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Noise Barrier Performance of a Sekisyu-Tile Roof

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Abstract: The Sekisyu tile is a regional product manufactured as an architectural roof material in the Japanese prefecture Shimane. The present study evaluated the noise barrier performance of a roof made from Sekisyu tiles. Measurements of sound insulation were made in three single-room house models having tiled, steel, and thatched roofs and measurements of rain noise were made in the models having tiled and steel roofs. In the measurement of sound insulation, the noise levels measured under the tiled and steel roofs were 10 dB lower than those measured under the thatched roof. Additionally, when the source position was above the center of the roof surface, the sound pressure levels at frequency bands of 500 and 1000 Hz were 6.6 dB lower under the tiled roof than under the steel roof. In the measurement of rain noise (for a precipitation rate of 2.2 mm/h), noise levels measured under the tiled roof were 4 dB lower than those under the steel roof. The sound of rain drumming on the steel roof included strong sound energy at frequencies above 500 Hz. In future work, I will examine how differences in the noise level affect speech intelligibility and sleep quality.

Key words: sound insulation, rain noise, tiled roof, steel roof, thatched roof, noise level

1. Introduction

The Japanese prefecture of Shimane is famous for its roof tiles (Kawara in Japanese), produced by the manufacturer in Sekisyu area. Shimane is located behind mountain ranges and faces the Japan Sea. Sea winds bring cold and rainy weather during winter. Sekisyu tiles are baked by firing at a temperature of 1300°C to produce a hard body that is resistant to cold-weather damage and salt damage. Many houses in Shimane adopt Sekisyu tiles for their roofs. The present study investigates the noise barrier performance of Sekisyu tiles.

A previous study [1] examined the ability of roofs of various shape (e.g., a gable roof and shed roof) to shield the outdoor of a house from noise produced in the surrounding environment. However, the effect of roof materials on the indoor environment has not been studied. I made two series of measurements to evaluate the noise barrier performance of the Sekisyu tile. A model of a house (comprising a single room with length 1.9 m, width 1.4 m, and height 1.2 m) was built with a tiled roof. The first series of measurements was of sound insulation, where noise originating from outside the model was measured inside the model. For comparison, the same measurement was made in two models of houses having a steel roof and thatched roof and the same dimensions (Fig. 1). The thickness and surface density of the roof materials were respectively 14.2 mm and 45.7 kg/m^2 for the Sekisyu tiles, 0.35 mm and 4.5 kg/m^2 for the steel, and 320 mm and 1.6 kg/m^2 for the thatch. The second series of measurements was of rain noise, where the sound of water drumming on the roof surface was measured. Shimane has high annual precipitation (1787.2 mm in the period 1981 to 2010). Additionally, in Japan, rain noise is a social problem in that it disturbs conversation under a membrane roof [2, 3] or a steel roof [4]. I measured the rain noise in the models with the tiled and steel roofs simultaneously on a rainy day. At the same time, the hourly precipitation was measured using a rainfall meter.

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(a)

(b)

(c)

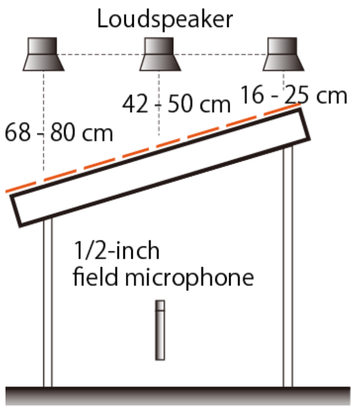
Fig. 1 Models of houses with (a) a tiled roof, (b) steel roof, and (c) thatched roof.

2. Method

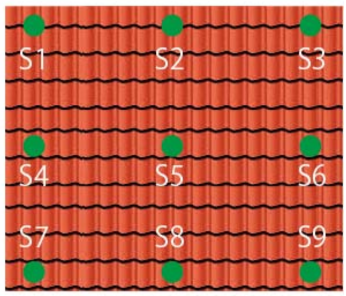
2.1 Measurement of Sound Insulation

I used a loudspeaker (6301, Fostex) in the measurement of sound insulation. The loudspeaker was located at nine positions above the roofs of the models with tiled and steel roofs as shown in Fig. 2, but only at three positions above the roof of the model with the thatched roof (s4 to s6) because of the height limit. The loudspeaker was hung with a tightly stretched rope. The cone of the loudspeaker faced downward. As the height of the loudspeaker above ground level did not change, the distance between the loudspeaker and the roof surface depended on the position.

A 1/2-inch condenser microphone (4191, Brüel & Kjaer) was used for recording after calibration. The microphone was mounted on a microphone stand and the transducer faced upward. The microphone was located at the center of the floor at a height of 40 cm. The background noise levels were 35.7, 36.5, and 41.6 dB respectively under the tiled roof, steel roof, and thatched roof.



