24th INTERNATIONAL CONGRESS ON SOUND AND VIBRATION
23–27 July 2017, London

ANALYSIS OF THE VIBRATION ISOLATION BARRIER EFFECT FOR THE INDOOR ENVIRONMENT VIBRATION OF BUILDING INDUCED BY RAIL TRANSIT

Yanan Wu

Beijing Municipal Institute of Labour Protection, Beijing, P.R.China

email: wuyubinwuyubin@163.com

Yubin Wu, Lei He and Dan Wu, Ruixiang Song, Wencheng Hu

Beijing Municipal Institute of Labour Protection, Beijing, P.R.China

Abstract: with the rapid development of urban rail transit, an increasing number of building have been built adjacent to rail transit lines, the environment vibration pollution resulting from train tracks is getting worse. The vibration isolation barrier can be used when the control measures of vibration source and receivers can't be implemented. On the basis of vibration test , the vibration isolation effect of underground continuous wall for a residential building adjacent to metro depot is analyzed by numerical simulation method. The result show that the vibration isolation effect of every floor is different, and the vibration isolation effect is affected by many factors such as the location, depth, material properties, structural style of barrier and the natural vibration characteristics of structure or floor. The vibration isolation barrier has a certain effect of vibration reduction for ground rail transit line, but it must be optimized design. The average vibration isolation effect of different floors of EPS wall and concrete-EPS composite wall are5.5dB and 4.3dB.

Keywords: Vibration isolation barrier, rail transit, environment vibration, numerical simultion

1. Introduction

With the accelerating urbanization, the available urban land is getting scarce. An increasing number of building have been built adjacent to rail transit lines, the environment vibration pollution resulting from train tracks is getting worse. The vibration isolation barrier can be used when the control measures of vibration source and receivers can't be implemented.

The location of the barrier and the depth of embedment have obvious influence on the vibration isolation effect [1-5]. Meterial and structure form play a significant role in the barrier design, as water and EPS[6-9].

Most of the studies were focus on analysis the effect of isolation barrier by ground measured point. but the researcher seldom study it by indoor vibration of building. However the ultimate objects of isolation barrier is building. Indoor vibration can fully reflect the effect of barrier. So this paper through indoor vibration assessment the effect of isolation barrier by numerical simulation method.

Corresponding author: Yubin Wu, assistant researcher, Ph.D., research fields: rail-induced vibration and control.

2. Vibration experiment

Beijing, a metro depot length 450m, width 270m, there is a residential building adjacent to metro depot. The distance between residential building and the center of subway line is 30m, from the metro auxiliary building to the residential building is 18m. The residential architectural need to be built 18 floors, however it just finish the 13th floor when measuring. The measuring time is 10pm-21pm and 4:30am-5:30am . The measuring points are divided into two parts: outdoor and indoor, and the two parts are tested synchronously.

2.1 Field Testing

The indoor measure point was located in the centre of the room in the western part of the buildin g. And the outdoor measure point was on the ground between the residential building and the wall neary the metroline. Figure1 could illustrate the specific location of the points. (S1 stands for the outdoor point, and S2,S3 are indoor points. S2 appears repeatedly on subcellar (f-2), the first floor(f1), the third floor (f3), the fifth floor (f5), and the seventh floor (f7), and S3 was only set on the first floor(f1)).

