Characteristics of noise and vibration from Kyushu, Sanyo, and Tokaido Shinkansen Lines

Hiroyuki Tetsuya[a],Takashi Yano[a], Shigenori Yokoshima[b], Atushi Ota[c], Takashi Morihara[d], Yasuhiro Murakami[e]

[a] Graduate School of Science and Technology, Kumamoto University, Kurokami 2-39-1 Chuo-ku, Kumamoto 860-8555, JAPAN, e-mail: tetsuya-h@pref.kumamoto.lg.jp
fax: +81-9-6342-3569 tel:+81-9-6342-3560

[b] Kanagawa Environmental Research Center, Shinomiya 1-3-39, Hiratsuka 254-0014, JAPAN

[c] Faculty of Urban Innovation,Yokohama National University,Tokiwadai 79-5 Hodogaya-ku,Yokohama 240-8501,JAPAN

[d] Department of Architecture,Ishikawa National College of Technology,Kitachujo Tsubata,Kahoku-gun,Ishikawa 929-0932,JAPAN

[e]Department of Architecture,Sojo Univiversity, Ikeda 4-22-1 Nishi-ku, Kumamoto 860-0082,Japan,JAPAN

Key words: noise/vibration, Shinkansen,frequency analysis

ABSTRACT

Since Tokaido Shinkansen Line was opened in 1964, noise and vibration caused by Shinkansen Line have been serious social problems. Japanese Government enforced the noise standard for Shinkansen noise in 1975. The national and municipal environmental administrations have promoted and the protection measures along the Shinkansen lines have been implemented by Japan Railway Company. Socio-acoustic surveys on Shinkansen noise and vibration have also been carried out along Tokaido, Sanyo and Kyushu Lines. In order to discuss community responses in detail, noise and vibration recordings from Shinkansen trains were performed along the three lines in 2012. The spectrum of noise and vibration showed a similar trend among the three lines. That is, the noise spectrum was characterized by about 4dB/oct and the vibration spectrum showed three peaks in the ranges from 6.3 to 8 Hz, around 20 Hz, and from 40 to 63 Hz. On the other hand, the noise and vibration exposures from recently opened Kyushu Shinkansen Line were quite lower than those from the other two lines.

TEXT

1. INTRODUCTION

About 50 years have passed since Tokaido Shinkansen Line was opened, and noise and vibration environment along the Shinkansen lines have changed with promotion of the national and municipal environmental administrations, and soundproofing, countermeasures against vibration by JR. Toida et al. [1] and Yokoshima et al [2] measured noise and vibration along Tokaido Shinkansen Line and showed that the noise level has decreased year by year, while the vibration has not reduced. Nakanishi et al. [3] performed social survey and noise/vibration measurement in the areas along Sanyo Shinkansen Line. They suggested that when noise levels of Shinkansen and conventional lines were the same, the vibration level of Shinkansen is higher than that of the conventional railway line. Shinkansen vibration appeared to strongly affect the community response. However, when the authors [4] performed the survey along Kyushu Shinkansen, high response to the Shinkansen vibration was not found. In this study, in order to understand community response to Shinkansen noise and vibration, noise and vibration from Shinkansen trains along the three lines were recorded and analyzed.

2. OUTLINE OF NOISE/VIBRATION MEASUREMENT

Three to five measurement lines were selected for noise and vibration recordings from each of three Shinkansen lines. The measurement points were set along the line 12.5m, 25m and 50m away from the near track center. Noise and vibration from about five trains each on the near and far tracks were recorded. The microphone was set 1.2m high and the vibration pickup was set just under the microphone. Outline of each measurement point is shown in Table 1.

3. RESULTS AND DISCUSSION

In this paper, the authors focus particularly on the speed and type of Series 700 and N700 trains, because this type was the most frequent. Vibration level in the vertical direction was used for analysis because this was the highest.

