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VARIANTS OF VIBRO-ISOLATION IN TRAM TRACKS AND EVALUATION OF THEIR EFFECTIVENESS ENGINEERING

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Abstract

The development of urban agglomerations makes it necessary to build new communication solutions. One of them is the construction of new tram lines or the renovation of degraded tracks. Activities related to the renovation of tracks result from numerous complaints from residents about the negative impact of vibrations generated by trams passing in the vicinity of inhabited buildings. The assessment of the impact of tram vibrations on the surrounding environment is an important aspect of tramway design and construction. The vibrations caused by the movement of trams can affect nearby buildings, structures, people, and the environment. The impact of tram vibrations on the surrounding environment can be evaluated through several methods, including numerical modelling, laboratory testing, and field measurements. The research concerned the vibrations of a selected representative building caused by trams. The building was erected using the traditional method. The building vibration measurements concerned three vibration components (two horizontal and a vertical component) and were performed by the rules specified in the standards. The source of vibrations was the passages of two types of trams with different speeds from 20 to 50 km/h. The analyzes focused on assessing the impact of the speed of trams and their types on building vibrations at two selected levels (ground level and third-floor level). The analysis of the test results shows that the vibration level of the building increases with the increase in the speed of the trams.

Keywords: Buildings, Humans, Vibration Impact, RMS Analysis, Assessment Methods, Polish recommendations for the vibration's impact on structures and humans

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1 INTRODUCTION

The recent growth in the use of the tram in urban areas highlights the need to investigate and mitigate the harmful effects on structures and humans in buildings. In general, the assessment of the impact of tram vibrations on the surrounding environment is an important aspect of tramway design and construction, as it can help ensure the safety and comfort of the people and the environment.

There are several methods to assess the impact of tram passages' origin vibrations on the surrounding. These vibrations can affect buildings nearby the tram lines and humans staying in buildings.

The numerical method is commonly used involving the use of computer software to simulate the vibrations caused by tram movements.

Another method is laboratory testing, which involves the use of exciters and laboratory equipment to simulate the transportation vibrations. This method can be used to study the behaviour of specific components of the tram and track system and to evaluate the impact of different design options on the vibration levels.

In-situ tests for transportation-induced vibrations refer to the measurement of ground-borne vibrations generated by vehicular traffic, such as trains and trams, in their actual operating environment. In-situ testing is an important step in the assessment of the impact of transportation-induced vibrations on structures and people. The results of these tests identify any potential problems and develop effective mitigation measures to reduce the impact of the vibrations. These tests are typically performed to assess the impact of the vibrations on nearby structures, such as buildings and underground utilities, and to evaluate the effectiveness of various mitigation measures, such as vibration isolation systems and track upgrades. Field measurements can also be used to assess the impact of tram vibrations on the surrounding environment. This involves the use of specific apparatus to measure the vibration levels in the field, such as accelerometers and seismographs. The results of the field measurements can be used to verify the accuracy of the numerical modelling and laboratory testing and to provide valuable data for the design and construction of the tramway. These measures can help to reduce the impact of tram vibrations on buildings and people, ensuring the safety and comfort of the surrounding environment. However, it is important to carefully assess the impact of each measure and to select the most appropriate approach for a given situation, taking into account the specific conditions and constraints of the site. Some of the common methods used for in-situ testing of transportation-induced vibrations include seismic measurements, ambient vibration measurements, field modal testing and structural monitoring [2].

In general, assessing the impact of tram vibrations on the surrounding environment is an important aspect of tramway design and construction, as it can help to ensure the safety and comfort of the people and the environment.

There are many ways to limit the impact of tram vibrations on buildings and people. These include the design of track and vehicle, soil improvement, vibration isolation systems, speed reduction and monitoring and maintenance. Limiting the impact of transportation vibrations on buildings and people can be achieved by base isolation, mass dampers, rubber bearings, air springs, vibration-absorbing pavements and acoustic barriers [3].

These vibration isolation systems can be effective in reducing the impact of transportation vibrations on buildings and people, but the specific type of isolation system required will depend on the specific conditions and constraints of the site [4]. The selection of an appropriate vibration isolation system should be based on a detailed assessment of the vibration levels, the sensitivity of the surrounding environment, and the overall design goals.

