PAWEES Conference, KOREA

EFFECTS OF HAND MADE PLASTIC HORN TO MEASURE THE ARITHMETIC MEAN ROUGHNESS OF CONCRETE SURFACE BY TRANSCEIVER TYPE AERIAL ULTRASONIC SENSOR

Mohammad Raihanul Islam*, NAGAOKA Seiya*, OKAJIMA Kenji*, ISHIGURO Satoru*, ITO Ryouei*, WATANABE Ken** and ITO Tesu***

*Graduate school of Bioresources, Mie University, 1577 Machiyacho, Kurima, Tsu, Mie 514-8507, JAPAN
**Maruei concrete industry Co., Ltd., 1518 Majima, Fukujyu-machi, Gifu 501-6293, JAPAN
***X-ability Co., Ltd., 4-15 Hongo, Bunkyo-ku, Tokyo 113-0033, JAPAN

ABSTRACT

In the present study was conducted to select one or more pattern of horn to measure the arithmetical mean roughness of concrete surface by transceiver type aerial ultrasonic sensor. The plastic made different types of horn was used to control the measuring range of the sensor. Total three types and nine patterns of horn were used in this study. One cylindrical type and two circular-tapered-conical shape types' horns were used. Height of the cylindrical horns and the slant height of the circular-tapered-conical shape horn were 2, 5 and 7 cm. The individual horn was placed in front of the measuring side of the aerial sensor. A digital oscilloscope was used to measure the measurement value and to get the measurement in wave form. The sensor was placed at 1m height from the measuring surface. We evaluated the amount of the reflective wave with the peak to peak value. When the arithmetical mean roughness was small, the peak to peak value was large. We considered the high peak to peak value, considerable variation of the measured peak to peak value and clear out range data to evaluate the performance of the used horns`. The cylindrical horn with the slant height of 7cm was preferred for the clear outrange value and the circular-tapered-conical shape horn with 5cm slant height was preferred for the high peak to peak value. These two horns controlled the measuring range of the used sensor effectively.

Keywords: aerial ultrasonic, peak to peak value, Arithmetical mean roughness, Horn, Performance evaluation

1. INTRODUCTION

Japan has possessed main concrete agriculture irrigation canals that have total length of 49,239km. These were constructed since 1954-1973 of the high economy growth. When canals became too old for work, they were necessary to be repaired. Especially, the hydraulic performance malfunction is used it as the repair factor. However, visual inspection is often used in the general maintenance of the roughness of the canal. Some canals managers want to assess quantitative of the roughness of the concrete surface of the canal quantitative. Since main concrete agriculture irrigation canals have enormous length, the method is required of quantitative assessment that is simple, short time and economical.

Flow velocity decreasing and water level raising are caused by the roughness of the concreate surface. These hydraulic performance malfunction of the concrete agriculture irrigation canal the roughness coefficient is assumed one of the evaluation criteria. The arithmetical mean roughness of the concrete surface is applied to the estimate of the roughness coefficient. However, the simple, short time and economical measurement of the arithmetical mean roughness is difficult. Over the years, considerable attention has been paid to the study of measurement of the arithmetical mean roughness. The first attempt to assess the roughness of the concrete surface of the canals was made by reference [1]. Reference [1] suggested using the moulage gauge in the measurement of the arithmetical mean roughness. This method is the simple measurement, since managers only pushes the moulage gauge to the concrete surface. However, managers need complication analysis that read displacement from one by one the moulage gauge. Reference [2] suggested using the laser displacement sensor in the measurement of the arithmetical mean roughness. Measurement range of this method is line information of the concrete surface. Reference [3] suggested using the three dimensional image processing in the measurement of the arithmetical mean roughness. Measurement range of this method is line information without three dimensional image of the concrete surface. However, these method is not used in the general maintenance of the roughness of the canal. Since the agriculture irrigation canals is long total extension distance, managers request measurement of wide range.

