〈Orignal Paper〉

Prediction of Railroad Noise

철도소음의 예측

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ABSTRACT

Railroad noise is one of the main causes of environmental impact. Whenever a new railroad line is planned or a housing project near an existing railroad is proposed, an estimate of the relevant noise levels is usually required. For this, it is necessary to quantify those parameters that affect the railroad noise. This paper presents an accurate prediction of railroad noise.

1. Introduction

Due to the increase of moving population and materials mobilization amount attendant on the rapid industrial development and economic growth the road traffic is heavy, and the social problem of a traffic jam and the economic loss occurs. Therefore the railroad of mass transportation which was out of public interest one time for the appearance of highway arouses public interest once again as the only alternative which is able to solve that kind of problem, and the subway and the high speed railroad are constructed as a part of that. Although the railroad plays such an important part as mass transportation and regular operation, its noise disturbs the wayside residents on the other hand.

Therefore we selected 39 sites in which the background noise is very low and the railroad is at grade and investigated the maximum sound level and the equivalent continuous sound level for one hour which 413 conventional trains generate passing through the above sites. We derived the prediction equation of the equivalent continuous sound level using the maximum sound level, the number of trains for one hour, and the time of passage. On the one hand the maximum sound level is estimated from the speed of train.

2. Measurement Results and Discussion

The noise of a passing train is measured at distances of 7.5, 15, 20 m and at a height of 1.2 to 1.5 m in the semi-free field based on the international standard, ISO 3095[1]. Four types of train has been measured : super express train(Saemaul) with 150 to 300 m length, express train(Moogungwa, Tongil) with 180 m length, local(slow) train, and freight train. The head of super express train is streamline shape and the

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others are rectangular shape.

2.1 Equivalent Continuous Noise Level by Railroad Line

Table 1 shows the equivalent continuous noise level of passing train for one hour at a distances of 7.5, 15, 20 m by railroad line.

We can see that doubling of distance from sound source results in a decrease in the equivalent continuous noise level of about 2.9~3.5 dBA averagely. It implies the distance attenuation of the typical line sound source.

2.2 Noise Level by Raillength

In order to grasp the noise characteristics by the raillength the rolling stock noise which comes from the wheel and rail interaction was measured at a distance of 7.5 m from the track center line to the exclusion of the propulsion system noise of locomotive, and it is shown in Table 2.

We see the rolling stock noise on the continuous welded rail with a length more than 400 m is lower averagely by 3 to 4 dBA[2,3] than that on the jointed rail with a length of 20 to 50 m irrespective of the train speed in Table 1. This is due to the impulsive noise which comes intermittently from the wheel/rail interaction in a gab of the jointed rail.

2.3. Comparison of Locomotive Noise with Rolling Stock (Coach) Noise

Table 1 Equivalent continuous noise level by railroad line

Line	$L_{eq(1h)}$, dBA			No. of measured site	No. of trains per hour
	7.5 m	15 m	20 m		
Kyungboo (S.W.-D.J.)	69.8~77.9 (76.0)	68.2~74.9 (72.5)	66.1~72.7 (69.7)	15	12~17
Kyungboo (D.J.-K.C.)	71.9~75.7 (74.3)	67.9~73.6 (71.4)	65.5~71.8 (68.8)	6	9~12
Honam (D.J.-I.R.)	69.1~77.6 (73.6)	66.1~74.2 (70.2)	64.5~72.4 (68.0)	13	4~ 5

※The values in parenthesis represent the mean values.

