CPT Pore Water Pressure Correlations With PDA Rebound to Indentify High Pile Rebound Soils : Case Studies in Florida

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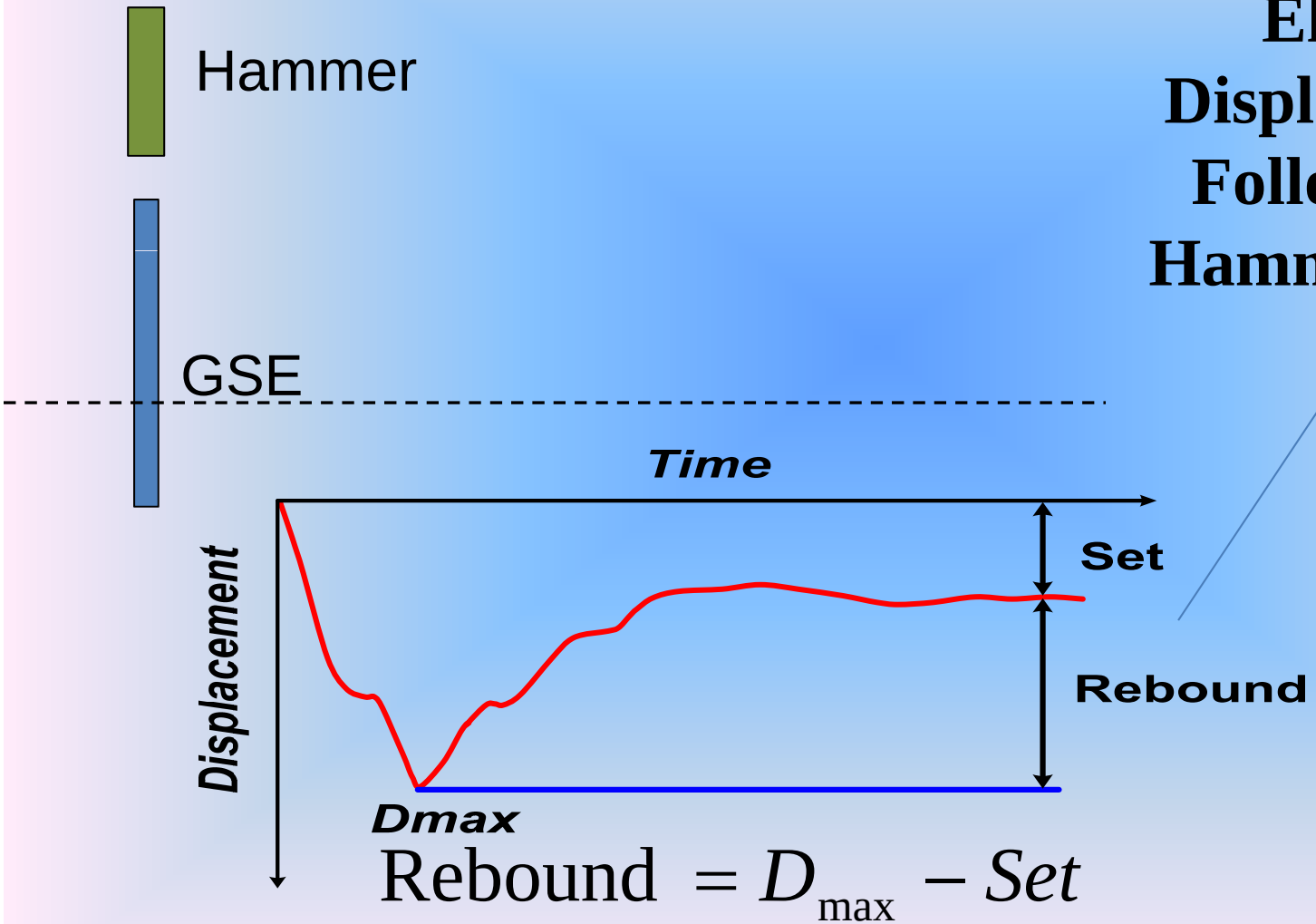
Project Overview

- Pile Driving Sites throughout Central Florida experience > 1/4 inch rebound during driving: up to 2 inches reported
- Pile Design Capacities & Depths not achieved
- Engineers want to predict this problem during Project Planning and Design Phase

Defining the Problem



Elastic Displacement Following a Hammer Blow

$$\text{Rebound} = D_{\max} - Set$$

Current Specification

- ***FDOT Section 455-5.10.3 Practical Refusal***
- 20 blows/inch when hammer at its highest fuel setting
- Less than 1/4 inch rebound per blow
- Stop driving when Engineer determines refusal

Overview of Rebound Sites

- High Pile Rebound (HPR) was evaluated at six Central Florida sites:
  - Four sites experienced excessive HPR with no or minimal set;
  - One site where the pile rebounded, followed by an acceptable permanent set;
  - One site where no rebound was noticed.

Research Objective

- Develop geotechnical testing processes that allow high pile rebound to be anticipated.

This will avoid:

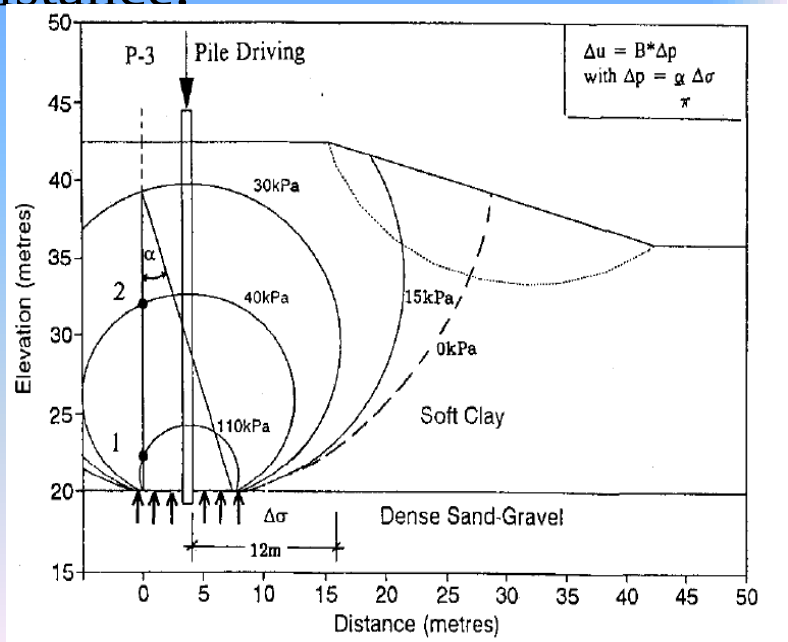
- damage to piles;
- construction delays;
- pile redesign.

