Relaxation of Driven Piles in Florida Soils
BED25-977-05

GRIP 2023

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Background/Introduction

- Driven piles can exhibit an increase or decrease in capacity relative to end of drive conditions defined as *set-up* or *relaxation*, respectively.

- Set-up is beneficial to pile performance; relaxation is not.

- The mechanism of pile relaxation has been attributed to dilative soil conditions that cause negative pore pressure making the soils respond stronger during driving (until the pore pressure dissipates).

Pile Relaxation

- Case studies have shown restrikes have regained capacity in as little as 0.5in or as much as 7 ft.

- Large displacement required to regain capacity is likely to be caused by negative pore pressure

- Small displacements required to regain capacity could be due to concrete creep/shortening

- Creation of a database to include all information from PDA EOID and Restrikes is the primary effort (Task 2)

Problem Statement

*Relaxation is the reduction in pile capacity with time. It is a phenomenon that has been observed in several projects, especially Design Build projects as a result of verification testing. There have been reported cases in which over **25% of the original measured capacity has been lost** after initial pile driving. Currently the Department **does not have a methodology** to assist designers estimate relaxation (protocols for In-Situ testing or laboratory testing), nor a process to establish a pile driving criteria to accept piles during construction when relaxation occurs. **This creates delays, extra testing and extra costs** during construction, especially because the problem is typically found after pile driving begins. In most cases the issue has been resolved by additional driving until the piles reach a stable bearing layer.*

Objectives

- The primary focus of this study is to document as many cases as possible from within the state of Florida where pile relaxation has been experienced.

- Determine what soil types and conditions are likely to create relaxation conditions

- Part 2?: to determining appropriate field and lab testing and/or protocols suitable for construction and design.

Revised Approach

- Collect any restrike data sets to show where both set-up and relaxation might occur

Work Tasks

- Task 1: Literature Search
- Task 2: Data Collection (data mining of the FDOT EDMS)
- Task 3: Data Analysis
- Task 4a: Draft Final Report
- Task 4b: Closeout Meeting / Presentation
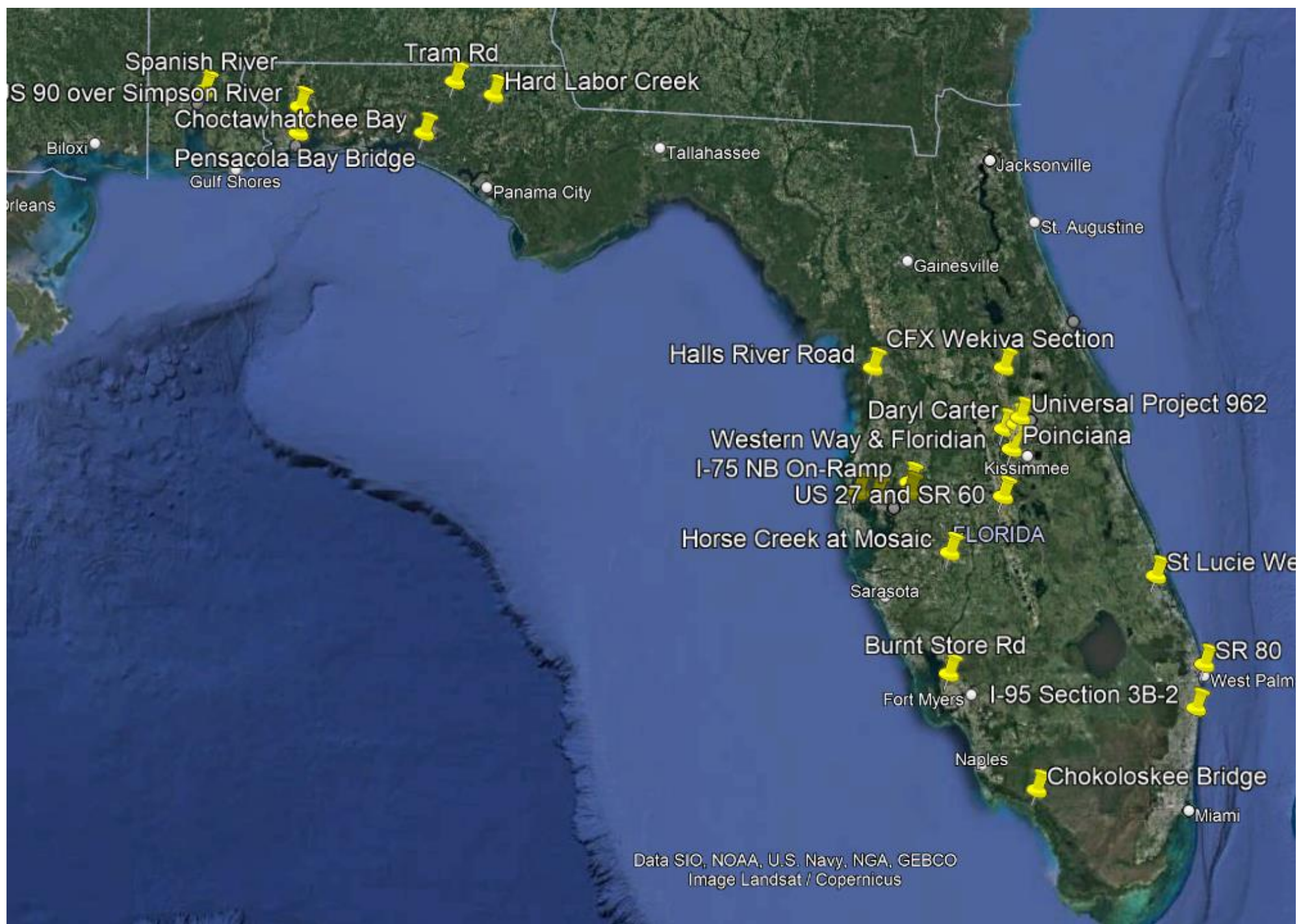- Task 5: Final Report

