Research Summary

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Project Information

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Research Administration

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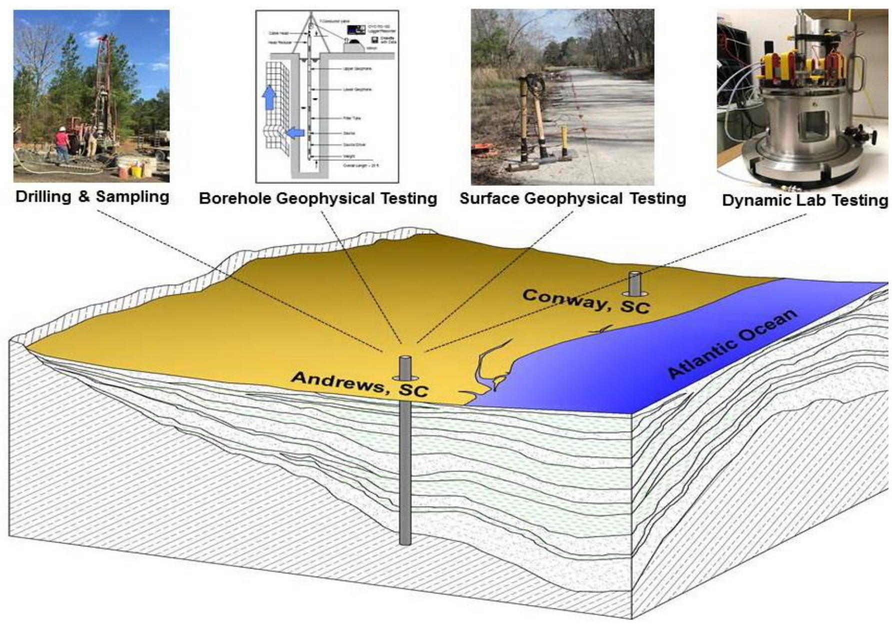
This final report is available online at:
http://www.scdot.scltap.org/projects/completed/

Deep Soil Test Borings to Determine Shear Wave Velocities Across South Carolina

South Carolina has one of the most challenging geological settings in the world. Near the coastline, the hard bedrock is very deep and can be several thousand feet below the ground surface. Sediment deposits above the hard bedrock are highly variable and pose uncertainties in designing for earthquakes. This project addresses the challenges by measuring deep soil and rock properties to depths of 505 and 615 feet deep at sites in Horry and Williamsburg counties. Advanced geotechnical and geophysical testing methods were implemented to assess engineering soil and rock properties and behaviors that can be used for future design of critical infrastructure in

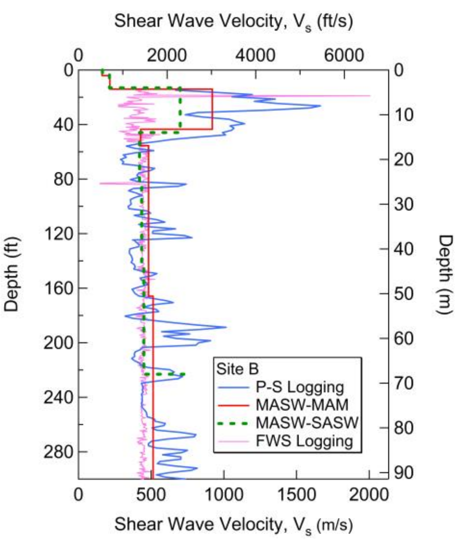


Problem

Having an accurate shear wave velocity profile and a better understanding of the dynamic behavior of deep soil deposits in the South Carolina Coastal Plain are critical for seismic hazard analyses of important transportation infrastructure. This report presents a study that obtained comprehensive field and laboratory measurements of shear wave velocity and dynamic soil behaviors for two sites in the South Carolina Coastal Plain where data was very limited. The developed shear wave velocity profiles obtained from several geophysical methods were compared, and the performance of these different methods was evaluated. Empirical predictions of dynamic soil behaviors were also evaluated to assess the accuracy of prediction methods typically used for South Carolina Coastal Plain.

Research

Geotechnical borings were drilled to depths of 505 and 615 ft at two locations to perform extensive geotechnical and geological site characterization. Site A is located near Conway in Horry County and Site B is located in Andrews in Williamsburg County. Shear wave velocity profiles were generated for the two sites using P-S suspension logging, full waveform sonic logging, combined multi-channel analysis and spectral analysis of surface waves (MASW-SASW), and combined multi-channel analysis of surface waves and microtremor array measurement (MASW-MAM) methods. Soil and rock samples were collected from both sites for dynamic characterization in the laboratory using resonant column and torsional shear testing methods. Shear modulus and damping behaviors were measured over a wide range of strains.



Shear Wave Velocity Profile for Site B

Results

Overall, the average shear wave velocities obtained from the surface methods within the top 200 ft were lower than that of the P-S suspension logging data. This resulted in a different National Earthquake Hazard Reduction Program (NEHRP) site class when using the average shear wave values in the top 100 ft for Site A, but not site B. The P-S suspension logging provided detailed characteristics of the soil profile and the results agreed with the visual observation of samples. However, the P-S suspension logging method did not provide the depth of soil sediment to the top of soft rock (i.e., the B-C boundary), as the depth was below the bottom of each borehole. The results from both surface methods were in agreement within the top 220 ft. The MASW-MAM method provides deep profiling and identified an estimated depth to the B-C boundary of 580 ft for Site A and 1343 ft for Site B. Results from both surface methods show that spatial variation of both sites are high, especially for Site A. The shear wave profiles from the surface wave methods represent the average profiles over a large volume of soil; whereas, the profiles from the borehole methods represent localized profiles within the tested borehole. Results from the different methods provide understanding of the range of uncertainty in the shear wave velocity profiles that should be accounted for when performing site response analysis.

Visual observation of samples collected from both sites showed that materials were highly variable with frequent transitions between soil-like to rock-like material. Highly cemented sand or clay with thicknesses varying from a few inches to several feet were observed at several depths throughout the soil profiles. The location of these rock-like materials corresponded with the high shear wave velocities observed from the P-S logging profile.

Laboratory testing results show that dynamic behaviors of soil and rock samples deviate from the predicted behaviors obtained based on soil index properties and geologic age provided in the literature. Relatively high damping values were observed particularly at low strains and the values were significantly affected by loading frequency applied using different testing methods. The effect of soil plasticity in relation to geologic age was evaluated for the shear modulus and damping, and no clear trend was observed for Tertiary and Cretaceous soil deposits. As a result, the shear modulus and damping behaviors were not accurately predicted by index properties for these soils. It is hypothesized that cementation is likely to be a significant factor affecting the dynamic soil behavior; however, detailed evaluation of cementation in relation to shear modulus and damping was beyond the scope of this study.


Soil and Rock Samples from Site B

Value & Benefit

Data from this study can be used directly to perform site-specific site response analysis for the sites studied herein with the recommendation to perform sensitivity analyses to account for uncertainty in the shear wave velocity profiles, depth of competent rock, dynamic soil behavior, and impacts of interbedded rock and cemented layers. Predictive equations found in the literature for shear modulus and damping behaviors are not recommended for Tertiary and Cretaceous deposits because this study showed that soil plasticity and geologic age alone are not dominant factors for older soil deposits, particularly for those samples with cementation.

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