Phase II: Field Load Testing of Shallow Foundations in Florida Limestone

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Presentation Outline

1. Project Description
2. Scope of Work
3. Planned Shallow Foundation Load Test
4. Discussion of the Tasks
5. Closing Page

Project Description

This research is separated into three phase project:

Phase 1: Assess strength envelope for Florida Limestone and develop Bearing Capacity Equations of shallow foundations on limestone. (finished)

- Guidelines for laboratory testing for the purposes of developing strength envelope for Limestone
- New design equations for bearing capacity of shallow foundations on Limestone

Phase 2: Validate the new Florida Bearing Capacity Equations derived in the current work by field testing. (expected to last 2 years)

Phase 3: Implement the validated equations into FB-Multipier. (expected to last 1.5 years)

An updated version of FB-Multipier capable of evaluating shallow foundations would be released after Phase 3.

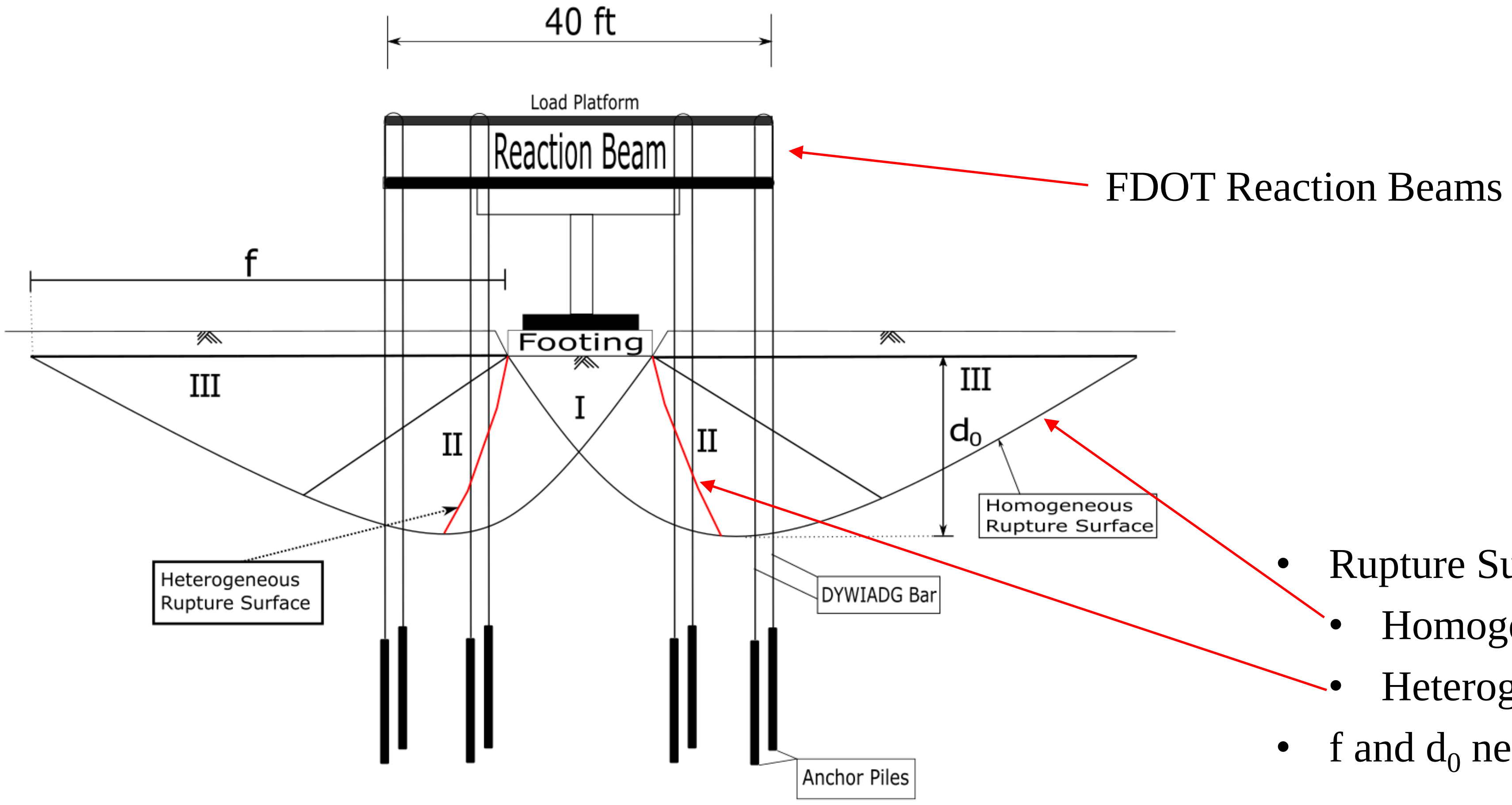
Scope of Work

- Task 1 – Locate and Setup for 3 shallow foundation load tests on Florida Limestone
  - Necessary materials will be purchased, equipment and instrumentation will be collected calibrated.
  - Site visiting and sizing girder jack stands.
- Task 2 – Shallow Foundation Load Test 1 (between West Palm beach and Flagler beach)
- Task 3 – Shallow Foundation Load Test 2 (Krome Avenue)
- Task 4 – Shallow Foundation Load Test 3 (I-75)