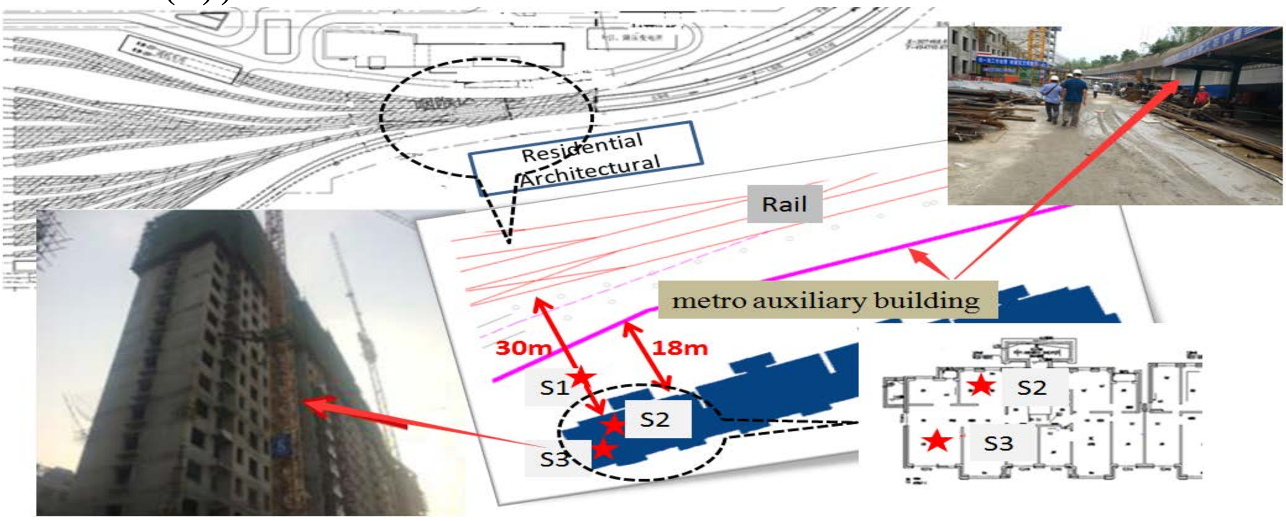

Figure 1: Field situation and measuring position diagram.

2.2 Data Analysis

Recorded the acceleration during train operation, selected 10 waveform and undisturbed test da-ta for analysis, S1 acceleration time history curve and spectrum curve was shown in thefigure 2, S2 and S3 VL_Zmax (maximum Z weighted vibration acceleration level) in different floors as shown in the Figure 3.

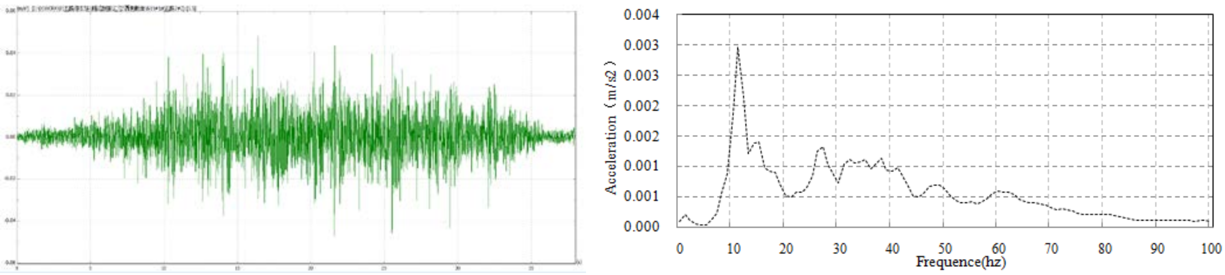

Figure 2: acceleration time history curve and spectrum curve

As we can see in the Figure 2 the main frequence is 12 Hz. Figure 3 shows that the average of Vlzmax of S3 on the first floor is 66.6dB, the maxmum of Vlzmax is 65.1dB.the average of

Vlzmax of S2 on the first floor is 69.7dB, the maxmum of Vlzmax is 68.4dB. The maximum value is above the average of about 3dB.

