EDC Phase II - LRFD Resistance Factors

FDOT BDV31 977-13

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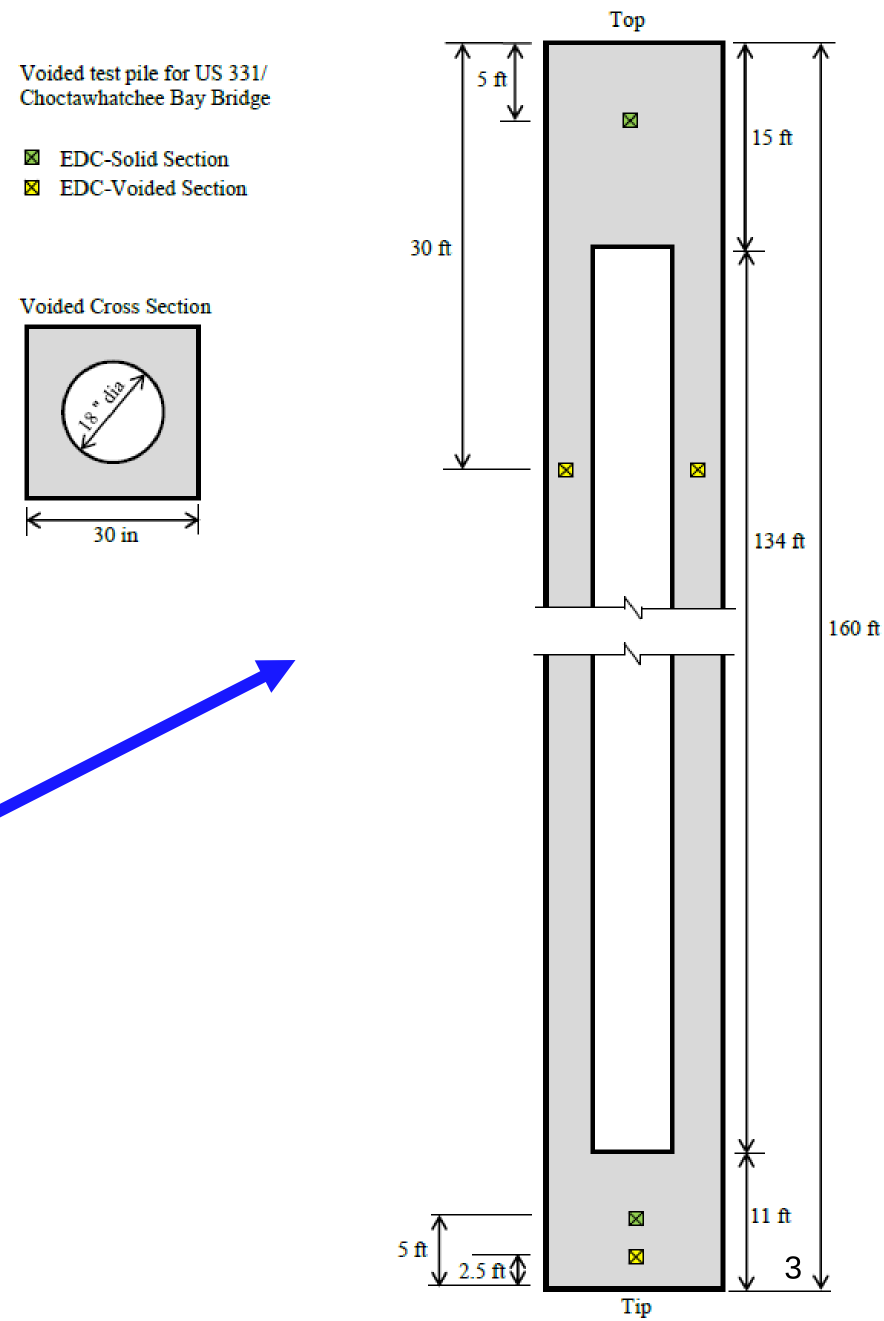
Scope of Work

- Task 1 – Test piles (5) at Choctawhatchee Bay bridge
  - EDC install
  - EDC monitoring during install
  - EDC measurements during static load tests
- Task 2 – Analysis and comparisons
  - UF method (SP Review) analysis for total, skin and tip
  - Tran et al (2012) methods for analysis of skin and tip
  - Analyze EOID and BOR blows for all 5 piles
  - Compare measured load test to EDC predictions (i.e., UF method and Tran et al methods)
- Task 3 – Develop LRFD resistance factors
  - Augment dataset from Phase I (**FDOT BDK-75-977-24**)
  - Determine method bias and resistance factors

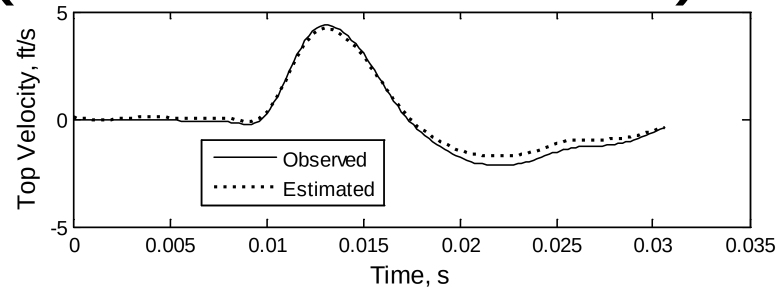
Choctawhatchee Bay Bridge Test Piles

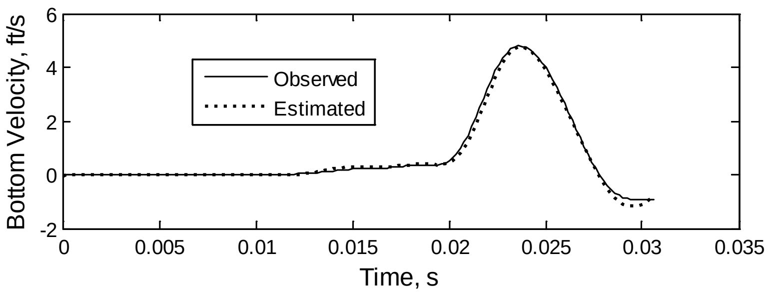
- Pier 13 test pile
  - 30 in square
  - Gauges 2B from top and bottom
  - 160 ft long
- Piers 25, 33, 59 & 84
  - 30 in square with void
  - Gauges in solid and voided sections
  - 160 ft long