High Pile Rebound History Summary

- Observed Rebound 0.50 to 1.50 inches;
- High Displacement Piles;
- Rebound Soils: Dense to very dense or Stiff to Hard;
- CPT Pore water pressure >20 tsf (Murrell 2008);
- Soils in the rebound layers typically contained silts and clays;
- Piles were longer than 40 feet;
- Pile driving hammers were single-acting.

Mechanism of Excess Pore Water Pressure during Pile Driving in Saturated Soils

- Bingjian 2011: Excessive pore pressure generated under the tip of the pile was equivalent to 1.25 of effective stress which led to decease shaft resistance along the pile and tip resistance.
- Eigenbrod (1996):Excess PWP during driving decreased the shaft resistance.
- Robertson et al. (1989):PWP can be extended laterally to a 30-35 pile diameter.



After Eigenbrod (1996)

Contin……

- Jackson et al. (2007) excessive pore pressure developed during the jacking process, reducing the shaft and the tip resistances.
- Chen et al. (2001) developed an approach to determine pile movement at the tip and top. The model also included the point and shaft resistances.
  - Neglected shaft resistance along , pile rebound was large.
  - Included the effect of shaft resistance, rebound was significantly decreased

Methodology

- Field Tests
  - Pile Driving Analyzer (PDA)
  - Electrical Cone Penetrometer Testing (CPT)

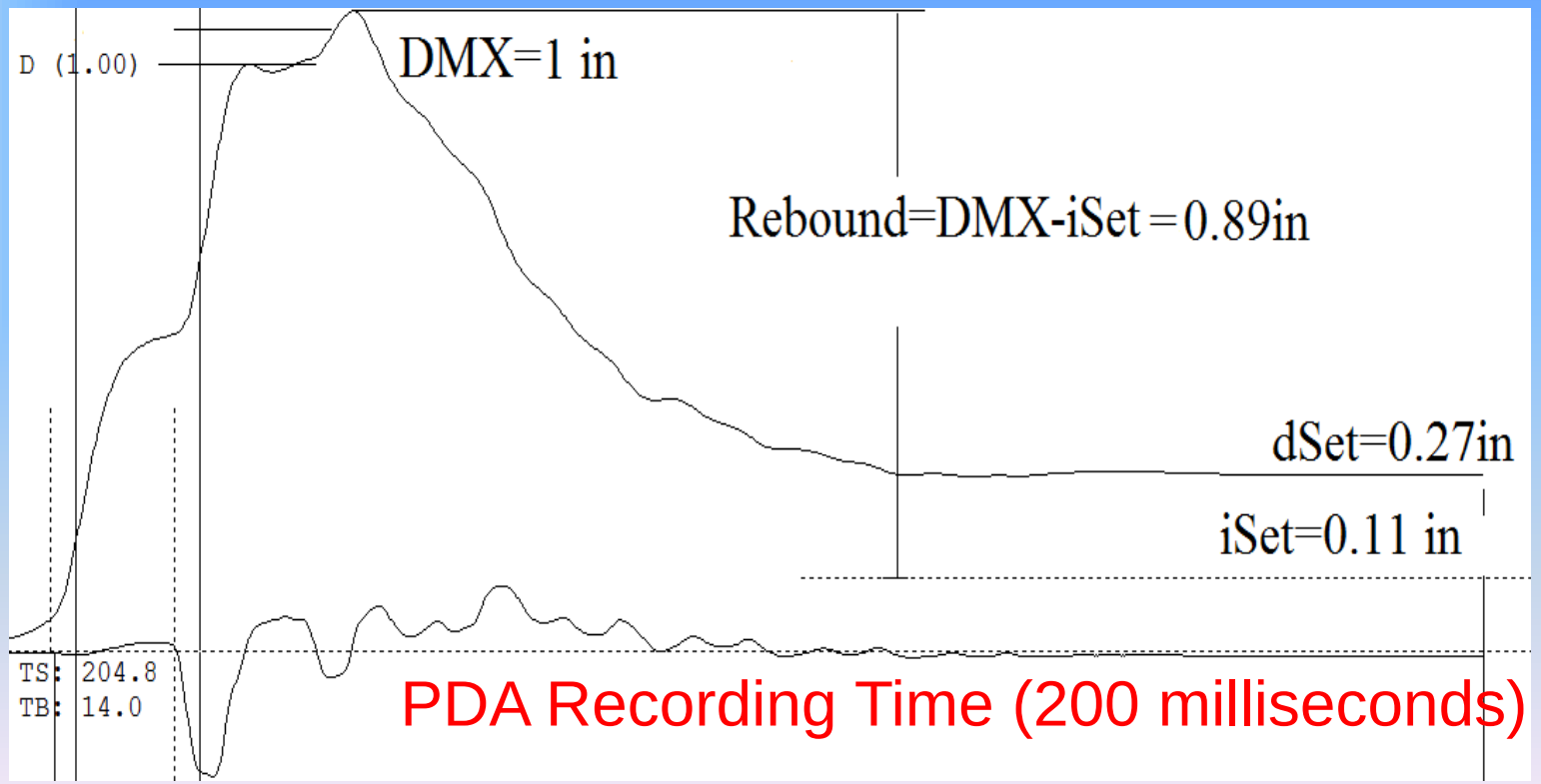
    with pore water measurement $\mathbf{U}_2$

Pile Driving Evaluation

- PDA Strain Gage and Accelerometers yield displacement and force versus time
- Time limited to about 200 milliseconds/blow
- Evaluated displacement vs. time
  - Maximum Displacement = DMX
  - Final Displacement = DFN (dSet)
  - *pile moves after 200 ms*
  - Inspector set (iSet) (blows/ft)
  - PDA Rebound = DMX-iSet

