Bearing Strength Comparison between STING and STING2

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Executive Summary

Data from two seabed penetrometers, STING and STING2, is compared. STING2 is designed to replace STING, so it is necessary to ensure that STING2 is functioning properly. Penetrometers are used to measure the bearing strength of a sediment. After analyzing the data collected from STING and STING2 at Boston Harbor in January 2016, the results showed that STING and STING2 had close bearing strength calculations, meaning that STING2 is indeed functioning properly. These results create confidence in the accuracy of STING2, and put researchers one step closer to replacing STING.

Introduction

In late 2015, researchers at the Naval Research Laboratory developed a new seabed penetrometer, named STING2. This new penetrometer was designed to eventually replace an older penetrometer, named STING [1]. STING contains a 1 axis accelerometer, a pressure sensor, and a temperature sensor. STING also uses proprietary software written by a company that no longer develops STING. STING2 contains two sensors, an MSR sensor, developed by MSR Electronics [2], and a Slam Stick X (SSX) sensor, developed by Mide Technology [3]. The MSR sensor contains a 1 axis accelerometer, while the SSX sensor contains a 3 axis accelerometer. Both the MSR and SSX sensors have pressure and temperature sensors. In addition, STING2 uses custom analysis software, developed in July 2016. This allows researchers to upgrade and modify STING2 as necessary, while also reflecting this change in the analysis software. Researchers would like to replace STING with STING2 because STING2 provides more data, has custom analysis software, and is a more modern device.

A penetrometer collects acceleration, pressure, and temperature from the sediment during an ‘impact’. This data is used to calculate bearing strength, a measurement of how strong a sediment is. STING and STING2 are seabed penetrometers, so they are used to determine the bearing strength of the seafloor. Bearing strength calculations are used in sediment analysis, underwater construction, and mine detection.

Developed in summer 2016 and improved in summer 2017, the STING2 analysis software reads in formatted data from the MSR and SSX sensors and uses the data to calculate bearing strength. Written in Visual Basic, the software can filter data and conveniently output all data in a single, comma separated value file. Screenshots from the STING2 analysis software are displayed in Figure 1.

Objective

The objective of this analysis was to compare the STING and STING2 penetrometers in order to determine if STING2 is a viable replacement for STING. Data for this analysis was collected from Boston Harbor in January 2016 as part of a larger experiment.

Advantages to STING2

Some advantages to a new penetrometer include: an increase in the data recording rate, newer hardware, and modifiable software. This enables researchers to not rely on proprietary hardware and software, which cannot be modified. A greater data recording rate ensures that finer details will be detected. In addition, the new bearing strength analysis software has the potential to support multiple bearing strength analysis models, which will be helpful in the future.

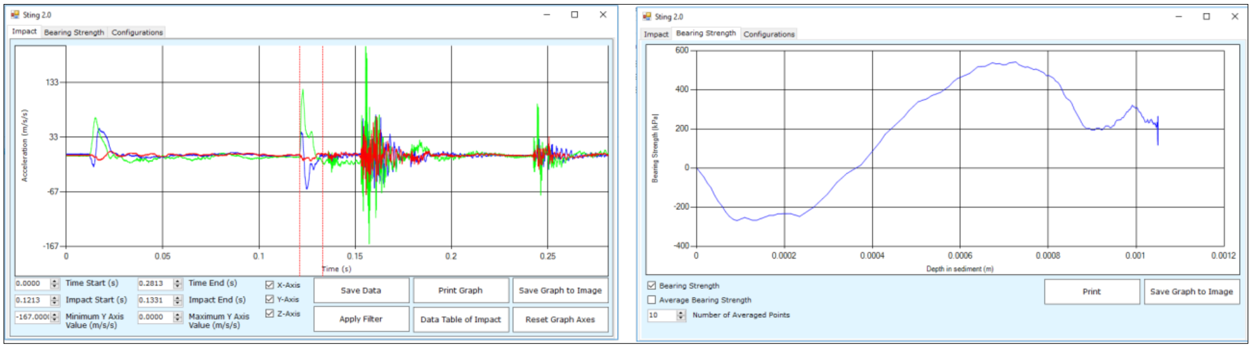

Figure 1 – STING2 Analysis software

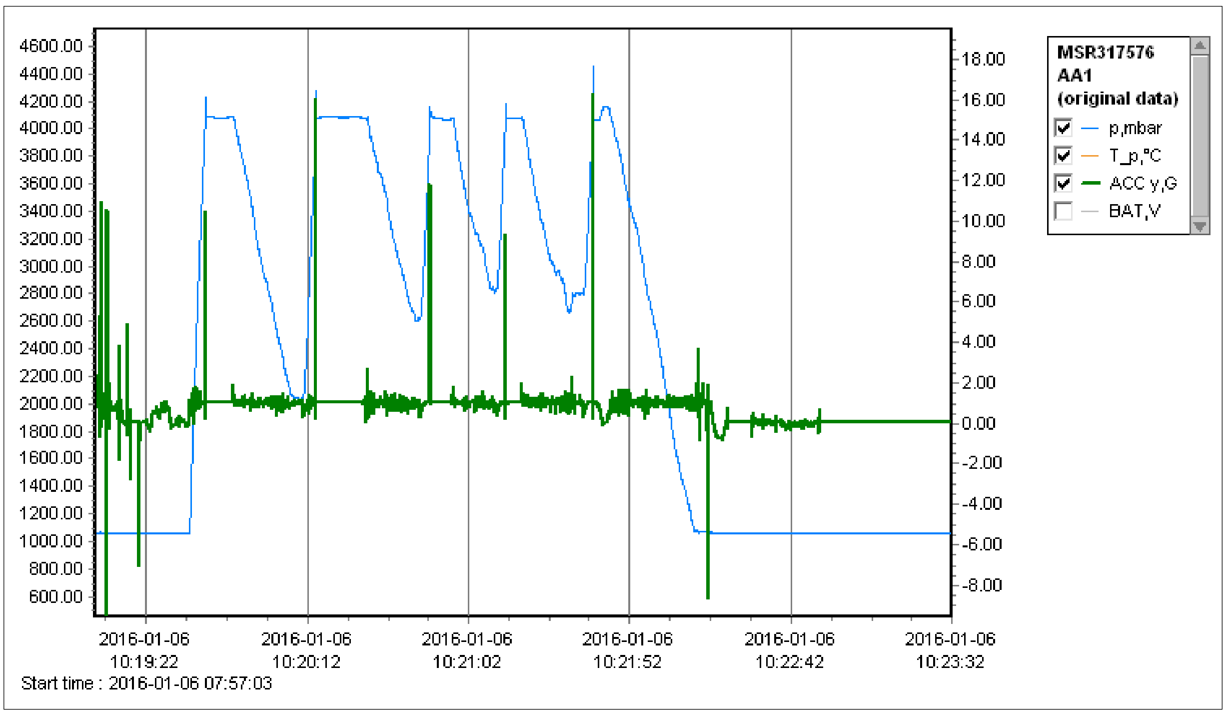

Figure 2 – MSR Data

MSR Data

Figure 2 contains some of the data collected by the MSR sensor. The blue curve shows the pressure data, while the green curve shows the acceleration data. It is clear to see a direct correlation between the upticks in accelerations and pressure. These upticks represent 'impacts', where the penetrometer is impacting the sediment. Looking at the data, it is trivial to select out impacts.