3.1 Frequency characteristic of Shinkansen super-express train noise

Comparing instantaneous 1/3 band sound pressure levels, clear difference was not found in the spectral patterns and therefore energy average values of the sound pressure levels of each band were calculated. Figure 1 (a)-(c) show the results at the 25m measurement point. In Figure 1 the spectrum patterns showed a similar trend among the three lines, that is, they were characterized by -4dB/oct, and relative maximums appeared around 2kHz. Nagakura [5] indicated that the aerodynamic sound, whose power grows in proportion to the sixth power of the train speed, greatly contributes to Shinkansen super-express train noise.
Since train speed at the measurement point of Tokaido and Sanyo Shinkansen is faster than that of Kyushu Shinkansen, it is presumed that the former spectral patterns are affected by the aerodynamic sound more than the latter one. On the other hand, Morifuji et al. [6] confirmed that peaks might be seen in bands below 100Hz by a noise measurement and suggested that sound (hereinafter called structural sound) that occurs due to vibration of the high bridge structure may affect. That may be why another peak appear around 63kHz in the spectrum pattern of Kyushu Shinkansen. The noise levels are high for Tokaido Shinkansen except T1

and lower for other two lines, indicating that noise reduction mainly on sound source measures is effective.

3.2 Frequency characteristic of Shinkansen vibration

Energy average values of vibration acceleration levels in each band were calculated at each measurement point as well as noise. Figures 2 (a)-(c) shows the results at the 25m measurement point. In Figure 2, the vibration spectrum showed three peaks in the ranges from 6.3 to 8 Hz, around 20 Hz, and from 40 to 63 Hz. This is a phenomenon commonly seen in vibration of Shinkansen with the speed of around 200km/h and it is thought that it is governed by train speed and axle arrangement [7] [8]. Comparing the spectrum among three lines, the vibration levels are smaller in newer lines, the middle frequency range is dominant in Tokaido and Sanyo Shinkansen while the peaks of the three bands almost equal in Kyushu Shinkansen. This indicates that difference in speed or vibration reduction measures may affect. Moreover, great difference is seen in prominent frequency bands at T1and T2 in particular along Tokaido Shinkansen Line. From the boring performed in the vicinity of each point of T1 and T2, it has been shown that hard layers that are mainly composed of sandy mudstones exist below the surface layer at T1. Whereas supporting layers exist at shallow locations, extremely soft layers such as humic soil or clay are thick, therefore it has been confirmed that there exists a supporting layer at the deep location at T2[9]. In other words, it is thought that characteristics of the ground affect the spectral forms of both points.

This suggests that few effective vibration reduction measures have been performed or that the measures may be ineffective.

4. CONCLUSIONS

This study is summarized as follows.

(1) In frequency analysis of Shinkansen noise, the spectral pattern of each line was similar with relative maximums around 2kHz. Moreover, in the measurement points along elevated tracks, peaks appeared around 63Hz, outstanding at points where the train speed is slow.

(2) In frequency analysis of Shinkansen vibration, the relative maximums appeared in three bands in all lines. Whereas the middle frequency range was the greatest for Tokaido and Sanyo Shinkansen Lines, those of the three bands were almost equal for Kyushu Shinkansen.

(3) In calculating Shinkansen noise and vibration levels, the maximum noise level, which exceeded 70dB (the environmental standard value) at four of five points, was the greatest for Tokaido Shinkansen. On the other hand, there are no points where the vibration levels exceeded 70dB, the standard value, and the levels are smaller for newer lines.

ACKNOWLEDGMENTS

This study was financially supported by Grant-in-Aid for Scientific Research C (No. 22560592). The authors appreciate Shuhei Oka and Koji Shimoyama, the graduate students of Kumamoto University, for their noise and vibration measurements.

REFERENCES

[1] Toida, M., Omiya, M., Kuno, K. (2005). Report of noise and vibration from the Tokaido Shinkansen in Nagoya city. Proc. of Annual Meeting of Architectural Institute of Japan, 103-104

[2] Yokoshima, S., Tamura, A. (2005). Shinkansen Railway Noise and Vibration in Kanagawa Prefecture (in Japanese). Proc. of Autumn Meeting of Institute of Noise Control Engineering of Japan, pp. 77-80, September.

[3] Nakanishi, T., Nakashima, Y., Morihara, T., Yano, T. (2005). Measurements of vibration from Shinkansen and conventional railway; Effects of vibration on community response to noise Part I (in Japanese). Proc. of Annual Meeting of Architecturall Institute of Japan, pp. 103-104

[4] Oka, S., Murakami, Y., Tetsuya, H., Yano, T. (2013) Community response to a step change in railway noise and vibration exposures by the opening of a new Shinkansen Line., Internoise2013, CD-ROM, September 2013

[5] Nagakura, K. (2011). Analysis and reduction technology for Shinkansen super-express railway noise (in Japanese)., Railway Technical Research Institute, RRR, Vol.68, No3, pp.32-35