Several types of tramway tracks can be used in urban areas. Some of the most common types include grooved rail, flange-less rail, ballasted track, embedded track and concrete track slab [3]. Each type of tramway track has its advantages and disadvantages, and the choice of the track will depend on various factors such as the specific requirements of the project, cost, and local regulations.

In article may provide a comprehensive understanding of the impact of tramway vibrations on buildings and people. The research concerned the vibrations of a selected representative building caused by two types of trams with variable speeds from 20 to 50 km/h. The building vibration measurements concerned three vibration components (two horizontal and a vertical component) and were performed by the rules specified in the standards [5,6].

2 MEASUREMENTS

A series of tests were carried out to assess the impact of parameters related to moving trams on the neighbouring buildings. Masonry building was selected for the study. The building was erected with traditional technology.

The selected building is a residential building with four floors above ground, with a basement - see Figure 1. The shape of the building in the plan view is regular. The structure of the building is masonry made of ceramic brick. The distance from the axis of the tram track to the building's front wall is around 9 m.

Figure 1: Building No. 1 (Google Maps).

The research aimed to assess the impact of vibrations from the tram line on the structures of the building and the people inside. For this purpose, controlled runs with different speeds were carried out. Two types of trams were also used in the research: type 105N (compare figure 2) and type 120N (compare figure 3). The trams moved at speeds of 20, 30 and 50 km/h. The tests were performed by the standards [5, 6].

Figure 2: Wagon type 105N (https://tramwar.pl/u1238-85070a.html).

Figure 3: Wagon type 120N (https://tramwar.pl/u1238-85070a.html).

Three components of vibration acceleration were measured: two horizontal x and y components and a vertical z component. The x direction is perpendicular to the road axis, tram and subway tracks (this is the direction of vibration propagation to the building) and the y component is parallel to the road axis.

The x, y, and z symbols next to the sensor numbers correspond to the vibration component measured by the given sensor.

The impact of vibrations on the structure was measured in a rigid node of the structure at the ground level. The impact of vibrations on people was measured on selected floors in the middle of the ceiling span on a 30 kg measuring disc according to standard [6].

The following specialized apparatus was used in the research to measure the accelerations and vibration frequencies of a building:

- 393B12 type accelerometer PCBs,
- the electronic data registration system ESAM Traveler Plus,
- PA16000 EC Electronics signal conditioning system,
- the analyzer (recording and analyzing system) LMS SCADAS Mobile,
- measurement of data analysis software (Matlab 7.3).

3 RESULTS OF MEASUREMENTS

Tables 1 and 2 present selected recorded results of vibration acceleration measurements at measurement points for individual vibration components. Table 1 presents the results for the passage of the 105N-type wagon, and Table 2 presents the results for the passage of the 120N-type wagon. Tables 3 and 4 show the average values of accelerations for individual travel speeds, respectively for the 105N and 120N wagons.

No.	Speed	Ground level measurement			3^{rd}-floor level - ceiling	
	km/h	x	y	z	y	z
		cm/s^2	cm/s^2	cm/s^2	cm/s^2	cm/s^2
1	20	12.51	8.78	4.00	22.83	57.95
2	20	6.80	5.28	3.70	13.27	32.84
3	20	6.45	4.50	2.66	11.33	22.63
4	20	6.30	4.23	2.75	13.94	21.89
5	20	7.51	6.00	2.38	10.71	23.24
6	30	15.62	10.88	4.77	24.32	44.77
7	30	11.50	7.45	4.13	24.27	43.19
8	30	12.09	9.00	4.83	15.02	34.89
9	48	8.35	6.91	4.17	21.81	40.58
10	50	8.91	6.37	3.99	21.98	41.68
11	50	9.07	7.22	3.41	15.00	38.56