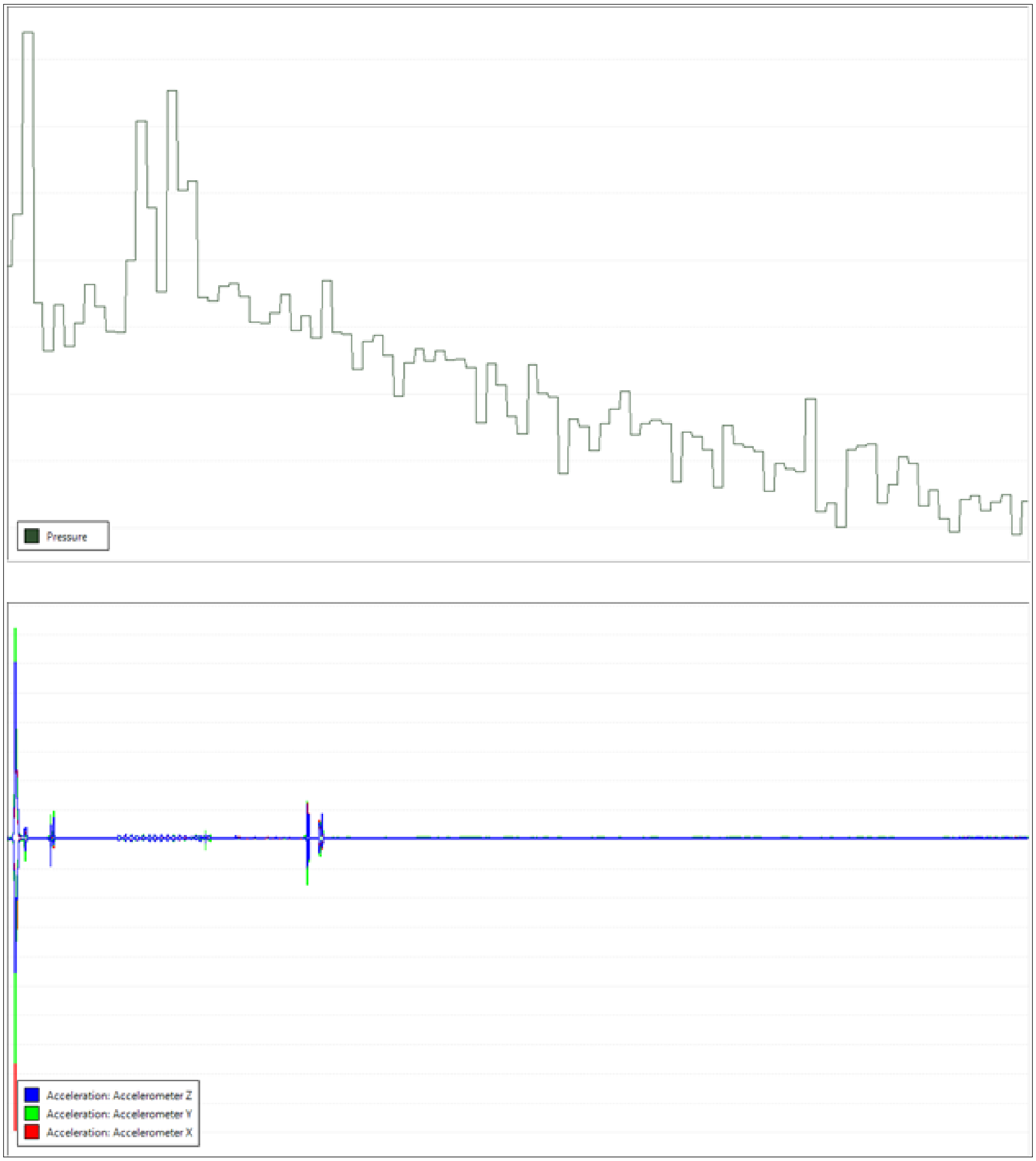

Figure 3 – SSX Pressure and Acceleration Data

SSX Pressure and Acceleration Data

Looking at the SSX acceleration and pressure data in Figure 3, there is no correlation between pressure and acceleration. The pressure sensor from the SSX is recording the pressure inside of STING2, as opposed to the MSR sensor, which is measuring external pressure, which is used to calculate sensor underwater depth estimate. As a result, pressure data from SSX cannot be used to isolate impacts. In order to select impacts from the SSX, it was necessary to rely on timestamps from the MSR impacts to give an idea of where to look for SSX impacts. There was an offset of four hours between the time series of the MSR and SSX sensors. MSR recorded data in local time, while SSX recorded in UTC. This offset needed to be taken into account when using timestamps from MSR.

Old STING impacts

Figure 4 shows a sample of a good impact collected by the STING penetrometer. Notice the 'V' shape in this impact, which is necessary to analyze the impact. The bearing strength calculation (see [1] for the derivation of the calculation) of this impact is shown in Figure 5. This calculation was performed by the old STING analysis software. This specific impact has a bearing strength of approximately 1200 kPa, with a depth of around 20 cm. It will serve as our target impact to test the STING2's accuracy.

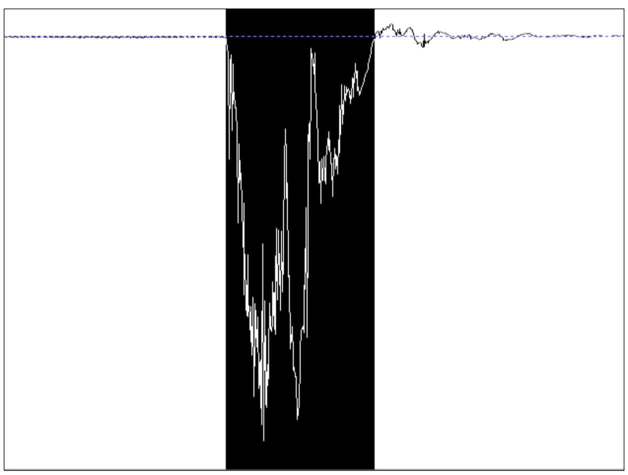

Figure 4 – Old STING impact

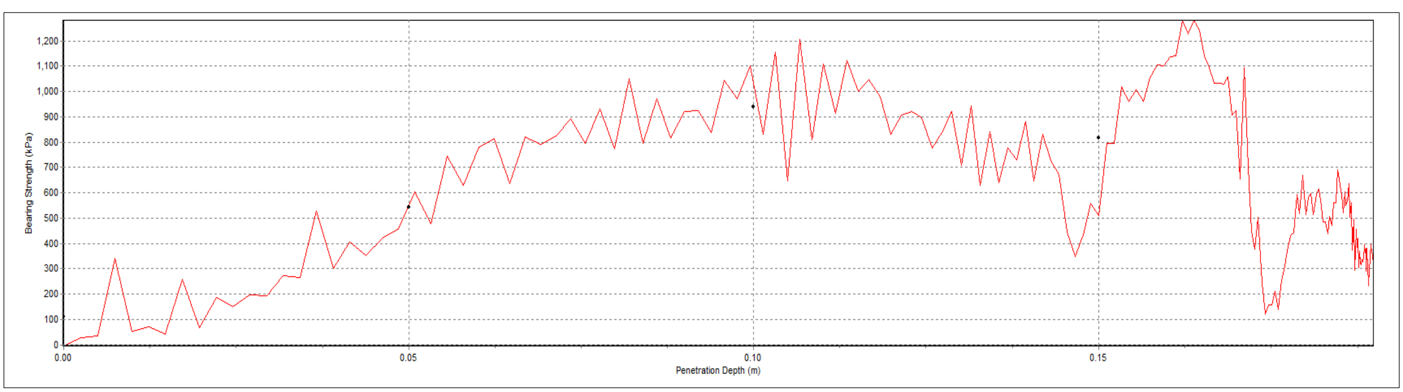

Figure 5 – Bearing Strength Calculation

STING2 impacts

An isolated impact is displayed in Figure 6. The impact's corresponding bearing strength calculation is shown in Figure 7. All of the isolated impacts have the 'V' shape that is needed for analysis. There were nine impacts from this experiment that could be analyzed. These nine impacts were compared against two impacts from STING. While there were more than two impacts from STING, the two selected impacts were dropped within 5 meters of the STING2 penetrometer. This maximizes the likelihood that STING and STING2 are dropped in similar sediment, enabling a reliable comparison.