Table 2 Rolling stock (coach) noise level by raillength dBA

Kind of train	Speed km/h	20~50 m		No. of trains	〉400 m		No. of trains
		Range	Mean		Range	Mean	
Super express	100~ 13 60~100	89~96 87~93	94 91	11 6	85~ 93 83~89	90 87	24 5
Express	100~130 60~100	91~10 88~98	96 94	15 20	88~ 9 85~93	93 90	69 18

Table 3 Noise level of locomotive and coach dBA

Speed km/h	Super express train					Express train				
	Locomotive		Coach		No. of trains	Locomotive		Coach		No. of Trains
	Range	Mean	Ramge	Mean		Range	Mean	Ramge	Mean	
100~138 60~100	89~97 88~93	93 89	85~93 83~89	90 87	24 5	96~107 94~105	101 100	89~96 85~93	93 90	69 18

The propulsion system noise of diesel locomotive is compared with the noise of rolling stock running on the continuous welded rail at a distance of 7.5 m from the track center line in Table 3.

When the trains travel on the continuous welded rail, the diesel locomotive noise of the super express train of which the power is seperated and the frontshape is streamline is higher averagely by 2 to 3 dBA[2,3] than its rolling stock noise in which the rolling and impulsive noise are the dominant sources. On the one hand the locomotive noise of the express train of which the power is concentrated on one place and the front shape is rectangular is higher averagely by 8 to 10 dBA than its rolling stock noise.

2.4 Time Evolution of Noise Level during Passge of Train

Fig. 1[2] shows the typical time evolution of the noise level during the passage of train at a distance of 7.5 m from the track center line. When the Saemaul which consists of two locomotive(one on each end) and six coaches(one coach length is 21 m) travels at the speed of 112 km/h it radiates noise for 6 seconds in the left of Fig. 1. In this Figure the peak level on each end indicates the engine noise and the others indicate the rolling noise from the wheel/rail interaction. The Moogungwha which consists of one locomotive and eight coaches generates noise for 6 seconds passing at the speed of 106 km/h and its locomotive noise is shown much more remarkably than that of the Saemaul. This is that the locomotive of the Saemaul is streamline and its power is seperated on each end while that of the Moogungwha is rectangular and its power is concentrated on one place.

2.5 Relationship between Speed and Noise of Train

The railroad noise at a specified distance is different according to the type of train, the operating speed, the rail conditions, the type of brake and so on. The relationship between the train speed and noise level is as follows.

$$L_{max} = k \log v + C \quad (1)$$

Where L_{max} is the maximum noise level dBA, v is the train speed km/h, and k, C are constants. For the speed less than 160 km/h a value of k is about 20 to 40[4,5] and for the high speed grater than 290 km/h one is nearly 60.[6]

Fig. 2 shows the relationship between the train speed and noise level at a distance of 7.5 m from the track center line when the Saemaul travels on the continuous welded rail(cwr) at the speed of 90 to 138 km/h. The relationship[2] between the maximum noise level and the train speed based on 17 trains of the Saemaul is

$$L_{max} = 21.76 \log v + 47.74. \quad (2)$$

The coefficient 21.76 belongs to the range of the constant k for the speed less than 160 km/h. This implies that doubling the speed results in an increase in noise level of about 6 dBA. 88 percentage of the measurement data lie within ± 3.5 dBA from the relationship equation.

When on the one hand the Moogungwha or Tongil travels on the cwr at the speed of 56 to 126 km/h the relationship between the maximum noise level and the train speed based on 27 sample trains is

$$L_{max} = 19.71 \log v + 62.04. \quad (3)$$

93 percentage of the measurement data lie within ± 2.8 dBA from the above equation.

2.6 Comparison of Measured Data with Predicted Data

The equivalent continuous noise level of the passing trains for one hour at the wayside is predicted as follows.

$$L_{eq} = \overline{L}_{max} + 10 \log(2n/T) - 15 \log(d/d_o) \quad (4)$$

Where $\overline{L}_{max}$ is the mean maximum noise level of the passing trains, dBA, at a distance d_o, n is the number of trains during the time period, T is the time period in consideration (seconds), d_o is a reference distance from the nearest track center line with known noise level L_{max} (m), and d is a prediction distance from the nearest track center line (m).

