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INFLUENCE OF PASSING UNDERGROUND TRAINS IN WARSAW ON THE ACOUSTIC CONDITIONS IN RESIDENTIAL BUILDINGS LOCATED NEAR THE TUNNELS

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Abstract

The tunnels of Warsaw Underground are located in the depth 15 meters max below ground level. On the some section these tunnels are passing in the distance only a few meters from residential buildings. The occupants of these buildings have been complaining of an existence in their flats the annoying vibroacoustic phenomena like low frequency noise and vibrations. The paper presents the results both vibration accelerations of building structure and results of estimation of influence vibrating building partitions on emission of low frequency noise into residential premises.

INTRODUCTION

After putting the 16th Warsaw underground station “Plac Wilsona” into operation measurements of vibration and low frequency noise were performed in buildings situated along Slowackiego Street between Wilsona Square and Krechowiecka Street. In these buildings, the measurements and evaluation of vibration impact on buildings structures as well as on the human beings caused by passing underground trains were performed. Additionaly the measurements of low frequency noise (increase in the sound pressure level for sound transmission by material path by the partitions confining the residential premises) in selected flats were performed too.

The Warsaw Underground Railway uses two types of trains - manufactured in Russia and manufactured by Alstom. The trains are in operation from 5 am until 12 pm. In peak hours, the frequency of service is 3-4 minutes in both directions.

TEST METHODS

The subject of investigations was as following:

- measurements and evaluation of vibration impact on residential buildings structures and human beings
- measurements of low frequency noise caused of vibrations existence on building partitions confining rooms under examination

Measurements of vibrations were provided with using by multi-channel registration of vibration accelerations time history acc. to:

- PN – 85/B- 02170 Assessment of harmfulness of vibrations transferred into buildings through basement,
- PN – 88/B- 02171 Assessment of impact of vibration on human beings in buildings

The base quantity obtained from performed analyses was the vibration acceleration in 1/3 octave bands (in each measurement points and each directions) for 1÷100 Hz frequency range.

The figures 1÷4 show in details in details measurements of vibration accelerations of ground as well as structure of buildings.

Figure 1 – Example of measurement in reference point [4]

Figure 2 – Example of measurement on the foundation of building [4]

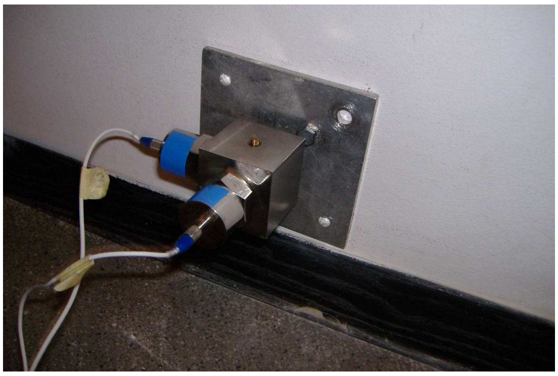


Figure 3 – Example of measurement on the façade in the flat [4]

Figure 4 – Example of measurement on the floor in the flat [4]

Measurements of low frequency noise in flats caused of vibrations existence on building partitions confining rooms were performed simultaneously registration of vibrations and sound pressure method (description in detail of this method were given in [1], [2], [3].

EQUIPMENT

In order to carry out the vibration measurements following measurement equipment and additional devices were used:

- piezoelectric accelerometers type 4338 and 4370 by B&K, type 3100B by DYTRAN, type 7754A-1000 by ENDEVCO,
- two 8-channel DAT recorders type PC208Ax by SONY,
- conditioning amplifiers type 5974 and NEXUS type 2692 by B&K,
- portable data acquisition unit PULSE type 3560-C by B&K,
- calibration exciter type 4294 by B&K
- probe for attaching accelerometer in the ground, connecting cables, etc.

In order to carry out the measurements of the increase in the sound pressure level of the sound transmission by material path in the partitions confining the residential premises, the following measurement equipment and additional devices were used:

- calibrator type 4230 by B&K,
- free field microphone type 4165 by B&K,
- microphone preamplifier type 2639 by B&K,
- piezoelectric vibration converter type 8306 by B&K,
- calibration exciter type 4294 by B&K,
- laser head type OFV-302 with laser vibration meter type OFV-3000 by POLYTEC,
- two-channel portable frequency analyzer type 2144 by B&K with programming type 7651 for narrow band analysis by FFT technique,
- tripod for laser head, probe for attaching accelerometer in the ground, connecting cables (BNC-BNC type, to microphone).

