Goble Pile Check versus the Pile Driving Analyzer

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Goble Pile Check

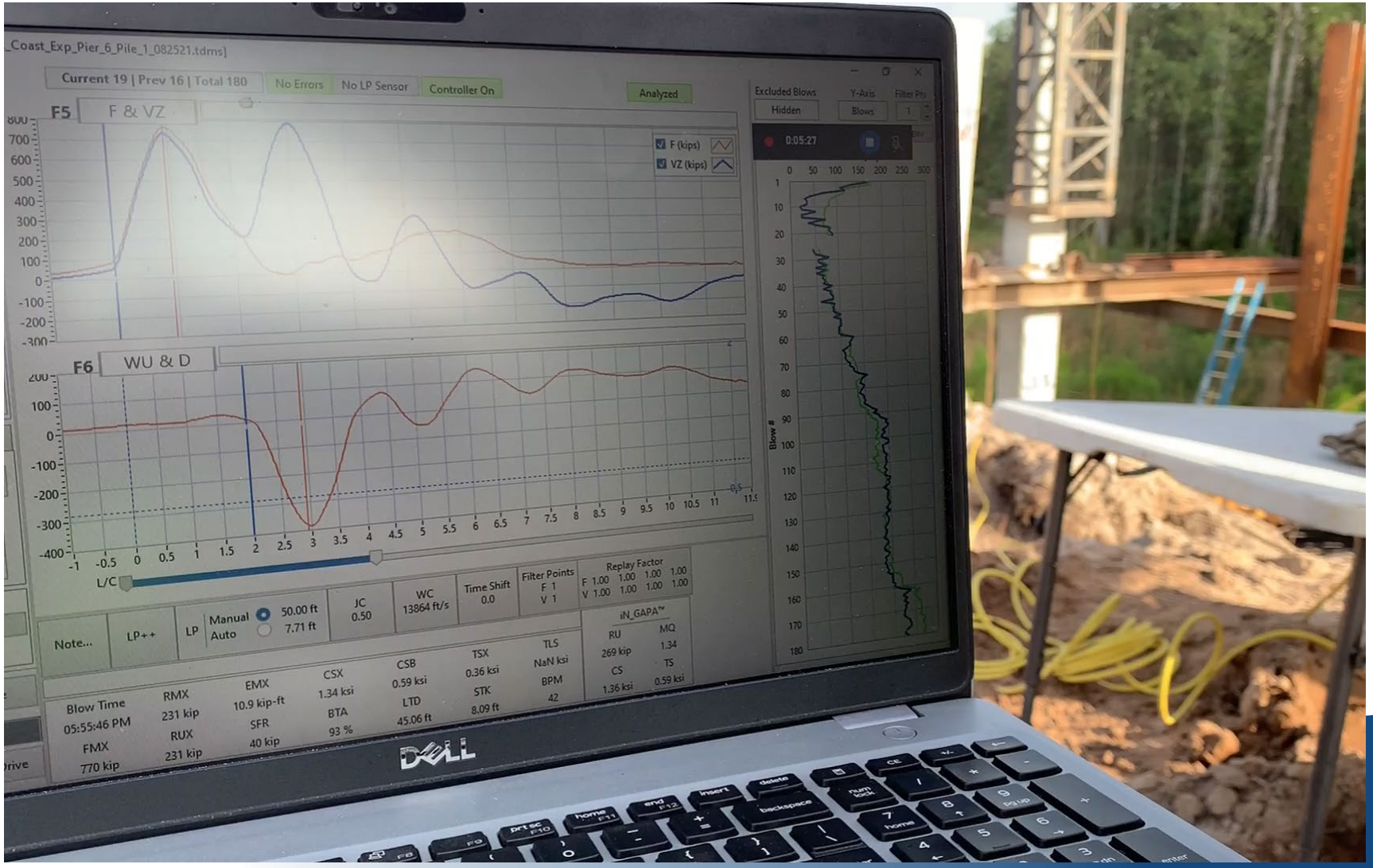
Dynamic Load Testing (DLT) Background

- Goble Pile Check (GPC) and Pile Driving Analyzer (PDA) both follow ASTM D4945.
- 2 to 4 set of gauges (near pile top)
- Gauges are externally mounted
- Gauges are reusable

Video:

Dynamic Load Testing (DLT) Background

Example video



CASE STUDY PROJECTS

- Numerous projects were carried out with both PDA and GPC instrumentations
- Different pile sizes:
  6-in (in Asia), 10-in and 14-in (condominium buildings),
  18-in, 24-in (bridges).
- Different hammer types: Drop, hydraulic, or diesel hammers

DATA COMPARISONS

- Raw data comparisons:

  Raw data are strain ε and acceleration a.

  However: $F = \varepsilon A E$

  $E = \rho W_S^2$

  $V = \int a dt$

  $VZ = V * E A / W_S$

Therefore, instead of comparing ε and a between the 2 systems, we can compare F and VZ, provided that A, E, W_S and ρ have identical parameter entries between the 2 systems.

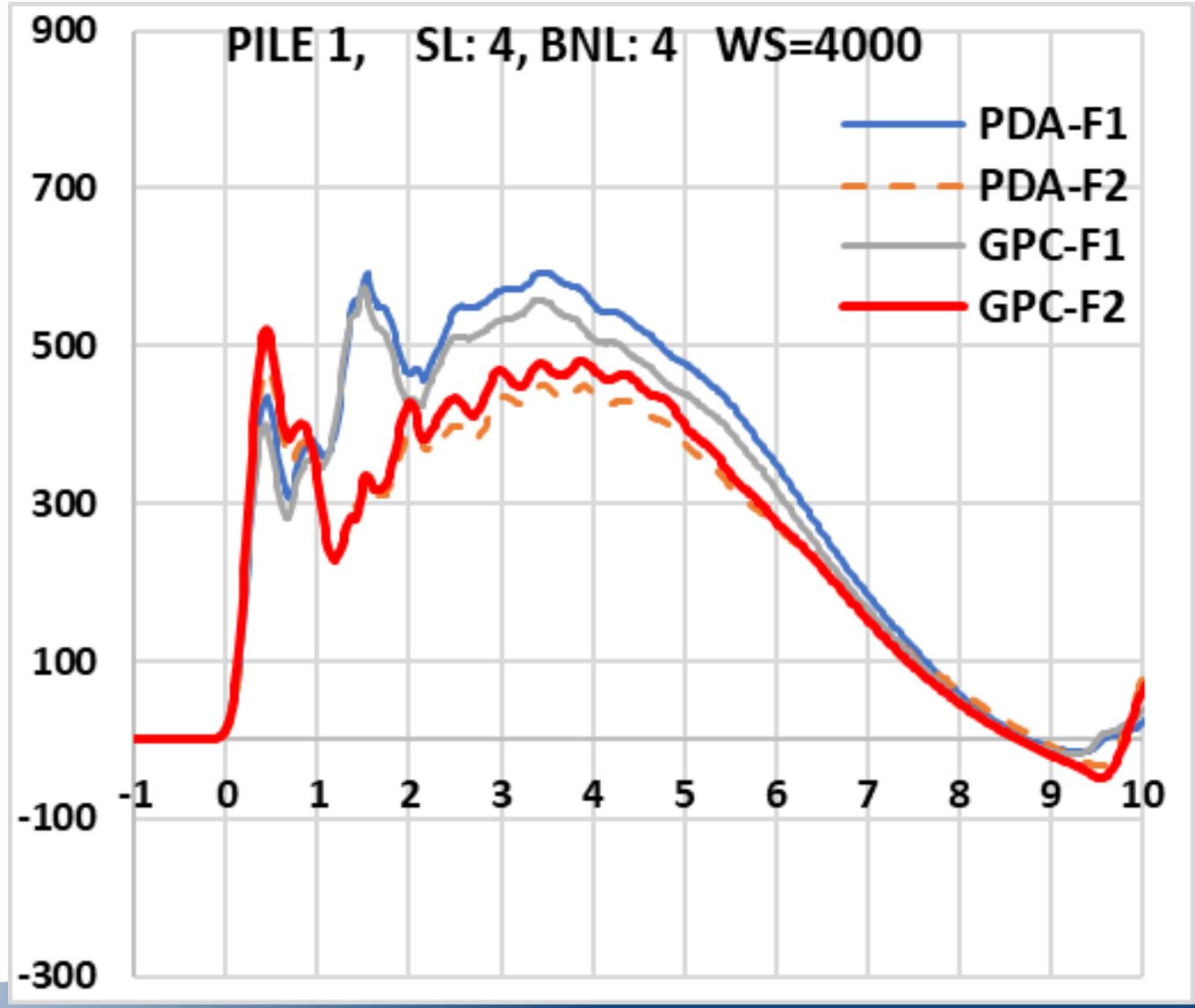
Force Trace Comparison

- Individual forces can vary slightly, especially sensors are mounted far from each other
- Example:
  - PDA gauges mounted approx. 1-inch from GPC gauges (i.e., very near each other)
  - PDA F1 slightly different than GPC F1
  - PDA F2 slightly different than GPC F2

- Note: Make sure to use same WS, A, E between 2 systems.