Work Tasks

- **Task 1: Literature Search (Completed)**
- Task 2: Data Collection (data mining of the FDOT EDMS)
- Task 3: Data Analysis
- Task 4a: Draft Final Report
- Task 4b: Closeout Meeting / Presentation
- Task 5: Final Report

Work Tasks

- Task 1: Literature Search
- **Task 2: Data Collection (in progress)**
- Task 3: Data Analysis
- Task 4a: Draft Final Report
- Task 4b: Closeout Meeting / Presentation
- Task 5: Final Report

Task 2 Data Collection

- 948 piles evaluated (EOID and Restrikes)
- 185 boring logs (some piles have same boring)
- 21 bridge sites throughout the state; 6 districts

Collected Data Types

- Pile
  - Manufacturer
  - Number
  - Length
  - Size
  - Type
  - Acceptance
  - Date Cast
  - Plumbness

- Hammer
  - Type
  - Rated E (k-ft)
- Boring Logs
  - SPT Counts
  - Soil Type
  - Soil Depth

- Ground Elevation
- Tip Elevation
- Time Driven
- Time Checked
- Total Drive Time
- Total Stopped Time
- Wave Speed

Collected Data Types

- Driving Records EOD
    - Blow Count
    - BLC (bl/ft)
    - RMX Values (RX4-RX8 depending on what is available) (kips)
    - CSX (ksi)
    - CSB (ksi)
    - STK (ft)
    - EMX (k-ft)

- Driving Records Restrike
    - Final and Max EMX of RS
    - Blow Count
    - BLC (bl/ft)
    - RMX Values (RX4-RX8 depending on what is available) (kips)
    - CSX (ksi)
    - CSB (ksi)
    - STK (ft)
    - EMX (k-ft)

Database at 948 piles currently

Sample Pile Installation Information

Howard Frankland Bridge - End Bent 1-1 Pile 3 15DSC Double Splice   30" PSC Pile Total Length 220ft.
OP: DFC/BF   Date: 13-July-2022