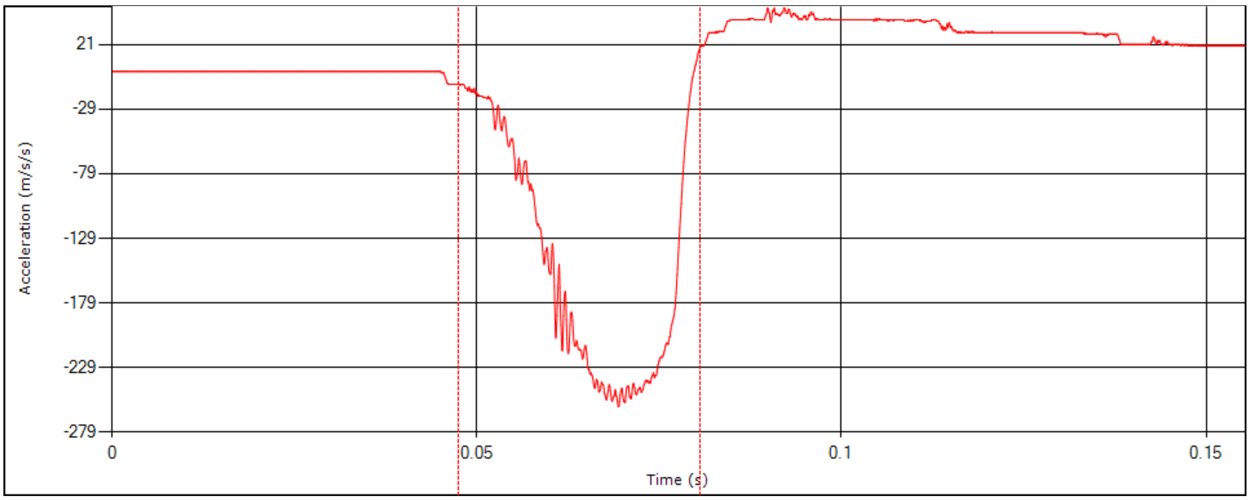

Figure 6 – SSX impact

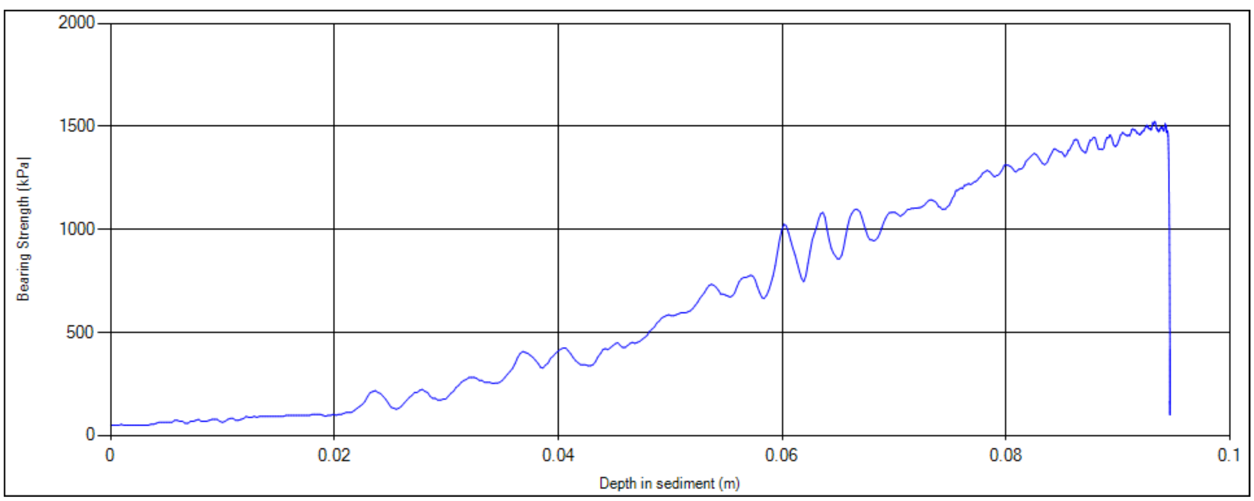

Figure 7 – Bearing Strength calculation

Impact	SSX Bearing Strength (kPa)	SSX Depth (m)
1	900	0.22
2	1000	0.24
3	800	0.07
4	500	0.12
5	1500	0.095
6	2000	0.18
7	1700	0.17
8	900	0.18
9	1000	0.09
Average	**1144**	**0.152**
STING impacts	**1200**	**0.2**
Error	**4.6%**	**24%**

Impact analysis

There were nine impacts from STING2 that were extremely close to two STING impacts, so these nine impacts were selected and compared to the two STING impacts. While there were more impacts from both STING and STING2, the penetrometers were not dropped within close proximity of each other, so these impacts were not used in the comparison. The average bearing strength and penetration depth from STING2 impacts were both less than STING impacts. This discrepancy is likely due to slight sediment variation on the seafloor, as well as differences between the sensors used to collect the data. However, it is clear that STING2 is able to accurately match the STING's capabilities.

Remaining issues

While STING2 functions well for a new device, there are still remaining issues with it. At the current time, STING2's SSX sensor is out of calibration and has almost reached its suggested lifetime of three years. The battery on STING2 seems to be quite poor, and there were some technical issues during data collection in January 2016 that resulted in the SSX not recording data. Finally, STING2 requires a user to import MSR and SSX data into proprietary software so it can be properly reformatted for use in the STING2 analysis software.

Conclusion

After analyzing data from STING and STING2 impacts within close proximity of each other, the data shows that STING2 can function as well as STING in the field. More tests will be conducted in 2018 that will compare STING, STING2, and another proprietary penetrometer to determine which penetrometer should be used in the future.

Acknowledgments

I would like to thank my mentors, Mary Peters and Sheila McDonnell, as well as the Naval Research Laboratory for hosting me this summer.

References

[1] Poeckert, Roland H, et al. *A Seabed Penetrometer*. Defence Research Establishment Atlantic, May 1997.

[2] “MSR.” *MSR Data Loggers*, MSR Electronics, www.msr.ch/en/.

[3] “Slam Stick X.” *Mide Technology*, www.mide.com/products/slam-stick-x-metal.

Additional Figures

The following figures show more of the STING2 analysis software, as well as the impacts and bearing strength calculations used in this report.