[6] Moritoh, Y., Zenda, Y., Nagakura, K. (1996). Noise control of high speed Shinkansen. Journal of Sound and Vibration, 193(1), pp319-334

[7] Ejima, A. (1979). Ground vibration and its measurement: from fundamentals and regulation to traffic and construction vibration (in Japanese). , Shubunsha, pp.160-161

[8] Ueda, C. (1984). The wooden house vibration due to high-speed running train and its reduction (in Japanese), Transactions of the Architectural Institute of Japan. (345), pp. 104-114

[9]Kanagawa Construction Technology Center. Kanagawa Boring Data Map (in Japanese). http://www.toshiseibi-boring.jp/

TABLE

Line/ Open year	Train type： Series /Number of rail car	Maximum speed/ Track	Location	Structure	Noise barrier
Tokaido 1964	・Series 700/ 16 ・Series N700/ 16	270km/h / Ballast	T1	Elevated	Direct type / Lambda type
			T2		Direct type
			T3	Bank	Direct type / Improved type (leveling)
			T4		Direct type / Lambda type
			T5	Canal	Direct type
Sanyo 1972	・Series 500 /8 ・Series 700 / 8 ,16 ・Series N700 /8,16-	300km/h / Slab	S1	Elevated	Direct type / Improved type (leveling)
			S2	Bank	Direct type
			S3		
Kyushu 2011	・Series 800 /6- ・Series N700 /8-	260km/h / Slab	K1	Elevated	Direct type
			K2		
			K3		