AR:	900.00 in²		SP: 0.150 k/ft³
LE:	215.00 ft		EM: 5,813 ksi
WS:	13,400.0 f/s		JC: 0.60

RMX: Maximum Case Method Capacity (JC)   DMX: Maximum Displacement
CSX: Compression Stress Maximum   ETR: Energy Transfer Ratio - Rated
TSX: Tension Stress Maximum - Full Record Search   BTA: Integrity Factor (1)
EMX: Maximum Energy   TLS: Tension Stress at Splice
STK: Hammer Stroke

BL#	Depth ft	BLC bl/ft	TYPE	RMX kips	CSX ksi	TSX ksi	EMX k-ft	STK ft	DMX in	ETR (%)	BTA (%)	TLS ksi
1	139.01	72	AV1	1,457	2.8	0.4	64.6	9.58	0.44	26.1	83.0	0.00
2	139.03	72	AV1	1,444	3.0	0.4	75.6	10.24	0.49	30.5	82.0	0.00
3	139.04	72	AV1	1,388	2.9	0.4	69.5	10.13	0.44	28.0	80.0	0.00
4	139.06	72	AV1	1,389	3.1	0.4	79.7	10.52	0.51	32.1	81.0	0.00
5	139.07	72	AV1	1,350	3.2	0.4	84.7	10.92	0.52	34.2	80.0	0.00
6	139.08	72	AV1	1,290	3.1	0.3	80.6	10.60	0.55	32.5	80.0	0.00
7	139.10	72	AV1	1,295	3.1	0.4	79.0	10.30	0.54	31.8	79.0	0.00
8	139.11	72	AV1	1,314	3.1	0.4	79.9	10.48	0.51	32.2	79.0	0.00
9	139.13	72	AV1	1,290	3.1	0.4	77.4	10.52	0.50	31.2	79.0	0.00
			Average	1,357	3.0	0.4	76.8	10.37	0.50	31.0	80.3	0.00

Total number of blows analyzed: 9

Exceed NBR (→ 1,457)

Average = 1,372 kips (→ RMX column)

All exceed 90% NBR (→ 1,314)