  At each test site:
  - Obtain cores in footing footprint, develop Strength envelope of rock– Size the footing (900 tons)
  - Install 8 anchors for each load test which will not impact load testing
  - Perform Load test – obtain Load vs. Settlement response of footing.
  - Compare Measured vs. Predicted load vs. settlement as well as bearing capacity
- Task 5 – Seismic field test to develop 3D In-situ density, Shear and Young Moduli
  - Compare with core unit weights, modulii, and recoveries

Planned 900 ton Shallow Foundation Load Test

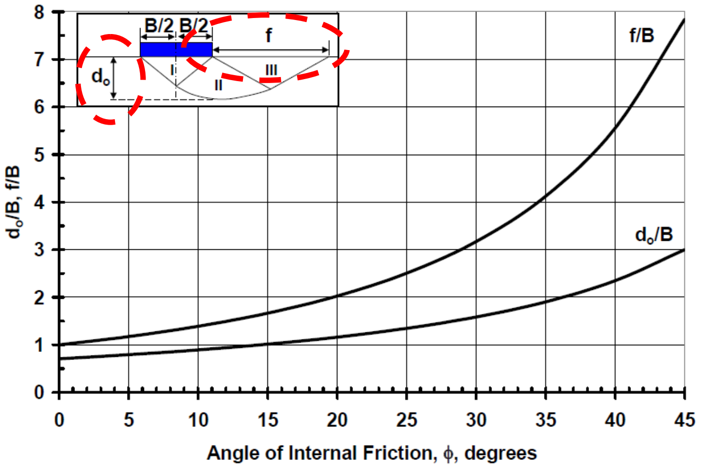
Reaction provided by 8 - 112 ton rock anchors



Schematic for plate load test and rupture surfaces

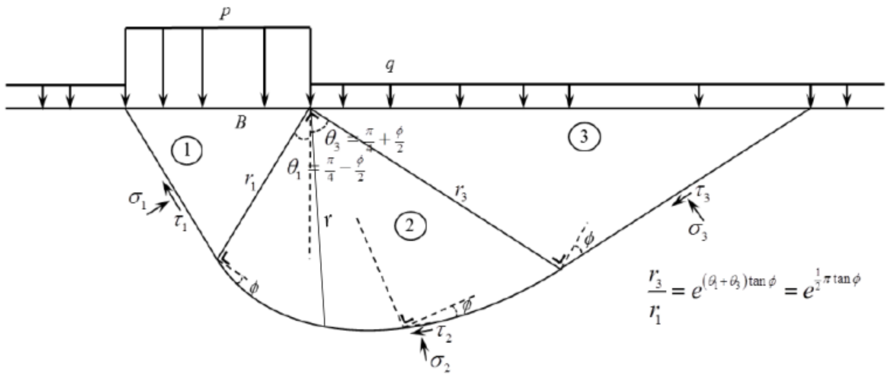
- Rupture Surface:
  - Homogeneous
  - Heterogeneous (two layer)
- f and d_0 need to be determined

Locating the Shallow Foundation Load Test Anchor System



Approximate variation of depth (d_0) and lateral extent (f) of influence of footing as a function of internal friction angle of foundation soil (FHWA–NHI-06-089)

Friction Angle (°)	B (m)	B (ft)	d_0 (m)	d_0 (ft)	f (m)	f (ft)
42.20	1.93	6.33	5.14	16.88	12.92	42.39
43.30	1.80	5.91	5.07	16.62	12.98	42.58
44.30	1.68	5.51	4.97	16.32	12.98	42.58
45.30	1.57	5.15	4.90	16.06	13.01	42.69
46.30	1.46	4.79	4.80	15.74	13.00	42.64
47.30	1.34	4.40	4.65	15.25	12.83	42.09
48.30	1.23	4.04	4.50	14.78	12.68	41.60
49.20	1.11	3.64	4.27	14.02	12.24	40.15
50.10	0.99	3.25	4.01	13.15	11.68	38.34
51.00	0.85	2.79	3.62	11.88	10.75	35.26



Prandtl-Wedge

$r = ae^{b\theta}$

Friction Angle (°)	B (m)	B (ft)	d_0 (m)	d_0 (ft)	f (m)	f (ft)
42.20	1.93	6.33	5.08	16.67	18.08	59.33
43.30	1.80	5.91	4.93	16.16	18.31	60.06
44.30	1.68	5.51	4.91	16.11	18.45	60.53
45.30	1.57	5.15	4.81	15.79	18.66	61.22
46.30	1.46	4.79	4.70	15.43	18.82	61.76
47.30	1.34	4.40	4.51	14.80	18.79	61.65
48.30	1.23	4.04	4.47	14.66	18.81	61.72
49.20	1.11	3.64	4.27	14.00	18.40	60.37
50.10	0.99	3.25	4.10	13.46	17.83	58.51
51.00	0.85	2.79	3.64	11.93	16.68	54.73

