Principal Investigator Post-Experiment Report

IRIS PASSCAL Project #201841: MASW in Shallow Marine Sediments

I. Description of Field Work Executed

The United States Navy (USN) currently utilizes a Rapid Penetration Test (RPT) on both land and in water as the means to determine whether sufficient soil bearing capacity for piles in axial compression exists prior to construction of the Elevated Causeway System (Modular) [ELCAS(M)] pile-supported pier system. The USN desires a replacement for the RPT because of issues with the method incorrectly classifying soils as well as the need to have a less labor and equipment intensive method for geotechnical investigation. The Multichannel Analysis of Surface Waves (MASW) method was selected as the potential replacement for the RPT. Geotechnical data produced by the MASW method was compared to data produced by the RPT method and then compared to ground-truth pile driving records to determine whether MASW is an acceptable replacement for the RPT.

The data collection routine for this experiment consisted of conducting the MASW method at the same locations where existing RPT investigations were conducted in early 2018. 1-D shear wave profiles were developed at each RPT site utilizing the MASW method and these shear wave profiles were correlated to soil type, expected SPT blow count, and expected soil bearing capacity.

II. Location of Field Work Executed

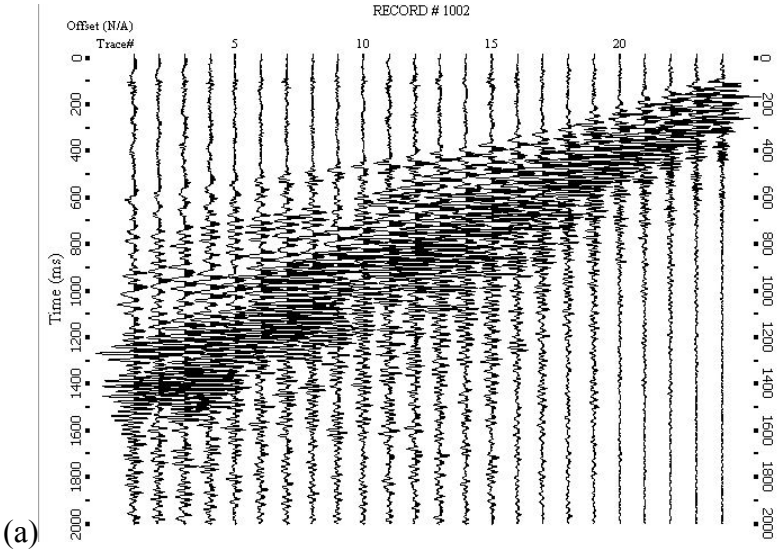
MASW was executed at the site of three existing RPT investigations in Virginia Beach, Virginia at Joint Expeditionary Base Little Creek-Fort Story The locations of the MASW locations are shown in *Figure 1*.

Figure 1. MASW Locations. (a) MASW #1: 36°55'37.5"N 76°09'53.1"W (onshore). (b) MASW #2: 36°55'38.1"N 76°09'53.0"W (surf zone). (c) MASW #3: 36°55'38.5"N 76°09'52.4"W (offshore)

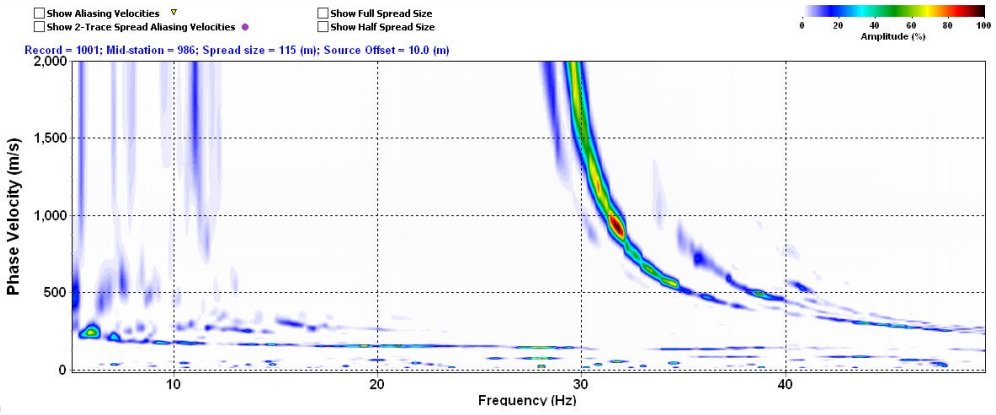
Surfseis software produced by the Kansas Geological Survey was used to perform dispersion and inversion analysis for all acquired seismic records.