RESULTS

Measurements of vibration were conducted at 21 buildings in 34 measurement sections (each of them consist 6 representative measurement points)

Point I -on the ground at the front of building– reference point

Point II -on the foundation wall (assessment of impact vibration on buildings)

Point III -on the wall at floor level, in a middle storey of building (assessment of impact vibration on buildings)

Point IV -on the wall at floor level, in the highest storey of building (assessment of impact vibration on buildings)

Point V -on the level of the first storey, at midpoints of floor (assessment of impact vibration on human being)

Point VI -on the level of the highest storey, at midpoints of floor (assessment of impact vibration on human being)

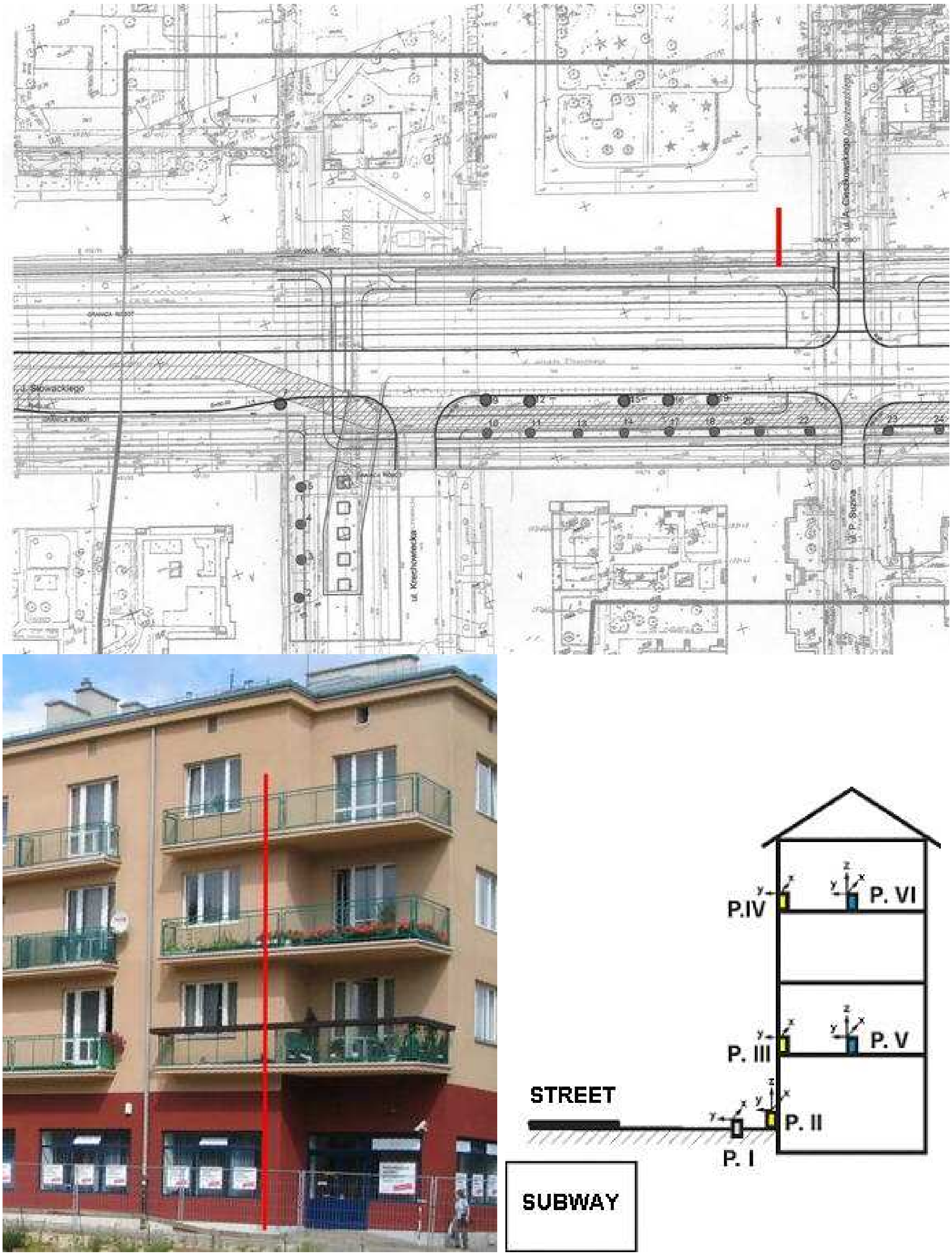


Figure 5 – – Exemplification of the object under investigations (plan, building sight, measurement points pattern) [4]

The information about measurement results of the vibration acceleration, including assessment of the vibration impact on the structure and human being (acc. to PN) in the hypothetical building, are presented in Tables 1÷5.

Table 1 Measurement results at point. V –vibration impact on human beings [4]

Frequency	acceleration, m/s^2		
f, Hz	**x-x**	**y-y**	**z-z**
1.00	0.000588	0.003388	0.002048
1.25	0.000729	0.002100	0.001307
1.60	0.000593	0.001103	0.001292
2.00	0.000608	0.000844	0.001397
