Laboratory measurement of vibration and secondary noise transmission loss for rubber elastomer mats

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ABSTRACT

Beijing Subway Line 6 West Extension and Beijing Shijingshan District Performance Center are both under construction. Line 6 will go through beneath the performance center. In order to lower the impact from the train to the performance center, it has been decided that the subway will conduct steel spring floating slab as its vibration control method, and the performance center will add a layer of rubber elastomer mats under the raft foundation of the building. For the purpose of predicting the vibration and secondary noise transmission loss of the rubber elastomer mats, Acoustic lab of Tsinghua University conducted a measurement according to the real load of this project with the standard tapping machine as the sound and vibration source on a vibration isolation platform. By comparing the environmental vibration deviation on the platform with and without the rubber elastomer mats, the vibration and secondary noise transmission loss for each octave band can be easily calculated.

BACKGROUND

Beijing Shijingshan District Performance Center will be one of the landmark buildings for the district standing in the west of Beijing down town, which started construction in 2016 and about to finish construction in 2019. There are one cinema, one theater and several recording rooms in the performance center, which makes it a noise and vibration sensitive building.

Figure 1: Design Visualizer of Shijingshan District Performance Center

Unfortunately, the planning route of Beijing Subway Line 6 West Extension is exactly under the performance center. But the good news is that both project has known each other and decided to cooperate reducing the noise and vibration impact for the auditoriums in the performance center. The subway side promised to conduct the steel spring floating slab as its vibration control method, and the performance center will add a layer of rubber elastomer mats under the raft foundation of the building.

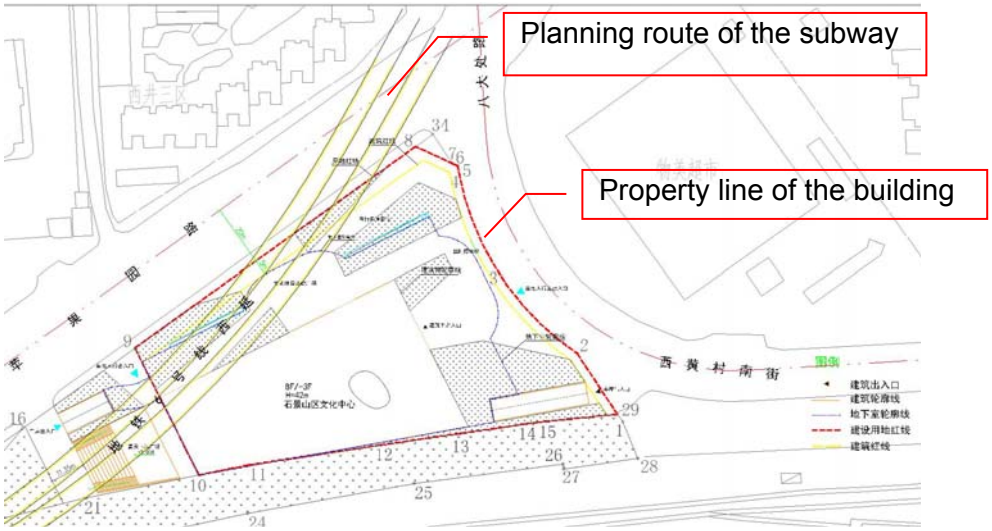

Figure 2: Horizontal relationship of the subway and the building

Figure 3: Sketch of the steel spring floating slab in subway

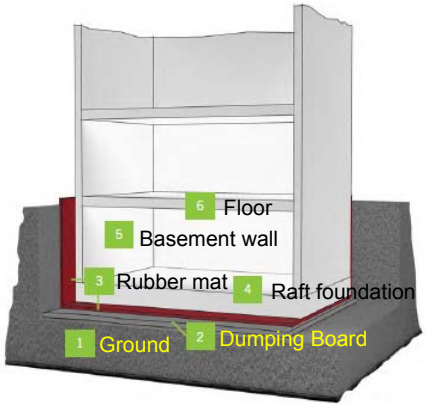

Figure 4: Sketch of floating building by adding a layer of rubber elastomer mats under the raft foundation

INSTRUCTION

The Shijingshan District Performance Center has a floor area about 6500 ㎡. The building is 11 stories high with 3 of them in the ground going down to a depth of -15.00m. After it was confirmed that the whole building will be floated by a layer of rubber elastomer mats under the raft foundation, the owner of building asked for the quantization of the transmission loss of the mats. The rubber mats manufacture provided a technical recommendation report with reference to the pressure plan of the flat foundation from the structure engineers including the load range, the deflection range and the natural frequency range of the rubber mats, but there is no transmission loss. Acoustical lab of Tsinghua University, the acoustical consultant of the project, has done some experiments to find out the answer. According to the <Standard for limits and measuring method of building vibration and secondary noise caused by urban rail transit>JGJ/T 170-2009, the frequency range of vibration is 4Hz~200Hz and the frequency range of secondary noise is 16Hz~200Hz. The result of this laboratory measurement of vibration and secondary noise transmission loss for rubber elastomer mats is the transmission loss on each 1/3 octave band from 4 Hz~200Hz under the upper limit of the optimal load range for each type of the rubber mats.