III. Summary of Results

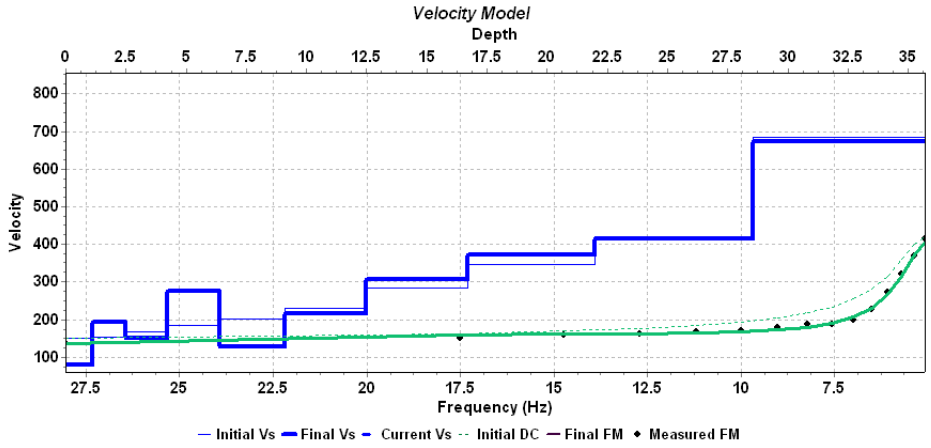
The seismic record, dispersion curve, and final Vs profile determined by the MASW method for Site #1are provided in Figure below.



(a)



(b)



(c)

Figure 2. MASW results for RPT/MASW Site #1. (a) Seismic record (b) Dispersion Curve (c) Vs profile with depth

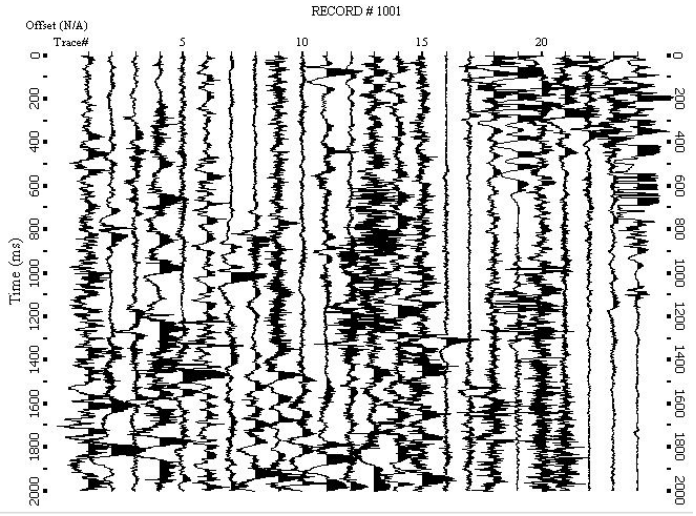
Analysis of this data by the *SurfSeis* software indicated that the overall quality of the seismic input data was excellent, the risk of contamination from higher modes was low, and that the overall sign-to-noise ratio was excellent. Comparison results are given in Table 1 below. Bearing capacity was calculated based on cohesionless soils.

Table 1

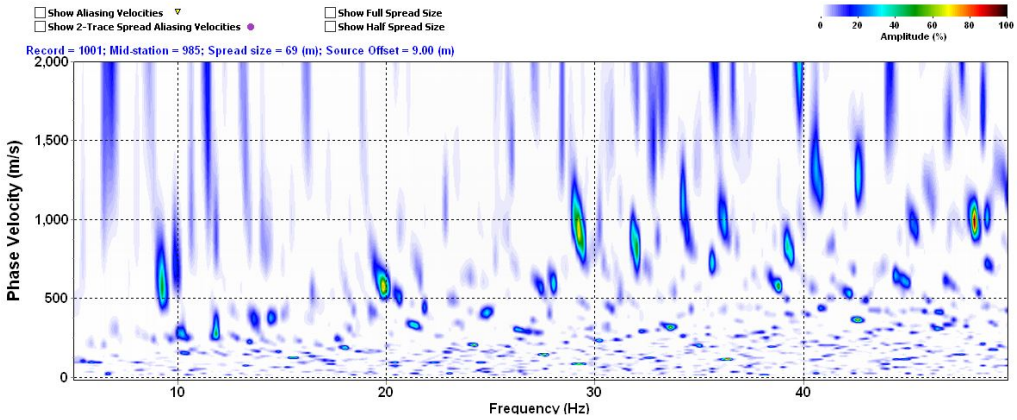
RPT/MASW Site #1: MASW, RPT, and pile driving log comparison

Investigation Method	Soil Type (USCS)	Depth @ 37 blows/ft (ft)	Bearing Capacity @ 37 blow/ft depth (tons)	Percent accuracy of depth @ 37 blows/ft as compared to pile driving log (abs | % |)
MASW	SC/SM, ML	63.4	404	~25%
RPT	SM	36.0	90	~31%
Pile Driving Log	---	51.8	---	---

