Proposed Foot Bridge (Brecksville Reservation)

Location of Boring: T.H. 2 - S. Side of Ford

Water Level	
Time	
Date	

Boring No. 2 Date 7/23/84 Sheet 1 of 2

Type of Boring Std. Pen. Rig ATV

Casing used ____ Size ____ Drilling mud used ____

Boring begun 7/13/84 Boring completed 7/13/84

Ground Elevation 645.35 referred to ____ Datum

Field Party: K. Myers

Depth of Casing, ft.	Sample No.	Sample depth from-to (in feet)	Blows/6" on Sampler	ID of Sampler (inches)	Tot. length of recov. sample	Length of Lab. sample	DEPTH IN FEET	SOIL GRAPH	VISUAL DESCRIPTION Soil type, color, texture, consistency, sampler driving notes, blows per foot on casing, depths wash water lost, observed fluctuations in water level, notes on drilling ease, etc.
		0.0							Topsoil - Moist
			2-2				0		Moist
	1	1.5	7		18"	6"	1		Loose Brown Sand & Gravel W/Sandstone fragments
		2.0	2-4				2		Loose Clayey brown sand - Moist
	2	3.5	7		18"	6"	3		
							4		
	3	5.0	2-4		18"	6"	5		
		6.5	8				6		Med. loose brown gravelly sand w/a few stone & shale fragments, small cobbles (SW-SM) Moist to Wet
							7		
		8.5	2-4				8		
	4				18"	6"	9		
		10.0	6				10		
							11		
							12		
		13.5	4-4				13		Med. loose gray silt - Wet
	5				18"	6"	14		
		15.0	5				15		
							16		
							17		
	6	18.5	1-4		18"	6"	18		
							19		
		20.0	5				20		Med. compact gray silty sand - Wet
							21		

Engineer R.D. Biasella, P.E., Cleve. Dist.

PITTSBURGH TESTING LABORATORY

LOG OF BORING

Job No. CLE-2236

Client Cleveland Metro Park Systems

Project Proposed Foot Bridge (Brecksville Reservation)

Location of Boring: T.H. 2 - S. Side of Ford	
Water Level	
Time	
Date	

Boring No. 2 Date 7/23/84 Sheet 2 of 2

Type of Boring Std. Pen. Rig ATV

Casing used ____ Size ____ Drilling mud used ____

Boring begun 7/13/84 Boring completed 7/13/84

Ground Elevation 645.35 referred to ____ Datum

Field Party: K. Myers

Depth of Casing, ft.	Sample No.	Sample depth (from-to) (in feet)	Blows/6" on Sampler	ID of Sampler (inches)	Tot. length of recov. sample	Length of Lab. sample	DEPTH IN FEET	SOIL GRAPH	VISUAL DESCRIPTION Soil type, color, texture, consistency, sampler driving notes, blows per foot on casing, depths wash water lost, observed fluctuations in water level, notes on drilling ease, etc.
		20.0	5				20–24		Med. loose gray clayey silty sand - Wet (Pile tip)
	7	25.0 – 26.5	2-4 -7		18"	6"	24–30		Med. compact gray silty sand - Wet
	8	28.5 – 30.0	2-4 7		18"	6"			
	9	33.5 – 35.0	4-8 13		18"	6"	30–40		Gray fine to medium sand, some silt, trace clay (SM) - Moist
	10	38.5 – 40.0	12-15 18		18"	6"			

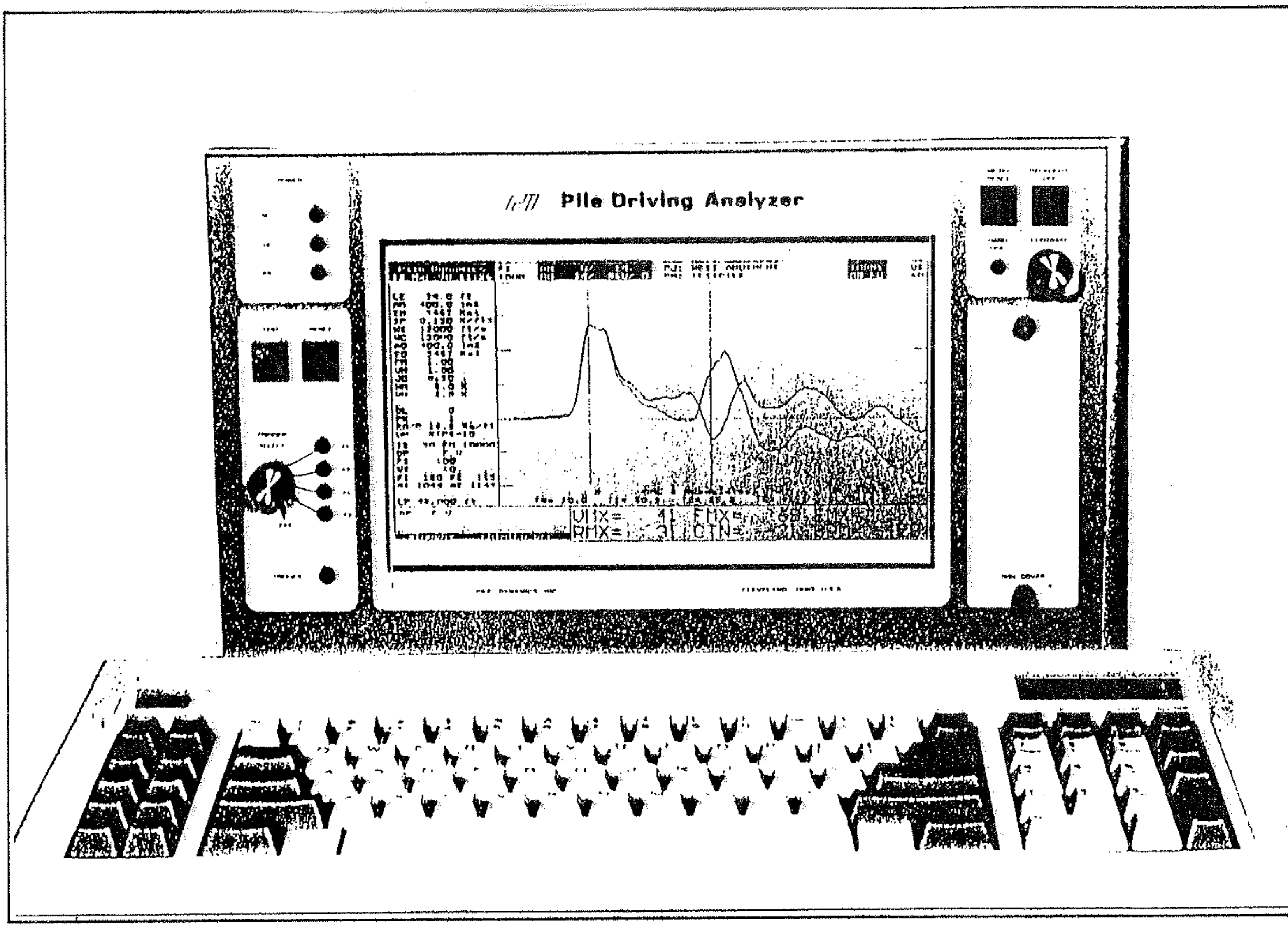
Encountered water 6.0

T.H. 2 is 79.5' off of centerline of road

↓(50')

Engineer R.E. Biasella, P.E. Cleve. Dist. Mgr.

Cleveland 1990



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