Comparison on the Characteristics of Natural Sound of Waves and Imitation Sound of Waves in Terms of Comfort Level

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***Abstract*-In general, the sound of waves in a calm sea is pleasant to the human while that in a stormy sea is unpleasant. In order to create an attractive urban space in the development of the waterfront, it is essential to perform a basic planning in consideration of the comfort level of the marine environment.**

Most of the sound of waves that urban people come into daily contact with is from CDs sold on the market, and it is mostly an imitation sound. Therefore, in this study, the characteristics of the natural sound of waves recorded in a natural environment (on the seashore) and the imitation sound of waves from CDs were compared and analyzed in terms of the comfort level.

The results of the analysis of their sound pressure spectrum and a questionnaire survey on the comfort level showed that natural sound of waves was more effective than the imitation sound of waves in terms of comfort level.

I. INTRODUCTION

In Japan, there are various problems concerning the environment of coastal zone in the field of ocean architecture. Among them, information on the visual environment, oscillation environment, light environment as well as the wind environment were compiled for basic planning and design [1].

Concerning the sound environment, the relationship between the environment and human psychology along with their behavior has been studied. However, studies on the environment in terms of the comfort level have not been conducted yet [2]. In the field of ocean civil engineering, the relationship between the comfortable environment of a waterfront and the elements of comfort such as the tone, rhythm and period of wave sound has been studied. Previously, the measurement research on the shore in Tokushima Prefecture, Japan [3] and a basic research on the role of wave sound as an element of a waterfront and the rhythmic characteristics of the waves have been made [4].

The sound of waves and wind heard on the waterfront are sometimes pleasant and unpleasant to the human ear.

Most of the sound of waves that urban people hear is from CDs sold on the market, which is mostly an imitation sound.

As a part of the basic research on the comfort level of the sound environment of a waterfront, the consciousness of the people living in northern Kyushu in Japan was surveyed and the basic characteristics of the sound of waves and wind on the coastline were studied [5]. Also, a field measurement and study on the basic characteristics of the wave sound in five different configurations of waterfronts (coastal zone) was conducted [6]. A field measurement also conducted on the comfort level of the sound environment of a coast where natural rocks were laid out on an artificial vertical embankment [7], whose results were reported before.

In this study, the characteristics of the natural sound of waves in a natural environment (on the seashore) and the imitation sound of waves from CDs were comparatively analyzed from the viewpoint of the comfort level.

II. OUTLINE OF SURVEY METHOD

A. Basic Survey Method

Natural wave sounds recorded at the coastal zone in Wakamatsu-ku, Kitakyushu City, Japan and imitation sound of waves from CDs sold on the market was used in this study. The characteristics of the sound pressure spectra and the results of a questionnaire survey on the comfort level of the each sound were comparatively analyzed.

B. Measurement Locations

Wave sound at three waterfront locations were measured and recorded and the data in terms of comfort level : natural sandy shore; natural rocky shore; and artificial shore (vertical embankment) in Kitakyushu City, Japan were reviewed (see Fig. 1).

C. Measurement Method

1) Sea and weather conditions

The wave height was measured by the visual observation and the wave period was measured using a stopwatch.

The instantaneous values of the wind direction and wind speed were measured with a hand anemoscope and anemometer. The instantaneous value of the temperature was also measured with a digital hygrometer and thermometer.

Fig.1 Measurement locations
(Kitakyushu City, Japan)

2) Sound environment

To obtain the measurements of the sound environment (sound of waves), Rion Co., Ltd.'s 1/3 octave band real time analyzer (SA-29) and precision sound level meter (NA-27) were used. Both devices were set to record frequency response for the measurement. The microphone to record the sound was placed 1.2 m above the ground and about 2.5 m away from the coastline.

3) Recording for the questionnaire survey on the comfort level of wave sound

At the measurement point, a precision sound level meter (NA-27) and Sony Corp.'s data recorder (PC-204 AX) were used to record the wave sounds for three minutes.

D. Analysis Method

1) Sound pressure spectrum

The sound pressure level (Pave) of the each sound was obtained by a power average operation of the data with a 1/3 octave band real time analyzer. Then the sound pressure spectra were comparatively analyzed.

2) Questionnaire survey on the comfort level of the wave sound

After playing the wave sound prerecorded at the measurement point and the wave sounds from a CD with Matsushita Electric Industrial Co., Ltd.'s Technics playback system, a survey on the Pleasantness, Rhythm, Impact (Dynamism) and Clearness of the sound was conducted in a laboratory. It has an evaluation system that classifies the levels into five grades of five points to one point; High, Relatively high, Average, Relatively low and Low.