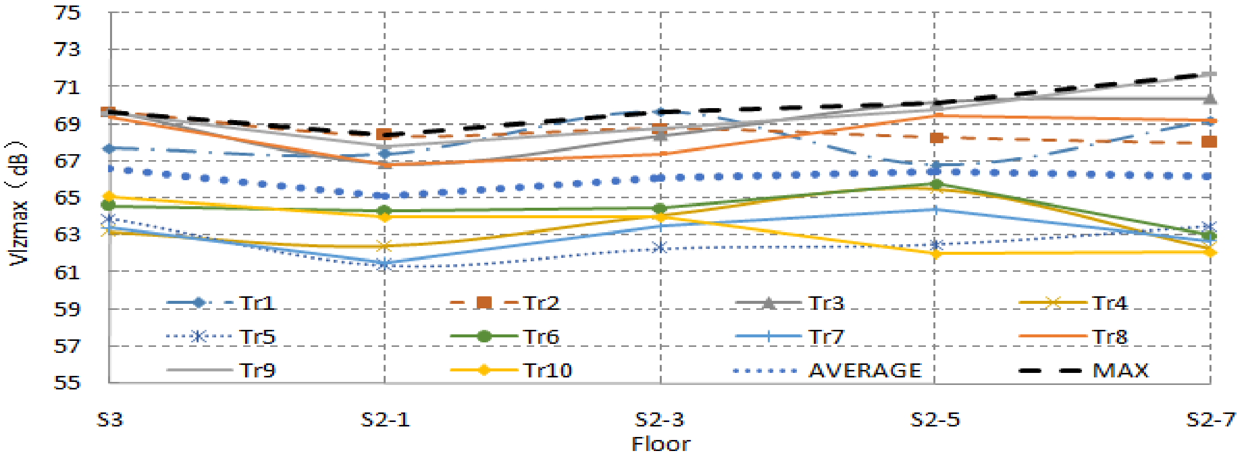

Figure 3: the Vlzmax of S2 and S3 on different floors

3. Finite element model for vibration

The finite element model for vibration used is 150m in length, 87m in width, 30m in depth, including steel rail, ballast, soil and residential architectural. The dimensions of finite element model is190 thousand elements and 163 thousand nodes.

Track bed and soil using solid45element, rail using beam188, the Boundary conditions using combine14. Building slab using shell elements of shell181, structural beam and pillar with beam188.The finite element model is shown in Figure 4

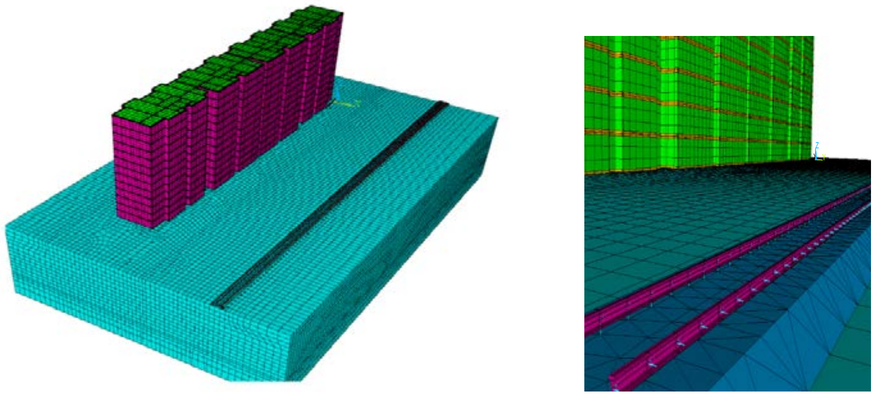

Figure 4: The finite element model and track detail

Main effect region for isolation barrier is the area in front of the architecture, simulation of the propagation characteristic of the region is essential, according to the source property, the site measuring points are calculated and measured data analysis. Compared calculated and measured data of ground based on source characteristics. The compared result of S1 acceleration time history curve and spectrum curve is shown Figure 5.

The indoor vibration is the ultimate reflection of the effect of vibration reduction, so the accuracy of indoor vibration is very important. Therefore, the floor vibration of different floors in the building was measured and calculated. The compared result of S2 acceleration spectrum curve is shown Figure 6.

Based on the above results, S1 calculated vibrational energy is concentrated in 10-20Hz frequency range, good agreement with the experimental results. Results show that this model and calculation methods can better reflect the actual soil vibration propagation and practical vibration characteristic, with high reliability, can be further used for calculation and analysis of vibration isolation effect of the barrier within the region. Besides building on each floor of the calculated peak frequency of the spectrum agree well with the measured results, due to position S2 testing room on f1 has a lot of litter, measured with the fact are slightly differences. The calculated values of vibration frequency of each floor are close to the measured values, which shows that the 3D model can reflect the vibration characteristics of the floor.

