1.1 Background/Objectives

The development of renewable energy from marine environments has emerged as a significant area of research and technological advancement, driven by the need to reduce reliance on fossil fuels, mitigate carbon emissions, and meet increasing global energy demands. Offshore renewable energy (ORE) systems, including wave and tidal technologies, whether floating or bottom-fixed, require reliable foundation and anchoring solutions capable of withstanding both operational and extreme loading conditions. As the ORE sector continues to expand, there is a growing demand for high-performance anchoring systems that enhance both the economic feasibility and structural reliability of these deployments.

1.2 Approach/Activities

The Retrievable Ocean Petal Anchor (ROPA) is a novel anchoring concept developed to support offshore marine renewable energy devices. The system is designed to minimize installation noise and accommodate complex, multidirectional loading conditions. ROPA consists of petal elements that remain folded during installation and expand radially upon deployment, thereby increasing anchorage capacity. Installation is achieved through soil fluidization using a high-pressure seawater jet, allowing the anchor to reach the desired embedment depth prior to petal deployment. Following installation, dissipation of excess pore water pressure generated during jetting enables the surrounding soil to regain strength, thereby providing resistance to applied loads. The retrieval process is intended to reverse the installation sequence. To evaluate the feasibility of this system, a series of laboratory experiments were conducted on fixed-petal ROPA models with petal angles of 10° and 30°, with results compared against a plain pile used as a reference. Testing was performed in a large-scale test pit (10 ft in diameter and 20 ft deep) filled with fine sand at the Constructed Facilities Laboratory at North Carolina State University. The experiments focused on assessing axial performance under both compression and uplift loading conditions.

1.3 Results/Lessons

The experimental findings indicate that the inclusion of petal elements significantly enhances the axial capacity of a plain pile under both compression and uplift loading conditions. The uplift capacity increased from less than 0.5 kips for the plain pile to approximately 1.5 kips for the configuration with 30° petals. The results also demonstrate the strong influence of petal angle on anchor performance, with larger angles leading to increased capacity due to the mobilization of a greater volume of surrounding soil during loading (e.g., 30° compared to 10°). These observations provide valuable initial insights into the geotechnical behavior of ROPA systems at the model scale. The findings can support future efforts in scaling analyses, numerical modeling of additional parameters, and the development of analytical design approaches for practical offshore applications.