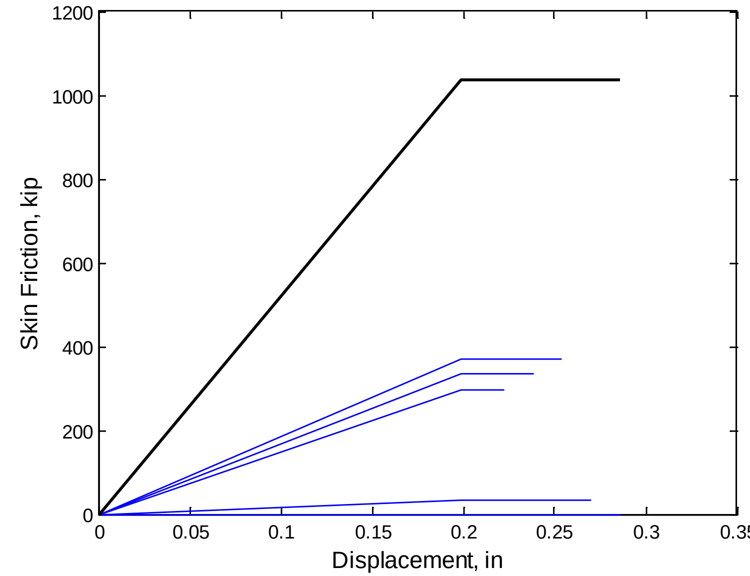


Choctawhatchee Bay – EDC New method (Tran et al., 2012)

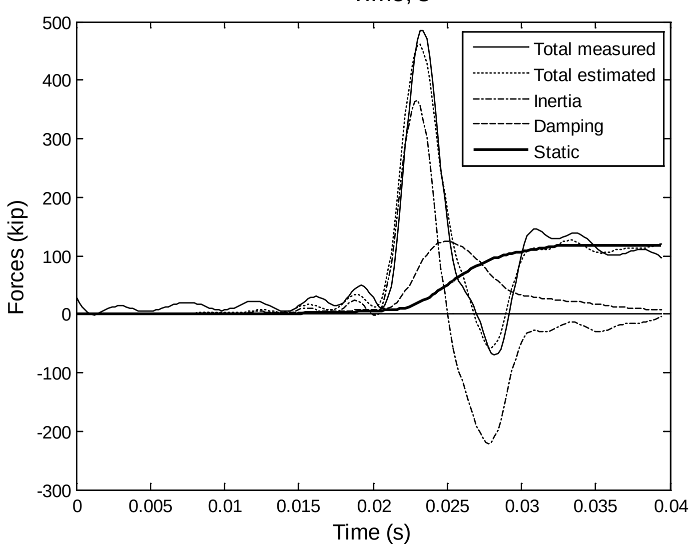
Skin

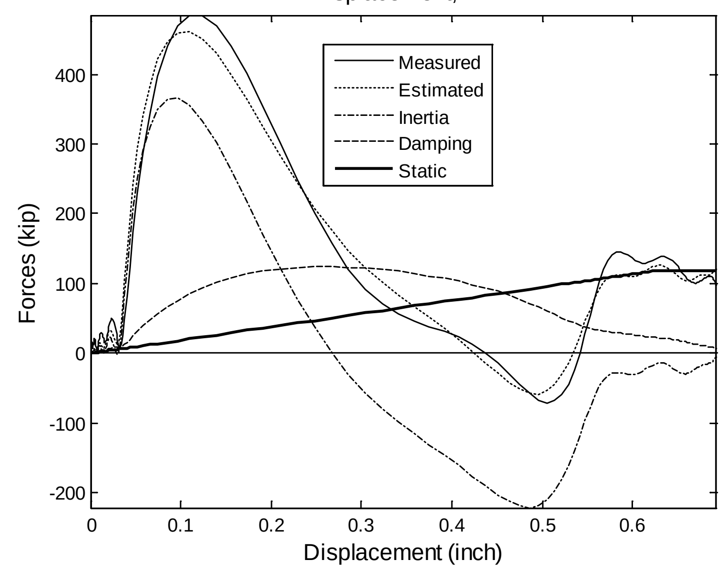






Tip





Choctawhatchee Bay – Pier 13

Pile Gauge Locations	Fixed Method	UF Method			New Method (Tran et al.)			CAPWAP			Load Test
	Total Capacity (Kips)	Total Capacity (Kips)	Skin Capacity (Kips)	Tip Capacity (Kips)	Total Capacity (Kips)	Skin Capacity (Kips)	Tip Capacity (Kips)	Total Capacity (Kips)	Skin Capacity (Kips)	Tip Capacity (Kips)	Total Capacity (Kips)
Top and Tip Gauges	593	548	414	134	625	425	200	699.6	434.7	264.9	1500

- Pile was driven, cut off, and load tested
- 3 days between EOID and BOR
- 38 days between BOR and load test
- EDC not accessible for load test and restrikes
- Measured/Predicted not useful