(a)



(b)

Fig. 2 Model of a house and locations of a loudspeaker and microphone in (a) cross-section and (b) plan views.

The output signal was white noise whose A-weighted sound pressure level (noise level) was 92 dB at a point 50 cm from the loudspeaker cone. The measured sound was regulated with a conditioning amplifier (NEXUS, Brüel & Kjaer) and digitized for subsequent analysis at a sampling rate of 44.1 kHz and 16-bit resolution (UA-101 analog-to-digital converter; Roland).

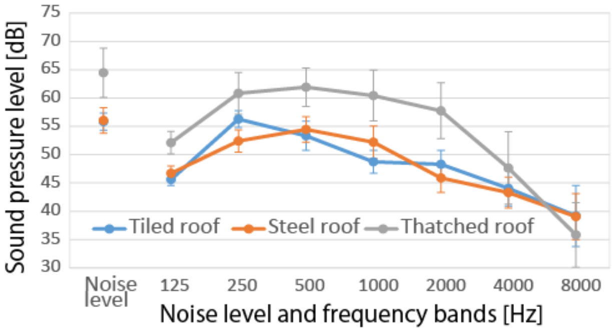
2.2 Measurement of Rain Noise

On a rainy day, I measured the rain noise when raindrops struck the surfaces of the roofs. In this measurement, the recording apparatus was the same as that used for the measurement of sound insulation, except that I added a calibrated 1/4-inch condenser microphone (4939, Brüel & Kjaer) and measured the rain noise in the two models with the tiled and steel roofs at the same time. The model with the thatched roof was not used in this series of measurements. During the measurement of rain noise, the precipitation in the area near the models was measured using a rainfall meter (WS9006, La Crosse).

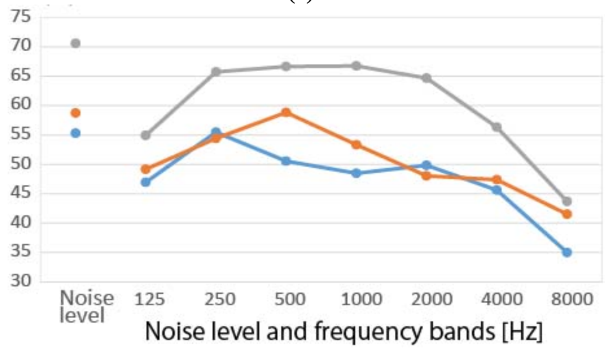
3. Results and Discussions

3.1 Sound Insulation Characteristics

Fig. 3 shows the spectral characteristics of the sound transmission through the different roof materials. If the transmission loss followed the mass law of an insulating wall theoretically, the sound energy in the models would be higher at lower frequency. However, the walls of the models were constructed with a single layer of plywood panels and had air gaps at the interstices. The transmission loss would thus be greater at frequencies lower than 500 Hz than what would be expected from the mass law [5], and the sound energy at 125 Hz might be attenuated. The sound transmission was much higher for the thatched roof than for the tiled and steel roofs; the difference in the noise level was approximately 10 dB. In Fig. 3a, the noise level averaged over the nine source positions was similar for the tiled and steel roofs. According to the mass law, the



(a)



(b)

Fig. 3 (a) SPLs averaged over all sound source positions and (b) SPLs for the center source position (s5).

room under the tiled roof should be quieter than the room under the steel roof because the thickness and surface density of the tiles were much greater than those of the steel. The actual results, which were similar for the two models, might be due to sound passing through the interstices of the walls. Fig. 3b compares the sound pressure levels (SPLs) for the center source position (s5) and shows that the SPLs in the one-octave frequency bands of 500 and 1000 Hz were remarkably lower for the tiled roof. Because the simplified walls of the models had interstices, the SPLs measured in source positions other than s5 could be more affected by sound transmission through the walls and sound leakage through the interstices. If the walls were layered with exterior and interior walls and insulating materials like the walls of a conventional home, the differences in SPL measured under the tiled and steels roofs would be larger. Since the sound energy of consonants lie in such frequency bands (i.e., 500 and 1000 Hz), it is possible that the tiled roof may improve speech intelligibility for conversations indoors.

3.2 Measured Rain Noise

Fig. 4 shows the levels of rain noise for the tiled and steel roofs as a function of time. The rain noise was generated when rain dropped on the surfaces of the roof materials, and the striking sound passed through the roof boards and the walls of the models and into the rooms of the models. The total duration of the measurement was 23 minutes and values were averaged for each period of 10 seconds. The rain noise was approximately 4 dB louder for the steel roof at the beginning of the measurement period, and the difference reduced with time as the rain eased off during the measurement period. The precipitation rate was 2.2 mm/h, which is a rate at which most people would choose to use an umbrella to walk even in a short distance. The level of rain noise increases with the precipitation rate [4]. I therefore have to accumulate rain noise data on various rainy days to clarify the relationship between the noise level and the rate of precipitation for the tiled roof. When the rate of precipitation was less than 2.2 mm/h, the rain noise that passed through the tiled roof was nearly independent of the rate of precipitation.

