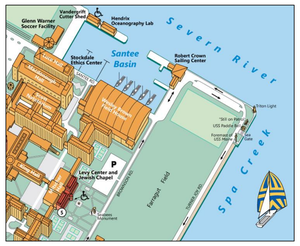
Sailing Center: Deep Foundation Pile Design

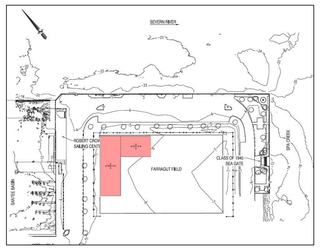
1/C Jacob D'Amico, Alistair Larson, Connor McKee, Jules Pellei
CDR Magoulick, Department of Ocean Engineering

Abstract

Anticipated sea level rise in Annapolis necessitates the development of highly resilient coastal infrastructure. Aligning with the Public Works Department's 30 and 100-year resilience plans, this project develops a structural deep-pile foundation design for the planned combining of the Robert Crown Sailing Center and Hendrix Oceanographic Laboratory to be located on Farragut Field.



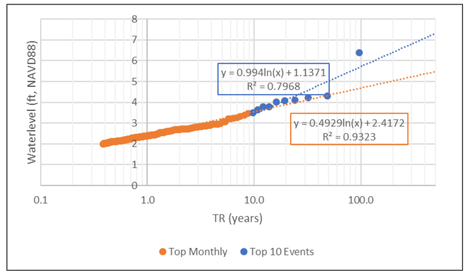
Naval Academy Grounds



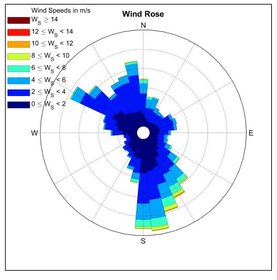
Building Orientation on Farragut

MetOcean Analysis

1. Analysis of Site: The team executed a site visit and analyzed boring samples from the man-made Farragut Field.
2. Data Processing: Water level return plots and wind roses were constructed from historical data at Buoy Station APAM2 - 8575512, located within the neighboring Santee Basin.
3. Design Selection: Four design alternatives were proposed and weighted using a decision matrix. An L shaped design was selected due to its optimization of weight dispersion, requiring the least enviornmental impact, and easiest rerouting of already existing plumbing and electrical lines.
4. Calculations and Modeling: dead/live loads, skin friction and pile quantity were calculated. COMSOL was used for finite element analysis and SolidWorks used for architectural drafting.



Projected Sea Level Rise For Annapolis



2024's Wind Rose From Station APAM2

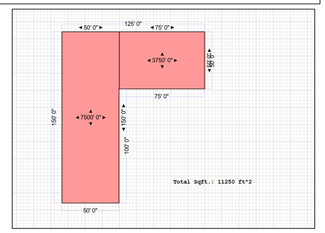
Calculations

$$Unfactored\ Load = \Sigma Live\ Loads + \Sigma Dead\ Loads$$
$$UFL = (225\,psf) + (210\,psf) = 435\,psf$$
$$Total\ Weight\ (W) = UFL \times Square\ Footage$$
$$W = 435\,psf \times 11,250\,ft^2 = 4,893,750\,lbs$$

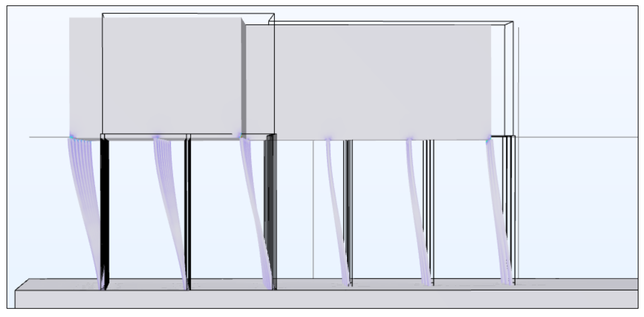
Meyerhof Equation for Point Resistance:

$$q_p = 0.4(N_{60})(\tfrac{L}{D}) \le 4(N_{60}) \qquad (\tfrac{L}{D}) = (\tfrac{85}{1.167}) = 72.8\ (larger\ than\ governing\ value\ of\ 10)$$
$$q_p = 4(N_{60}) = 4(40)$$
$$q_p = 320ksf\ or\ 320,000\ lb/pile$$
$$Q_p = (320ksf)(1.36ft^2) = 435.84\ kips$$