  Reason: $F = \varepsilon A E$

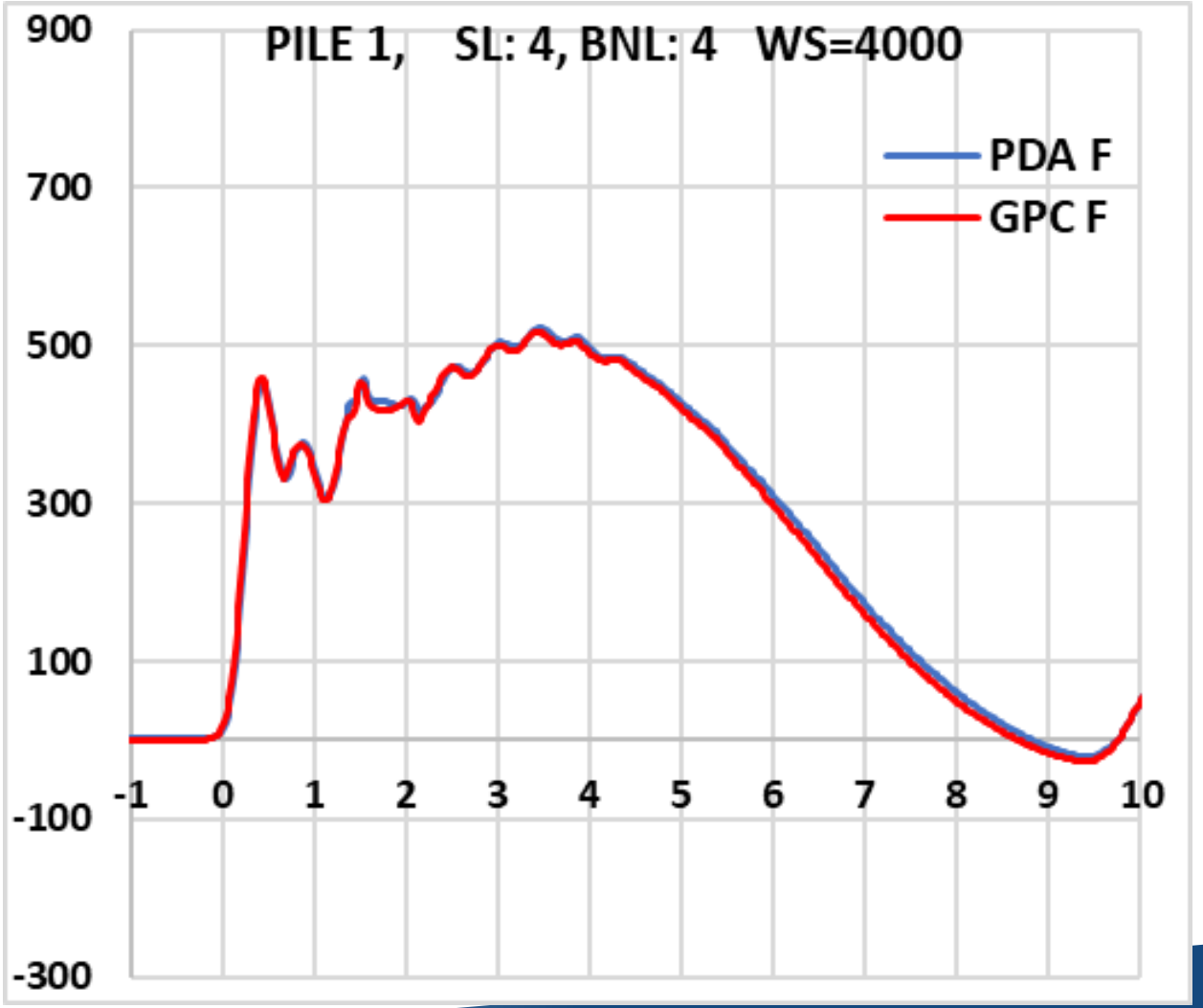
  $E = \rho WS^2$



Force Trace Comparison

- Despite bending force, the average forces are similar:
  PDA F = GPC F
  with $F = (F_1 + F_2) / 2$

  particularly when GPC and PDA were mounted near each other.



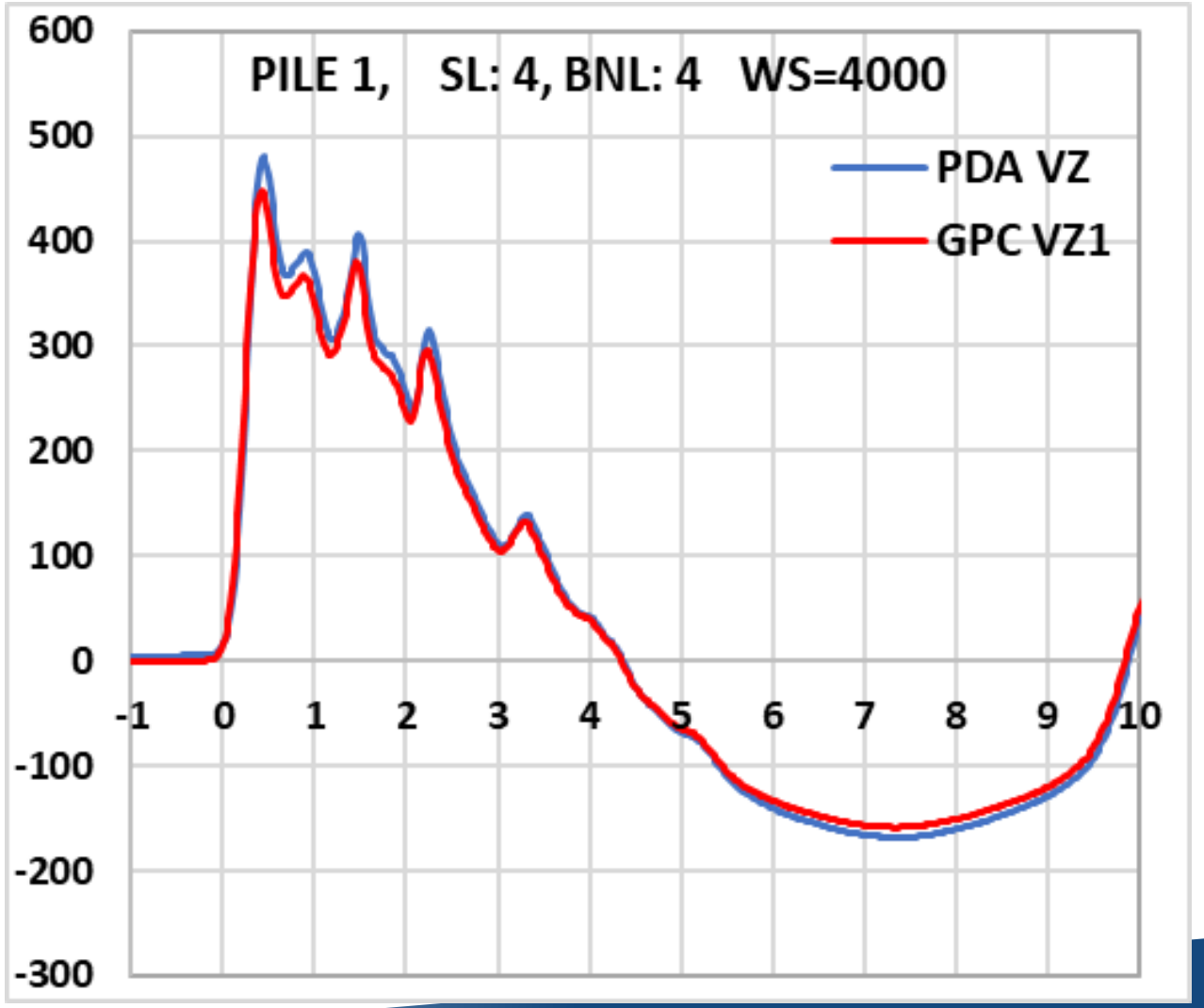
Velocity Trace Comparison

In this example:

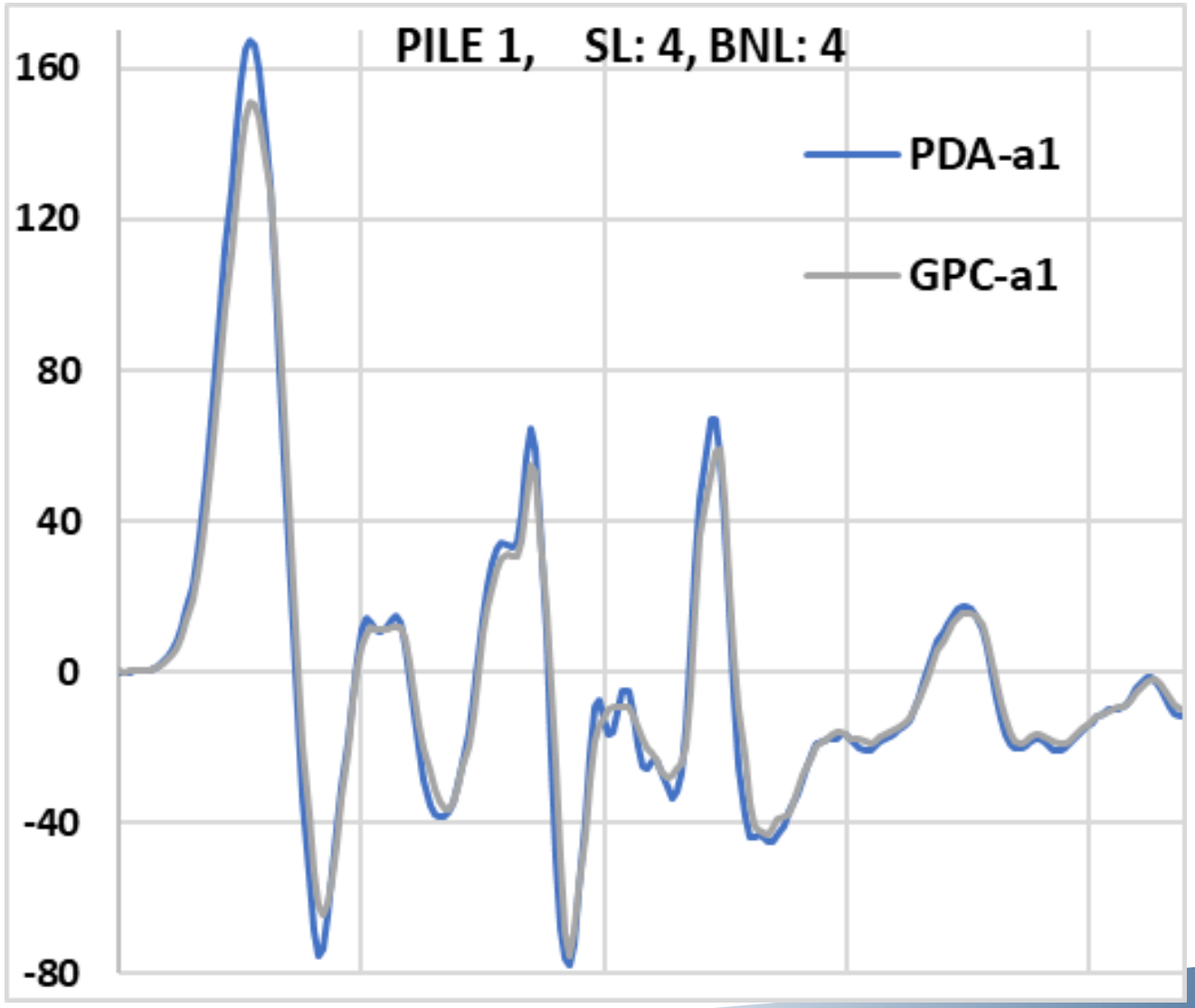
- The velocity traces differ somewhat between the 2 systems at the time of maximum velocity (VMX)
- Then velocities are essentially the same

Notes:

Both systems use PR accelerometers.



Acceleration (g) Comparison

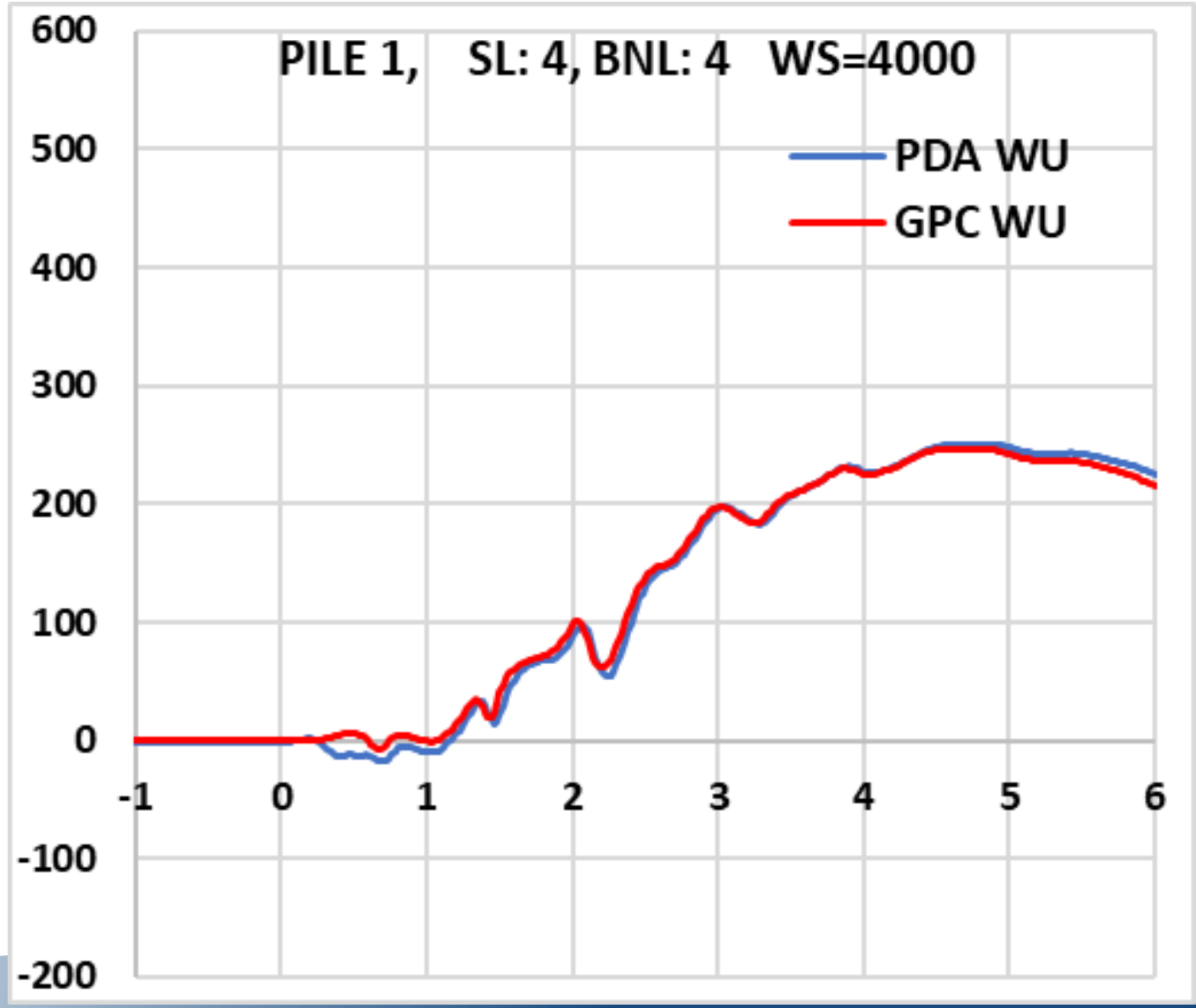


Both system use PR accelerometers.

UpWave Traces

- UpWave traces are nearly identical: WU = (F – VZ) / 2
- CASE method capacity as well as signal matching capacity are based on the UpWave traces.

  Therefore, it can be expected that capacities are similar when UpWave traces are similar

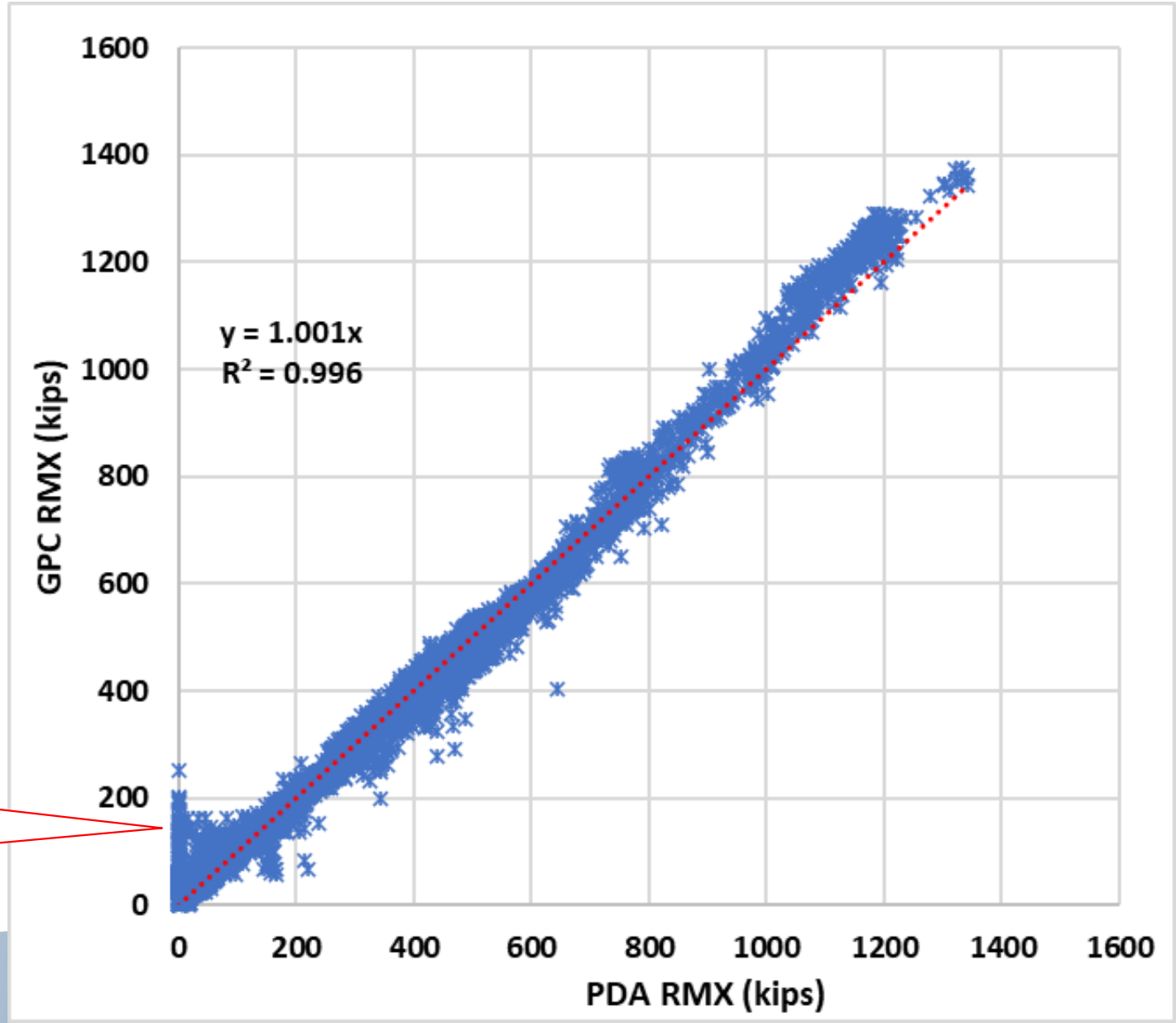


Max CASE method comparison

- CASE method results generally agree between 2 systems:

  R^2 near 1
  (note: statistical population is large)

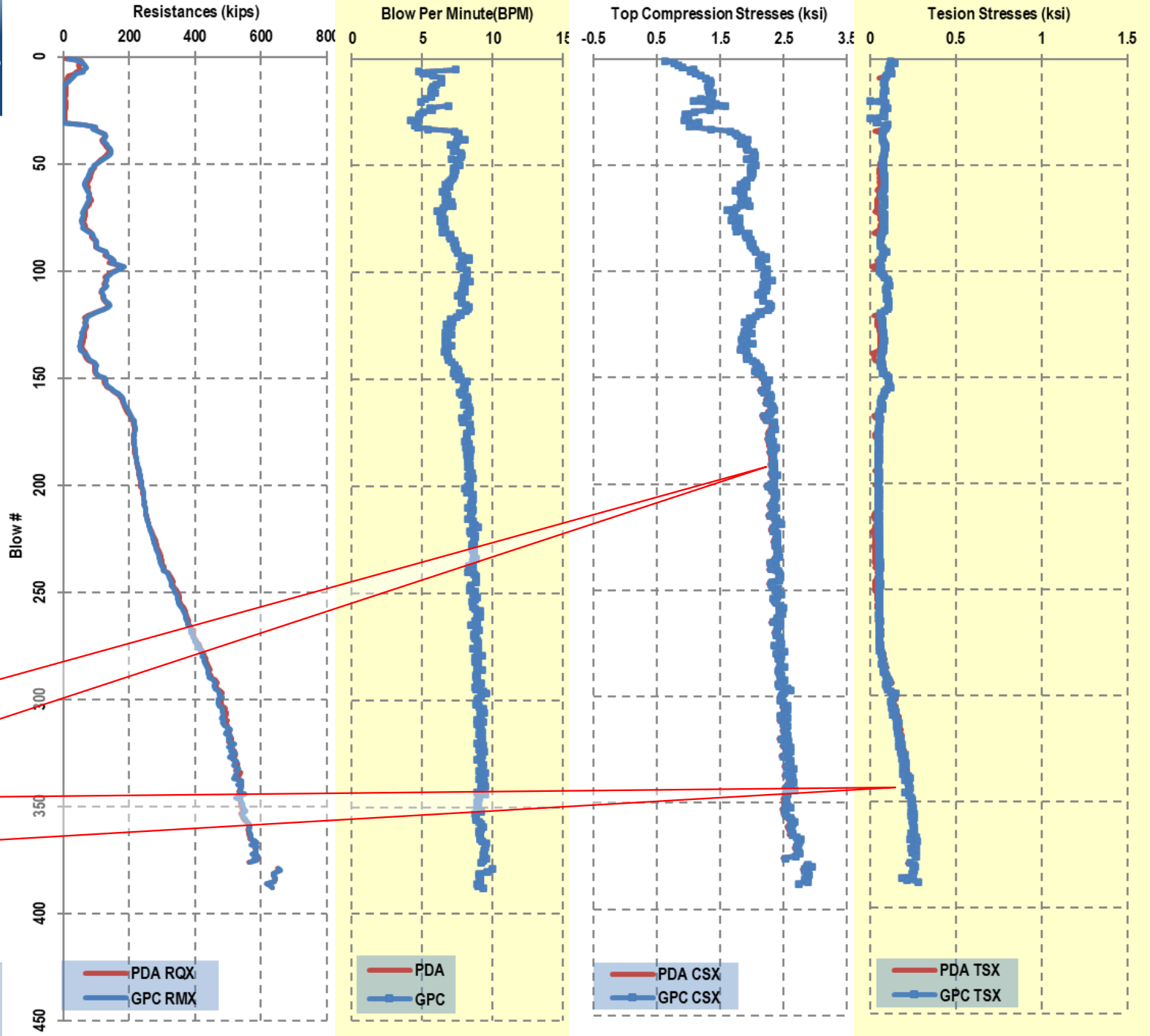
But large difference when PDA RMX =0



Example 1: CASE method results

- Typically, near identical results between 2 systems.
- Example: Dolphin Condo, Test #2

CASE method stresses agree between 2 systems

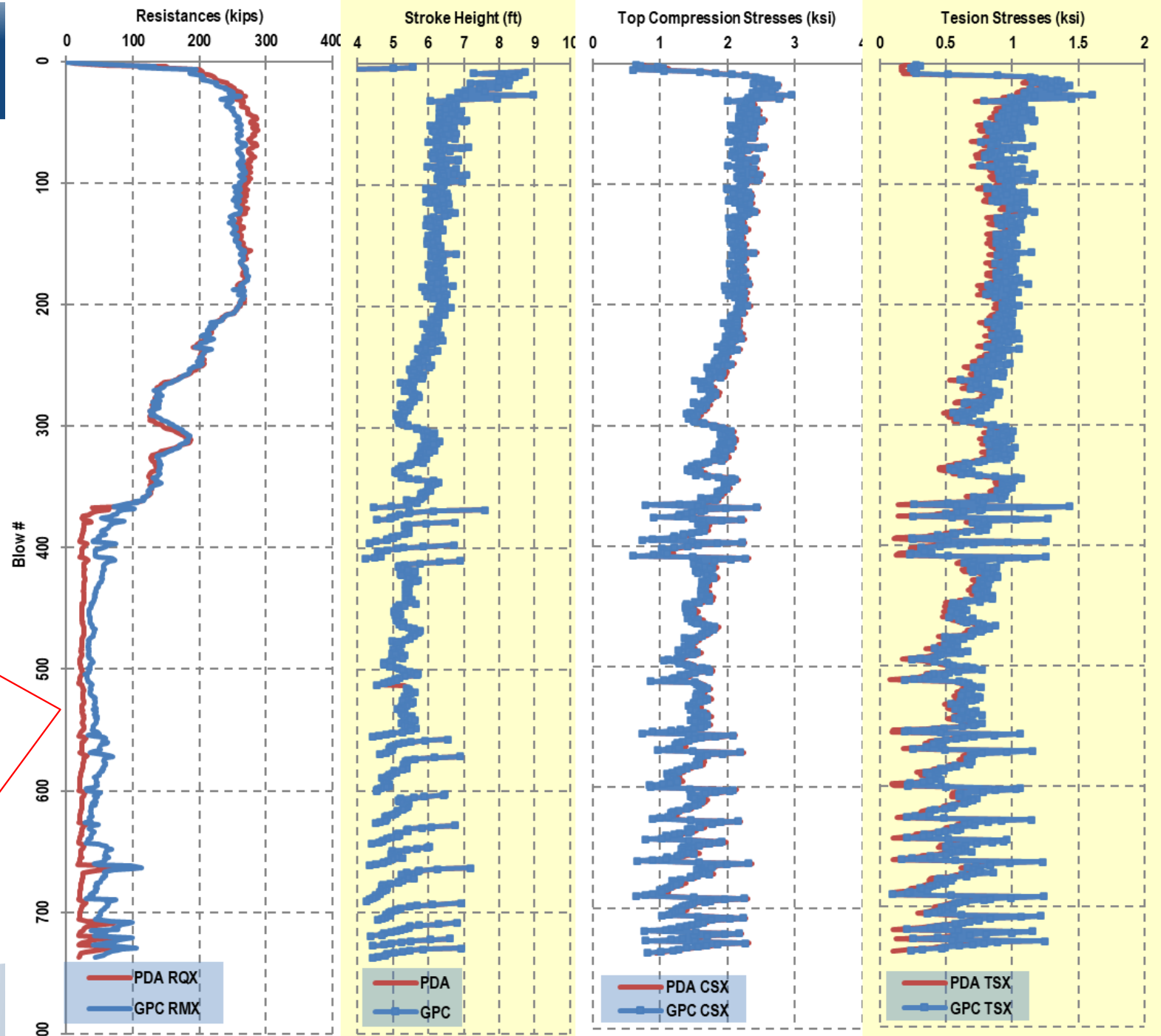


Example 2 - CASE method results

However, Max CASE method results do differ significantly when driving in soft (low resistance) soils. This is due to differing in engineering judgement of the programmers.