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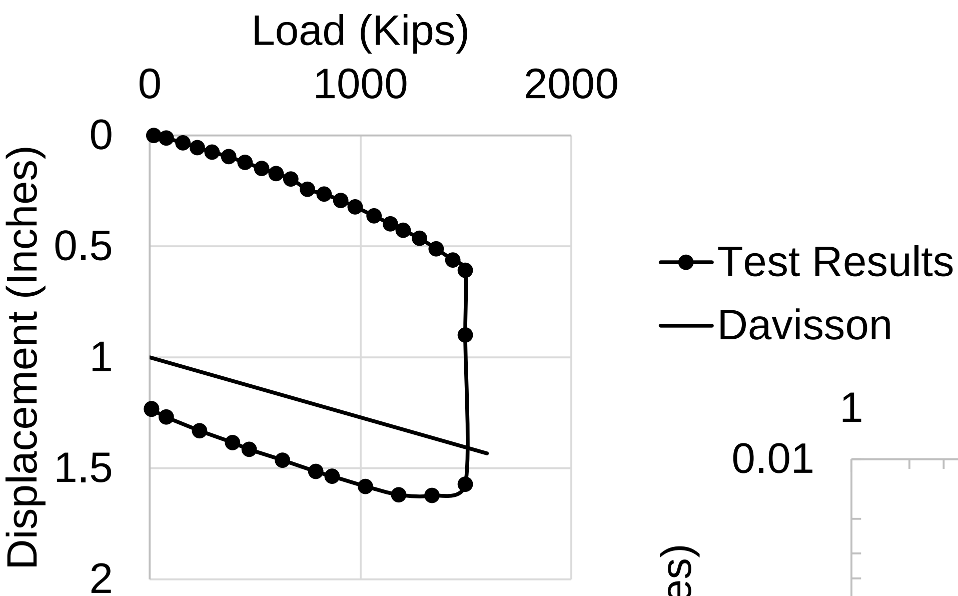
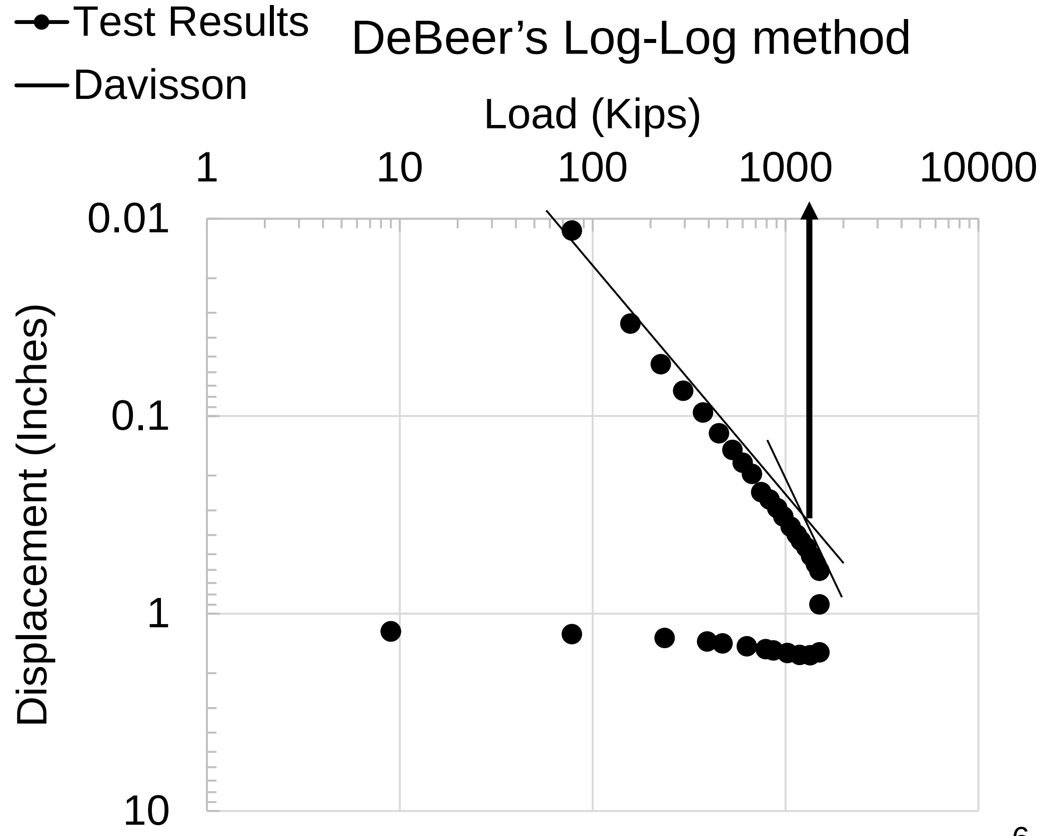
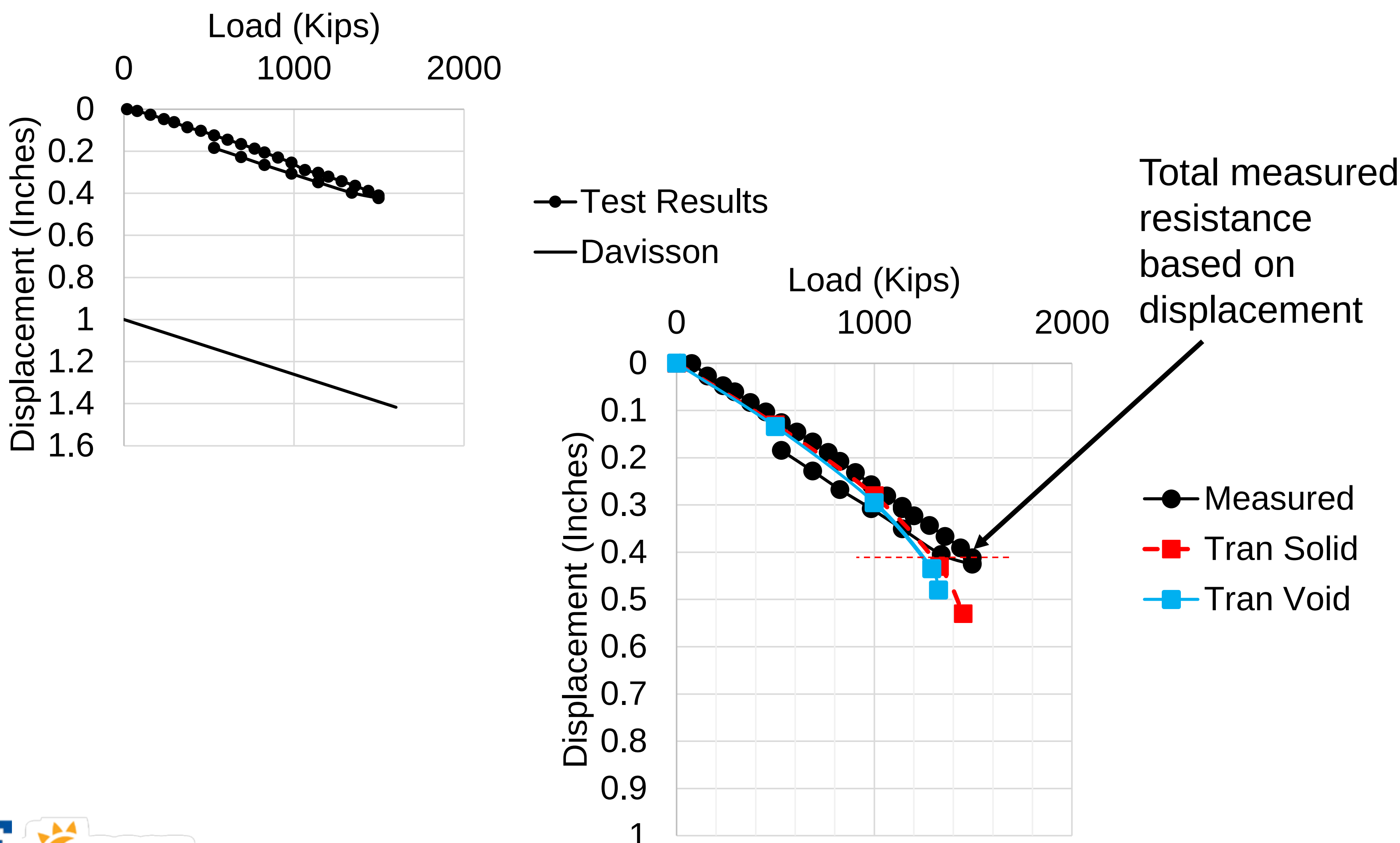
Choctawhatchee Bay – Pier 25 Load Test