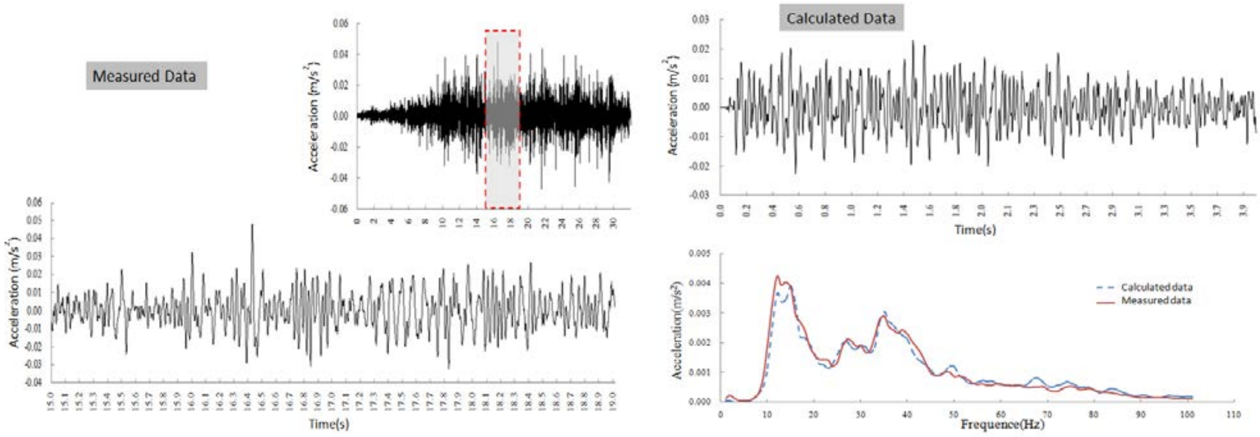

Figure 5: S1 acceleration time history curve and spectrum curve

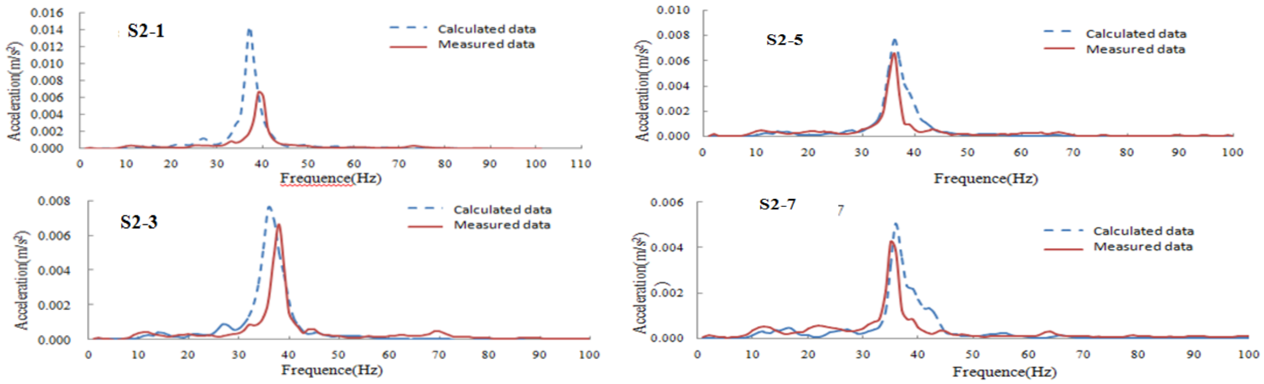

Figure 6: S2 acceleration spectrum curve

4. The effect of design parameters of EPS filled wall and it's optimization analysis.

According to the relevant research of scholars, it is found that the design parameters of isolation barrier have a great influence on the vibration isolation effect. Therefore, this paper mainly focused on the analysis of the location, depth, the type of filling material and the structure of the EPS composite isolation wall. In particular the residential architectural is the final status with 18 floors in this optimization analysis.

4.1 The effect of barrier's location

The calculated distance between the barrier and architecture include 4m, 9m, 14m, and 18m, other parameters remain. Figure 7 shows the vibration insert loss of the measuring point S 2 and S 3 of the architecture for the above four distances

For S2, the best position of isolation effect is 9m away from the construction, followed by 4m, 15-18 floor vibration insertion loss is about 10dB, the distance of 14m and 18m in the 12 floor merely have no isolation effect; For S 3, the best position of isolation effect is 18m away from the construction, the insertion loss is relatively stable in each floor, about 5.4-8.4dB, 9m's barrier isolation effect is the worst.

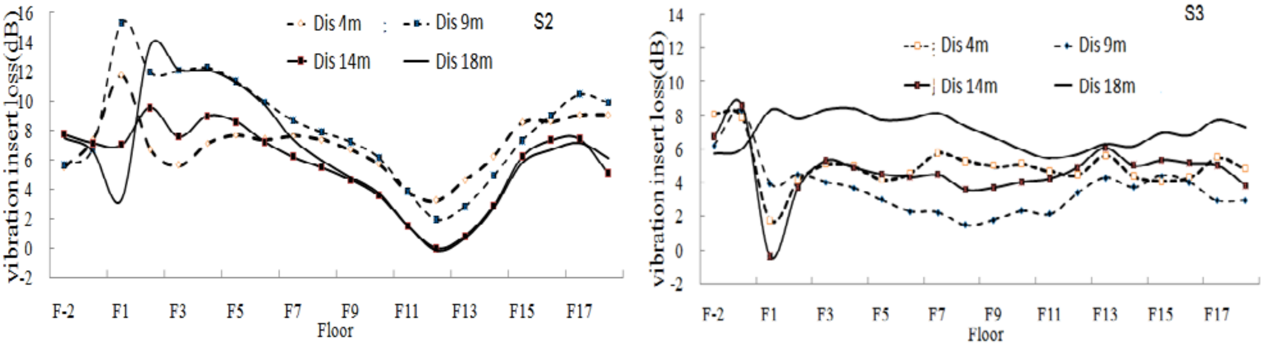

Figure 7: EPS filled wall's vibration insert loss of the measuring point of the construction for different distances.