Digital Record of Rebound from PDA Sensors

DMX= max displacement

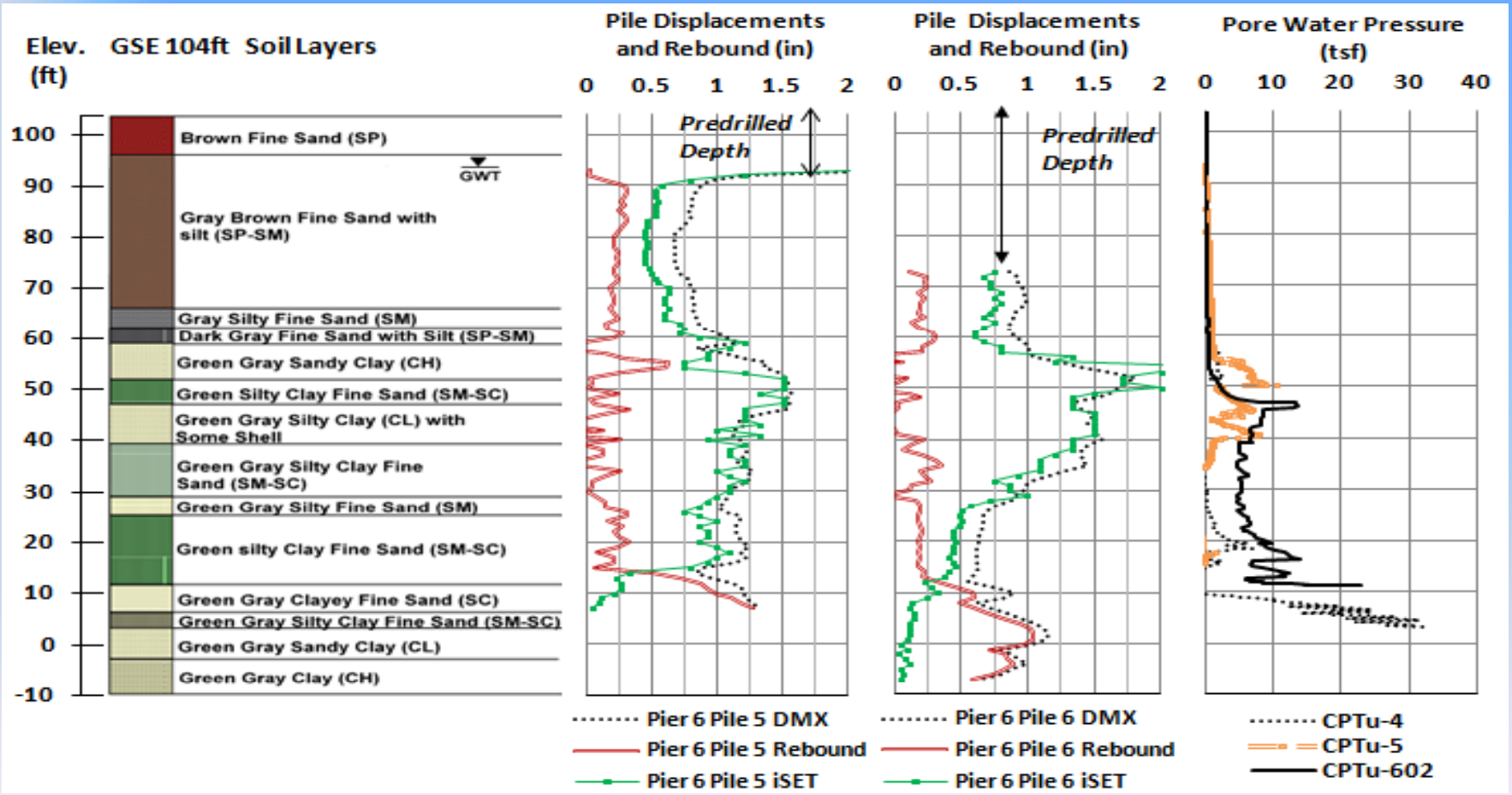


Site 1 : Anderson Street Overpass (Pier 6)

Rebound = 1" followed by no or minimal set

Pile :24" Prestressed Concrete Piles

Hammer : Delmag D62 single-acting diesel



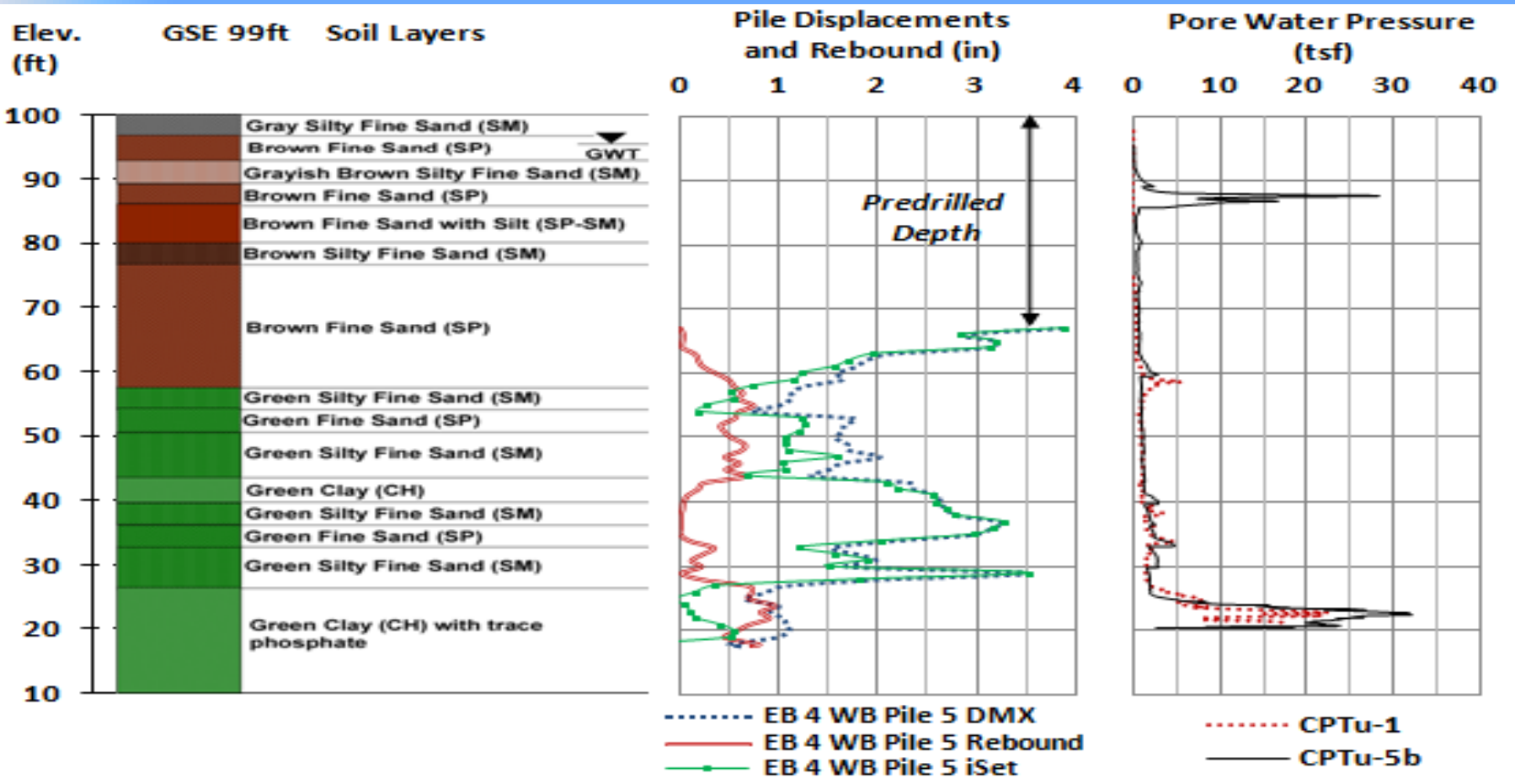
Foundation were redesigned and replaced with H-Piles