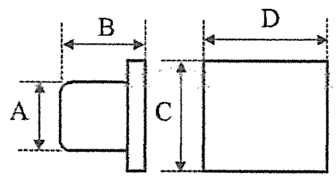
In this study, we attempted using the aerial ultrasonic wave of the transceiver type with different types of hand-made horns to measure the arithmetical mean roughness and to control the measuring surface

2. THE MEASUREMENT EQUIPMENT

We used LZ-EZ1 (Max Botic, Inc) as the aerial ultrasonic sensor of transceiver type. The sensor used designed for the ultrasonic measuring sensor. We selected a frequency from relationship of attenuation in the air. Since ultrasonic waves higher 80 kHz in frequency attenuates from distance of 2000(mm) and ultrasonic wave of the lower 20kHz in frequency may become the audible range, we selected about the 40kHz. The ultrasonic wave of 40kHz can measure from distance of 500~2000(mm) without attenuation. Next, we compared the open type (the sensitivity: min. -80.5dB) and the waterproof type (the sensitivity: min. -58.2dB) in sensitivity. The open type has 13 times higher sensitivity than the waterproof type at each output voltage. So, we selected the open type. But measurement of the aerial ultrasonic wave must limit not to get wet. Other specification shows table.1. Experiment date of the peak to peak value was acquired by the digital oscilloscope TBS1152 (Tektronix, Inc).

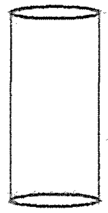
Table 1 Specification the aerial ultrasonic transducer of transceiver type

frequency		42	KHz
dimension	A	16.4	mm
	B	15.5	
	C	19.9	
	D	22.1	
weight		4.3	grams

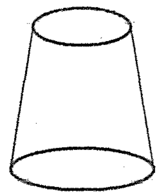


HAND-MADE HORN

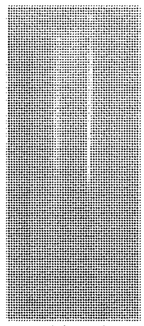
Hand-made horn was used in this study. Total three types and nine patterns of horn were used in this study. One cylindrical type and two circular-tapered-conical shape types' horns were used. Height of the horns was 2, 5 and 7 cm. The individual horn was placed in front of the measuring side of the aerial sensor.



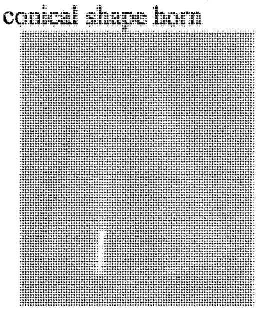
Diagrammatic view of the cylindrical shape horn



Diagrammatic view of the circular-tapered-conical shape horn



Photographic view of the cylindrical shape horn



Photographic view of the circular-tapered-conical shape horn

Fig. Hand-made plastic horn used in this study

Prepared horns` were classified and defined according to the following table:

Type	Identical name	Description of the horn
Cylindrical horn	3 cm	Height of the horn is 3 cm
	5 cm	Height of the horn is 5 cm
	7 cm	Height of the horn is 7 cm
Conical horn	20-3 cm	Slant height of the horn is 3 cm
	20-5 cm	Slant height of the horn is 5 cm
	20-7 cm	Slant height of the horn is 7 cm
	60-3 cm	Slant height of the horn is 3 cm
	60-5 cm	Slant height of the horn is 5 cm
	60-7 cm	Slant height of the horn is 7 cm

Basis of the present study

In our previous study we found that the dominant measuring range of the used sensor is about 200mm. to measure the mean arithmetic mean within the dominant range, decided to use the horn in front of the measuring side of the sensor.

THE MEASUREMENT PRINCIPLE

Figure1 shows the measurement principle of measurement of the arithmetic mean roughness of the concrete surface by the aerial ultrasonic wave of transceiver type. The wave of the aerial ultrasonic wave is reflected by the concrete surface. The reflection wave was diffusely reflected by the roughness of the concrete surface. We evaluated amount of the reflection wave with the peak to peak value. The peak to peak value is difference between the maximum value and the minimum value of the reflection wave value.

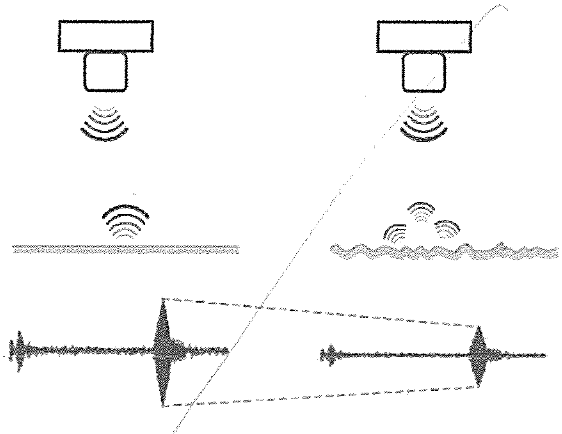


Fig. 1 The measurement principle of the ultrasonic sensor

ARITHMETIC MEAN ROUGHNESS

The Moulage Gauge and Determination

In this study the arithmetic mean roughness was measured by the moulage gauge. The length of the moulage gauge is 147(mm). The number of steel sticks is 183. Measurement interval is 0.8(mm). Figure2 shows the measurement surface of the arithmetic mean roughness 0.30(mm).