Table 1: Vibration measurements – wagon type 105N

No.	Speed	Ground level measurement			3^{rd}-floor level - ceiling	
	km/h	x	y	z	y	z
		cm/s^2	cm/s^2	cm/s^2	cm/s^2	cm/s^2
1	15	11.01	5.67	4.20	11.81	24.77
2	20	11.36	8.47	5.25	12.01	32.71
3	20	15.13	7.67	4.94	15.31	32.88
4	20	13.60	8.50	5.10	14.26	34.17
5	20	14.82	8.80	4.93	17.16	29.47
6	30	12.14	7.73	3.53	13.51	30.06
7	30	10.91	7.15	4.25	13.95	39.59
8	30	11.15	8.25	3.80	15.95	46.40
9	50	16.78	11.69	4.76	19.17	50.71
10	50	17.21	10.07	4.61	18.09	54.11
11	50	16.36	10.33	4.59	18.12	52.44

Table 2: Vibration measurements – wagon type 120N

Speed	Ground level measurement - mean acceleration			3rd-floor level - ceiling mean acceleration	
km/h	x cm/s^2	y cm/s^2	z cm/s^2	y cm/s^2	z cm/s^2
20	7.91	5.76	3.10	14.42	31.71
30	13.07	9.11	4.58	21.20	40.95
50	8.78	6.83	3.86	19.60	40.27

Table 3: Vibration measurements – mean values– wagon type 105N

Speed	Ground level measurement - mean acceleration			3rd-floor level - ceiling mean acceleration	
km/h	x cm/s^2	y cm/s^2	z cm/s^2	y cm/s^2	z cm/s^2
20	13.18	7.82	4.88	14.11	30.80
30	11.40	7.71	3.86	14.47	38.68
50	16.78	10.70	4.65	18.46	52.42

Table 4: Vibration measurements – mean values– wagon type 120N

Tables 1 - 4 clearly show the difference in the intensity of interactions with two different types of trams. In the case of the 105N tram, vibrations are amplified at a speed of 30 km/h. A slightly different nature of the impact has a tram type 120N, where vibration accelerations are the smallest at 30 km/h.

Figures 4 and 5 show the results of the average values of vibration accelerations on the building structure at the ground level, respectively for the 105N and 120N wagons. The results show the difference in the characteristics of the excitation with different types of trams.

Figures 6 and 7 show the average values of vibration accelerations on the selected floor of the 3rd floor.