However, low resistance capacities are not typically applicable to pile acceptance.

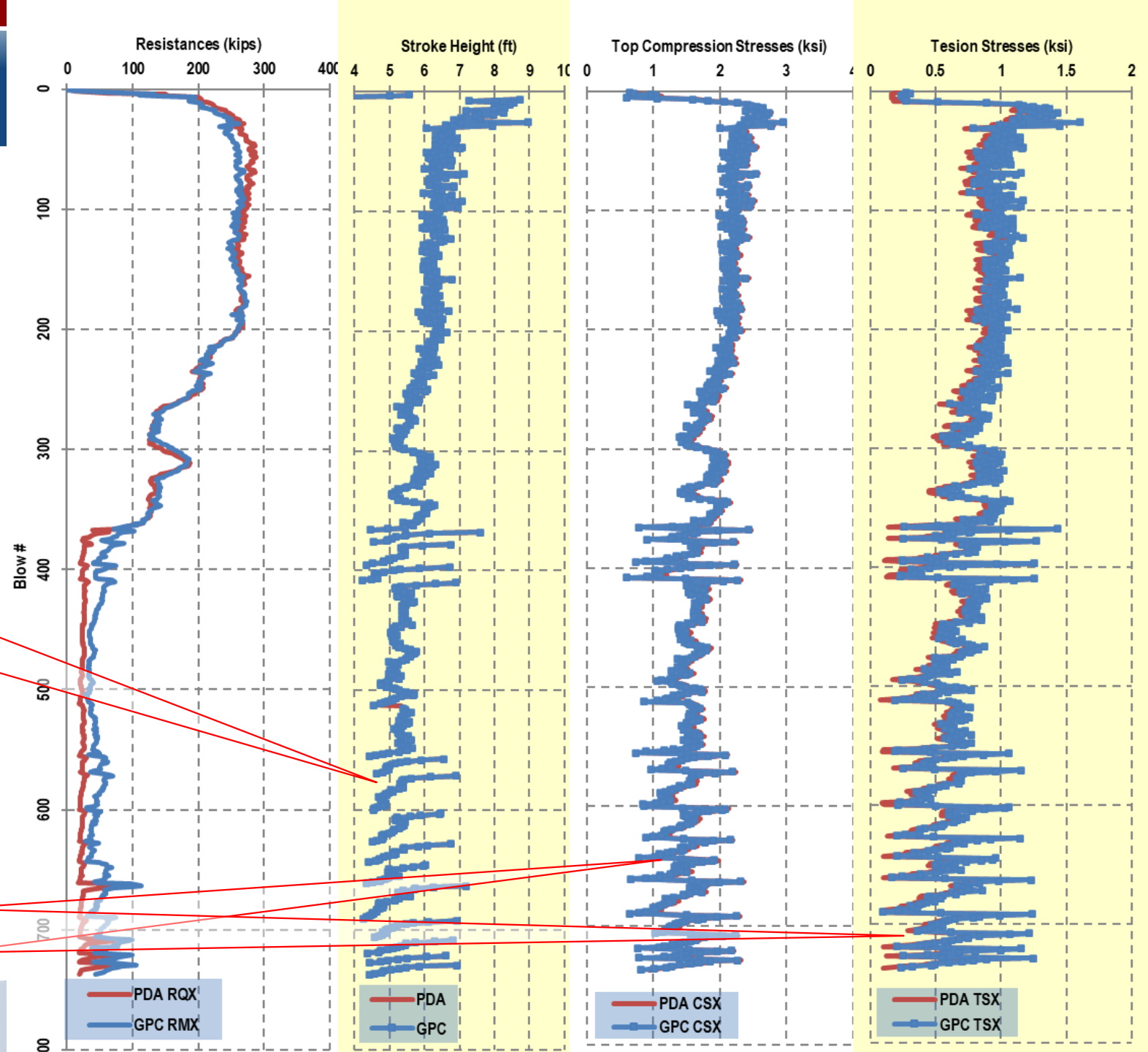
Example: OIA Pile 4 (before splicing)



CASE method results

Hammer stalled many times (stroke height dropped below 4.5 ft or 5 ft and not operational

CASE method stresses agree between 2 systems



Max CASE method results in soft (low resistance) soils

Other than the bullets here, a detailed discussion is not part of this presentation. However, please ask any questions during Q&A or during presentation break periods if there is interest:

- Per definition: The Max CASE (RMX) method searches for the maximum resistance during the entire blow, and thus overcomes some of the limitations of the RSP method…"
- GPC programmers apply that definition.
- PDA programmers however apply the search for only 50 ms to be conservative. This creates the following situations:

  Blow #1 at 6:01:41pm, RMX=152 kips (EMX=32 k-ft, STK=0 as this is starting blow)

  Blow #1 mobilized right before 50 ms

  Blow #2 at 6:01:42pm, RMX=0 kips (EMX=63 k-ft, STK=8.75-ft)

  Blow #2 (under more energy) was experiencing larger quake and was mobilizing resistance after 50 ms.

  Thus, the RMX search produced RMX = 0.
- To alleviate RMX = 0, PDA has a "hybrid" parameter, called RQX:

  RQX = Max (RMX within 50 ms from impact, ½ of Energy Method Capacity Q_{BC})

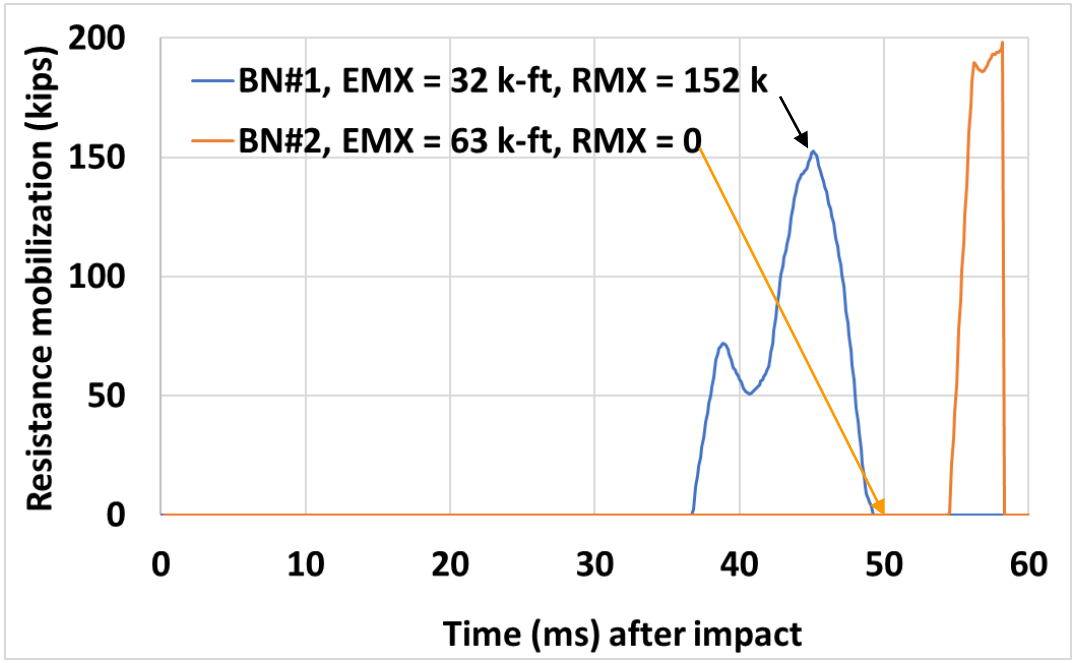
  Q_{BC} = Capacity per Energy Method

There are two reasons for GPC programmers to stick to the RMX definition:

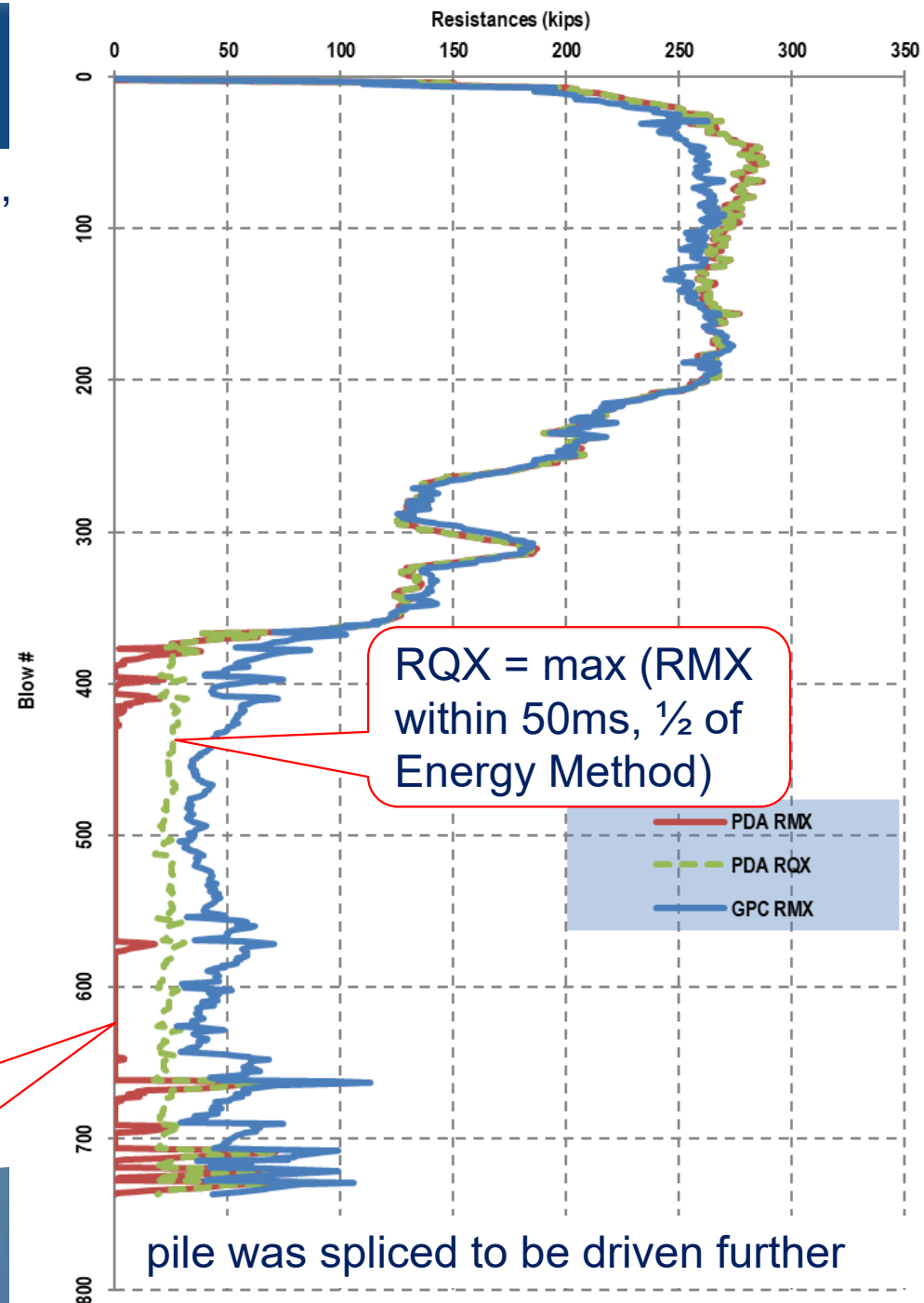
1) Low resistance is not to be used anyway for pile acceptance.

Max CASE method results in soft (low) resistance

- Similarly, presentation timeslot does not afford a detailed discussion, please feel free to clear/ answer in break-time if still interested:



RMX within 50ms from impact
will stays at 0 most of the time in soft driving.
Once in a while, it hops up when resistance
was mobilized before 50 ms



Max CASE method results in soft (low resistance) soils

- Anyway, this difference has no significant meaning. Both PDA and GPC users are not using max CASE method resistances in soft soils to accept piles.
- Author only want to shows the reason why there is a gap between PDA and GPC on this non-importance result.

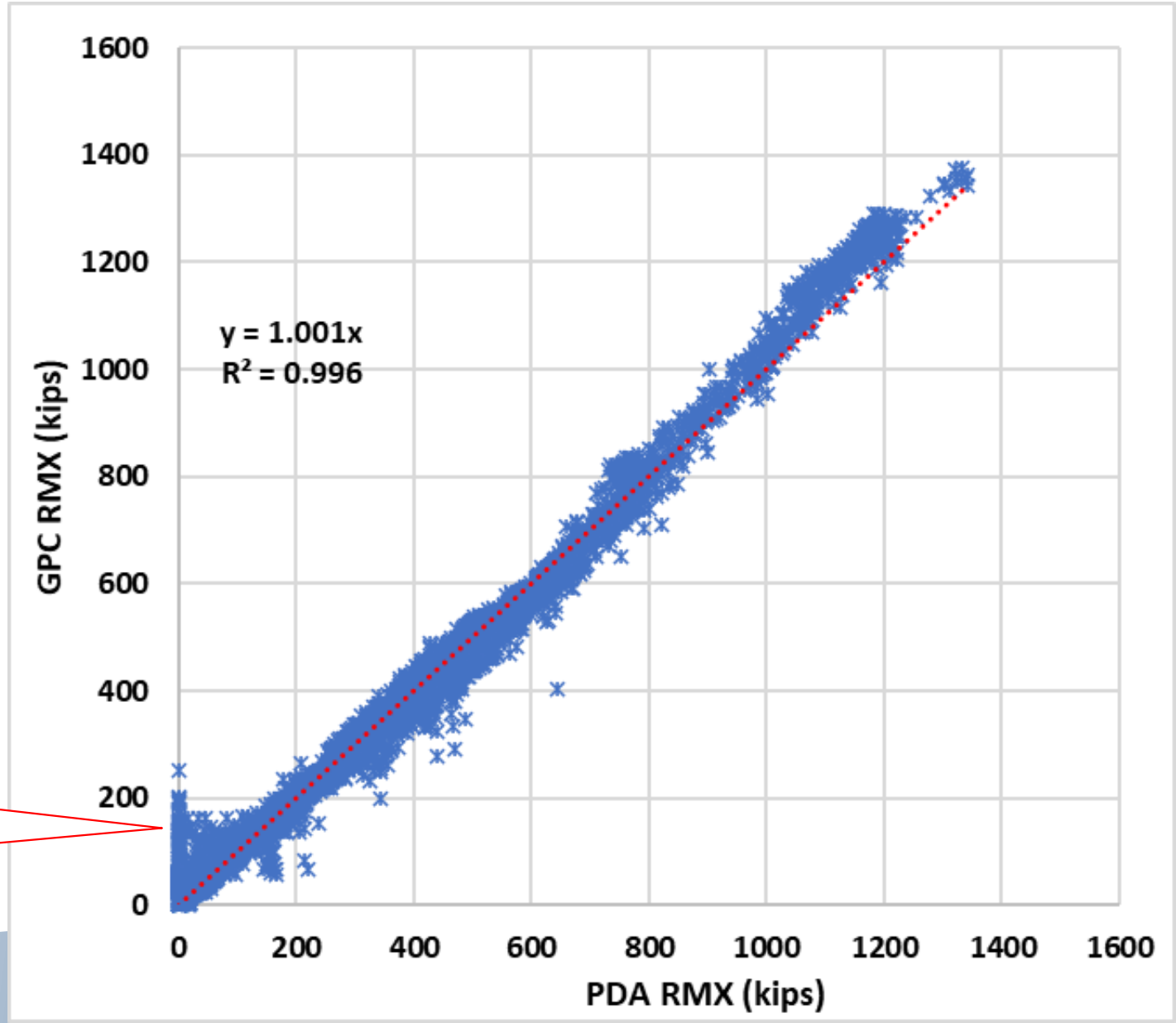
Max CASE method comparison

REPEAT SLIDE (Summary):

- CASE method results generally agree between 2 systems.

  R^2 near 1
  (statistical population is large)