Site 2: SR50 Over SR 436

Rebound = 1” followed by no or minimal set

Pile :24” Prestressed Concrete Piles

Hammer : Delmag D42 single-acting diesel

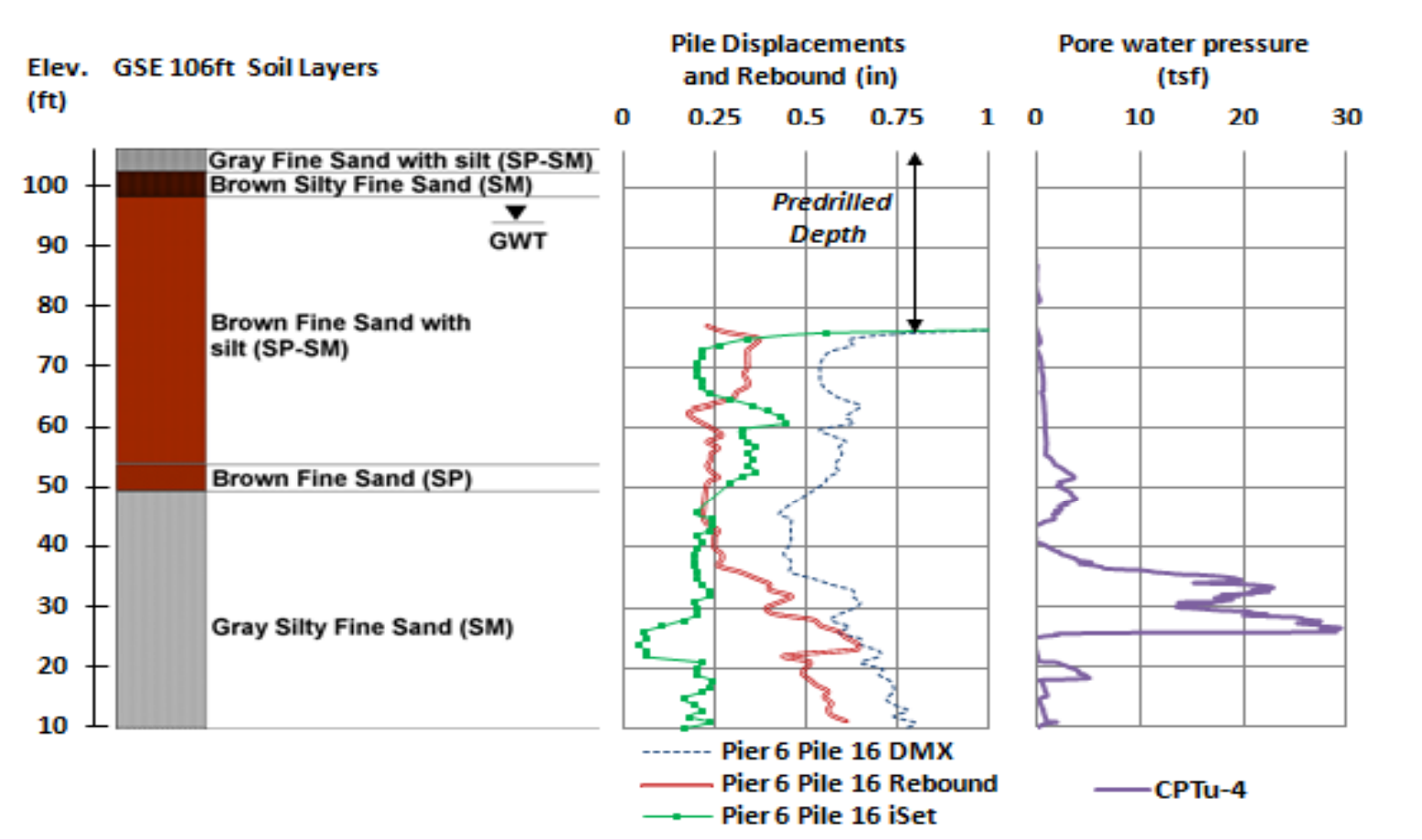


Due to refusal (20 blows/in), several piles did not reach design depth

Site 3 : I-4/US192 (Ramp CA Pier 6)

Rebound = 1" followed by minimal set

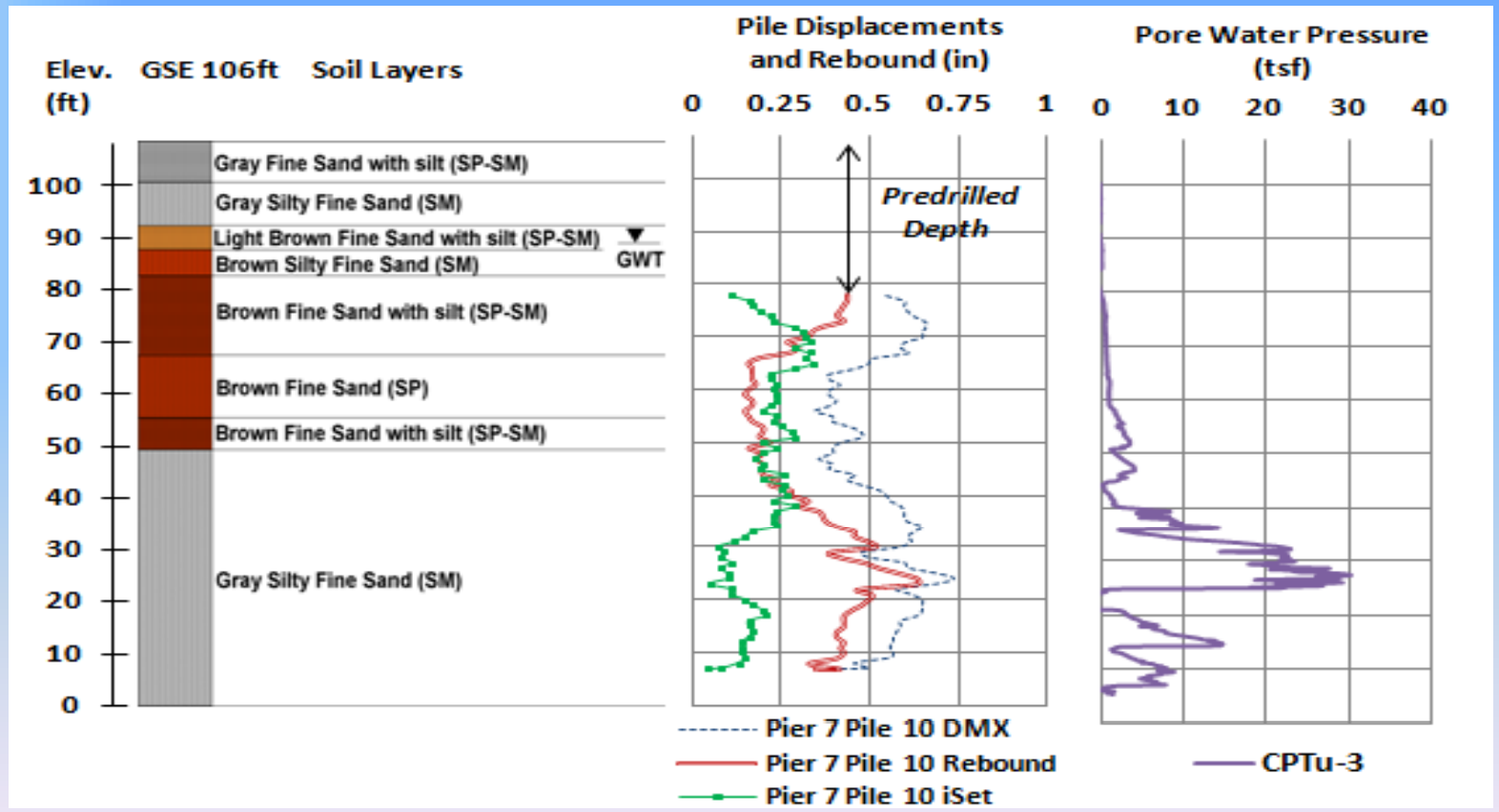
Pile :24" Prestressed Concrete Piles
Hammer : ICE-20 single-acting diesel