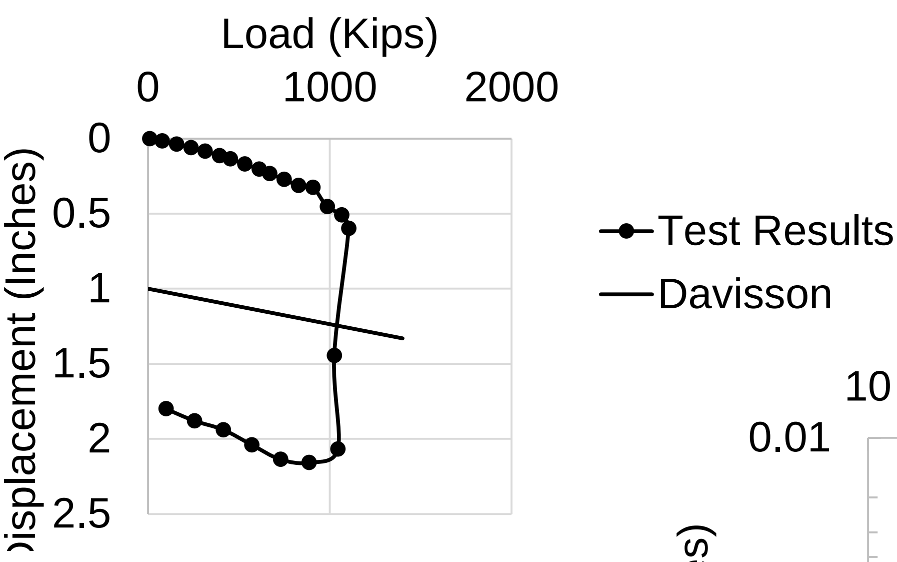




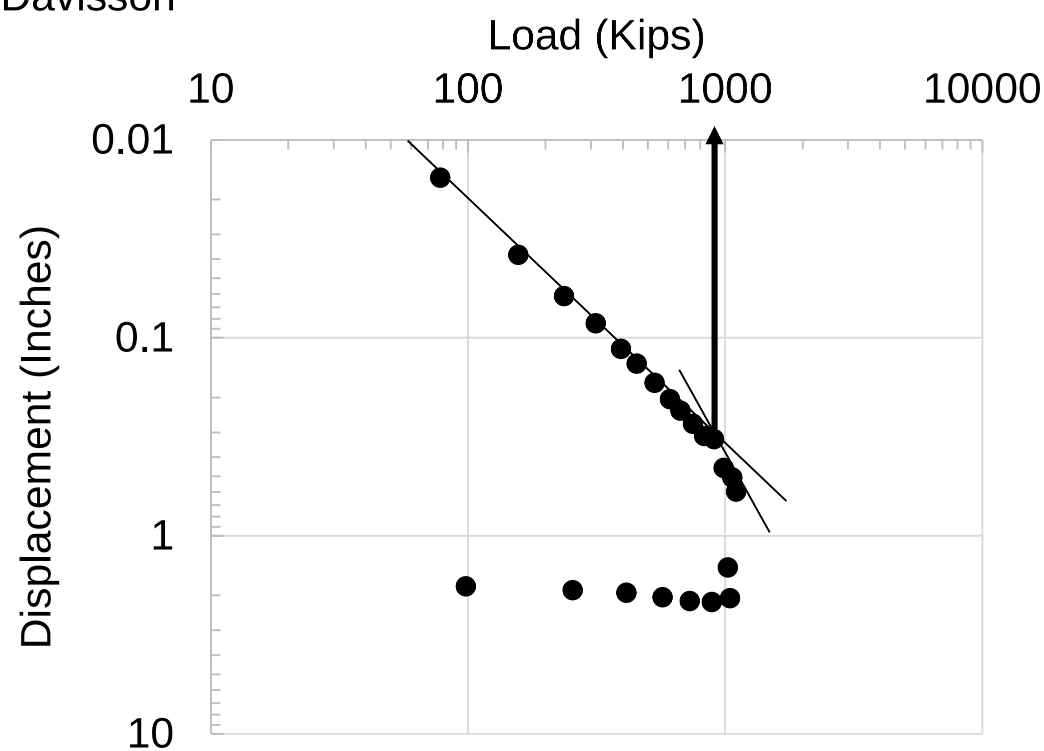
Choctawhatchee Bay – Pier 33 Load Test



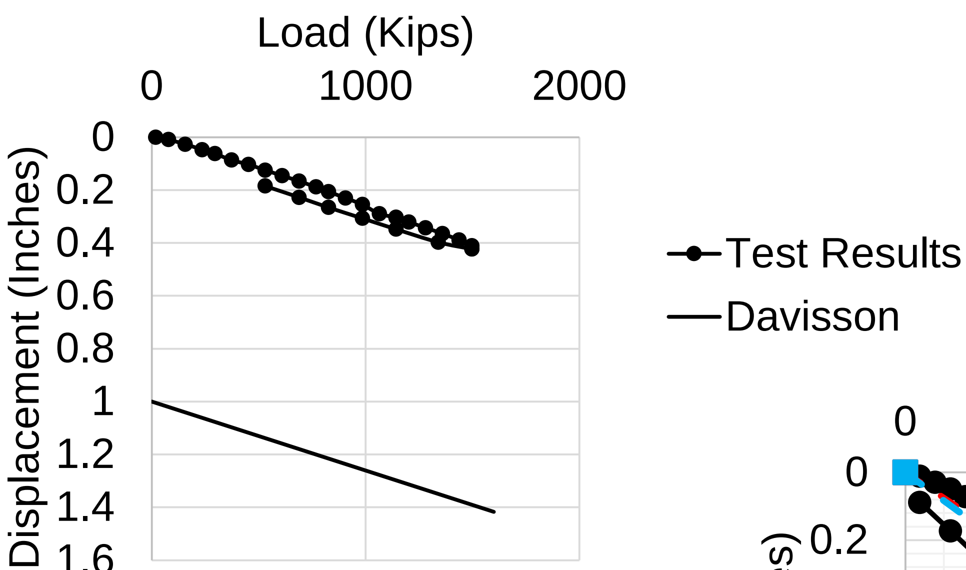
Choctawhatchee Bay – Pier 59 Load Test



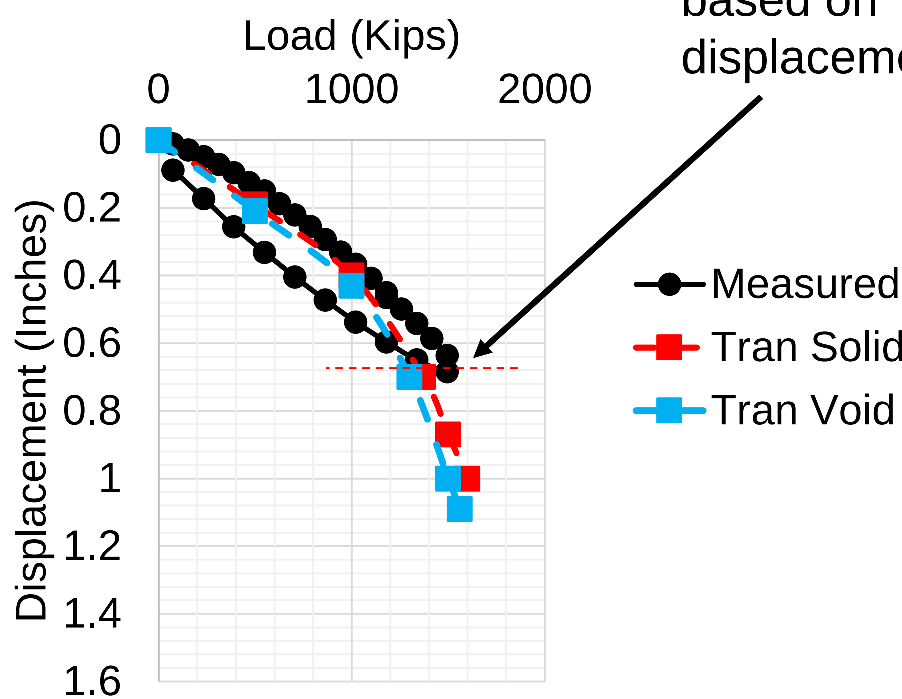
DeBeer's Log-Log method



Choctawhatchee Bay – Pier 84 Load Test



Total measured resistance based on displacement



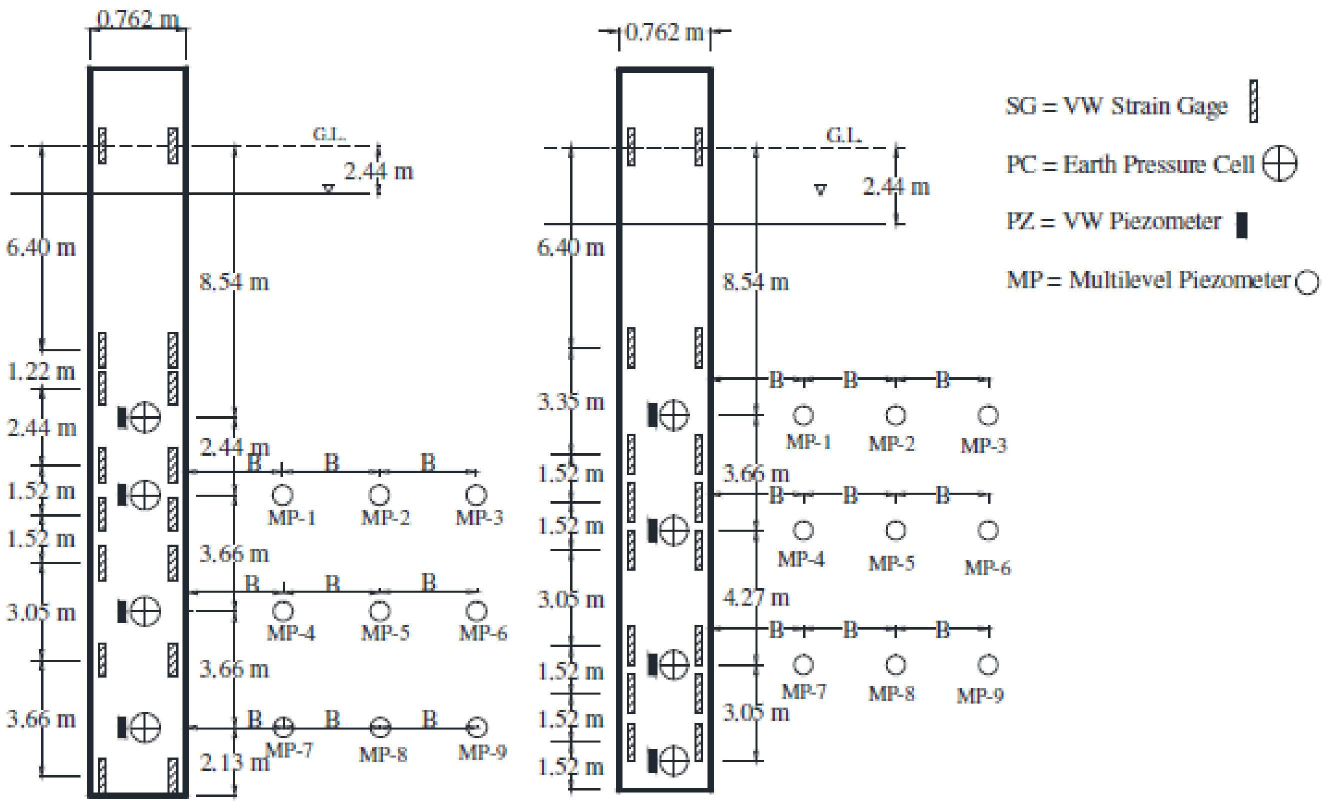