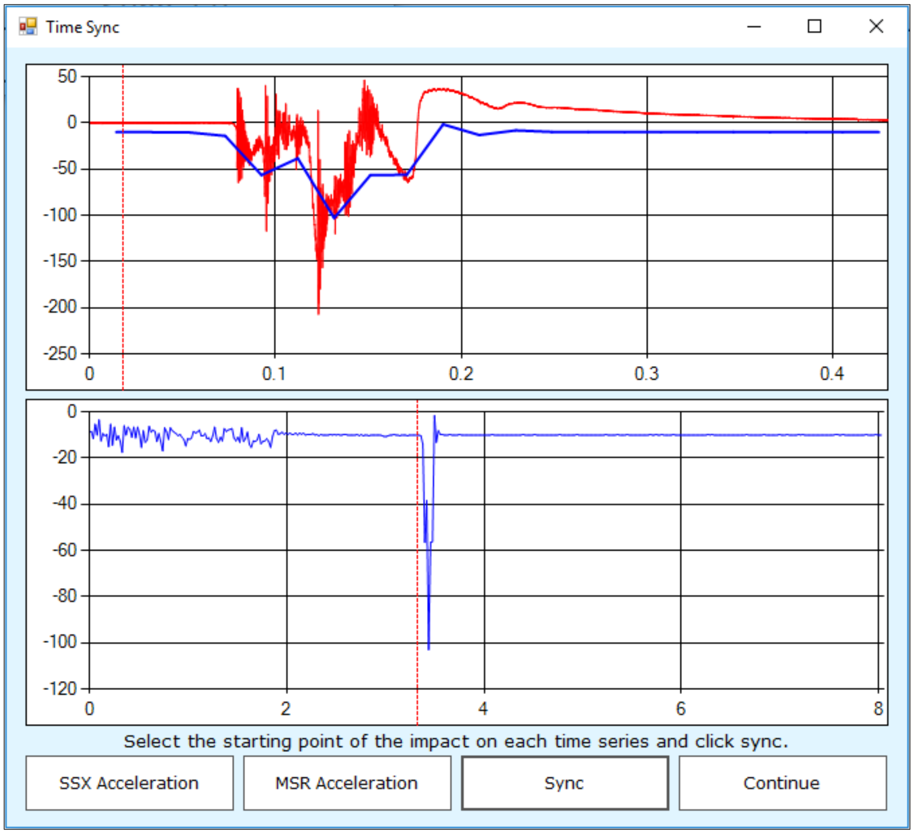

Figure 8 – STING2 analysis software

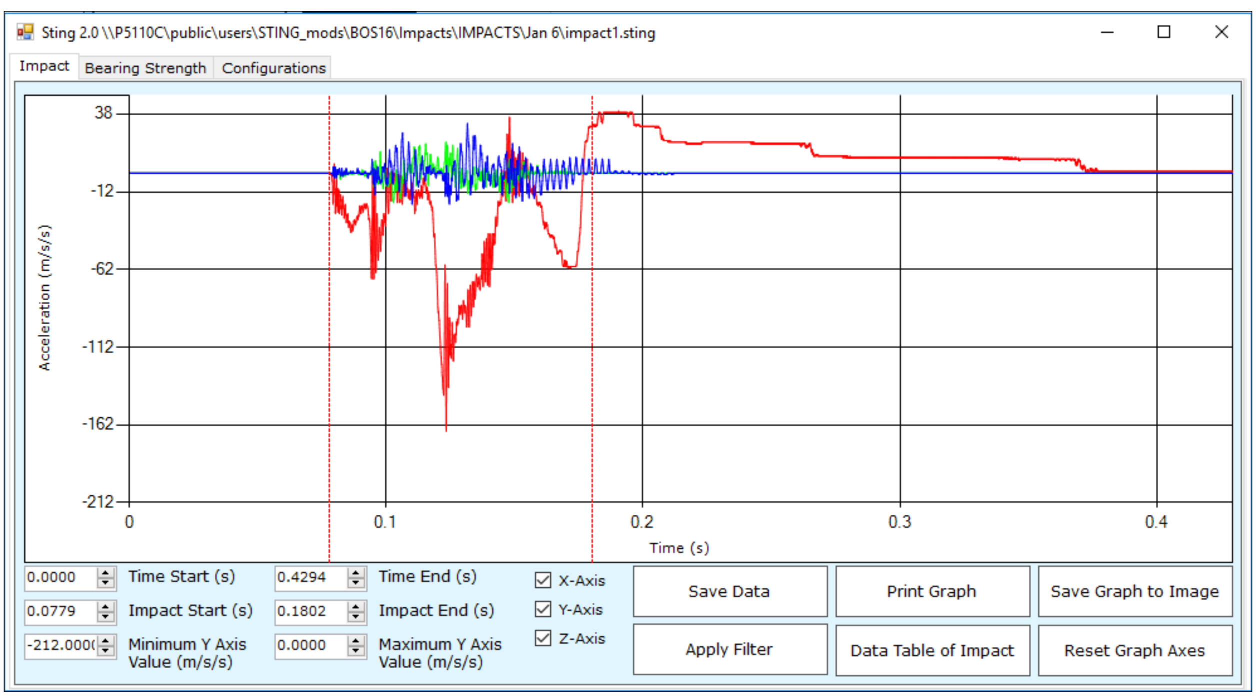

Figure 9 – STING2 analysis software

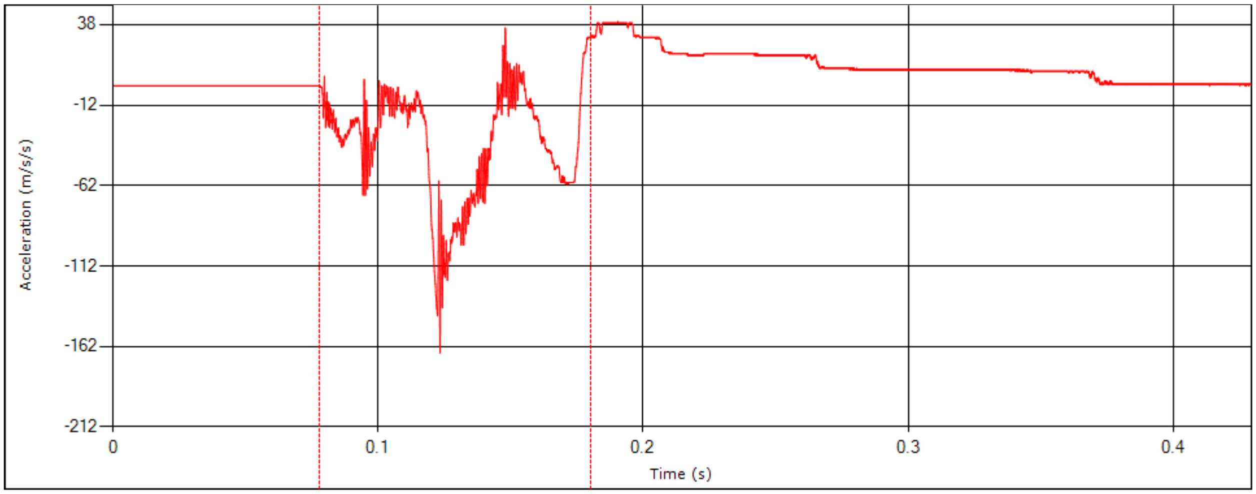

Figure 10 – Impact 1

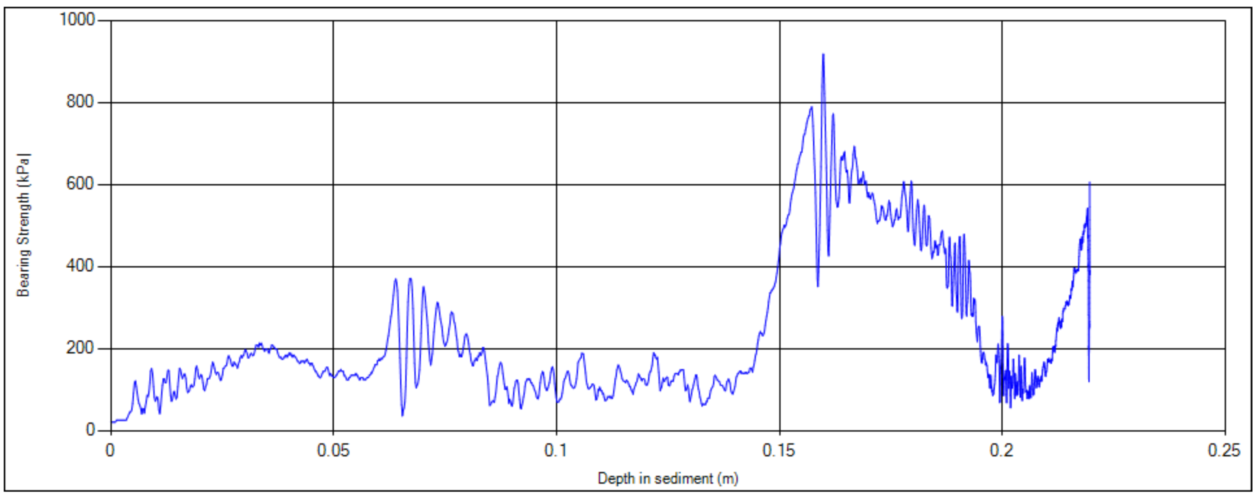

Figure 11- Impact 1 Bearing Strength