III. SURVEY RESULTS AND DISCUSSION

A. Sound Pressure Spectrum of Wave Sound

The sound of waves is generated mainly because waves break far out at sea or they surf and hit the shore. The sound of waves when they surf and hit the shore naturally has a relation to the configuration of the shore.

Each sound pressure spectra of the recorded natural wave sound and the imitation wave sounds on a natural sandy shore, a natural rocky shore (surf), and an artificial shore (wharf) are shown in Figs. 2 ~ 4.

The sound pressure spectrum of the natural wave sound recorded on the natural sandy shore is similar to a pink noise with a decreased sound pressure level along with a frequency in the intermediate and high frequency band.

Meanwhile, the sound pressure spectrum of the imitation wave sound on the sandy shore is relatively flat and it is similar to a white noise. It is assumed that the sound from a CD has components of a high frequency band so that the sound would have a broad frequency in order to be easy to listen to. (See Fig. 2.)

The sound pressure spectrum of the natural wave sound on the natural rocky shore is similar to a pink noise with a decreased sound pressure level along with a frequency in the intermediate and high frequency band of more than 1.0 kHz. The sound pressure spectrum of the imitation wave sound on the surf (rocky shore) is similar to a white noise with high frequency components. (See Fig. 3)

The sound pressure spectrum of the natural wave sound on the artificial shore (vertical embankment) is similar to a pink noise with a decreased sound pressure level along with a frequency in the intermediate and high frequency band of more than 1.0kHz while the sound pressure spectra of the imitation sound at the artificial shore (wharf) has high frequency components and is similar to a white noise. (See Fig. 4)

From the shapes of the spectrum, it was found that the characteristics of the natural wave sound at any configuration of the shore are close to those of a pink noise while the characteristics of the imitation sound on any configuration of the shore are close to those of a white noise.

B. Questionnaire Survey Results concerning the Comfort Level of Wave Sound

The survey results are shown in Tables 1 ~ 2 and Figs. 5 ~ 7. The numbers in the parentheses in the Tables are the average points.

In the general evaluation, the natural wave sound on the natural sandy shore is "Relatively high" and the sound

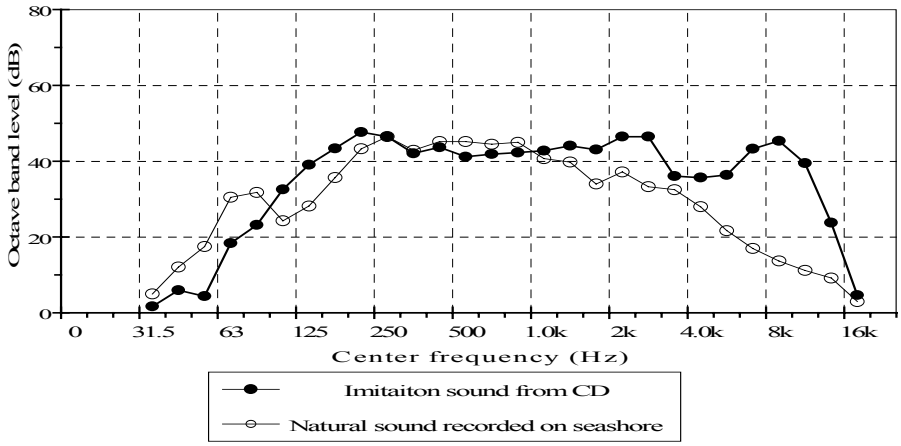

Fig.2 Wave sound pressure spectra of the natural sound recorded and imitation sound from CD on the natural sandy shore