Selection of Footing Size for Bearing Capacity – Example Miami Limestone

$$Q_u = \min(Q_{u1}, Q_{u2}) * \xi / N_R$$

$$Q_{u1} = n * c * N_c + q * N_q$$

$$Q_{u2} = n * [c * N'_c + p_p * N_\gamma] + q * N_q$$

$$N_c = \frac{1.8\ \cos\varphi}{0.8 - \sin\varphi}$$

$$N'_c = \frac{1.8\ \cos\varphi}{0.8 - \sin\omega}$$

$$N_\gamma = \frac{1.8\ [\sin\varphi - \sin\omega]}{0.8 - \sin\omega}$$

$$N_q = (1.5 * \frac{p_p}{\sigma_a} - 10) * (3 * \sin\varphi - 1)$$

σ_a = Sea level standard atmospheric pressure

$n = \left(\frac{4}{B\ in\ meter}\right)^{-0.055}$ or $n = \left(\frac{4}{0.3B\ in\ ft}\right)^{-0.055}$

ξ= shape factor = $1 + 0.245 \left(\frac{B}{L}\right)^{0.66}$

N_R = Rock thickness reduction factor

$N_R = 0.86 * R^{-0.25}$ if R < 0.3

$N_R = 1.2 - 0.1 * R$ if R≥ 0.3

$R = T^2 E_{soil} / E_{rock}$, limit R to 2.0

T = Rock thickness in meter (if T is in ft, then $R = 0.093\ T^2 E_{soil} / E_{rock}$)

E_{soil} / E_{rock} = Modulus ratio of soil and rock layers

New Florida Bearing Capacity Equations (FDOT BDV31-977-51)

Soil Properties of Miami Rock for REC = 100, GSI = 81

Form-ation	q_{dt} (psi)	q_u (psi)	γ_{dt} (pcf)	φ (°)	ω (°)	c (psi)	p_{peak} (psi)	T (ft)	E_{soil}/E_{rock}
Miami	37	188	90	42.2	-3	42	247	4.6	0.03
	43	230	95	43.3	-1.4	50	274	4.6	0.03
	50	281	100	44.3	0.8	59	306	4.6	0.03
	58	343	105	45.3	3.7	71	345	4.6	0.03
	67	419	110	46.3	7.3	84	390	4.6	0.03
	78	512	115	47.3	11.6	100	445	4.6	0.03
	91	626	120	48.3	16.5	119	510	4.6	0.03
	106	764	125	49.2	22.2	142	588	4.6	0.03
	123	934	130	50.1	28.5	169	682	4.6	0.03
	143	1140	135	51	35.5	202	795	4.6	0.03

Summary of Footing Size and Bearing Capacity

Form-ation	γ_{dt} (pcf)	N_c	N_c'	N_r	N_q	B (ft)	n	L (ft)	ζ	N_R	D (ft)	q (psf)	Q_U (tsf)	Bearing Capacity (tons)
Miami	90	10.39	1.56	1.53	15.74	6.33	0.96	6.33	1.25	1.7	0.33	29.53	22.3	894.05
	95	11.47	1.59	1.55	19.4	5.91	0.96	5.91	1.25	1.7	0.33	31.17	25.6	892.94
	100	12.68	1.64	1.57	23.71	5.51	0.95	5.51	1.25	1.7	0.33	32.81	29.27	889.29
	105	14.19	1.72	1.58	29.1	5.15	0.95	5.15	1.25	1.7	0.33	34.45	33.81	897.06
	110	16.14	1.85	1.59	35.48	4.79	0.95	4.79	1.25	1.7	0.33	36.09	39.21	899.69
	115	18.76	2.04	1.6	43.43	4.4	0.94	4.4	1.25	1.7	0.33	37.73	46.16	892.09
	120	22.44	2.32	1.61	53.07	4.04	0.94	4.04	1.25	1.7	0.33	39.37	55.07	896.82
	125	27.35	2.79	1.62	64.5	3.64	0.93	3.64	1.25	1.7	0.33	41.01	67.03	888.99
	130	35.16	3.58	1.62	78.74	3.25	0.93	3.25	1.25	1.7	0.33	42.65	84.61	892.64
	135	49.57	5.17	1.61	96.13	2.79	0.92	2.79	1.25	1.7	0.33	44.29	113.94	886.12

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Assessing Anchor Lengths and DYWIDAG Bar Anchor Details

FDOT drilled shaft design:

Skin Friction $= \frac{1}{2} * \sqrt{q_u * q_t}$

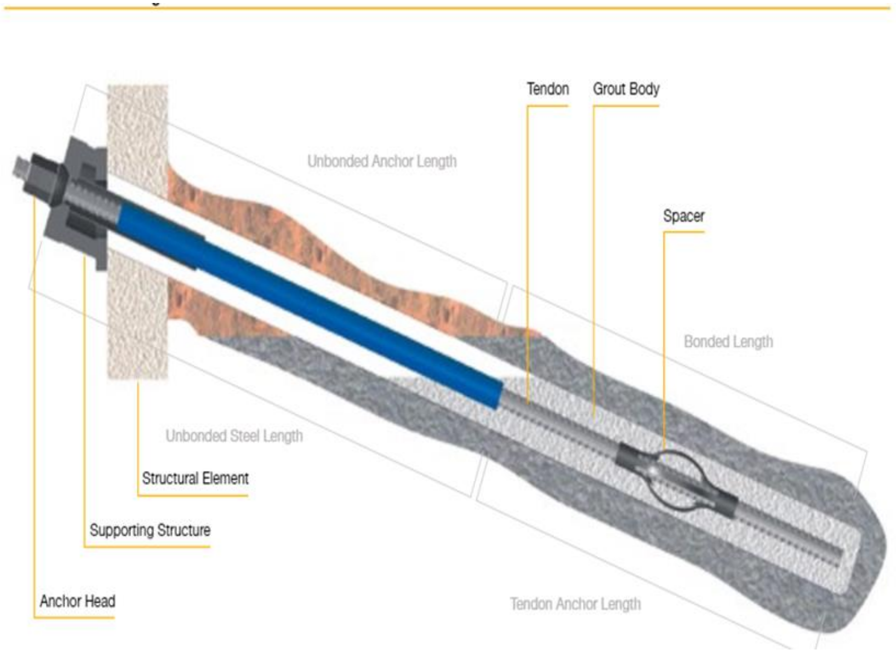
q_u = Unconfined Compression Strength

q_t = Splitting Tension Strength

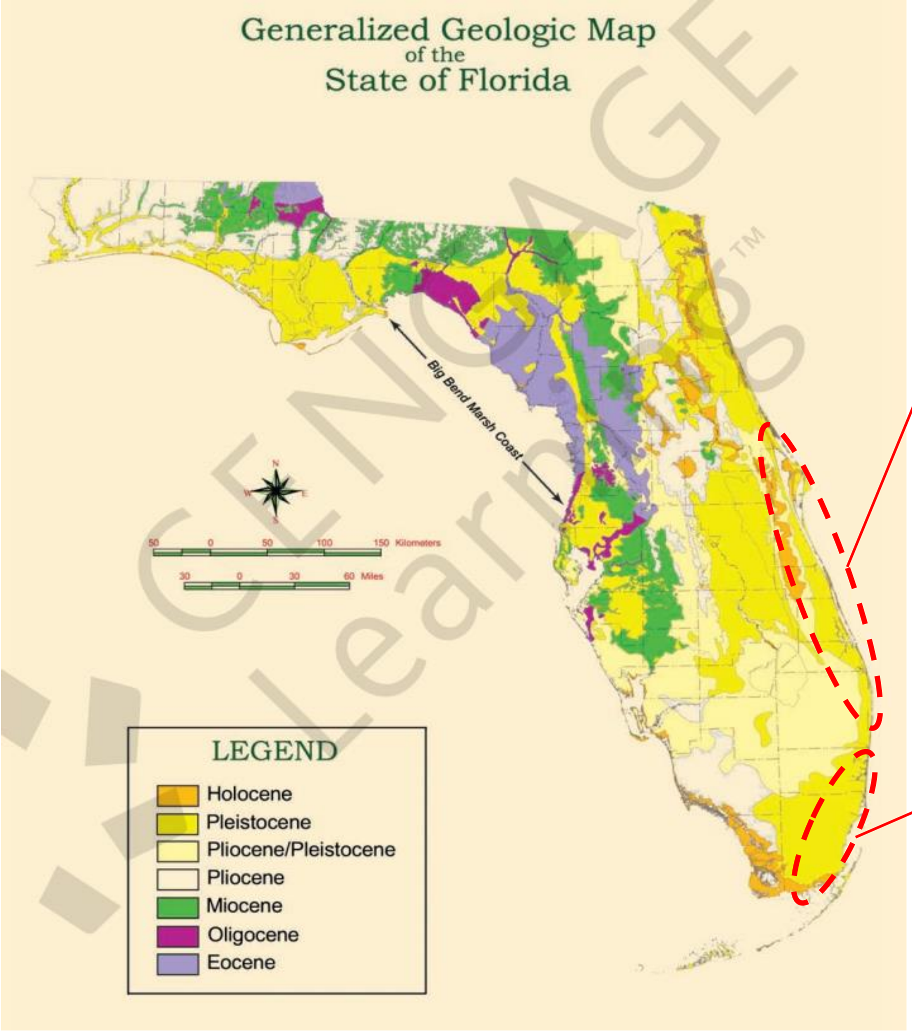
For the design: #18 Grade 80 THREADBAR will be employed which has a minimum yield load of 320 kips each. The total resistance of the DYWIDAG bar anchors system is 1280 tons.