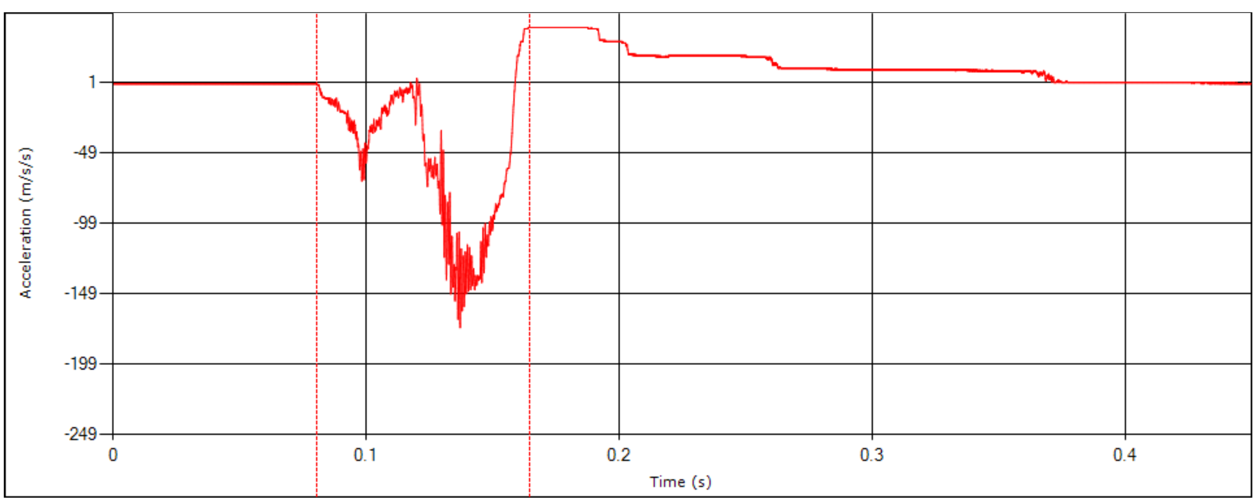

Figure 12 – Impact 2

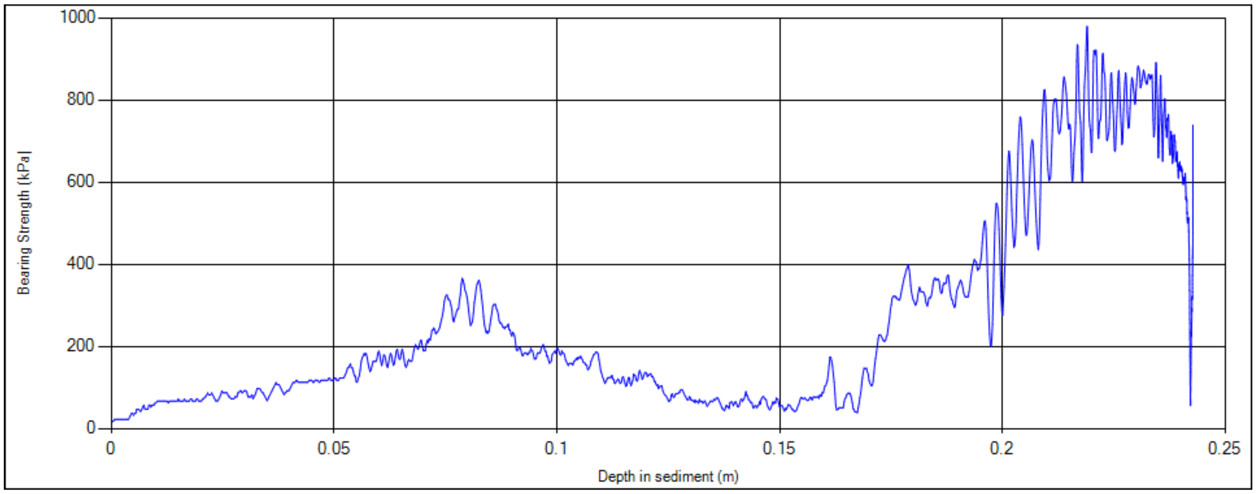

Figure 13 – Impact 2 Bearing Strength

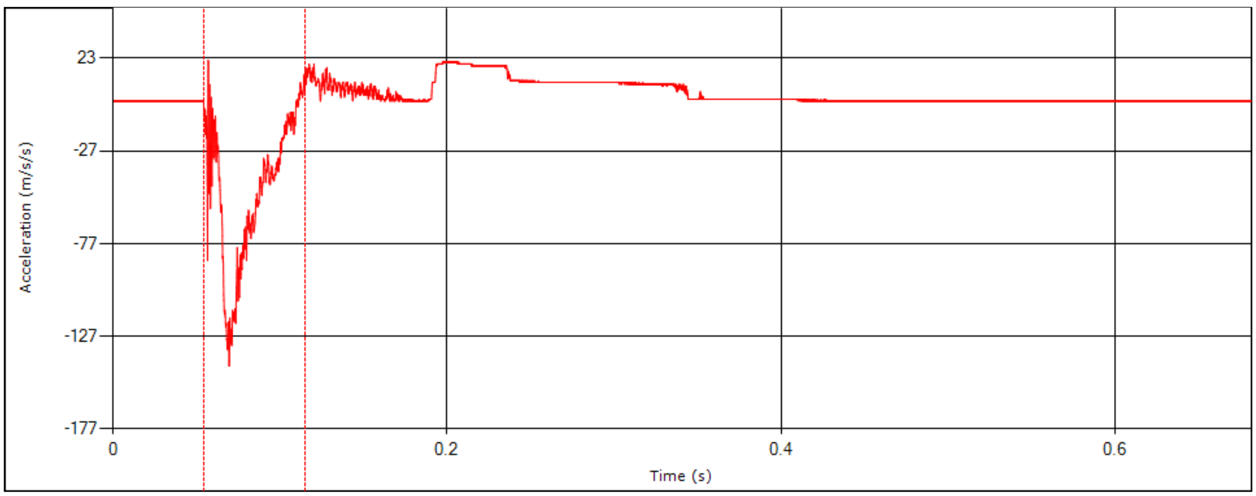

Figure 14 – Impact 3

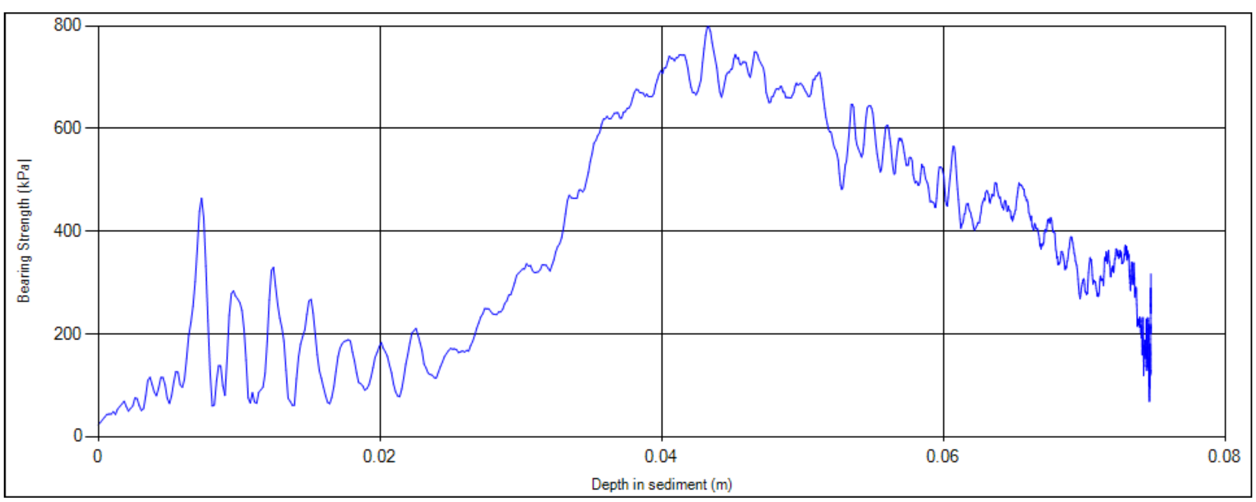

Figure 15 – Impact 3 Bearing Strength