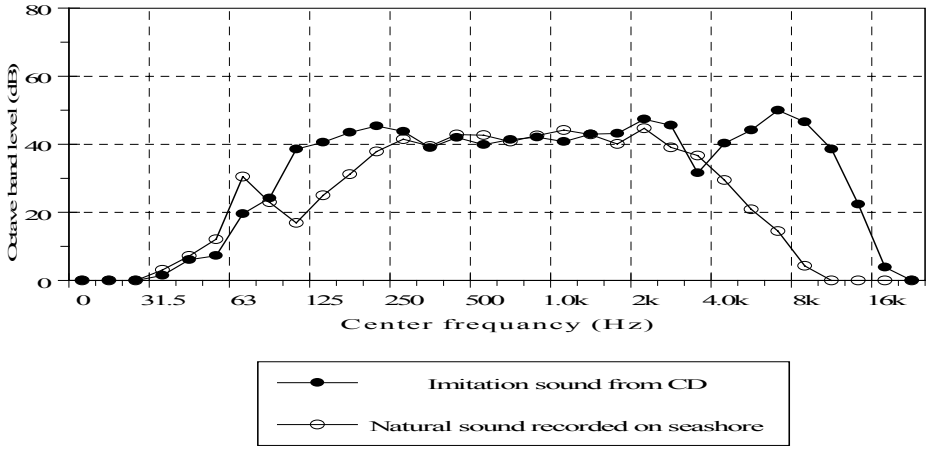

Fig.3 Wave sound pressure spectra of the natural sound recorded and imitation sound from CD on the natural rocky shore (surf)

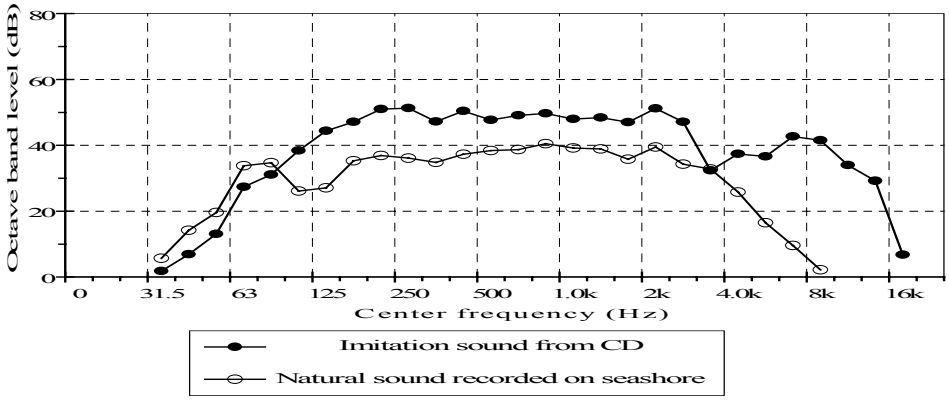

Fig. 4 Wave sound pressure spectra of the natural sound recorded and imitation sound from CD on the artificial shore (wharf)

Table 1 Questionnaire survey results concerning the comfort level of the natural wave sound recorded on the seashore

Shore configuration	Evaluation item	Rating	General evaluation
Natural sandy shore	Pleasantness	Average (3.45)	Relatively high (3.50)
	Rhythm	Average (3.15)	
	Impact(dynamism)	Relatively high (4.10)	
	Clearness	Average (3.30)	
Natural rocky shore	Pleasantness	Average (3.05)	Average (3.04)
	Rhythm	Average (3.10)	
	Impact(dynamism)	Average (3.25)	
	Clearness	Average (2.75)	
Artificial shore (vertical embankment)	Pleasantness	Average (3.25)	Average (2.95)
	Rhythm	Relatively high (3.50)	
	Impact(dynamism)	Average (3.05)	
	Clearness	Relatively low (2.00)	

Table 2 Questionnaire survey results concerning the comfort level of the imitation wave sound from CD

Shore configuration	Evaluation item	Rating	General evaluation
Natural sandy shore	Pleasantness	Relatively high (3.55)	Average (3.45)
	Rhythm	Relatively high (4.05)	
	Impact(dynamism)	Average (2.55)	
	Clearness	Relatively high (3.65)	
Natural rocky shore (surf)	Pleasantness	Average (3.30)	Average (3.00)
	Rhythm	Average (2.85)	
	Impact(dynamism)	Average (2.80)	
	Clearness	Average (3.05)	
Artificial shore (wharf)	Pleasantness	Relatively low (2.10)	Average (2.80)
	Rhythm	Average (2.80)	
	Impact(dynamism)	Relatively high (3.80)	
	Clearness	Average (2.50)	

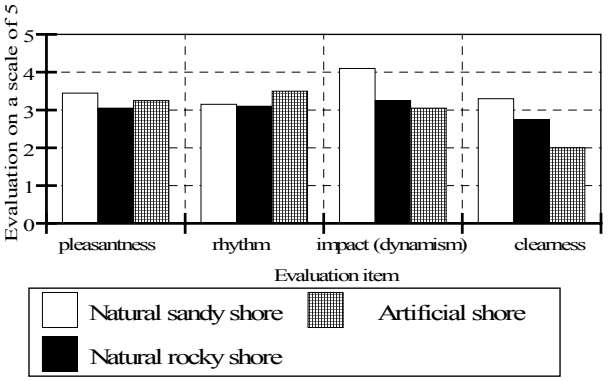

Fig.5 Questionnaire survey results concerning the comfort level of the natural sound recorded on the seashore