For S2 and S3, these two positions' barrier isolation rules are not the same, it's not easy to pick out the best barrier position. Give an overall consideration of the vibration source energy loss of B1-B2 floor of the construction (soleplate) and average vibration insert loss in each floor, aiming to measure reduction of vibration isolation wall to construction's basic vibration input and the stability of vibration isolation in each floor. As shown in Figure 8, 14m position have a better effect to the soleplate, but the vibration attenuation effect of the upper floors are unstable, 4m and 18m at the position of the foundation slab and the floor vibration effect is similar, considering the feasibility of real execution, we selected 4m away from the building is the best isolation position.

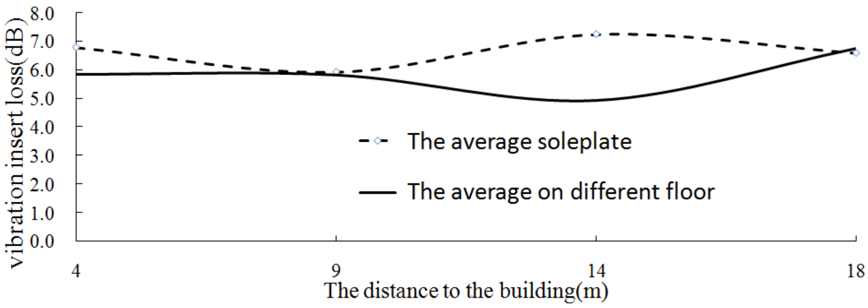

Figure 8: the EPS filled wall's changing regulation of vibration insertion loss of building vibration points in different position

4.2 The effect of barrier's Depth

The calculated depths are 4m, 9m and 15m.Figure 9 shows the vibration insert loss of the measuring point S 2 and S 3for the above three distances.

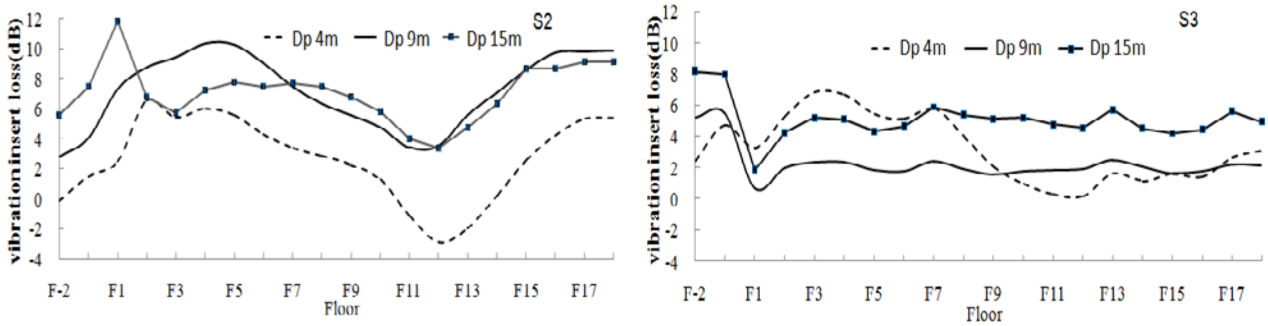

Figure 9:EPS filled wall's vibration insert loss of the measuring point of the construction for different depth

In the building's soleplate, EPS filled wall's vibration attenuation rises with the depth of the barrier increases, but the floors above the ground effected by soleplate's vibration input and floor's vibration characteristics, vibration performance of insertion loss is more complex. In S2, the attenuation effect on the ground floor in 9m and 15m depth are similar, 3.4-11.8dB. On the 12 floor, vibration input loss get minimum, 4m depth shows a bad effect,12 floor has disadvantages effect on vibration amplification.