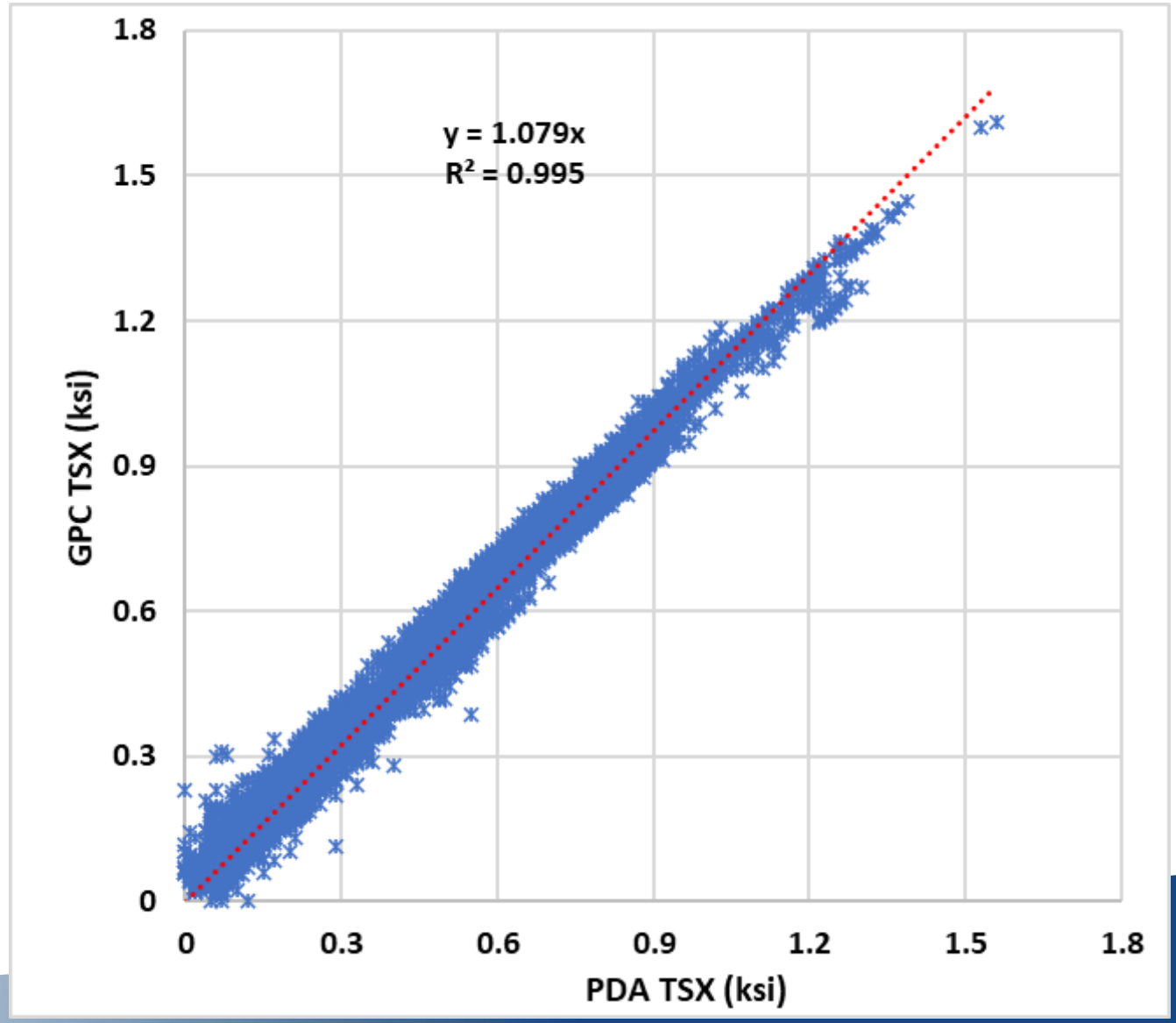
PDA RMX =0



CASE method comparison

- Pile estimated stresses generally agree between 2 systems.

  R^2 near 1
  (statistical population is large)

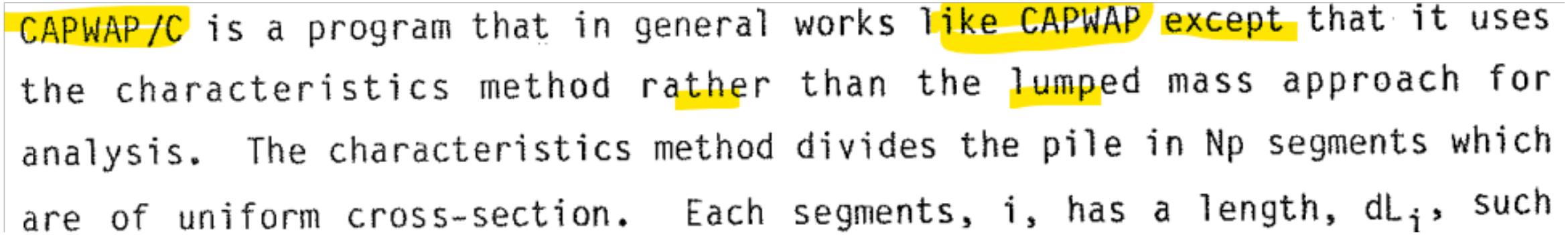


Signal Matching Analyses

PDA system: use CAPWAP.

- Original model: **Lumped Mass Approach.**
- Since 1983: **Method of Characteristics:**
  Pile modeled as a series of continuous uniform sections (characteristics model).
  Revised program was initially called CAPWAP/C (C for Characteristics)
  Eventually, Method of Characteristics stay, but the name is simplified back to CAPWAP.

  Ref: CAPWAP Analysis using the Characteristics Approach, Frank Rausche, 1983:



CAPWAP/C is a program that in general works like CAPWAP except that it uses the characteristics method rather than the lumped mass approach for analysis. The characteristics method divides the pile in Np segments which are of uniform cross-section. Each segments, i, has a length, dL_i, such

Prior to that, **Method of Characteristics** was implemented in TNO-Wave (TNO, the Netherland) (1978)

Signal Matching Analyses

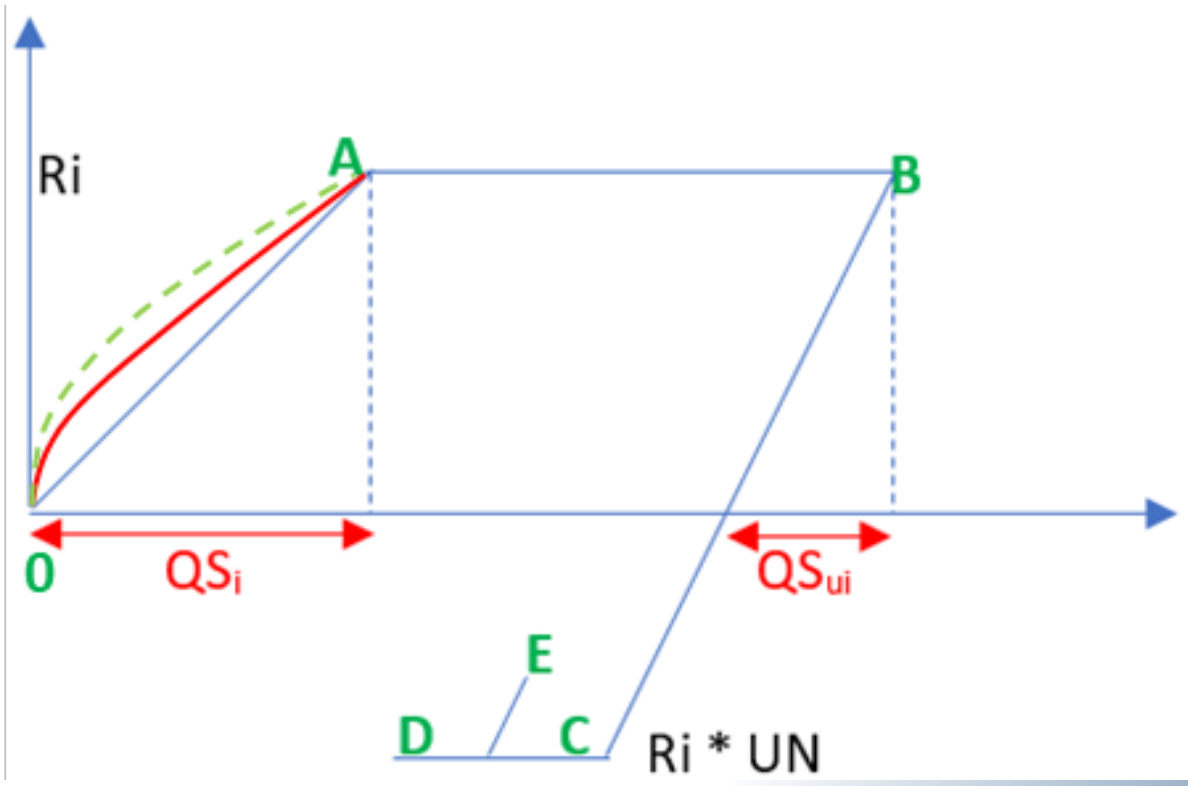
GPC system: use N_GAPA

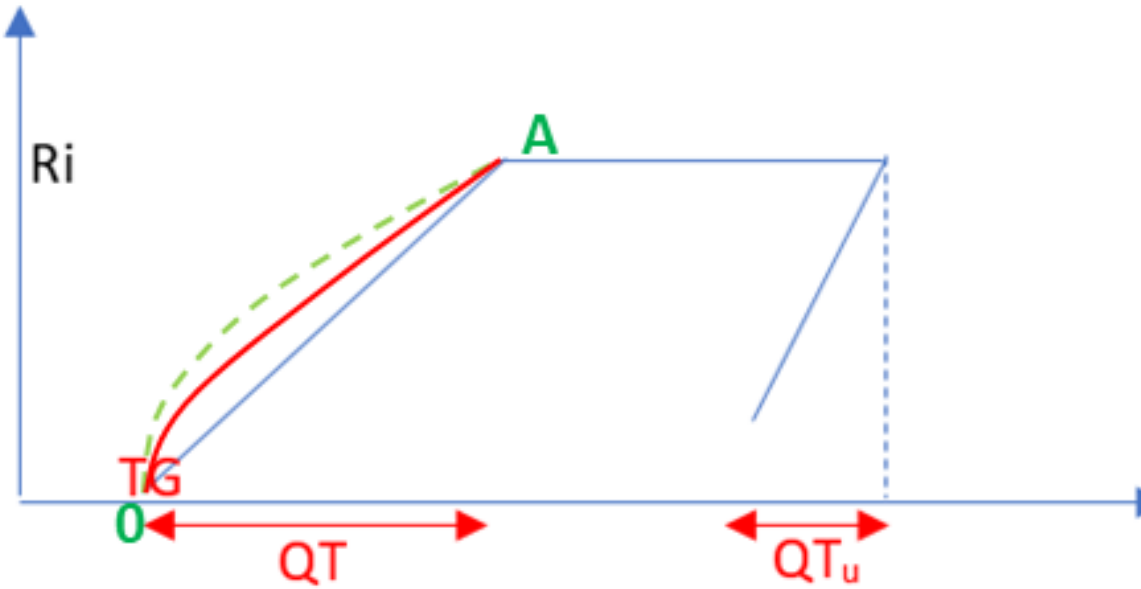
Use the same **Method of Characteristics,** as with other signal matching programs.

Use the same resistance models, as with CAPWAP.