2.50	0.000575	0.000842	0.000847
3.16	0.000834	0.000996	0.001049
4.00	0.000626	0.000851	0.000740
5.00	0.000582	0.000637	0.000708
6.30	0.000648	0.000780	0.000747
8.00	0.000489	0.000872	0.000762
10.00	0.000431	0.000847	0.000822
12.50	0.000596	0.000717	0.000719
16.00	0.000480	0.000711	0.000608
20.00	0.000506	0.000740	0.000628
25.00	0.000842	0.000871	0.002054
31.60	0.001863	0.002763	0.003119
40.00	0.011061	0.017500	0.003712
50.00	0.004339	0.001670	0.005012
63.00	0.002385	0.000832	0.003435
80.00	0.002147	0.001192	0.002763
100.00	0.000492	0.000844	0.003192

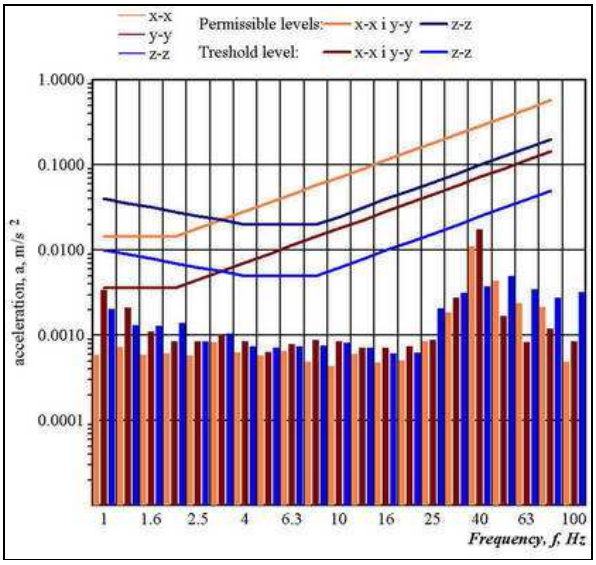


Table 2 Measurement results at point. VI –vibration impact on human beings [4]

Frequency	acceleration, m/s^2		
f, Hz	**x-x**	**y-y**	**z-z**
1.00	0.000202	0.000372	0.000191
1.25	0.000166	0.000208	0.000212
1.60	0.000122	0.000173	0.000097
2.00	0.000135	0.000129	0.000181
2.50	0.000101	0.000086	0.000111
3.16	0.000109	0.000114	0.000085
4.00	0.000155	0.000184	0.000100
5.00	0.000138	0.000127	0.000078
6.30	0.000166	0.000198	0.000113
8.00	0.000242	0.000158	0.000373
10.00	0.000133	0.000148	0.000706
12.50	0.000119	0.000140	0.000609
16.00	0.000165	0.000142	0.000309
20.00	0.000142	0.000216	0.000625
25.00	0.000263	0.000286	0.001168
31.60	0.000267	0.000206	0.002949
40.00	0.000439	0.000323	0.001932
50.00	0.001871	0.000634	0.004261
63.00	0.003271	0.000906	0.005017
80.00	0.002351	0.001651	0.002401
100.00	0.002084	0.001842	0.002438