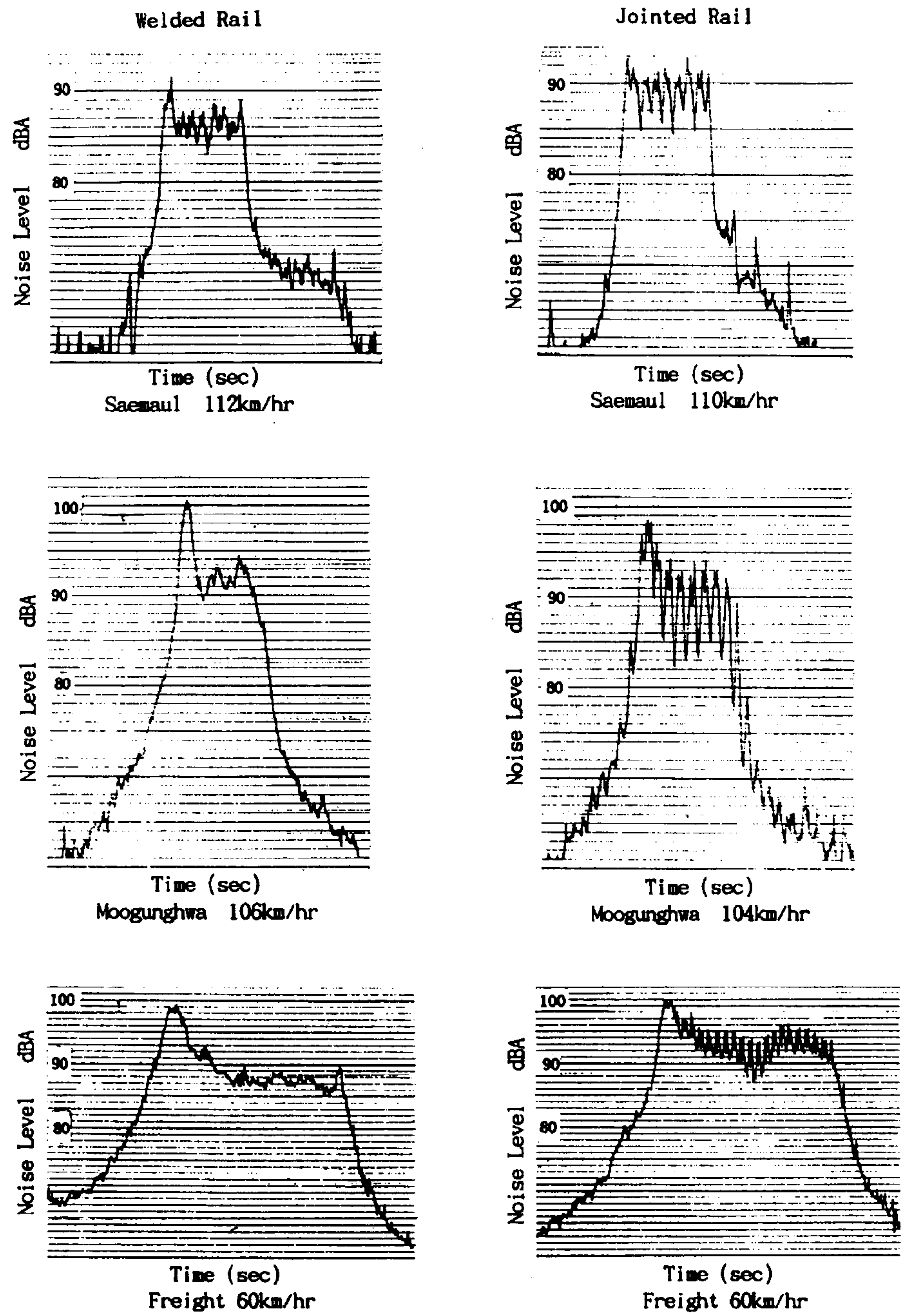

Fig. 1 Time evolution of noise level during passage of a locomotive-hauled train at 7.5m from the track center line.