Figure3 shows the image of the arithmetic mean roughness. The formula $f_{(x)}$ is the roughness curve of the concrete surface. The formula $Y_{(x)}$ is liner approximation that is calculated from the roughness curve.

R_a is calculated by ration between the integral value of $|f_{(x)} - Y_{(x)}|$ and the length of the moulage gauge.

$$R_a = \frac{1}{l}\int_0^l |f_{(x)} - Y_{(x)}|\, d_{(x)} \qquad (1)$$

R_a: The arithmetic mean roughness
$f_{(x)}$: The roughness curve
$Y_{(x)}$: The Formula of liner approximation
l: The length of the moulage gauge

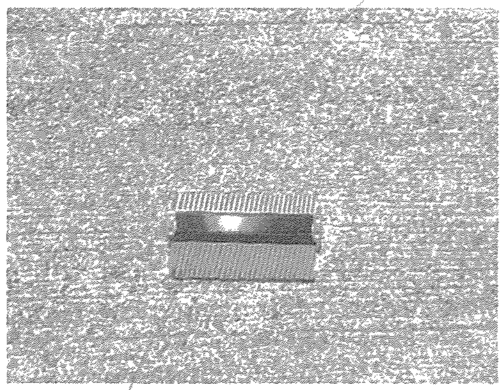


Fig. 2 The measurement surface of the arithmetic mean roughness in 0.30(mm)

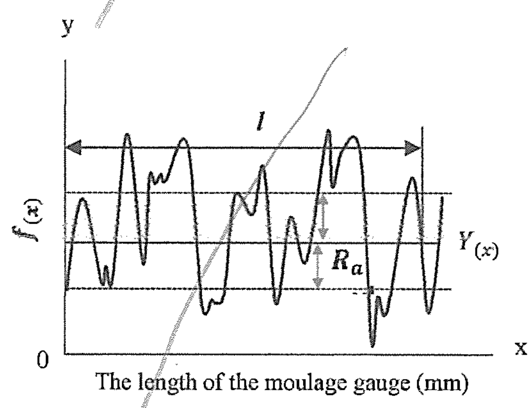


Fig. 3 The image of the arithmetic mean roughness

5.2 The Application of Measurement of the Arithmetical Mean Roughness

We measured the peak to peak value. The aerial ultrasonic measured from distance of 1000(mm). We measured five concrete surfaces that is 0.00~0.67 (mm) in the arithmetical mean roughness.

It is clear from figure5 that the peak to peak value was decreased with increasing the arithmetical mean roughness. In addition the formula of liner approximation had high correlational relationship. The formula of liner approximation is used to estimate the arithmetic mean roughness from the peak to peak. Measurement of the transceiver type aerial ultrasonic wave can estimate the arithmetical mean roughness well.

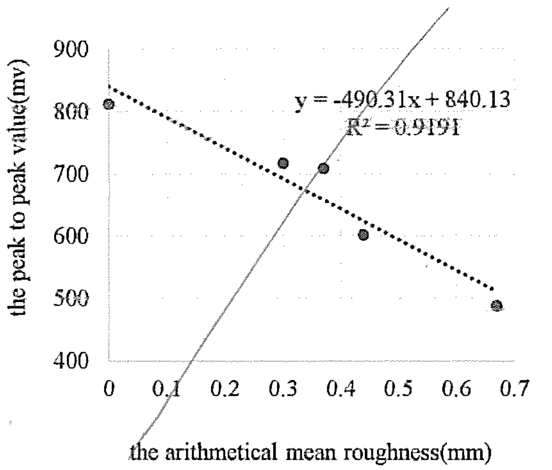


Fig. 5 The relationship between the peak to peak value and the arithmetical mean roughness

Experimental Program

Measurement of the aerial ultrasonic can measure the wide range. However, the measurement range that has inference on the measurement value is uncertain. To calculate the correct measurement range is almost impossible. The purpose is to clarify the measurement range that has inference on the measurement value.