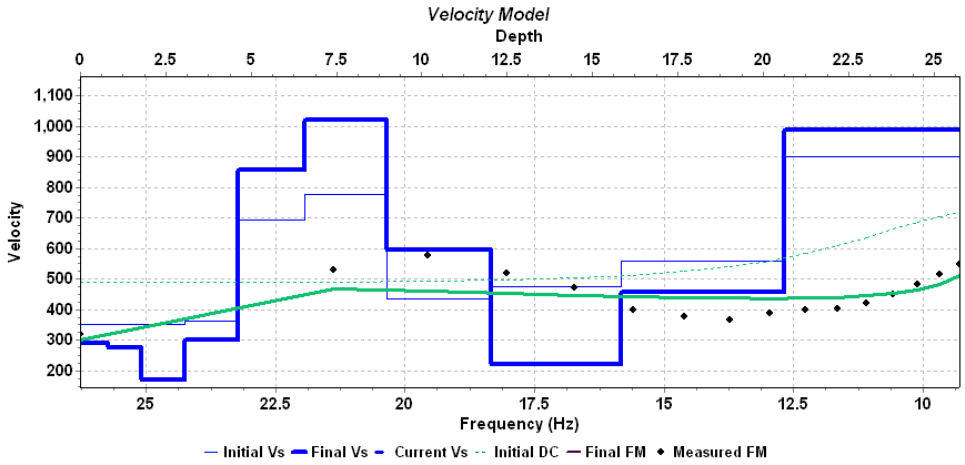
The seismic record, dispersion curve, and final Vs profile determined by the MASW method for Site #2 are provided in Figure 3 below.



(a)



(b)



(c)

Figure 3. MASW results for RPT/MASW Site #2. (a) Seismic record (b) Dispersion Curve (c) Vs profile with depth

Analysis of this data by the *SurfSeis* software indicated that the overall quality of the seismic input data was excellent and the risk of contamination from higher modes was low but that the overall sign-to-noise ratio was poor. It was difficult to perform dispersion and inversion analysis of the data at this location as there was very little trace or dispersive energy identified for the analysis. As such, it was determined that the data for this location was invalid, but an inversion analysis was still performed. Comparison results are given in Table 2 below. Bearing capacity was calculated based on cohesionless soils.

Table 2

RPT/MASW Site #2: MASW, RPT, and pile driving log comparison

Investigation Method	Soil Type (USCS)	Depth @ 37 blows/ft (ft)	Bearing Capacity @ 37 blow/ft depth (tons)	Percent accuracy of depth @ 37 blows/ft as compared to pile driving log (abs | % |)
MASW	SC/SM, ML	16.8	178	~68%
RPT	SM	18.0	120	~65%
Pile Driving Log	---	51.8	---	---

The seismic record, dispersion curve, and final Vs profile determined by the MASW method for Site #3 are provided in Figure 4 below.