Fig. 3 shows the correlation between the measured and the predicted equivalent continuous noise level for one hour based on the equation (4). The correlation between 39 measured and predicted equivalent noise level for one hour at distances of 7.5, 15 and 20 m respectively from the nearest track center line is 0.899. 85 percentage of the measured noise level lie within ±2.5 dBA from the predicted noise level.

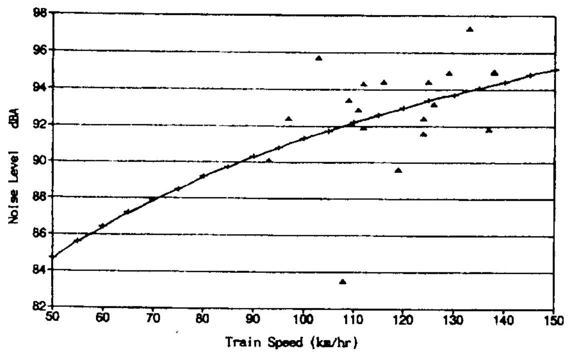

Fig. 2 Noise level of the Saemaul as a function of speed at 7.5m

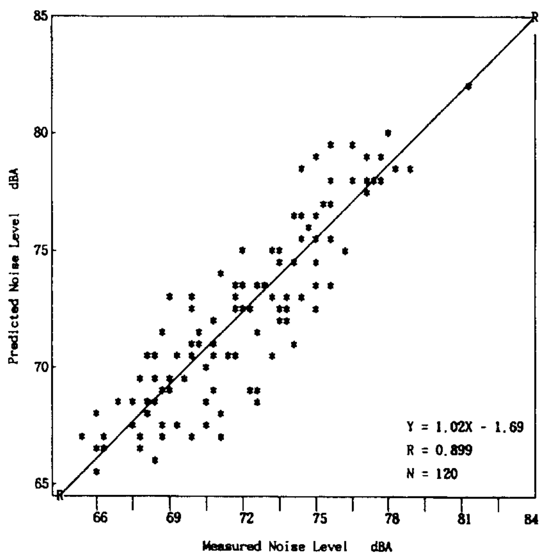

Fig. 3 Correlation between measured and predicted noise level

2.7 Prediction of High Speed Rail System Noise

With the advent of high speed train (i.e > 250 km/h), we are concerned about its noise impact on the environment. A number of studies have been made of this noise.

C.E. Hansen[6] suggested the prediction of high speed rail noise as follows.

$$L_{eq} = L_{max} + 10 \log[2.56(2n)/T] \quad (5)$$

H.J. Saurenman[(7)] et al. suggested the following prediction of it.

$$L_{eq} = L_{max} + 10 \log[n(1.5d + l)/v] - 30 \quad (6)$$

C.E.T.U.R.[(8)] suggested the following prediction.

$$L_{eq} = L_{max} + 10 \log[(3.6l/v + 6d/100)n/T] \quad (7)$$

$$L_{max} = L_o - 12 \log d/d_o$$

where

L_{max} = the maximum noise level of the passing train,

L_o = the reference noise level at a distance d_o.

n = the number of the trains during the time period T,

T = the time period in consideration in seconds,

d = a distance from the track center line in meters,

l = the mean train length in meters,

v = the speed of train in km/h.

We can see that there are differences in the exposure time and the multiplication coefficient between the conventional train and the high speed train noise.

3. Conclusion

It is not easy to make an accurate estimate of the railway noise, for it differs according to the type of train, the train length and speed, the type of track, the train operating condition such as the acceleration, the deceleration and the steady state, the surface roughness of wheel and rail, the type of brake,the track structure, and the locomotive power. Nevertheless, the prediction of the conventional rail system noise is derived from a large number of the measured data. This can be used as an index of assessment of the conventional train noise impact when a housing project near an existing railroad is proposed or a new railroad line is planned.

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