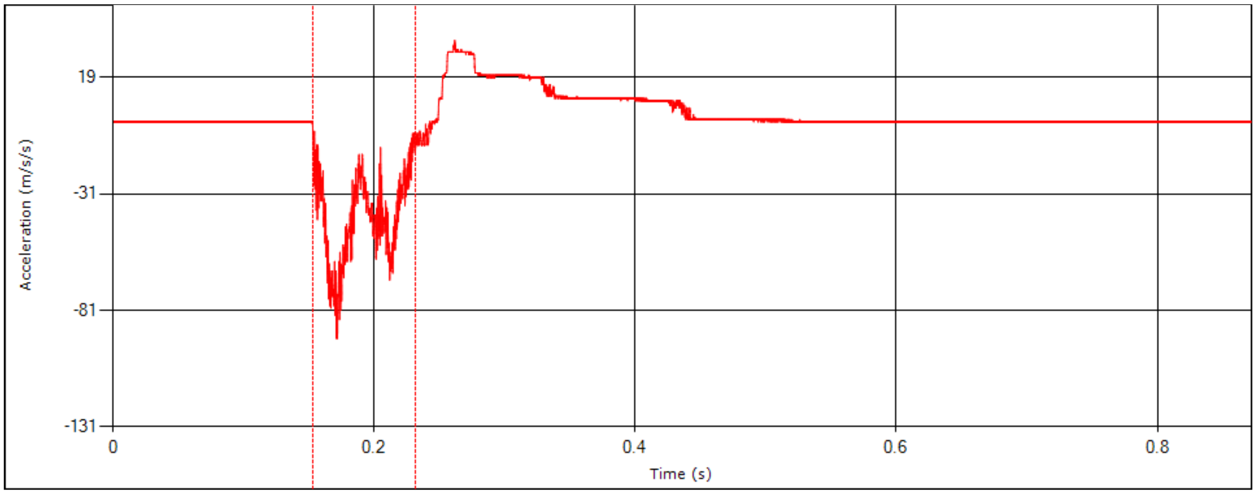

Figure 16 – Impact 4

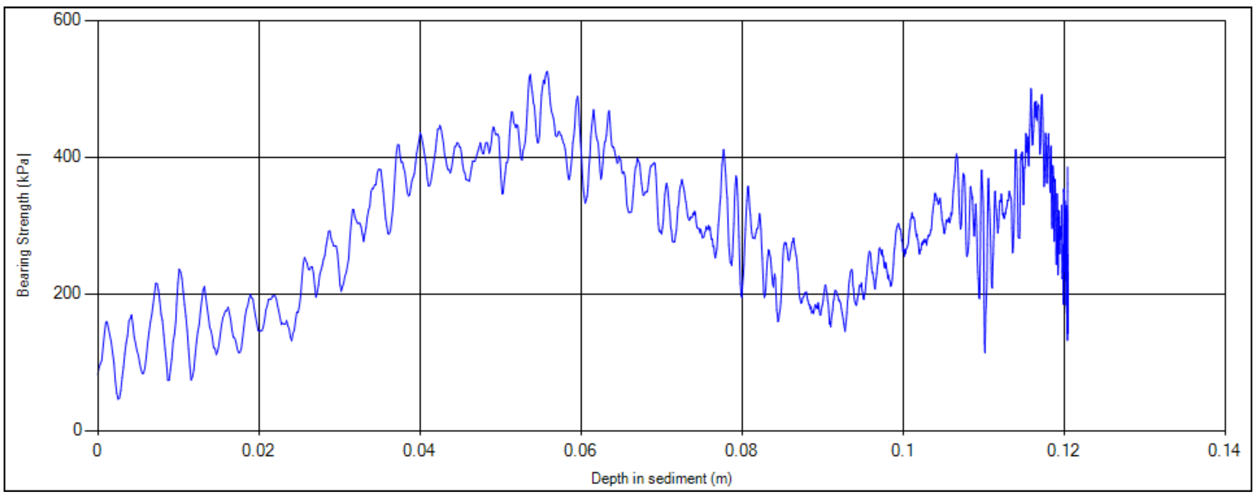

Figure 17 – Impact 4 Bearing Strength

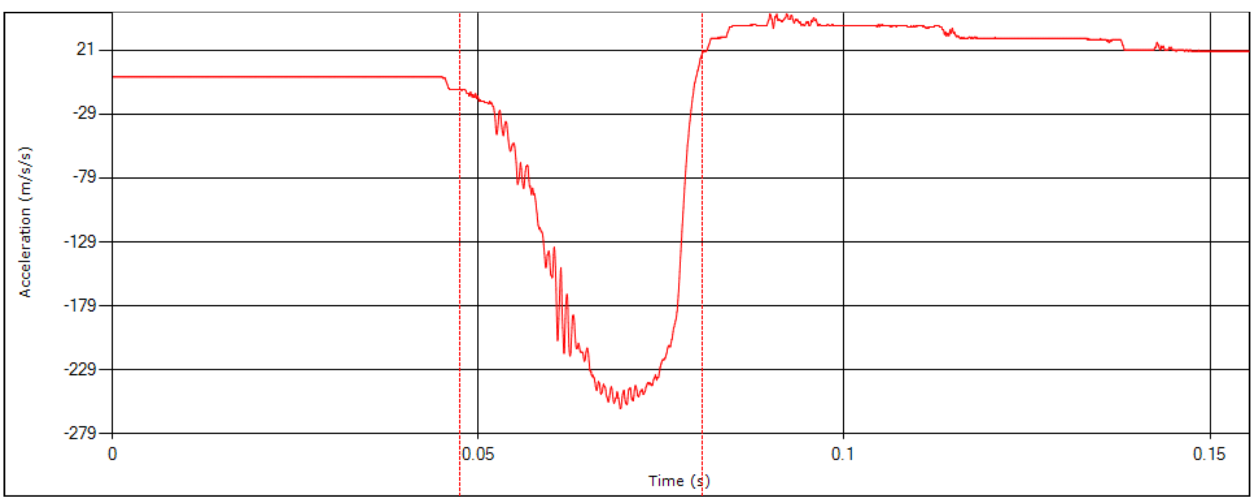

Figure 18 – Impact 5

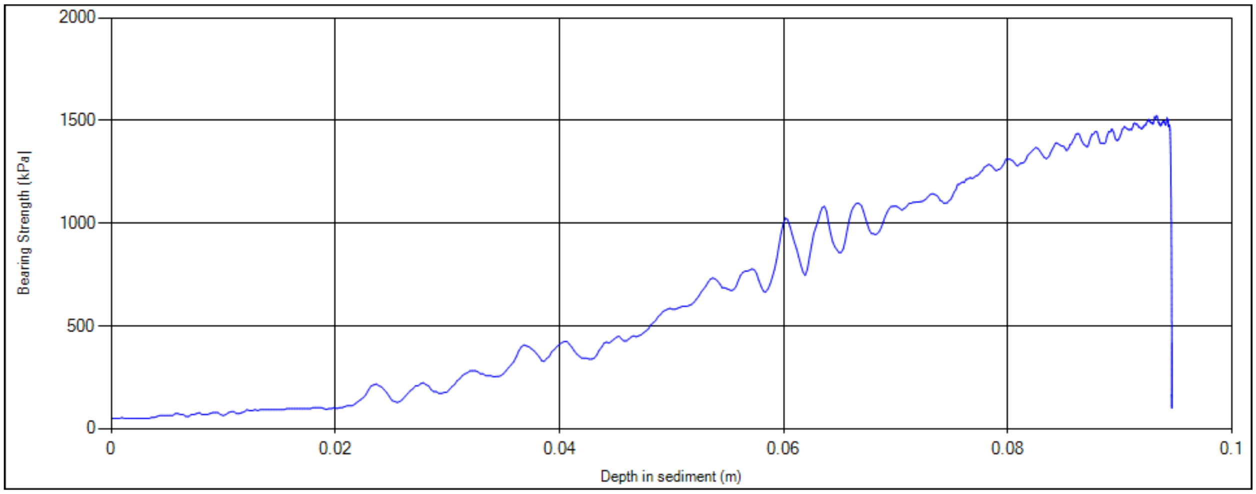

Figure 19 – Impact 5 Bearing Strength