Summary of Anchor Piles

Form-ation	q_{dt}	q_u	f_s (MPa)	f_s (tsf)	Diameter of Anchors (in)	length of Anchors (m)	length of Anchors (ft)	Number of Anchors	Capacity (tons)	Capacity (kN)
	psi									
Ft. Thomp-son	22	97	0.16	1.66	6	13.97	45.83	8	957.10	8518.18
	26	118	0.19	1.99	6	11.68	38.33	8	959.80	8542.26
	30	144	0.23	2.37	6	9.78	32.08	8	953.23	8483.79
	35	176	0.27	2.82	6	8.26	27.08	8	960.88	8551.86
	41	216	0.32	3.39	6	6.86	22.50	8	957.15	8518.63
	47	263	0.38	4.00	6	5.84	19.17	8	963.28	8573.18
	55	322	0.46	4.79	6	4.83	15.83	8	952.49	8477.15



Task 1: Locate and Setup for 3 shallow foundation load tests in Florida Limestone



Load Test 1

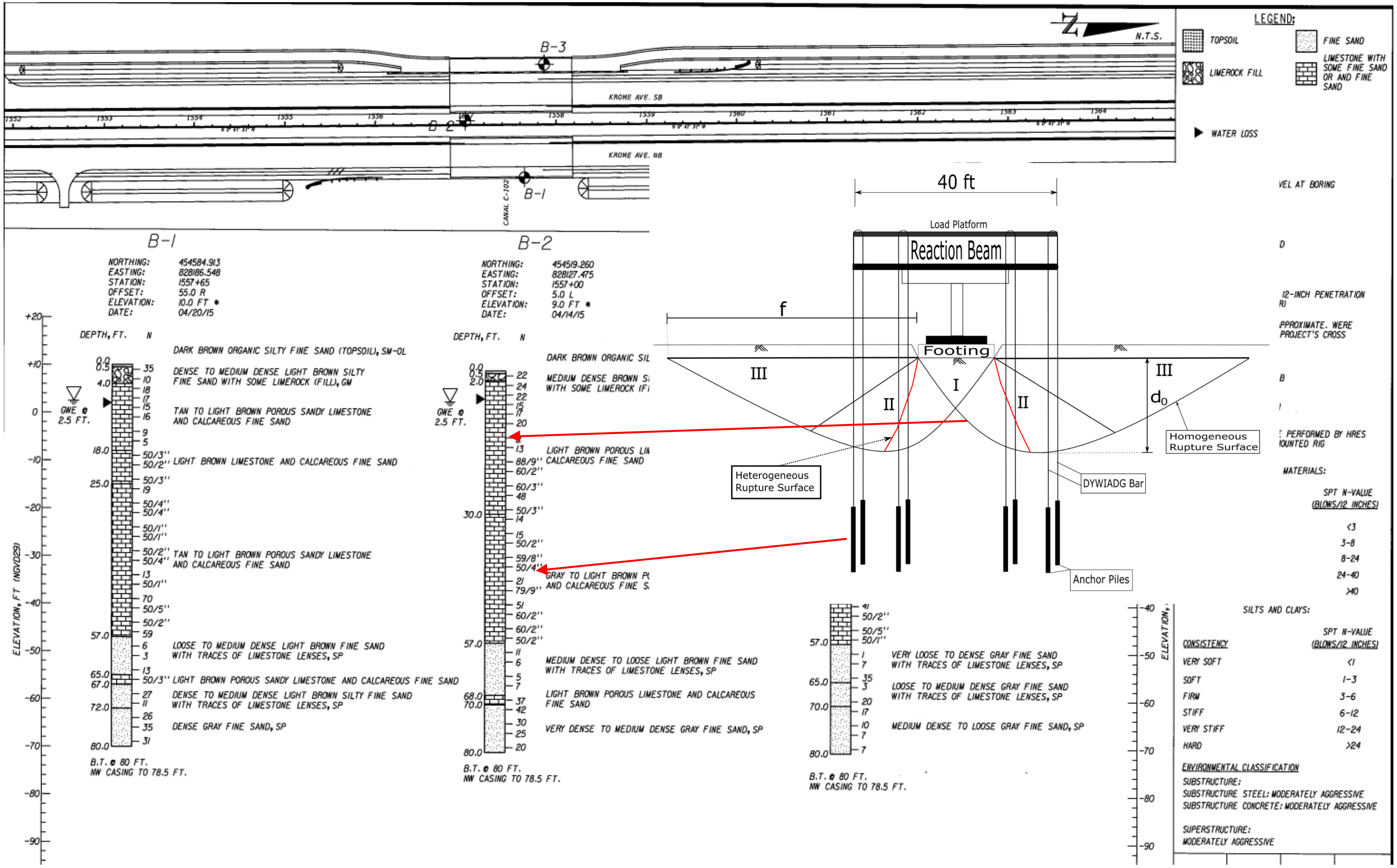
Load Test 2 and 3

ADAPTED FROM OPEN-FILE REPORT 80 - GEOLOGIC MAP OF FLORIDA

Eon	Era	Period		Epoch	Comments	Subsurface	Millions Years
Phanerozoic	Cenozoic	Quaternary		Recent or Holocene	ice age ends	Soils (Qh)	
						Soils (Qal Qbd Qtr Qu)	0.01
				Pleistocene	ice age begins	Anastasia/ Key Largo/ Miami	
						Soils (TQu, TQd, TQuc); S/LS mix (Tqsu) TQsu	1.6
		Tertiary	Neogene	Pliocene	earliest humans	Tic: Intracoastal LS; Soils (Tt, Tjb, Tci, Tmc, Tc) Soils (Thcc, Thp, Thpb)	5.3
				Miocene		Chatahoochee DS; St Marks LS; Torreya (Soils/LS); Other soils (Trm, Tab, Th, Thc, Ths) Arcadia formation (Tha, That)	23.7
			Paleogene	Oligocene		Suwannee LS; Some dolostone (Ts, Tsm)	36.6
				Eocene		Ocala LS/ Avon Park (To, Tap)	57.8
				Paleoenece			66
	Mesozoic	Cretaceous					144
		Jurassic					208
		Triassic					245
	Paleozoic	Permian					
		Carboniferous	Pennsylvanian				
			Mississippian		First reptiles		
		Devonian			First amphibians		
		Silurian					
		Ordovician			First land plants		
		Cambrian			First fish		545
Precambrian						Note: LS - Limestone	4600