Figure7 shows the experiment principle. We examined measurement range by widening diameter of the grave on the flat board. The flat board is 0.00(mm) in the arithmetic mean roughness. The grave of particle size is 2mm. Figure8 shows the used grave. The aerial ultrasonic measured from distance of 1000mm.

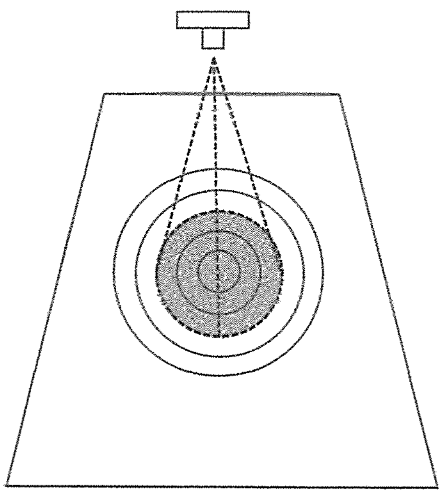
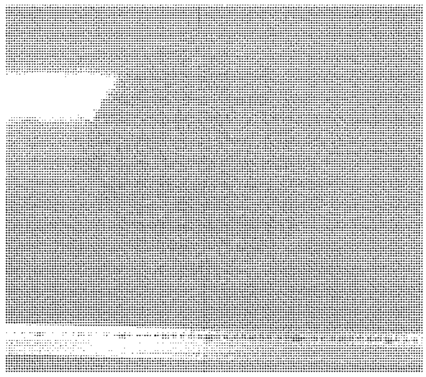


Fig. 7 The diagram of experiments for searching the measuring range



RESULTS

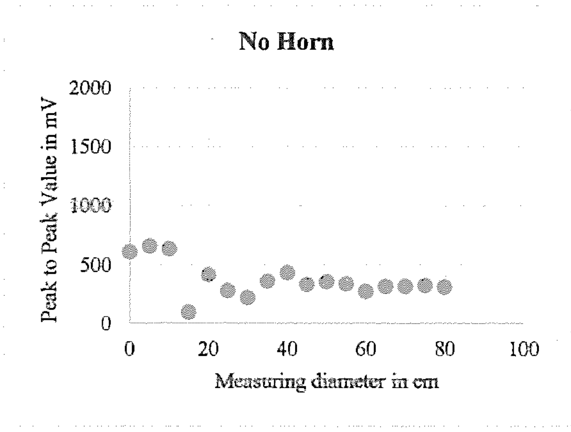


Fig. Relation between the measuring diameter and the peak to peak value measured without any horn

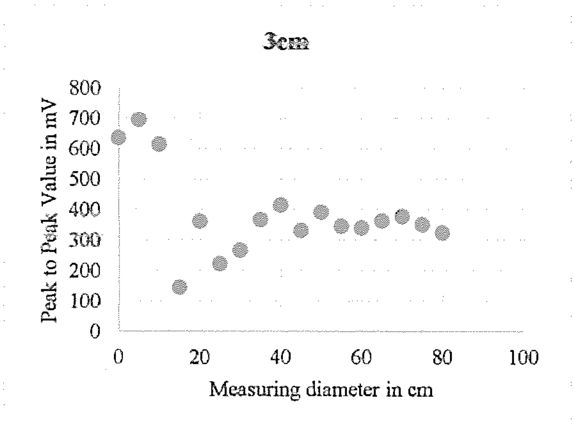


Fig. Relation between the measuring diameter and the peak to peak value measured by the help of 3cm cylindrical horn

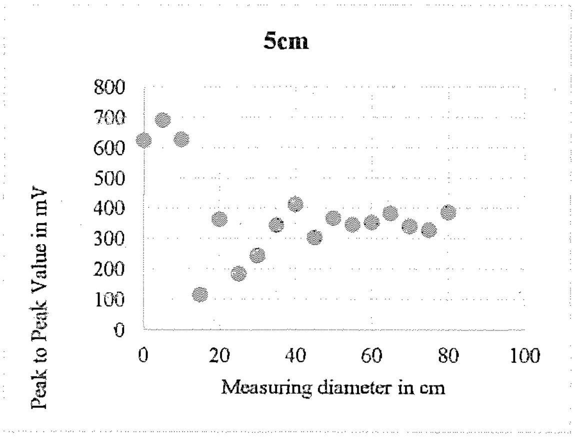


Fig. Relation between the measuring diameter and the peak to peak value measured by the help of 5cm cylindrical horn

