A study on the development of sonar roughness profiling system (SRPS)

Byeonghan Jeonⁱ⁾, Yongkyu Choiⁱⁱ⁾, Chaemin Kimⁱⁱⁱ⁾ and Byeongdeok Song^{iv)}

i) Ph.D. Student, Department of Civil and Environmental Engineering, Kyungshung University, 309, Suyeong-ro, Korea.

ii) Professor, Department of Civil Engineering Kyungshung University, 309, Suyeong-ro, Korea.

iii) Ph.D. Student, Department of Civil and Environmental Engineering, Kyungshung University, 309, Suyeong-ro, Korea.

iv) Deputy Director, Department of domestic wastewater, Busan Metropolitan City, 1001, Jungang-daero, Koera.

ABSTRACT

Sonar Roughness Profiling System (SRPS) that can be used in the construction site was developed and verification tests were conducted to evaluate the applicability of SRPS. Firstly, in the indoor test, objective was to study the ability of sonar sensors. It was tested to check the effect of different shapes and turbidity using five specimens. It was found that the sensors had an accuracy of 1 mm. Plus, it was not greatly affected by the change of the shapes and turbidity. Secondly, in order to confirm field application of SRPS, tests were carried out on site. Although some problems were found, test was completed properly according to test procedure. Based on the test results, it was confirmed that SRPS could be used to measure socket roughness on site where shaft were drilled in rock.

Keywords: Sonar Roughness Profiling System, Sonar sensors, drilled shaft.

1 INTRODUCTION

Civil engineering structures are recently being built higher and bigger, and thus, the load condition that foundations should support has increased. Because of this reason, drilled shafts have been widely used. They make it possible to support the load of super structures due to end bearing capacity and skin friction. It is known that the skin friction of rock-socketed piles is affected by the socket roughness, the initial normal stress, the pile diameters, and the unconfined compression strength of the rock. In particular, the socket roughness plays a key role in evaluating the skin friction. Its importance has been studied by several researchers such as Horvath (1983), Seidel et al. (2001), Nam (2004) and so on. However, they did not probe the whole socket roughness profiles because there were no devices to measure roughness on site directly.

Therefore, the aim for this study was to develop a new roughness profiling system. Additionally, the new device was tested in the laboratory and construction site.

2 DEVELOPMENT OF SRPS

2.1 Sonar Sensors

The aim was to develop four sensors after taking into account where they would be used. The sensors boast an accuracy of up to 1.0mm, can measure a wall to be cut from a minimum distance of 15.0 mm, have a margin of error of $\pm 0.5\%$, can measure more than 100 NTU and can withstand a maximum of 1MPa under water. They are illustrated in Figure 1.

Fig. 1 Sonar Sensors

2.2 Software

Software for SRPS was also developed. The sensor program allows sonar sensors to check measured data in real time and to save it in Microsoft Excel format. Communication occurs through the sensors, the STM, and a UTP cable, making it possible to control the TVG (Time Varied Gain), the PWD (Pulse Width), the Gain, the Blank, the Draft, and the Threshold in the software. STM's program helps users manipulate the movement of STM automatically. The software is illustrated in Figure 2 below.

2.3 Hardware

TM320F2812 DSP was used as the main processor that receives and processes data from the sonar sensors. This model is equipped with a 32 bit CPU and "Event Manager" that can perform arithmetic calculations with speed of 150MHz and receive signals from 12 bit ADC, PWM, QEP and CAP.

Fig. 2 Programs of SRPS:
(a) Sensors Program; (b) STM's Program

2.4 STM (Sensor Transferring Machine)

STM helps to locate the sonar sensors according to researcher's requirement up to 100m and move up and down by 1mm. Furthermore, STE was developed to apply different size of drilled shaft sockets into rock. Its workability was assured by making it in heat-treated aluminum. The STE is illustrated in Figure 3 below.

Fig 3 Sensor Transferring Machine

3 VERIFICATION TESTS

3.1 Indoor Test

In order to verify the ability of sonar sensors, tests were conducted for various given in-situ conditions. The testing conditions are illustrated in detail in Table 1 and five specimens for the verification test are listed in Figure 4 below.