Site 3 : I-4/US192 (Ramp CA Pier 7)

Rebound = 0.6" followed by minimal set

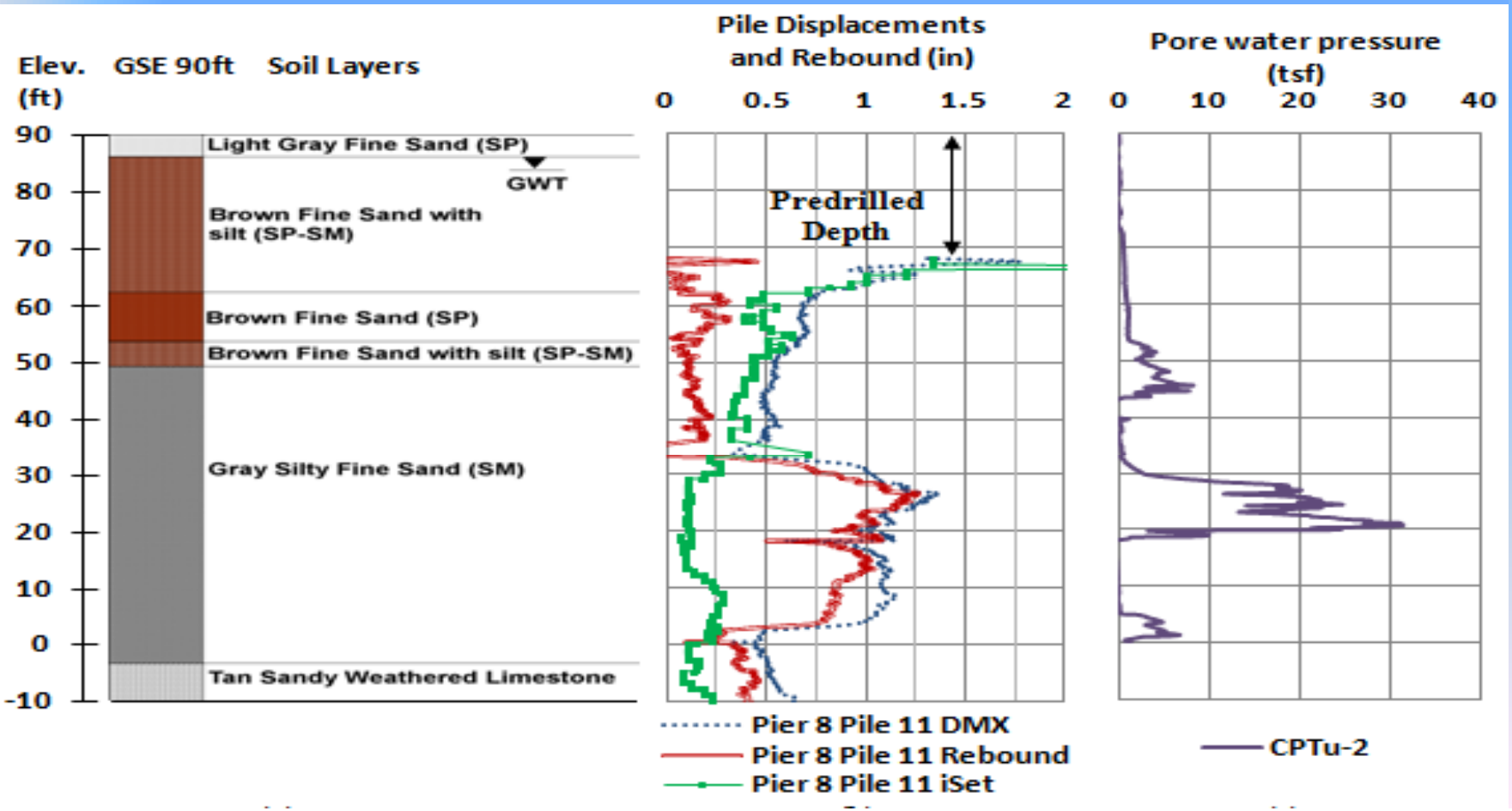
Pile :24" Prestressed Concrete Piles
Hammer : ICE-20 single-acting diesel



Site 3 : I-4/US192 (Ramp CA Pier 8)

Rebound = 1.25" followed by no or minimal set;