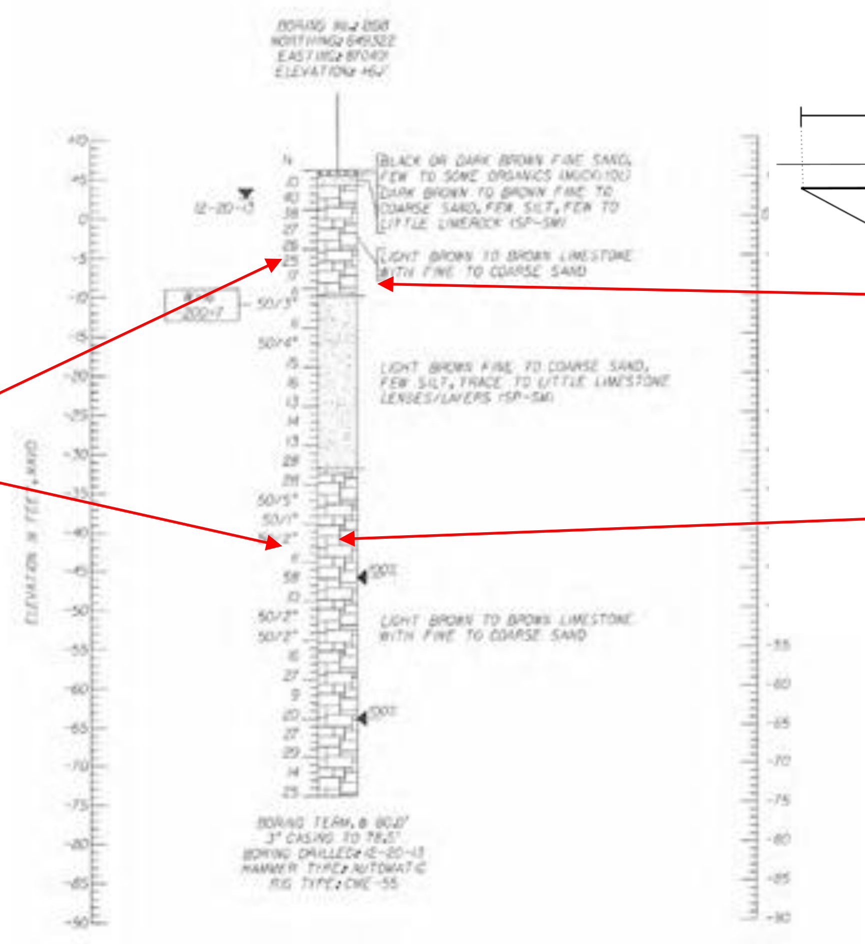
Task 1: Site 2 – SR 997/Krome Ave (Miami-Dade)