Table 1. Test terms

Classification	Terms	Type of Specimen
Accuracy	Arranged in tiers Clearance 1.0mm	Specimen A
Shape	Square	Specimen 1
	Triangle	Specimen 2
	Trapezium	Specimen 3
	oval	Specimen 4
Turbidity	200NTU	Specimen 1, 2, 3, 4
	600NTU	
	1000NTU	
	Site(480NTU)	

Fig. 4 Verification test specimens: (a) Specimen A (corrugated step height: 1.0 mm, width: 30.0mm); (b) Specimen 1 (square height 1.0mm, Width: 1.0mm); (c) Specimen 2 (Triangle height: 14.0mm, width: 28.0mm); (d) Specimen 3 (trapezium upper base: 20.0mm, lower base: 48.0mm, height: 14.0mm); (e) Specimen 4 (oval height: 10.0mm, width: 26.0mm)

3.1.1. Accuracy of Sonar Sensors

Specimen A was tested to check whether the sonar sensors with an accuracy of 1 mm worked properly. Ten tests were performed when the sensor moved 1.0 mm, and the ten measurement values were obtained without any modification. The dimensions of specimen A are drawn in a solid line and measurement values are drawn in dotted line. As shown in Figure 5, the measurement values are consistent with the solid line.

Fig. 5 Test result on the accuracy

3.1.2 Effect of Shape

The surface of rock sockets does not look like a cylinder but actually appears to have diverse shapes. Because of that, it was essential to verify whether the

Fig. 6 Measurements of differently shaped specimens: (a) specimen 1; (b) specimen 2; (c) specimen 3; (d) specimen 4

Fig. 7 The measurement values of specimen 4 based on the change in the level of turbidity: (a) 200NTU; (b) 600NTU; (c) 1000NTU; (d) Site (480NTU)

sonar sensors could measure socket roughness accurately. Tests were implemented using specimen 1, 2, 3, and 4, and the results are presented in Figure 6.

3.1.3 Effect of Turbidity

Usually, there is a mix of sewage, floating particles,

and bentonite slurry in a borehole. The level of turbidity in the borehole ranges from 300 to 800 NTU, which serves as a key factor in measuring the roughness on the site. Therefore, it was needed to confirm the effect of turbidity. Tests for specimens 1, 2, 3, and 4 was implemented using three types of water samples

mixed with bentonite, and another water sample collected on the site. The measurement values of specimen 4(curve) with the most unfavorable conditions are presented in Figure 7 to check the effect of turbidity.

3.2 Field Test

In order to check the field application of SRPS, test was implemented in a site located in Busan, Korea. The pile type was rock socketed drilled shaft, length of pile was 37.24 m and diameter was 2500 mm. It was tested to measure roughness of soft rock layer from 35.20 m to 38.70 m as shown figure 8. The testing procedure is illustrated in Figure 9 blow.

Fig. 8 Photo of Installation of SRPS

Fig. 9 Testing procedure

3.2.1. Analysis of test results

Among the various methods for analysis of roughness of rock socket, the design method of Horvath et al. was used to analyze the test results. In accordance with the method, average height of asperities (Δr), roughness factor (RF), and adhesion factor ($\dots$) were determined as shown in Table 2.

Table 2. Analysis of test result by Horvath method.

Section (m)	Δr (mm)	RF	$\dots$
35.20 - 36.20	7.4	0.0131	0.1137
36.60 - 36.68	7.1	0.0107	0.1037
37.00 - 37.07	9.1	0.0113	0.1036
38.00 - 38.07	9.3	0.0101	0.1011
38.30 - 38.40	6.3	0.0067	0.0844

38.60 - 38.70	7.0	0.0067	0.0841

4 SUMMARY AND CONCLUSION

This study was focused to unveil the Sonar Roughness Profiling System, SRPS. Plus, Indoor and field test are implemented to verify the application of SRPS. Based on test results, following are the findings and conclusion obtained;

1. Sonar sensors with an accuracy 1.0 mm were developed, and dimensions and measurement values were the same after measuring specimen A (a corrugated specimen was 1.0 mm in step height).
2. The socket roughness on the site had diverse shape. Therefore, it was tested to check the effect of shapes with square, triangular, trapezoid and oval shapes specimens. The measurement values of specimen with a square shape were consistent, while some measurement values of the other specimens showed a margin of effort of 1.0-3.0mm, which is attributed to the features of the waveforms of the sonar sensors. However, the dimensions and field values could be the same if the errors are corrected.
3. The test for effect of turbidity was implemented using three types of water samples mixed with bentonite. The changes in the level of turbidity did not affect the measurement values, and the measured errors were within the normal range.
4. To check up on application of SRPS, field test was carried out on the site. It was target to measure socket roughness of soft rock. Although some problems were found, test was completed according to testing procedure, and data was collected using Horvath method.
5. It is not sure if data reliability for socket roughness of soft rock is high because comparison target did not exist. However, the applicability of SRPS to site was confirmed.

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