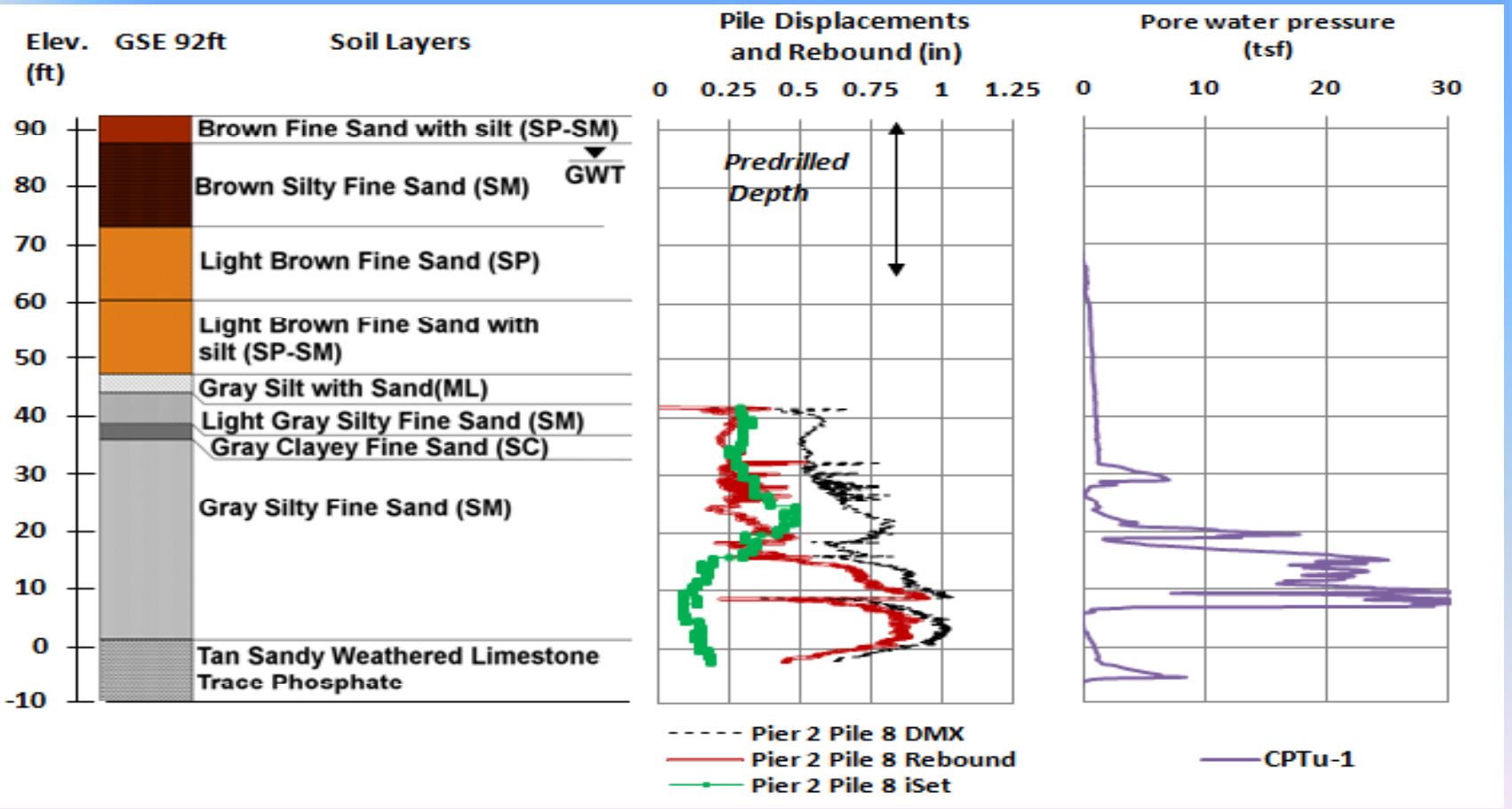
Pile :24" Prestressed Concrete Piles
Hammer : ICE-20 single-acting diesel



Site 4: I-4/ Osceola Parkway (Ramp D2)

Rebound = 0.80" followed by minimal set

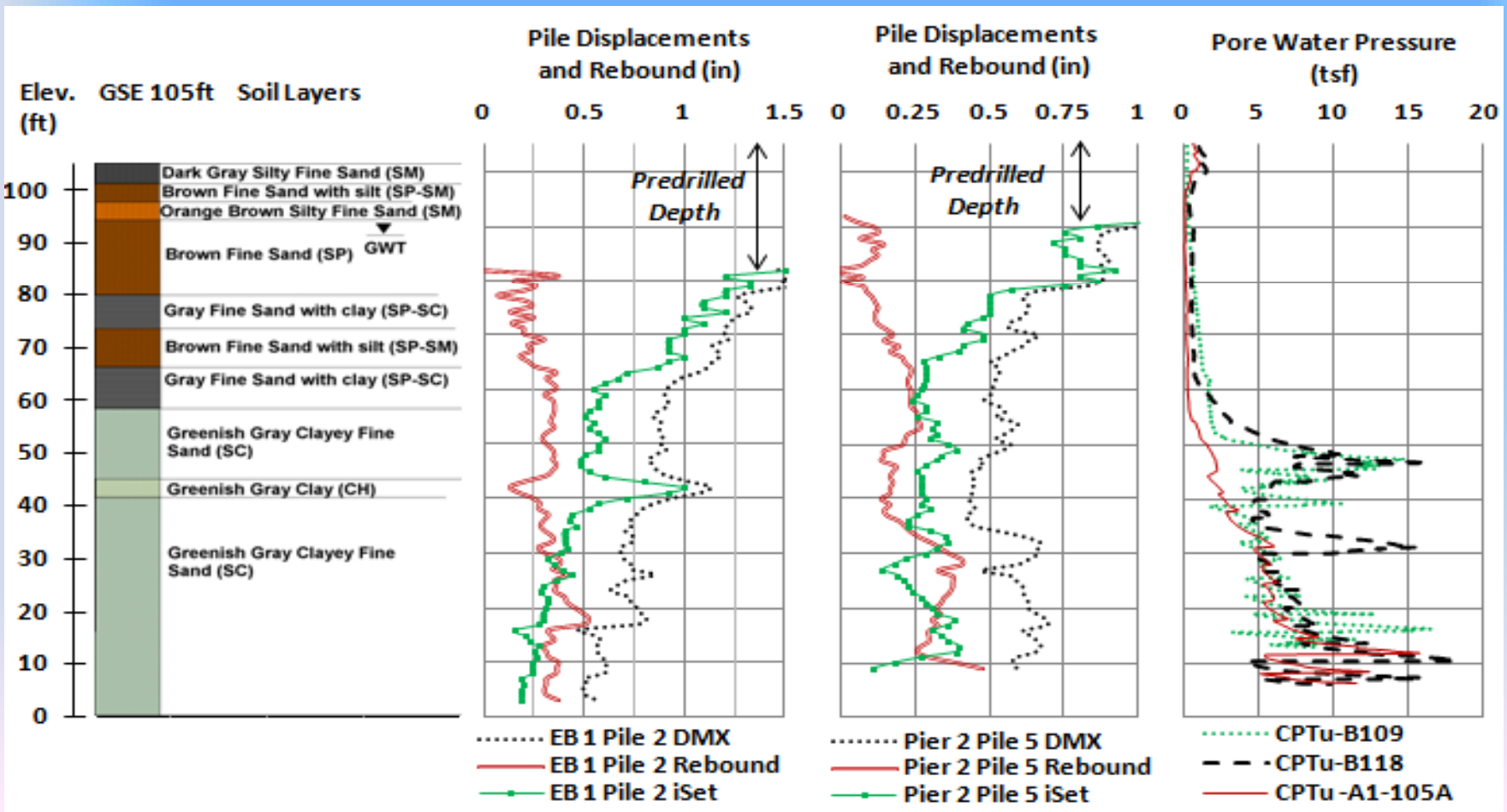
Pile :24" Prestressed Concrete Piles
Hammer : ICE-20 single-acting diesel



