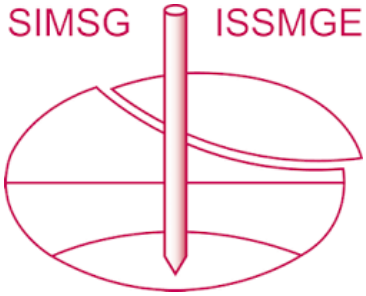
INTERNATIONAL SOCIETY FOR
SOIL MECHANICS AND
GEOTECHNICAL ENGINEERING



This paper was downloaded from the Online Library of the International Society for Soil Mechanics and Geotechnical Engineering (ISSMGE). The library is available here:

https://www.issmge.org/publications/online-library

This is an open-access database that archives thousands of papers published under the Auspices of the ISSMGE and maintained by the Innovation and Development Committee of ISSMGE.

The paper was published in the proceedings of the 6th International Conference on Geotechnical and Geophysical Site Characterization and was edited by Tamás Huszák, András Mahler and Edina Koch. The conference was originally scheduled to be held in Budapest, Hungary in 2020, but due to the COVID-19 pandemic, it was held online from September 26th to September 29th 2021.

Development of Free Fall Cone Penetration Testing System

Hyoun. Kang / primary author
KOREA INSTITURE OF OCEAN SCIENCE & TECHNOLOGY, Busan, KOREA, hkang@kiost.ac.kr

Osoon. Kwon / additional authors2 (from same institution)
KOREA INSTITURE OF OCEAN SCIENCE & TECHNOLOGY, Busan, KOREA, oskwon@kiost.ac.kr

Changjoo. Shin / Other author (from same institution)
KOREA INSTITURE OF OCEAN SCIENCE & TECHNOLOGY, Busan, KOREA, cjshin@kiost.ac.kr

Jungmin Seo / Other author (from same institution)
KOREA INSTITURE OF OCEAN SCIENCE & TECHNOLOGY, Busan, KOREA, jmseo@kiost.ac.kr

Insung. Jang / Other author (from same institution)
KOREA INSTITURE OF OCEAN SCIENCE & TECHNOLOGY, Busan, KOREA, isjang@kiost.ac.kr

ABSTRACT: For the rigorous design of offshore structures, the geotechnical characteristics of the seabed ground should be rigorously investigated. In the deep water, seabed ground surveys usually need complex and expensive equipments. Free fall type ground survey equipment can provide the geotechnical properties of shallow ground depth at the sites where the submarine cables or pipelines are constructed..

In this study, FFCPT was developed. Based on behavior results of numerical model simulation new type of FFCPT, it was manufactured. Water depth was obtained using pressure sensor and penetrated depth was estimated by the double integration of acceleration signal. In addition, vetical penetration was veified penetration at real field test of FFCPT using 2 axis of inclinometer.

The performance of new FFCPT model was evaluated by comparing with the seabed type offshore CPTu experiment data, which was performed at the same test site.

Keywords: FFCPT (cone penetration testing system), tip resistance, sleeve friction, pore pressure

1. INTRODUCTION

Recently, various types of equipment that are operated underwater have been developed. Among them, it is very important to characterize the seabed ground for the movement of equipment. However, there is not much technology of the equipment to understand the characteristics of the seabed ground, The size of the equipment is large, and it takes a very complicated process to identify the characteristics of the seabed ground.

Marine field surveys at sea have many limitations compared to land surveys because they can be used to remotely operate power supply and ground survey operations at sea.

In addition, most of the marine field surveys conducted at sea are using the ground survey equipment on the land by using barges.

CPT(Cone Penetration Test) is the most accurate field survey method to measure the geotechnical properties of seabed ground. In the ocean, CPT(Cone Penetration Test) can be conducted by aid of various tools such as seabed type of equipment of free-fall type equipment.

The cone penetration test (CPT) is used as a test to understand the physical properties of the ground, which is included as an investigation test item in the design criteria of various offshore structures. Accordingly, equipment capable of performing CPT underwater is essential equipment for various marine developments.

Conventional CPT devices are being developed and utilized under land conditions, and under water conditions, there is a problem that it is difficult to test under the same conditions as on land due to water resistance.

In this study, compared to the equipment used on land, it is relatively easy to carry in the marine field, a Free Fall Cone Penetration Testing System(FFCPT) was developed to obtain accurate ground data(tip resistance, friction resistance), and the characteristics of the seabed ground were identified by the sea trials.

2

In addition, the depth of subsea ground and ground data were compared with the results of the seabed type offshore cone penetration test and Free Fall Cone Penetration Testing System in the same area to assess performance.