Basic models:

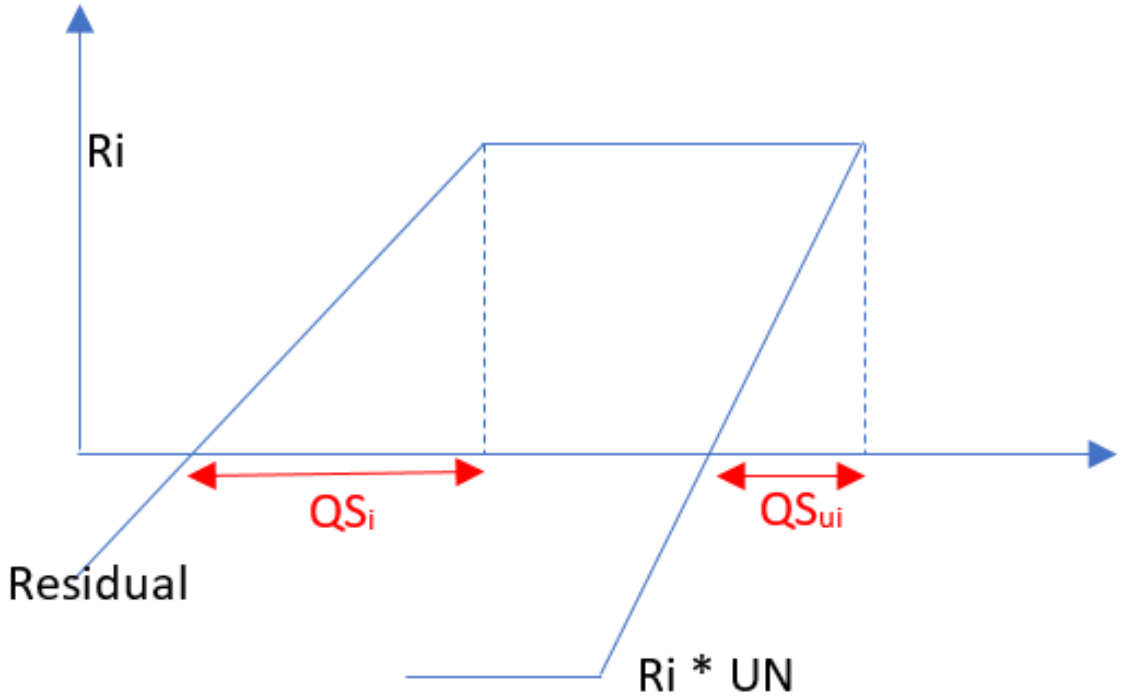
Static Soil Behavior Model (Spring)

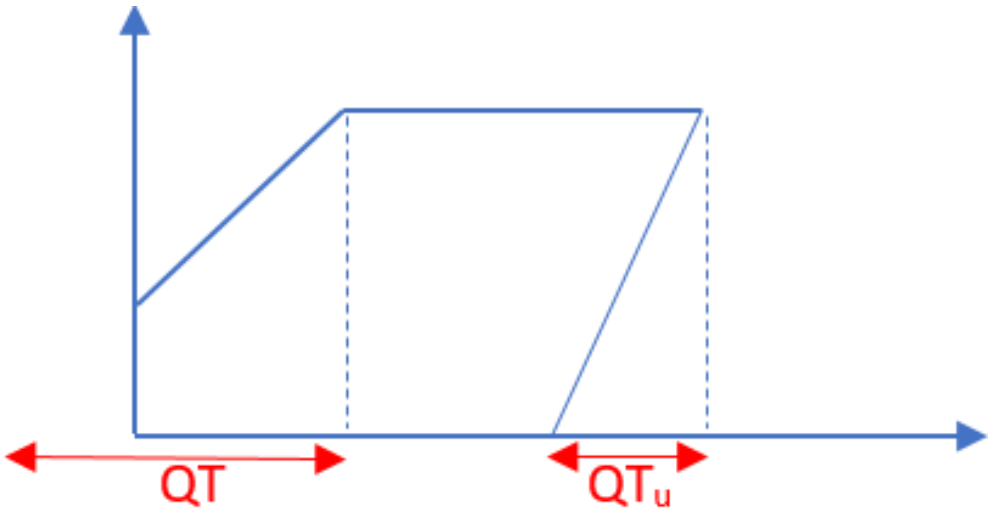




Signal Matching Analyses

Static Soil Behavior Model, Residual Stress Analysis





Signal Matching Analyses

Dynamic Soil Behavior Model
(Damping Dashpot)

J_{CASE} (dimensionless) – Case Damping

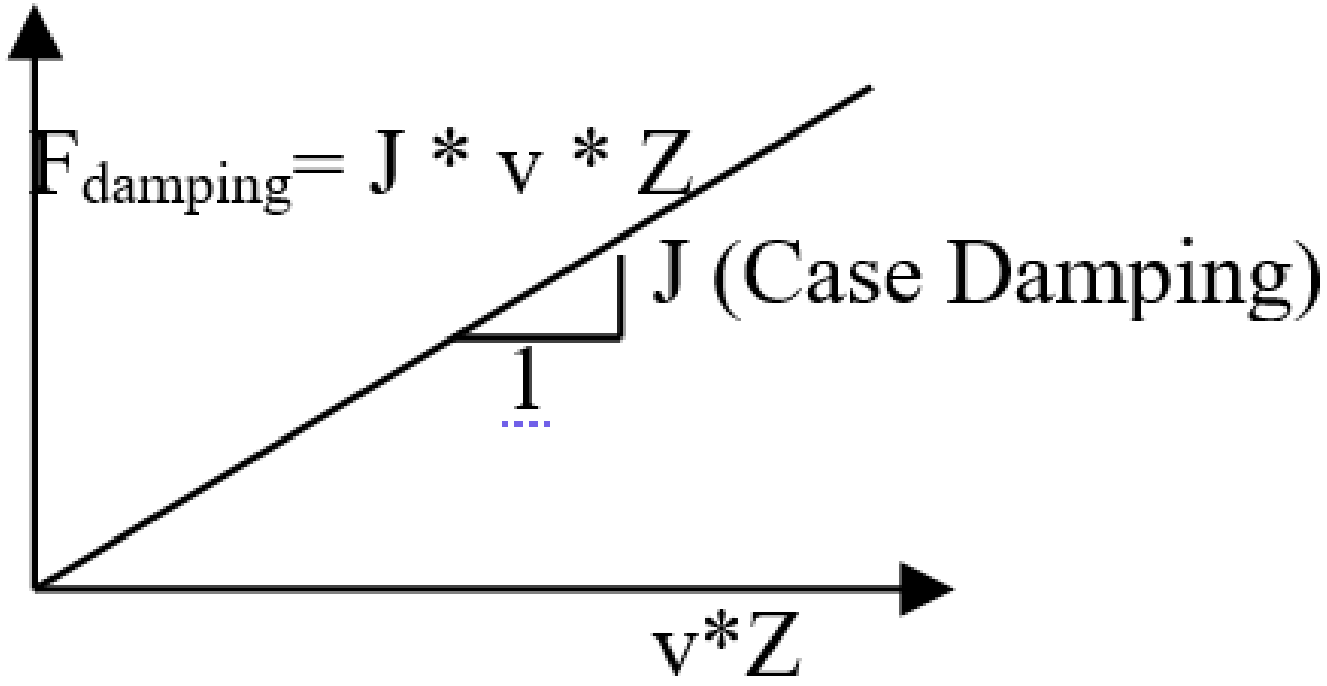
Smith Damping:

S_S (s/ft) = J_S Z / R_S

S_T (s/ft) = J_T Z / R_T

$_S$ subscript is for shaft element

$_T$ subscript is for toe element



Signal Matching Analyses

Good agreement between the 2 signal matching programs

Type	Pile	CAPWAP	N_GAPA	**Difference**
H Pile	240-ft	492.7	497.0	0.87%
H Pile	24.1-ft	366.5	362.0	-1.23%
H Pile	24.5-ft	356.9	357.0	0.03%
Concrete	large QT	463.8	459.0	-1.03%
Concrete	long rise time	983	981.0	-0.20%
Concrete		909.9	910.0	0.01%
Stinger	Stinger pile	1388.4	1338.0	-0.37%
H Pile	41-ft	323.2	323.0	-0.06%
H Pile	107-ft	435.3	446.0	2.46%
Concrete	56.5-ft	1360.3	1343.0	-1.27%
Concrete	gradual rise	312.1	315.0	0.93%
Becker	BPT	99.9	98.0	-1.90%
Pipe pile	115-ft	874.5	872.0	-0.29%
Pipe pile	153.7-ft	1038.1	1029.0	-0.88%
Concrete	End Bearing	1950.8	1939.0	-0.60%
Augercast	140-ft; D=36-in	2391.8	2387.0	-0.20%
Augercast	140-ft; D=36-in	2229.3	2236.0	0.30%
H Pile	End Bearing	835.4	863.0	3.30%
	Average	931.6	931.0	-0.01%

Summary

- GPC & PDA both follow ASTM D4945.
- Both use the same type of instrumentations (Full Bridge Strain Gauges and Piezo Resistive Accelerometer)
- Gauges are both externally mounted (reusable).
- CASE method results and signal matching results agree with each other.

Thank you !

Questions ?