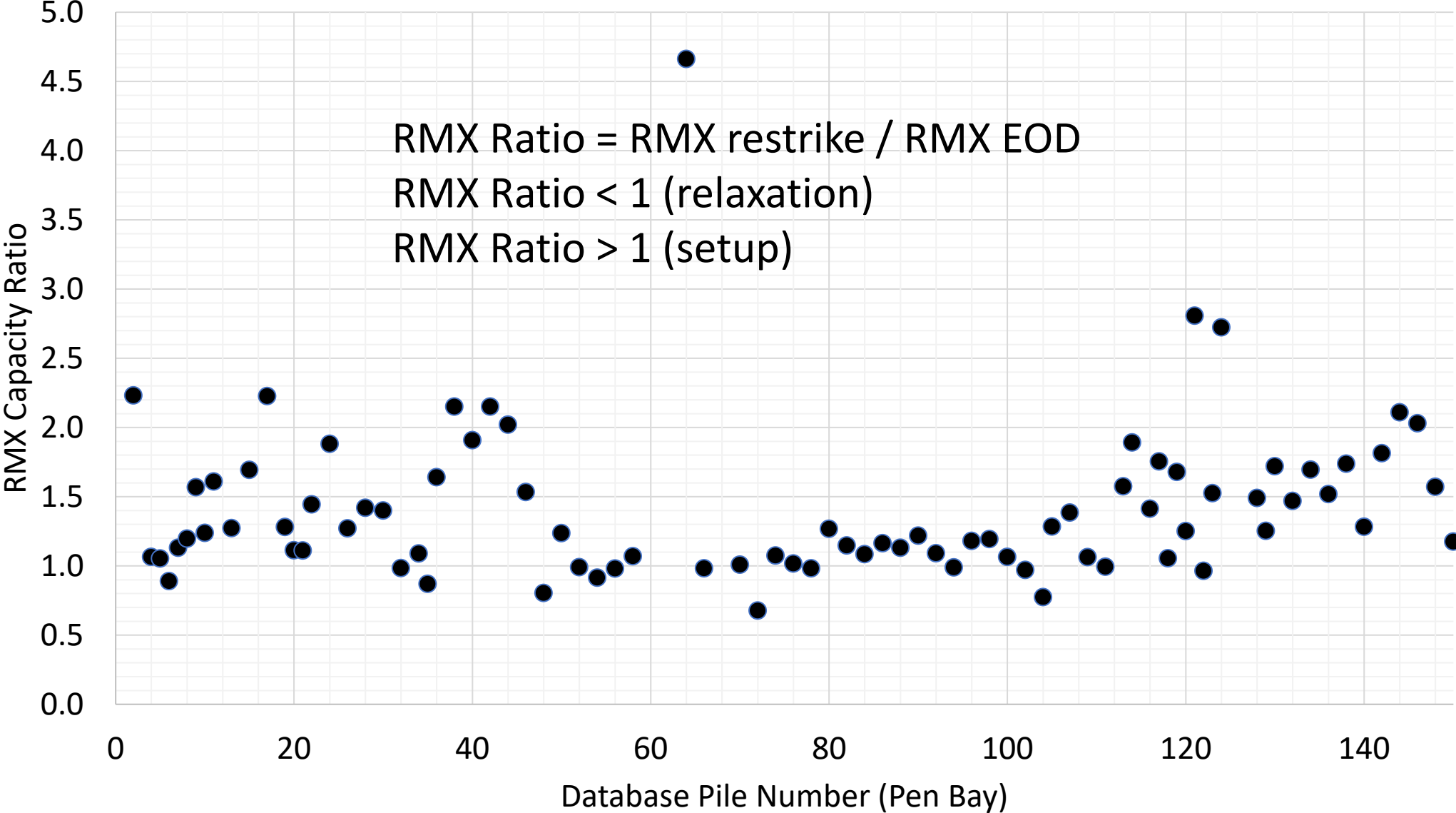RS Instance vs. Hours Driven after Initial Drive (n=910)
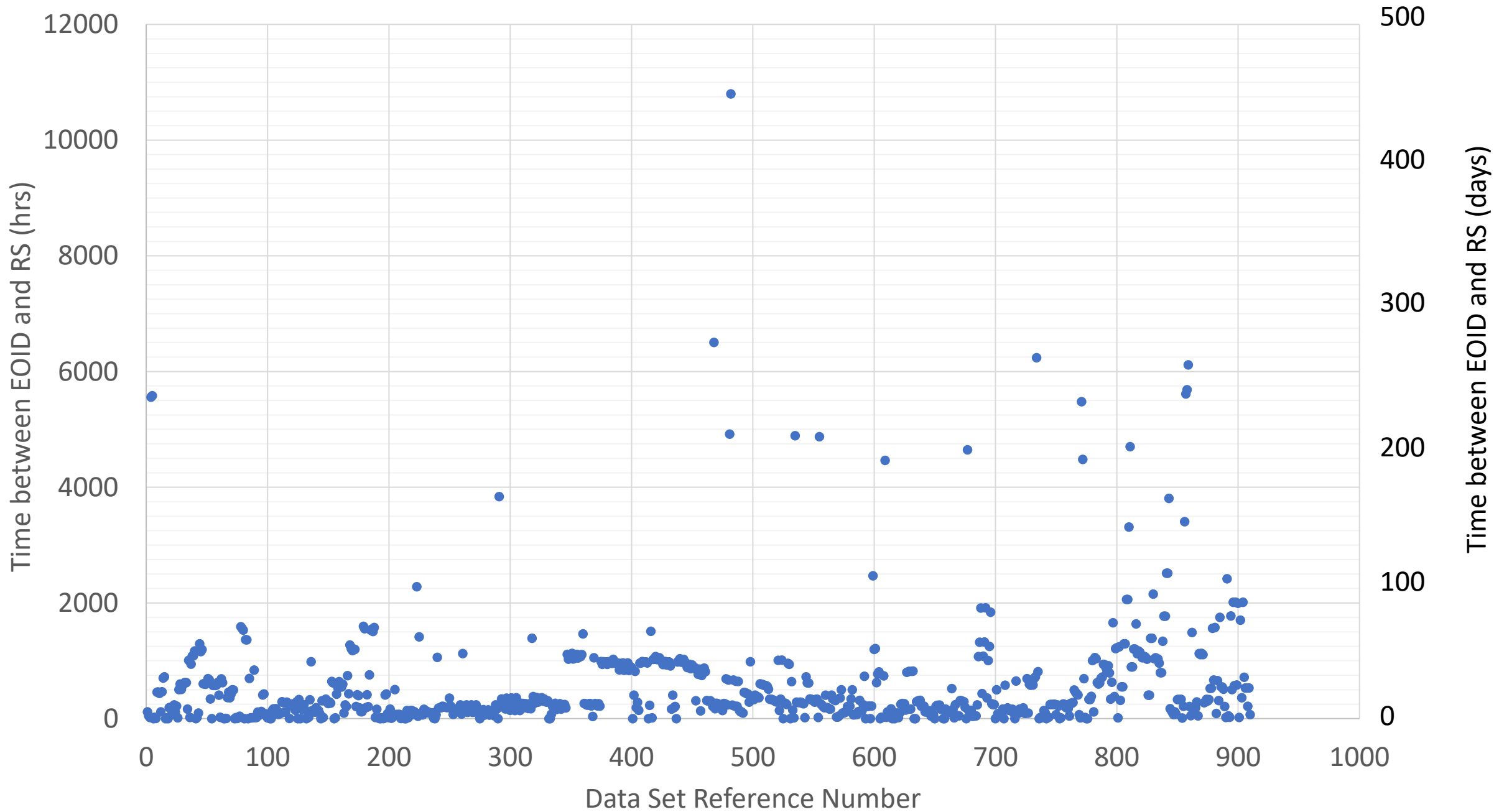