Site 5: I-4/SR408 Interchange (Ramp B)

Rebound = 0.3 to 0.5" followed by an acceptable set

Pile :18" Prestressed Concrete Piles
Hammer : D36-32 single-acting diesel

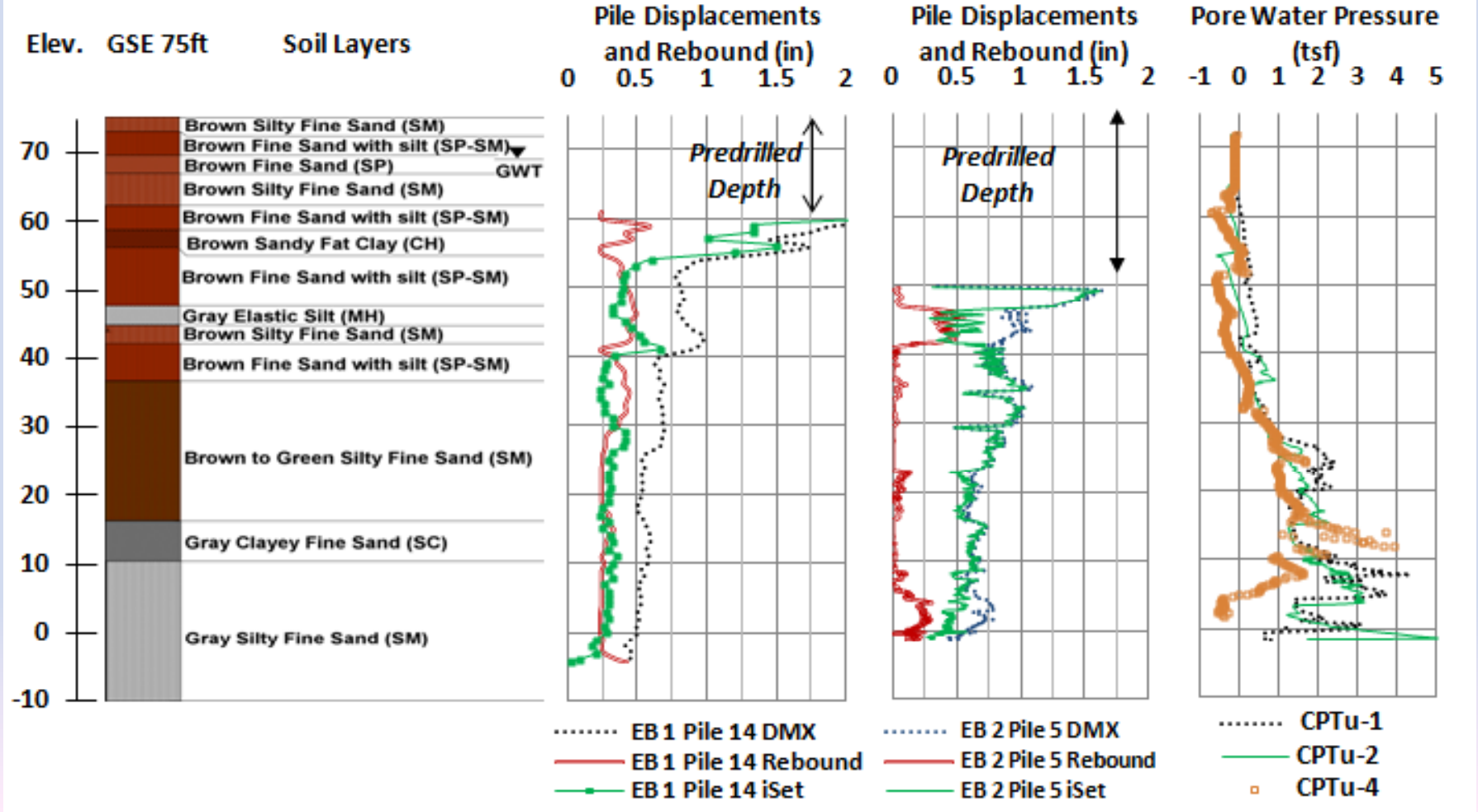


Site 6: I-4/SR417 Interchange

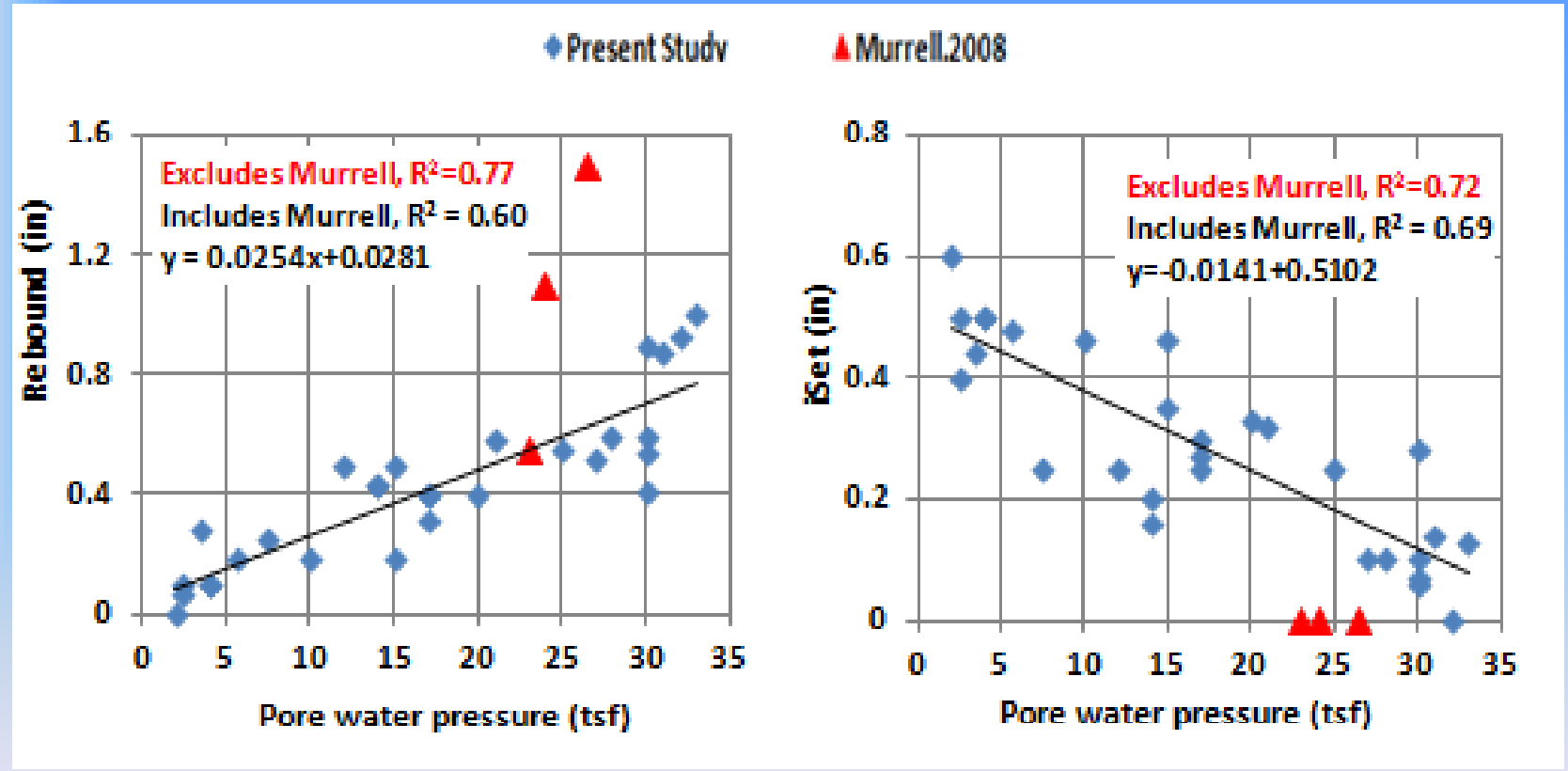
Rebound < 0.25" followed by large undergoing set