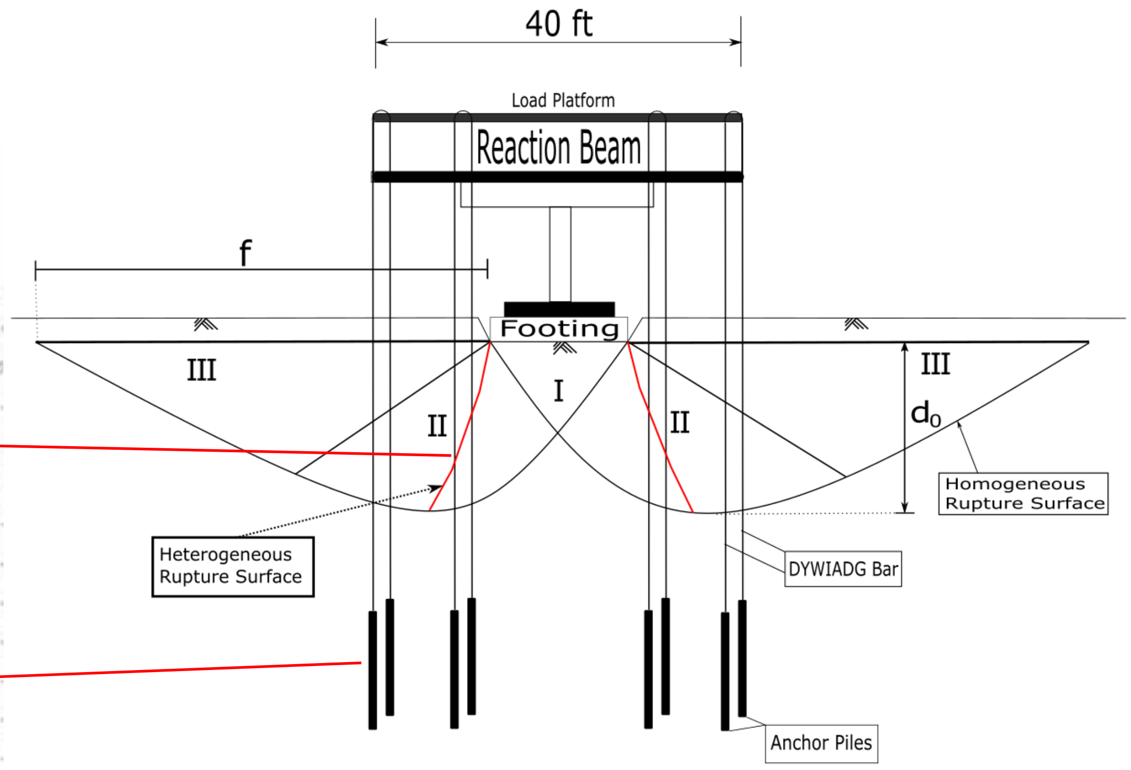
Homogeneous Rock



Task 1: Site 3 – I-75 (North of Griffin Road to I-595, Broward County)

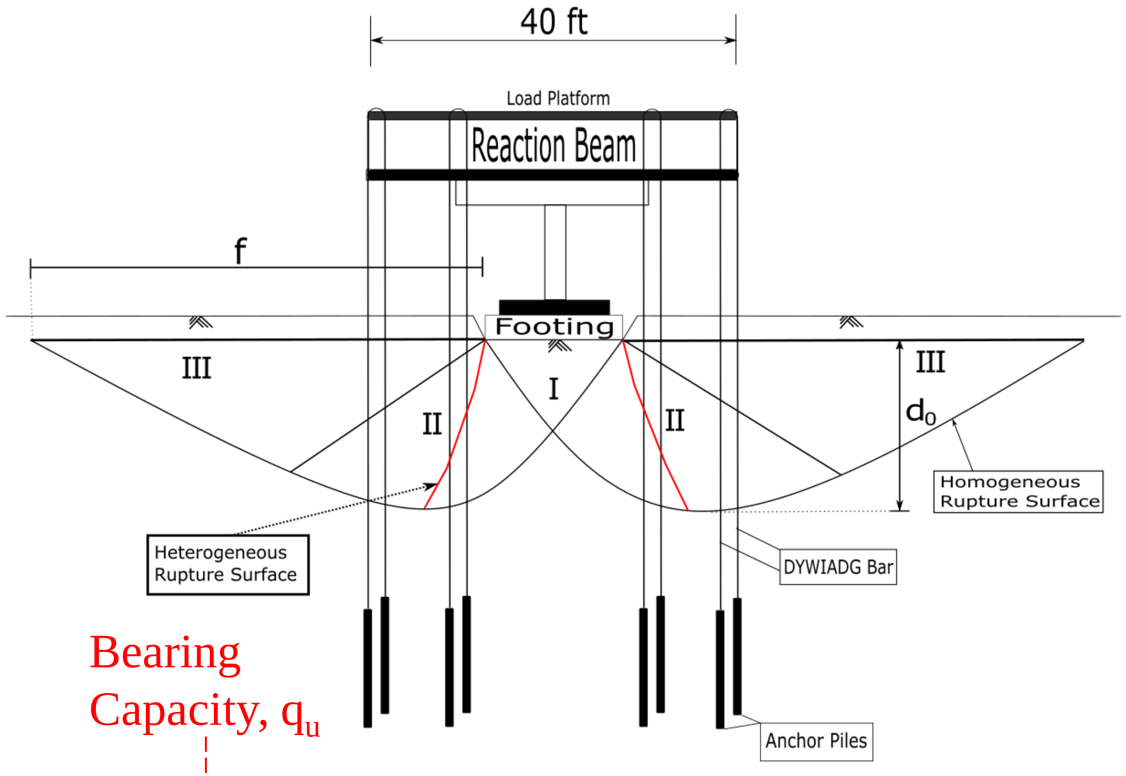
Core Borings for I-75, Heterogeneous Rock Layering