Choctawhatchee Bay – Time Between EOID, BOR, and Load Test

Pier – Test Pile			
25	33	59	84
EOD 1 (3/12/14) Tip El. -115 ft	EOID (3/26/14) Tip El. -130 ft	EOID (4/22/14) Tip El. -106 ft	EOD 1 (5/7/14) Tip El. -86 ft
BOR 1 (3/20/14)	BOR (4/1/14)	BOR (4/22/14)	EOD 2 (5/9/14) Tip El. -96 ft
EOD 2 (3/26/14) Tip El. -125 ft			EOD 3 (5/13/14) Tip El. -105 ft
BOR 3 (4/1/14)			EOD 4 and BOR (5/15/14) Tip El. -115 ft
Load Test (4/22/14)	Load Test (5/3/14)	Load Test (5/9/14)	Load Test (5/19/14)

Note: For the test pile at pier 25, EDC gages were not monitored during restrike on 3/24/14.

Bayou Lacassine Bridge, Louisiana

- 2 Test piles (Haque et al., 2014)
  - 30 in^2 – 75 ft long with 16.5 in diameter void, 70 ft long



(a) TP-1 (b) TP-3

Measured & Predicted – UF Method

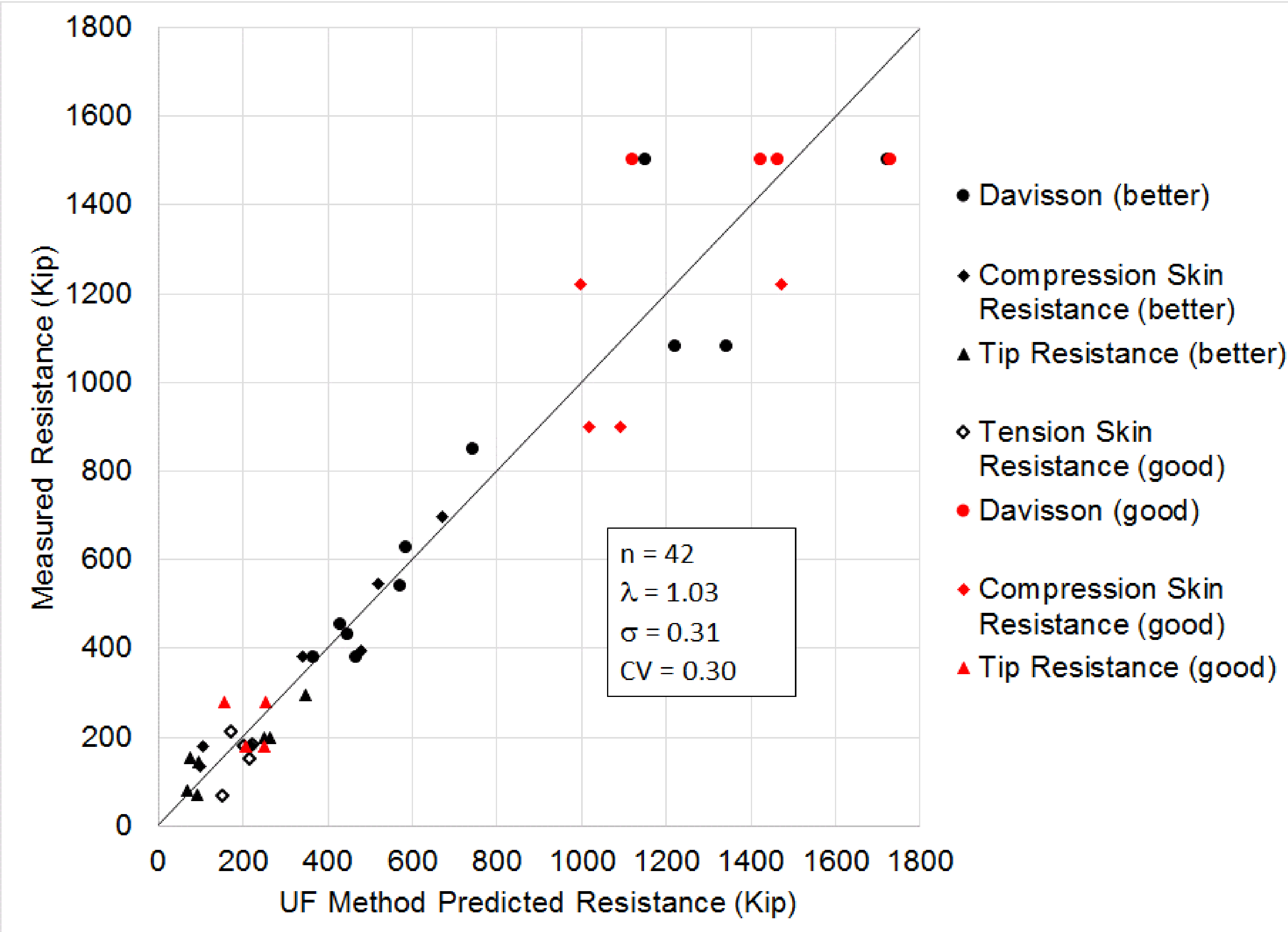
- 16 piles
- 34 values
  - US 331 solid section
- 42 values
  - US 331 solid & voided section