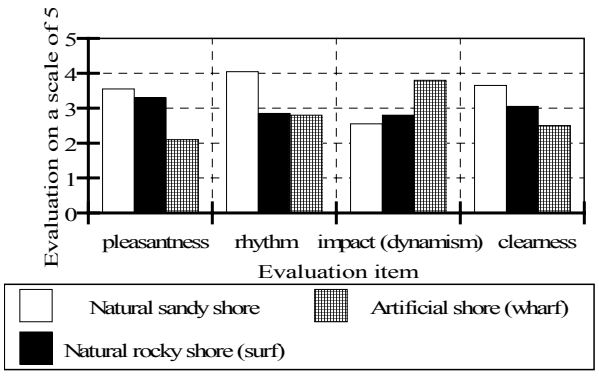

Fig. 6 Questionnaire survey results concerning the comfort level of the imitation sound from CD

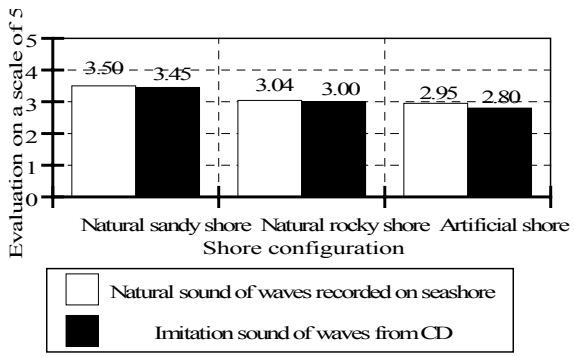

Fig. 7 Questionnaire survey results concerning the comfort level of the wave sound
(General evaluation by average point obtained)

on the other two configurations of the shore is "Average", which is shown in Table 1 and Fig. 5. Although, more specifically, the sound on the artificial shore (vertical embankment) is rated as "Relatively high" in Rhythm and "Relatively low" in Clearness. The sound on the natural sandy shore is rated as "Relatively high" in Impact (Dynamism), and "Average" in Pleasantness, Rhythm as well as Clearness. In reference to Impact (Dynamism), only the sound on the natural sandy shore is rated as "Relatively high" among the three configurations of shore.

As shown in the general evaluation (See Table 1 and Fig. 7), the comfort level of the natural wave sound on the natural sandy shore is ranked first. The natural rocky shore is ranked second and the artificial shore is ranked third.

The survey results of the imitation wave sound from CDs on each configuration of shore are shown in Table 2, and Fig. 6. In the general evaluation, the sound on the natural sandy shore, natural rocky shore (surf) and the artificial shore (wharf) is rated as "Average" in all evaluation items. However, the evaluation of the sound on the natural sandy shore is slightly better than that of the other two shores for all items except Impact (Dynamism).

Therefore, concerning the imitation wave sound, the sound on the natural sandy shore is ranked first, the sound on the natural rocky shore (surf) is ranked second, and the sound on the artificial shore (wharf) is ranked third, which is the same as the results of the natural wave sound.

Comparing the natural wave sound to the imitation wave sound, the former is slightly better than the latter in Impact (Dynamism) while the latter is a little better in Clearness. It is assumed that the imitation wave sound from CDs has many components of the high frequency band so that the sound would be easy to listen to.

From the survey results on the comfort level of wave sound (See Fig. 7, General evaluation), both the natural wave sound and the imitation wave sound on the natural sandy shore is ranked first, those on the natural rocky shore are ranked second, and those on the artificial shore are ranked third.

IV. CONCLUDING REMARKS

The comparative analysis of the natural wave sound and the imitation wave sound on the shore is concluded as mentioned below.

A. Sound Pressure Spectrum of the Wave Sound

It can be said that the shape of the sound pressure spectra of the natural wave sound is close to a pink noise while that of the imitation wave sound from CDs is close to a white noise.

B. Questionnaire Survey Results on the Comfort Level of the Wave Sound

From the survey results, it was found that the natural wave sound is evaluated a little bit more highly than the imitation wave sound. Concerning the configuration of the shores, both natural and imitation wave sounds on the natural sandy shore is ranked first, those on the natural rocky shore are ranked second and those on the artificial shore are ranked third by a narrow margin.

However, in terms of easy listening, the imitation wave sound from CDs is better than the natural wave sound.

From the results mentioned above, the imitation wave sounds from CDs are easier to listen to than the natural wave sounds. Although, in terms of comfort level, the latter is better than the former.

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