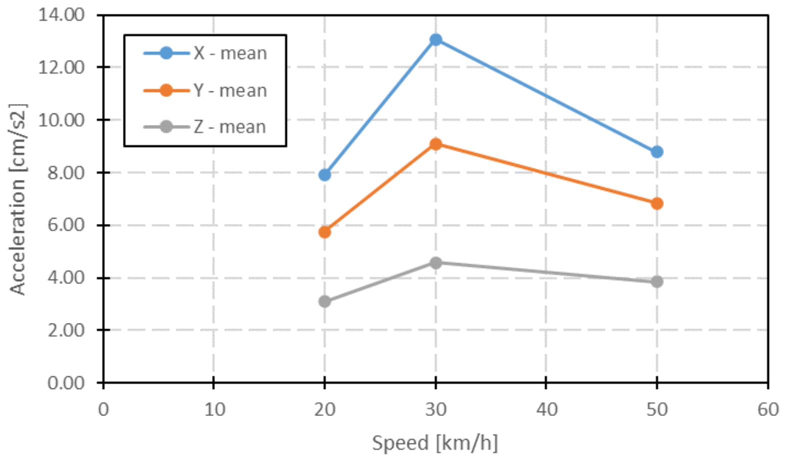

Figure 4: Mean values of accelerations on the ground level - wagon type 105N

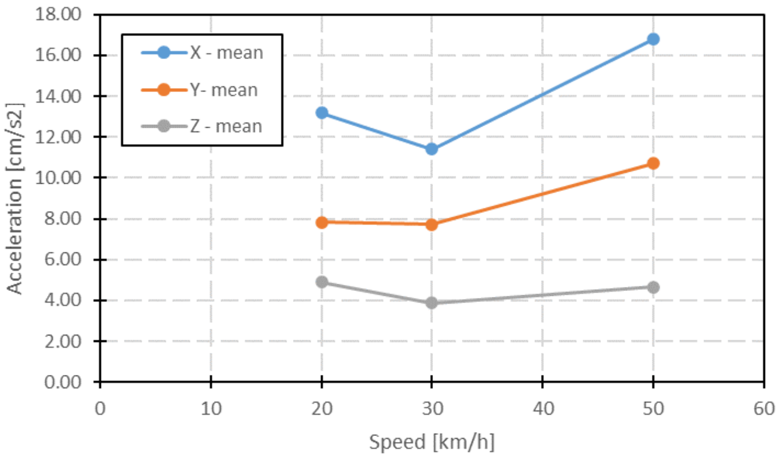

Figure 5: Mean values of accelerations on the ground level - wagon type 120N

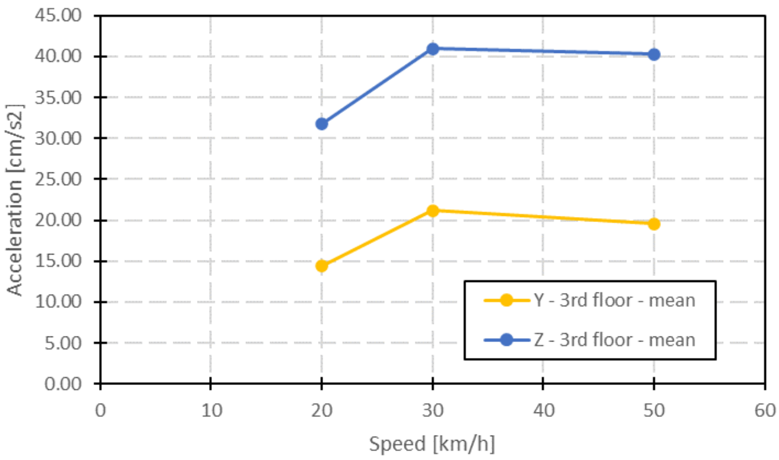

Figure 6: Mean values of accelerations on 3rd-floor level - wagon type 105N

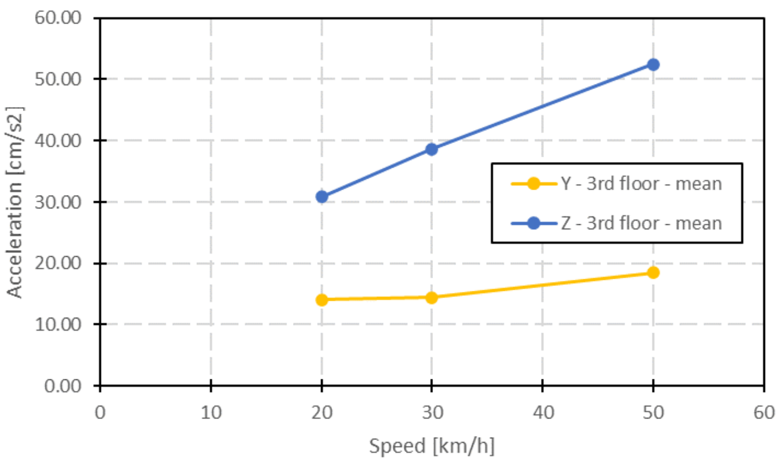

Figure 6: Mean values of accelerations on 3rd-floor level - wagon type 120N

The analysis of the results presented in tables 1 - 4 and figures 6 and 7 allows us to conclude that with the increase in speed, the level of vibration acceleration on people in the building increases. The increase in acceleration is not directly proportional to the speed of the tram. In the case of the 105N tram, a similar level of vibration acceleration was recorded for the speed of 30 and 50 km/h. In the case of the 120N tram, the vibration level increases more significantly with increasing speed.

4 CONCLUSIONS

The paper presents selected results of the impact of vibrations on the building structure and people in the building from the nearby tram line. The conclusions were based on field research on a selected building located approximately 9 m from the tram line.

During the tests, vibration accelerations were measured at the ground level and on the selected ceiling of the 3rd floor. The measurements were carried out by the current standards for measuring the impact of vibrations on the structure of buildings [5] and people in buildings [6]. The tests were carried out by an accredited laboratory.

The work analyzes the influence of the speed and type of wagon on the level of generated vibrations. A significant influence of the speed of the tram on the level of generated vibrations was found. Also, the type of wagon has a significant impact on the impact of vibrations on the structure of the building and the people staying in it. The conducted tests can be the basis for the selection of appropriate solutions to minimize vibrations, such as vibroinsulating mats, block supports, and rail pads.

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