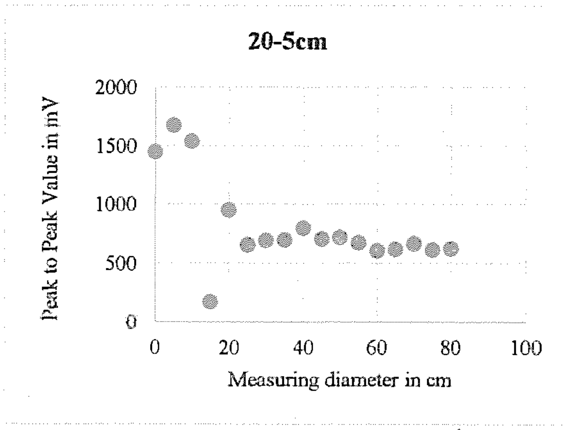


Fig. Relation between the measuring diameter and the peak to peak value measured by the help of 20-5cm circular-tapered-conical shape horn

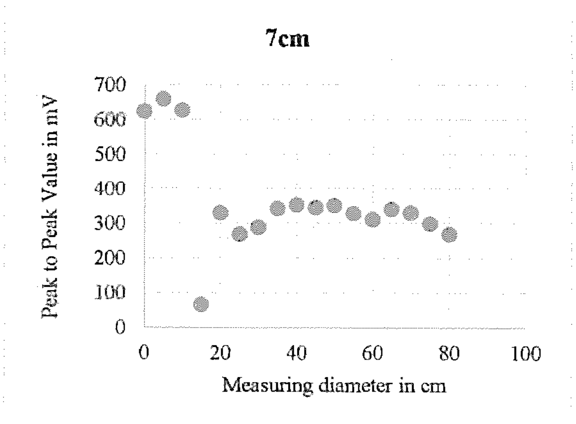


Fig. Relation between the measuring diameter and the peak to peak value measured by the help of 7cm cylindrical horn

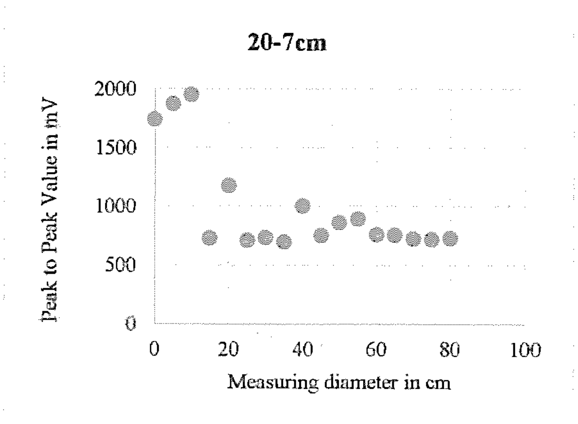


Fig. Relation between the measuring diameter and the peak to peak value measured by the help of 20-7cm circular-tapered-conical shape horn

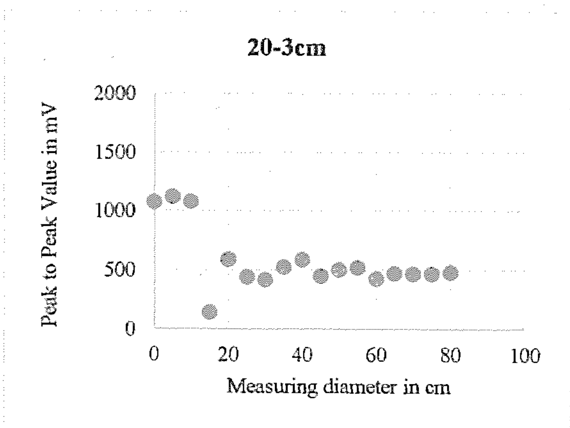


Fig. Relation between the measuring diameter and the peak to peak value measured by the help of 20-3cm circular-tapered-conical shape horn