METHOD

The measurement of vibration and secondary noise transmission loss for rubber elastomer mats Type 480, 550,800 was conducted on the vibration isolation platform in the acoustical lab of Architecture School, Tsinghua University. The vibration and noise source is a rubber ball meeting the criteria in ISO 10140-5<Acoustics – Laboratory measurement of sound insulation of building elements – Part 5: Requirements for test facilities and equipment> and free falling from 1m high. A certain concrete slab was seemed as the building. The slab was supported by the three types of rubber mats or a rigid supporter. To get the upper limits of the optimal load range for each type of the rubber mats, the mat area of each type was different. The vibration acceleration level of the concrete slab of different supporter are measured. The difference between vibration level of the rigid supporter and the rubber mats on each 1/3 octave band was the transmission loss.

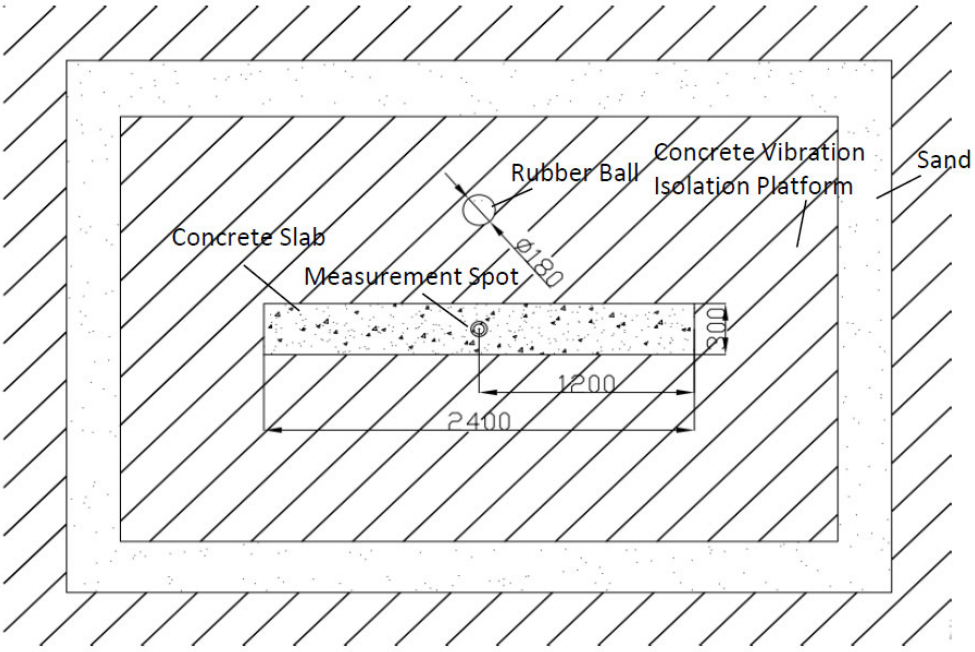

Figure 5: Plan of the measurement system

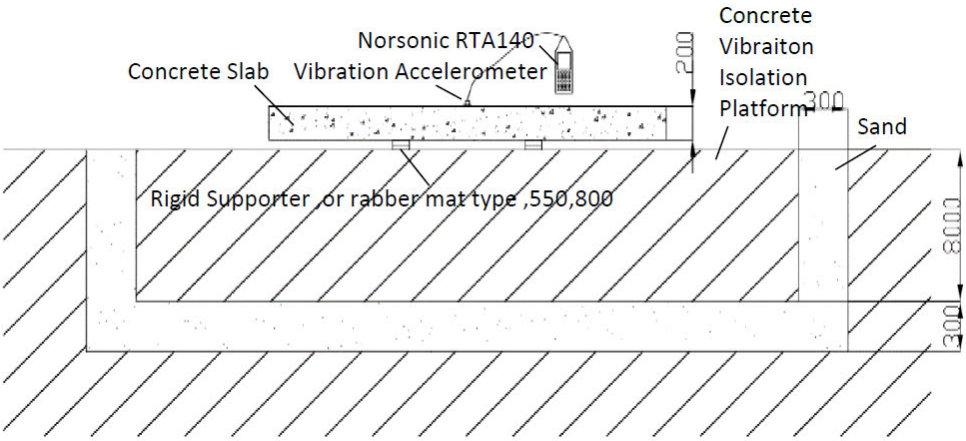

Figure 6: Cross section of the measurement system

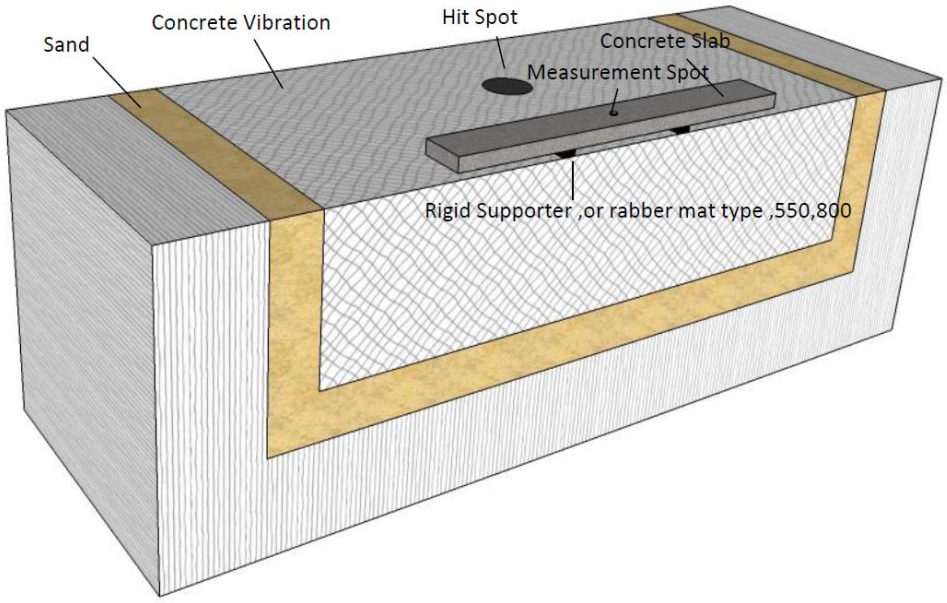

Figure 7: 3D Sketch of the measurement system

Table 1: Upper limits of the optimal load range and natural frequency of each type of the rubber mats

	Type 480	**Type 550**	**Type 800**
Upper limits of the optimal load range(N/mm^2)	0.15	0.30	0.80
Natural frequency(Hz)	13	13	13

RESULTS

The vibration acceleration level measurement were conducted three time for each supporter. Then the average value of them are considered as result. The measurement results are shown in Table 2.

Ideally, the vibration acceleration level of the rubber mats scenario should be lower than the rigid supporter scenario, which is exactly the original intention of using the rubber mats. But actually that only happens at the frequencies higher than $2^{1/2}$ times of the natural frequency of