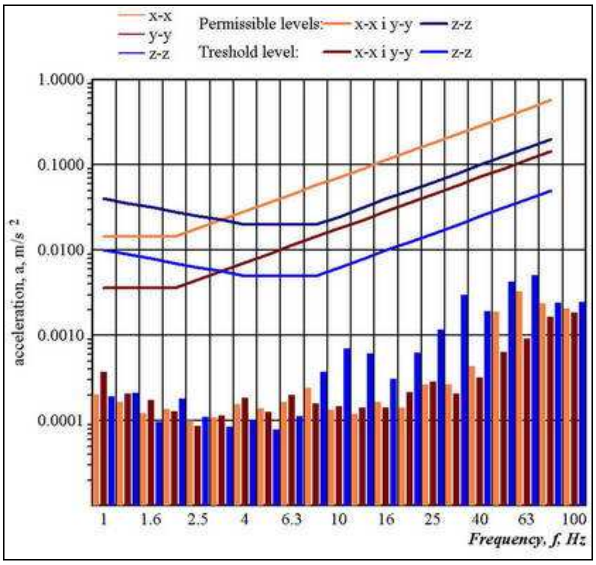


Table 3 Measurement results at point. II –vibration impact on building [4]

Frequency	acceleration, m/s^2		
f, Hz	x-x	y-y	z-z
1.00	0.000193	0.000068	0.000131
1.25	0.000233	0.000068	0.000114
1.60	0.000029	0.000015	0.000025
2.00	0.000038	0.000017	0.000020
2.50	0.000025	0.000028	0.000032
3.16	0.000024	0.000032	0.000035
4.00	0.000044	0.000039	0.000046
5.00	0.000028	0.000024	0.000047
6.30	0.000100	0.000040	0.000089
8.00	0.000197	0.000074	0.000298
10.00	0.000246	0.000164	0.000521
12.50	0.000140	0.000116	0.000365
16.00	0.000073	0.000124	0.000153
20.00	0.000149	0.000155	0.000199
25.00	0.000155	0.000271	0.000130
31.60	0.000124	0.000467	0.000246
40.00	0.000193	0.000626	0.000319
50.00	0.000593	0.000997	0.001199
63.00	0.000530	0.000444	0.000480
80.00	0.001924	0.000564	0.000742
100.00	0.004497	0.000669	0.000987

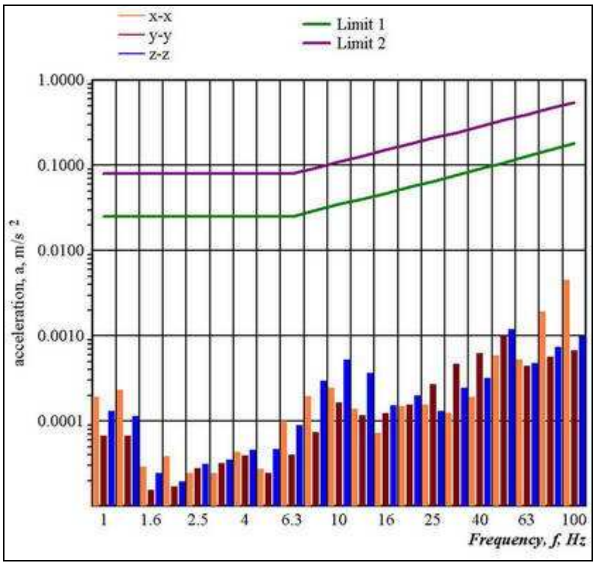


Table 4 Measurement results at point. III –vibration impact on building [4]