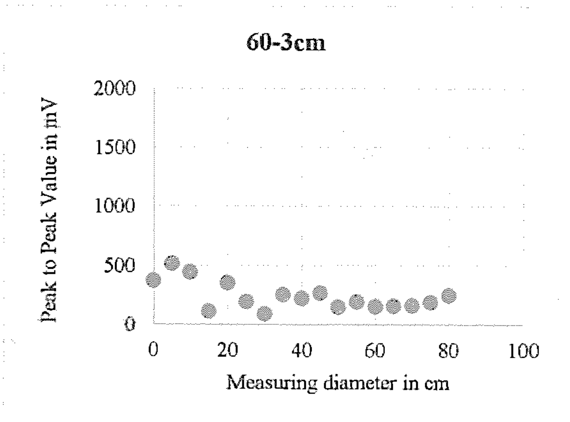


Fig. Relation between the measuring diameter and the peak to peak value measured by the help of 60-3cm circular-tapered-conical shape horn

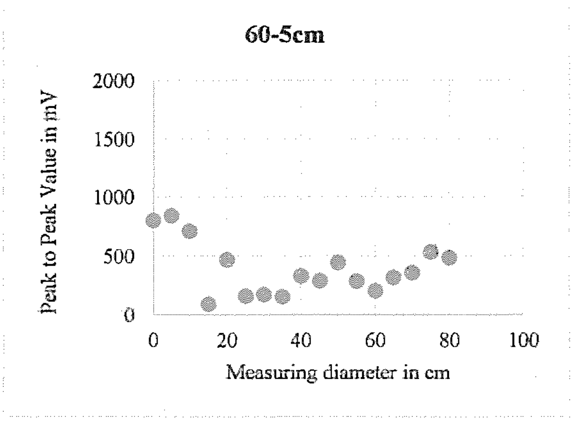


Fig. Relation between the measuring diameter and the peak to peak value measured by the help of 60-5cm circular-tapered-conical shape horn

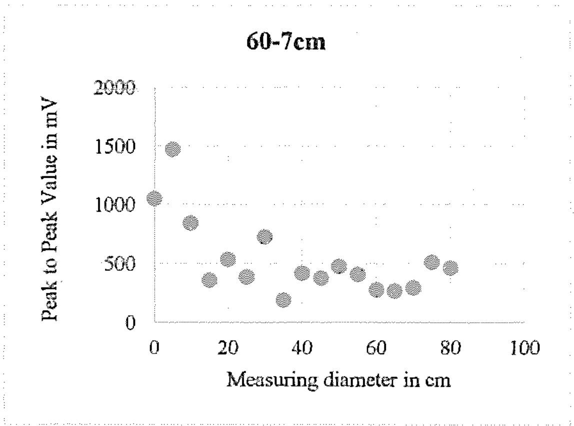


Fig. Relation between the measuring diameter and the peak to peak value measured by the help of 60-7cm circular-tapered-conical shape horn

The cylindrical horn with the slant height of 7cm was preferred for the clear outrange value and the circular-tapered-conical shape horn with 5cm slant height was preferred for the high peak to peak value. Other horns were rejected for unclear outrange, low peak to peak value and the presence of confusing data range.

6 CONCLUSION

We examined influence of the dispersion of the measurement values, relation between the arithmetical mean roughness and the peak to peak value of the reflection wave, and the verification of the measurement rang. As a result, following became clear. The peak to peak value of the reflection wave could estimate the arithmetical mean roughness well. The average of 15 times of measurement values were sufficient accuracy. The dominant range of measurement was 200(m) in diameter from distance of 1000(mm). The cylindrical horn with the slant height of 7cm and the circular-tapered-conical shape horn with 5cm slant height was preferred for measuring peak to peak value and to control the measuring range.

When manager estimate the arithmetical mean roughness, only evaluate the peak to peak of the reflection wave. We think of measurement range is wide. The results of this study reveal that measurement of the arithmetical mean roughness of the concrete surface can using the aerial ultrasonic sensor of transceiver type.

It remains a challenge for future research to verification of the measurement in various weather such as temperature and wind velocity, and measurement of the canal on field.

ACKNOWLEDGEMENTS

This study is funded by the Ministry of Agriculture, Forestry and Fisheries.

REFERENCES

[1] Kato T, Honma S, Kitamura K and Imaizumi M, "Deterioration of Irrigation Canals and Change in Roughness Coefficient", Tech. Rep. Natl. List. Rural Eng. Japan, Vol. 207, pp. 183~193. 2008.