Table 1. Outline of measurement

FIGURES

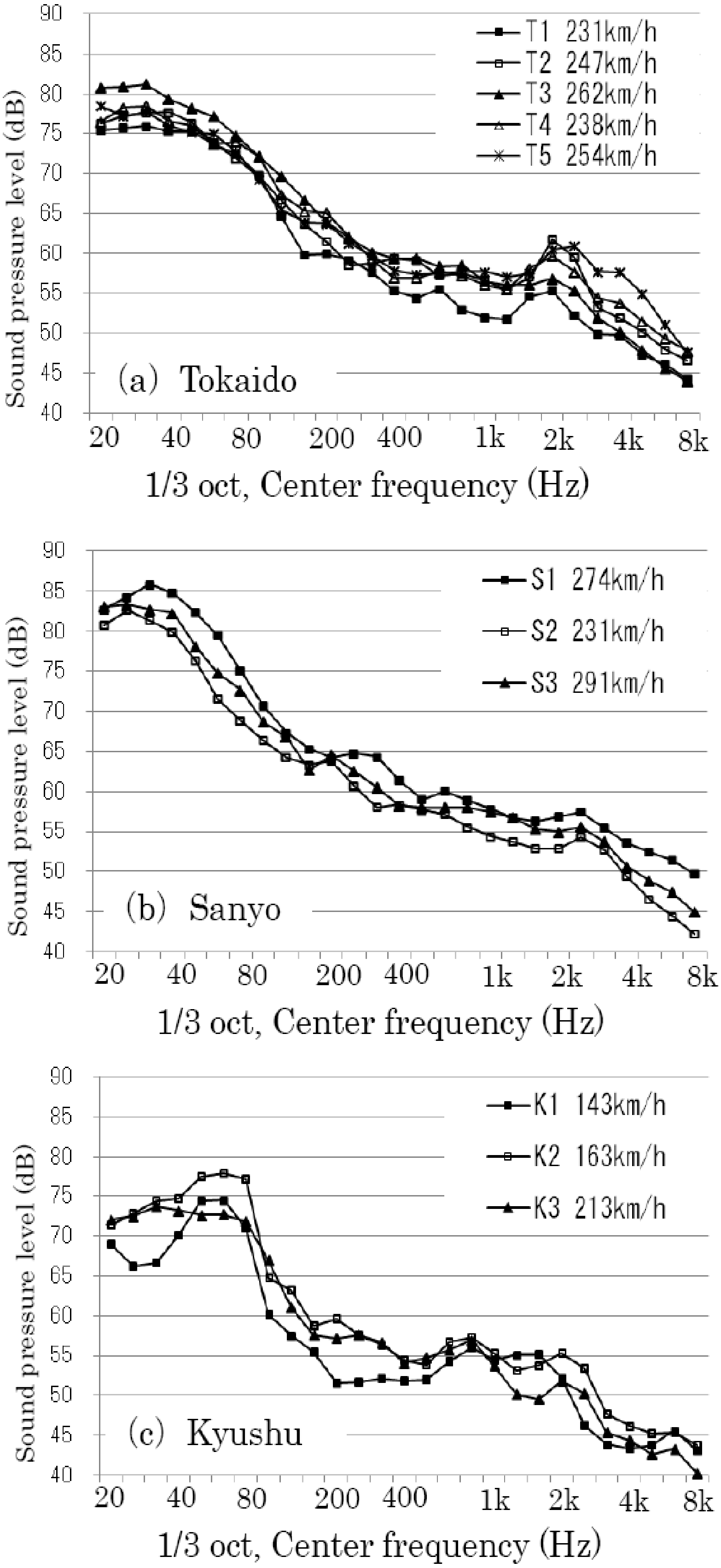

Figure 1. Frequency analysis of Shinkansen super-express train noise

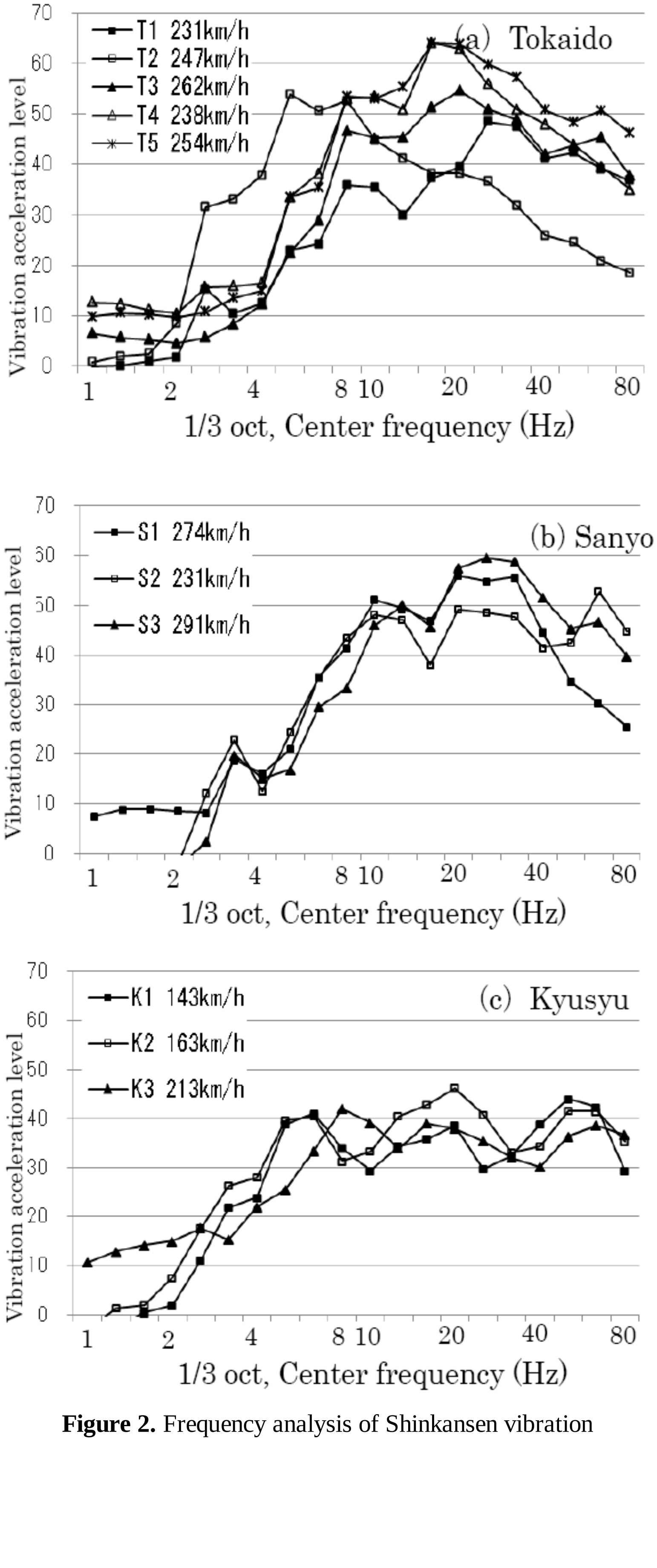

Figure 2. Frequency analysis of Shinkansen vibration