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EXPERIMENTAL STUDY ON VIBRATION REDUCTION BY ISOLATED RAILWAY

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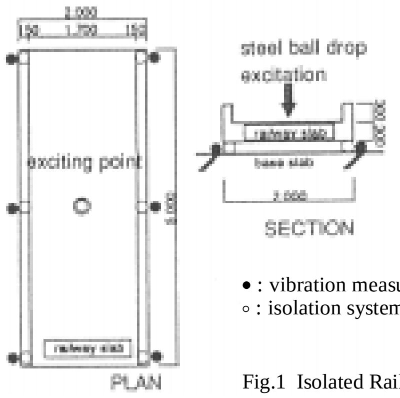
INTRODUCTION

Recently, buildings such as hotels, apartment houses, concert halls etc. wherein silent environment is required have been constructed at the sites nearby railway. In this case, it is necessary to reduce sufficiently the vibration and structure-borne noise generated by railway trains. We are carrying out the studies on the method for prediction and control of railway vibration and noise. The investigations on the vibration reduction of the railway supported by vibration isolation system were carried out through the scale model experiments in the laboratory. In this paper, these results are described.

OUTLINE OF THE ISOLATED RAILWAY MODEL

The investigated isolated railway model is composed of the reinforced concrete slab and the isolation systems as shown Fig.1. The railway slab is supported by each isolation system shown in Table.1 at six positions on the base slab.



• : vibration measurering point
◦ : isolation systems

Fig.1 Isolated Railway Model

Table.1 Valious Vibration Isoration System

No.	type	spring constant in catalogue (kig / cm)
1	rubber isolator A	1,600
2	rubber isolator B	4,700
3	coil spring	780

MEASUREMENTS

The center of the railway slab supported by each isolation system was excited five times by dropping steel ball (weight 30kg). Then, vibration acceleration level (dB re 1E-5m/s^2) at the measuring points on the base slab shown in Fig.1 were measured and averaged. The same measurements for the railway slab set directly on the base slab without isolation system were carried out. In this paper, vibration isolation effects are defined as the reduction of vibration transmitted to the base slab with and without the insertion of isolation systems (Insertion Loss).

$$\text{Insertion Loss I.L} = \text{LFrigid} - \text{LFiso}$$

Here, LFrigid represents V.A.L.(vibration acceleration level) of base slab in case of the system without isolator, LFiso V.A.L. of base slab in case of the system with isolator.

EXPERIMENTAL RESULTS

(1)Vibration isolation effects obtained by isolation systems

The vibration isolation effects obtained by isolation systems are shown in Fig.2. From this result the followings are pointed out.

a) The vibration isolation effects have the tendency to increase due to the decrease of vertical resonance frequency of the isolation system in the frequency range of 16～125 Hz.

b) The vibration isolation effects drop off at the vertical resonance frequency of isolation systems.

c) The vibration isolation effects drop off at the frequencies of 63Hz and 250Hz. These frequencies coincide with bending resonance frequencies of railway slab calculated by bending vibration theory of beam with free ends (The former is resonance frequency of the long side, the latter is the short side).

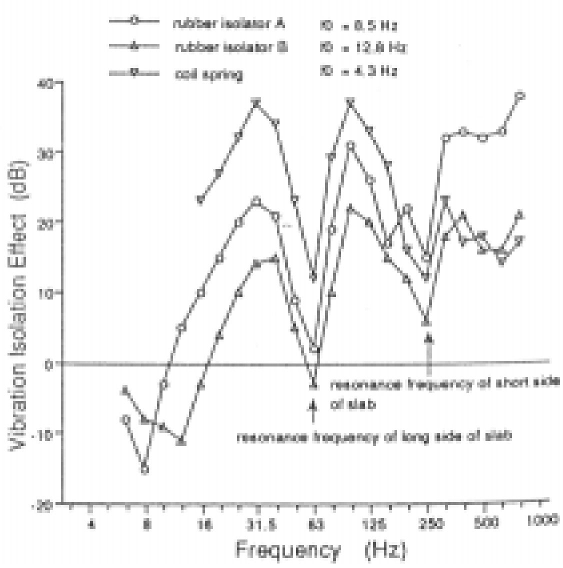


Fig.2 Vibration isolation effects obtained by isolation systems

(2)Driving point impedance of railway slab

Driving point impedance level (dB re 1 Ns/m) obtained by three kinds of isolation systems are shown in Fig.3. Driving point impedance drops off at the frequencies at which vibration isolation effects drop off (Fig.2).

So, it is found that the vibration isolation effects are affected by the resonance vibration characteristics of the railway slab.

(3)Comparison with calculated transmission loss on the assumption of one-mass system.

The transmission losses calculated by equation (1) on the assumption of one-mass system are shown in Fig.4 in-comparison with the measured results.

$$Tr = \sqrt{\{1+(2h\,f/fr)^2\} \;/\; \{(1-f^2/fr^2)^2+(2h\,f/fr)^2\}} \qquad (1)$$

$$T.L = 20\log_{10}(1/Tr)$$

Here, Tr represents the force transmissibility, h the critical damping ratio, f the frequency (Hz), fr the fundamental resonance frequency of isolation system (Hz).

From this result, it is clear that the vibration isolation effects of all isolation systems agree with the calculated transmission losses at the low frequency range, but drop off in comparison with the calculated values at and above the middle frequency range.