[2] Nakaya T, Tokashiki M, Mori M and Mori T, "Estimation of the Coefficient of Roughness from Surface Characteristics og Abraded Concrete Channel", Trance of JSIDRE, No. 258, pp. 23~28, Dec 2008.

[3] Otagaki K, Hasegawa Y, Suzuki T, Matsumoto S and Sato S, "Study on Measurement Method of Surface Roughness of Concrete Canal by Three Dimensional Image Processing ", J of JSIDRE, NO. 280, pp. 7~13, Aug 2013.

論文７

空中超音波センサによる農業用水路コンクリート表面粗さ測定における風速による測定結果への影響

Influence of wind velocity in the measurement of the roughness of the concrete agriculture irrigation canal with the aerial ultrasonic sensor

○長岡 誠也*，岡島 賢治*，石黒 覚*，伊藤 良栄*，渡部 健**，伊藤 哲***

NAGAOKA Seiya，OKAJIMA Kenji，ISHIGURO Satoru，ITO Ryouei，WATANABE Ken， ITO Tetsu

1 はじめに

農業用水路では摩耗劣化が主な補修要因として挙げられる．水路の特徴として延長距離が長いため，照査において簡易で・面的な測定法が不可欠であると考えられる．そこで，長岡ら(2015)が簡易で面的な測定が可能な空中超音波測定を提案した．空中超音波は粗さ面に対して波が散乱し，最大触れ幅が減衰する特徴を有する．これまでの研究では農業用水路コンクリート表面の粗さを測定するための基礎研究と位置付け，粗さ面測定への適用，測定範囲，センサ法線と測定面のなす角が及ぼす影響，最適なセンサ素子数の決定を行った．しかし，測定現場を想定した場合，環境的な問題が生じることが想定される．特に空中超音波センサは，風向・風速計に用いられることがあるため，風速による影響は無視することが出来ない．そこで本研究では，測定中に生じる風に着目をし，風速による測定結果への影響を検討した．

2 空中超音波センサと測定面

本研究では長岡ら(2015)が使用したセンサと同様の LV-EZ1(MaxBotix.inc)を使用した．また本研究からホーンを装着することにより，超音波の広がりを制限し，測定範囲を明確にしている．測定面は遅延剤を用い，人工的に表面を洗い出した摩耗模型コンクリートパネルを３枚製作した．最大粒径 20(mm)，使用した骨材は砕石で，寸法は 700×700×50(mm)である．加藤ら(2008)が，供用 40 年後の 2 水路の算術平均粗さは，0.4~1.0(mm)，0.3~1.0(mm)であると報告している．したがって，本研究では摩耗進行状況に合わせ，算術平均粗さ 0.04，0.32，1.02(mm)のコンクリートパネルを製作した．

3 実験概要

風速は開放型風洞実験装置により人工的に発生させた．水路内で発生する風の向きは，水路延長方向であると想定される．したがって，風洞装置に対して水平方向に超音波が照査されるようにセンサを設置した．実験の概略図を**図 1 に示す．一般的に風速 10(m/s)を超える場合は，屋外での測定が困難であることを想定し，測定限界風速とした．測定は 2(m/s)間隔で 0~10(m/s)の測定を行った．**

高さ 1.00(m)から測定面に対して鉛直方向に空中超音波を照射し，オシロスコープにより反射波の最大触れ幅(mV)・波形を取得した．最大触れ幅は 31 回平均の値を用いた．

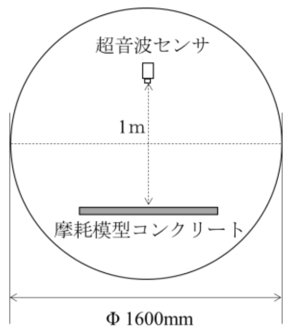


図 1 風洞実験正面図

*三重大学大学院生物資源学研究科 Graduate school of Bioresources，Mie University

**丸栄コンクリート工業株式会社 Maruei concrete industry Co.，Ltd.

***株式会社クロスアビリティ X-ability Co., Ltd.

空中超音波，粗度係数，コンクリート

4　実験結果と考察

実験結果のエラーバーは，測定結果のばらつきを表すため，31 回の標準偏差を用いた．風速 0(m/s)での最大振れ幅の値が異なるのは，測定面の粗さによる波の散乱による影響である．