In S3, 15m depth barrier effect are better than 9m the barrier on each floor, the difference is about 2.3-3.4dB, 4m depth have a better effect between 1-7 floors, and significantly reduced between 8-18 floors, vibration input loss are not stable on each floor.

In summary, we selected 15m for the best depth of EPS filled wall.

4.3 The effect of barrier's type of filling material

Each type of EPS material parameters are shown in Table 1 (ASTM, 2011).

Table 1Each type of EPS material property

Material parameters (*minimum*）	standard：ASTM D6817						
	EPS12	EPS15	EPS19	EPS22	EPS29	EPS39	EPS46
density（kg/m^3）	11.2	14.4	18.4	21.6	28.8	38.4	45.7
Stress/0.01 strain（MPa）	0.015	0.025	0.040	0.050	0.075	0.103	0.128
elastic modulus（MPa）	1.5	2.5	4.0	5.0	7.5	10.3	12.8
Yield strength（MPa）	0.069	0.172	0.207	0.276	0.345	0.414	0.517

The typical EPS12, EPS19, EPS29 material and EPS46 material as the barrier material are calculated (EPS wall) by the number of material number increases, the density and elastic modulus of materials are also rises; Figure 10 shows the vibration input loss of construction's measuring point S 2 and S 3completely filled with the above four kinds of materials.

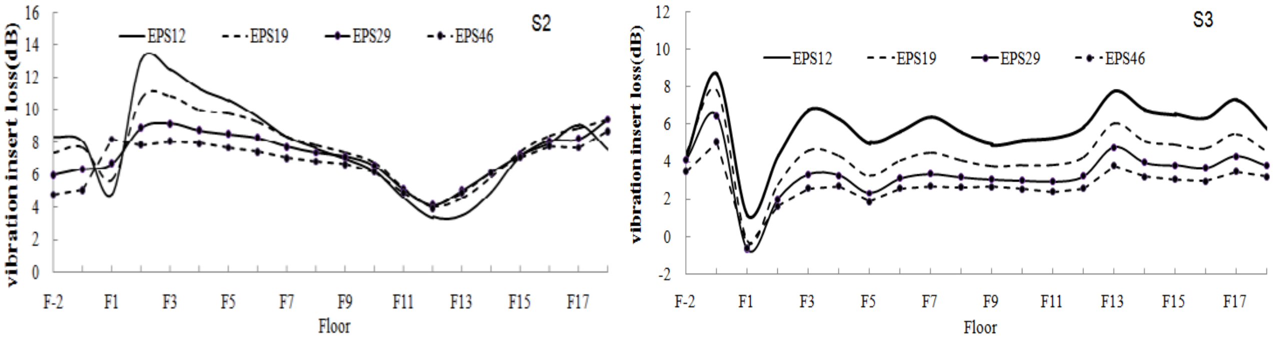

Figure 10:the composite isolation wall's vibration insert loss of the measuring point of the construction for different type of filling material.

In S2 and S3, the vibration input losses of EPS12 wall in each floor are the best (exclude 11-16 floor in S2, but comparing with other conditions, the gap is less than 1dB). The maximum insertion loss is in S2 is 13.1dB (floor 2), the minimum is 3.4dB (floor 12) . The maximum insertion loss is in S3 is 1.1dB (floor 1), the rest of the floor is relatively stable, about 4.4-7.8dB.

In summary, we selected EPS 12 as the best filling material for composite isolation wall.

4.4 The effect of structure of composite isolation wall.

This research use concrete wall clipping EPS foam material to form a composite isolation wall, wall's thickness is 1m, compare the advantages and disadvantages of damping effects in below two conditions: The section size of concrete wall and EPS material is 1:2:1 and 1:8:1. Figure 11shows the vibration insertion loss of the S2 and S3 of the EPS isolation wall and two different structural forms.

EPS wall shows a better effect than composite wall in these two positions, the number of vibration input loss is bigger than composite wall, about 0.4-2.4dB. Comparing the two composite walls, the 1:8:1 type wall's effect is slightly better than the 1:2:1 type, the biggest gap is 0.8dB.

In summary, EPS wall and the type of 1:8:1composite wall are worth recommending.