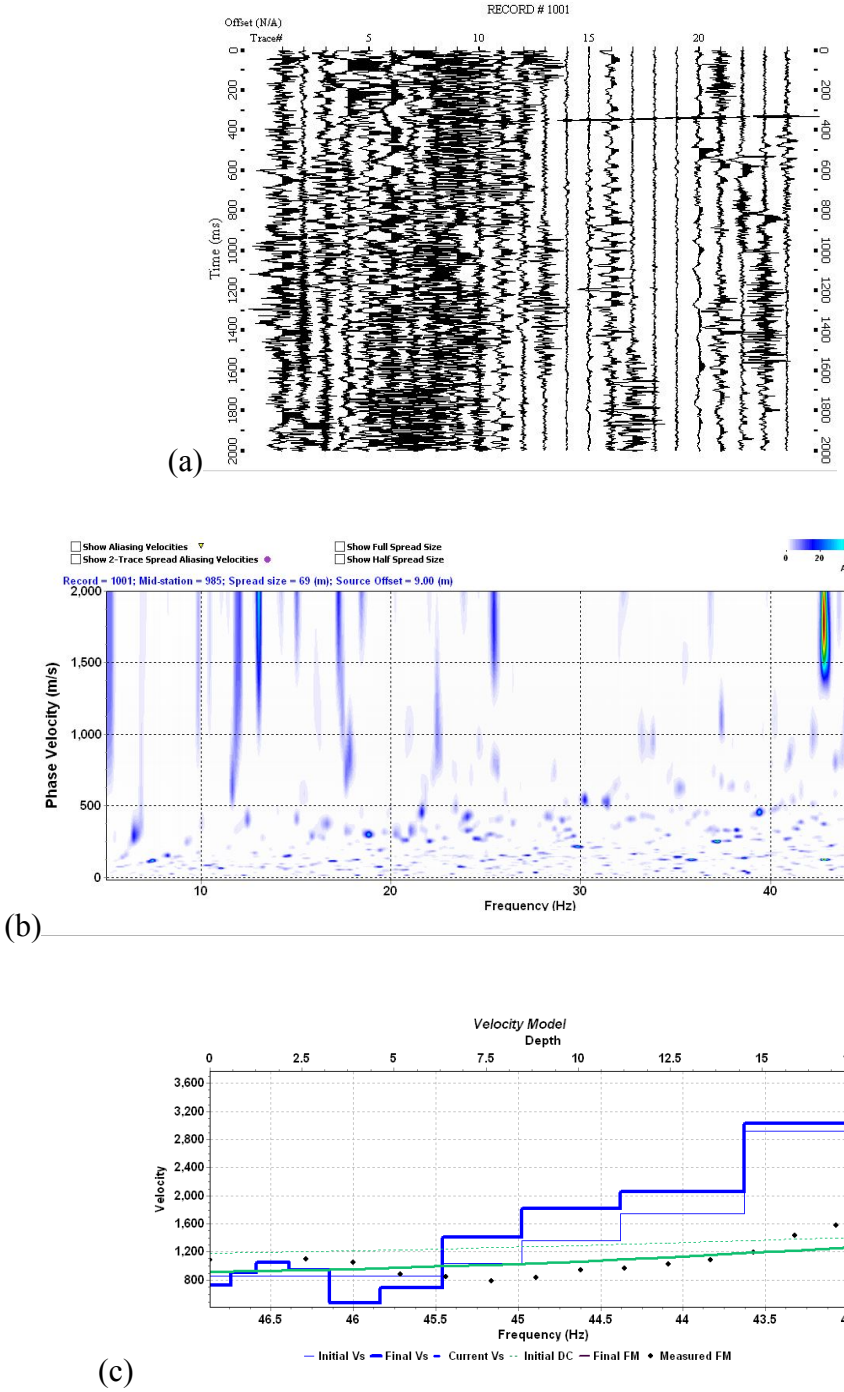


Figure 4. MASW results for RPT/MASW Site #3. (a) Seismic record (b) Dispersion Curve (c) Vs profile with depth

Analysis of this data by the *SurfSeis* software indicated that the overall quality of the seismic input data was poor, the risk of contamination from higher modes was high, and that the overall signal-to-noise ratio was poor. It was difficult to perform dispersion and inversion analysis of the data at this location, as the seismic signal was so poor, and there was very little trace or dispersive energy identified for the analysis. Furthermore, the *SurfSeis* software was unable to detect a surface wave trend in the data. As such, it was determined that the data for this location was invalid, but an inversion analysis was still performed. Inversion produced unrealistic values for Vs velocities and SPT-N blow counts. Comparison results are given in Table 6 below. Bearing capacity was calculated based on cohesionless soils.

Table 3

RPT/MASW Site #3: MASW, RPT, and pile driving log comparison

Investigation Method	Soil Type (USCS)	Depth @ 37 blows/ft (ft)	Bearing Capacity @ 37 blow/ft depth (tons)	Percent accuracy of depth @ 37 blows/ft as compared to pile driving log (abs | % |)
MASW	SC/SM/ML (assumed)	6.10	177	~88%
RPT	SM	34.0	100	~34%
Pile Driving Log	---	51.8	---	---

This researcher found that the MASW method was reliable in predicting the required properties for terrestrial sites but was not successful in predicting those properties for underwater

marine sites. Issues with equipment and field setup were determined to be the causes for the lack of success of the MASW method underwater. Future areas of improvement are recommended to address these issues and, due to the success of the method on land, it is expected that once the issues are addressed the MASW method will be a reliable replacement for the RPT method.

IV. Recommendations for future research

Based upon the confidence gained from the RPT/MASW Site #1 testing conducted on land, once the issues with executing the MASW method underwater are mitigated, and once additional field testing is executed and experience is accumulated, the MASW method has a high potential to be used as a replacement for the RPT method both from soil property determination and labor and equipment efficiency standpoints. In order to reach the level of confidence needed to replace the RPT with the MASW method, the following areas for future research and improvement are recommended:

1) Execute a series of MASW tests, RPT tests, and pile driving with supporting boring logs at the same location for a variety of sites with varying soil conditions for comparison.
2) Develop an underwater seismic source that is reliable and whose associated seismic energy production underwater is greater than the seismic energy production associated with a 20-lb hammer strike on a metal plate on land.
3) Develop a hydrophone string/streamer that is flexible enough to be transported but can also be made rigid enough during testing to allow for straight-line acquisition of seismic surveys underwater.

4) Perform further research on measures to mitigate background noise associated with water waves and underwater currents to ensure that high resolution seismic records clearly capturing the seismic surface wave trace can be produced.