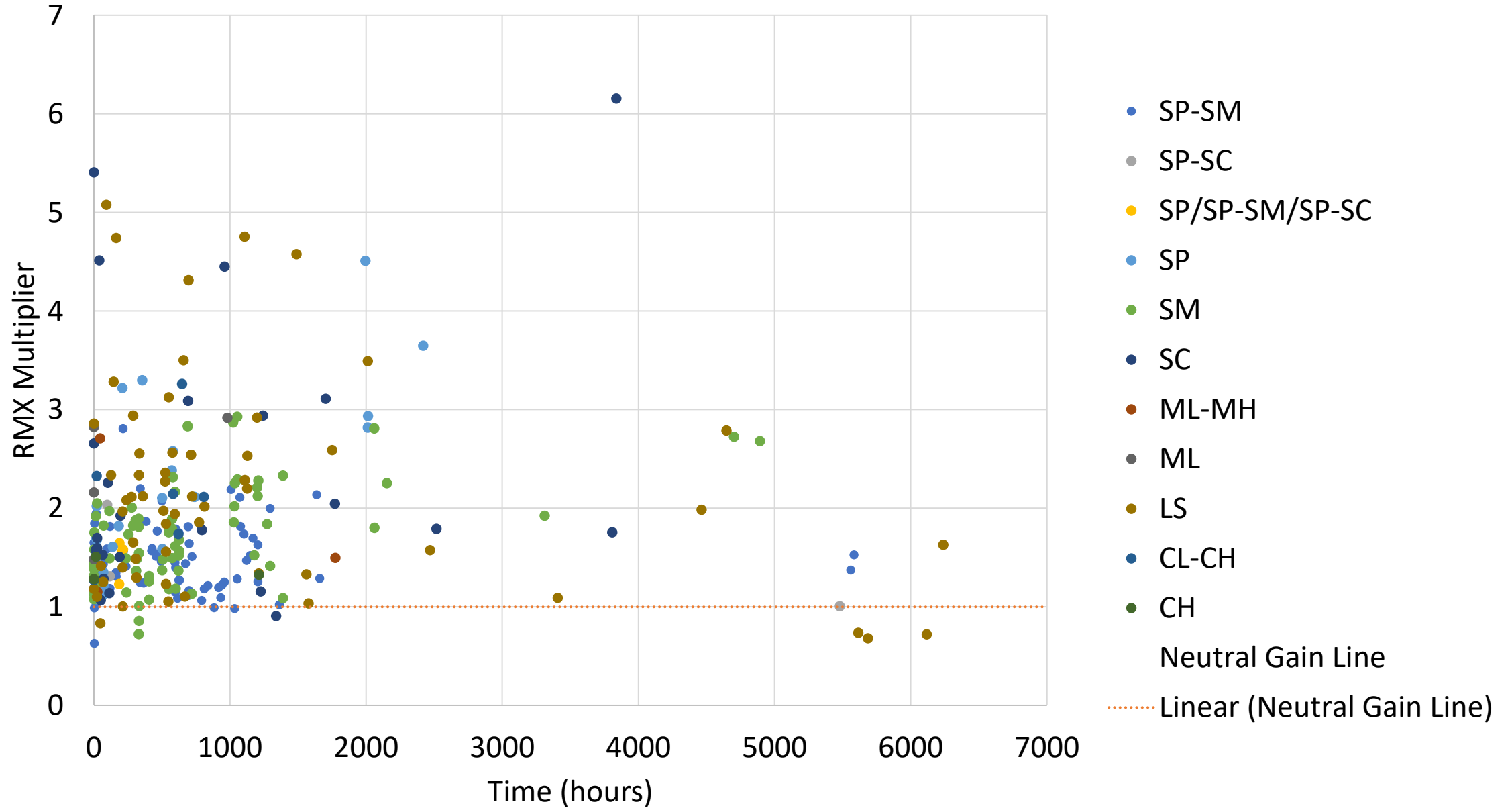
Bearing Strata Soil Types (n=839)
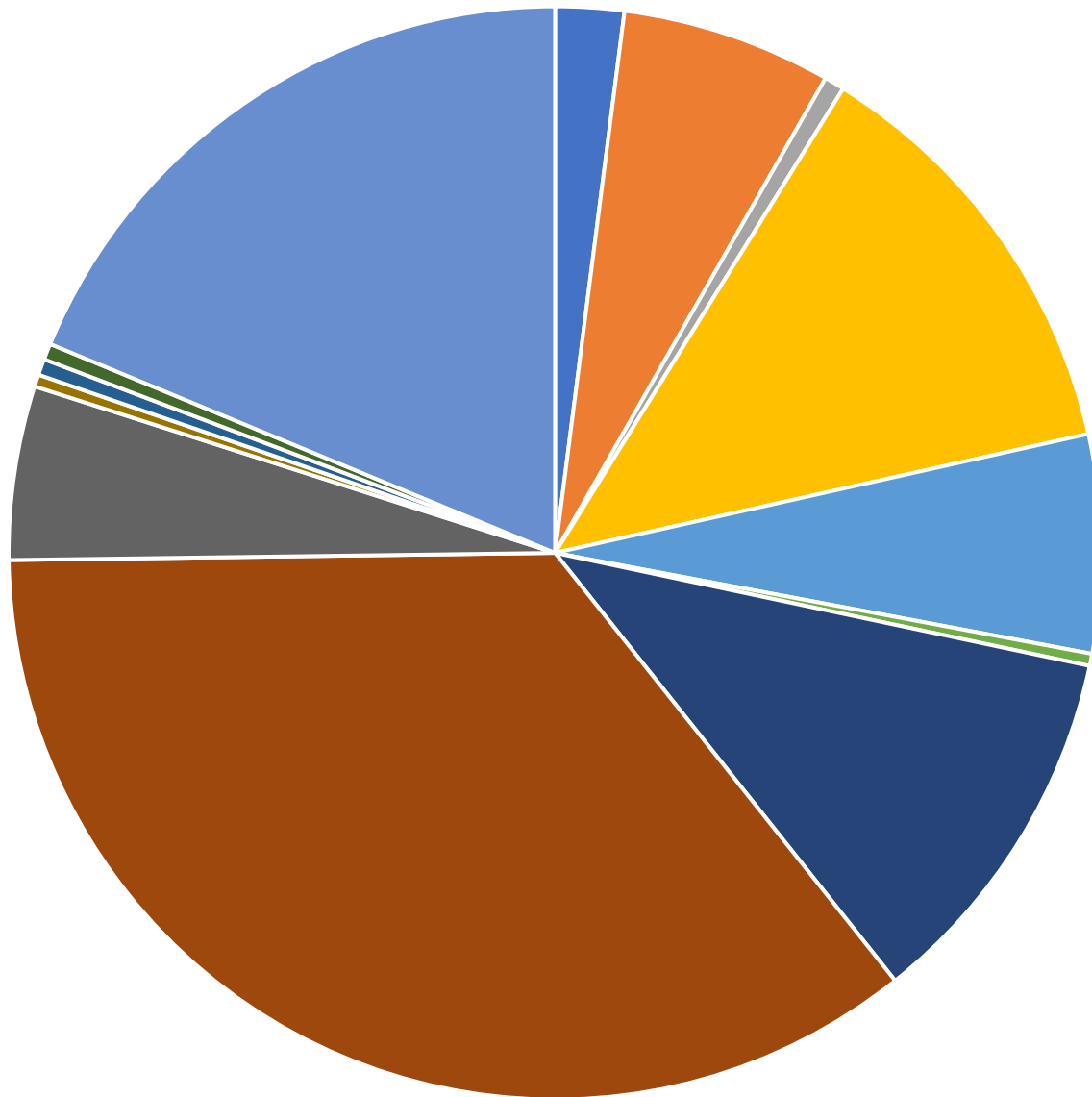
Legend:
- CH
- CL
- CL-CH
- LS
- ML
- ML-MH
- SC
- SM
- SP
- SP/SP-SM
- SP/SP-SM/SP-SC
- SP-SC
- SP-SM