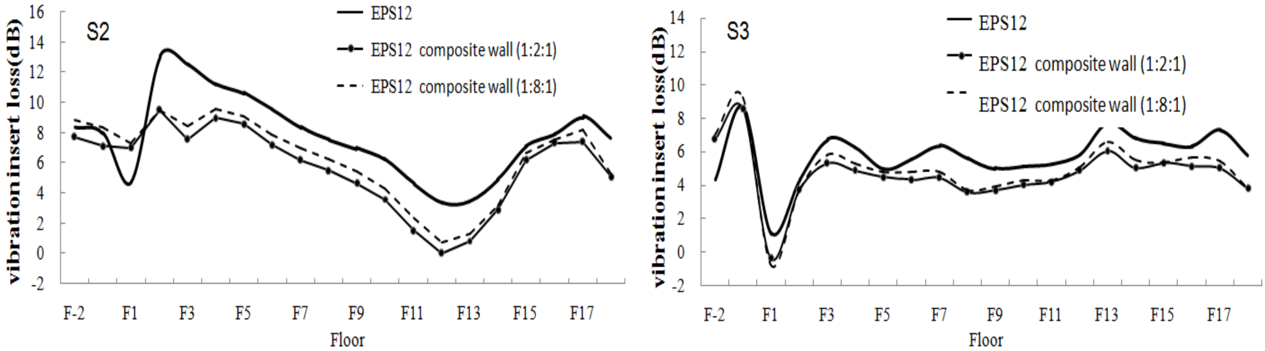

Figure 11:the insert loss of different barrier.

4.5 Isolation Effect Analysis

The study of vibration isolation parameters optimization measures based on the optimization measures of vibration isolation wall parameters. The best and reasonable parameters as follow: located in front of building 4m, wall thickness is 1m, depth is 15m,material is EPS12 and the structure of isolation wall is EPS12 or the section size of concrete wall and EPS material is 1:8:1.

After take the EPS isolation wall and EPS-concrete composite isolation wall measures. The vibration results of indoor are shown in Figure 12. The insertion loss curve of two kinds of vibration measures in each floor is shown in Figure 13.

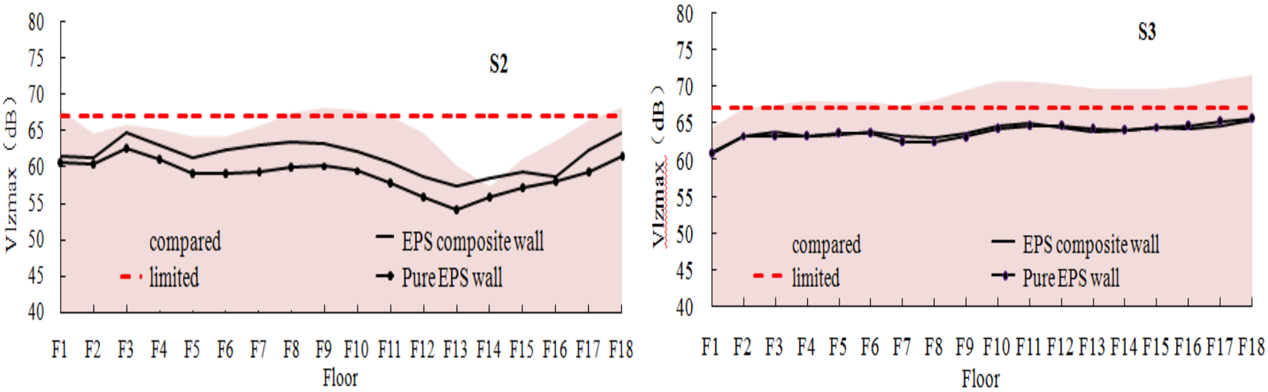

Figure 12:each floor's vlzmax

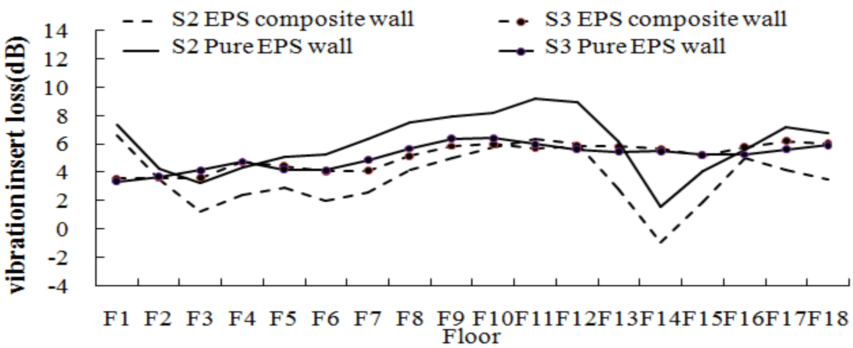

Figure 13: each floor's vibration input loss in western

As we can see from the above results, for S2 and S3, VL_Zmax with volatility rise in each floor by the floor's increased. According to GB10017-88 (standard of environment vibration in urban area), for S2, floor1, 8-10 floor and the 18 floor, the VL_Zmax is more than 67dB. For S3,exclude 1-2 floor, the other floors' VL_Zmax is more than 67dB.compared to no measure conditions, applying EPS isolation wall and EPS filled composite isolation wall, the VL_Zmax in each floor for S2 and S3 were reduced to below 67dB.