2. DEVELOPMENT OF FFCPT

In order to acquire the enough penetration force of FFCPT, the power cable or commnication line need to be away from the FFCPT during the free fall process.. Therefore, all parts such as power source, electronic board, sensors, etc. must be installed in body of the FFCPT except recovery wire.

Fig. 1 shows the configuration of FFCPT. The canister for electronic part is made of aluminum alloy to have a light weight and buoyancy compared to the rod and cone probe which are made of iron. Since the center of buoyancy is set to be 0.6m upper than the center of mass, the flip-over motion of FFCPT can be prevented during free fall.

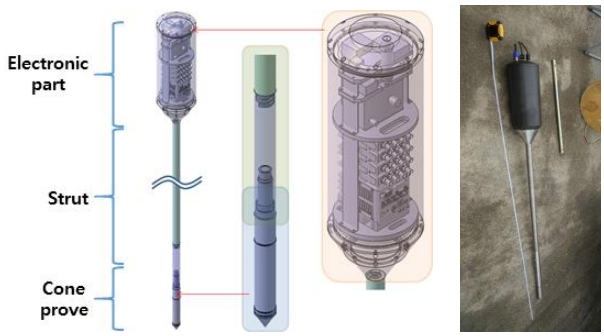
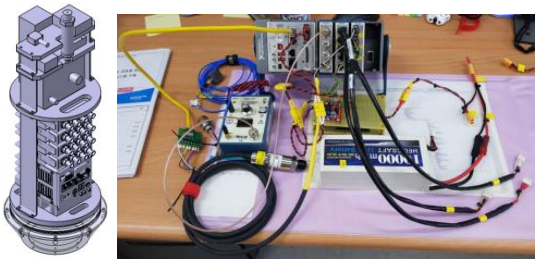


Figure 1. Configuration of FFCPT

Several sensors and electronic parts such as DAQ, battery, etc. are embedded as shown in Fig. 2(a). To obtain these signals, NI crio for DAQ was applied. A DC-type accelerometer and 2-axis inclinometer are to monitor the underwater free fall motion. The pressure sensor was applied to check the water depth at the test point. According to Newton's Law, the underwater terminal speed just before impact is calculated by integration of the obtained acceleration.



(a)Electronic part (B) DAQ system

Figure 2. Detailed design of electronic part in the FFCPT

3. TESTING METHODS AND RESULTS

3.1. SITE CONDITIONS ANDINVESTIGATION

In this study, experiments were conducted in Gunsan, located on the west coast of South Korea, as shown in Fig. 3.

As shown in Fig. 4, the feasibility of the experimental location was evaluated by the seabed type offshore cone penetration test subsea survey results, and the subsea ground survey results were shown.

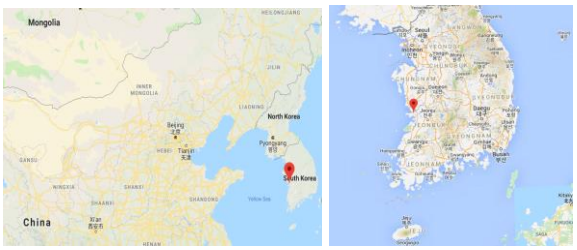


Figure 3. Test site location map

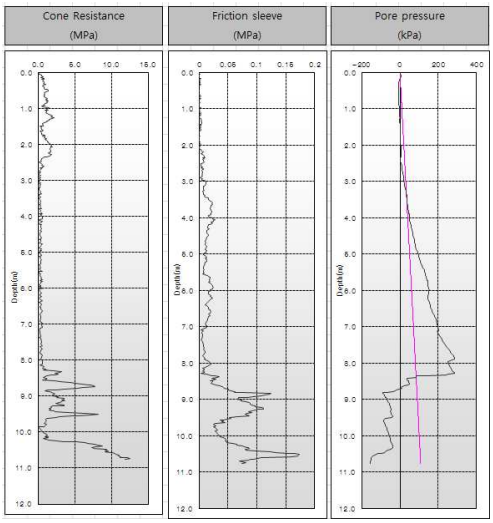


Figure 4. Result of The Seabed Type Offshore Cone Penetration Test

3.2. TESTING METHODS

The an experiment was conducted to obtain subsea ground data (cone tip resistance, friction resistance) using the developed FFCPT as shown in Fig. 5.



Figure 5. FFCPT

Fig. 6. shows the FFCPT with a length of 4m and weight of 38kg was placed on a moving crane and dropped freely in sea 20m deep. In order to verify the performance of the developed FFCPT, free fall experiments were repeated five times and data were obtained.