Pile :24" Prestressed Concrete Piles

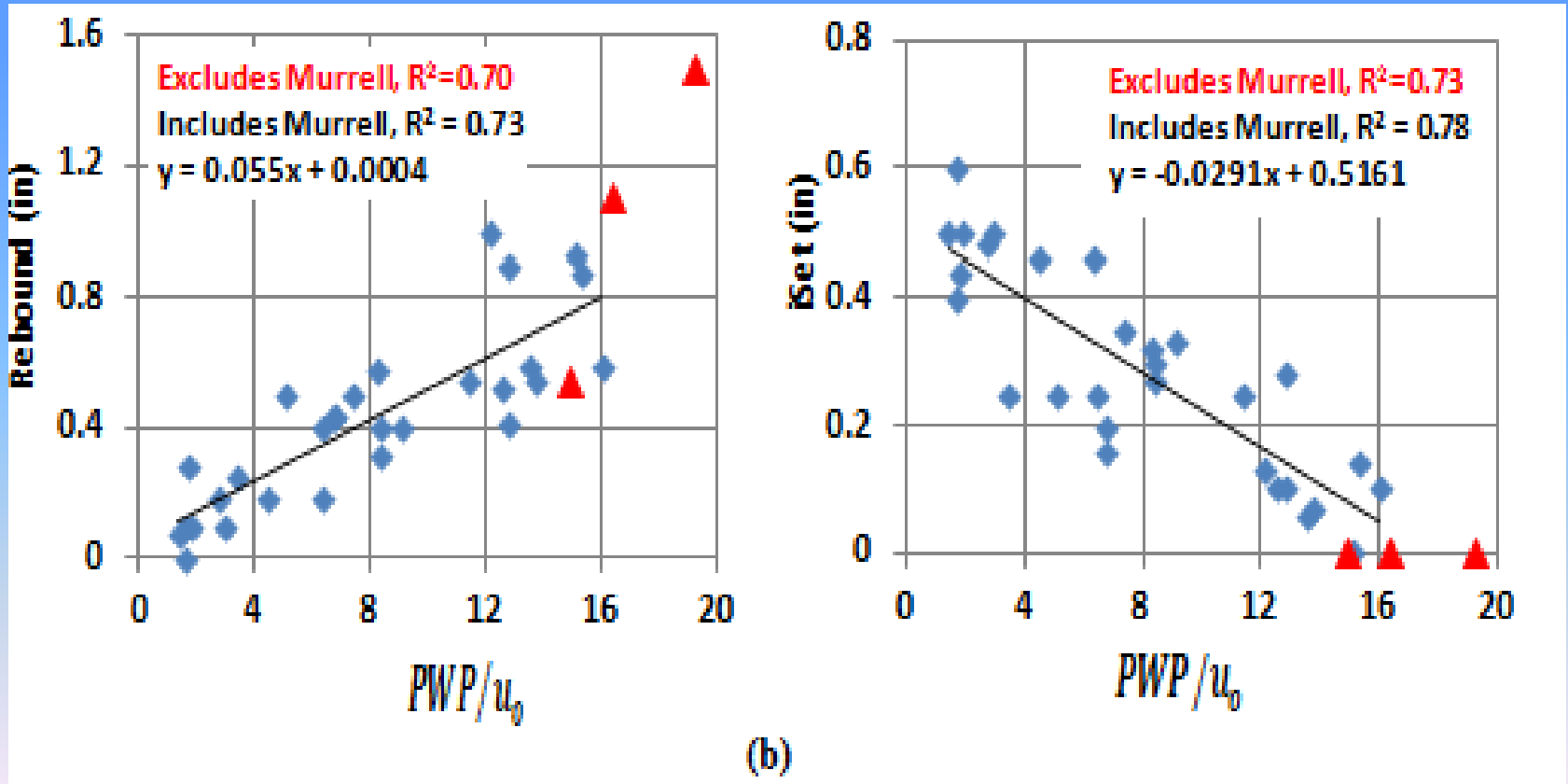
Hammer : APE D46-42 single-acting diesel



Correlations Between Rebound, inspector Set and CPT Pore Water Pressure



Correlations Between Rebound, inspector Set and Ratio of CPTu pore water pressure and hydrostatic pressure



Conclusions

This study shows the following:

- HPR soils: SC, SM-SC, SM, CL, SP-SM, SP-SC and CH;
- The overburden depth at which HPR occurred was typically greater than 50 ft;
- PWP< 5 tsf Produced rebound of less than 0.25 inches;
- PWP> 5 and < 20 tsf Produced rebound between 0.25 and 0.5 inches followed by an acceptable permanent set;
- PWP > 20 tsf produced rebound larger 0.5 inches followed by unacceptable or minimal permanent set.

Recommendations

The CPTu PWP can be used as a tool to predict HPR problems when driving displacement piles through saturated fine silty sand to sandy silt or clayey sand

CPTu PWP	Potential of High Pile Rebound	Permanent set
< 5 tsf	Not expected	Large enough
> 5 tsf and < 20 tsf	May occur	Acceptable
> 20 tsf	Will occur	No or Minimal

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Thank you

Questions?