Solid Section

Voided Section

Site & Pile	Measured			Predicted		
	Davisson Capacity (Kip)	Tip Capacity (Kip)	Skin Capacity (Kip)	SmartPile Total Capacity (Kip)	SmartPile Tip Capacity (Kip)	SmartPile Skin Capacity (Kip)
Dixie Highway End Bent 1	430	296	134	448	349	99
Dixie Highway Pier 8	380	200	180	470	250	220
Caminada Bay Bent 1 LADOT	540	144.8	395.2	574	94	480
Caminada Bay Bent 7 LADOT	625	80	545	587	67	520
Bayou Lacassine Bent 1 Pile 1 LADOT	452	71	381	432	91	341
Bayou Lacassine Bent 1 Pile 3LADOT	850	153	697	745	74	671
I-95 Jax	380	200	180	369	263	106
Dixie Highway Pier 4			212			171
5th St Bascule Pier 2 Pile 37			185			220
5th St Bascule Pier 2 Pile 53			180			200
5th St Bascule Pier 3 Pile 9			68			150
5th St Bascule Pier 3 Pile 42			153			215
US 331 Choctawhatchee Bay Pier 25	1500	*280*	*1220*	1726	255	1471
US 331 Choctawhatchee Bay Pier 33	*1500*			1466	158	1308
US 331 Choctawhatchee Bay Pier 59	1080	*180*	*900*	1343	251	1092
US 331 Choctawhatchee Bay Pier 84	*1500*			1731	866	865
US 331 Choctawhatchee Bay Pier 25	1500	*280*	*1220*	1151	155	996
US 331 Choctawhatchee Bay Pier 33	*1500*			1122	96	1026
US 331 Choctawhatchee Bay Pier 59	1080	*180*	*900*	1224	206	1018
US 331 Choctawhatchee Bay Pier 84	*1500*			1424	793	631

Measured vs Predicted – UF Method



Measured & Predicted – Tran et al Method

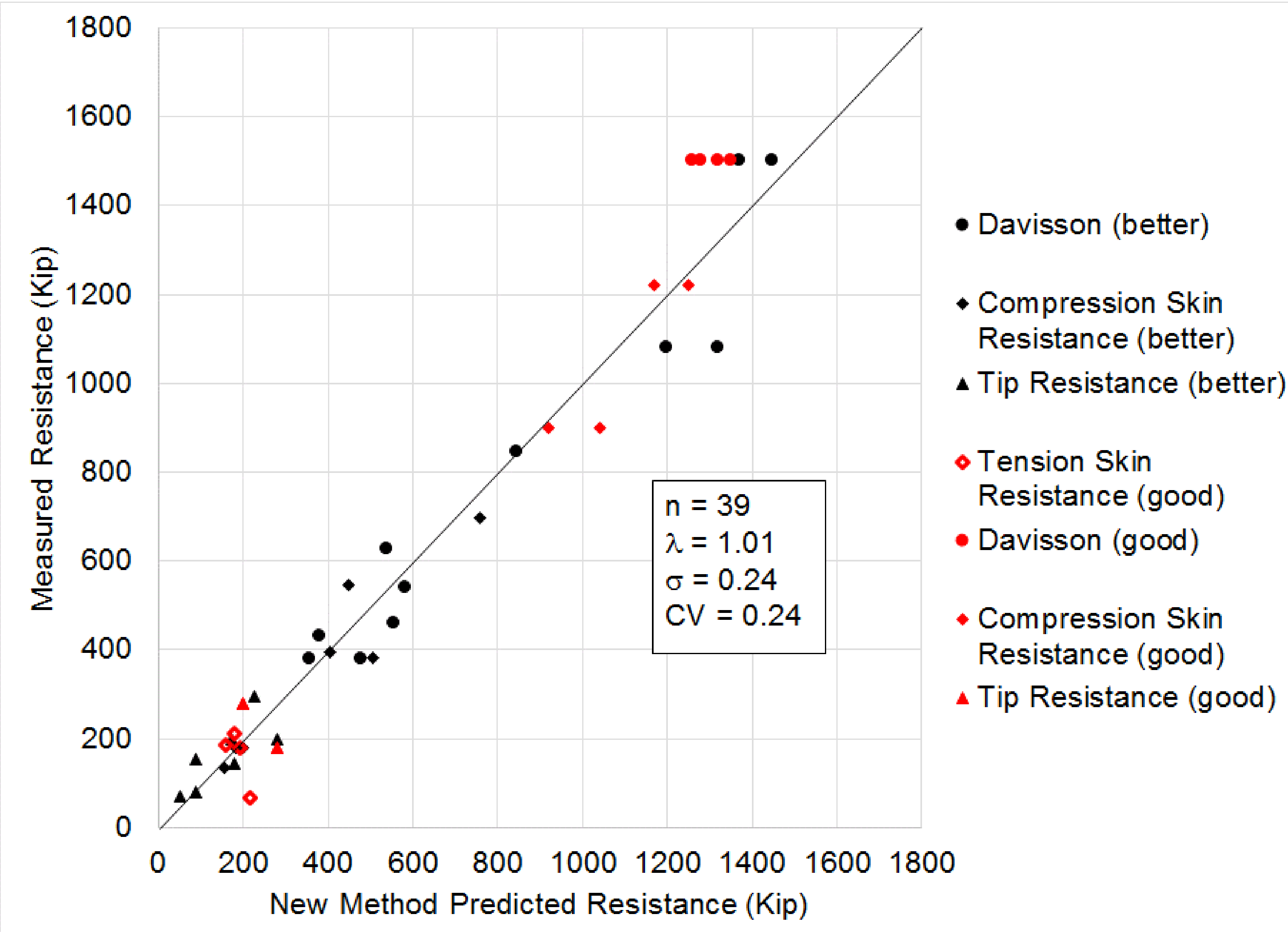
- 15 piles
- 33 values
  - US 331 solid section
- 39 values
  - US 331 solid & voided section