Figure 6. Drop test of FFCPT-1

3.3. RESULT OF TEST

In this study, subsea ground characteristics data(cone tip resistance, friction resistance) were obtained using the developed FFCPT(Free Fall Cone Penetration Testing System).

As shown in Table 1, the final penetration depth was 0.21 m, 0.24 m, 0.26 m, 0.22 m and 0.49 m, and the average was 0.28 m.

Table 1. Result of test

	Final penetration depth(m)	Cone resistance(MPa)	friction resistance(MPa)
FFCPT-1	0.21	0.0048~5.2755	0.0~0.0153
FFCPT-2	0.24	0.0006~4.8709	0.0~0.0118
FFCPT-3	0.26	0.0141~5.3009	0.0~0.0114
FFCPT-4	0.22	0.0131~4.2026	0.0~0.0116
FFCPT-5	0.49	0.0006~2.5260	0.0~0.0115

3.3.1. RESULT OF FFCPT

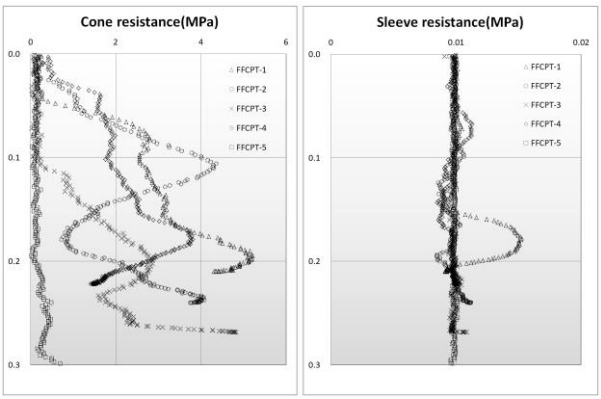


Figure 7. Result of FFCPT-1

Fig. 7 shows the final penetration depth of FFCPT-1 was 0.21m and ground data (cone tip resistance, friction resistance) values were measured. The results of the experiment were shown as follows.

The distribution range of cone tip resistance was measured in the range of 0.0048 to 5.2755MPa, and the distribution range of the friction resistance was measured in the range of 0.0000 to 0.0153MPa.

FFCPT-2 was 0.24m and ground data (cone tip resistance, friction resistance) values were measured. The results of the experiment were shown as follows.

The distribution range of cone tip resistance was measured in the range of 0.0006 to 4.8709MPa, and the distribution range of the friction resistance was measured in the range of 0.0000 to 0.0118MPa.

FFCPT-3 was 0.26m and ground data (cone tip resistance, friction resistance) values were measured. The results of the experiment were shown as follows.

The distribution range of cone tip resistance was measured in the range of 0.0141 to 5.3009MPa, and the distribution range of the friction resistance was measured in the range of 0.0000 to 0.0114MPa.

FFCPT-4 was 0.22m and ground data (cone tip resistance, friction resistance) values were measured. The results of the experiment were shown as follows.

The distribution range of cone tip resistance was measured in the range of 0.0131 to 4.2026MPa, and the distribution range of the friction resistance was measured in the range of 0.0000 to 0.0116MPa.

FFCPT-5 was 0.49m and ground data (cone tip resistance, friction resistance) values were measured. The results of the experiment were shown as follows.

The distribution range of cone tip resistance was measured in the range of 0.0006 to 2.5260MPa, and the distribution range of the friction resistance was measured in the range of 0.0000 to 0.0115MPa.

3.3.2. COMPARISON OF FFCPT AND SEABED TYPE OFFSHORE CPTu

Fig. 8 shows the performance of new FFCPT model was evaluated by comparing with the seabed type offshore CPTu experiment data, which was performed at the same test site.

Seabed Type Offshore Cptu is performed after the equipment is lowered on the seabed surface, and the FFCPT uses free fall.

Seabed Type Offshore Cptu was able to achieve stable tests after it was lowered to the surface of the sea floor. However, the FFCPT depends heavily on natural conditions such as tidal current and wave.

The FFCPT has become a variable in which natural phenomena such as tidal currents, waves, and wind affect safety and test reliability. It was also a problem to

maintain the speed and vertical conditions of penetration into the ocean ground through the sea.

Also FFCPT uses small ship, it cannot experiment exactly in the same place. So the results were compared with the most similar FFCPT-5 test results.There was a very similar tendency for cone resistance, and the friction resistance is very small and difficult to compare at thin depths.