Frequency	acceleration, m/s^2	
f, Hz	x-x	y-y
1.00	0.000096	0.000216
1.25	0.000064	0.000166
1.60	0.000068	0.000261
2.00	0.000071	0.000228
2.50	0.000112	0.000120
3.16	0.000063	0.000168
4.00	0.000097	0.000155
5.00	0.000080	0.000106
6.30	0.000081	0.000166
8.00	0.000103	0.000105
10.00	0.000164	0.000218
12.50	0.000239	0.000182
16.00	0.000137	0.000111
20.00	0.000260	0.000213
25.00	0.000257	0.000290
31.60	0.000233	0.000129
40.00	0.000615	0.000556
50.00	0.000379	0.000515
63.00	0.000458	0.000291
80.00	0.000465	0.000763
100.00	0.000389	0.000338

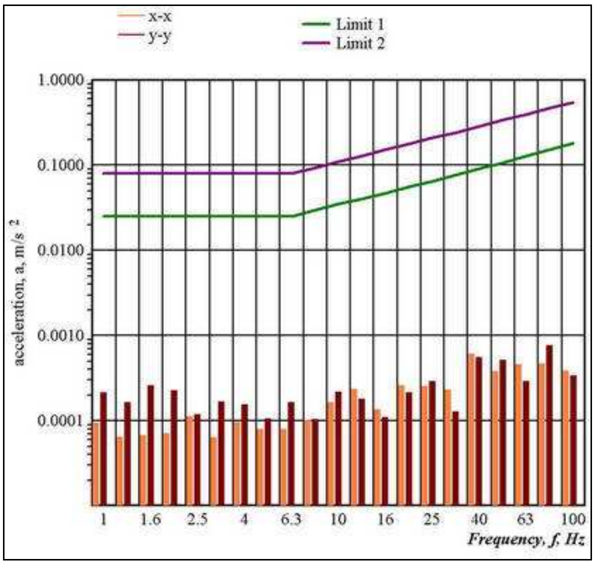
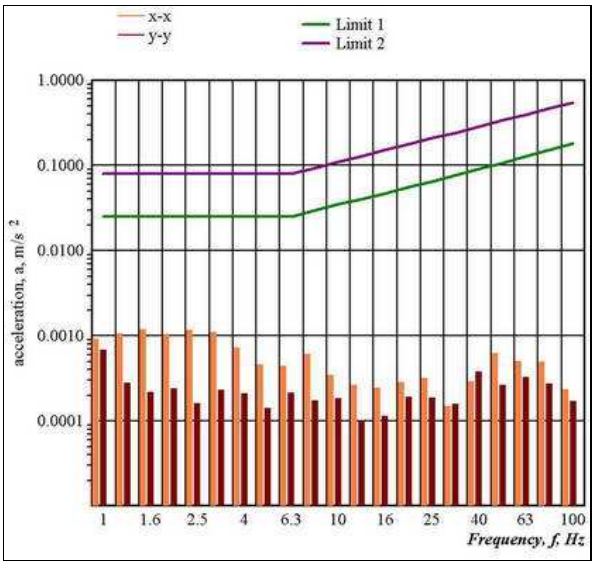


Table 5 Measurement results at point. IV –vibration impact on building [4]

Frequency	acceleration, m/s^2	
f, Hz	**x-x**	**y-y**
1.00	0.000917	0.000687
1.25	0.001059	0.000279
1.60	0.001202	0.000218
2.00	0.001051	0.000241
2.50	0.001178	0.000161
3.16	0.001106	0.000233
4.00	0.000728	0.000213
5.00	0.000459	0.000141
6.30	0.000441	0.000216
8.00	0.000611	0.000175
10.00	0.000348	0.000183
12.50	0.000266	0.000103
16.00	0.000248	0.000114
20.00	0.000286	0.000191
25.00	0.000322	0.000188
31.60	0.000149	0.000159
40.00	0.000291	0.000379
50.00	0.000623	0.000263
63.00	0.000502	0.000328
80.00	0.000501	0.000273
100.00	0.000236	0.000171