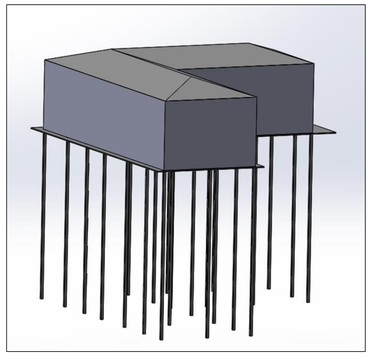
Safety Factor	3	2.5	2.0
Q_a (*kips*)	$\frac{435.8}{3} = 145.1\ kips$	$\frac{435.8}{2.5} = 174.88\ kips$	$\frac{435.8}{2} = 217.68\ kips$
Minimum # of piles (*rounded up to nearest whole pile*)	$\frac{4,893.75}{145.1} = 34$	$\frac{4,893.75}{174.88} = 28$	$\frac{4,893.75}{217.68} = 23$
$Q_{effective} = \frac{W}{min\ \#\ piles}$	$\frac{4,893.75}{34} = 143.93\ kips$	$\frac{4,893.75}{28} = 174.80\ kips$	$\frac{4,893.75}{23} = 212.77\ kips$



Proposed Design and Footprint



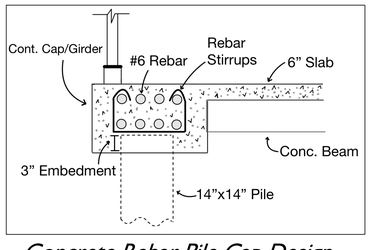
COMSOL Deformation Model, Scale of 6



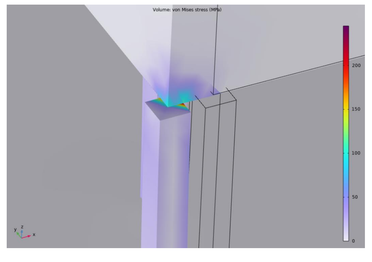
Solidworks Building Model

Results

1. **Foundation Piling: 28–34 piles** (Factor of Safety: 2.5–3.0) driven to **85.5 ft**. This depth is required to bypass the unconsolidated top 44 ft of soil, which loses structural integrity during a 100-year storm.
2. In accordance with UFC and ASCE 7-22 requirements, the foundation sustains a building weight of just under **5 million lbs**.
3. The foundation can withstand a base shear of **41.55 psf** and an upward wind thrust of **19.2 psf** due to hurricane force winds.
4. A 6 inch slab of concrete will be supported with beams consisting of 6 inches and pile caps that are 1 foot thick. Pile's will be embedded 3 inches into the cap.



Concrete Rebar Pile Cap Design



Magnified Stress Concentration (COMSOL Model)

Conclusion

A resilient, compliant baseline foundation prototype was successfully engineered for the consolidated facilities. Adhering to ASCE and UFC codes, structural survivability, and operational continuity against 100 year storm conditions and projected sea level rise were ensured.

Future Investigations

Conduct *in situ* pile load testing to reduce the needed compliance to the overall Factor of Safety, thereby optimizing the final pile count and lowering costs. Develop logistical solutions to mitigate the loss of parking spaces displaced by the new footprint.

Acknowledgements

- Thank you to Joe Zurzolo (PWD Annapolis) for providing floor plan and boring sample data.
- Thank you to Professor Metzger for assisting in beam and pile cap calculations. Thank you to Professor Radice for COMSOL assistance.
- Thank you to CDR Magoulick as Technical Advisor, and Doctor Gish as Project Advisor.

Link to References