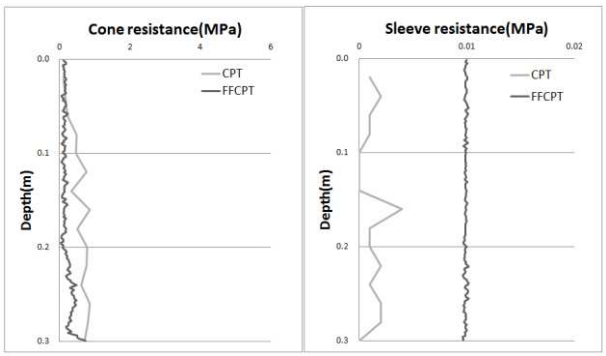


Figure 8. Result of FFCPT and seabed type offshore CPTu

4. CONCLUSIONS

Analysis of this study, subsea ground characteristics data were obtained using the developed FFCPT.

However, we were only able to analyze FFCPT trends with a penetration depth of less than 1m, and it is deemed that more experiments are needed for later experiments.

The analysis results are as follows.

(1) The final penetration depth was 0.21 m, 0.24 m, 0.26 m, 0.22 m and 0.49 m, and the average was 0.28 m. This is judged not to penetrate more than 0.49m because it is not deep water and it is light weight of ffcpt.
(2) FFCPT1 to 5 are the distribution range of cone tip resistance was measured in the range of 0.0006 to 5.3009MPa, and the distribution range of the friction resistance was measured in the range of 0.0000 to 0.0153MPa.
(3) According to the comparative analysis of the seabed type offshore cone penetration test and FFCPT, it was difficult to accurately compare the locations of the test sites because it was judged that there was a gap of up to 5 to 10 meters due to the movement of the ship.

Due to the following conclusions, it is deemed necessary to estimate the appropriate depth of water in future field experiments. In addition, it is deemed necessary to increase the weight of the FFCPT even if the depth of the water is not deep enough to improve the final penetration depth.

ACKNOWLEDGMENT

This research was supported by the project "Development of the support vessel and systems for the offshore field test and evaluation of offshore equipments (PM61181)" funded by Korea Institute of Ocean Science & Technology(KIOST).

5. REFERENCES

[1] Changjoo Shin, Sung Gyu Won, OSoon Kwon, In Sung Jang, Jung-min Seo, Hyoun Kang, 2019. Estimation of Ground Penetration Depth for Underwater Free Fall Cone Penetration Tester. Proceeding of Korean Marine Robot Technology Society, Seoul, South Korea, 62-64.
[2] Evans and Ashley D., "Hydrodynamics of mine impact burial," Naval Postgraduate School, 2002.
[3] John Osler, Arnold Furlong, Harold Christian and Mike Lamplugh, "The integration of the free fall cone penetrometer(FFCPT) with the moving vessel profiler(MVP) for the rapid assessment of seabed characteristics," The International Hydrographic Review, vol. 7(3), pp. 45-53, 2006.
[4] Koumoto, T et. al, "Theory and practice of the fall cone test", Vol. 51, No. 8, 2001, pp.701-712
[5] Kurt Seifert and Oscar Camacho, "Implementing position algorithms using accelerometers," Freescale Semiconductor Application Note, AN3397, 2007
[6] McCarty JL, Carden HD, 1962. Impact characteristics of various material obtained by an acceleration-time history technique applicable to evaluating remote targets. NASA technical report(NASA-TN-D-1269), University of Texas at Austin.
[7] Stegmann, Sylvia et. al, "Design of a modular, marine free-fall cone penetrometer", Sea Technology, Vol. 47, No. 2, 2006, pp.1-27.
[8] Stegmann, Sylvia et. al, "Initial Results of a new Free Fall-Cone Penelromeler (FF-CPT) for geotechnical in situ characterisation of soft marine sediments", Vol. 86, No. 3, 2006, pp.1-199.
[9] Sung-Chul Lee, 2008. A study on the Estimation on Undrained Shear Strength and Preconsolidation Pressure Using N-Value Obtained from Standard Penetration Test, Graduate School of Korea Maritime University.
[10] Sylvia Stegmann, Tobias Morz and Achim Kopf, "Initial results of a now free fall-cone penetrometer for geotechnical in-situ characterization of soft marine sediments," Norwegian Journal of Geology, No. 86(3), pp. 199-208, 2006.
[11] Yanli Yang, Yanfei Zhao, Dali Kang, 2016. Integration on acceleration signals by adjusting with envelopes. Journal of Measurements in Engineering, 4(2), 117-121.
[12] Youngshin Consultant, [Online] (Updated 2010) Available at:<http://www.piletest.net/product_3_2_4.html> [Accessed July 2019].