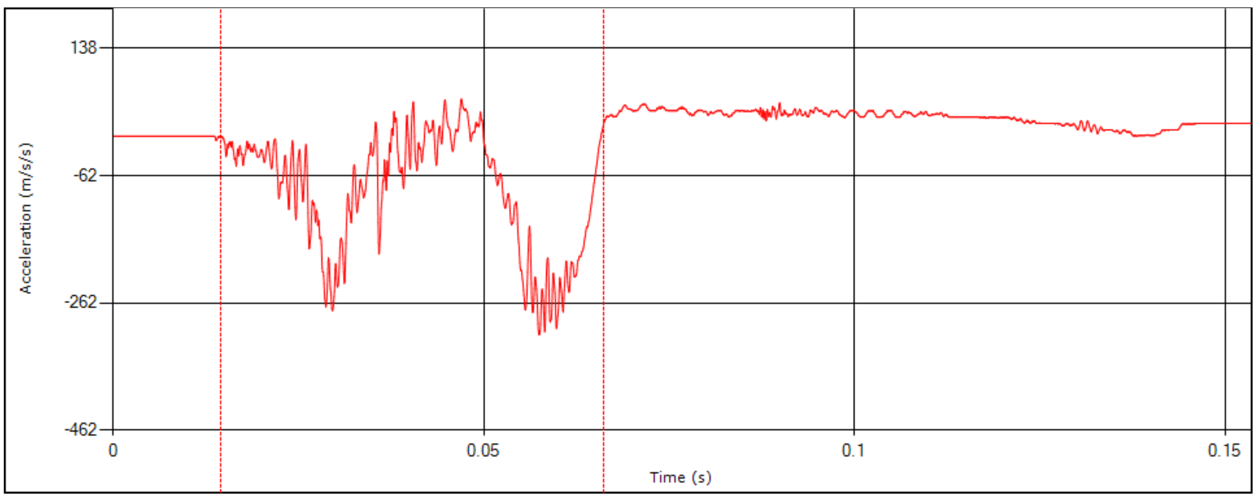

Figure 20 – Impact 6

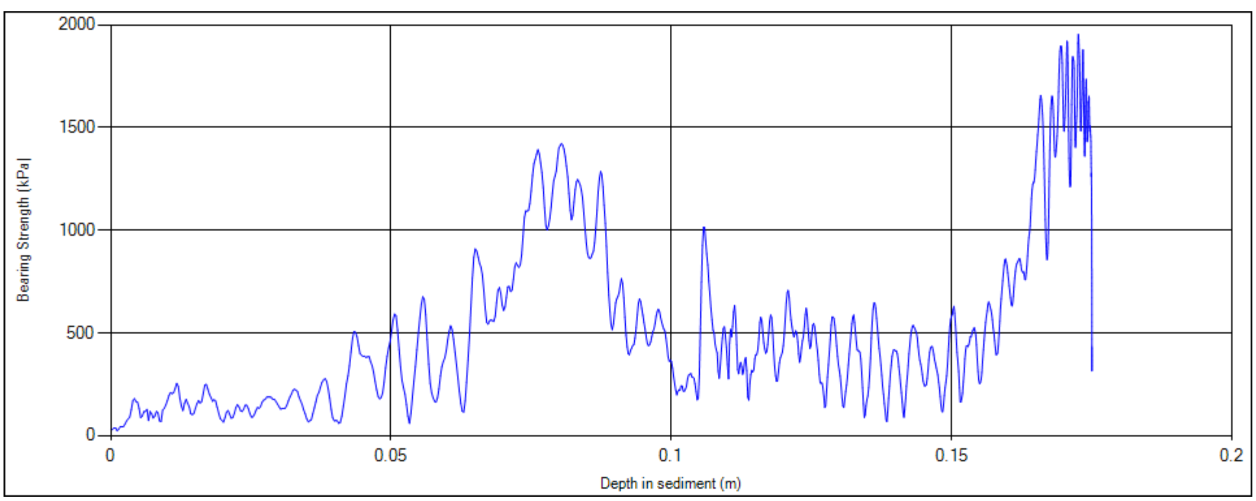

Figure 21 – Impact 6 Bearing Strength

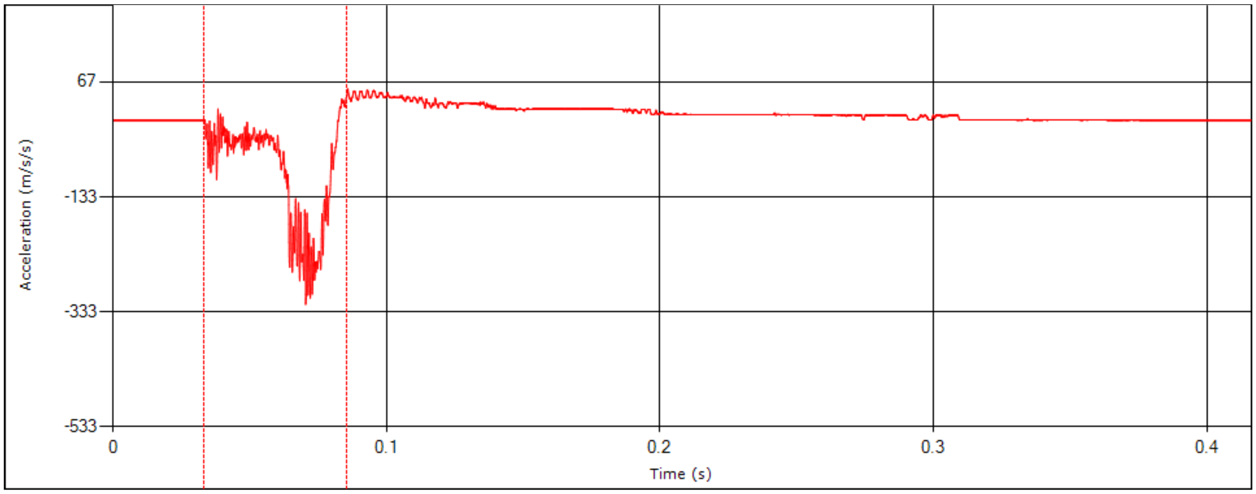

Figure 22 – Impact 7

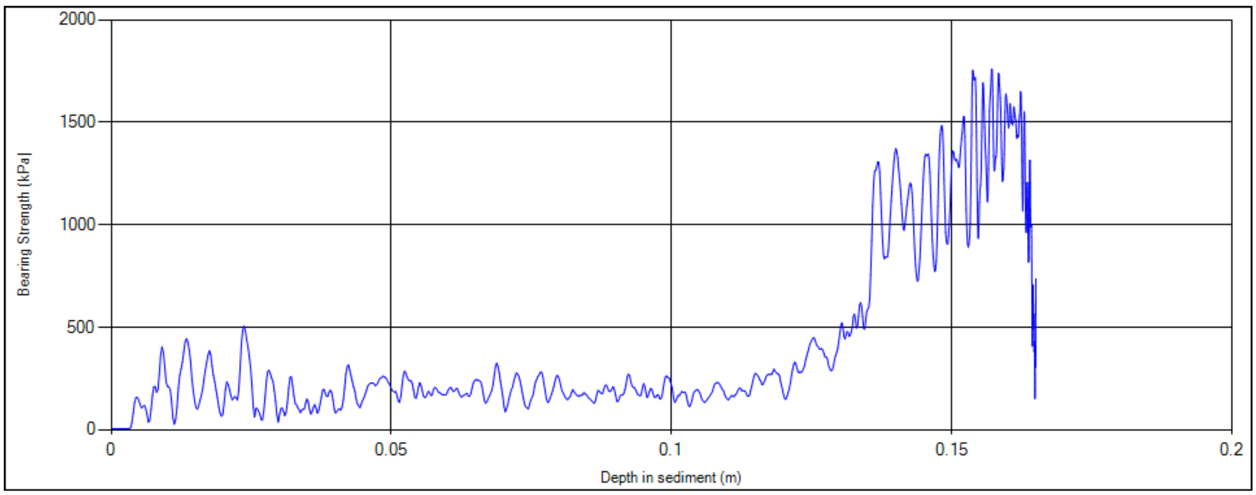

Figure 23 – Impact 7 Bearing Strength