Example Restrike Capacity Ratio (Pen Bay)

RMX Ratio = RMX restrike / RMX EOD
RMX Ratio < 1 (relaxation)
RMX Ratio > 1 (setup)

RMX Multiplier vs Set Time (n=895)
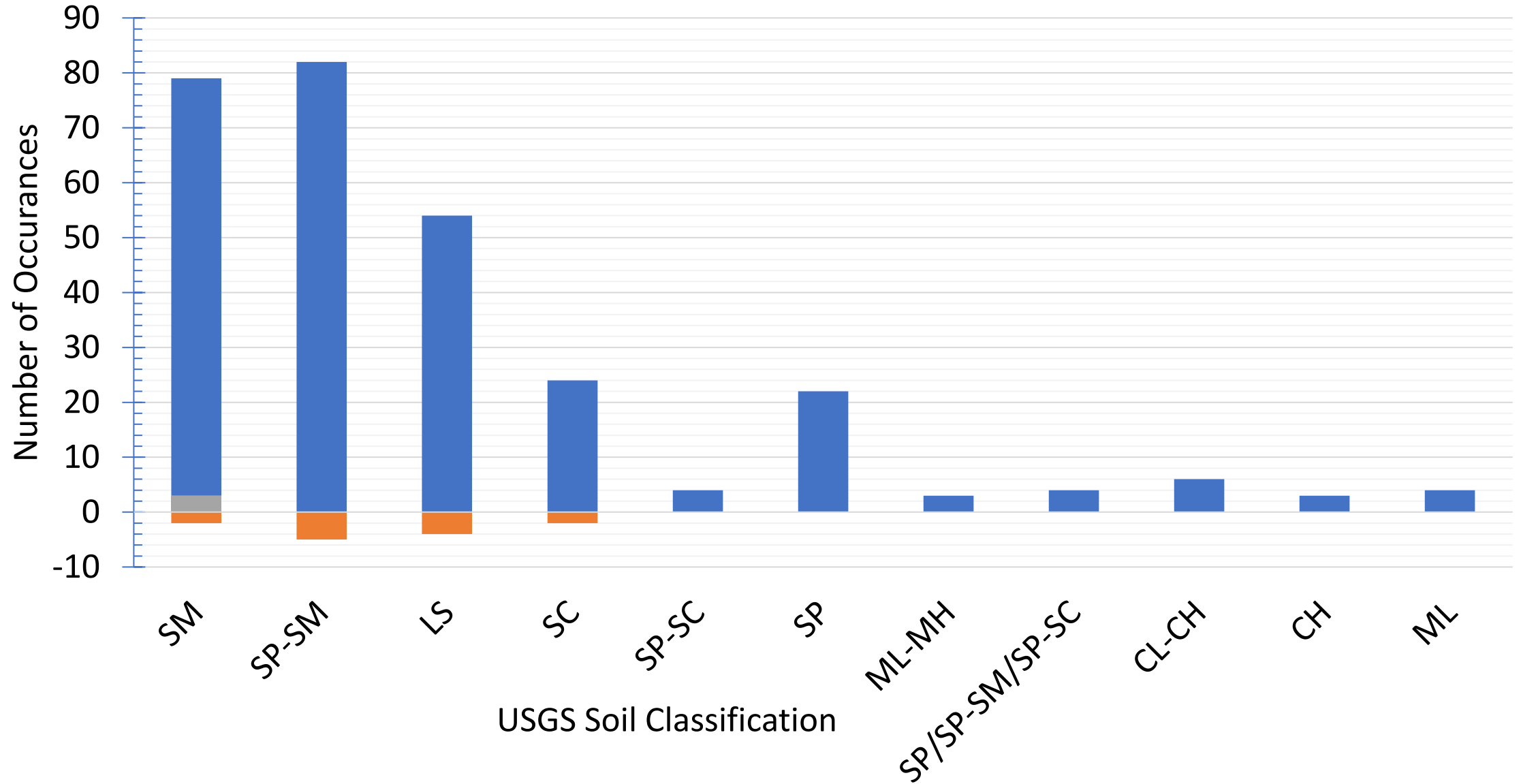
RMX Ratio vs. EMX Ratio (n=298)