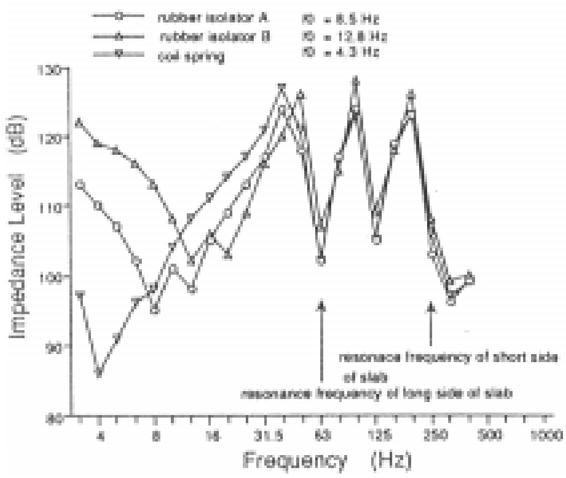


Fig.3 Driving point impedance of railway slab

(4)Comparison with calculated transmission loss on the assumption of two-mass system

Trial calculation was made in order to investigate the effect of the resonance vibration characteristics of railway slab for the vibration isolation effect. The transmission losses on the assumption of two-mass system shown in Fig.5 are calculated. The transmission loss of this model is given by equation (2).

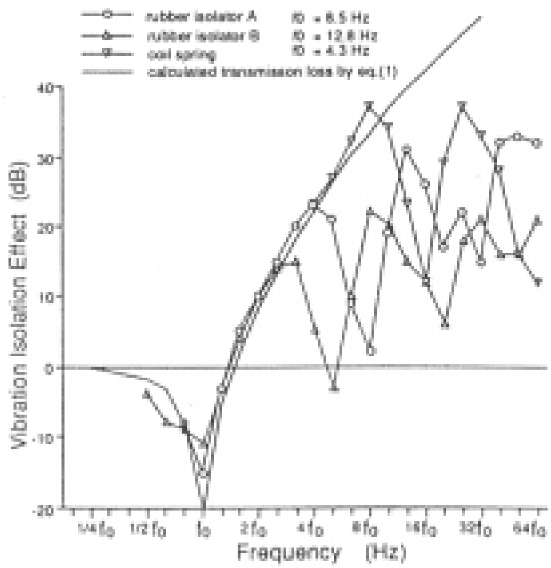


Fig. 4 Comparison of calculated transmission loss on the assumption of one - mass system with measured one

$$\mathrm{Tr} = \frac{\mathrm{F}}{\mathrm{F_0}} = \beta^2 \sqrt{\frac{1+\gamma 1^2 a^2}{\left\{(1-a^2)(\beta^2-a^2)-(\mathrm{m}+\beta\gamma 1\gamma 2)a^2\right\}^2 + \left\{\gamma 1(\beta^2-a^2)+\beta\gamma 2(1-a^2)-\mathrm{m}\gamma 1 a^2\right\}^2 a^2}} \qquad (2)$$

$$a = \mathrm{f}/\mathrm{f1}, \quad \beta = \mathrm{f2}/\mathrm{f1}, \quad \mathrm{m} = \mathrm{m1}/\mathrm{m2}, \quad \mathrm{m1} = 48\mathrm{EI}/4\pi^2\,\mathrm{f1}^2\,\mathrm{Q}^3$$

$$\mathrm{T.L} = 20\log_{10}(1/\mathrm{Tr})$$

Here, F represents the transmitted exciting force, F0 the exciting force, γ1 the critical damping ratio of railway slab (0.03), γ2 the critical damping ratio of isolator support system (0.01), f1 the resonance frequency of the bending vibration system of railway slab (Hz), f2 the vertical resonance frequency of the isolation system (Hz), m1 the effective mass contributed to the bending vibration (kg), m2 the value deducted railway slab mass from m1 (kg).

Figure.6 shows the comparison of the calculated transmission loss obtained by equation (2) and the measured insertion loss. From this result, the experimental insertion loss agrees fairly well with the theoretical transmission loss on the assumption of two-mass system up to the fundamental resonance frequency of the railway slab.

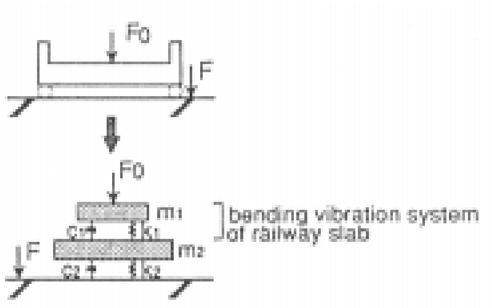


Fig. 5 model of isolation system

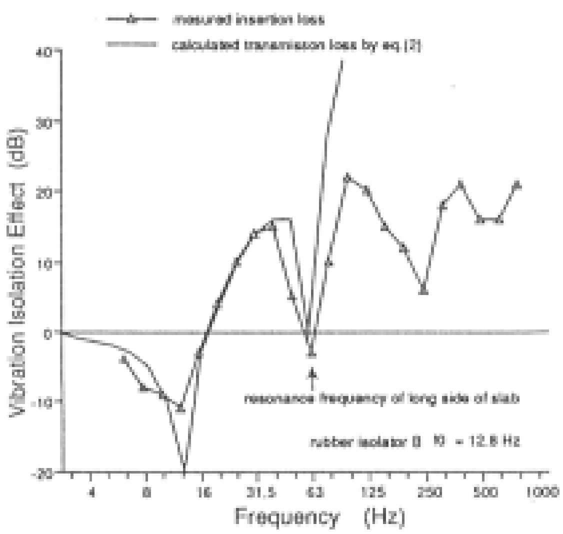


Fig. 6 Comparison of calculated transmission loss on the assumption of two - mass system with measured one

CONCLUSION

From the results of these investigations, the followings are concluded.

1) The insertion loss representing the vibration isolation efficiency is affected by the resonance vibration characteristics of the railway slab. Sufficient vibration isolation effect can not be obtained around the fundamental resonance frequency of the railway slab.
2) The experimental insertion loss agrees fairly well with the theoretical transmission loss based on the assumption of two-mass system.