the vibration system, which can easily can be seen in Table 3, the transmission loss of each type of mats at each 1/3 octave band from 4Hz to 200Hz.

Table 2: Results of vibration acceleration level measurement of concrete slab with different supporter

Frequency(Hz)	Vibration acceleration level of Rigid Supporter scenario	Vibration acceleration level of Type 480 scenario	Vibration acceleration level of Type 550 scenario	Vibration acceleration level of Type 800 scenario
4	31.3	32.7	33.6	35
5	34.7	36	38	36.5
6.3	37.3	42.1	40.5	38.9
8	41.4	47.7	46	45
10	46.9	53.7	53.9	54
12.5	52.8	62	67.9	67.5
16	61.6	70	70.7	69
20	70.7	58.4	68.2	63.3
25	68.7	51.9	53.6	52.2
31.5	62.8	69.9	69.4	69.5
40	62.3	60.7	62	62.2
50	64.9	46.9	55.7	50.1
63	72.5	41.9	48	49.2
80	60.4	40.2	24.8	31.4
100	48.3	35.1	18.9	18
125	49.2	32.2	28.1	30.2
160	28.5	13.1	10.9	11.9
200	11.9	4.5	4.9	4.3

Table 3: Results of the transmission loss of each type of rubber mats

Frequency(Hz)	Transmission loss of Type 480	Transmission loss of Type 550	Transmission loss of Type 800
4	-1.3	-2.3	-3.6
5	-1.3	-3.2	-1.6
6.3	-4.7	-3.2	-1.6
8	-6.4	-4.7	-3.6
10	-6.7	-7.0	-7.1
12.5	-9.1	-15.1	-14.7
16	-8.4	-9.2	-7.5
20	12.3	2.5	7.4

25	16.8	15.1	16.5
31.5	-7.1	-6.5	-6.7
40	1.6	0.3	0.1
50	18	9.2	14.8
63	30.6	24.5	23.3
80	20.2	35.6	29
100	13.1	29.3	30.3
125	17	21.1	19
160	15.4	17.6	16.6
200	7.4	7.0	7.6

CONCLUSION

At the frequencies higher than 21/2 times of the natural frequency of the vibration system, the rubber mats could effectively reduce the vibration and the secondary noise. This laboratory measurement method is an accuracy and effective way to quantize the transmission loss, which is usually not a parameter provided by the manufacture. Since this transmission loss is frequency dependent, the calculated single value evaluation such as improved vibration level or improved secondary noise A sound pressure level could be difference for the same rubber mats due the difference of the vibration and noise source.