The vibration input loss of each floor in two isolation measures: the effect of EPS isolation wall in the S2are mostly better than that in S3. the insertion loss of S2 is in the range of 1.5-9.2dB, the average isolation effect is 6dB. The insertion loss of S3 is in the range of 3.3-6.4dB, the average isolation effect is5.1dB. The effect of the composite isolation wall in the S2 are slightly not good than that in S3. the insertion loss of S2 is in the range of (-1.0)-6.6dB, the average isolation effect is3.6dB. The insertion loss of S3 is in the range of 3.5-6.2dB, the average isolation effect is 5.0dB.

The average vibration isolation effect of different floors of EPS wall and concrete-EPS composite wall are 5.5dB and 4.3dB.

5. CONCLUSIONS

In this paper, the analysis of the location, depth, the type of filling material and the structure form of the EPS composite isolation wall and the optimization design parameters. analysis the vibration of residential building in metro depot by the numerical simulation method. The conclusions are as follows.

1、The vibration isolation effect of every floor is different.

2、The vibration isolation effect is affected by many factors , such as the location, depth, material properties, structural style of barrier and the natural vibration characteristics of structure of floor.

3、The vibration isolation barrier has a certain effect of vibration reduction for ground rail transit line, but it must be optimized design. The average vibration isolation effect of different floors of EPS wall and concrete-EPS composite wall are 5.5dB and 4.3dB.

Acknowledgments

This work is jointly supported by Beijing Municipal Public Finance Project PXM2016_178304_000011. and Beijing Academy of Science and Technology 15L00004.

REFERENCES

1 Woods, R. D. (1968). Screening of surface waves in soils. J. Soil Mech. Found. Div.,94(4), 951–979.

2 Segol, G., Abel, J. F., & Lee, P. C. Y. (1978). Amplitude reduction of surface waves by trenches. Journal of the Engineering Mechanics Division, 104(3), 621–641.

3 Al-Hussaini, T. M. (1992). Vibration isolation by wave barriers. Buffalo, NY: State University of New York.

4 Real, J. I., Galisteoa, A., Real, T., & Zamorano, C. (2012). Study of wave barriers design for the mitigation of railway ground vibrations. Journal of Vibroengineering, 14(1), 408–422.

5 Jiang, J., Toward, M. G. R., Dijckmans, A., Thompson, D. J., Degrande, G., Lombaert, G., & Ryue, J. (2015). Reducing Railway Induced Ground-Borne Vibration by Using Trenches and Buried Soft Barriers. In J. C. O. Nielsen, D. Anderson, P.-E. Gautier, M. Iida, J. T. Nelson, D. Thompson, … P. de Vos (Eds.), Noise and Vibration Mitigation for Rail Transportation Systems SE - 65 (Vol. 126, pp. 555–562). Springer Berlin Heidelberg. http://doi.org/10.1007/978-3-662-44832-8_65

6 Ulgen, D., & Toygar, O. (2015). Screening effectiveness of open and in-filled wave barriers: A full-scale experimental study. Construction and Building Materials, 86, 12–20. http://doi.org/10.1016/j.conbuildmat.2015.03.098

7 Alzawi, A. M. (2011). Vibration Isolation Using In-filled Geofoam Trench Barriers. Electronic Thesis and Dissertation Repository. Paper 265. The University of Western Ontario.

8 Murillo, C., Thorel, L., & Caicedo, B. (2009). Ground vibration isolation with geofoam barriers: Centrifuge modeling. Geotextiles and Geomembranes, 27(6), 423–434. http://doi.org/10.1016/j.geotexmem.2009.03.006

9 Ulgen, D., & Toygar, O. (2015). Screening effectiveness of open and in-filled wave barriers: A full-scale experimental study. Construction and Building Materials, 86, 12–20. http://doi.org/10.1016/j.conbuildmat.2015.03.098