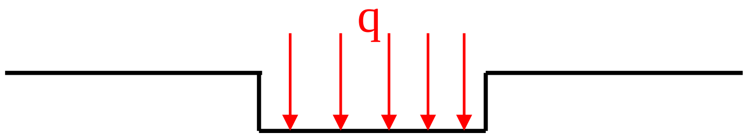


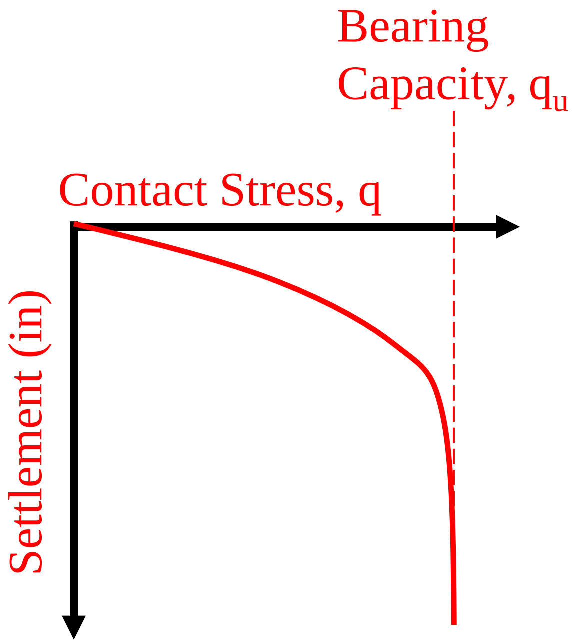


Tasks 2, 3 & 4: Individual Shallow Foundation Load Test

- SPT Drilling and Rock Coring (District 4/6)
- Assessing the strength envelope (State Materials Office)
- Sizing the shallow foundation (UF researchers)
- Installation of Rock Anchors (SPT Contractor)
- Setting up, recording and analyzing (measured vs. predicted load vs. settlement & BC) each shallow foundation load test





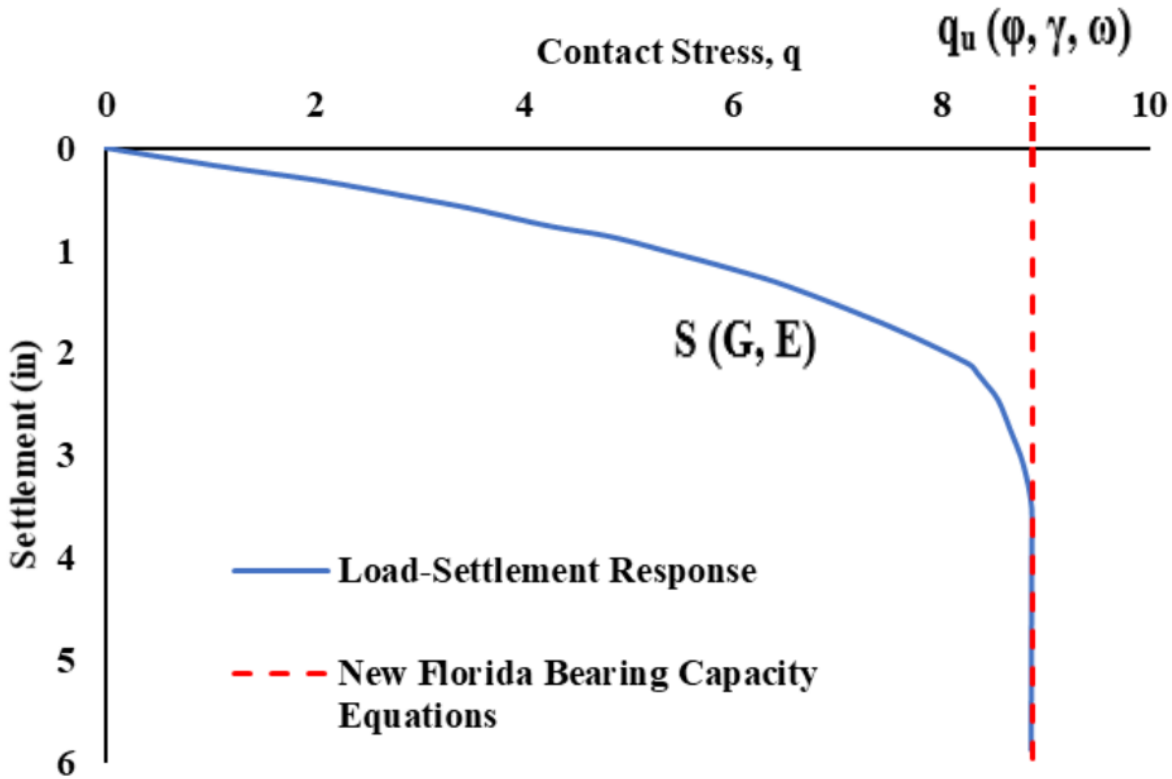


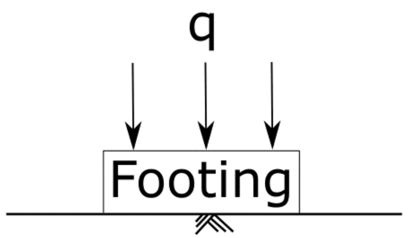
Task 5: Seismic field test to develop 3D In-situ density, Shear and Young's Modulus

- UF developing 2D full waveform inversion of SH and Love waves (2D SH-FWI) will be used to obtain in-situ soil/rock density (ρ).
  - Noted that the density of Florida Limestone is directly related to the rock strength (FDOT BDV31-977-51) or bearing capacity of the shallow foundation.
- Advanced 3D full waveform inversion of Rayleigh and body waves as well as SH will be used to characterize both S-wave and P-wave velocities (V_s and V_p), in-situ shear (G) and Young (E) moduli can be determined as:

  $G = \rho V_s^2$,

  $E = \rho V_s^2 (3V_p^2 - 4 V_s^2) / (V_p^2 - V_s^2)$.





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Thank You!

Q & A