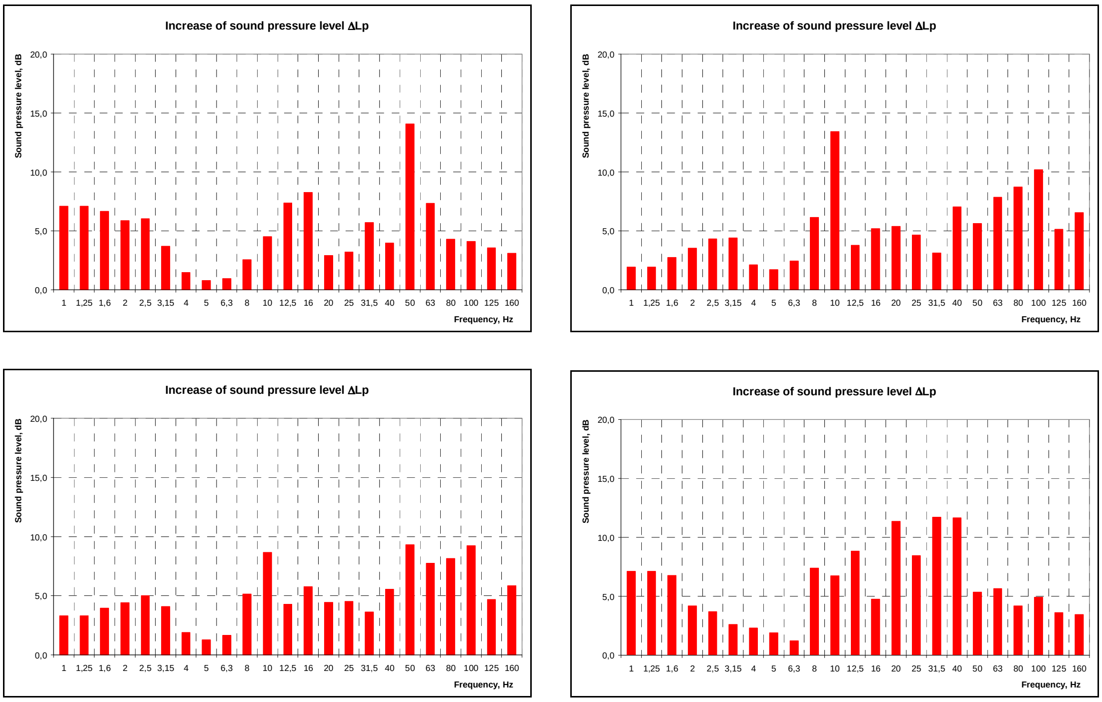


Figure 6 – Measurement results of low frequency noise caused of vibrations existence on building partitions confining rooms under examination (chosen cases)

The calculation results of the increase in the sound pressure level caused by the sound transmission by material path in the partitions confining the residential premises is shown in Figure 6. On this Figure, the results of chosen buildings situated along Slowackiego Street between Wilsona Square and Krechowiecka Street were shown.

Calculation were made on the basis of simultaneously registration of sound pressure in the premises and velocity vibrations on the partitions confining the residential premises acc. to the method described in [2] and [3]

SUMMARY AND CONCLUSIONS

Analyzing the results of the influence of vibrations generated by passing underground trains on 21 buildings situated along Slowackiego Street between Wilsona Square and Krechowiecka Street, described in details in [4], we can conclude that the vibration accelerations in each of buildings are occurred below the noticable levels for building structures and human beings.

Despite not registered of exceeded noticeable levels generated by passing underground trains calculated increase in the sound pressure level for sound transmission by material path by the partitions confining the residential premises reach significant values in these premises.

Increases in sound pressure levels reach values in the order 5÷15 dB for individual 1/3 octave bands from low frequency range.

REFERENCES

[1] M. Niemas: „Ocena wpływu jednoczesnego występowania hałasu i drgań od ruchu komunikacyjnego na warunki akustyczne w budynkach mieszkalnych". Ph.D. Thesis. Promotor prof. Jerzy Sadowski. Warszawa 1999, (in Polish)

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[4] Badanie, analiza i ocena wpływu drgań od naziemnej komunikacji miejskiej i obciążeń dynamicznych od projektowanej linii metra – stacji pl. wilsona wraz z torami odstawczymi, na konstrukcję 21 budynków mieszkalnych, położonych wzdłuż ul. Słowackiego w Warszawie, na odcinku od pl. Wilsona do ul. Krechowieckiej oraz oddziaływania na przebywających tam ludzi –Faza II. Research Report No 4295/PK/04. made by Consortium Building Research Institute, and Warsaw University of Technology Warsaw 2005. (in Polish)