Fig. 5 shows spectral characteristics of the rain noise for the tiled and steel roofs. The drumming sound of rain on the steel surface had higher sound energy than that on the tiled roof at frequencies above 500 Hz. A comparison with the sound insulation performances in Fig. 3 reveals that the sound energy in such a high frequency range is a particular characteristic of rain noise on the steel roof. Therefore, on a rainy day, people indoors may experience difficulty in identifying consonants during conversation.

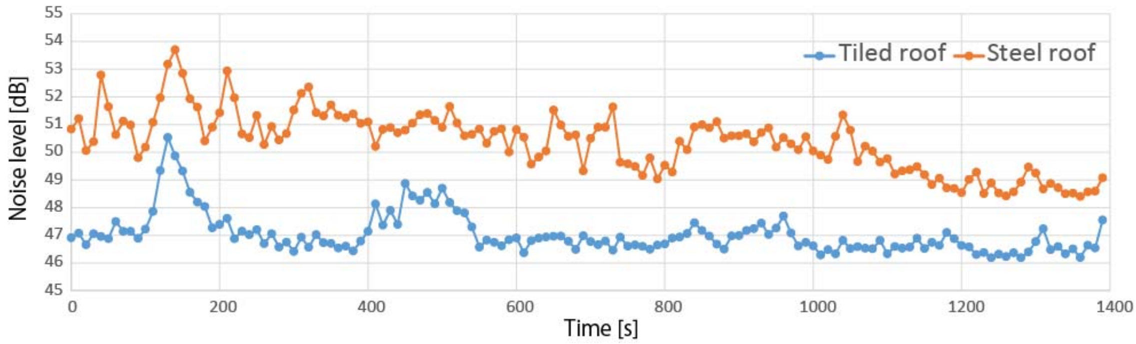


Fig. 4 Level of rain noise as a function of time.

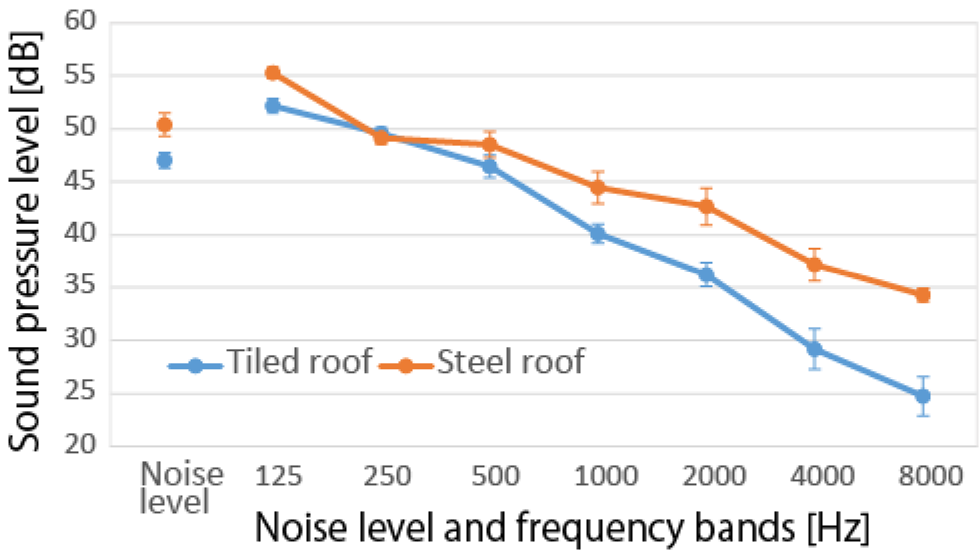


Fig. 5 SPLs of rain noise.

4. Conclusion

I compared the noise barrier performances of roof materials. Measurements of sound insulation revealed that tiled and steel roofs performed much better than a thatched roof, and the tiled roof provided better sound insulation than the steel roof in the frequency range around 500 and 1000 Hz. Measurements of rain noise revealed that the tiled roof created a quieter room environment than did the steel roof. Although the noise barrier performance of the tiles was higher than that of the other materials overall, the present study did not clarify whether the difference affects speech intelligibility or quality of sleep. In future work, I will measure the noise barrier performances of other types of roof tiles (e.g., Sansyu Kawara and Awaji Kawara) and evaluate various aspects of indoor conditions.

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