風速 4(m/s)以下の測定結果は，標準偏差の範囲内であるため，測定に影響は少ない．

風速 4~6(m/s)は、標準偏差の範囲内ではあるが，図 4 のように減衰の傾向が見られるパターンもある。それは，無風条件下に比べ標準偏差が，平均して 30(mV)程大きくなる．また，風速が強くなるにつれて，標準偏差が大きくなる傾向があるため，測定結果に測定誤差範囲内のばらつきが生じる可能性がある．

風速 6(m/s)以上は線形に減衰を示した．表 1 より各パネルの減衰量は異なり、減衰率を比較すると，算術平均粗さが大きくなるにつれて減衰率が大きくなる傾向がある．したがって，風速の影響に対する補正について考えると，図 2, 3, 4 の近似式が示すように粗さごとの補正式が必要となる．しかし，上記でも述べたように風速が強くなるにつれ，標準偏差が大きくなるため，測定結果にばらつきが生じる可能性があり，高い精度での補正は困難であると考えられる．

5.　まとめ

本研究では測定中に生じる風に着目をし，風速 0，2，4，6，8，10(m/s)の条件下で空中超音波センサを用いて，風速による測定結果への影響を検討した．

風速 4(m/s)以下では，測定結果への影響は少ないことがわかった．

風速 4~6(m/s)では，測定結果への影響は少ないが，測定結果に測定誤差範囲内のばらつきが生じる可能性があることがわかった．

風速 6(m/s)以上では，線形に減衰を示した．しかし、標準偏差が大きくなるため，測定結果にばらつきが生じる可能性があり，高い精度での補正は困難であることがわかった．

以上より，風速が 6(m/s)以下であれば，屋外での測定に影響は少ない．

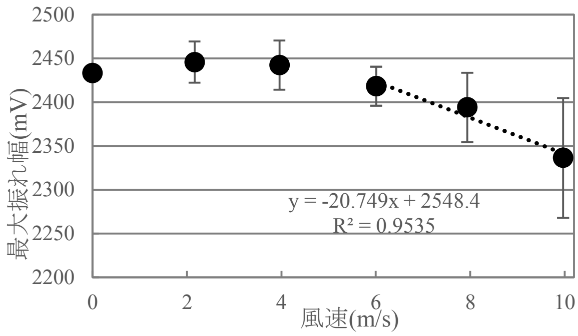


図 2　算術平均粗さ 0.04(mm)実験結果

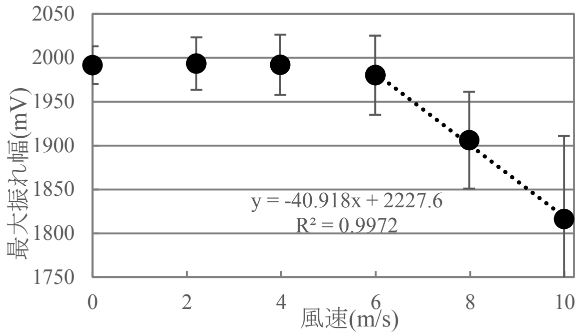


図 3　算術平均粗さ 0.32(mm)実験結果

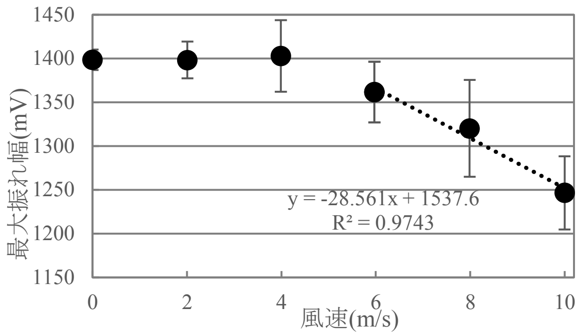


図 4　算術平均粗さ 1.02(mm)実験結果

表 1　0(m/s)~10(m/s)までの減衰量と減衰率

Ra(mm)	0.04	0.32	1.02
減衰量(mV)	96.94	175.10	151.97
減衰率(%)	3.98	8.79	10.87

謝辞: 本研究は平成 26 年度官民連携新技術研究開発事業により補助をいただきました．

参考文献

1) 長岡ら(2015)：空中超音波によるコンクリート表面粗さ測定の送信・受信素子数による比較検討，農業農村工学会大会講演会講演要旨集，p676-677

2) 加藤ら(2008): 農業用水路コンクリートに生じる摩耗に関する調査手法，コンクリート工学年次論文集，Vol31，No.1