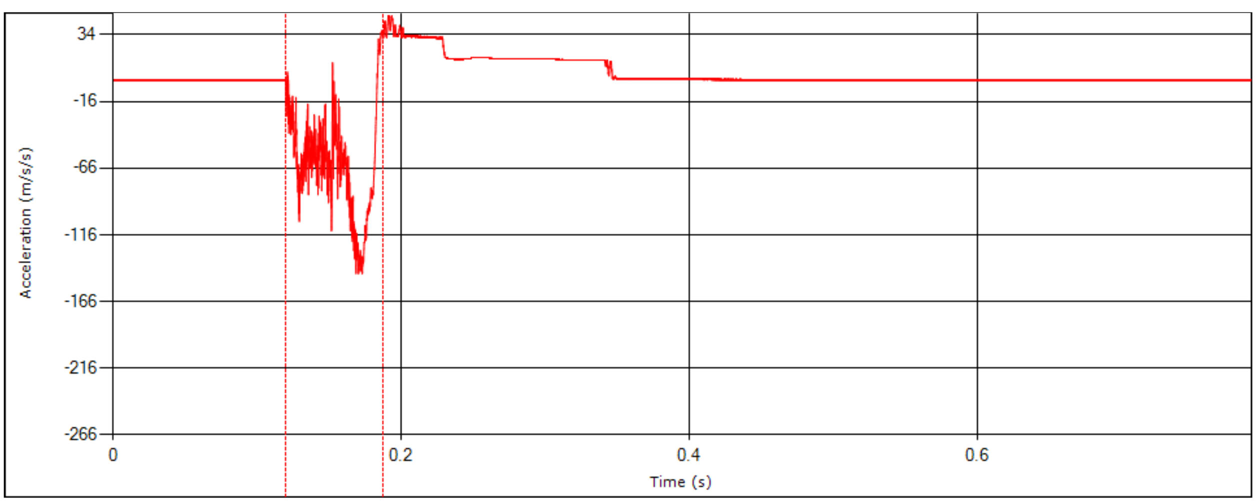

Figure 24 – Impact 8

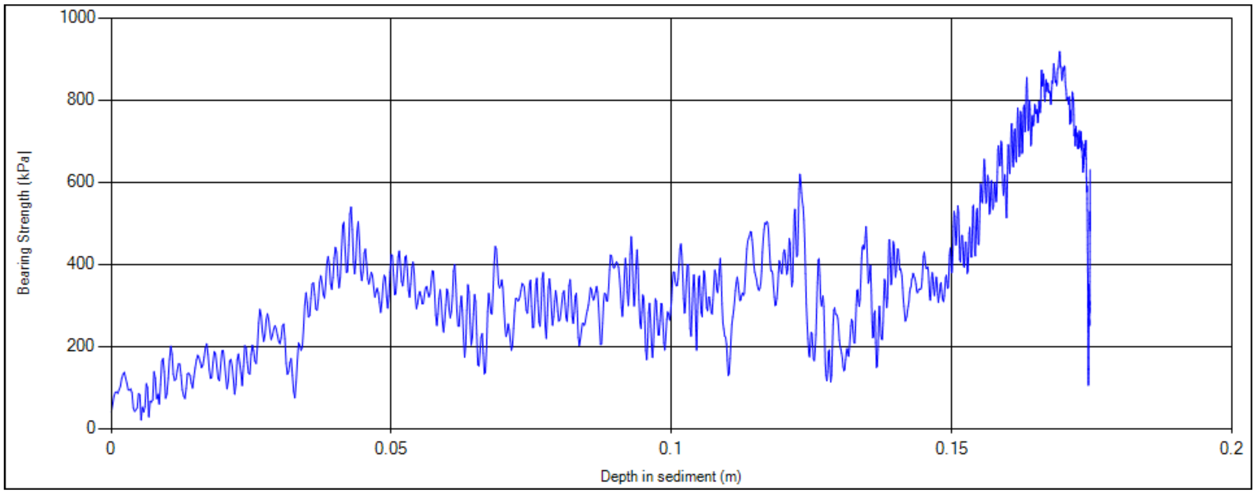

Figure 25 – Impact 8 Bearing Strength

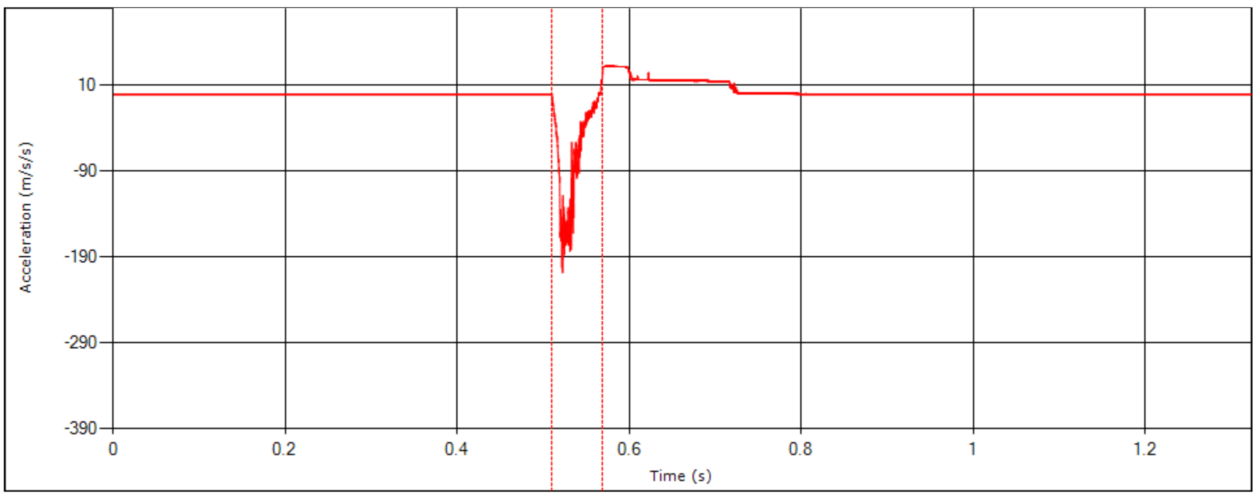

Figure 26 – Impact 9

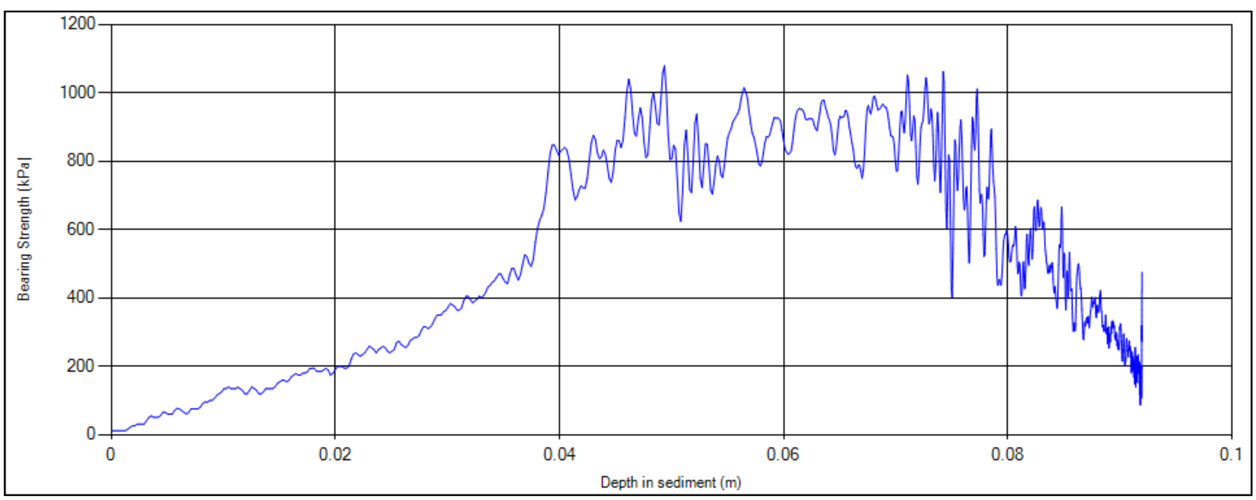

Figure 27 – Impact 9 Bearing Strength