# 3P2-15

## Detection of internal defects of concrete by non-contact acoustic inspection method －Evaluation of healthy part of concrete－

非接触音響探査法によるコンクリート内部欠陥の検出―健全部の評価―

Kazuko Sugimoto[1†], Tsuneyoshi Sugimoto[1], Noriyuki Utagawa[2] and Chitose Kuroda[2]
([1]Toin university of Yokohama; [2]Sato Kogyo Co., Ltd.)
杉本和子 [1†]，杉本恒美 [1]，歌川紀之 [2] 黒田千歳 [2] ([1] 桐蔭横浜大学院　工, [2] 佐藤工業㈱技術研究所)

### 1. Introduction

In Japan, social needs for maintenance of concrete structures constructed during the high growth period are increasing. In our laboratory, we have studied a method to inspect internal defects of concrete remotely using non-contact acoustic inspection method. We have proposed a defect detection algorithm[1)] using two acoustic features, vibrational energy ratio and spectral entropy. Quantitative statistical evaluation for a healthy part of concrete has been found to be important in order to distinguish internal defects of concrete from a healthy part and an abnormal measurement point. As for a healthy part of concrete, because of the property of concrete, there are difference due to factors such as aged deterioration, moisture content, mixed aggregate, etc. It is thought that statistical evaluation could be possible using acoustic features obtained from our measurements. In this research, experiments and analyzes were conducted on the actual concrete structure (concrete wall of tunnel, etc.), and an evaluation of healthy part of concrete was quantitatively performed. At the same time, elastic wave velocity and compressive strength by Schmidt hammer were measured, and the validity of this method was examined.

### 2. Extraction algorithm of healthy part of concrete by detecting outlier

When concrete surface seen as a healthy area was measured by non-contact acoustic inspection method, a singularity (or an abnormal measurement point) may be measured due to aged deterioration and surface condition of concrete, such as surface unevenness and reflectance. However, our purpose is to extract a healthy area of concrete by automatically detecting and eliminating singularity points etc. deviating from a healthy part of concrete. In our concept, a healthy part of concrete may be regarded acoustically uniform and isotropic. Although it also depends on aged deterioration and composition of concrete aggregate and the like, based on our experiences, our measured distributions of two acoustic feature quantities, such as vibrational energy and spectral entropy for a healthy part, follow the normal distribution. So, we

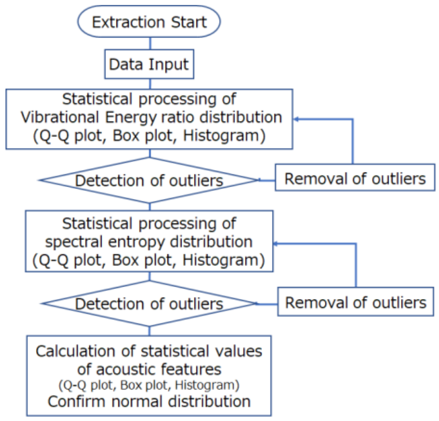


**Fig.1 Concrete healthy part extraction.**

handle it as a standard. The extraction algorithm of the healthy part is shown in **Fig.1**. Distribution of two acoustic feature quantities were obtained from vibration velocity data at each measurement point. The normality of vibrational energy ratio is judged by Q-Q plot and outliers are detected statistically by box plot with respect to vibrational energy ratio distribution and spectral entropy alternately. Outliers are eliminated. As a result, a healthy part of concrete is extracted. The normal distribution is confirmed, and the statistics (average and standard deviation) of the distribution of the two acoustic feature quantities are obtained.

### 3. Measuring method

Plane sound waves are radiated from a sound source of long range acoustic device (LRAD) to excite the concrete measurement surface. Using a laser Doppler vibrometer (Polytec, PSV-500Xtra Scanning Vibrometer), the vibration velocity distribution on the two-dimensional lattice point is measured by automatic scanning. A time-frequency gate process was performed on the obtained data, then after the FFT process, an extraction algorithm of a healthy part was applied.