Relaxation

Setup

The check here is to see if an equal or more energy was imparted when Relaxation occurred. This would suggest the restrike was not hit hard enough

EMX Ratio

RMX Ratio

- CH
- CL-CH
- LS
- ML
- ML-MH
- SC
- SM
- SP
- SP/SP-SM/SP-SC
- SP-SC
- SP-SM

Strength Gain / Lost per Bearing Soil Type

Update on Work Performed

- Data continues to be collected and processed

- Data collection more difficult than expected

- Data mining using Python code is now in progress

- Data numbers are expected to be into the thousands
  - examples
  - US331 (Choctawhatchee) has 1300 restrike documents from 85 piers
  - Howard Frankland has 400 restrike documents from 113 piers
  - Pensacola Bay 119 piers

Timeline / Schedule

Deliverable # / Description as provided in the scope (included associated task #)	Anticipated Date of Deliverable Submittal (month/year)	TO BE COMPLETED BY RESEARCH CENTER (performance monitoring)
Project Kickoff Teleconference / Presentation webinar	4/2022	
Task 1: Literature Search Deliverable 1 – a written report providing a summary of literature collected and gaps in the literature	9/2022	
Task 2: Data Collection Deliverable 2 – a written report providing a summary of case studies will be submitted.	8/2023	
Task 3: Data Analysis Deliverable 3 – a written report providing the results of the data analysis will be submitted.	1/2024	
Deliverable 4a – Draft Final Report – Ninety (90) days prior to the end date of the contract, the university will submit a draft final report. The draft final report will contain at a minimum a description of all the work conducted, a discussion of the test results, final conclusions and recommendation, and related documents.	1/2024	
Deliverable 4b – Closeout Meeting / Presentation	3/2024	
Deliverable 5 – Final Report	4/2024	