Site & Pile	Measured			Predicted (Tran et al)		
	Davisson Capacity (Kip)	Tip Capacity (Kip)	Skin Capacity (Kip)	New Method Total Capacity (Kip)	New Method Tip Capacity (Kip)	New Method Skin Capacity (Kip)
Dixie Highway End Bent 1	430	296	134	380	225	155
Dixie Highway Pier 8	380	200	180	358	174	184
Caminada Bay Bent 1 LADOT	540	144.8	395.2	585	180	405
Caminada Bay Bent 7 LADOT	625	80	545	540	90	450
Bayou Lacassine Bent 1 Pile 1 LADOT	460	71	381	558	53	505
Bayou Lacassine Bent 1 Pile 3LADOT	845	153	697	846	87	759
I-95 Jax	380	200	180	480	280	200
Dixie Highway Pier 4			212			180
5th St Bascule Pier 2 Pile 37			185			158
5th St Bascule Pier 2 Pile 53			180			194
5th St Bascule Pier 3 Pile 9			68			216
5th St Bascule Pier 3 Pile 42			153			
US 331 Choctawhatchee Bay Pier 25	1500	*280*	*1220*	1450	200	1250
US 331 Choctawhatchee Bay Pier 33	*1500*			1320	330	1080
US 331 Choctawhatchee Bay Pier 59	1080	*180*	*900*	1320	280	1040
US 331 Choctawhatchee Bay Pier 84	*1500*			1350	700	900
US 331 Choctawhatchee Bay Pier 25	1500	*280*	*1220*	1370	200	1170
US 331 Choctawhatchee Bay Pier 33	*1500*			1260	330	990
US 331 Choctawhatchee Bay Pier 59	1080	*180*	*900*	1200	280	920
US 331 Choctawhatchee Bay Pier 84	*1500*			1280	700	860

Solid Section

Voided Section

Measured vs Predicted – Tran et al Method



Data Quality

Better Data

- Pile tested to failure
- Pile EDC observed during load test (i.e., measured skin and tip capacity)
- Pile compression tests

Good Data

- Pile not loaded to failure
- Predictions used based on pile movement (pile not loaded to failure)
- Estimated measured skin and tip pile capacity (i.e., application of DeBeer's method)
- Pile tension tests

Resistance Bias, λ_R Better and Good Data

- Bayesian updating of summary statistics
- Technique to account for "quality" of data subsets
- Applied in pile capacity predictions (Kwak et al, 2010; Yu, 2006; Zhang and Tang, 2002)
- Updated summary statistics, μ_U and σ_U^2 (Ang and Tang, 1975)

$$\mu_U = \frac{\mu_B \sigma_G^2 + \mu_G \sigma_B^2}{\sigma_G^2 + \sigma_B^2} \qquad \sigma_U^2 = \frac{\sigma_G^2 \cdot \sigma_B^2}{\sigma_G^2 + \sigma_B^2}$$

Method	Better	Good	Updated
UF	$\mu_B = 1.06$ $\sigma_B = 0.318$ $CV_B = 0.298$ N = 25	$\mu_G = 0.981$ $\sigma_G = 0.304$ $CV_G = 0.310$ N = 17	$\mu_U = 0.998$ $\sigma_U = 0.212$ $CV_U = 0.212$ N = 42
Tran et al (2012)	$\mu_B = 1.01$ $\sigma_B = 0.229$ $CV_B = 0.226$ N = 25	$\mu_G = 1.0$ $\sigma_G = 0.268$ $CV_G = 0.266$ N = 14	$\mu_U = 0.991$ $\sigma_U = 0.169$ $CV_U = 0.17$ N = 39

Resistance Factors

- LRFD Φ for AASHTO (2014) parameters: $q_D/q_L = 2$, dead load factor γ_D=1.25, live load factor γ_L=1.75, dead load bias λ_D=1.08, live load bias λ_L=1.15, CV_D=0.128, CV_L=0.18, β = 2.33 (single pile in a group)

Calibration Method	Prediction Method		
	UF	Tran et al	PDA/CAPWAP
FOSM	0.64 (β=2.33)	0.68 (β=2.33)	(0.65 β=2.5, FDOT)
FORM	0.71- 0.74	0.79- 0.81	Not computed yet

FOSM: First Order Second Moment; FORM: First Order Reliability Method

- Calculated resistance factors for single tested piles
- Based on monitored solid (14) and solid top/tip with void piles (6)
- Not based on cylinder piles
- Due to the limited database, results from the first two columns should be considered preliminary

References

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Thank You!

Questions?