†E-mail : kazukosu@toin.ac.jp

## 4. Measurement result

A scatter diagram by vibrational energy ratio versus spectral entropy is shown in **Fig.2**. Its data was obtained by measuring a healthy area at sidewall of a tunnel using our method. Healthy points are gathered on the left side of the figure. The proposed algorithm was applied to data points in the region surrounded by a dotted line and a healthy part of concrete sidewall was extracted. As

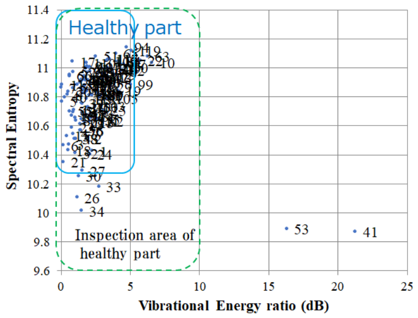


**Fig.2 Scatter diagram of vibrational energy ratio vs spectral entropy at tunnel sidewall (healthy part).**

shown in **Fig.3**, a scatter diagram by obtained vibrational energy ratio versus spectral entropy as a result of measuring the tunnel ceiling including a region of healthy concrete area. For the measured points with vibrational energy ratio≦4 dB, healthy part extraction algorithm was applied.

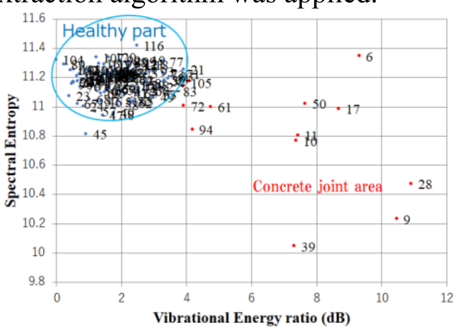


**Fig.3 Scatter diagram of vibrational energy ratio vs spectral entropy at tunnel ceiling (healthy part).**

A visual image by vibrational energy ratio is shown in **Fig.4**. Excluded the concrete joint and a periphery which is running right and left in the center of the figure, spread blue regions are healthy parts of concrete. A correlation diagram of rebound value by Schmidt hammer test versus elastic wave velocity is shown in **Fig.5** using results at several areas. A healthy part of tunnel ceiling was found to have larger rebound degree and larger elastic wave velocity than the healthy part at sidewall of tunnel. Generally, the harder the concrete is the harder to vibrate. The same phenomenon can be seen in **Fig.6**. The vibrational energy at ceiling is lower than at the sidewall. The dispersion of rebound degree is slightly larger at the sidewall than at the ceiling, and the same tendency can be seen with vibrational energy in **Fig.6**. In other words, a variance of vibrational energy at the sidewall is larger than at the ceiling. In **Figs. 5 and 6**, a plot shows two average values of acoustic parameters of each axis. And an arm length is expressed by ± 0.5*standard deviation.

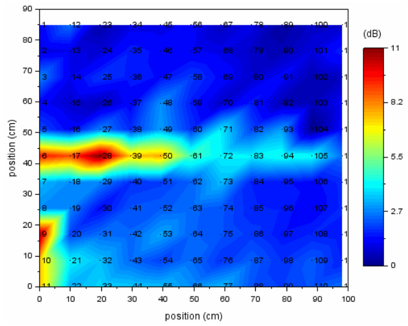


**Fig.4 Acoustic image by vibrational energy ratio at tunnel ceiling (healthy areas and concrete joint).**

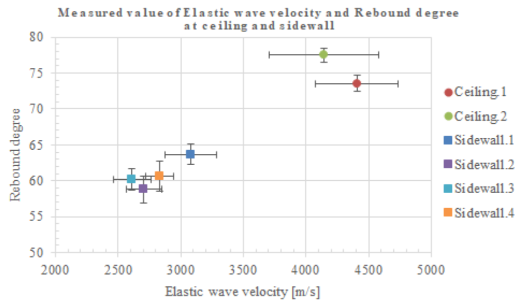


**Fig.5 A correlation diagram of Elastic wave velocity and Rebound degree at ceiling and sidewall of tunnel.**

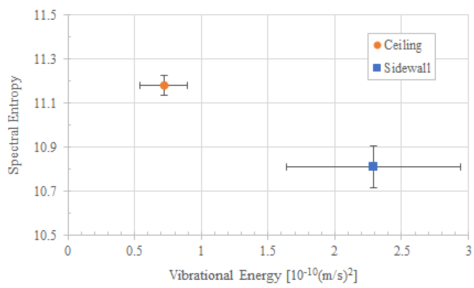


**Fig.6 A plot diagram of Vibrational energy ratio vs Spectral entropy at ceiling and sidewall of tunnel.**

## 5. Conclusion

Quantitative evaluation was performed for a healthy part of concrete by non-contact acoustic inspection method, and the same tendency as a result of repulsion degree by Schmidt hammer was obtained. From now on, I would like to study whether stable quantitative evaluation is possible by accumulating experimental data.

**Acknowledgment**

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**References**

1. K.Sugimoto, R.Akamatsu, T.Sugimoto, N.Utagawa, C.Kuroda and K.Katakura, Jpn. J. Appl. Phys., **54** (2015) 07HC15.